

HEATHLANDS
AND ASSOCIATED COMMUNITIES
IN KUJAWY AND POMERANIA:
MANAGEMENT, TREATMENT
AND CONSERVATION



MARSZAŁEK WOJEWÓDZTWA
KUJAWSKO-POLMORSKIEGO
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REZERWAT BIOSFERY
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i Gospodarki Wodnej w Toruniu**

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Preface

Heathlands are strictly dependent on human activity. Cessation of land use, consisting in livestock grazing, burning and mowing, triggers off the succession processes, which quickly bring transformations of grasslands and heaths into fringe, thicket and forest communities. In the conditions of modern Poland, heaths generally develop over small areas in the landscape of pine forests, less frequently mixed forests. Those are forest glades, unsuccessful forest plantations, division lines, roadsides, railway embankments etc. Nowadays, larger areas of the aforementioned heaths occur only on military training grounds or in the nature reserves, frequently formed on former military areas where active protection must be applied.

This book presents heterogeneity of heaths occurring in Poland and the problems related to their protection, reconstruction and management necessary to maintain their effective ecosystem services. The first chapter deals with two main types of heathlands occurring in Poland, i.e. wet and dry heathlands. The second chapter describes some of the important heathlands, mostly nature reserves and Natura 2000 conservation sites in the northern part of the Kujawy region, in the vicinity of Toruń located on the left bank of the Vistula River, as well as the central and eastern parts of Pomerania. Also other types of ecosystems and plant communities occurring in the vicinity of heathlands are presented, for which active conservation is also required. The types and the range of treatments applied by institutions governing these areas are described for each site.

Most of the presented heaths grow on the former military training grounds which are under the State Forests administration. The project "Environmental restoration of degraded lands and former military training grounds used by State Forest" (implemented by local forest

divisions under Priority Axis II of the Infrastructure and Environment Operational EU Programme) restores the heathlands and associated plant communities, making them available to the public for recreational, tourist, educational and research purposes, and as resources for processing and industry.

Active conservation implemented on the other heaths described in this book, which often involves reduction of water runoff, is implemented by people working in environmental protection services in close cooperation with people of science studying the history and the present time of heaths, based on which they build scenarios of their development from the past to the future.

We hope that this book will serve as a guide for field sessions and the basis for discussions during the 14th European Heathland Network Workshop, Poland 2015. The information and the observations included in the book may also serve as references and arguments in further discussions at future biennial conferences organised by and for people fascinated by heaths, working for their proper use, preservation and reconstruction.

Toruń, June 2015

the Authors

1. Types and ecology of heathlands in Poland

1.1. Introduction

According to Matuszkiewicz (2007), heaths occurring in Poland may be classified into two main types of plant communities: 1 – Atlantic communities of wet heaths from the class *Oxycocco-Sphagnetea* Br.-Bl. et R.Tx. 1943 and 2 – dry heaths from the class *Nardo-Callunetea* Prsg. 1949.

The former include Atlantic communities of wet heaths occurring in oceanic climate of north-western Europe on peat and gley-podzol soils in depressions with considerable fluctuations in the groundwater level in the annual cycle. In floristic terms, the communities are characterised by a high percentage of Atlantic species, the absence of continental-boreal species and a small contribution of peat-forming tufty *Sphagnum* species.

According to Matuszkiewicz (2007), the order *Sphagno-Ericetalia* is represented in Poland by one association – *Ericetum tetralicis* R.Tx. 1937 – which comprises wet heathlands with the dominant cross-leaved heath *Erica tetralix* occurring at relatively many sites on the South Baltic Coast, as well as in the west of Wielkopolska and Lower Silesia regions. In Poland, the association reaches the absolute eastern limit of its range and is clearly floristically impoverished compared to typical Western European forms.

The latter type of heaths is represented by low-shrubs communities with the dominant heather *Calluna vulgaris* and, at most, sparsely scattered specimens of common juniper and the undergrowth of birch or pine. They occur on infertile acid podzol soils developed from loose or slightly loamy sands, usually within the influence of oceanic climate. They are an Atlantic vegetation type, particularly widespread and phytosociologically heterogeneous in the lowlands of North-Western Europe where until recently they dominated in the landscape as English “heaths”, French “landes” or German “Heiden”. The long-term discussion

on their genesis and issues related to their natural status showed that in the vast majority of cases, these are anthropogenic communities replacing forest as a result of a specific land-use method, i.e. extensive sheep and pig grazing (local breed Heideschnucken) combined with a removal of the groundcover vegetation from the soil together with raw ectohumus (Plaggenwirtschaft), repeated every few years to obtain bedding material for cattle, which is then used for fertilization of infertile sandy arable lands. The heaths in Poland are of anthropogenic origin – they develop only after coniferous or mixed coniferous forests are cut down, and consequently contribute to the intensification of soil podzolization. The Polish dry heaths are very poor in species because most of their characteristic species do not reach the western border of Poland. The majority of dry heaths occurring in Poland should be considered as an atypical borderland form of various syntaxa.

Characteristic features and the distribution in Poland, as well as threats and recommended protection forms of both types of heaths are presented below after Matuszkiewicz (2007), Herbichowa (2004), Pawlaczyk (2004) and Markowski (1997).

1.2. Wet heathlands

1.2.1. Syntaxonomic classification, the conditions of occurrence, structure and distribution

Matuszkiewicz (2007) presented (in accordance with the principles proposed by Braun-Blanquet) the following classification of wet heaths in the hierarchical system of Polish plant communities:

Class: ***Oxycocco-Sphagnetea* Br.-Bl. et R.Tx. 1943**
Order: ***Sphagno-Ericetalia* Br.-Bl. 1948 em . Moore (1964) 1968**
Alliance: ***Ericion tetralicis* Schwick. 1933**
Association: ***Ericetum tetralicis* R.Tx. 1937**

According to Herbichowa (2004), wet heaths with cross-leaved heath *Erica tetralix*, classified within habitat 4010 in the Natura 2000 Programme are almost exclusively semi-natural habitats which throughout their geographical range developed as a result of extensive grazing, removal of turf and periodic fires.

Their genesis in Poland is similar. In addition, they occur in places left after the exploitation of acid peat with a thin peat layer preserved.

There also occur in wet dune depressions in the coastal zone, developed as a result of succession without a direct human interference. Their distribution is limited to lowlands, organic-mineral and mineral margins of raised bogs or areas outside the bogs, ground depressions with relatively high but varied groundwater levels in the annual cycle. The substrate is acid and poor in nutrients, built of sandy deposits of varying origin and sand-loam deposits, usually with some admixture of organic matter which, however, does not accumulate in the form of peat. This feature distinguishes wet heathlands as a type of habitat including degraded raised bogs, on which also phytocoenoses with a heath physiognomy may occur (Herbichowa, 2004). The distribution of wet heaths in Poland is presented in Fig. 1. It appears from the map that habitats of wet heaths occur in the eastern part of the Kashubian Coast, near Kołobrzeg, the northern part of Drawskie Lake District, Goleniów Forest and occasionally in Lower Silesian Forests.

Contrary to Matuszkiewicz (2007), Herbichowa (2004) reports that wet heaths with *Erica tetralix* are rare in Poland and they cover only a small area. The eastern limit of the geographical range of this extremely rare type of habitat runs through Poland, although it does not cross the line of the Vistula River. According to Herbichowa (2004), wet heaths in Poland occur in depressions between dunes in the zone of coastal dunes and at inland sites, but only in the regions under a strong impact of Atlantic climate. In the first case, they develop in the most distant from the sea, stabilized sandspit zone, where they form small enclaves within the most humid variant of the coastal crowberry pine forest *Empetro nigri-Pinetum ericetosum tetralicis*. In the inland areas, they are distributed along the peripheries of open raised peat-bogs or in the spatial complex of excavation pits left after peat extraction where, depending on the water level, different stages of bog-vegetation regeneration occur, and on dykes – dry heathlands or degraded variants of bog pine forest.

The substrate of wet heathlands is composed of calcium-free and nutrient-poor sea sand or other types of sand, usually overlain by amorphous organic matter with a thickness ranging from a few to ca. 40 cm. The substrate reaction ranges from 4 to 5.5 pH. Soils are classified as peat and gley-podzol. They are constantly wet, but the water level may considerably vary in the annual and long-term cycle. In the zone of up to 2 km inland, these fluctuations depend not only on the amount and the distribution of precipitation, but also on the changes in the water level of the Baltic Sea.

Wet heathlands with *Erica tetralix* (code 4010)

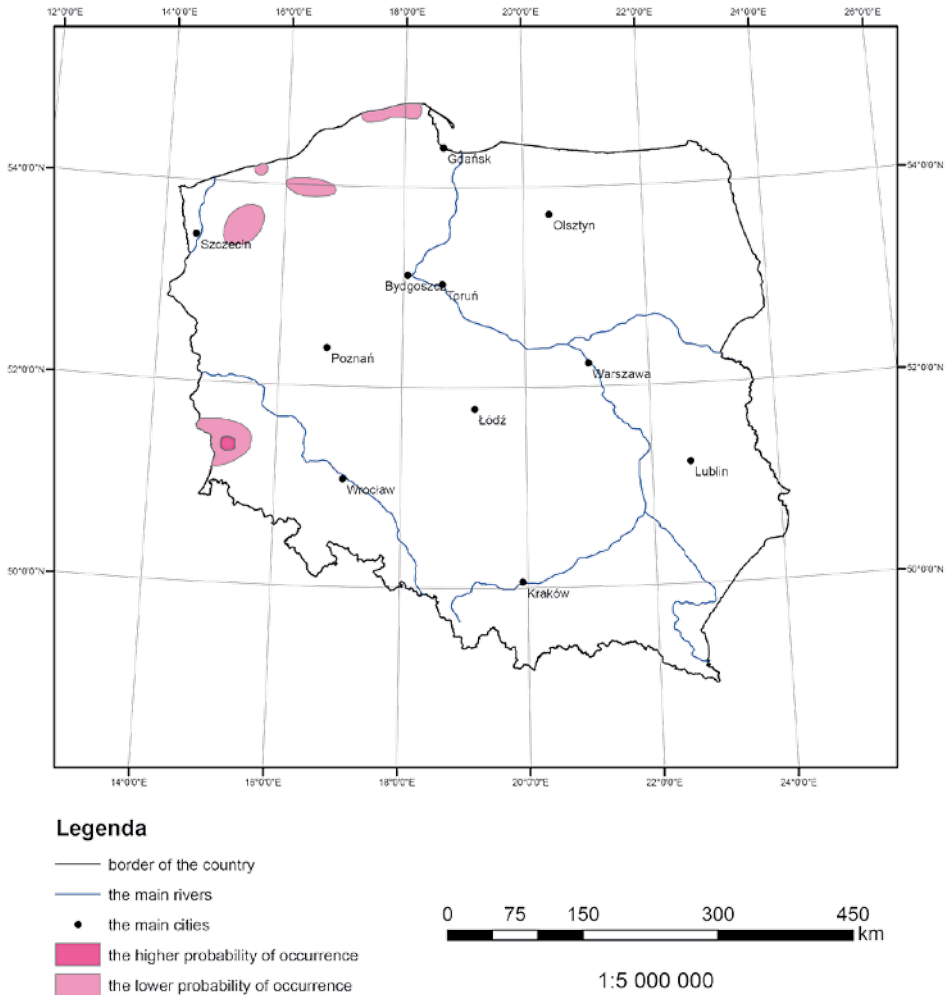


Figure 1. Distribution of wet heathlands with *Erica tetralix* in Poland

The species composition of wet heaths consists of a small number of species (on average ca. 20, very rarely less than 15 or above 25) and in phytogeographical terms, they are distinguished by the presence of a significant number of taxa requiring mild climate. Geographical ranges of some of them do not reach the Polish borders, hence the Polish wet heathlands are floristically impoverished compared to those from Western Europe. Usually, the heather *Calluna vulgaris* is a constant component of the vegetation cover, while the cross-leaved

heath *Erica tetralix*, occurring with varying abundance, is a differential species. In some phytocoenoses, *Trichophorum caespitosum* and *Juncus squarrosus* are co-dominants instead of the heather. Herbichowa (2004) described this type of phytocoenoses as **the association Junco-Trichophoretum** within the alliance *Ericion tetralicis*.

Apart from the above-mentioned species of vascular plants, also woody species occur on wet heathlands: *Pinus sylvestris*, *Betula pendula* and *B. pubescens*, with a height of up to 3 m. In constantly wet places with the highest moisture content, herbaceous plants are represented by common cottongrass *Eriophorum angustifolium*, cranberry *Oxycoccus palustris* and common sedge *Carex nigra*; additionally sweet gale *Myrica gale* occurs in coastal depressions between dunes, as well as septfoil *Potentilla erecta* and purple moor grass *Molinia caerulea* in places with a varied water level.

Bryopsida (*Hypnum cupressiforme*, *Aulacomium palustre*, *Pleurozium schreberi*), a few peat mosses (*Sphagnum compactum*, *S. auriculatum*, *S. molle*, *S. papillosum*, *S. tenellum*), liverworts (*Odontoschisma sphagni*, *Gymnocolea inflata*) and lichens (*Cladina portenosa*, *C. incrassata*) are constant components of wet heathlands, even though they are represented by a small number of species. The quantitative contribution of these groups in the composition of phytocoenoses depends on the moisture content of the substrate and the extent of human impact during their development.

1.2.2. Ecological importance, land-use, threats and protection

The habitat of 4010 wet heaths enriches the biodiversity of coastal landscape at the ecosystem level. Apart from purely natural values – particularly abundant (considering the climate conditions of Poland) occurrence of Atlantic and Subatlantic plant species, including many endangered species in Poland or at least in Pomerania, the presence of species from Annex I of the Birds Directive such as short-eared owl *Asio flammeus*, montagu's harrier *Circus pygargus*, common crane *Grus grus*, the habitat represents also significant cultural values associated with the historic extensive land-use method and the development of heterogeneous and ecologically sustainable landscape. In the past, the heaths were used to obtain bedding turf for animals, for livestock grazing and production of heather honey. At present, they

may be important for hiking and horse-riding tourism, even though the heath patches moderately trampled or compacted are characterised by a withdrawal of heather, replaced by large tussocks of *Trichophorum caespitosum* and aggregations of *Juncus squarrosus*, sometimes also *Nardus stricta*. Based on the example of land-use history and vegetation changes in the area and in the vicinity of the Baltic peat-bog "Bielawskie Błoto", Herbichowa (2004) reported that a decline of wet heaths, reaching ca. 80% of the original area, was mostly a consequence of afforestation, attempts at agriculture and cultivation of meadows, as well as incidental destruction caused mainly by fires. On the basis of the previous observations, Herbichowa (2004) reported that the habitat of wet heaths is particularly sensitive to lower water levels, changes in the light climate (shading by trees), raising the trophic status, reduction of soil reaction, as well as fires, extensive trampling by people and horses.

To protect wet heaths, in addition to those occurring in natural coastal depressions between dunes, Herbichowa (2004) proposes a number of measures stabilizing the best preserved phytocoenoses and some relevant treatments improving the condition of the degraded ones. The author recommends the removal of trees encroaching on the heathlands, and if possible – also raising the groundwater table, because the high water level reduces the possibility and the rate of conifer forest formation. According to the author, the type and frequency of applied protection treatments should be determined experimentally and by conducting studies at permanent plots. Furthermore, liming, intensive fertilization or plant protection products should not be used in the vicinity of wet heathlands. Afforestation, ploughing, transformation into grasslands and crop fields, and recreational or permanent building development should be entirely eliminated. Tourism and horse-riding recreation must be limited and their effects monitored.

Because of the rarity of the habitat, monitoring is recommended for all wet heaths located in the nature reserves and landscape parks. According to Herbichowa (2004), monitoring should involve: 1 – systematic, up-to-date recording of such events as fires, winterkilling of heather, changes in hydrological conditions and – based on mapping conducted every five years – the size of the total area covered by a habitat, 2 – monitoring of vegetation responses to applied active conservation measures by making relevés at permanent experimental and reference plots every year, 3 – assessment of the vegetation and soil resistance to human trampling and horse riding.

1.3. Dry heathlands

1.3.1. Heterogeneity, genesis, the conditions of occurrence and distribution

According to Matuszkiewicz (2007), the class *Nardo-Callunetea* includes two orders: 1 – *Nardetalia* Prsg 1949, i.e. acidophilous short grasslands and meadows with the dominant mat-grass *Nardus stricta*, and 2 – *Calluno-Ulicetalia* (Quant. 1935) R.Tx. 1937, i.e. heaths occurring on infertile podzol soils developed from loose or slightly loamy sands. Within the former, non-heath order, the association *Calluno-Nardetum strictae* Hrync. 1959 is characterised by a higher contribution of *Calluna vulgaris*. It is a community with the intermediate physiognomy between *Nardus* grassland and heathland, typically developed as a result of heather *Calluna vulgaris* and common heathgrass *Sieglingia decumbens* dominance, while *Nardus stricta* is less important. This association does not belong to heathlands and occurs in the foothills and lower subalpine forest, in places extensively and even excessively grazed by sheep and cattle, representing the last stage of vegetation degeneration. Communities classified within *Calluno-Nardetum strictae* are characteristic and unfortunately still quite common components of the landscape in the Beskid Foothills and the Beskid Mountains – until recently overpopulated regions.

On the other hand, the order *Calluno-Ulicetalia* (including dry heaths) is differentiated into four alliances, including 1, 3, 2 and 3 basic syntaxonomic units in the rank of association or plant community. Three alliances include inland dry heaths, and one alliance – coastal dry heaths with *Empetrum nigrum*. According to Matuszkiewicz (2007), dry heaths in the area of Poland can be classified as follows:

Class: ***Nardo-Callunetea* Prsg. 1949**

Order: ***Calluno-Ulicetalia* (Quant. 1935) R.Tx. 1937**

I. Alliance: ***Calluno-Genistion* Duving. 1944**

1. Association: ***Calluno-Genistetum* R.Tx. 1937**

II. Alliance: ***Pohlio-Callunion* Shimwell 1973 em. Brzeg 1981**

1. Association: ***Pohlio-Callunetum* Shimwell 1973 em. Brzeg 1981**

2. Community: ***Hypnum juflandicum* Balcerk. et Brzeg 1978**

3. Association: ***Sieglingio-Agrostietum* Brzeg 1981**

III. Alliance: ***Calluno-Arctostaphylon*** R.Tx. et Prsg. 1949

1. Association: ***Arctostaphylo-Callunetum*** R.Tx. et Prsg. 1940
2. Association: ***Scabioso canescentis-Genistetum*** Balcerk. et Brzeg 1993

IV. Alliance: ***Empetrium nigri*** Böcher 1943

1. Association: ***Carici arenariae-Empetretum nigri*** R.Tx. et Kawamura 1975 em. Barendregt 1982
2. Association: ***Vaccinio uliginosi-Empetretum nigri*** R. Markowski 1997 (nomen nudum)
3. Community: ***Empetrum nigrum-Vaccinium vitis-idaea*** Mark. 1997

I. The alliance ***Calluno-Genistion*** encompasses inland dry heaths widespread in Western Europe, probably anthropogenic but largely preserved as typical components of the landscape, on the infertile sandy habitat of acidophilous oak woods (*Quercetea roboli-petraeae*). In Poland, these communities are floristically impoverished, most of the characteristic species do not reach the western border of Poland.

1) The association ***Calluno-Genistetum*** encompasses dry heaths represented in Poland by anthropogenic communities developing on poor sandy soils as a degeneration phase of pine and mixed forests. Locally they occur in some regions of north-western, western and central Poland in open forest stands, at logging sites, firebreaks and along soil-surfaced forest roads.

II. According to Matuszkiewicz (2007), the alliance ***Pohlio-Callunion*** encompasses a group of heaths characterised by a lack of diagnostically important species, such as *Genista anglica*, *G. pilosa*, *Genistella sagittalis*, *Dicranum spurium*, *Festuca tenuifolia*, *Galium saxatile* and others, and a considerable contribution of small bryophytes *Dicranum scoparium*, *Hypnum jutlandicum* (= *H. ericetorum*) and *Pohlia nutans* and fruticose lichens (*Cladonia chlorophaea*, *C. furcata* subsp. *furcata* and others). According to Matuszkiewicz (2007), the above-mentioned bryophytes and lichens are quoted as characteristic species of the alliance, although it seems that they are rather differential species, because their amplitude is very broad and goes beyond the heath communities. The above author also believes that several associations were distinguished or identified in Poland, including highly anthropogenic vicarious (secondary) communities from a dynamic range of conifer forest associations. Both individual associations and the alliance are critical units which need to be further researched and confirmed on larger material.

1) The association *Pohlio-Callunetum* is the most common syntaxon within the alliance *Pohlio-Callunion*. According to Matuszkiewicz (2007), it is a “central community” of the alliance, without its own characteristic species. The moss *Pohlia nutans* is the only constant species affiliated with this unit. *Calluna vulgaris* dominates in the layer of herbaceous plants and low shrubs, and *Pleurozium schreberi* dominates in the groundcover. Characteristic species of the class *Vaccinio-Piceetea* play a significant role in the floristic composition of the community, which results from the spatial contacts of these syntaxa. *Polio-Callunetum* is a secondary plant community to fresh coniferous forests (mainly Subatlantic *Leucobryo-Pinetum*) and is common at logging sites, firebreaks, roadsides in coniferous forests, or even in thinned-out pine forest stands.

2) According to Matuszkiewicz (2007), the *Hypnum jutlandicum* community is a poorly researched and documented syntaxon in the alliance *Pohlio-Callunion*. The moss species (*Hypnum jutlandicum* = *H. ericetorum* = *H. cupressiforme* var. *ericetorum*) dominates in the abundant ground layer, while the layer of herbaceous plants and low shrubs is poorly developed. Only *Festuca ovina* s. str. occurs constantly in this community and in larger numbers, whereas *Calluna vulgaris* is of minor importance. Matuszkiewicz (2007) reported that the above-mentioned community was observed within the pine forest (*Leucobryo-Pinetum*) range along local roads, roadsides and paths, both in sunny and shaded places, only slightly trodden or compacted by vehicles.

3) The association *Sieglingio-Agrostietum* includes grass communities dominated by *Agrostis capillaris* and *Danthonia decumbens* – characteristic species of the association, accompanied by frequently occurring *Festuca ovina* s. str. Heather *Calluna vulgaris*, on the other hand, occurs in small numbers, or is completely missing in some variants of the association (like in the community of *Hypnum jutlandicum*). According to Matuszkiewicz (2007), the syntaxon has a relatively broad habitat range and therefore is differentiated into subassociations and variants. The typical form of the association belongs to a dynamic range of suboceanic fresh conifer forest *Leucobryo-Pinetum*, but some subassociations show certain affiliation with subcontinental fresh conifer forest (*Peucedano-Pinetum*), or with more humid forms of pine forests, e.g. with *Molinio-Pinetum*. According to Brzeg (1982) and Matuszkiewicz (2007), the described association has been observed on forest roads in different locations, most often on ridges but also in ruts of roads with less compacted surface. The latter author believes that the exact

distribution and, in particular, the range of the association have not been determined yet.

III. The alliance *Calluno-Arctostaphylon* encompasses the subcontinental bearberry heathlands with the centre of occurrence in the eastern part of Central Europe and in Eastern Europe. Their floristically impoverished variants occur at the sites located far west and they are considered to be rare relict communities that should be protected.

1) The *Arctostaphylo-Callunetum* association is the main syntaxon of the described alliance. It has a boreal-continental type of range, distinguished by the presence of kinnikinnick bearberry *Arctostaphylos uva-ursi* as a subdominant species, accompanied by other continental species of psammophytes. The range of this association has not been determined in detail and according to Matuszkiewicz (2007), its centre is located in the Baltic countries and in Belarus. In Poland, *Arctostaphylo-Callunetum* is common in north-eastern and eastern Poland, with sites located e.g. in the Kampinos Forest, Pisz Forest, Kurpie Forest, Białowieża Forest, Knyszyn and Augustów Forest.

2) So far, the association *Scabioso canescentis-Genistetum*, referred to as “flowery heath”, has been found in Gorzowska Basin in central-western Poland (Balcerkiewicz and Brzeg, 1993; Rakowski 2002, 2003). According to Matuszkiewicz (2007), the actual range of the association has not been determined yet. According to the above-mentioned authors, the physiognomy of the community represents a loose type of heath with the dominant heather *Calluna vulgaris* and cowberry *Vaccinium vitis-idaea*, a compact layer of mosses (mainly *Pleurozium schreberi*) and the presence of many flowering, colourful herbaceous plants. Characteristic species of the association include *Scabiosa canescens* and *Genista tinctoria*. According to the above sources, differential species within the order include: *Achillea pannonica*, *Dianthus carthusianorum*, *Polygonatum odoratum*, *Solidago virgaurea* and *Vincetoxicum hirudinaria*. The species composition of phytocoenoses is distinguished by a considerable contribution of thermophilic and slightly calciphilous species, partly characteristic of thermophilous tall herb vegetation (so called “saum” or fringe vegetation) (class *Trifolio-Geranietea*) or grasslands (class *Festuco-Brometea*), and in certain variants – also species characteristic of fresh meadows (alliance *Arrhenatherion*). The described community usually occurs on road escarpments inclined at a considerable angle, often occupying large areas, sometimes quite distant from forest. The substrate is gravel sand, containing probably

a certain amount of calcium carbonate. *Scabioso canescentis-Genistetum* is, at least locally, a well-identifiable syntaxon among other types of heaths, even though its systematic position is not clear. Therefore Matuszkiewicz (2007), following other authors, temporarily classified the syntaxon into the alliance *Calluno-Arctostaphylion*, allowing for its subcontinental character. According to Matuszkiewicz (l.c.), further research is necessary to explain the systematic position of the community.

IV. The alliance *Empetrium nigri* includes coastal heaths with *Empetrum nigrum* occurring in dune areas on the coast of the North Sea in Scotland, the Netherlands and Germany as well as on the southern Baltic coast in Sweden, Denmark, Germany, Poland and further east to the Curonian Spit. Matuszkiewicz (2007) reports that those communities were previously recognized as one association *Salici-Empetretum nigri* R.Tx. 1955, irrespective of the genesis. At present, their natural primeval communities and anthropogenic secondary communities are distinguished as separate syntaxa.

1) The association *Carici arenariae-Empetretum nigri* belonging to the described alliance includes Boreal-Atlantic natural communities with the dominant crowberry *Empetrum nigrum*, accompanied by willows *Salix arenaria*, developing in the form of very low ground vegetation patches similar to dry heaths on treeless dunes. The factor limiting further succession towards the forest communities is, in this case, very strong wind. This association represents, however, also natural succession stage in the process of afforestation of a grey dune between the grassland *Helichryso-Jasionetum* and crowberry pine forest *Empetro nigri-Pinetum*. The association *Carici arenariae-Empetretum nigri* occurs in Poland only in the north-western part of the Kashubian Coast and on the Słowiński Coast.

2) The association *Vaccinio uliginosi-Empetretum nigri* encompasses low-shrubs communities of humid and wet fields and blowouts on coastal dunes with active aeolian processes. The floristic composition of the association is complex because heath plants and coastal psammophytes are accompanied by species of peat-bogs and pine forests. According to Markowski (1997), *Juncus balticus* is not a particularly good characteristic species, and the following species are differential of the class *Nardo-Callunetea*: *Vaccinium uliginosum* and *Drosera rotundifolia*, *Gymnocolea inflata* and *Polytrichum commune* var. *pergoniale*. The described association occurs only on the Łeba Sandspit, and perhaps on the Sarbsko Sandspit (in the fragmentary form). According

to Matuszkiewicz (2007), there are reasonable grounds to believe that the association was more common in the past, and now it is becoming extinct as a result of reduced aeolian processes due to progressive stabilization of shifting dunes.

3) The community *Empetrum nigrum-Vaccinium vitis-idaea* encompasses anthropogenic secondary phytocoenoses of the coastal crowberry pine forest, hitherto recognised as one of the variants of *Carici arenariae-Empetretum nigri*. Due to the different genesis and abundant occurrence of differential pine forest species, such as *Cladina arbuscula* subsp. *arbuscula*, *C. portentosa*, *Deschampsia flexuosa*, *Dicranum polysetum*, *D. scoparium*, *Pleurozium schreberi*, *Pseudoscleropodium purum*, Markowski (1997) classified them as a separate syntaxon without characteristic species, but representing a specific type of ecosystem. This community is common in the complex of crowberry pine forests all along the coast, especially on the Słowiński Coast, and on the dunes of the Wolin Island – the special variant with *Polypodium vulgare*.

1.3.2. Structure, land-use, threats and protection of the main plant community types

Of the above-mentioned seven associations and two plant communities, three associations play a significant role in the landscape development in Poland. According to Kujawa-Pawlaczyk, their habitat codes in the Natura 2000 Programme are as follows:

4030-1 Genista heaths *Calluno-Genistetum*

4030-2 heaths with *Pohlia nutans* *Pohlio-Callunetum*

4030-3 bearberry heaths *Arctostaphylo-Callunetum*

Data on the land-use, threats, conservation recommendations and the monitoring range are presented below for each type of heaths based on the study by Kujawa-Pawlaczyk (2004) prepared for the purpose of the Natura 2000 implementation.

Genista heaths *Calluno-Genistetum* occur in the form of dwarf shrub heath, with a clear two-layer structure. The first layer is built of the dominant: *Genista germanica* and *Calluna vilgaris*. The second layer consists of low, often creeping plants such as *Euphrasia micrantha*, *Veronica officinalis*, *Viola canina* as well as bryophytes and lichens. In addition, single and dispersed tree species occur: *Betula pendula*,

Populus tremula and shrubs, mostly *Juniperus communis*. The height of plants ranges from a few to ca. 30–50 cm, with cover-abundance dependent on the succession stage – up to 60–70% for the herbaceous layer and 50–60% for the moss layer. In addition to the above-mentioned species, the following species often occur in the community: *Agrostis capillaris*, *Vaccinium myrtillus*, *Cuscuta epithymum*, *Genista pilosa*, *Carex ericetorum*, *Sarothamnus scoparius*, *Peucedanum oreoselinum*, *Solidago virgaurea*, *Luzula multiflora*, *Pleurozium schreberi*, *Polytrichum formosum*, *P. juniperinum*, *Cladonia chlorophaea*.

In Europe, *Genista* heaths occur mainly in Subatlantic and subcontinental areas of the continent, extrazonally throughout the area. In Poland, they occur mainly in western and northern parts of the country, as well as at the eastern border, seldom in the central part (Fig. 2). Depending on the geographical location, two different variants develop: Subatlantic and subcontinental. The Subatlantic variant is distinguished by the presence of many species from the central part of the distribution range in the western part of Europe such as: *Leucobryum glaucum*, *Teucrium scorodonia*, *Hypericum pulchrum*. This variant occurs only in the western part of Poland.

The subcontinental variant is distinguished by species occurring in the eastern part of Europe, including: *Calamagrostis epigejos*, *Antennaria dioica* and *Peucedanum oreoselinum*. Most of the sites located in Poland represents this variant.

They mostly occur on artificially formed margins of forests, along roads and communication routes, on the still existing firebreaks and in open fragments of forests in the vicinity of acidophilous beech forests *Luzulo pilosae-Fagetum*, oak-beech forests *Fago-Quercetum petraeae* and acidophilous oak forests *Calamagrostio-Quercetum* as well as pine forests planted on the habitat of acidophilous oak forests from the class *Quercetea robori-petraeae*.

Dry *Genista* heaths are the habitat for many threatened species of plants and invertebrates, in particular beetles, dipterans, hymenopterans and orthopterans, hemipterans and butterflies. As peripheral sites of the association *Calluno-Genistetum*, they represent a geobotanical peculiarity among heaths occurring in Poland. On the list of plant communities from the Wielkopolska Region (Brzeg and Wojterska, 2001), *Genista* heaths are included in the category referred to as vulnerable communities (category V).

Calluno-Genisetum (code 4030-1)

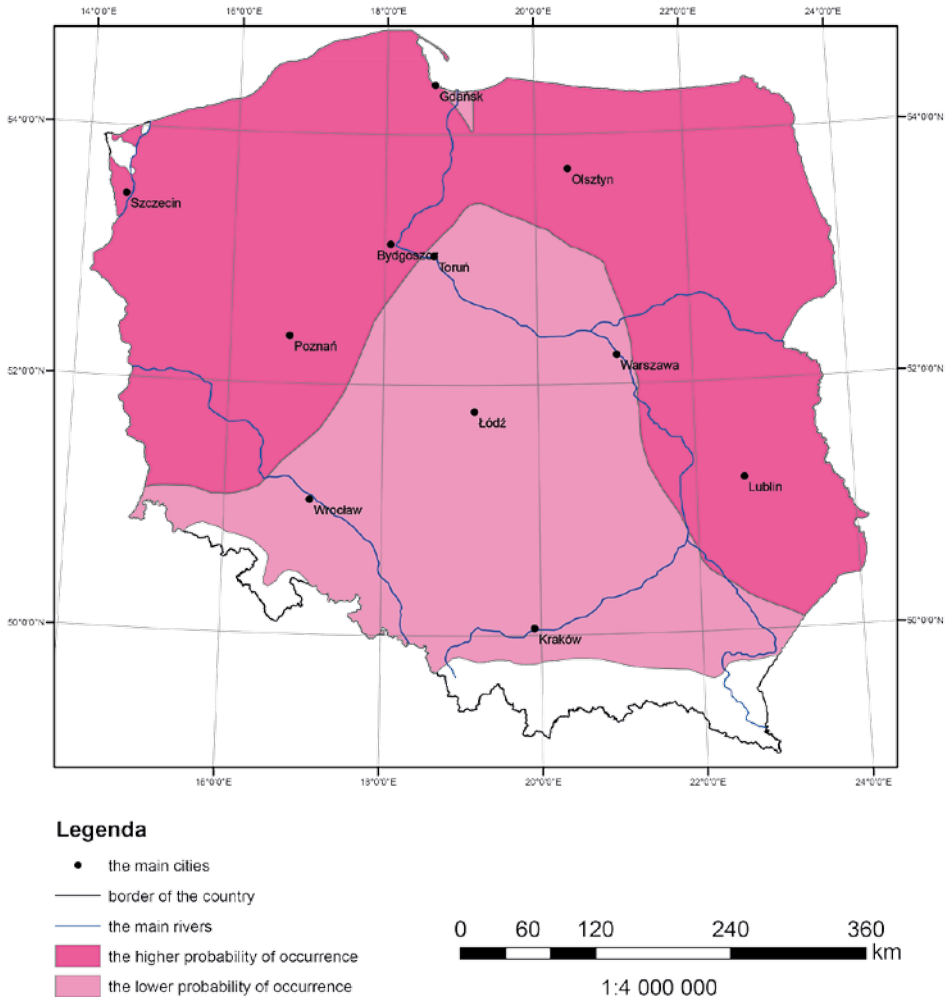


Figure 2. Distribution of dry heathlands *Calluno-Genistetum* in Poland

The biggest threats to the habitat result from the very limited spatial range of these communities, peripheral character of the association as well as considerable dispersion of the sites. In recent years, changes in the forest management significantly contributed to the reduction of heath areas. In particular, the abandonment of fire protection methods involving the maintenance of open areas along the forest peripheries, i.e. firebreaks, induced the process of secondary succession. This leads to the accumulation of dead, undecomposed organic matter, gradual

shading of soils and an increase in the moisture content. Such conditions are conducive to the occurrence of tree seedlings whose growth leads to changes in the habitat conditions. Hence the most important objectives of the conservation plans prepared for the *Genista* heaths should aim at preventing the sunlight access reduction as well as an increase in the trophic status and soil moisture. The heterogeneity of these heathlands may be preserved through implementation of active protection measures, which involve prevention of shading and exposure of forest margins, including mainly periodic removal of trees and shrubs encroaching on the heaths and the immediate vicinity. Such actions are carried out on a large scale on *Calluno-Genistetum* heaths by forest divisions of Borne Sulinowo and Czarnobór as part of the active protection of so-called "Wrzosowiska Kłomińskie" (Kłomino Heaths) with the nature reserve "Diabelskie Pustacie" (Devil's Wastelands). They contribute to the sustainability of specific landscape, protection of rare and threatened plant and animal species, as well as they provide conditions for recreational, tourist and educational activities, production of heather honey and picking mushrooms.

Protection treatments and the use of heaths should be accompanied by monitoring of the structure and functioning of these ecological systems. According to Kujawa-Pawlaczyk (2004), field monitoring carried out for this habitat should rely on a field survey carried out every 5 years at selected sites. The assessment should cover the dynamics of different vegetation patches, including in particular their species composition with special emphasis on seedlings of trees and shrubs as well as locations of valuable vascular plant species. Relevés and photographs should be part of the documentation. The amount of the deposited organic matter should be also assessed. When active protection measures are implemented, records of the process and its effects should be kept, as well as the results should be compared with the results from sites where active protection is not applied.

In Poland, ***Pohlio-Callunetum* heaths** occur over large areas, especially on military training grounds. Also this type of heaths has a two-layer structure. The first layer is built of common heather and the second one – of species such as *Hieracium pilosella*, *Agrostis capillaris*, *Carex arenaria* as well as rich moss flora and lichen biota. Single trees of *Pinus sylvestris* and *Betula pendula* occur, and shrubs of *Sarothamnus scoparius*. Phytocoenoses of *Molinia caerulea* occur in places with varying soil moisture content. The height of dwarf shrubs is ca. 30–50 cm with the cover-abundance dependent on the succession

stages – up to 70–80% for the herbaceous layer and 75–90% for the layer of mosses and lichens. In addition to the above-mentioned species, the following species occur in the communities: *Festuca ovina*, *Carex ericetorum*, *Juncus squarrosus*, *Euphrasia nemorosa*, *E. micrantha*, *Pohlia nutans*, *Pleurozium schreberi*, *Dicranum scoparium*, *D. spurium*, *D. polysetum*, *Dicranella heteromalla*, *Brachythecium oedipodium*, *Cladonia chlorophaea*, *C. arbuscula* subsp. *mitis*, *C. deformis*, *C. pyxidata* subsp. *pyxidata*, *C. coniocraea*, *C. glauca*.

According to Kujawa-Pawlaczyk (2004), the association is divided into five subassociations: *Pohlio-Callunetum typicum*, *Pohlio-Callunetum caricetosum arenariae*, *Pohlio-Callunetum sarothamnetosum*, *Pohlio-Callunetum cladinetosum mitis* and *Pohlio-Callunetum molinietosum*.

The heterogeneity of heaths with *Pohlia nutans* results from the fact that they develop in the vicinity of different forest habitats. The heaths border and develop along the margins of pine forests, open forests, mainly acidophilous beech forests, oak-beech forests and acidophilous oak forests as well as pine woods planted on habitats of acidophilous oak forests from the class *Quercetea roboli-petraeae*. The mesic subassociation *Pohlio-Callunetum molinietosum* develops in the contact zone between humid coniferous forests and humid birch woods. The subassociation *Pohlio-Callunetum cladinetosum mitis* develops in the vicinity of psammophilous grasslands and lichen Scots pine forests *Cladonio-Pinetum*. Whereas the subassociation *Pohlio-Callunetum caricetosum arenariae* borders on coastal crowberry pine forests and communities of coastal dunes.

Heaths with *Pohlia nutans* are one of the most common in Poland types of heaths with the occurrence centre in the western and north-western regions of the country (Fig. 3). They occur over large areas on former and modern training grounds of Western Pomerania, Lower Silesia and the Land of Lubusz; scattered sites are found in the large forest complexes of western Poland: in Noteć and Drawa Forest, in Primeval Rzepin (Lubusz) Forest, in Skwierzyna and Tuchola Forest. They grow on division lines, at roadsides, former firebreaks, in places between power lines and in open forest fragments. Discontinuation of the military use on certain training grounds and abandonment of fire protection methods (involving the maintenance of open areas) are conducive to the processes of secondary succession and reduce the area of heaths with *Pohlia nutans*. In the case of this association, as in the case of *Calluno-Genistetum*, the growth of trees and shrubs overshadowing the heaths as well as causing an increase in the moisture

content and trophic status of the habitats is one of the biggest and most common threats to this syntaxon.

Pohlio-Callunetum (code 4030-2)

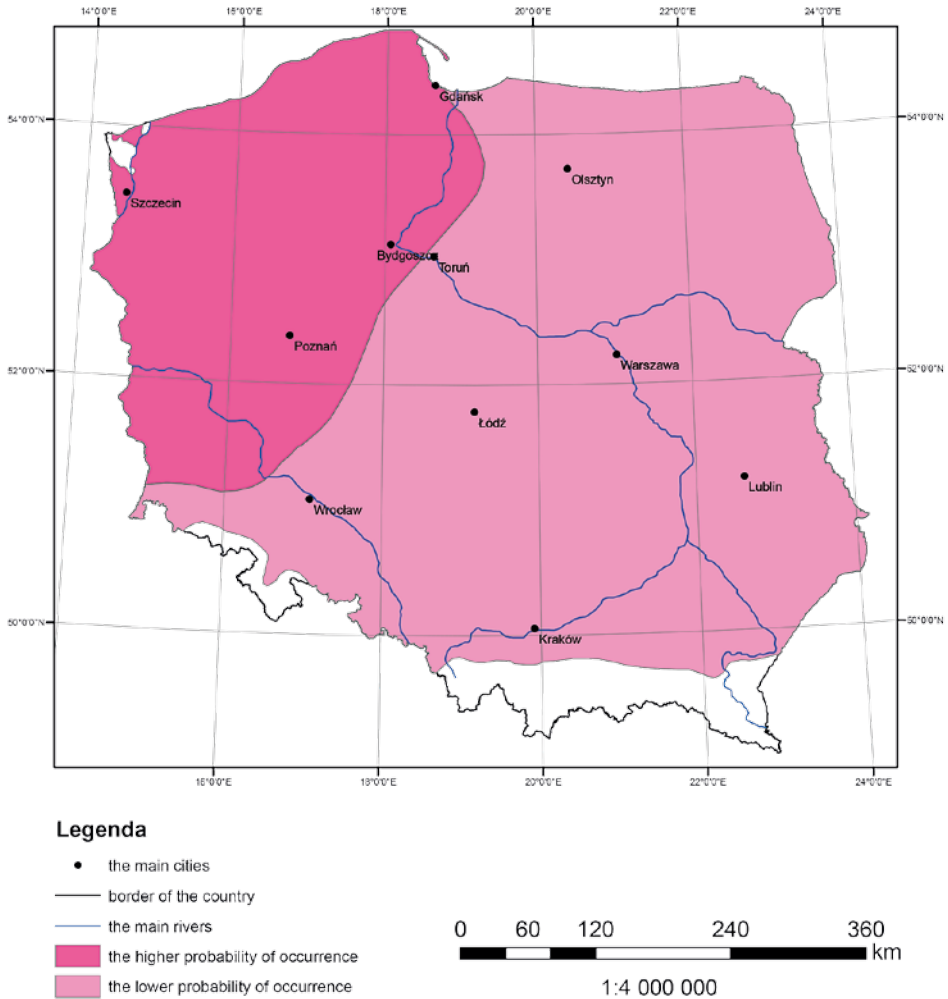


Figure 3. Distribution of dry heathlands *Pohlio-Callunetum* in Poland

A significant part of sites with *Pohlio-Callunetum* heaths is located in the areas not covered by any form of protection, interventions or treatments, and this should change to active protection. There are several rare and threatened plant species in their species composition, e.g. *Botrychium lunaria*, *Pedicularis sylvatica*, *Lycopodium clavatum*,

Polygala oxyptera, *Juncus squarrosus*, *Euphrasia nemorosa*, and *E. micrantha*. These species are floristic peculiarities in the regions of Western Pomerania, Wielkopolska and Lower Silesia. Also rare species of invertebrates occur in these ecological systems.

Active conservation in large areas of *Pohlia nutans* heaths should be conducted towards preservation of the suitable habitat conditions. According to Kujawa-Pawlaczyk (2004), mowing, removal of trees and shrubs, as well as periodic and selective grazing and burning should be applied on these heaths.

Mowing of heaths should be applied every 3–5 years in late summer or autumn, necessarily after spillage of seeds. It is also recommended to exclude “ecological zones” or to apply alternate mowing (i.e. mowing of different parts of heath in subsequent years). The biomass of cut and dry heather should be removed from heaths, because the presence of larger amounts of organic matter accelerate succession. Trees and shrubs should be removed whenever necessary. The best time for this treatment is early spring (April – early May, before the development of leaves on trees), because otherwise it may bring reverse effects, i.e. stronger regrowth and expansion of trees and shrubs. The most effective method consists in removal of tree and shrub stumps, which results in soil and heath exposure.

Also grazing on dry heathlands is recommended, which should be carried out using “primitive” animal breeds, preferably “wrzosówki” sheep. Furthermore, rotational (strip) grazing is recommended. This type of treatments should not be applied for the whole heath area, as this could lead to invasion of undesirable species such as bushgrass *Calamagrostis epigejos*.

The recommended method of protecting the dry heaths with *Pohlia nutans* involves also monitored burning as a factor restoring this type of plant communities. Any such action should be consulted with an expert in fauna of invertebrates regarding the time and extent of the procedure. The recommended time for burning is late winter/early spring, after disappearance of snow cover and drying of vegetation cover, but before the onset of warm days and the beginning of the growing season. Each time only part of the heath area should be burnt and the treatment should not be repeated too often, i.e. no more often than every 8–10 years. Active conservation of heaths with *Pohlia nutans* along roadsides, division lines, on deforested firebreaks and under power lines should involve mainly the periodical removal of trees and shrubs encroaching on heaths and the immediate vicinity.

Monitoring of *Pohlio-Callunetum* heaths should involve the same actions and procedures as in the case of the association *Calluno-Genistetum*.

Arctostaphylo-Callunetum (code 4030-3)

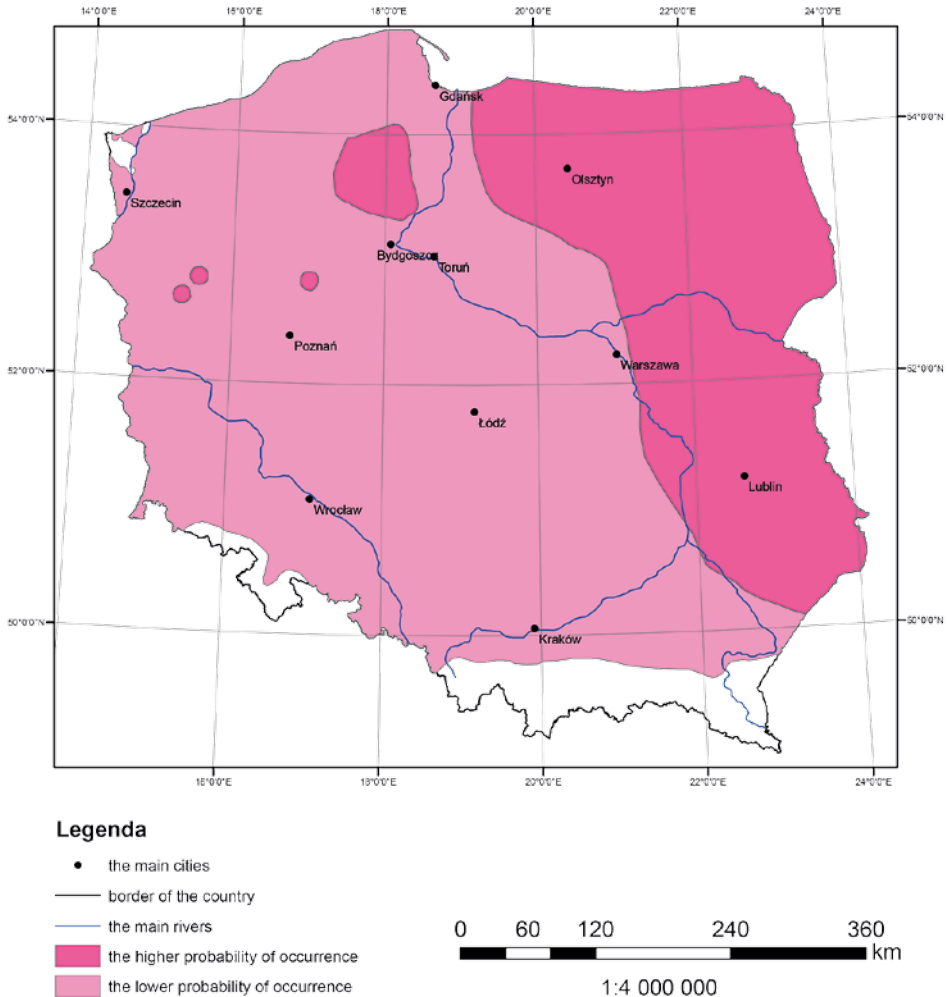


Figure 4. Distribution of dry heathlands *Arctostaphylo-Callunetum* in Poland

Bearberry heaths *Arctostaphylo-Callunetum* occurring in the boreal-continental areas of Europe. In Poland, the occurrence centre of their distribution reaches the north-eastern regions of the country (Fig. 4). They usually develop along margins of pine woods (mainly dry

pine woods *Cladonio-Pinetum* and fresh coniferous forest, subcontinental *Peucedano-Pinetum* and suboceanic *Leucobryo-Pinetum*), along roads, communication routes, on forest division lines and firebreaks in north-eastern Poland: in Pisz Forest, Kurpie Forest, Augustów Forest, Białowieża Primeval Forest. In central Poland, they occur in Bydgoszcz Forest, in particular near the city of Toruń, and in the Kampinos Forest. Single sites are located in the Tuchola Forest, the region of Wielkopolska, mainly in Noteć Forest and in the Gorzów Basin.

Heaths classified into the association of *Arctostaphylo-Callunetum* have characteristic physiognomy dominated by common heather *Calluna vulgaris* and bearberry *Arctostaphylos uva-ursi*; the latter occurs as a creeper in isolated patches. The structure of phytocoenoses consists of two layers, i.e. herbaceous plant and moss. Heather and bearberry occur in the first layer; the later grows in open spaces between clusters of heather. The second, lower layer is composed of *Hieracium pilosella* and *Festuca ovina* as well as a rich flora of mosses and lichen biota. Trees and shrubs occur as single and scattered specimens, including mainly: *Pinus sylvestris*, *Betula pendula* and *Juniperus communis*. In addition to the above-mentioned species, the following species frequently occur: *Carex ericetorum*, *C. praecox*, *Peucedanum oreoselinum*, *Scorzonera humilis*, *Solidago virgaurea*, *Thymus serpyllum*, *Corynephorus canescens*, *Geranium sanguineum*, *Trientalis europaea*, *Lycopodium clavatum*, *Polytrichum piliferum*, *Ceratodon purpureus*, *Hypnum jutlandicum*, *Pohlia nutans*, *Ptilium ciliare*, *Cladonia arbuscula* subsp. *arbuscula*, *C. arbuscula* subsp. *mitis*, *C. chlorophaea*, *C. crispata*, *C. furcata* subsp. *furcata*, *C. gracilis*, *C. uncialis*, *Cetraria aculeata*. The cover of the herbaceous layer of *Arctostaphylo-Callunetum* heaths varies from 55% to 90%, depending on the light conditions.

According to Kujawa-Pawlaczyk (2004), the association in Poland is differentiated into three subassociations: *Arctostaphylo-Callunetum typicum*, *Arctostaphylo-Callunetum cladinetosum mitis* and *Arctostaphylo-Callunetum vaccinietosum myrtilli*. Ciosek (2000), on the other hand, distinguished four subassociations based on the analysis of differences in bearberry heaths occurring in central-eastern Poland: *Arctostaphylo-Callunetum cladinetosum*, *Arctostaphylo-Callunetum typicum*, *Arctostaphylo-Callunetum thymetosum serpyllii* and *Arctostaphylo-Callunetum vaccinietosum myrtilli*, and in each subassociation – 3, 3, 4 and 4 variants, respectively. Furthermore, Kujawa-Pawlaczyk (2004) found that species characteristic of thermophilous tall herb vegetation (so called “saum” or fringe vegetation) from the class *Trifolio-Geranietea*

sanguinei, psammophilous grasslands from the class *Koelerio glaucae-Corynepherea canescentis* and less frequently xerothermic grasslands from the class *Festuco-Brometea* occur in relevés made in phytocoenoses of bearberry heaths in Poland, in addition to species characteristic of the association and the alliance *Calluno-Arctostaphyllion*.

According to Kujawa-Pawlaczyk (2004), the rate of natural succession processes is relatively high in bearberry heaths. In the most extreme habitats, *Arctostaphylo-Callunetum* occurs as a long-term community. An increase in the substrate eutrophication and, in particular, changes in the light and edaphic conditions result in the transformations of this community towards mesophytic fringe communities, followed by forest communities. It follows from the above relationships that the causes of bearberry heath extinction are similar as in the case of lichen Scots pine forests *Cladonio-Pinetum*.

Succession processes may contribute to the withdrawal of bearberry-heath components, including many rare and threatened (on a regional scale) plant species. According to Kujawa-Pawlaczyk (2004), such protected and threatened species (components of bearberry heaths) include e.g. *Botrychium lunaria*, *Lycopodium clavatum*, and *Arctostaphylos uva-ursi*. On the other hand, species from Appendix II of the EU Habitats Directive are represented by *Botrychium simplex* and *Thesium ebracteatum*. Bearberry heaths are also the potential habitat of the butterfly *Polyommatus eroides*.

As evidenced by the observations conducted by Chojnacka et al. (2010a, b) on the military training ground in Toruń, as well as by Kunz and Nienartowicz (2010) in the district of Glinki in the south-western part of Toruń, the extinction of *Arctostaphylos uva-ursi* might be caused by withdrawal of this species, replaced by heather *Calluna vulgaris*. It appears from observations that the community of *Arctostaphylo-Callunetum* is a pioneering system as compared to *Pohlio-Callunetum*.

To preserve the process of changes in the habitat and the species withdrawal, it is necessary to implement, as in the case of *Pohlio-Callunetum* heaths, active conservation which consists in prevention of heath overshadowing and an increase in trophic status and soil moisture. The only new form of active conservation of bearberry heaths, in relation to treatments recommended for heaths with *Pohlia nutans*, applies to the subassociation *Arctostaphylo-Callunetum cladinetosum mitis*. This type of heaths develop on the most infertile, driest and warmest habitats, often accompanied by psammophilous grasslands from the class *Koelerio glaucae-Corynepherea canescentis*

and should be subjected to a special treatment consisting in periodic removal ("tearing off") of the vegetation layer to expose the bare soil. This treatment can be carried out along the margins of pine forests, roadsides and on sunny escarpments. If bearberry heaths occur within dry pine forests, gaps between forest stands (allowing light penetration) should be preserved. This treatment is feasible through proper types of forest cutting, in particular selective felling.

Conservation measures should be followed by monitoring of the habitat status and assessment of the ongoing changes. According to Kujawa-Pawlaczyk (2004), the range of observations and monitoring procedures should be the same as in the case of *Pohlio-Callunetum* heaths.

2. Heathland tour in Kujawy and Pomerania

The second part of the book consists of 12 chapters. The first one presents heaths occurring on the active artillery range in the southern part of Toruń and in the vicinity of the city. The area is located on the left bank of the Vistula River and is part of the historical region referred to as Kujawy. The south-western boundary of this region runs along the Upper Noteć River.

The other eleven sites described in the second part of the book are located in the region of Pomerania. Three of these sites are heaths occurring on the former training grounds. One of them (JAR) was thoroughly inspected by sappers and cleared of unexploded shells, and then designated for a residential district. At two sites (near Okonek and Borne Sulinowo), works are continued under the project implemented by State Forests to clear the area of dangerous material, to restore the environmental values, and to make the area available for recreation and tourism.

The European dry heaths occur at most of the described sites. Wet heathlands occur at only one of them (Bielawa nature reserve). At one of the described sites (Przymuszewo Forest Division), large heathlands used for sheep grazing occurred in the 19th century. At present, these lands are almost completely afforested. One of the sites (Odry) is an archaeological and nature reserve. This part of the book presents methods of heath-landscape exploitation in the past.

No heaths occur at two sites, i.e. Gruczno and Staniszewskie Błoto. However, interesting and effective methods of active conservation of xerothermic grasslands, peat bogs and forests are applied.

Location of the sites is presented in Fig. 1.



Figure 1. The route of the 14th European Heathlands Network Workshop, Poland 2015

2.1. Structure and functioning of heathlands in the artillery range in Toruń and its surroundings

2.1.1. Introduction

In the present conditions of Poland, heaths generally develop over small areas in the landscape of pine forests, less frequently mixed forests. Those are forest glades, unsuccessful forest plantations, land division lines and power lines, roadsides, railway embankments etc. Larger areas of the aforementioned heaths occur most frequently on the military training grounds.

The effects of operations carried out by soldiers during their training courses on the military grounds, such as explosions of shells and missiles, fires of forests, devastation of the soil and vegetation by tanks, conveyors and artillery guns, construction of trenches, observation points and battle stations, as well as trampling the ground by people act as inhibitors of the succession process of phyto- and zoocenoses, and ecosystems.

There are seven large training areas in Poland, with a total area of over 90,000 ha. 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 created at the beginning of the 17th century and extended during the next centuries, reaching the area of more than 12,000 ha (Wasilewski, 2004). Since the beginning of the 1990s, the area of the so-called working range, used for training of artillery armed forces, has gradually decreased. At present, besides a decrease in the training area, also the frequency and the intensity of military trainings have decreased. Species of shrubs and trees, previously destroyed by artillery, have begun to encroach on dunes covered with heaths and psammophilous grasslands.

The flora and plant communities of the artillery training ground in Toruń, especially the heaths and psammophilous grasslands developing in the conditions of unique human influence inspired the interest of botanists and ecologists a long time ago. The oldest, published floristic data related to the studied area come from the papers by Scholz (1896), Abromeit et al. (1898) and Preuss (1912). According to other botanical observations conducted in this area by, inter alia, Tüxen (1942),

Gawłowska (1964), Werdyn (1964), Walas (1969), Wilkoń-Michalska (1971), Ceynowa-Gieldon (1984) and Nienartowicz et al. (2010), the training ground and the whole Toruń Basin are one of the main regions of the abundant occurrence of kinnikinnick bearberry and bearberry heaths in Poland.

However, a difficult access to 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 the exploitation and implementation of the EU Programme Natura 2000 in Poland, the area of the training ground is more accessible by naturalists, not only from Poland but also from other parts of Europe. This creates favourable conditions for understanding the structure and the determination of directions in further transformations of ecological systems occurring in the area. With the conviction that the results of international research will provide further information on the chorology as well as spatial and temporal variability of heaths, both in Poland and in Europe, we present an interesting reference study area – the “artillery training range in Toruń”.

2.1.2. Location of the artillery range

The artillery range stretches from the Toruń city limits in the north (Figs 1 and 2) to the surroundings of Aleksandrów Kujawski in the south. It borders on the railway lines Toruń – Aleksandrów Kujawski in the east and on the road Toruń – Gniewkowo – Inowrocław in the west. The southern boundary runs along the Tążyna rivulet, at the longitude of the Otłoczyn village, to the Grabie village and further to the village of Suchatówka along the road leading to the town of Inowrocław. The training ground has a shape of pentagon and covers more than 12,000 ha; its total length is ca. 16 km, and the width – ca. 13 km (Wasilewski, 2004). It is located within the commune of Wielka Nieszawka. Since the area is included in the Forest Division of Gniewkowo, which is under the Regional Administration of State Forests in Toruń, it represents the property of State Treasury. The training ground is used by the Centre for Artillery and Weaponry Training in Toruń.

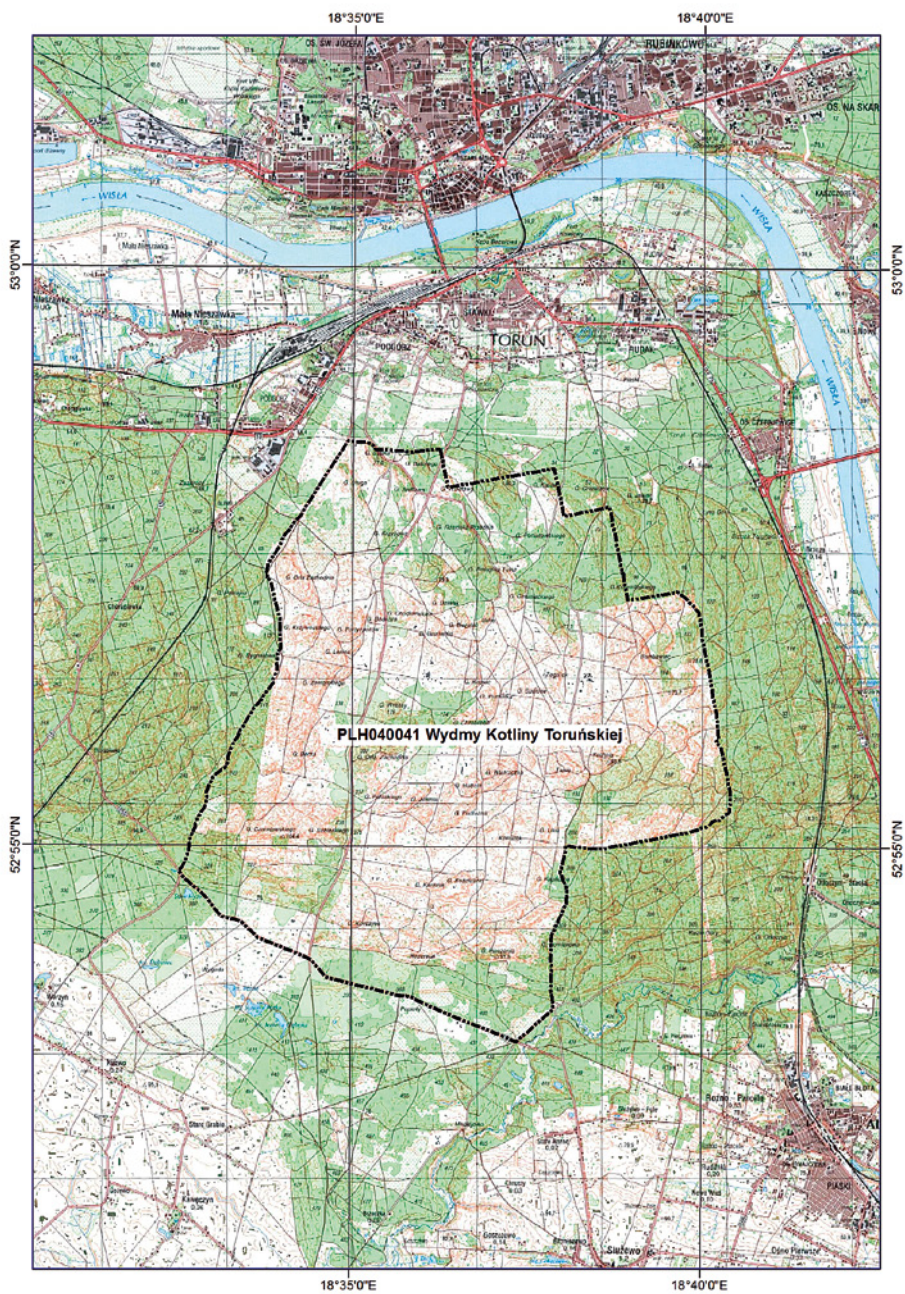


Figure 1. Military grounds near Toruń with the boundary of the Nature 2000 site “Wydmy Kotliny Toruńskiej” (“Dunes of the Toruń Basin”)



Figure 2. Military grounds near Toruń on the orthophotomap

According to the regional, physical and geographical division of Poland presented by Kondracki (2001), 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 Basin (also called the Toruń-Bydgoszcz Basin, which is 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 presented 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).

2.1.3. History of the artillery range

The 400-year long history of the training ground is closely connected with the city of Toruń which was ruled by different states 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; while the area south of the city, together with the bridge abutment protecting the access to the bridge and the city, was the place of fierce battles. Therefore, the city had to maintain relatively strong defence forces (mostly artillery), which had to be trained and prepared for wars. The area was needed for military tasks. Beyond the Vistula River, the present-day central part of the training ground (south of the city) was not inhabited due to infertile soils. And thus, the area could be used for military trainings (Wasilewski, 2004).

The most intensive development of the training ground took place 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 the prisoners of war for all the work. At that time, a railway siding was built for the ammunition depots as well as a narrow-gauge railway running along the then boundaries of the working field of the training ground, which was used for the distribution of supplies and ammunition. Large areas of forests were cut down for that purpose. Until 1884, the area of about 900 ha was developed. During the next years, almost 4900 ha were purchased for the military purposes pursuant to the Prussian act on the land

purchasing. About two-thirds of that area was designated for the military training ground. Already before World War I, a training camp for about 20,000 soldiers was located in the training ground located directly at the Prussian-Russian border. During the 1st World War, the training ground covered 3293 ha.

In January 1920, Toruń together with the adjacent training ground returned under the rule of the Polish State. In 1921, the School of Artillery Firing was opened as part of the Artillery Training Centre. At that time, the area of the artillery range used by the Polish Army was 3,890.7 ha.

The last years before World War II were characterized by systematic intensification of trainings on the Toruń training ground. The invasion of the Wehrmacht troops in 1939 and the Nazi occupation in the following years completely changed the nature of this place. At the beginning of the occupation, a training yard for anti-tank artillery was built. For that reason, hundreds of hectares of forest were cut leaving the dunes exposed, which were then turned into a training ground 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.

After World War II, the area was used as an artillery range for the Polish Armed Forces. During that time, access roads were extended, the working field was protected against fires of grass and forest, margins of the training ground were marked, the equipment was modernized. The training ground became a base for the education and training of artillerymen, e.g. at the Military Academy of Missile and Artillery Forces in Toruń. During the 1970s, the intensive artillery firing was practiced. At that time, tens of thousands of tons of ammunition were allocated and stored. During the 1980s and the 1990s, the military trainings were continued but due to financial reasons, they were performed over a smaller area as compared to the previous trainings (Dzięgielewski, 1997).

2.1.4. Management of military training grounds

At present, the training ground represents ca. 54% of the Gniewkowo Forest Division, including almost the entire District of Ołtoczyn. Forests of the training ground (5,138.51 ha) represent over

34% of the Gniewkowo Forest Division. The training activity of the armed forces is limited and any land use must be agreed with the administration of State Forests. The largest part of the training ground is represented by areas of miscellaneous use (6,934.26 ha), where the Forest Division does not conduct any silviculture and which is reserved for training sessions, classes and firing by armed forces. This part represents a working field of 7,850.90 ha, isolated from the remaining area of the training ground. Training and technical facilities, firing and bombardment zones, fire stations and observation points are located in this area. After World War II, the area of the working field within the training ground has slowly decreased. Intensive development of the area takes place in the northern side, especially along the communication routes. During the last few years, a clearway was built at the northern end of the training ground, which represents a southern ring road of Toruń.

2.1.5. Nature of the artillery range

2.1.5.1. Geology, geomorphology and other abiotic factors

In the District of Otłoczyn (part of the Gniewkowo Forest Division), within the boundaries of which the artillery range is located, two geological and soil formations cover most of the area: aeolian deposits, dunes and aeolian sands – 51.7% of the total area, and the fluvial sands of the old Pleistocene river terraces – 36.1% of the District's area.

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

Dunes located in Poland are the central part of the European sand belt (Fig. 3), which stretches from Great Britain to the east border of Poland (Zeeberg, 1998), or even to the basin of the Pechora River (Mangerud et al., 1999). The sand belt is divided into two zones east of the Polish borders. The southern zone stretches across Belarus and Ukraine, while the northern zone stretches in a north-east direction.

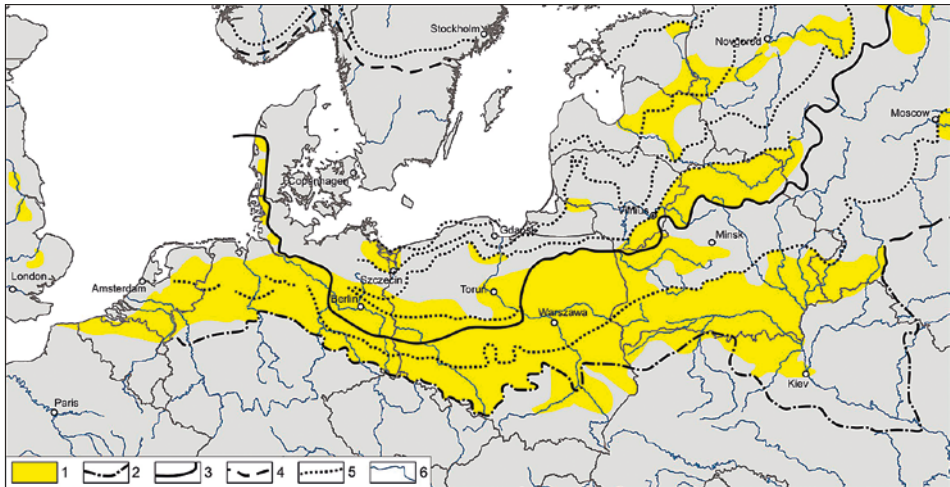


Figure 3. Location of the Toruń Basin in relation to the European Sand Belt (Andrzejewski and Weckwerth, 2010, after Zeeberg, 1998). 1 – sand belt, 2 – Saalinian maximum ice margin, 3 – Weichselian maximum ice margin, 4 – ice margin in the Younger Dryas, 5 – substage range, 6 – main rivers

Dunes in the Toruń Basin are distributed on all Vistula terraces and they form large dune groups. Locally, they are also found on the adjacent morainic plateaus. Mrózek (1958) distinguished six dune fields: I – the Bydgoszcz Dune Field between Lake Jezuićkie, the valley of the Old Noteć River and the city of Bydgoszcz; II – the Łabiszyn Dune Field between Brzoza, Łabiszyn and Smolniki; III – the Solec-Chrośna Dune Field between Solec Kujawski, Osiek Wielki, Nowa Wieś Wielka and Lake Jezuićkie; IV – the Toruń-Aleksandrów-Gniewkowo Dune Field; V – the dune field between the Mień River and the Drwęca River; and VI – the dune field between the Drwęca River and the Vistula gap at Fordon. The aeolian forms at the two latter locations are, however, often scattered over large areas.

The artillery range is located within the dune field no. IV (the towns of Toruń, Aleksandrów and Gniewkowo), on the left margin of the ice-marginal valley between the Zielona River and the Tążyca River. In this part of the valley, aeolian deposits occur mainly on the upper, middle (V, VI) and lower terraces, and in smaller assemblages – also on the alluvial terrace no. 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 deficiency 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 runoff very quickly, infiltrating deep into the soil. On the other hand, the supply of rainwater is small. The precipitation in the neighbourhood of Toruń is one of the lowest in Poland. According to the data obtained by the Base Station in Koniczynka under the 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 (Uscka-Kowalkowska and Kejna, 2009).

The training ground is characterized by a relatively homogeneous soil cover. The rusty soil dominates and covers 83.5% of the total area, including the subtype of podzolized soil – 62.4%. Those are mainly soils developed from aeolian sands and sands of old river terraces. They cover the largest part of the remaining complex of the Otłoczyn District. In the northern and central part of the complex (also included in this study), soils developed from loose rocks occur on the tops of dunes or on flat surfaces of aeolian sands, exposed to secondary aeolian processes. They cover 4.5% of the District's area.

2.1.5.2. Vegetation

2.1.5.2.1. Non-forest plant communities

A total of 10 associations (W. Matuszkiewicz, 2007) and four plant communities were identified in the course of phytosociological studies conducted on the non-forest area of the artillery range. They are classified within 4 classes:

Class: EPILOBIETEA ANGUSTIFOLII R. Tx. et Prsg 1950

Order: *Atropetalia* Vlieg. 1937

Alliance: *Epilobion angustifolii* (Rubel 1933) Soo 1933

Calamagrostietum epigeji Juraszek 1928

the typical form

the form with *Vincetoxicum hirundinaria*

Alliance: *Sambuco-Salicion* R. Tx. et Neum. 1950

the community with *Betula pendula*

the community with *Populus tremula*

the community *Salix acutifolia-Epipactis atrorubens*

Class: KOELERIO GLAUCAE-CORYNEPHORETEA CANESCENTIS

Klika in Klika et Novak 1941

Order: *Corynephorretalia canescentis* R. Tx. 1937

Alliance: *Corynephorion canescentis* Klika 1934
Spergulo vernalis-Corynephoretum (R. Tx. 1928) Libb. 1933
Corniculario-Corynephoretum (R. Tx. 1928) Steffen 1931
Caricetum arenariae Steffen 1931

Alliance: *Koelerion glaucae* (Volk 1931) Klika 1935
Caricetum ligericae Kępczyński et Rutkowski 1988
Festuco psammofilae-Koelerietum glaucae Klika 1931
Festuco psammophilae-Elymetum arenarii Steffen 1931

Class: FESTUCO-BROMETEA Br.-Bl. ex R. Tx. 1943

Order: *Festucetalia valesiaca* Br.-Bl. et R. Tx. 1943

Alliance: *Festuco stipion* (Klika 1931) Krausch 1961
Scorzonero purpureae-Stipetum joannis (Ceynowa 1968)
Brzeg in Brzeg et M. Wojterska 2001

Class: NARDO-CALLUNETEA Prsg 1949

Order: *Calluno-Ulicetalia* (Quant. 1935) R. Tx. 1937

the community with *Cytisus scoparius*

the typical form

the form with *Dianthus carthusianorum*

Alliance: *Pohlio-Callunion* Shimwell 1973 em. Brzeg 1981

Pohlio- Callunetum Shimwell 1973 em. Brzeg 1981

the variant with *Dianthus carthusianorum*

the subvariant with *Molinia caerulea*

the typical subvariant

the form with *Pleurozium schreberi*

the typical variant

the form with *Pleurozium schreberi*

Alliance: *Calluno-Arctostaphylion* R. Tx. et Prsg 1949

Arctostaphylo-Callunetum R. Tx. et Prsg 1940

the variant with *Thymus serpyllum*

the typical variant

Calamagrostietum epigeji is the most common association in the study area. It occurs mainly in the central and southern part of the artillery range. Despite the abundant occurrence, the population of *Calamagrostis epigejos* does not reduce the development of other plants, therefore it consists of 65 species of vascular plants, 12 taxa of lichens and 10 mosses. Apart from the dominant species, also species from the classes *Nardo-Callunetea* and *Festuco-Brometea* occur in relatively large numbers. The association is composed of rare species, such as: *Oenothera pycnocarpa*, *O. royfraseri*, *Pulsatilla pratensis* and

Rosa sherardii. The aforementioned association is extremely expansive. It became a dominant community in the southern part of the artillery range and continuously extends its range.

The community with *Betula pendula* and the community with *Populus tremula* are represented by groves with young birch and aspen trees scattered in the open landscape. Both were classified as syntaxonomic units of the class *Epilobietea angustifolii* and the alliance *Sambuci-Salicion*.

The community of *Salix acutifolia*-*Epipactis atrorubens* is rich in species. It is composed of 66 species of vascular plants, 11 species of bryophytes and 19 taxa of lichens. *Botrychium lunaria* occurs only in this community, at one location. *Astragalus arenarius*, *Festuca psammophila* and *Helichrysum arenarium* occur in the largest numbers. The average cover of the shrub layer is 29%. In addition to *Salix acutifolia*, the following species occur: *Berberis vulgaris*, *Betula pendula*, *Crataegus monogyna*, *Frangula alnus*, *Pinus sylvestris*, *Populus x canescens*, *P. tremula*, *Padus serotina*, *P. virginiana*, *Pyrus pyraster*, *Quercus robur* and *Sorbus aucuparia*. The existence of the community may be threatened by cessation of the military penetration on dune crests, the increased density of the shrub layer, or the dominance of *Calamagrostis epigejos*.

Epipactis atrorubens, the population of which consists of up to ca. 2300 specimens within the artillery range, occurs as a component of thickets and xerothermic grasslands in central Europe. The presence of this species on coastal dunes (stabilized also by *Salix acutifolia*) was described by e.g. Wojterski (1957), Wojterski and Bednorz (1982) and Filingier (1992). It seems that this helleborine species prefers poorly stabilized dunes, bare or overgrown with thermophilous thickets of shrubs, including willows.

The association *Spergulo vernalis*-*Corynephorum* covers a very large area. It develops in the most complete form on insolated slopes of the southern, less frequently western exposure. The association is characterized by the dominance of the tussock grass *Corynephorus canescens*, which is accompanied by *Spergula vernalis*. This pioneer, scattered, floristically poor community initiates the process of secondary succession on sandy dunes (Namura-Ochalska, 2004). Annual species occur in spring on bare sand between tussocks of *Corynephorus canescens*, including previously mentioned *Spergula vernalis* which vanishes just after seeding. In the more advanced developmental phases, when the substratum is increasing stable, smaller or bigger clusters of

lichens begin to appear, mostly from the genus *Cladonia* and mosses, including mainly *Polytrichum piliferum*. The frequent presence of heath plants, such as: *Hieracium pilosella* and *Calluna vulgaris*, is a significant characteristic feature of this association. As compared to typical dry heaths, the latter species occurs less abundantly and usually on the peripheries. Also species differential of the coniferous forests from the class *Vaccinio-Piceetea* are components of *Corynephorus* grasslands in the studied area. Scots pine *Pinus sylvestris* and European white birch *Betula pendula* frequently occur.

Corniculario-Coryneporetum is one of the most common associations within the artillery range. It is composed of 59 species, including 39 species of vascular plants, 4 species of mosses, 15 taxa of lichens and 1 alga. *Corynephorus canescens* and *Spergula morisonii* are the dominant species. In the initial phases of the association, the vegetation structure is very scattered, and first the turfs of *Polytrichum piliferum* and thalli of *Klebsormidium crenulatum* appear on the sand. *Cetraria aculeata*, *Cladonia macilenta* and *C. cervicornis* dominate in the layer of lichens and mosses. Among the accompanying plants, species from the class *Nardo-Callunetea* occur in large numbers, particularly *Carex ericetorum*.

The association *Caricetum arenariae* was described by Kępczyński and Rutkowski (1988) from the Toruń Basin. It is rich in species and comprises 34 vascular species, 13 lichens and 6 bryophytes. It covers small areas (50–300 m²) in the northern and western part of the artillery range. Occasionally it occurs as an initial community, contributing to the stabilization of dunes. The remaining species from the class *Koelerio-Coryneporetea*, and particularly *Helichrysum arenarium* and *Polytrichum piliferum* play an important role in the association.

The association *Caricetum ligericae* also occurs on small areas in the northern part of the range, often in the vicinity of the association of the sand sedge. It prefers a stabilized sand with a well-developed soil (Kępczyński and Rutkowski, 1988). The composition of the association consists of 50 species, including as many as 47 vascular plants, and just 1 moss and 2 lichen species. *Carex ligerica* dominates in all the studied phytocoenoses.

The association *Festuco psammophilae-Koelerietum glaucae* is one of the rarest associations within the artillery range and some larger patches are present only at two sites in its central part. The association is floristically poor – 34 species, including 28 species of vascular plants, 3 lichens and 3 mosses. *Koeleria glauca* is the dominant species, and

Hieracium pilosella and *Festuca duvalii* are co-dominants. Locally *Tragopogon floccosus* is a good differential species. The association is floristically poorer than the one described by Symonides (1972) from the Zadroże Dune, where the presence of 49 plant vascular species was recorded, as well as 10 species of lichens and 1 moss species. In the Wielkopolska Region, Brzeg and Wojterska (2001) defined this community as rare, exposed to impoverishment and simplification of the structure.

The association *Festuco psammophilae-Elymetum arenarii* is a pioneer community growing on dunes. Its occurrence in the Vistula River valley is accounted for by migration from coastal areas and human activity. Within the artillery range, it covers elevated roadsides, firebreaks strips and tank routes. Phytocoenoses of the association are usually small and occur mainly in the northern part of the range. The association is characterized by a small contribution of characteristic species, mainly *Corynephorus canescens* and *Polytrichum piliferum*. Also *Klebsormidium crenulatum* occurs. In total, 45 species were recorded in the association, including 32 vascular plants, 9 lichens and 4 mosses. As in the Wielkopolska region, it is a rare xenospontaneous community under indeterminate threat (Brzeg and Wojterska, 2001).

The association *Scorzonero purpureae-Stipetum joannis* occurs mainly in the eastern part of the range ("Piaski"). In the remaining area, it occurs in the form of small patches on the slopes of dunes, in the depressions between elevations and along roadsides. The association is rich in species. It consists of 90 species, including 68 species of vascular plants, 14 species of lichens and 8 species of bryophytes. Between tussocks of *Stipa joannis*, the following species grow: *Asperula tinctoria*, *Filipendula vulgaris*, *Helianthemum nummularium* ssp. *obscurum*, *Phleum phleoides*, *Pulsatilla pratensis*, *Scorzonera purpurea*, *Thesium linophyllum*, *Veronica jacquinii* and others. In the Wielkopolska region, the association has a status of a very rare community, directly threatened with extinction (Brzeg and Wojterska 2001).

The community with *Cytisus scoparius* covers areas adjacent to heathlands *Pohlio-Callunetum* and *Arctostaphylo-Callunetum*, as well as grasslands of the grey clubawn grass *Spergulo vernalis-Corynephoretum*. Based on the analysis of relevés from the training ground, two forms of the described community, i.e. the typical one and with *Dianthus carthusianorum* were distinguished by Chojnacka et al. (2010a).

The typical form covers gentle slopes with northern or southern exposure. Apart from the dominance of common broom *Cytisus*

scoparius, 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 should be emphasized that due to considerable shading in the central parts of the vegetation patches, caused by the common groom, the aforementioned species (similarly to lichens and mosses) usually occur along the peripheries of the community.

The form with *Dianthus carthusianorum* differs from the typical form mainly in the higher abundance of species. Usually it develops in flat places. The phytocoenoses are distinguished by the presence of *Dianthus carthusianorum*, as well as by a high constancy of *Hypericum perforatum* and species from the class *Koelerio glaucae-Corynephoretea canescentis*, such as: *Jasione montana*, *Scleranthus perennis*, *Hypochaeris radicata*, *Helichrysum arenarium* and *Rumex acetosella*. The layer of mosses and lichens is more properly developed compared to the typical form. Among others, *Pohlia nutans*, *Dicranum scoparium*, *Cladonia coniocraea*, *C. deformis* from the class *Nardo-Callunetea* occur, 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, including mainly: *Solidago virgaurea* and *Deschampsia flexuosa*, and single specimens of *Pinus sylvestris* and *Betula pendula*.

The phytocoenoses of ***Pohlio-Callunetum*** occur in the form of dwarf shrubs, distinguished by the dominance of Scots heather *Calluna vulgaris*. 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* and heath sedge *Carex ericetorum*. Forest succession occurs in some of the vegetation patches, which is manifested in the presence of seedlings and undergrowth of trees, especially Scots pine *Pinus sylvestris* and European white birch *Betula pendula*.

According to Chojnacka et al. (2010a), the association *Pohlio-Callunetum* is differentiated into two variants: typical and with clusterhead pink *Dianthus carthusianorum*. The typical variant is poor in species. It is characterized by strong dominance of *Calluna vulgaris*. In addition to the aforementioned species, the herb layer is composed mostly of *Carex ericetorum*, *Hieracium pilosella*, *H. umbellatum* from the order *Calluno-Ulicetalia* and from the class *Nardo-Callunetea*. The species characteristic and differential of the association *Pohlio-*

Callunetum and the alliance *Pohlio-Callunion* are represented by mosses and lichens occurring in small numbers: *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 species from the class *Vaccinio-Piceetea* – mainly by *Deschampsia flexuosa*.

The form with *Pleurozium schreberi* was distinguished within the vegetation patches classified into the typical variant. Its phytocoenoses cover shaded places with northern or north-eastern exposure, usually in the vicinity of coniferous forests. They are characterized by a 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 distinguished 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 with purple moor grass *Molinia caerulea*. The latter develops mainly in the 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, forming a relatively well-developed layer of mosses and lichens. Apart from the purple moor grass *Molinia caerulea*, usually also chee reedgrass *Calamagrostis epigejos* occurs in the layer of herbaceous vegetation. Mosses and lichens are represented mainly by: *Pohlia nutans*, *Dicranum scoparium*, *Polytrichum piliferum*, *Ceratodon purpureus*.

The typical subvariant may differentiate into the form with *Pleurozium schreberi*, which develops in places adjacent to pine forests. The 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*.

Arctostaphylo-Callunetum – phytocoenoses of the bearberry heath cover a much smaller area. They develop in the form of two variants: typical and with wild thyme *Thymus serpyllum*.

The typical variant usually covers insolated sites on the tops of dunes and hills, less frequently on slopes with small inclination and southern

exposure. *Arctostaphylos uva-ursi* clearly dominates. Clusters of heather are small and very sparse. Therefore, heliophilous species of lichens may occur on the exposed soil beneath the heather, mainly *Cladonia arbuscula* subsp. *mitis*, *C. furcata*, *C. cervicornis* and *C. chlorophaea* s. l. The high abundance of kinnikinnick bearberry is related to the type of habitat, which is open and exposed to strong insolation (Fig. 4). In addition to bryophytes and lichens, often other short plants occur in the patches of the described community, e.g. *Hieracium pilosella*. Also seedlings of trees and shrubs occur as scattered single specimens, including mainly Scots pine *Pinus sylvestris* and European white birch *Betula pendula*. Depending on the light conditions, the groundcover is 80–90%, and the moss layer – from 5 to 20%.



Figure 4. *Arctostaphylos uva-ursi* on heathlands located in the vicinity of military grounds in Toruń

The variant with *Thymus serpyllum* is most common at sites with sunny and warm exposure, but not on the tops of hills and other elevations. Usually it occurs on flat areas or on slopes with small inclination. The phytocoenoses are characterized by the dominance of *Calluna vulgaris* which often forms facies. The heather reduces the access of light and consequently 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 phytocoenoses of the variant, which are characterized by a higher number of species, ranging from 23 to 36. At the same time, their floristic composition is represented by many species of sandy grasslands from the class *Koelerio glaucae-Corynephoretea canescentis*, such as the aforementioned *Thymus serpyllum*, or *Corynephorus canescens* and *Potentilla argentea*. Whereas the heath plants are represented by *Hieracium pilosella* and 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*, as well as lichens and mosses: *Cladonia arbuscula* subsp. *arbuscula*, *C. fimbriata* s. l., *C. rangiferina*, *Dicranum undulatum*, *Pleurozium schreberi*. Furthermore, also species from the class *Festuco-Brometea* and *Trifolio-Geranietea* occur: *Potentilla arenaria*, *Hypericum perforatum*, *Galium verum*, *Dianthus carthusianorum*, *Euphorbia cyparissias*, *Anthericum ramosum*, *Achillea pannonica* and *Filipendula vulgaris*.

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

In the numerical classification of *Arctostaphylo-Callunetum* relevés carried out with the use of three agglomerative hierarchical methods, the association *Arctostaphylo-Callunetum* from the artillery range near Toruń is clearly different from the sets of relevés from bearberry heaths from the central-eastern and north-eastern parts of Poland and

heathlands near Leningrad in Russia. Sometimes relevés form clusters with relevés from the central and western part of Poland (Fig. 5).

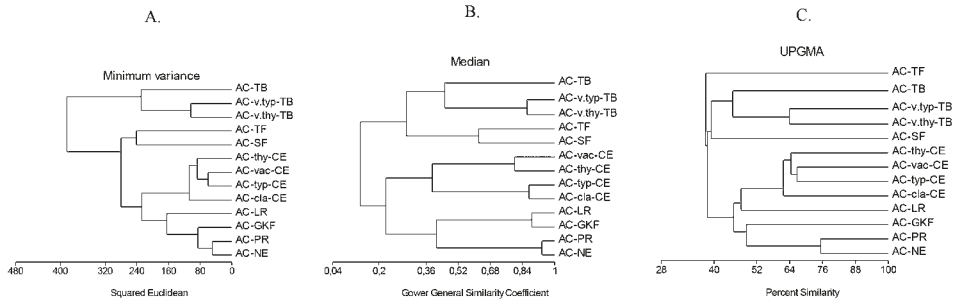


Figure 5. Dendrograms constructed with the minimum variance method (A), median method (B) and UPGMA (C), for 13 sets of relevés made in *Arctostaphylo-Callunetum* and in similar plant communities. Symbols of objects: 1 – AC-NE – *Arctostaphylo-Callunetum*, Białystok near Elk, North-Eastern Poland, source: Faliński & Bartel (1965); 2 – AC-P&R – *Arctostaphylo-Callunetum*, North-Eastern Poland and Russia, Tüxen (1942); 3 – AC-GKF – *Arctostaphylo-Callunetum*, Green Kurpie Forest, Faliński (1965); 4 – AC-LR – *Arctostaphylo-Callunetum*, Lublin Region, Fijałkowski (1993); 5 – AC-SF – *Arctostaphylo-Callunetum*, Skwierzyna Forest, Balcerkiewicz and Brzeg (1993); 6 – AC-cla-CE – *Arctostaphylo-Callunetum cladonietosum*, Central-Eastern Poland, Ciosek (2000); 7 – AC-typ-CE – *Arctostaphylo-Callunetum typicum*, Central-Eastern Poland, Ciosek (2000); 8 – AC-thy-CE – *Arctostaphylo-Callunetum thymetosum serpylli*, Central-Eastern Poland, Ciosek (2000); 9 – AC-vac-CE – *Arctostaphylo-Callunetum vaccinietosum myrtilli*, Central-Eastern Poland, Ciosek (2000); 10 – AC-v.t-TB – *Arctostaphylo-Callunetum* typical variant, artillery range near Toruń, Chojnacka (2008); 11 – AC-v.Ts-TB – *Arctostaphylo-Callunetum* variant with *Thymus serpyllum*, artillery range near Toruń, Chojnacka (2008); 12 – AC-TB – *Arctostaphylo-Callunetum*, Toruń Basin, Gugnacka-Fiedor and Adamska (2009); 13 – AC-TF – *Arctostaphylo-Callunetum*, Tuchola Forest, Meller (1994)

2.1.5.2.2. Regularities in the occurrence of heathlands in dune fields

The pattern of heather patches and patches of other plant species in dune fields of the artillery range in Toruń was studied by Jankowski (2010). He observed that up to 30 m high bow-shaped dunes at the Chorągiewka study site form a regular pattern of parallel ridges stretching from the north-east to the south-west. Also the vegetation shows a clear regularity regarding the exposure. Slopes of dunes facing the south-east (distal) are covered with grasslands of *Calamagrostis epigejos* and north-western slopes (proximal) are overgrown with dense heathlands. Patches of both types of vegetation form mosaics also at the bottoms of depressions between dunes.

A regular pattern in the distribution of vegetation reflects the site conditions. Although topoclimate and light relationships are rather obvious, the soil conditions seem to be more complex. The pattern of soils follows the exposure. Arenosols are typical soils of grasslands on south-eastern slopes and podzolized soils (haplic podzols, albic arenosols) – on north-western slopes covered with heather. Flat bottoms of depressions between dunes are built of slightly richer glaciofluvial sediments and are covered by generally well-preserved rusty soils (IUSS 2007: brunic arenosols).

Arenosols under the dense cover of *Calagrostis epigejos* are different from those found in the other parts of the military grounds, i.e. under *Spergulo-Corynephorretum* developed on the former eroded soil (Bs, BC or C) with a well-developed humic Ad horizon. Podzolic soils under the heather investigated by Jankowski (2010) at the Chorągiewka site on the military ground represent the early stage of podzolization. Their structure is: AE-E-Bs-C, but the Bs horizon does not meet the criteria of the spodic horizon according to the WRB classification (IUSS 2007).

The clear variability of the soil cover resulting from the exposure of dune slopes is interpreted as a consequence of varied susceptibility to deflation and erosion in case of vegetation destruction. The south-eastern slopes (distal) are more steep and more dry. They are eroded very easily, which results in the development of the next generation of young soils (arenosols). The north-western slopes are less sunny and more humid, and thus more resistant to geomorphological processes. Thus, older podzolic soils could be much more preserved as relics of the former forest landscape. In the surrounding area, podzolization is the dominant soil-forming process on dunes overgrown with pine forests, regardless of the exposure (Jankowski, 2003, 2007, 2010). In the literature, heather is considered as a plant that induces the podzolization process in the soil, although to a lesser extent than coniferous trees (Nørnberg et al., 1993; Mossin et al., 2001).

On the other hand, arenosols under grasslands show higher accumulation of nitrogen together with organic matter in the sod humic Ad horizon, which stimulates the expansion of grasslands and reduces the development of heathlands (Heil and Diemont, 1983). It is noteworthy that due to the development of the sod-like humic horizon, arenosols under *Calamagrostis epigejos* on the south-eastern slopes can be periodically even more humid than podzolized soils under the heather covering the north-western slopes.

2.1.5.2.3. Forests and groves of birch and aspen trees

At present, heaths and psammophilous grasslands dominate in the studied part of the artillery range near Toruń but in many places, the landscape is enriched with forests of varying size and varying developmental phases. Communities dominated by pine dominate. A large area is covered by groves of birch and aspen trees, as well as birch and pine woods. Their age varies and ranges from 5 to 65 years. Most of the tree stands are 21–30 years old.

Moreover, a small area is covered by forests with some contribution of oak and hazel thickets. In phytosociological terms, pine forests from the class *Vaccinio-Piceetea* dominate in the study 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*.

According to Melkowska (2009), pine forests of the artillery range belong to the subcontinental association *Peucedano-Pinetum* which differentiates into three variants: the variant with *Geranium sanguineum*, the typical variant and the poor variant. They differ in the number of species occurring in their species composition. 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 m². In the typical and the poor variant, the average number of species ranges from 22 to 16, respectively.

Out of the three variants, the variant with *Geranium sanguineum* is the most heterogeneous in terms of the species composition. It differentiates into two subvariants: the subvariant with *Molinia caerulea* and the typical one.

Melkowska (2009) distinguishes the following syntaxa of deciduous forests: the community with *Corylus avellana* on 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* on the habitat of pine forest *Peucedano-Pinetum*.

The syntaxonomic classification of forest communities occurring in the artillery range in Toruń and described in various literature sources is as follows:

Class: VACCINIO-PICEETEA Br.-Bl. 1939

Order: *Cladonio-Vaccinetalia* Kiell.-Lund 1967

Alliance: *Dicrano-Pinion* Libb. 1933

Suballiance: *Dicrano-Pinenion* Seibert in Oberd. (ed.) 1992 em.

Peucedano-Pinetum W. Mat. (1962) 1973

the variant with *Geranium sanguineum*

the subvariant with *Molinia caerulea*

the typical subvariant

the typical variant

the poor variant

Class: QUERCETEA ROBORI-PETRAEAE Br.-Bl. et R. Tx. 1943

Order: *Quercetalia roboris* R. Tx. 1931

Alliance: *Quercion robori-petraeae* Br.-Bl. 1932

Calamagrostio arundinaceae-Quercetum petraeae

(Hartm. 1934) Scam. et Pass. 1959

Class: QUERCO-FAGETEA Br.-Bl. et Vlieg. 1937

Order: *Quercetalia pubescenti-petraeae* Klika 1933 corr. Moravec
in Beg. et. Theurill 1984

Alliance: *Potentillo albae-Quercion petraeae* Zól et Jakucs n. nov.
Jakucs 1967

Potentillo albae-Quercetum Libb. 1933

Order: *Fagetalia sylvaticae* Pawł. in Pawł., Sokół. et Wall. 1928

Alliance: *Carpinion betuli* Issl. 1931 em. Oberd. 1953

Tilio cordatae-Carpinetum betuli Tracz. 1962

the community with *Corylus avellana*

2.1.5.3. Flora

The number of species of native and domesticated vascular plants in the Kujawy-Pomerania region comes to ca. 1500 (Rutkowski, 1997; Boiński et al., 2001). A total of 458 species were found in the artillery range, including 360 vascular plants and 98 species of other taxonomic groups: algae (1 species), bryophytes (25 species) and lichens (72 taxa). The following species are pioneers in the stabilization of sand dunes: *Klebsormidium crenulatum*, *Cetraria aculeata*, *Diploschistes muscorum*, *Polytrichum piliferum*, *Calamagrostis epigejos*, *Carex arenaria*, *Corynephorus canescens*, *Koeleria glauca* and *Leymus arenarius*. In more stabilized, insolated and treeless areas, the following species occur in large numbers: *Festuca trachyphylla*, *Hieracium pilosella*, *Spergula morisonii* and *Thymus serpyllum*. A characteristic feature of the

landscape are heaths on the dune slopes dominated by *Arctostaphylos uva-ursi* and *Calluna vulgaris*, usually accompanied by many species of cup lichens, including: *Cladonia cariosa*, *C. cenotea*, *C. crispata*, *C. gracilis* ssp. *elongata*, *C. gracilis* ssp. *turbinata*, *C. macilenta*, *C. rangiferina* and *C. squamosa*. Lichens *Baeomyces rufus* and *Trapeliopsis granulosa* seldom occur in these communities. Crests of dunes are covered with the willow *Salix acutifolia*, which occurs in large numbers and is accompanied by: *Hippophaë rhamnoides*, *Pinus sylvestris*, *Robinia pseudacacia* and *Salix repens*, while *Epipactis atrorubens* frequently occurs in the herbaceous layer. The exposed terraces are habitats of the following species (seldom on other habitats of the artillery range): *Alyssum montanum*, *Aster amellus*, *Avenula pratensis*, *Koeleria grandis*, *K. macrantha*, *Peucedanum cervaria*, *Prunella grandiflora*, *Pulsatilla patens*, *Scorzonera purpurea*, *Stipa joannis*, *Thesium ebracteatum*, *T. linophyllum*, *Trifolium lupinaster*, *Veronica austriaca*, *V. jacquinii* and others. Most of them were recognized as nearly extinct, vulnerable or rare species in the Kujawy-Pomerania Province (Rutkowski, 2005). *Cerasus fruticosa* is a floristic peculiarity of the artillery range. The species is threatened with extinction; it occurs at few sites, including „Góra Żymierskiego” where it is exposed to fires, repeated several times every year (field of fire). In the vicinity of „Góra Dziwak”, the presence of a very rare liverwort was recorded – *Riccia huebeneriana* on the shores of a small water reservoir overgrown with vegetation. Mosses occurred only on bunkers and other concrete constructions – *Grimmia apocarpa* and *G. pulvinata*. Constructions of any kind were accompanied by species of alien origin, including: *Amaranthus retroflexus*, *Galinsoga parviflora*, *Lepidium densiflorum*, *Oenothera acutifolia*, *O. hoelscheri*, *O. pycnocarpa*, *O. royfraseri*, *O. depressa*, and *Sporobolus cryptandrus* – found at a transfer station in the village of Otłoczyn.

At present, the flora of the artillery range is represented by 47 protected species, including 30 taxa strictly protected by law and 17 taxa partially protected. Only 17 species were recognized as endangered in Poland (Cieśliński et al., 2006; Kaźmierczakowa and Zarzycki, 2004), including lichens in the category of critically endangered species (CR) – *Bryoria subcana*, endangered species (EN) – *Ramalina fraxinea*; *B. fuscescens* and *Peltigera praetextata*, and vascular plants: *Prunus fruticosa* and *Pulsatilla patens* recognized as vulnerable species. As many as 30 species endangered on a regional scale occur in the artillery range, including species threatened with extinction – *Aster amellus* and *Prunella grandiflora*.

Out of the 335 species of vascular plants reported from the artillery range by Scholz (1896), Abromeit et al. (1898) and Preuss (1912), as many 270 species were confirmed during the current research, which represent 80.6% of the original number. The group of 65 species (19.4%), not recorded for the second time, includes species recognized as extinct in the region: *Adenophora liliifolia*, *Cephalanthera damasonium*, *C. rubra*, *Dracocephalum ruyschiana* and *Gladiolus paluster*.

During the century separating the two research periods, the artillery range gained 95 new species, usually kenophytes: *Acer negundo*, *Amelanchier spicata*, *Armoracia rusticana*, *Cotinus coccygrina*, *Echinocystis lobata*, *Padus serotina*, *P. virginiana*, *Pinus strobus*, *Robinia pseudacacia*, *Sisymbrium loeselii*, *Solidago gigantea*, *S. canadensis*, the aforementioned species from the genus *Oenothera* and archaeophytes: *Descurainia sophia*, *Digitaria ischaemum*, *Lepidium ruderales*, *Papaver rhoeas* and others.

In other studies, particularly those presenting the nature qualities of the military training ground in connection with its recommendation as a Natura 2000 site, the following vascular plants were included in the group of other important species: *Trifolium lupinaster*, *Oxytropis pilosa*, *Arctostaphylos uva-ursi*, *Aster amellus*, *Inula hirta*, *Epipactis atrorubens*, *Pulsatilla pratensis*, *Carlina acaulis*.

A total of 96 lichen taxa and 4 species of lichenicolous fungi were identified in the artillery range near the city of Toruń. Out of the total number of species identified on the military training ground near Toruń, 16 species are listed on the Red List of threatened lichens in Poland (Cieśliński et al. 2006), including: 1 Critically Endangered (CR) – *Bryoria subcana*; 3 Endangered (EN) – *Physconia distorta*, *Ramalina fraxinea*, *Tuckermanopsis sepincola*; 9 Vulnerable (VU) – *Bryoria fuscescens*, *Cetraria islandica*, *Peltigera canina*, *P. polydactylon*, *P. praetextata*, *Ramalina farinacea*, *Stereocaulon condensatum*, *Tuckermanopsis chlorophylla*, *Usnea hirta*; 2 Near Threatened (NT) – *Evernia prunastri*, *Hypogymnia tubulosa* and one Least Concern (LC) species – *Phaeophyscia sciastra*.

Pursuant to the Regulation of the Minister of the Environment on wild species of fungi in Poland from 2014, seventeen taxa are protected, including 4 strictly protected: *Bryoria subcana*, *Peltigera praetextata*, *Ramalina fraxinea*, *Tuckermanopsis sepincola* and 13 partially protected: *Bryoria fuscescens*, *Cetraria islandica*, *Cladonia arbuscula*, *C. ciliata*, *C. portentosa*, *C. rangiferina*, *Hypogymnia tubulosa*, *Peltigera canina*, *P. polydactylon*, *Ramalina farinacea*, *Stereocaulon condensatum*, *Tuckermanopsis chlorophylla*, *Usnea hirta*.

A total of 36 epigeic lichen species were found on the military training ground near Toruń, as well as 34 taxa of epiphytes, 19 species of lichens on concrete constructions (walls of shelters and bunkers) and 13 species on the wood. Twenty five species of epigeic lichens were associated with heaths. Species from the genus *Cladonia* occurred in particularly large numbers. Also *Stereocaulon condensatum* with well-developed thalli and apothecia occurred in large numbers.

2.1.5.4. Selected groups of invertebrate

Heaths covering a large part of the artillery range are accompanied by bee communities (*Hymenoptera: Apoidea: Apiformes*). The research on their structure and functioning were carried out by Pawlikowski (1992, 2010). The most important conclusions following from his studies conducted in 1984 and 1985 are as follows:

Altogether, 97 bee species were recorded at the selected sites.

In the succession and developmental sequence of the site with heather patches starting from a young coppice forest, through a developed coppice forest until a forest stand, the number of species was decreasing. This decrease proceeded in the approximate ratio of 2:1:1 in 1984 and 3:1:1 in 1985. On the other hand, average density changed according to the ratio of 5:4:1 in 1984 and 7:7:1 in 1985.

Succession of the heath on dune fields in the Toruń Basin towards the forest reduces the habitat attractiveness for bees. As the heath area has been successively overgrown with pine, two- threefold decrease in the number of species was observed.

Blooming of heather increased the food attractiveness of heath and grassland patches for species of social bees, especially bumblebees. Furthermore, it enriched the structure of communities with relatively numerous oligolectic species: *Colletes succinctus* and *Andrena fuscipes*.

In the analysis of seasonal dynamics of communities, the influence of honeybees (from portable apiaries) on the functional conditions of bee communities becomes evident. Placing the apiary in 1984 in the vicinity and within the heathland certainly maintained the whole structure of communities at a more stable level in functional terms (calculated evenness index values closer to the value of 0.5) as compared with the next year, i.e. without the portable apiary (Pawlikowski, 2010).

In other studies, particularly those presenting the nature qualities of the military training ground in connection with its recommendation as a Natura 2000 site, spiders and insects from different taxonomic groups

are listed as important invertebrate species (<http://natura2000.gdos.gov.pl/datafiles>). The list of species is as follows:

- Araneae: wasp spider *Argiope bruennichi*, *Eresus moravicus*, jumping spider *Philaeus chrysops*.
- Insecta: Hymenoptera – the European red wood *Formica polyctena*, red-tailed bumblebee *Bombus lapidarius*, buff-tailed bumblebee *Bombus terrestris*, sand wasp *Bembix rostrata*, *Bembecinus tridens*, *Scolia hirta*, *Stizus perissii*, *Eoferreola rhombica*, *Poecilagenia rubricans*, *Euchreus purpuratu*; Orthoptera – blue-winged grasshopper *Oedipoda caerulescens*, rattle grasshopper *Psophus stridulus*; Coleoptera – *Lixus cylindricus*, *Gnorimus variabilis*, *Typhoeus typhoeus*; Lepidoptera: moth *Zygaena cynarae*, netted mountain moth *Macaria carbonaria*, spotted fritillary *Melitaea didyma*, tree grayling *Hipparchia statilinus*, common yellow swallowtail *Papilio machaon*; Diptera: *Eumerus tricolor*, *Spilomyia diophthalma*, *Germaria angustata*, *Melisoneura leucoptera*.

2.1.5.5. Wolves in the Toruń Basin

The range of the European wolf has significantly decreased during the last centuries, which was also reflected in the present area of Poland. In the mid-19th century, wolves became very rare in the western part and common in the eastern part of the present Polish territory (Okarma, 1992). Even then, forests of the Toruń Basin were an important refugium for wolves. Between 1815 and 1841, 16 adult and 83 young wolves were killed (hunted or taken from wolf lairs; Suchocki, 1926 after Sewerniak, 2010) in the area called “Wódek”, the western part of the present Forest Division of Cierpiszewo. By the end of the 19th century, wolves were entirely exterminated west of the Bug, the Narew and the Biebrza rivers (Kowalski, 1953, after Sewerniak, 2010).

After World War I, the range of wolves spread further to the west, beyond the Bug River (Kowalski, 1953), and wolves were observed again in the Toruń Basin. However, their existence in the region did not last long. The attempt to colonize the region brought about the intensive activity of hunters, which resulted in 2 adult wolves killed in the Bydgoszcz Primeval Forest in 1925 (Suchocki, 1926, after Sewerniak, 2010). According to Okarma (1992), just before World War II, wolves were again entirely exterminated in the areas located further to the west, beyond the line of the Bug, the Narew and the Biebrza rivers.

Since every war results in the expansion of wolves (Kowalski, 1953), wolves populated the forests of the Toruń Basin after World War II.

According to Mastyński (1964), the culmination of wolf invasion in Pomerania occurred in 1952. Taking into account the facts presented by Mastyński (1964, 1967), it can be assumed that in the early 1950s, forests of the Toruń Basin were populated by some wolf packs and wolves successfully reproduced in the region. After the begin of wolf extermination in 1955, the size of the wolf population significantly decreased. In 1964, however, the stable population of wolves still existed in the Toruń Basin. At that time, the number of wolves in the Basin (together with some adjacent areas) was estimated at 20–30 individuals (Mastyński, 1964). In the 1960s, wolves were permanently exterminated and in 1966, there were no wolves in the Toruń Basin and the whole former Bydgoszcz District (Mastyński, 1967).

The next successful attempt to introduce wolves in the Toruń Basin took place in the 1980s. This was described by Andrzejewski and Wołk (1991). According to the authors, the colonization was a consequence of the “Martial Law” introduced in Poland in 1981 and seizure of hunters’ guns. From 1983 until at least 1986, wolves occurred and reproduced in the present Forest Division of Toruń (in the 1980s – part of the Dobrzejewice Forest Division). The wolf pack was seriously decimated during the hunting on the 27th of December 1986, when 3 out of 5 encountered wolves were hunted down and another one (injured) was killed few days later (Andrzejewski and Wołk, 1991). The last (in the 20th century) reproduction of wolves in the Toruń Basin took place in 1986. Starting from the aforementioned winter hunt on the 27th December 1986 until the end of the 20th century, wolves were observed in the Toruń Basin only occasionally, mainly in the eastern part (the Dobrzejewice Forest Division). As the Basin is an important part of the traditional migration route of wolves from the eastern to the western part of Poland (Fig. 6), wolves could try to colonize or only cross the region while migrating westwards. There were cases when wolves were hunted down by hunters because they were mistaken for wild, feral dogs, for instance in 1989 in the Forest Division of Cierpiszewo (Sewerniak, 2010).

At the turn of the 20th and 21st centuries, wolves occurred in the eastern part of the Toruń Basin (the Dobrzejewice Forest Division). The population dynamics of the wolf pack from the Dobrzejewice Forest Division has not been well recognized. Based on the field observations of local foresters, it can be assumed that until 2003, the pack consisted of more than 4 wolves (Sewerniak, 2008, 2010). Since 2003, their estimated number has decreased and until now it has oscillated around

2–4 individuals. In spite of the decrease, wolves still populate and reproduce in the eastern part of the Toruń Basin. In the Dobrzejewice Forest Division, three wolf dens were found, including two dens used for raising the pups in 2008 and in 2009.

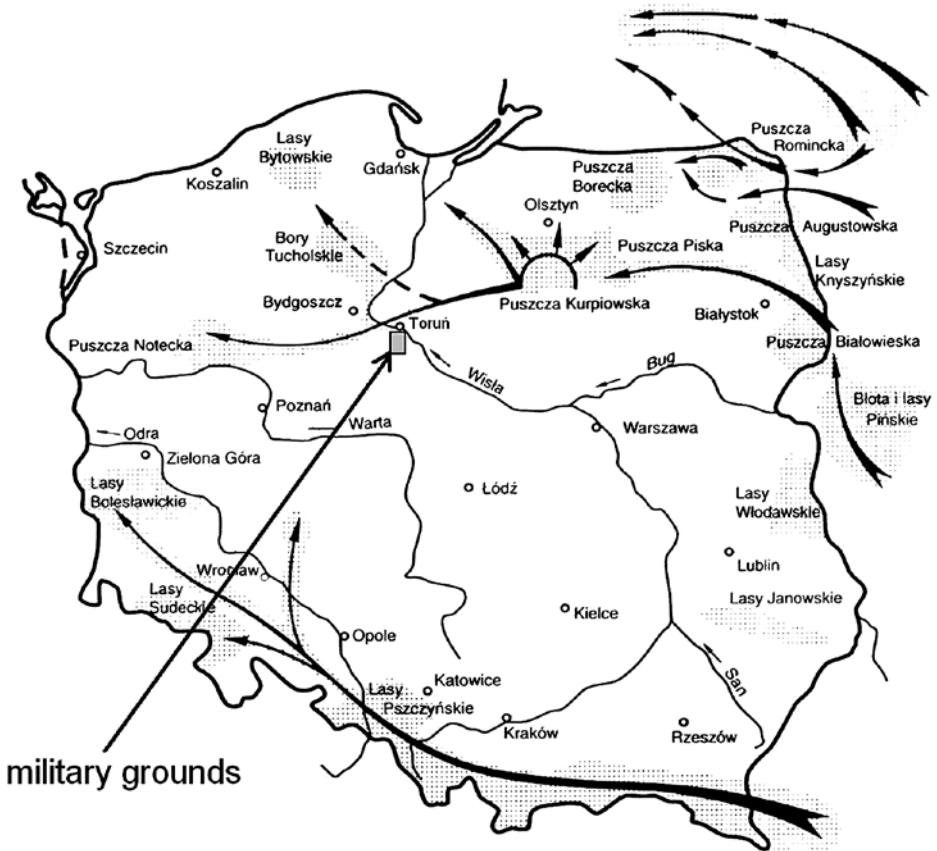


Figure 6. Wolf migration routes since at least 150 years, according Sewerniak (2010, after Kowalski, 1953, and Bereszyński, 1998)

At present, the pack occurring in the Dobrzejewice Forest Division is the only one that populates the forest situated on the right Vistula bank of the Toruń Basin. In the Toruń Forest Division, which includes forests located north and north-west of Toruń, the occurrence of wolves has not been confirmed in this decade.

More information is available on the occurrence of wolves in the Bydgoszcz Primeval Forest located in the Toruń Basin on the left Vistula bank. This also applies to the colonization course and population dynamics.

It can be assumed that the present, stable wolf population started in this Forest, in 2004. The grey wolf in the forest between Bydgoszcz and Toruń occurred first in the western part. In 2004, wolves and their tracks were observed in the Forest Division of Solec Kujawski and in the western part of the Cierpiszewo Forest Division (Krzemień, 2008). At that time, predators visited the Gniewkowo Forest Division (the eastern part of the Bydgoszcz Primeval Forest) only occasionally. At least since 2004, wolves have successfully reproduced in the Forest. In 2004, a wolf den was observed in the Łążyn Forest District and in 2005 – in the Żółwin Forest District where also wolf pups were observed (Krzemień, 2008).

In 2005, wolves have moved to the eastern part of the Bydgoszcz Primeval Forest and after 2006, traces of their occurrence have been observed less and less frequently in the Forest Divisions of Solec Kujawski and Bydgoszcz (Krzemień, 2008). The reproduction area has also been changed at that time. Wolves have dug some dens that are periodically and alternately used in the eastern part of the Forest.

The estimated dynamics of the population of wolves in the Bydgoszcz Primeval Forest in 2004/2005–2009/2010 is presented in Figure 7. The largest number of wolves (13 individuals) in the whole decade occurred in the winter of 2007/2008 (Sewerniak, 2010).

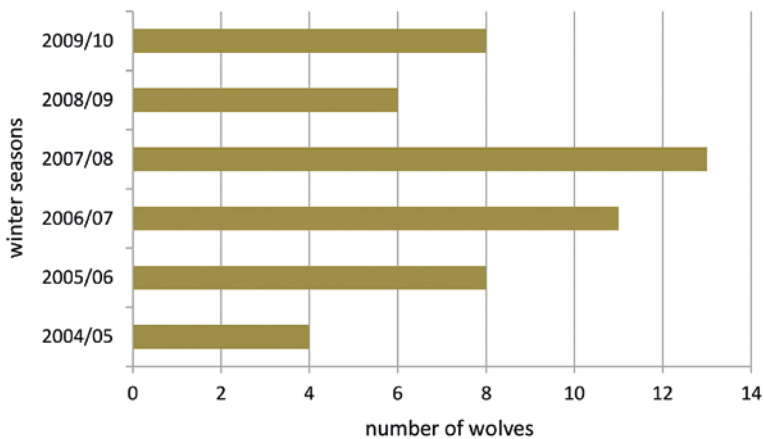


Figure 7. Population dynamics of wolves in the Bydgoszcz Primeval Forest in winter seasons 2004/2005–2009/2010, according to Sewerniak (2010)

There are two areas of primary significance for the occurrence of the present-day pack of wolves that populate the Bydgoszcz Primeval Forest. The first one is a huge post-fire area, located mainly in the Cierpiszewo

Forest Division, where nearly 30 km² of pine stands were burnt in 1992. Today the area is covered mostly by ca. 20-year-old pine thickets that are not easily penetrated by people, and thus offer a good shelter for wolves.

The second area (ca. 40 km²) – the central part of the artillery range is located in the Gniewkowo Forest Division. The area encompasses the military training yards and their buffer zone where only minor activity of both soldiers and foresters has been observed in recent years. The buffer zone is mostly covered with heathlands and grasslands, mixed with pine and birch forests, which developed as a result of natural succession.

Sewerniak (2010) estimates the territory of the present-day pack of wolves from the Bydgoszcz Primeval Forest at about 350 km². It includes both the above described areas and the surrounding planted pine forest. In comparison with the territories of wolves described by Jędrzejewska and Jędrzejewski (2001) from the Białowieża Primeval Forest (154–343 km²), it is a relatively large territory. It is interesting that when two packs of wolves occupied the Bydgoszcz Forest, their territories partly overlapped. This implies that these two packs could be closely related. The telemetric research conducted by Jędrzejewska and Jędrzejewski (2001) proved that overlapping of territories may occur when packs of wolves are closely related.

2.1.6 Habitat conservation area PLH040041 “Wydmy Kotliny Toruńskiej” (“Dunes of the Toruń Basin”)

On the 28th of January 2014, the Council of Ministers approved the proposal to include the new habitat conservation area in the Natura 2000 network in Poland, due to the unique nature conservation value resulting from the occurrence of valuable habitats and species: PLH040041 Wydmy Kotliny Toruńskiej (Dunes of the Toruń Basin) with an area of 5,289.91 ha, covering the Forest Division of Gniewkowo used as a military training ground. The description of the conservation area PLH040041 presented in this paper follows the database of the Ministry of the Environment of the Republic of Poland (<http://natura2000.gdos.gov.pl/datafiles>).

The refugium covers a large, mostly unforested fragment of the Toruń-Bydgoszcz Basin, and includes one of the largest inland dune areas in Poland. The morphological picture of the Basin consists of terraces and fault scarps of varying age, many undulating relief forms, longitudinal ridges, usually of arcuate shape and aeolian origin.

The shapes of these forms and the shapes of crescentic-parabolic dunes with arms modelled to a varying extent, as well as inclination of slopes indicate that the main force modelling the dunes in the Basin were westerlies. The concentration of dunes in the central and eastern parts indicates translocation of aeolian deposits from west to east. In this area, one can observe dune fields of ellipsoidal shapes, truncated from the west. At present, they are usually inactive landforms covered with pine forest, less frequently heaths. The accumulated dunes form six large dune fields in different parts of the Basin. The refugium covers a large part of field IV Toruń-Aleksandrów-Gniewków, located on the left bank of the Vistula ice-marginal valley between the rivers Zielona and Tążyna, which are tributaries of the Vistula River. The eastern limit is formed by the Vistula River, and the southern scarp – by a plateau along the Aleksandrów-Gniewkowo section. Aeolian deposits in the Basin occur mainly on the upper, middle (V, VI) and lower terraces, and to a lesser extent also on over-floodplain terrace II (in the town of Nieszawa and in Rudak – an administrative subdivision of Toruń).

The described area is mainly covered by dunes with a relative altitude ranging from 10 m to 25 m, with the maximum elevation of ca. 45 m, and they are located on higher valley levels and on the moraine plateau. Dunes located on the over-floodplain terraces are usually smaller, and their relative altitude is up to 10 m.

The entire refugium is located in the Protected Landscape Area referred to as “*Obszar wydm śródlądowych na południe od Torunia*” (Inland dunes south of Toruń), which is covered with forests and heaths in 99.4%. The whole forest area is situated within the protection forest zone around Toruń representing its southern “green lung”.

Dune heaths and grasslands dominate in the central part of the refugium. Spontaneously developing pine forests with a varied age structure, as well as birch and birch-pine groves, occasionally with some admixture of aspen, add some variety to the landscape. Small fragments of oak woods occur in more fertile places. In the east, west and north, the described area borders on the commercial forest dominated by coniferous communities. In the south, the refugium partially encompasses the edge zone of the Kuyavian Plateau where habitats are more fertile and small fragments of oak-hornbeam forests and thermophilous oak woods are found among pine plantations.

In the process of habitat inventory conducted in State Forests, habitats with the following codes were identified in the described area: 2330 inland dunes with open *Corynephorus* and *Agrostis* grasslands

– 718.37 ha, 6120 thermophilous inland arenaceous grasslands – 23.8 ha, 4030 European dry heaths – 789.25 ha, as well as habitat 9170 subcontinental lime-oak-hornbeam forest – 3.17 ha and 9110 thermophilous oak woods – 1.06 ha.

The created Special Area of Conservation is an important link in the natural ecological corridor of international importance for the migration of large carnivores and ungulates. It is referred to as the North-Central Corridor and represents a route of wolf migration from strong populations in eastern Poland and Belarus towards the west. The functioning of this connection is reflected in the increasingly strong local population of this predator in the Forest Division of Dobrzejewice (the eastern part) as well as in the Bydgoszcz Forest (the western part), in the forest divisions of Gniewkowo, Cierpiszewo and Solec Kujawski. In the area referred to as PLH040041, the breeding of wolf was confirmed and the size of its population is estimated at min. 9 individuals.

The wolf refugium is slightly threatened by human interference. Due to the fact that the area is used by the army, it is not accessible to visitors. No intensive forest management is conducted in the area, and only certain parts are periodically used by the army.

Other Natura 2000 sites are located in the vicinity of the artillery range in Toruń: PLH040001 Strongholds in Toruń (hibernation places of bats), PLH040011 Dybowska Dolina Wisły (Dybowo Vistula Valley), PLH040012 Nieszawska Dolina Wisły (Nieszawa Vistula Valley), PLH040044 Leniec in Chorągiewka, the Kępa Bazarowa nature reserve (protected lowland willow-poplar floodplain forest) on the left bank of the Vistula River, the Protected Dune Landscape Area in the Toruń-Bydgoszcz Basin (the eastern part) and the Protected Landscape Area of Inland Dunes (south of Toruń).

2.2. Disappearance of heaths as a result of urbanization on the former military training ground JAR in Toruń

2.2.1. Location and history of military ground

The research plot JAR is located in the northern part of Toruń (Fig. 1) between the street Grudziądzka, which turns into the road A1 Toruń – Gdańsk, as well as streets Ugory, Polna and the northern boundary of the city (Fig. 2). It is situated at the foreland of fort V,

one of 15 defensive elements of this type from the former Prussian stronghold Thorn. Fort V (formerly III Scharnhorst, at present Jan Karol Chodkiewicz) was erected in 1878–1884 as a northern part of the defensive line of the city and defence of a railway line to Grudziądz.

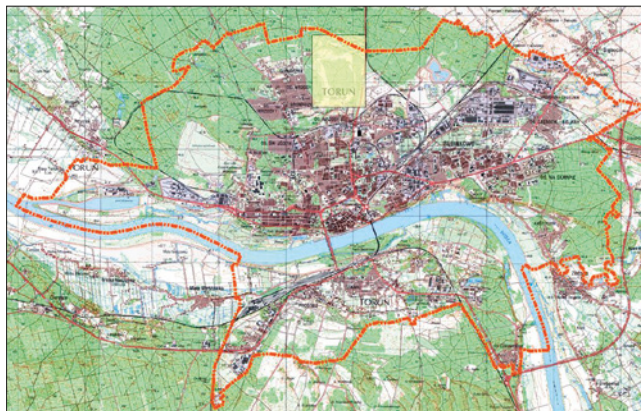


Figure 1. Location of site JAR on the topographic map of Toruń

The research plot JAR is separated from the nearby residential district Wrzoso (located west of JAR) by a zone of forests, mainly young pine growths, included within the Forest Division of Toruń. Also a strip of old pine forest is included within this forest division, which separates the JAR area from the road A1.

In the 19th century, a manor existed within the territory of the present-day district Wrzoso. From the beginning of the 20th century, this part of Toruń has been developing as a villa district. Recently apart from low residential buildings, multi-family houses are being built, mainly 5-storey buildings. Whereas, the research area of JAR was uninhabited and overgrown with pine forest until the 19th century. In the 19th century, the area was exploited by the Prussian cavalry for manoeuvres. In 1916, an ammunition depot was built in this area, as well as a system of roads and railway sidings was developed. During the interwar period, the area was also exploited by the Polish army. In 1940, the area of the ammunition depot was extended up to the size of the whole present-day JAR area. In 1945–1991, this was the place where the Engineer Pontoon Battalion was stationed together with its equipment park, as well as air force units and depots of the Soviet Army. It is where the name of the research area JAR comes from– the Unit of the Soviet Army (in Polish – Jednostka Armii Radzieckiej).

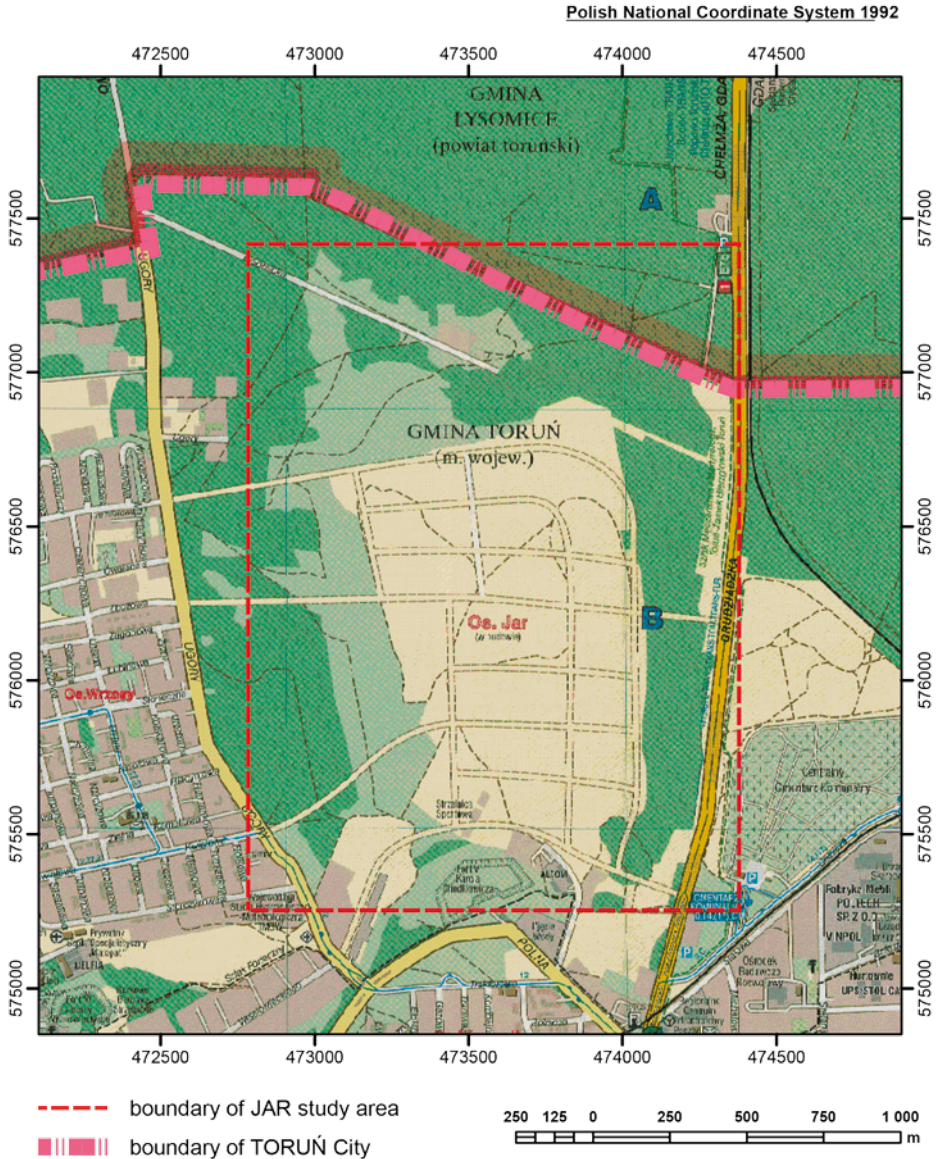


Figure 2. Location of the site JAR on the street plan of Toruń from 2007

The central part of the JAR area is afforested. A strip of ground devoid of vegetation ran around the forest complex. The whole area was surrounded by a double barbed-wire fence. Between the two wire fences, a road hardened with limestone rubble ran, along which a guard was walking.

After the Soviet Army left this area in 1991, the land was quickly transformed into wastelands, dominated by wilding pine trees and heather. Also psammophilous species encroached on the area; the association *Spergulo-Corynephorretum* developed here. Double embankments were built inside the fences around the forest complex. The existing dune hills were used for their construction. Shooting ranges were located between the embankments.

The terrain was intersected by concrete roads and ditches connecting the observation points, fire stations and military hardware warehouses. Warehouses are still situated in the southern part of the area. From the south, were boards with information on the danger of explosions and entry ban until 2010. Nevertheless, the area was penetrated by people, particularly from the side of the residential district of Wrzosa, from which it is separated by a strip of forest. The forests are under the administration of the Forest Division of Toruń, with the registered office by Polna Street. This street constitutes the former military motor road connecting the main strongholds and infantry, artillery and ammunition bunkers. In the eastern and northern part of the JAR area, a high voltage power line runs, which supplies the city of Toruń with electric energy. In the vicinity of the research site, at the junction of streets Grudziądzka and Polna, the Main Power Supply Station is located. The general direction of the power line is from north-west to south-east. The general direction of the power line is from the northwest to the southeast. Under the power line, wilding pine trees were removed every few years, which was conducive to the development of heaths and psammophilous grasslands.

After the Soviet Army left the area, the decision was taken by Toruń City Council to build a housing estate in this place. It will comprise the commercial building sector on the eastern side along the road A1, the sector of multi-family housing construction in the southern part and the sector of single-family housing construction in the northern part of the area. The management plan of the residential district JAR was enacted on March 1, 2007 (<http://pl. Wikipedia.org/Wiki/JAR/Torun>). The terrain was measured and inspected by sappers. The sale of plots began in 2010.

2.2.2. Changes in distribution of heaths

In the research on the occurrence range of heaths at the JAR area, historical and contemporary topographic maps were used, as

well as aerial photos and a high-resolution satellite image Ikonos (Kunz and Nienartowicz, 2010). The oldest maps came from 1892 and 1936. Maps describing the three subsequent states, in both cases concerned the years of 1963, 1971 and 1987. The latter one, i.e. the youngest state of the JAR area was evaluated based on the topographic map from 2003. All the maps were at the scale of 1:25,000. Aerial photos of the JAR area were made in 1975, 1996, 2004 and 2008. The satellite image Ikonos came from August 19, 2005.

For a more precise location of places where heaths occurred in 2009, the geodesic TopCon HiperPro GPS receiver was used. Field coordinates were obtained in the RTK mode (Real Time Kinematic) and corrections of coordinates were obtained from the ASG-EUPOS network. The location results were collected in the form of dots. Also the surface area was defined for particular vegetation patches dominated by common heather – *Calluna vulgaris*, as well as the total area covered by patches of this dwarf shrub.

Further research work was conducted with the GIS technology, using software packages to gather and process the data. Data on the contemporary location of heaths, after being processed with the desktop software Arc GIS ArcView 9.3, were presented on the topographic map in the form of polygons. After completing the procedure of georeferencing and geometrical rectification of all cartographic and remote-sensing materials, the area of heather patches was plotted at both sites in all previous developmental states.

Data on the distribution of heaths over the JAR area, acquired through field measurements were also superimposed on the plan of a future housing estate drawn up by the Urban Planning Laboratory in Toruń in 2007. As a result of superposition of two information layers, future changes of particular fragments of the research site were determined, as well as the threats posed by urbanization processes to all heather patches occurring within its range.

The changes in the distribution of heaths over the JAR area between 1892 and 2009 are present in Figures 3 and 5. On the German topographic map of Toruń 1510, sect. Thorn from 1892, the heaths occurring in the northern part of the JAR research area were presented as five patches of very different shapes and sizes (Fig. 3A, Fig. 5A). The largest of them had the area of 7.8665 ha and the smallest one – about 1.4968 ha. The total area of heather patches amounted to 21.0210 ha. Apart from heaths, also forest areas occurred in the studied area, situated mainly in the central-western part and more to the north

of the heather patches. A small forest complex also occurred in the eastern part of the JAR area. Built-up areas and areas exploited by a local population as grazing and agricultural lands are mainly located in its northern area. In the central, sandy part of the area, the military training ground is situated and in the south-western part – some buildings, which were certainly used by the Prussian army.

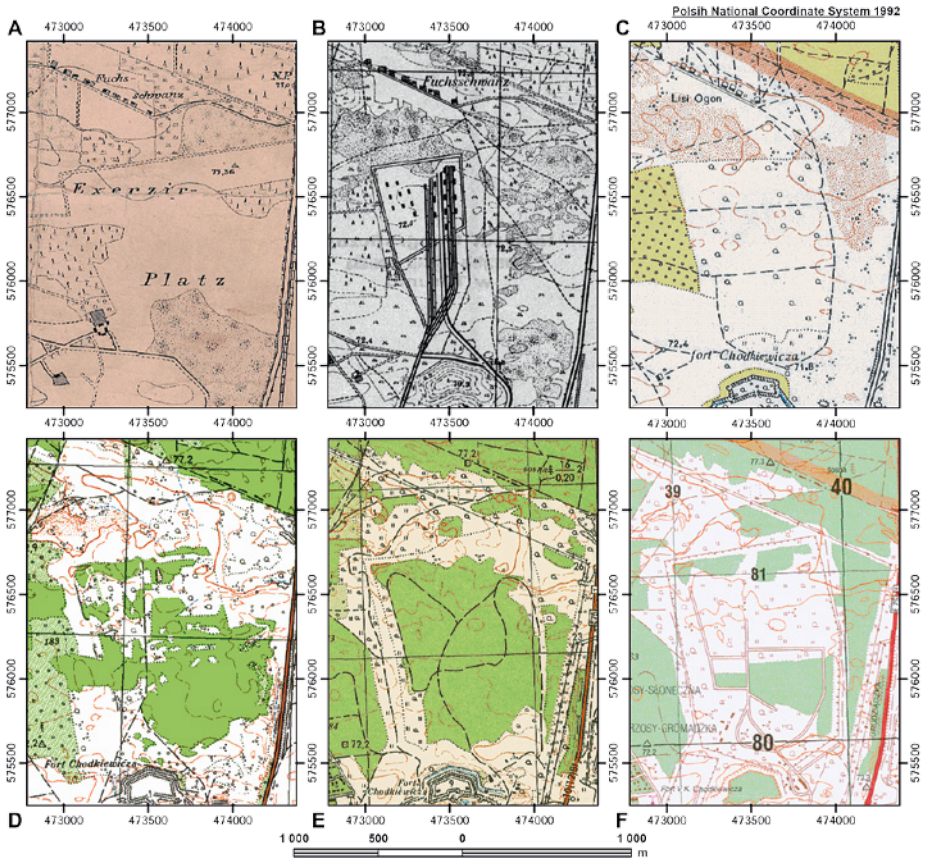


Figure 3. Changes in the JAR area on the temporal series of topographic maps (A – Prussian topographic map from 1892, the original scale 1:25,000, sheet 1510 Thorn; B – German topographic map from 1936, the original scale 1:25,000, sheet 2977 Thorn; C – topographic map from 1963, the original scale 1:25,000, sheet no. 5; D – topographic map from 1971, the original scale 1:25,000, sheet 355.14 Łysomice; E – topographic map from 1987, the original scale 1:25,000, sheet N-34-98-C-c Toruń; F – topographic map from 2003, the original scale 1:25,000, sheet N-34-98-C-C,D Toruń – 1)

There are no industrial plants on the map or any other larger infrastructure important from the strategic point of view.

Figure 3B is another German topographic map 2977 sect. Thorn from 1936 (1:25,000), which presents the city area from the period between the 1st and the 2nd World War. In the central part of the research area, one can see some facilities of an ammunition factory, which was erected at the foreland of the stronghold V, as well as military warehouses and fragments of a railway line and a railway siding. Around these facilities there are heathlands. Heather patches are particularly abundant on the eastern and the south-western side of the military facilities (Fig. 5B). There are 17 heather patches and their total area amounted to 128.3260 ha, what constituted 37.21% of the whole JAR area (344.8672 ha). The size of the largest patch was 66.2666 ha and the smallest one – only 0.3203 ha. In the northern part of the research area, forests and buildings occur, as well as agricultural lands of the village Lisi Ogon. On the map, also hardened roads and tracks are plotted, which at that time ran through the studied area.

From the topographic map of 1963 (Fig. 3C), it appears that the area of JAR was dominated by non-forest communities. However, no heaths were distinguished among them, which certainly does not mean that such plant communities did not occur within the JAR area in the early 1960s. Whereas, the map presents the occurrence of single trees, shrubs and their clusters of different size. They were distributed mainly in the central part of the studied area. In the eastern part of the area, a small complex of young forest was located.

On the two other maps: 355.14, the sheet of Łysomice from 1971 and N-34-98-C-c, the sheet of Toruń from 1987 (Fig. 3D, 3E respectively), a gradual increase in the range of forests on the JAR area is evident. On the former map, the forest occurring in the central part of the area is characterized by considerable fragmentation. On the map from 1987, a dense forest complex is located in the central part of the map. When comparing the map from 1971 with the aerial photo from 1975 (Fig. 4A), it appears that high saturation of the area with newly erected fortifications and military equipment was the cause of strong fragmentation of the forest complex and consequently the smaller forest area during this period as compared with the state of 1987. No heaths were distinguished on the maps from both periods, i.e. 1971 and 1987. Most probably they occurred mainly along forest edges, especially in the northern part of the analysed JAR area. This kind of distribution was observed during the field observations in 2009.

In comparison with the map from 1987 (Fig. 3E), the map from 2003 (Fig. 3F) reveals the disappearance of forest areas in the central part of

the study area. However, similarly like on the earlier map, places with heaths were not plotted. As compared with the map from 16 years ago, on the map from 2003, there are buildings in the southern part of the JAR area and new tracks in its central part. Whereas, when comparing the map from 2003 with aerial photos of this area from 1996 and 2004 (Figs 4B and 4C), as well as with satellite images Ikonos from August 2005, presented in the panchromatic and coloured mode (Figs 4D and 4E), one can draw a conclusion that the mapping of forests was done with rather little accuracy. Because in the central part of the research site there are more forest areas on the remote sensing materials than it was plotted on the map.

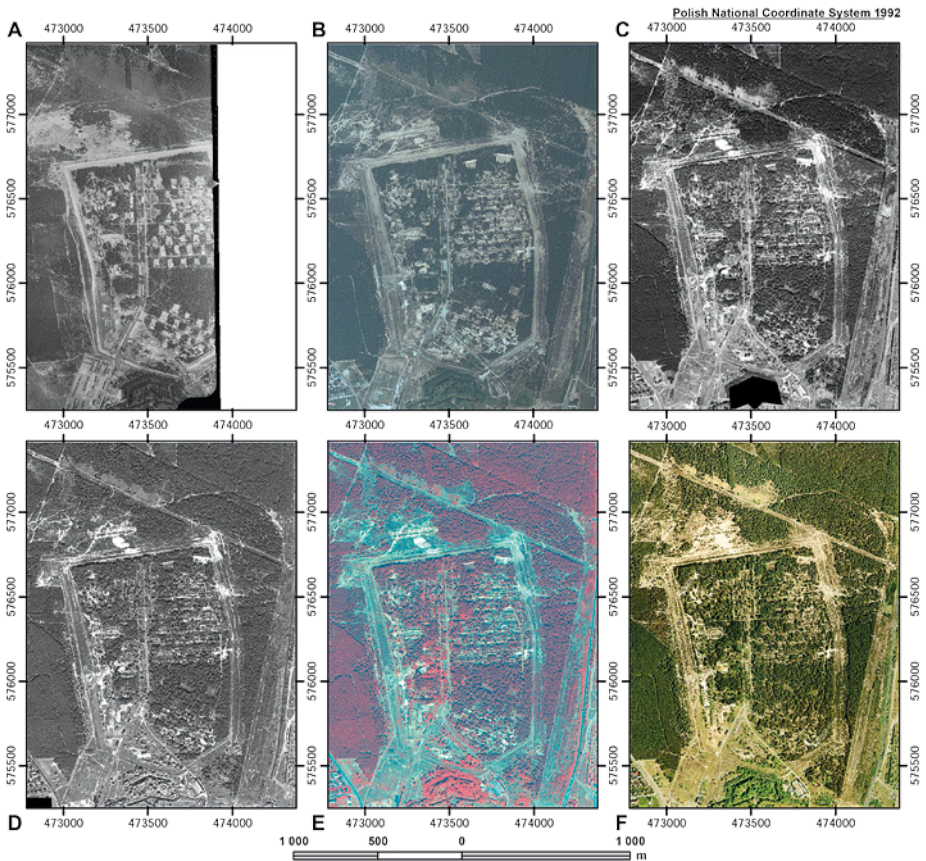


Figure 4. Changes in the land cover/land use of JAR in aerial and satellite photographs (A – panchromatic aerial photo from 1975, the original scale 1:16,000; B – colour aerial photo from 1996, the original scale 1:26,000; C – panchromatic orthophotomap from 2004, the original scale 1:10,000; D – panchromatic satellite imagery IKONOS from August 2005; E – colour satellite imagery IKONOS from August 2005; F – colour aerial photo from 2008, digital photo)

The aerial photo from 2008 (Fig. 4F) reveals the extent of vegetation destruction in the studied area after the army left. New footpaths appeared within the unsupervised area, as well as depressions originated as a result of illegal land use by motorcyclists and drivers of quads and racing cars. Those disturbed areas are distinguishable by light background, which are particularly numerous in the northwestern part of JAR.

In 2009, heather patches occurred mainly in the northern and eastern part of JAR (Fig. 5C). They are less abundant on the eastern side of the main area, which until 1991 was exploited by the army. In the northern part, heather patches occur under a power line, across the research area. In the western part, they concentrate at the end of the road that runs through the forest, facing the residential district of Wrzosy. On the eastern side, patches of low shrubs occur along the road, which constitutes a boundary of the main part of the military ground.

Altogether 22 heather patches occurred on the area of JAR in 2009. The largest of them is ca. 2.0954 ha in area. It is a patch situated in the western part of the study area from the residential district of Wrzosy. It borders on the forest area and is separated from other heather patches by footpaths developed as a consequence of passing by quads and motorcycles. The smallest polygon has the area of 0.0259 ha and is located between sparse pine trees. The total area of heaths located within the whole JAR site in 2009 came to 11.7328 ha, which constituted 3.4% of the total study area (345.0825 ha).

Figure 5D presents the distribution of heather patches in 2009 with reference to the spatial development plan of the future housing estate JAR. Areas allotted for residential and commercial buildings were designated on the plan. New housing estate roads and electricity power lines were marked out, as well as pedestrian and bicycle lanes. The general boundary of the residential district was delimited. This way, there were presented lands, which will remain unchanged, as well as those, which will be transformed. Also future greenery areas were marked on the plan, as well as the current forest lands, which most probably will be preserved. From the superposition of both information layers, performed with the GIS technology, it appears that the majority of the existing heather patches will be destroyed. Only heather patches located on the western side of the JAR research area have the chance to survive.

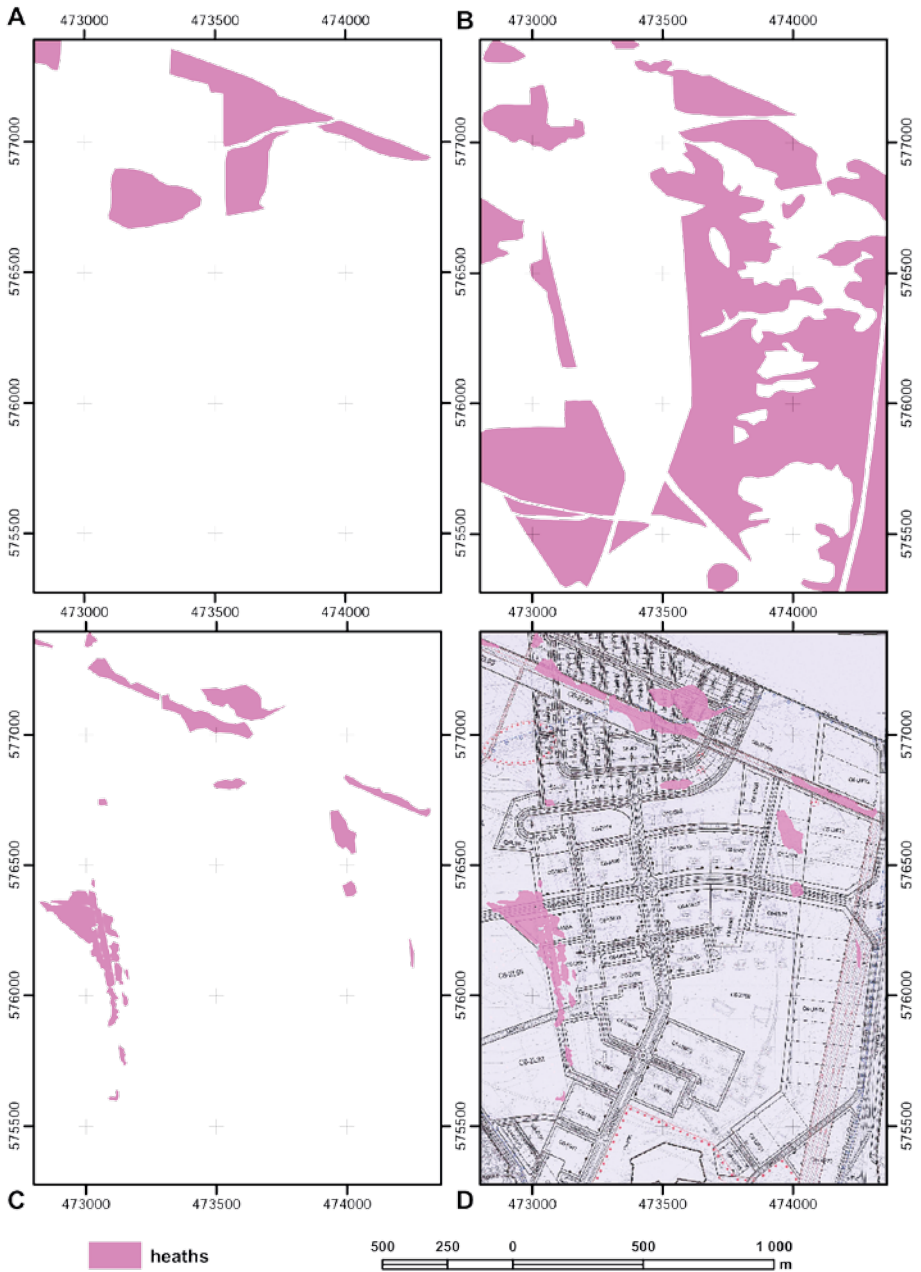


Figure 5. The size, shape and the spatial distribution of vegetation patches dominated by heather over the research area JAR (A – in 1992, determined on the basis of the topographic map at the scale of 1:25,000; B – in 1936, based on the topographic map at the scale of 1:25,000; C – based on the field research and measurements by a GPS receiver; D – the range of heather patches in 2009, superimposed on the spatial development plan of the housing estate JAR prepared by the Urban Planning Laboratory of the Municipal Council of Toruń)

2.2.3. The last investments in JAR

The plan of Toruń presented in Fig. 6 shows more realistic and up-to-date situation at the site of JAR. You can see the streets, the delimitation of which started in 2013. Some of them have already been built, while the construction of others is still continued.

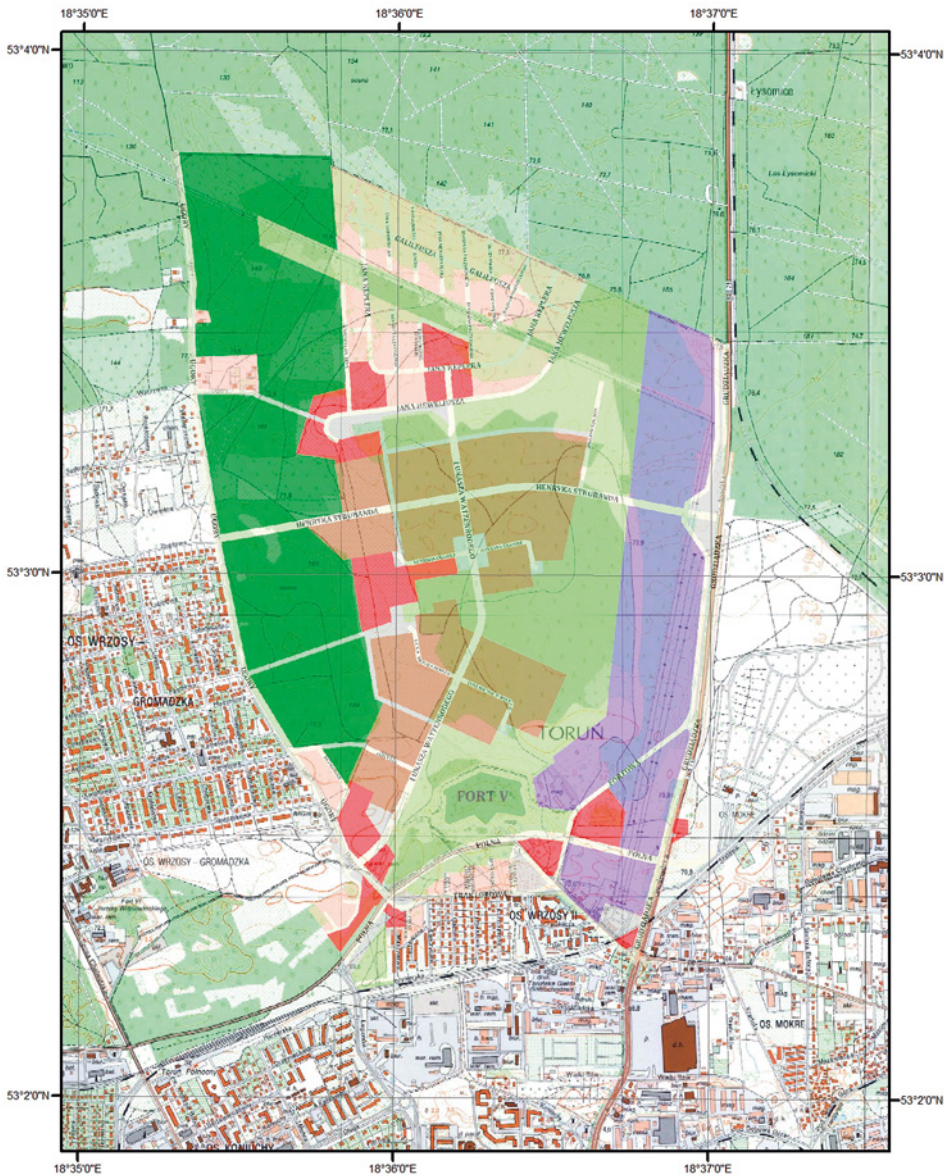


Figure 6. Location of the site JAR on the street plan of Toruń from 2014

Investors of the housing estate have undertaken some actions in the southern part of JAR, in the vicinity of Polna and Ugory streets. The most intensive construction of residential houses has been carried out at Watzenrode street (the first street in this residential district). According to the information given in the local newspaper (Gazeta Pomorska; www.pomorska.pl/apps), the Bud-Tech company operates in the area. Bud-Tech scheduled the construction of the housing estate "Green JAR", between Watzenrode and Freytag streets, for three stages. In the first stage implemented in 2013, three buildings were built (Fig. 7). By September 2014, six further blocks of flats were built. The third stage, during which three other buildings will be erected, has been planned for the period between September 2014 and September 2015. However, the company Bud-Tech. has more extensive plans, and therefore in 2013, it bought another plot from the city.



Figure 7. New buildings of the housing estate in JAR

An additional building plot was also purchased by the Youth Housing Association, which plans to build a housing estate in northern Toruń. In 2013, the group of investors was joined by the Lem-Bud company, which has so far built apartments in Toruń on the left bank of the Vistula River. In JAR, Lem-Bud is planning to build from 8 to 10 two-story buildings with 200 apartments. The first ones will be ready in

2015. Also Toruńskie Towarzystwo Budownictwa Społecznego (Toruń Public Housing Association) is joining the JAR construction market. Five buildings commissioned by the city company will be built by Bud-Tech at Watzenrode street for the total amount of 21.9 million PLN net. The investment project will take 22 months.

But this is only a fraction of possibilities offered by JAR. The whole area covers 417 ha (the former military ground and the adjacent lands), including 270 ha that belong to the city. The municipal council allotted ca. 90 ha for single- and multi-family housing in the middle of the residential district. A lane allotted for services, trade and light industry will run parallel to Grudziądzka street. According to urban planners, ca. 20,000 people will accommodate in the new residential district of Toruń.

The arrival of estate developers is followed by investors. The supermarket Inter-marche was built at Watzenrode street – near the roundabout Na Ugorach. Furthermore, the city intends to create an economic zone in the eastern part of the district. At the same time, the municipal council continues the development of infrastructure in the JAR investment area. In 2013, the officials applied for EU subsidies under the Regional Operational Programme. The entire project will cost ca. 17 million PLN, including 14.4 million PLN of subsidies. Part of this amount will be used to finance the construction of a new road for the economic zone. The funds for the road section between Grudziądzka and Forteczna will be provided by the European Union, and between Forteczna and Polna – by the city of Toruń. It will be a two-lane expressway with a one-sided sidewalk and a bike path. There are also plans to build a bike path at Polna street, a sidewalk at Watzenrode street, Freytag street, and several sections of Forteczna street between Traktorowa and Strobanda. In a few years, a tram line will run in JAR. The first trams will reach the southern part of the district.

2.3. Active Nature Protection in the “Ostnicowe Parowy Gruczna” (Stipa Ravines in Gruczno) Reserve

2.3.1. Locality, abiotic factors and the history of floristic research

The “Ostnicowe Parowy Gruczna” nature reserve was established by ordinance no. 93/99 of the governor of the Kujawy-Pomerania province on 12 May 1999. The reserve is situated in Świecie powiat [district],

Świecie community, south of Gruczno village on a steep slope of the Vistula valley (Figs 1, 2 and 3). It is a steppe reserve under partial protection, with an area of 23.82 ha where active protection is applied. Remnants of unique flora as well as plant communities with steppe and forest steppe components are protected in the reserve.



Figure 1. Topographic map with the location of nature reserves at the Lower Vistula Valley

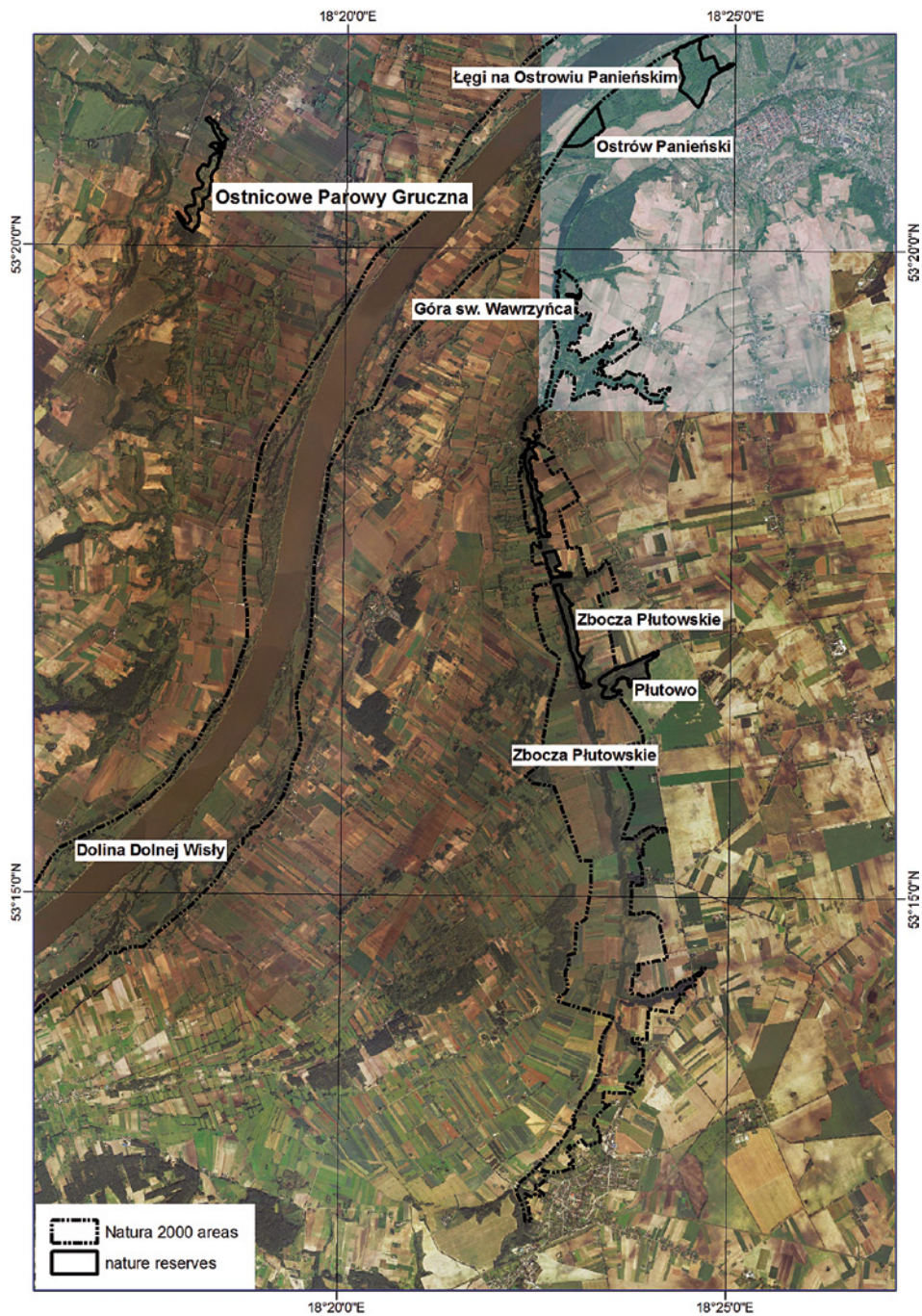


Figure 2. Location of the nature reserves at the Lower Vistula Valley on the orthophotomap



Figure 3. Nature reserve "Ostnicowe Parowy Gruczna" (*Stipa* ravines in Gruczno) on the orthophotomap

In physico-geographical terms, the reserve is located in the macroregion of the Lower Vistula Valley and the mesoregion of Fordon Valley (Kondracki, 2001). The geobotanical regionalization (Matuszkiewicz, 2008) places the reserve in Chełmno-Dobrzyń Land, in the contact zone of two districts: Świecie Upland (Pruszcz subdistrict) and the Lower Vistula Valley (Fordon-Grudziądz subdistrict of the Vistula Valley). According to the climatic regionalization of Poland (Wiszniewski and Chlebowski, 1975), the reserve is located in the Bydgoszcz district which is transitional between a drier and warmer central district and a cooler Pomeranian district with higher annual precipitation. The reserve is located in the Complex of Chełmno and Vistula Landscape Parks and on plot 384/5 of the Dąbrowa Forest Division.

The reserve area resembles an irregular strip with a length of 1.5 km and a width of 100–400 m. The borders are 5,115 m long. The reserve is surrounded by cultivated fields, replaced by gardens and buildings of Gruczno in the north-eastern part, while the southern boundary of the reserve is adjacent to a wooded valley which used to serve as a shooting range.

This area has been subject to constant anthropogenic influence with varying intensity for hundreds of years. There is a remnant of an early medieval fortified settlement in the immediate vicinity of the reserve which is called “Góra Św. Jana” (“St. John’s Mount”). Another similar settlement, “Talerzyk” stronghold is located about 4 km south of the reserve. They were part of a large settlement complex existing in the times of the early Piast monarchy (10th-12th centuries) whose centre was situated on the opposite bank of the Vistula. The former arable use of some slope parts enclosed within the reserve boundaries is confirmed by the presence of a baulk that used to separate fields and can be seen at half height of the slope.

The flora in the Lower Vistula Valley, including the area of the “Gruczno *Stipa* Ravines” reserve, has long been an object of interest for botanists. The earliest research was conducted in the area by Grütter (1887–1896), Abromeit (1898–1940), Scholz (1896, 1905) and Preuss (1912). The first detailed description of the vegetation in the present reserve was prepared by Gostyńska (1958). Later, Sulma and Walas (1963), and Sobieralska and Pająkowski (1998) wrote about the plans to establish this reserve. Data on xerothermic grassland communities and the population of *Stipa joannis* of Gruczno are also found in the works by Ceynowa (1968), Ceynowa-Giełdon (1976) and Ceynowa-Giełdon and Waldon (2001).

The reserve is located on the edge of a diluvial upland plateau descending towards the Vistula Valley from an elevation of 75–80 m to 40 m above sea level. The slope is carved by numerous valleys and denudation troughs which are best established in the upper slopes. They evolved in the process of water erosion mostly under harsh climate prevailing immediately after the retreat of the continental glacier and in the first periods of the late glacial era. Usually, the slope is inclined at an angle of 15–30° but in some places, it becomes almost flat, while in others, its inclination increases up to 40°. The slope is built of clays intertwined with glaciofluvial sands and gravels deposited during the last glaciation. This layer has a thickness of 50 to 60 m. Underneath, there are deposits accumulated 130–115,000 years ago, during the Eemian interglacial period. The top of the deposits extends at an elevation of 30 m above sea level which explains why they are exposed only randomly here and there in the lower parts of the slopes of the Lower Vistula Valley (Andrzejewski, 2001). The diverse geological structure resulted in the formation of different soil types in the reserve with the prevalence of brown soil.

There are no permanent water reservoirs in the reserve, only water effusions and seasonal streams. The bottoms of valleys and some denudation troughs are wet and often inundated.

2.3.2. General description of vegetation

As indicated on the maps of today potential natural vegetation (Matuszkiewicz et al., 1995), the nature reserve is a typical habitat of Central European deciduous and mixed forest of subboreal linden, oak and hornbeam *Tilio cordatae-Carpinetum betuli* forest of fertile and infertile varieties (Traczyk, 1962). On the sunlit slopes, there are also isolated habitats of continental mixed forests of *Quercus roboris-Pinetum* and *Serratulo-Pinetum*. This is evidenced by the presence of species typical of luminous oak forests in the reserve grasslands, such as *Peucedanum oreoselinum* and *Hieracium umbellatum* with their massive occurrence, and common heather, *Calluna vulgaris* which occurs rarely in this area. The Vistula Valley at the foot of the reserve is a riparian forest habitat: elm-ash *Ficario-Ulmetum*, willow-poplar *Salici-Populetum* and ash-alder *Fraxino-Alnetum*.

Long lasting human settlement and intensive farming on fertile soils of the Vistula Valley and the upland plateau resulted in almost

complete deforestation of the area. Trees are found mainly along roads and field baulks. In the past, the slopes of the Vistula Valley were used primarily for sheep grazing, thus the present-day woods and thickets are secondary plant communities. They develop spontaneously in places where former land use was abandoned or are planted to protect the slopes from erosion. In some places, they have already form dense tree stands, but in general, their floors completely lack species typical of forest communities. Shrub species and those typical of forest margins frequently occur. Grasslands prevail at the sites used for hay making or grazing for a longer time. In less sunny, damp and moderately damp places, meadow communities are found while xerothermic grasslands occur on dry habitats with intensive exposure to sunlight.

A total of 30 plant associations and communities were identified in the "Gruczno *Stipa* Ravines" reserve (Ceynowa-Giełdon, 2002), including two syntaxa of xerothermic terricolous lichen from the class of *Psorettea decipiensis* Mattick ex Follmann 1974 emend Drehwald in 1993, which are not found at the lower Vistula outside the reserve near Gruczno, as well as 28 communities of vascular plants representing eight different classes. The group of syntaxa with the dominance of lichens encompasses: *Toninio-Psoretum decipientis fulgensetosum bracteatae* and *Toninio caeruleonigricans*. The former syntaxon is a community of the utmost nature conservation value among all the communities occurring in the reserve (Ceynowa-Giełdon, 2002).

Xerothermic grasslands from the *Festuco-Brometea* class, for the protection of which the reserve was created, are generally unstable. In many places, they are transitional in their nature from typical xerothermic grasslands to shrub, meadow, or synanthropic communities. The best developed xerothermic grasslands persist on extremely xerothermic habitats where the competition of mesophilic plants is limited by natural environmental conditions. The most valuable xerothermic grasslands in the reserve are the communities of Ass. *Potentillo-Stipetum* Libb. 1933 em Krausch 1960, followed by plant communities belonging to the *Festuco-Brometea* class with the dominance of *Brachypodium pinnatum*, *Centaurea stoebe*, *Bromus inermis* and *Artemisia campestris*, *Salvia pratensis*, *Phleum phleoides*, *Peucedanum oreoselinum* and *Vincetoxicum hirudinaria* (Fig. 4).

Avenula pratensis is present in the transition zones between xerothermic grasslands and meadows, while meadow communities are dominated by *Arrhenatherum elatius* accompanied by *Briza media*, *Linum catharticum* and *Centaurea jacea*. At the sites which were

grazed for a longer period, there are *Ononis spinosa*, *Eryngium planum* and *Carlina vulgaris*. In lower parts of the slopes on the least fertile sands, psammophilous grasslands of the class of *Koelerio glaucae-Corynephoretea canescentis* Klika in Klika et Novak 1941 are found which are represented mainly by *Koeleria glauca* and *Silene otites* communities accompanied by *Helichrysum arenarium*. In many places, on both sunny and shady slopes, *Calamagrostis epigejos* dominates and intensively spreads across the reserve. *Solidago gigantea* is similarly expansive.



Figure 4. Xerothermic grasslands in the nature reserve "Ostnicowe Parowy Gruczna" (*Stipa* ravines in Gruczno)

The sites richer in nitrogen, located in the vicinity of human developments or along the border of crop fields, particularly those with fertiliser run-off from uplands, are mostly overgrown with synanthropic species such as: *Artemisia vulgaris* and *Tanacetum vulgare*, *Falcaria vulgaris* or *Lathyrus tuberosus* in some places. Fur-covered animals, especially rabbits contribute to the spread of some plants on the slopes. Next to their burrows, *Medicago minima* – a species typical of xerothermic grassland – is found, is quite often accompanied by *Lappula squarrosa*. On landslips and fresh earth falls, *Poa compressa*, *Bromus inermis* and *Anthemis tinctoria* are found, and places with water seepage

are dominated by *Eupatorium cannabinum*. Wet meadows occur only over limited areas, i.e. at the bottom and outlets of denudation valleys. *Phragmites australis*, *Carex acutiformis* and *Juncus inflexus* occur occasionally.

Shrubs, especially *Rosa canina* and *R. rubiginosa*, *Crataegus monogyna* and *C. laevigata*, *Cornus sanguinea*, *Berberis vulgaris*, *Prunus spinosa* and tree undergrowth encroach on the grasslands throughout the area. Moreover, *Rubus caesius* occur in many places densely creeping over the slopes. In the marginal zone of the reserve, the areas adjacent to crop fields are covered with dense thickets dominated by *Prunus spinosa*. They play an important role preventing erosion and fertiliser run-off from the neighbouring fields. Xerothermic grasslands are threatened by shrub vegetation found in central parts of the slopes and therefore, they have to be cut down. The undergrowth in those shrubs is poorly developed, and in many places, they lack any ground vegetation. In addition to blackthorn shrubs, also thickets of *Corylus avellana* occur at those sites. They grow over small areas and are unlikely to threaten the vegetation of xerothermic grasslands which are actually endangered by tall trees that shade photophilous species of xerothermic grasslands. The most common trees in the reserve include: *Populus alba*, *P. tremula* and *P. nigra*. Moreover, in some areas, *Betula pendula* is self-sown. *Ulmus minor* is also quite frequent but less expansive. Less common trees are: *Fraxinus excelsior*, *Quercus robur* and *Q. petraea*, *Acer platanoides*, *A. pseudoplatanus*, *Tilia cordata* and *T. platyphyllos*, *Fagus sylvatica*, *Salix fragilis*, *Prunus communis*, *Cerasus avium* and *Pinus sylvestris*.

In dense tree stands, the undergrowth is very poor. In less dense birch stands, the following plants are found: *Vincetoxicum hirudinaria*, *Vicia tenuifolia*, and in marginal zones, *Stachys recta*, *Pulsatilla pratensis*, *Stipa joannis* (Fig. 5), *Scorzonera humilis*, *Campanula sibirica* and other xerothermic species.

In general, the flora occurring in the reserve is relatively rich since its composition is determined by heterogeneous land relief and the resulting diversity of habitats, from exceptionally dry and highly sunlit to damp and shady. The abundance of species also derives from the location of the reserve along the largest route of plant migration in Poland, which is the Vistula valley. The list of species compiled by Ceynowa-Giełdon (2002) includes 59 lichen taxa, 27 moss species and 361 species of vascular plants. The southern and central parts of the reserve represent the highest floristic value.



Figure 5. Association *Potentillo-Stipetum* in the nature reserve "Ostnicowe Parowy Gruczna" (*Stipa* ravines in Gruczno)

Twelve lichen taxa occurring in the reserve are included on the Polish red list of endangered lichens (Cieśliński et al., 2006): one critically endangered (CR) species, *Fulgensia fulgens* and three taxa classified as EN (endangered): *Collema coccophorum*, *Heppia lutosa* and *Squamarina lentigera*; four vulnerable (VU) species: *Caloplaca cerina*, *C. cerina* var. *muscorum*, *Endocarpon pusillum* and *Fulgensia bracteata*; three near-threatened (NT) species: *Collema bachmanianum*, *Evernia prunastri* and *Toninia sedifolia* [syn. *Toninia coeruleonigricans*]. One species was classified as NT, i.e. near-threatened – *Agonimia gelatinosa* [syn. *Polyblastia gelatinosa*]. Three lichen species are listed as strictly protected species: two species of the *Fulgensia* genus, i.e. *Fulgensia bracteata* and *F. fulgens*, and *Squamarina lentigera* (Ceynowa-Giełdon, 2002; Regulation of the Minister of the Environment, 2014). The lichen nomenclature is quoted after Diederich et al. (2015) and <http://www.mycobank.org/>.

Two moss species are partially protected: *Polytrichum commune* and *Calliergon cuspodatum*.

Strictly protected vascular plants are represented in the reserve by following: *Stipa joannis*, *Scorzonera purpurea*, *Campanula sibirica* and *Pulsatilla pratensis*.

The list of partially protected plants encompasses: *Epipactis helleborine*, *Centaureum erytrea*, *Helichrysum arenarium* and *Ononis spinosa*.

Plants threatened by extinction and endangered in Western Pomerania and Wielkopolska (Żukowski and Jackowiak, 1995) include: *Stachys recta*, *Rosa micrantha*, *Cucubalus baccifer* – V (vulnerable) and *Eryngium planum*, *Avenula pratensis* and *Viola mirabilis* – R (rare).

According to Rutkowski (1997) and Ceynowa-Giełdon (2002), the following species rarely encountered in Poland deserve special attention: *Veronica preacox*, *Medicago minima*, *Seseli annuum*, *Koeleria macrantha*, *Koeleria glauca* for. *vivipara*, *Vicia tenuifolia* and *Achillea pannonica*.

The process of extinction of valuable species has been taking place for over a hundred years. Already during Preuss' study (1912), many species identified by Grütter and other previous researchers, could not be found. According to Ceynowa-Giełdon (2002), the following native and protected species (rarely found in Poland) were extinct in the nature reserve or in its immediate vicinity before its establishment: *Anemone sylvestris*, *Stipa capillata*, *Gentianella amarella*, *Orchis morio*, *Orchis ustulata*, *Cerastium brachypetalum*, *Thesium linophyllum* and *Thesium ebracteatum*.

Thymelea passerina could be added to the above group since Ceynowa-Giełdon (2002) reported its presence in the fields adjacent to the reserve in 1980. *Anemone sylvestris* is still found in a locality situated 3 km south of the reserve where it should be protected (Waldon, 1998; Ceynowa-Giełdon, 2002).

The protection plan for the reserve (Ceynowa-Giełdon, 2002) classified 12 lichen species and 14 species of vascular flora as those of special concern. The following species adversely affect the condition of vegetation in the reserve: *Robinia pseudacacia*, *Betula pendula*, *Pinus sylvestris*, *Padus serotina*, blackthorn *Prunus spinosa* and *Calamagrostis epigejos*.

In the Lower Vistula Valley on the slopes of the reserve and in the vicinity of Gruczno, 87 species of wild bees were found, which represent about 25% of all species reported from Poland and 30% of species recorded in the Kujawy-Pomerania region (Pawlikowski 2002, after Ceynowa-Giełdon, 2002). Some of them are steppe species very rarely found in Poland: *Andrena curvungula*, *Tetralonia macroglossa* and *Bombus humilis*. A steppe and taiga bee species – *Bombus semenoviellus* partially protected in Poland – also occurs in the area. The valley habitats

around Gruczno are the only place where this species is found in the Kujawy-Pomerania region and the third one in Northern Poland.

All species of wild bees nested or were somehow associated with their nesting ground in the slope zone from where they spread to habitats located at the bottom of the valley and the nearby habitats of the plateau. From several nearby small apiaries with up to 20 hives, workers of the honeybee *Apis mellifera* were searching for flower nectar and pollen. Although their contribution accounted for nearly 40% of the entire bee population, they did not affect significantly the number of wild bee species.

2.3.3. Principles and methods of protection

The abandonment of hay making and grazing, as well as grass burning created favourable conditions for the processes of secondary vegetation succession, encroachment of shrubs, and excessive spread of wood small-reed (*Calamagrostis epigejos*) which together threaten the lichen communities and xerothermic grasslands. Another threat is posed by erosion processes initiated in the upper parts of slopes. For the above reasons, the reserve requires active protection consisting mainly in the removal of trees and shrubs from the slopes, and their planting to form vegetation belts on the plateau, at the marginal zone. The vegetation belts are supposed to prevent erosion and reduce fertiliser run-off from the farmed upland. The thickets of *Prunus spinosa*, *Cornus sanguinea* and *Crataegus* sp. div. growing on the slopes need to be removed or thinned. Tall tree stands, especially in places where they shade grasslands, should be removed, thinned and their species composition should be changed. For tree and shrub re-planting on the plateau and in the upper parts of slopes, it is recommended to use plant seedlings from different parts of the reserve. Spontaneous spread of tree and shrub seedlings and the competition from herbaceous plants that threaten vulnerable species can be eliminated by mowing and grazing grasslands. Several years ago, the managers of the Complex of Chełmno and Vistula Landscape Parks decided to keep a flock of Wrzosówka sheep to implement the grazing programme in the "Gruczno *Stipa* Ravines" reserve and other steppe reserves located in the Lower Vistula Valley (Fig. 6). The flock is used for grazing in two other steppe reserves which are located in the Complex of Chełmno and Vistula Landscape Parks, i.e. "Góra Św. Wawrzyńca" ("St. Lawrence Mount") and "Zbocza Płutowskie" ("Płutowo

Slopes”) reserves near Chełmno (Figs 1 and 2). The conservation plan for the “Gruczno *Stipa* Ravines” reserve assumed grazing by 20 animals throughout the nature reserve (Ceynowa-Giełdon, 2002).



Figure 6. Sheep grazing on xerothermic grasslands of the Chełmno Landscape Park

Wrzosówka sheep is a small, primitive fur breed, one of the oldest in Poland. The first information about its breeding come from the 18th century in north-eastern Poland. The breed was described and classified by Prof. M. Czaja in 1937, and it became almost extinct in the 1960s. Since 1972, Dr. S. Zalewska from the Animal Research and Development Station at Czechnica near Wrocław has worked on its restitution. Using the rescued population of 160 ewes and 27 rams, she reproduced the flock of up to 2,000 heads. Once the herd was expanded, the sheep returned to north-eastern Poland for preservation breeding, and later on, amateur breeders (including organic farmers) started breeding the sheep throughout the country.

Wrzosówka is a perfect breed for extensive farming. It has very limited requirements when it comes to nutrition and breeding conditions. It can take less nutritional fodder, and thrives even on very infertile pastures. It easily adapts to different climatic and environmental conditions. It can also withstand any adverse conditions. The breed is

recognised for its vigour, longevity and resistance to diseases such as lameness. The leather obtained from Wrzosówka is very strong, light and warm. It is perfect for light and very warm sheepskin coats. The dark meat of the sheep tastes excellent and its savour resembles venison.

Active conservation in the reserve is carried out by the Bydgoszcz Regional Directorate for Environmental Protection under the “Active protection of Kuyavian and Pomeranian Xerothermic Grasslands” programme, and encompasses mowing, and tree and shrub removal over an area of 5.7 ha. in 2013, and 7.5 ha in 2014.

There are also plans to reintroduce *Anemone sylvestris* and, if *Thymelea passerine* is re-discovered in Gruczno, to transfer this species to a narrow crop field directly adjacent to the nature reserve.

2.3.4. The Complex of Chełmno and Vistula Landscape Parks

The Complex of Chełmno and Vistula Landscape Parks is a body in charge of the reserve established in 1999 by merging two parks designated in 1993 on the left and in 1998, on the right Vistula bank. Initially, the expanded entity was called the Lower Vistula Valley Landscape Park. In 2003, the park name was changed to Chełmno and Vistula Landscape Parks, which is effective until now. It is the largest protected area in the Kujawy-Pomerania province. It extends along the Vistula from Bydgoszcz to Nowe and is nearly 100 km long with a total area of over 60,000 hectares. It is located in 4 districts and 16 communes. The Complex includes: 14 nature reserves, 97 live nature monuments (mostly trees or tree groups) and 4 inanimate nature monuments (one cave, one boulder rock and two springs).

The Complex of Parks has also a valuable cultural monument under protection which is an eighteenth century Mennonite cottage located at Chrystkowo approximately 4 km of the “Gruczno *Stipa* Ravines” reserve (Fig. 7). On the plot with an area of 3.6 ha adjacent to the cottage, an orchard with a collection of old varieties of apple trees and pastures for old breeds of farm animals were established.

About 3 km east of the reserve and Chrystkowo, the “Nadwiślański” (“Vistula”) hiking trail with a length of 52 km runs through from Bydgoszcz to Świecie. When following this trail on foot or riding a bicycle, you can visit the nature reserves located on the left slope of the Vistula Valley, including the “Gruczno *Stipa* Ravines”.



Figure 7. Former Mennonites' cottage from 1770; an educational and museum centre in the Complex of Chełmno and Vistula Landscape Parks

2.4. The Biosphere Reserve “Tuchola Forest”

2.4.1. Location and area

The Tuchola Forest Biosphere Reserve – the largest biosphere reserve in Poland, i.e. over 3195 km², was designated on June the 2nd, 2010 under the UNESCO MAB Programme (Nienartowicz et al., 2010). The Biosphere Reserve is situated in north-western Poland on the border between the Pomerania province (territory of 9 communes and the towns of Brusy and Czersk in two districts: Chojnice and Kościerzyna) and the Kujawy-Pomerania province (territory of 13 communes and part of the Tuchola town in two districts: Świecie and Tuchola) (Figs 1 and 2).

In the territory of the Tuchola Forest Biosphere Reserve, forestry is the main economic branch. Forests cover over 60% of the area. There are 13 forest districts in the area, including one (Osusznica) under the Regional Administration of State Forests (RDLP) in Szczecinek, three districts (Kaliska, Kościerzyna and Lipusz) under RDLP in Gdańsk and nine districts (Czersk, Dąbrowa, Osie, Przymuszewo, Rytel, Trzebciny,

Tuchola, Woziwoda, Zamrzenica) under RDLP in Toruń. Five forest districts from the Regional Administration of State Forests in Toruń (i.e. Dąbrowa, Osie, Trzebciny, Tuchola, Woziwoda), located in the southern part of the biosphere reserve, constitutes the so-called Promotional Forest Complex (LKP). It is one of the 19 nature-economic areas of the State Forests in Poland. It was created in order to implement and demonstrate the sustainable development principles in forestry. In the LKP territory, each forest district implements proecological technologies of afforestation, forest cultivation, logging and exploitation of other forest by-products. In Promotional Forest Complexes, special attention is paid to non-economic functions of forest, including the ecological education.



Figure 1. Location of the Tuchola Forest Biosphere Reserve in Europe and Poland

The following coordinates describe the location of the Biosphere Reserve “Tuchola Forest”:

- the central point: $53^{\circ}47'26''$ north latitude and $17^{\circ}59'08''$ east longitude;
- external points of the buffer zone: $17^{\circ}23'34''$ and $18^{\circ}35'12''$ east longitude, and $53^{\circ}26'04''$ to $54^{\circ}08'49''$ north latitude.

The altitudinal range (meters above sea level) is: +55 to +206.2 (Mt. Wolność).

The total area of the “Tuchola Forest” Biosphere Reserve is 319,524.61ha.



Figure 2. Location of the Tuchola Forest Biosphere Reserve in the background of provinces' boundaries in Poland

2.4.2. The hierarchical spatial structure

Twenty six units (one national park and 25 nature reserves, including 7 forest reserves, 12 – peat bogs, 2 – landscape reserves, 2 – faunistic reserves, 1 – floristic/aquatic reserve, 1 – archaeological reserve) form the core zone. Four landscape parks and 19 nature reserves form the buffer zone around the national park. The buffer zones exist around six reserves located outside the landscape parks. There is one large transition zone around 10 buffer zones. Since there are 26 and 10 units in the core and buffer zones (respectively) and one large transition zone around the units, the BR Tuchola Forest is defined as a “cluster BR” (Fig. 3).

The core zone consists of: the Tuchola Forest National Park (4613.05 ha) and the following 25 nature reserves: the Nature Reserve “Dolina Rzeki Brdy” /the Brda River Valley/ (1681.50 ha), the Nature Reserve “Bagna nad Stążką” /Swamps on the Stążka River/ (478.45 ha), the Nature Reserve “Źródła Stążki” /Sources of the Stążka River/ (250.02 ha), the Nature Reserve “Jezioro Piaseczno” /Lake Piaseczno/ (159.78 ha), the Nature Reserve “Brzęki im. Zygmunta Czubińskiego” (102.21 ha), the Nature Reserve “Miedzno” (86.01 ha), the Nature Reserve “Cisy Staropolskie im. Leona Wyczółkowskiego” /Leon Wyczółkowski Old-Polish Yews/ (85.73 ha), the Nature Reserve “Jezioro Laska” /Lake Laska/ (70.40 ha), the Nature Reserve “Mętne” (53.28 ha), the Nature Reserve “Bór Chrobotkowy” /Lichen Scots Pine Forest/ (41.50 ha), the Nature Reserve “Bagno Stawek” /the Swamp Stawek/ (40.80 ha), the Nature Reserve “Jezioro Ciche” /Lake Ciche/ (37.96 ha), the Nature Reserve “Jezioro Małe Łowne” /Lake Małe Łowne/ (37.83 ha), the Nature Reserve “Piecki” (19.42 ha), the Nature Reserve “Cisy nad Czerską Strugą” /Yews on the Czersk Stream/ (17.19 ha), the Nature Reserve “Kręgi Kamienne” (16.91 ha), the Nature Reserve “Jezioro Zdręczno” /Lake Zdręczno/ (15.74 ha), the Nature Reserve “Krwawe Doły” (13.02 ha), the Nature Reserve “Dury” (12.59 ha), the Nature Reserve “Jezioro Kozie” /Lakes Kozie/ (12.30 ha), the Nature Reserve “Nawionek” (10.67 ha), the Nature Reserve “Ustronie” (9.64 ha), the Nature Reserve “Bagno Grzybna” /the Swamp Grzybna/ (6.26 ha), the Nature Reserve “Jelenia Góra” (4.39 ha), the Nature Reserve “Martwe” (4.07 ha).

The total area of the core zone is 7880.72 ha, i.e. 78.81 km². The National Park and the above mentioned nature reserves represent the most valuable natural areas in the Tuchola Forest region.

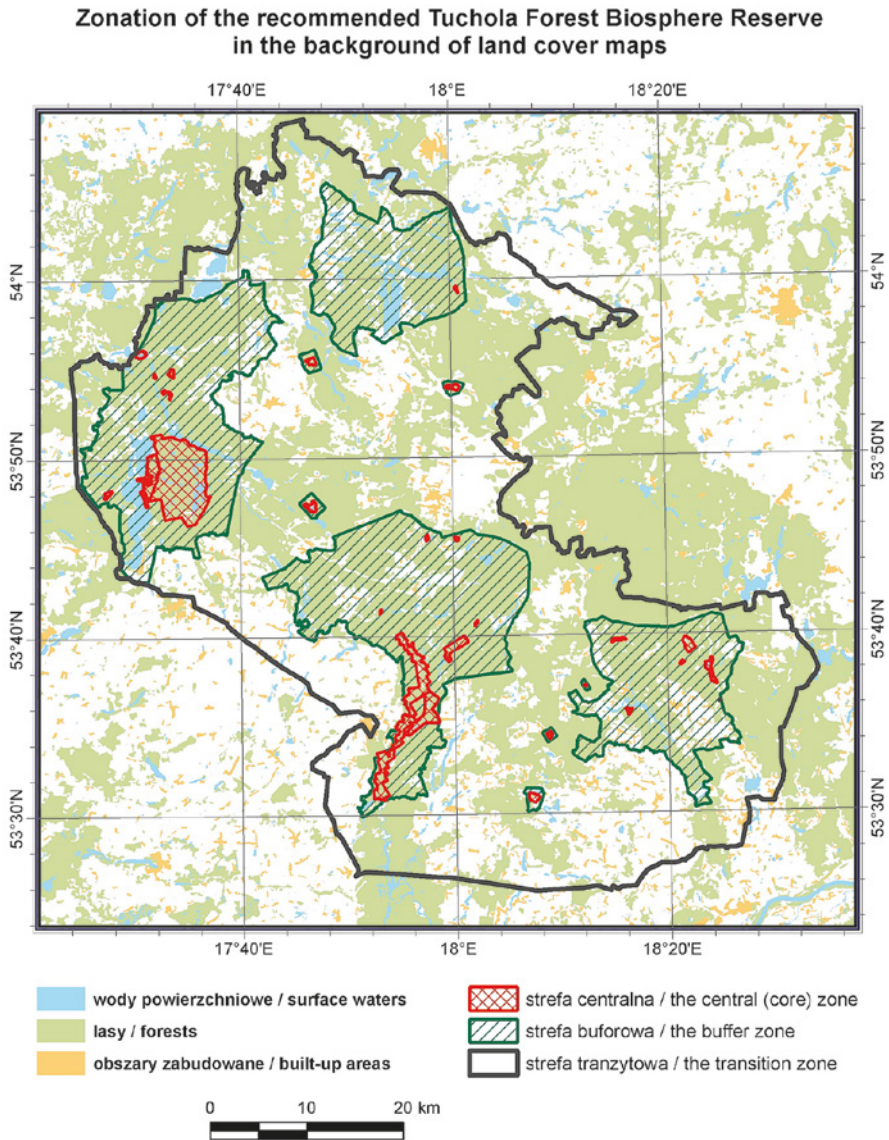


Figure 3. Zonation of the Tuchola Forest Biosphere Reserve in the background of land cover map.

The buffer zone includes mainly four landscape parks, excluding the area of nature reserves located within those parks. The aforementioned nature reserves represent the core zone. These are the following landscape parks:

1. the Wdzydze Landscape Park – created in 1983 (the total area 17,832.00 ha, including 13.02 and 17,818.98 ha of the core and buffer zones, respectively),
2. the Tuchola Landscape Park – created in 1985 (the total area 36,983.00 ha, including 2471.10 and 34,511.90 ha of the core and buffer zones, respectively),
3. the Zaborski Landscape Park – created in 1990 (the total area 34,026.00 ha, including 179.12; 29,640.22; 4206.66 ha of the core, buffer and transition zones, respectively),
4. the Wda Landscape Park – created in 1993 (the total area 23,786.36 ha, including 398.55; 21,212.80; 2175.01 ha of the core, buffer and transition zones, respectively).

Peripheries of the Wda and Zaborski Landscape Parks are included in the transition zone of the biosphere reserve.

The buffer zone also encompasses forest and meadow areas around 6 nature reserves situated outside the landscape parks. The buffer zones of the six nature reserves are located within the protected landscape, which are one of the nature conservation forms in Poland.

The four aforementioned landscape parks were created already several years ago and since then they have served as a buffer zone for nature reserves located within the parks. Even before the landscape parks were created, the economic activity conducted in their areas was consistent with the principles of sustainable development.

The total area of the buffer zone of the Tuchola Forest Biosphere Reserve is 104,779.32 ha.

The transition zone includes 22 communes, which were not included in the national park, nature reserves, landscape parks or the buffer zone around the six nature reserves situated outside the landscape parks: Bukowiec, Cekcyn, Dragacz, Gostycyn, Drzycim, Kęsowo, Lniano, Lubiewo, Osie, Śliwice, Świekatowo, Tuchola (town and commune), Warlubie in the Kujawy-Pomerania province; and Brusy (town and commune), Chojnice, Czernik, Czernik (town and commune), Dziemiany, Karsin, Konarzyny, Kościerzyna, Lipusz, Stara Kiszewa in the Pomerania province.

The transition zone is almost twice as large as the total area of the core and buffer zones. The region is economically homogeneous, focused on the forestry, processing of wood and other forest by-products, agriculture, recreation and leisure. All the economic activities are performed in accordance with the nature conservation principles.

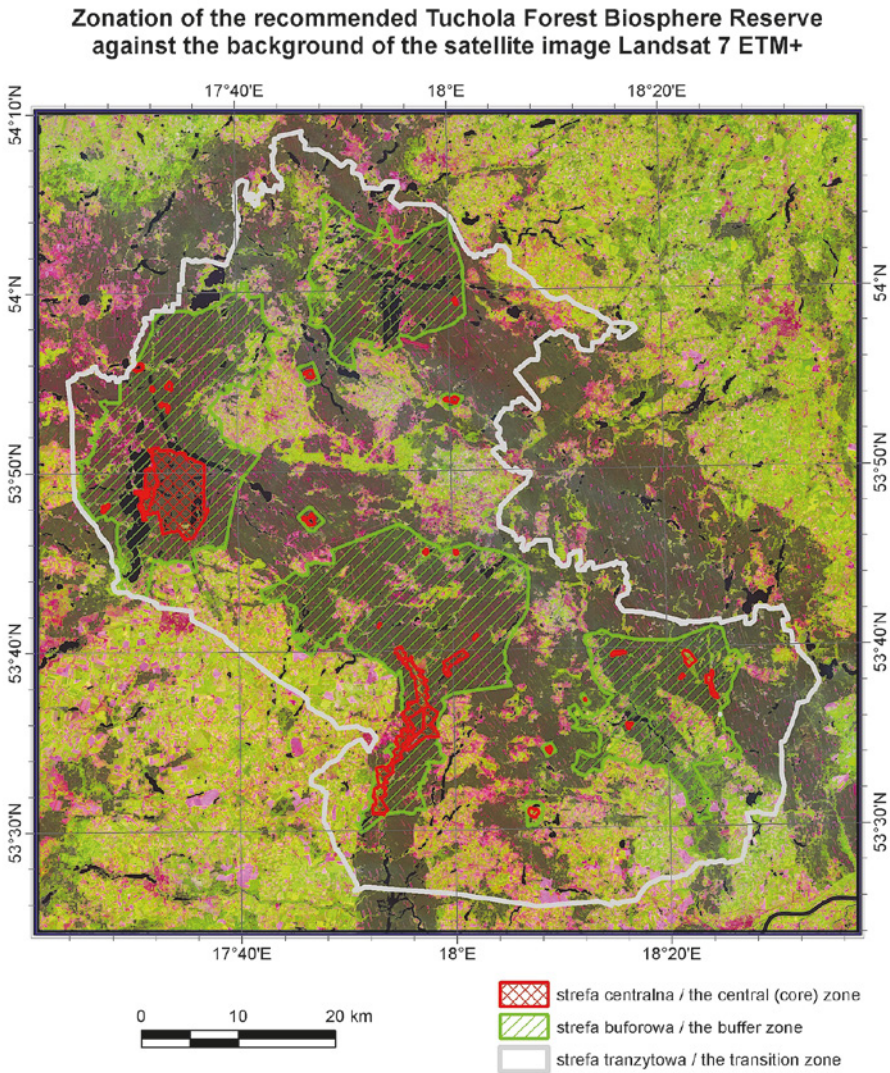


Figure 4. Zonation of the Tuchola Forest Biosphere Reserve against the background of the satellite image Landsat 7 ETM+

In the transition zone of the biosphere reserve, there are some areas with high nature conservation values, including ten protected landscape areas:

1. the Lipuski Protected Landscape Area,
2. the Tuchola Forest Protected Landscape Area,

3. the Protected Landscape Area of the Tuchola Forest's Fragment,
4. the Northern Protected Landscape Area, the western part,
5. the Northern Protected Landscape Area, the eastern part,
6. the Protected Landscape Area of Chojnice and Tuchola,
7. the Śliwice Protected Landscape Area,
8. the Eastern Area of the Tuchola Forest Protected Landscape,
9. the Świecie Protected Landscape Area,
10. the Protected Landscape Area of the Koronowo Reservoir.

The transition zone of the biosphere reserve partially includes also three nature-landscape units:

1. the "Ryszka River Valley" Nature-Landscape Unit,
2. the "River Sobińska Struga Valley" Nature-Landscape Unit,
3. the "Prusina River" Nature-Landscape Unit.

Nature monuments are yet another form of nature conservation. There are a few hundred nature monuments in the Tuchola Forest Biosphere Reserve.

2.4.3. General description including heathlands

The Tuchola Forest Biosphere Reserve is one of the largest forest complexes in Poland. It is located in the north-western part of Poland, in the Pomerania region, about 50 km south-west of Gdansk in the Baltic coast. The present-day relief of Tuchola Forest developed during the glacial age, particularly during the last Baltic glaciation, the Pomeranian Phase. Fluvioglacial alluvial plains dominate in the Biosphere Reserve; they are mostly afforested and built of sand layers. The region is characterized by a lowland, lakeland type of landscape. The area is quite heterogeneous in respect of altitude. The relief diversity is connected with the occurrence of concave geomorphological forms (subglacial gullies, river valleys, small glacial melt-water features), as well as aeolian convex forms (dunes, aeolian hills). The area of the Biosphere Reserve is intersected by two Holocene river valleys: the Brda and the Wda, running from NW to SE. The Biosphere Reserve is located within the temperate climate zone with a slight influence of oceanic air masses.

About 17,140 people live in the buffer zone of the biosphere reserve (in total 102,500 people in 2006). The average density of the human population in the whole area is 32 persons/km². It drops to 16 persons/km² within the buffer zone and almost to zero within the core zone. The former interactions and settlement processes resulted in three major

ethnic groups in the Biosphere Reserve. Those groups are formed by: Borowiacy from the Tuchola region (in the southern part of the area), Borowiacy from the Kashubia region (in the north-western part) and Zaboracy (in the northern part). Their material culture and everyday life, in the past and today, are presented in several museums, an ethnographic park, exhibitions and memorial chambers.

People mostly depend on forestry and tourism. At the same time, however, the major source of their income is exploitation of forest ecosystems (logging, Fig. 5, mushroom and berry picking, hunting) and water ecosystems (fishing), as well as cultivation of small agricultural fields, which together with housing settlements form forest “islands”. In recent years, agritourism combining the traditional farming forms with tourism and recreation, as well as craft development based on the local timber processing, has become one of the most intensively developing branches of economy in the transition zone.



Figure 5. Fuel wood preparation in the village of Asmus in the Zaborski Landscape Park (photo by Andrzej Nienartowicz)

Long-term traditions of efficient economic management exist in the area. For political reasons, in the 19th century and at the beginning of the 20th century, the area of Tuchola Forest was economically

developed, both by Prussia who was bringing settlers from other regions of the country, and by effectively managed Polish social and economic organizations (cooperative banks, trade companies) established in this area to maintain the Polish character of the lands. The creation of the Biosphere Reserve in the large and, at the same time, naturally and economically homogeneous ecoregion contributed to the harmony between the biosphere, sociosphere and technosphere, as well as the promotion of sustainable development.

The following types of pine forest dominated in the Tuchola Forest BR: fresh pine forests (associations *Leucobryo-Pinetum* and *Peucedano-Pinetum*), dry pine and heather forests (ass. *Cladonio-Pinetum* and the community *Pinus sylvestris-Calluna vulgaris*), humid and marshy coniferous forests (*Vaccinio uliginosi-Betuletum pubescentis*, *Vaccinio uliginosi-Pinetum sylvestris* and *Molinio-Pinetum*), mixed pine forests (*Querco roboris-Pinetum*) and young pine forests, which are anthropogenic plant communities derived from Scots pine plantations on the habitats of deciduous forests. The following types of broadleaf deciduous forests (whose habitats in the past were largely used for pine cultivation) are still significant vegetation elements in the region: acidophilous oak forests (*Fago-Quercetum* and *Calamagrostio arundinaceae-Quercetum petraeae*), thermophilous oak forest (*Potentillo albae - Quercetum petraeae*), lime-oak-hornbeam forests (*Stellario-Carpinetum*, *Galio sylvatici-Carpinetum*, *Tilio-Carpinetum*, the community *Acer platanoides-Tilia cordata*), acidophilous beech forest (*Luzulo pilosae - Fagetum*), alder woods (*Sphagno squarrosi-Alnetum*, *Ribeso nigri-Alnetum*) and alluvial forests (*Fraxino-Alnetum*, *Stellario nemorum-Alnetum glutinosae* and *Ficario-Ulmetum*). The protected tree species, abundantly occurring in some forest reserves, are represented by yew (*Taxus baccata*; Fig. 6) and wild service tree (*Sorbus torminalis*).

Aquatic ecosystems are represented by lakes, which cover a considerably large area. Some of the lakes from the Tuchola Forest are among the largest lakes in Poland (Lake Wdzydze, 1656 ha; Lake Charzykowskie, 1367 ha). Many genetic and limnological lakes are located in this area, including the following characterized by high nature conservation values: small isolated lakes with crystal clear water – lobelia lakes with characteristic unique vegetation (*Lobelia dortmana*, *Isoëtes lacustris*, *I. echinospora*) and dystrophic lakes surrounded by large *Sphagnum* carpets (Fig. 7).

In forest complexes, peat bogs are frequent ecological systems that differentiate into raised bogs (the class *Oxycocco-Sphagnetea*), transition

mires (the class *Scheuchzerio-Caricetea nigrae*), and fens (mainly from the class *Phragmitetea*).



Figure 6. Trees in the Nature Reserve "Cisy Staropolskie im. Leona Wyczółkowskiego" – Leon Wyczółkowski Old-Polish Yews (photo by Marian Boinski)

In deforested areas, psammophilous grasslands occur (pioneer arenaceous grasslands on aeolian dunes, ass. *Spergulo vernalis-Corynephorretum*), as well as heathlands represented by heaths with nodding thread-moss (ass.

Pohlio-Callunetum) and subcontinental bearberry heaths (ass. *Arctostaphyllo-Callunetum*).



Figure 7. Peat bogs in the nature reserve "Jeziorka Kozie" (photo by Marian Boinski)

Heaths occur mainly along the land division lines (Fig. 8), firebreaks and former airstrips used by firefighting, pest-control and forest-fertilization aircrafts. After being abandoned, they gradually become overgrown with forest.

Semi-natural and anthropogenic, fresh and wet meadow and pasture communities (the class *Molinio-Arrhenatheretea*), as well as cereal crops, buckwheat and potatoes, vegetables and flowers in gardens largely contribute to the land-use structure of agricultural areas.

Those habitats and plant communities are ecological systems, typical of lowlands in Central Europe where many rare, relict and protected species of vascular plants occur (trees, bushes, dwarf shrubs, herbaceous plants) and cryptogamic plants (algae, lichens, mosses and liverworts), fungi, as well as invertebrates and vertebrates. Many of these species are listed on the Polish Red Lists of endangered species (in 2010, when the biosphere reserve was created: algae – 10 species from the red list, 149 lichens, 29 mosses, 136 vascular plants (212 on the local list; 38 species nearly extinct, included on the national and local list),

33 fungi, 2 cyclostomes, 11 fishes, 8 amphibians, 5 reptiles, 53 birds and 15 mammals).



Figure 8. Heaths in the neighbourhood of the “Tuchola Forest” National Park (photo by Magdalena Kochanowska)

2.4.4. Natura 2000 sites

The recent designation of Natura 2000 sites in Poland supports the nature conservation. Sixteen Natura 2000 sites (Fig. 9) were designated in the Tuchola Forest Biosphere Reserve, including two Habitat Conservation sites created based on the EU Birds Directive and 14 Special Conservation Areas created in compliance with the Habitat Directive:

- 1) PLB22001 Great Sandur of the Brda River;
- 2) PLB220009 Tuchola Forest;
- 3) PLH040017 Sandur of the Wda River;
- 4) PLH040023 Valley of the Brda and Stążka Rivers in Tuchola Forest;
- 5) PLH040034 Church in Śliwice;
- 6) PLH220026 Sandur of the Brda River;
- 7) PLH220034 Wdzydze Lakes;
- 8) 220056 Red Water at Babilon;

- 9) PLH220057 Zapceń Refuge;
- 10) PLH220058 Valley of the Brda and Chocina Rivers;
- 11) PLH220060 Freedom Wood;
- 12) PLH220061 Mętno;
- 13) PLH220070 Krąg Lake;
- 14) PLH220077 Młosino-Lubnia;
- 15) PLH220082 Stary Bukowiec;
- 16) PLH220094 the Wierzyca River Valley.

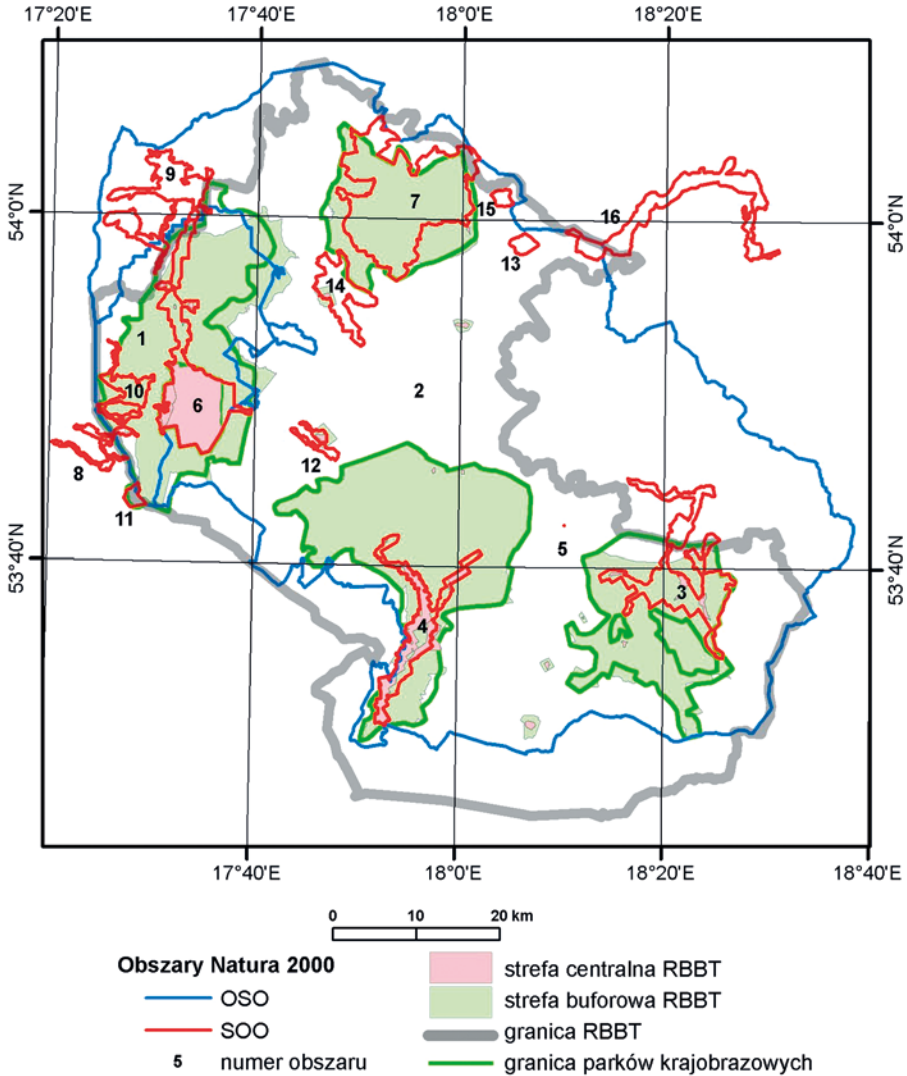


Figure 9. Distribution of Natura 2000 sites in the Tuchola Forest Biosphere Reserve (number symbols denote in the text)

Seven of the aforementioned sites are entirely located within the biosphere reserve, and nine sites – only partially. Tuchola Forest PLB00220009, with a total area of 322,535.9 ha, is the largest Natura 2000 area in the biosphere reserve, nominated based on the EU Birds Directive. As much as 73.8% of the PLB220009 area, i.e. 238,201.8 ha, overlaps with the biosphere reserve area.

According to the Standard Data Form – Natura 2000, posted on the website of the Ministry of the Environment of the Republic of Poland, Tuchola Forest PLB220009 covers the eastern part of the South Pomeranian Lake District. The following mesoregions are included: Tuchola Forest, the eastern part of the Charzykowska Plain, the north-eastern part of the Krajna Lake District, the northern part of the Brda River Valley and the northern part of the Świecka Upland. The area is a relatively homogeneous outwash plain, cut through by the Brda and Wda valleys, with many lakes, ponds and hills of a ground moraine. Forest habitats dominate, including mainly pine forests.

It is a typical young glacial area encompassing mostly infertile sands. The heterogeneous land relief of the refugium includes plateaus, extensive elevations, many hills, valleys and channels. The hydrological network is well developed (waters cover ca. 14% of the area). The refugium is drained by the Brda River together with several tributaries, the most important being Zbrzyca. Many rivers are characterized by a steep gradient and a strong water current. There are several flow-through (open) lakes connected to the Brda River water network, several oligotrophic and mesotrophic lakes, a few eutrophic lakes, and some dystrophic lakes near peat bogs. In total, there are about 60 lakes, including the largest Charzykowskie Lake – 1363 ha, and the deepest Ostrowite Lake – 43 m. Forests (ca. 70% of the total area) are represented mainly by fresh pine forests, as well as marshy and dry forests, oak-hornbeam forests, beech-oak forest, riparian forests and alder woods. There are many peat bogs. Arable lands, meadows and grazing lands cover ca. 15% of the total area.

At least 28 bird species from Annex I of the Birds Directive and 6 species from the Polish Red Data Book occur in PLB00220009 Tuchola Forest refugium. A total of 107 bird species nest in the area. During the breeding season, the area is inhabited by at least 1% of the country's population of the following bird species: white-tailed eagle, black kite, red kite, ferruginous duck, Eurasian eagle owl, Black terns, common tern, common kingfisher, common crane, common goldeneye, goosander, red-breasted merganser; and western marsh harrier occurring in a relatively high density.

At least 1% of the whooper swan population (up to 400 individuals) and the common crane population (up to 1800 individuals per roosting) occur during the migration season.

The following features contribute to the high conservation value of the area: the largest group of lobelia lakes on a regional scale, rich lichen flora, well-preserved peat bogs and forest communities, sites of many rare and endangered species, including relict species, rich chiropterofauna.

The following species are listed in the Standard Data Form – Natura 2000 as species covered by article 4 of directive 2009/147/WE and species from annex II of directive 92/43/EEC:

Birds – *Actitis hypoleucos*, *Aegolius funereus*, *Alcedo atthis*, *Anas crecca*, *A. querquedula*, *A. strepera*, *Anser anser*, *Anthus campestris*, *Ardea cinerea*, *Aythya nyroca*, *Botaurus stellaris*, *Bubo bubo*, *Bucephala clangula*, *Caprimulgus europaeus*, *Charadrius dubius*, *Chlidonias hybridus*, *Ch. niger*, *Ciconia ciconia*, *C. nigra*, *Circus aeruginosus*, *C. cyaneus*, *C. pygargus*, *Columba oenas*, *Crex crex*, *Cygnus columbianus bewickii*, *C. cygnus*, *C. olor*, *Dendrocopos medius*, *Dryocopus martius*, *Emberiza hortulana*, *Ficedula parva*, *Galinago galinago*, *Gallinula chloropus*, *Gavia stellata*, *Grus grus*, *Haliaeetus albicilla*, *Ixobrychus minutus*, *Lanius collurio*, *Larus argentatus*, *Lullula arborea*, *Mergus merganser*, *M. serrator*, *Milvus migrans*, *M. milvus*, *Motacilla cinerea*, *Pandion haliaetus*, *Pernis apivorus*, *Phalacrocorax carbo sinensis*, *Podiceps cristatus*, *P. nigricollis*, *Porzana porzana*, *Rallus aquaticus*, *Sterna hirundo*, *Tachybaptus ruficollis*, *T. ochropus*, *Upupa epops*;

Cyclostomes – *Lampetra fluviatilis*, *Lampetra planeri*;

Mammals – *Castor fiber*, *Lutra lutra*;

Plants – *Liparis loeselli*, *Luronium natans*, *Saxifraga hirculus*.

2.4.5. Scientific research and monitoring

The scientific research and monitoring are conducted based on 10 main field stations, which belong to 6 universities from Toruń (the Nicolaus Copernicus University, station in Laska), Bydgoszcz (the University of Technology and Life Sciences; field stations in Srebrnica, Tleń and Drzewicz; the Kazimierz Wielki University; the field station in Stara Rzeka, the University of Economy, the field station in Tleń), Gdańsk (the University School of Physical Education, a sport centre in Raduń), Łódź (the University of Łódź; the Ecological Station in Suszek and the

Archaeological Station in Białe Błota). In the Tuchola Forest, intensive and long-term research has been conducted also by universities from Poznań – the University of Adam Mickiewicz and the University School of Physical Education. Few years ago, the research activity in the region was undertaken by the Koszalin University of Technology and the Educational Branch Centre and the University Grammar School was created in Chojnice, as well as the non-public Higher School of Environmental Management in Tuchola, which focused on education and research within the scope of forestry and landscape ecology. Another non-public school conducting the teaching activity in the Chojnice region is the Bishop People's University. Within the territory of the biosphere reserve, environmental studies are also conducted by specialized research institutes from Warsaw, such as the Research Institute of Forestry, the Institute of Environmental Protection and the State Geological Institute.

The scientific work include: monitoring of air, soil and surface water, the history of vegetation, modern pollen rain, monitoring of rare, endangered and non-native species, succession, phytosociology, current and potential carbon resources in ecosystems and landscape, impact of technologies applied in the forestry on the biodiversity and landscape heterogeneity, the use of natural resources by the local community, energy flow on the landscape level, indicators of sustainability, GIS databases, satellite images, mapping, complex analysis of ecosystems and modelling.

2.4.6. Education and tourism

The educational activity is carried out in the biosphere reserve based on:

1. the Educational and Scientific Laboratory of the Tuchola Forest National Park in Charzykowy,
2. educational laboratories in Landscape Parks: the Wda Landscape Park in Osie, the Tuchola Landscape Park in Tuchola, the Wdzydze Landscape Park in Kościerzyna and the Zaborski Landscape Park in Charzykowy,
3. educational laboratories in ten research stations of universities and other tertiary-level schools,
4. nature museums in the Promotional Forest Complex (the Centre for Nature-Forest Education in Woziwoda) and in the Tuchola Forest

- National Park (a nature museum under construction in Chociński Młyn),
5. the Dendrological Park in Gołąbek (Tuchola Forest District) and the Dendrological Garden in Lipinki within the Forest District of Dąbrowa,
 6. Field Schools in Woziwoda (Tuchola Landscape Park), in Schodno (Wdzydze Landscape Park), and Field Classes (in Lipniki and Gołąbek within the Promotional Tuchola Forest Complex),
 7. laboratories in primary and secondary schools where classes are conducted by employees of forest districts, scholars and social workers,
 8. the Ornithological and Natural Centre „Kokoszka” in the Forest District of Przymuszewo,
 9. ecological education rooms and historical chambers in 13 forest districts, as well as educational stations in several forest administration regions,
 10. altogether 26 natural and educational trails in forest districts (including botanical, zoological, ornithological, forest trails focused on problems related to forest protection against insect pests, lichenological and cultural, hydrobiological, historical along the route of Teutonic Knights’ castles, astronomical; educational trails equipped with boards and leaflets describing the routes and individual nature objects; among the existing trails there are also routes for disabled people, routes for blind and short-sighted people marked with Braille),
 11. the Scout Centre of Ecological Education in Funka,
 12. museums of forestry: the Museum of Forestry in Woziwoda, the seed husking plant in Klosnowo in the Forest District of Rytel (a modern seed husking plant is located in the vicinity of the museum; it is entirely computerized and available for classes; one of the seven Polish Seed Testing Stations is located in the area), the Room of Forestry History in the registered office of the Tuchola Forest District in Gołąbek,
 13. historical and ethnographic museums: the Historical and Ethnographic Museum in Chojnice, the Tuchola Forest Museum in Tuchola, the Museum of the Zabory Land in Wiele, the Kashubian Ethnographic Park in Wdzydze Kiszewskie, museums dedicated to the art of regional folk artists (the Jan Karnkowski Museum Room in Brusy, “Jasnochówka” – the villa of Kazimierz Jasnocha, the painter of Kashubian landscapes, the Memorial Room in Karsin; the Hieronim

Derdowski Museum in Wiele), private collections, e.g. historical and regional collection of the Makowskis family from the town of Chojnice.

New recreational, educational and conference centres in Fojutowo and Cekcyn (both in the Kujawy-Pomerania province), as well as a new tourism centre and the Museum "Kaszubska Chata" (Kashubian Cottage) in Brusy, and the Centre of Education and Development in Chojnice play an important role in promotion of the culture of two Polish ethnic groups: Borowiacy and Kashubians, and the dissemination of the ecological knowledge and scientific achievements.

All forms of tourism – recreational, scientific and educational – are developed in the Tuchola Forest Biosphere Reserve. Tourist and recreational infrastructure comprises regular, all-year-round holiday centres, hotels, agritourism farms, seasonal camping sites, as well as regular and seasonal gastronomic outlets. Based on these facilities, people take part in sailing, canoeing, horse riding, cycling, hunting, collection of forest undergrowth products, hiking along marked tourist trails, as well as educational excursions along organised nature and forest trails in order to learn about flora, fauna, ecosystems, history, tradition and folklore of the region.

2.4.7. Administration and management

Administration of the Tuchola Forest Biosphere Reserve is part of the Tuchola Forest National Park under the authority of the Ministry of the Environment, and the Zaborski Landscape Park and Wdzydze Landscape Park under the authority of the Marshal Office of the Pomerania Province, the Tuchola Landscape Park and Wda Landscape Park under the authority of the Marshal Office of the Kujawy-Pomerania Province.

The registered office of the biosphere reserve is located in the building of the Tuchola Forest National Park Headquarter in Charzykowy in the Pomerania Province. The registered office of the Tuchola Landscape Park in Tuchola (Fig. 10) coordinates operations in the nature reserve located in the Kujawy-Pomerania province.

The celebration of the 5th anniversary of the Tuchola Forest Biosphere Reserve is on the 2nd June 2015.

More details about the Tuchola Forest Biosphere Reserve is presented in the book: Kunz M., Nienartowicz A., eds, 2014. – Biosphere Reserves in Poland, Wydawnictwo Naukowe NCU, Toruń.



Figure 10. The registered office of the Tuchola Landscape Park in Tuchola (photo by Mieczysław Kunz)

2.5. Tuchola Forest National Park

2.5.1. The general description

LOCATION. Tuchola Forest National Park (TFNP) covers a small part of the large forest complex called Tuchola Forest. It was created on the 1st of July 1996 over the area of 4,613.04 ha. The park is situated in the Pomerania Province, the Chojnice district and two communes Chojnice and Brusy. It is surrounded by a protected zone of 12,980.52 ha (Chybowska et al., 2012) and Zaborski Landscape Park (Fig. 1).

The Park includes lands of State Treasury. Forests, meadows and peat bogs were separated from the Klosnowo forest district, the Rytel Forest Division, whereas lakes – from the Agricultural Property Agency of the State Treasury. The lakes were used by the Fish Farm in Charzykowy.

TFNP partly includes the Zaborski Landscape Park created in 1990 to preserve the outstanding natural and cultural values of the southern part of Kashubia, referred to as the Zabory Region. Protection of this

area had been requested repeatedly since 1948 due to the fact that one of the largest wood-grouse refugia existed in this part of Pomerania till the late 1970s.

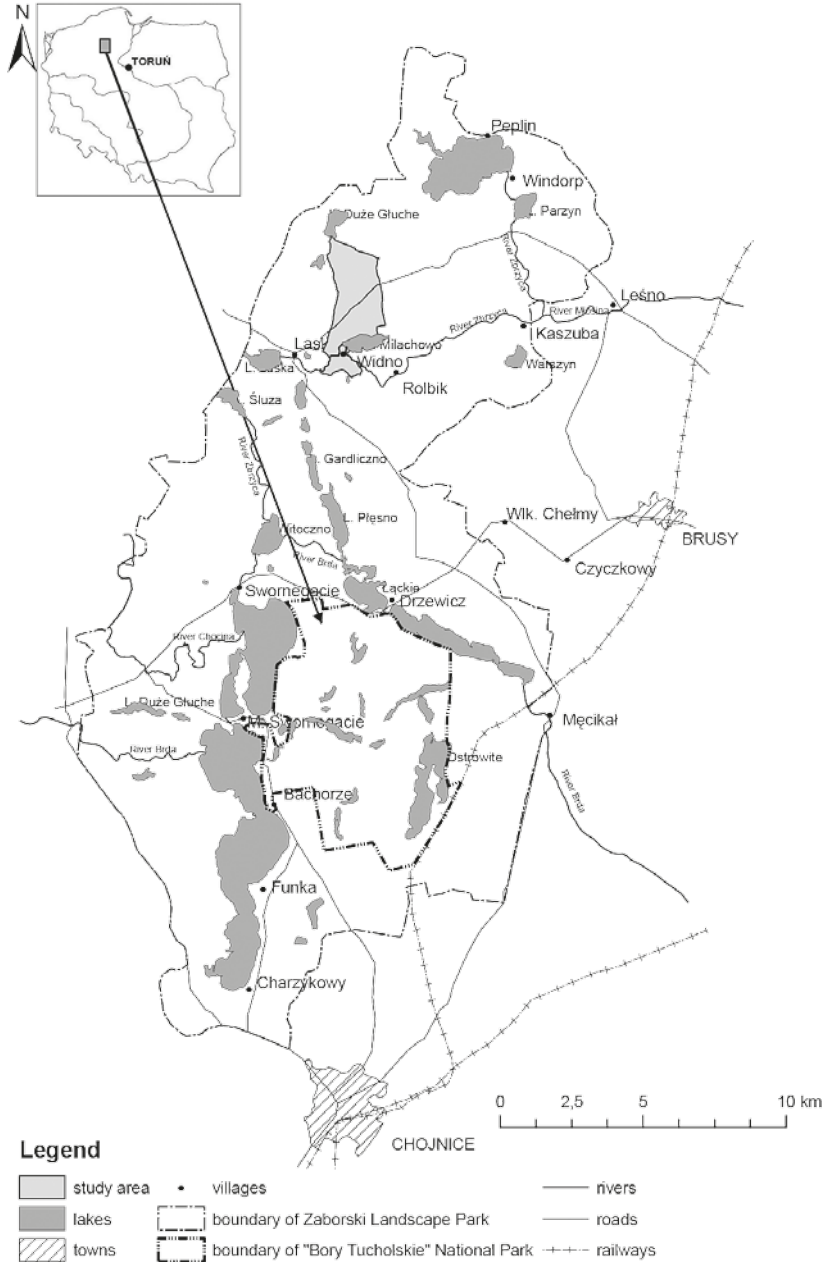


Figure 1. Location of Tuchola Forest National Park inside Zaborski Landscape Park

GEOLOGY AND GEOMORPHOLOGY. The land relief of Tuchola Forest was formed by the Scandinavian glacier during the Baltic glaciation. The dominant land form in this area are sandy outwash plains – the Great Sandur of the Brda River – developed as a result of erosion and accumulation processes induced by meltwater. There are numerous dunes, tunnel valleys and kettle-holes on the outwash plains. The largest group of inland dunes in Tuchola Forest is located near Lake Charzykowskie. The most characteristic feature of the outwash plains are tunnel valleys of elongated shape and meridional course. Lakes Charzykowskie, Karsińskie, Długie and Witoczno are located in the largest valley – 17 km long, situated in the buffer zone of TFNP. The Park area is dominated by infertile podzol, pseudopodzolic and brown soils. In the vicinity of the lakes, muck-peat and peat soils occur.

According to Turowski (ed.), the soils occurring in the Park include: 1 – autogenic soils – podzolic and rusty soils and specific podzolic soils created from loose sands and slightly clayey sands, in some places – shallow and medium-deep dunes underlain by loose sands (95.4% of the Park's forest area), as well as specific rusty soils (0.2%); 2 – semi-hydrogenic soil is represented by black-earth, gley podzolic soils, rain-gley soils and earth-gley soils and covers about 2.5% of the total park's area; 3 – boggy hydrogenic soil of transitional and raised bogs covering about 1% of the forest area and post-bog soils – peat and muck soils and half-bog soil (0.3% of the forest area); 4 – poor lithogenic soil (aeolian) – covers about 0.6% of the Park's forest area, mainly habitats of dry and poor fresh coniferous forests.

CLIMATE. The climate conditions are transitional due to the geographic location in the Eastern Pomerania Region. The influence of polar-maritime and polar-continental air masses is observed here. The local climate is also a result of a large forest and water area in the Park. Turowski (ed.) presents the following data characterizing the local climate: average annual precipitation: 577 mm, average temperature in January: -2.5°C, average temperature in July: +18.0°C; growing season: 190–200 days.

WATERS. The objective of TFNP is to preserve the unique types of ecosystems characteristic of Pomerania, in particular lake ecosystems (*Lobelia* lakes, *Chara* lakes). The Park is located in the catchment area of the Brda River. The following rivers flow through the buffer zone: Brda, Chocina, Czerwona Struga (Kopernica) and Jarcewska Struga. There are 21 lakes in TFNP (Fig. 2), including particularly valuable *Lobelia* lakes

with crystal clear water (Małe Gacno, Wielkie Gacno, Głuche, Nierzybno, Wielkie Krzywce, Małe Krzywce, Kocioł, Łyska). *Lobelia* lakes are oligotrophic, mostly acid and extremely susceptible to contamination.



Figure 2. Land cover and the status of the area, tourist and educational trails in Tuchola Forest National Park (after Chybowska et al., 2012, modified)

Also small dystrophic lakes (e.g. Kacze Oko, Rybie Oko) containing large amounts of humic compounds are unique to the described area. One of the nature peculiarities in the Pomeranian Lake District is Struga Siedmiu Jezior (Seven Lakes Stream) running through the park area. It is a small river with a length of 9.4 km flowing out from Lake Ostrowite and connecting the following lakes: Zielone, Jeleń, Bełczak, Główka, Płesno, Skrzyńka and Mielnica. The waters of the Struga are discharged into Lake Charzykowskie. The TFNP area covers nearly the entire drainage basin of the Struga (3680 ha). It consists of lakes: Ostrowite (area 272.27 ha, depth 43 m), Zielone (25 ha), Jeleń (48 ha), Bełczak (4 ha), Główka (9 ha), Płesno (46 ha), Skrzyńka-Mielnica (30 ha). Lake Ostrowite is an example of *Chara* lakes with water quality of class I.

VEGETATION. The pine forest stand is a dominant component of the park, and covers over 85% of the total area. The stands vary from very dry coniferous pine forests to fresh, wet and boggy coniferous forests. The average stand age in the park is about 70 years and the stand resources – 212 m³/ha.

A total of 37 plant communities were distinguished in the National Park. Ecosystems of fresh pine forests dominate, with i.a. twinflower *Linnaea borealis* in the herbaceous layer. Also Scots pine forests with a frequent and abundant occurrence of rare lichens, including *Cladonia* species, cover relatively large areas. The flora of lichens is represented by ca. 200 species, including a significant contribution of *Cladonia*, *Usnea* and *Bryoria*. In addition, a number of fungi species occur in the herb layer of forests. The total number of hitherto identified macrofungi is 483 (www.pnbt.com.pl/grzyby...). Extremely valuable components of the park's flora are plants associated with lobelia lakes: water lobelia *Lobelia dortmanna* and lake quillwort *Isoetes lacustris*. Floating water-plantain *Luronium natans* (code 1831 in the Natura 2000 Programme) – a rare species across Europe – also occurs in these lakes. Sandy shores of *Lobelia* lakes are overgrown with marsh clubmoss *Lycopodiella inundata* and wolf's-foot clubmoss *Lycopodium clavatum*. An interesting Atlantic species – saw sedge *Cladium mariscus* occurs on the shores of Lake Ostrowite, Lake Zielone and Lake Jeleń. Raised and transitional peat bogs are habitats of bog sedge *Carex limosa*, common sundew *Drosera rotundifolia*, great sundew *D. longifolia* and oblong-leaved sundew *D. intermedia*, beak-sedge *Rhynchospora fusca*, marsh calla *Calla palustris* and others. Meadows located in the middle of forests, with e.g.

southern adders-tongue *Ophioglossum vulgatum*, add a lot of variety to the forest landscape. Inland sand dunes overgrown with pioneer moss *Polytrichum piliferum*, psammophilous grass *Corynephorus canescens*, and small patches of heaths *Calluna vulgaris* are located at the western boundary of the park (Fig. 3).



Figure 3. Sand dune at the western boundary of the national park (photo by K. Lubińska)

A total of 634 vascular species occur in the National Park and represent 33% of the total lowland flora of Poland, including 43 legally protected species (www.tfnp.com.pl/rosliny_vascular-637).

Animals. A number of protected and endangered species occur in Struga Siedmiu Jezior (Seven Lakes Stream), e.g. bivalves – inter alia swan mussel, compressed river mussel and thick shelled river mussel. A total of 144 bird species were identified in the whole Park area, including 108 breeding species, e.g. common crane, Eurasian eagle owl, white-tailed eagle, common goldeneye and common kingfisher. The bird species – western capercaillie (wood grouse) – is a symbol of TFNP, which has recently occurred in large numbers in Tuchola Forest, especially in the Forest Division of Klosnowo. There are plans to reintroduce this gallinaceous bird into the park area. Struga Siedmiu Jezior and its banks are feeding grounds for many mammal species.

For instance, preying of eight bat species has been observed in this area (e.g. Natterer's bat, pond bat and common pipistrelle), while only three species occur deep in the forests (Chybowska et al., 2012). Large mammals are represented by: red deer, roe deer, wild boar, foxes, marten, raccoon dogs, otters and badgers. In 1978, the European beaver was reintroduced in the area of Struga Siedmiu Jezior and the population size of the species increases every year.

Furthermore, 25 species of fish, 43 species of mammals, 13 species of amphibians and 6 species of reptiles occur in the park area (www.borytucholskie.pl/park,narodowy). Bats play a particularly important role in the environment: Nathusius' pipistrelle, brown long-eared bat, greater mouse-eared bat, Daubenton's bat and Natterer's bat. In the lakes of the Park, the following fish species occur: freshwater whitefish, vendace, European eel, perch, tench, bream, amur bitterling, spined loach and burbot. Amphibians are represented by common frog, moor frog, green and common toads, as well as great and smooth crested newts. The common European adder is the most common reptile in the Park (www.borytucholskie.pl/park,narodowy).

2.5.2. Protected areas and refugia

To protect natural values of the Park, the following areas were designated (Chybowska et al., 2012):

- strictly protected areas which represent 7% of the total area (324.30 ha),
- partially protected areas, both non-invasive (preservation) and active protection, which represent 91% of the total area (4,209.78 ha),
- landscape conservation areas located in 2% of the Park area (78.96 ha).

There are 10 strictly protected areas:

1. Lake Kacze Oko – the total area of 2.42 ha; protection of the dystrophic lake and the surrounding bog pine forest.
2. Lake Głuche – protection of the lake with an area of 3.47 ha; the objective is to protect natural development processes in the lobelia lake.
3. Lake Olbrachta – an area of 19.02 ha; protection of the lake together with the direct catchment area.
4. Lake Rybie Oko – the total area of 1.49 ha; protection of the dystrophic lake and the surrounding bog pine forest.

5. Lake Małe Gacno – the total area of 109.27 ha; the objective is to protect natural development processes in the lobelia lake and its direct catchment area.
6. Lake Kocioł – the total area of 135.43 ha; the objective is to protect natural development processes in forest ecosystems in the absence of any human interference; the area is dedicated to forestry studies.
7. Lake Kociołek – the total area of 1.53 ha; protection of the dystrophic lake and the surrounding bog pine forest.
8. Lake Błotko – the total area of 5.88 ha; protection of the lake with a peat bog where saw sedge *Cladium mariscus*, wild rosemary *Ledum palustre*, common sundew *Drosera rotundifolia* occur.
9. Lake Nierybno – the total area of 19.07 ha; the objective is to protect natural development processes in the lobelia lake and its direct catchment area.
10. Peninsula on Lake Ostrowite – the total area of 26.72 ha; the objective is to preserve natural development processes in forest ecosystems and to compare the changes occurring on the Peninsula with changes occurring in regions where active protection is permissible.

Protection zones of refugia, breeding sites and sites of regular presence of protected animals were designated in the Tuchola Forest National Park, as well as protection zones of refugia and stands of protected plants, lichens and fungi. These are protection zones of refugia, breeding sites and sites of regular stay of the white-tailed eagle and the Eurasian eagle owl. Whereas among plant species identified in the park area, the floating water-plantain *Luronium natans* occurring in lakes Wielkie Gacno, Małe Gacno, Nierybno and Małe Krzywce is covered by zonal protection. Zonal protection includes also lichens, i.e. *Usnea subfloridana*, *Usnea hirta* and *Usnea filipendula*.

2.5.3. Material culture and tourism

Important Tuchola Forest tourist centres are located by Lake Charzykowskie and Lake Karsińskie. In particular, farm tourism developed in recent years, e.g. in the village of Swornegacie. The Brda River has long been known as a canoe trail. Apart from the Brda River, the Zbrzyca and Chocina rivers are perfect for canoeing. The village of Charzykowy is famous as a birthplace of inland sailing in Poland. Lake Charzykowskie with its numerous bays is very attractive for sailors in summer and iceboaters in winter. Bike trails run through the most

beautiful and interesting places in Tuchola Forest. Marked hiking trails lead through the Park. The Julian Rydzkowski Kashubian red trail is one of the most interesting trails in terms of nature and culture; it leads from Chojnice to Wiele. Forest trails lead a tourist through villages and hamlets in the Region of Zabory. Zabory is an old historical name referring to the land located “beyond the coniferous forest” when looking from old centres of secular and clerical authorities and administration. The historical Zabory Region encompassed the lands of old parishes Brusy, Wiele and Czersk. Later, the parish of Swornegace was incorporated into the region, and at present also the environs of Dziemiany and Lipusz, but only in the ethnographic sense. Residents of the Zabory Region are referred to as Zaboracy or Krebanie. Wooden Kashubian cottages have been preserved in the villages of Swornegace and Męcikał (www.borytucholskie.pl/park,narodowy).

Two sections of the blue “Brda Hiking Trail” run through the Park area. The trail leads along the main river of Tuchola Forest, i.e. the Brda River.

In addition, two short connecting trails were designated in the Park – the black and yellow ones. They connect main trails and facilitate the movement of tourists throughout the Park.

Also two bike trails – blue and black – were designated. Bike trails in the National Park are connected with trails of the so-called Kashubian Route leading through the district of Chojnice. Together they form a system of bike trails with a total length of 186.54 km.

2.5.4. Environmental education

Three educational nature trails and one hiking trail were created in the Park to meet the comfort of tourists who wish to combine a passion for hiking with environmental education. The trails follow along the most interesting and most valuable fragments of the Park (Fig. 2). The fourth educational trail was created near the Park’s headquarters in Charzykowy for people who have difficulty covering long distances (Chybowska et al., 2012). A collection of plants easily identifiable and most frequently encountered along the hiking and bike trails was prepared over a relatively small area.

Trails created in the Park:

1. Blue educational trail “Piła Młyn” (5.7 km long, hiking time 2.5 h); it leads through the most appealing areas in the Park reflecting its

floristic and faunistic diversity, as well as different types of genetic and limnological lakes.

2. Red educational trail "Łąki Józefowskie" (5.3 km; 2.5 h); it leads through a variety of Park's ecosystems – forest, meadow and lake's environs.
3. Green educational trail "Lake Wielkie Gacno" (6.6 km; 3.5 h); it runs along lobelia lakes with characteristic vegetation and succession in the littoral zone and on the dune.
4. Hiking trail "Pętla Lipnickiego" with a peat bog along the way; foot-bridges enable the visitors to observe changes occurring on the peat bog.
5. Tuchola Forest National Park organizes also classes, both in the field and in the conference hall located in the Park's office in Charzykowy, at ul. Długa 33 (street Długa 33). Up to 30 people can participate in the classes. Lectures can accommodate 50 persons. For students of secondary and higher grades, thematic workshops are organized. They can accommodate up to 30 persons.

Package tourism (tour groups) should be organised under the supervision of a tourist guide or an employee appointed by the Director of the Park. Tour groups must be limited to 30 people.

2.5.5. Some of the study sites

2.5.5.1. Lake Gacno Wielkie

Lake Gacno Wielkie (Fig. 4) is one of the main and best known objects and research sites in the Tuchola Forest National Park. In the 1980s, palynological analysis of fossil deposits of this lake was conducted by Hjelmroos-Ericsson (1981) from the University of Lund, Sweden, as part of her PhD dissertation. The study was supervised by Prof. Bjorn Berglund, a doctor honoris causa of Nicolaus Copernicus University in Toruń. Following the publication of the results of this study, Lake Gacno Wielkie became a benchmark for research on the vegetation history, not only of the national park but also of the whole Tuchola Forest region and Polish Lowlands.

Lake Gacno Wielkie is a closed (i.e. with no outflow) lobelia lake, oligohumic, well oxygenated with a depth of ca. 7 m (Marszelewski and Nowicka, 2012). Its total area is 13.5 ha, the maximum depth – 5.5 m, the maximum length – 870 m and the width – 220 m. The water volume of the lake was estimated at 418,500 m³ (Gwoździński and Mazur, 2002). The water of the lake contains very few minerals, hence its low

electrolytic conductivity (ca. $30 \mu\text{S}\cdot\text{cm}^{-1}$; Zdanowski et al., 2004). Low sedge rush, e.g. filiform sedge *Carex lasiocarpa* and higher, dispersed reed rush surrounded the lake. The flat flood plain, covered with telmatophytes like mosses, sundew (mainly *Drosera rotundifolia*) and marsh club moss *Lycopodiella inundata*, enclose the basin. Water lobelia *Lobelia dortmanna*, quillwort *Isoetes lacustris*, bur-reed *Sparganium angustifolium* and alternate water-milfoil *Myriophyllum alterniflorum* represent the plants specific for lobelia lakes. Lobelia, bulbous rush and water-milfoil occur in shallow (to 1.5 m) and sandy parts of the lake (Szmeja and Chmara, 2006). In the dark, organic and shallow places there occur: water-plantain *Luronium natans*, bur-reed and several other plants like common reed *Phragmites australis* and common cattail *Typha latifolia*. Quillwort and mosses *Sphagnum denticulatum* and *Warnstorfia exannulata* representing over 90% of the plant mass in the lake occur in deeper parts of the lake (1.5–3.0 m). In the deepest part, only mosses occur. Small bays are covered with a dwarf water lily *Nymphaea candida* and water knotweed *Polygonum amphibium* (Szmeja and Chmara, 2006).



Figure 4. Lake Wielkie Gacno (photo by B. Grabowska)

According to Królikowska et al. (2012), 63 plant taxa from 32 families occur in the littoral and pelagic zones of Lake Wielkie Gacno, including

the following strictly protected species: *Lobelia dortmanna*, *Isoetes lacustris*, *Drosera rotundifolia*, *Nymphaea candida* and six *Sphagnum* species (*Sphagnum subsecundum*, *Sph. denticulatum*, *Sph. palustre*, *Sph. magellanicum*, *Sph. rubellum*, *Sph. cuspidatum*). In addition, *Sph. fallax* and *Polytrichum strictum* and *P. commune* are partially protected.

The green educational trail leads to Lake Wielkie Gacno. One of the Tuchola Forest NP educational points, as well as a bicycle parking ground and a wooden pier are located in the middle of the eastern shore of the lake.

2.5.5.2. Observations and experiments in a heath located in the northern and eastern part of the National Park

A heath located in NE part of the National Park overgrowing the former firebreak, is a research site at which active nature conservation has been implemented. It is located at a junction of forest units no. 11 and 12, 25 and 25, 38 and 39, 50 and 51. It stretches as a narrow strip between Lake Jeleń and Lake Dybrzk (Fig. 5).

The development of lichens and species diversity of epigeic lichens as well as interactions between this group of species with other components of the heath, mainly heather *Calluna vulgaris*, juniper *Juniperus communis* and grasses have been observed at the site (Fig. 6). The objective of the research is to define practical recommendations for the preservation of sustainability of heaths, and in particular lichens occurring in these communities.

In the studies conducted so far along three transects consisting of three squares each, delimited in different fragments of the site with a varying dominance of heather, Lipnicki (2012) reported the occurrence of 38 lichen species. The genus *Cladonia* is represented by as many as 28 species, the genera: *Stereocaulon*, *Cetraria*, *Trapeliopsis* and *Placynthiella* – by two species each, and the genera: *Baeomyces* and *Peltigera* – by one species each. Four species of the total number of 38 are strictly protected in Poland (*Stereocaulon tomentosum*, *S. condensatum*, *Peltigera rufescens*, *Cetraria muricata*), and five species are partially protected (*Cladonia arbuscula*, *C. mitis*, *C. portenosa*, *C. rangiferina*, *Cetraria aculeata*). All the above-mentioned partially protected species and *Stereocaulon condensatum* and *Peltigera rufescens* (strictly protected) are common in Tuchola Forest. The others, i.e.

Stereocaulon tomentosum and *Cetraria muricata*, are rare both on a regional scale and in the entire country. Both species from the genus *Stereocaulon* and *Cetraria muricata* as well as *Cladonia sulphurina* are included on the Polish Red List of endangered lichens in Poland.

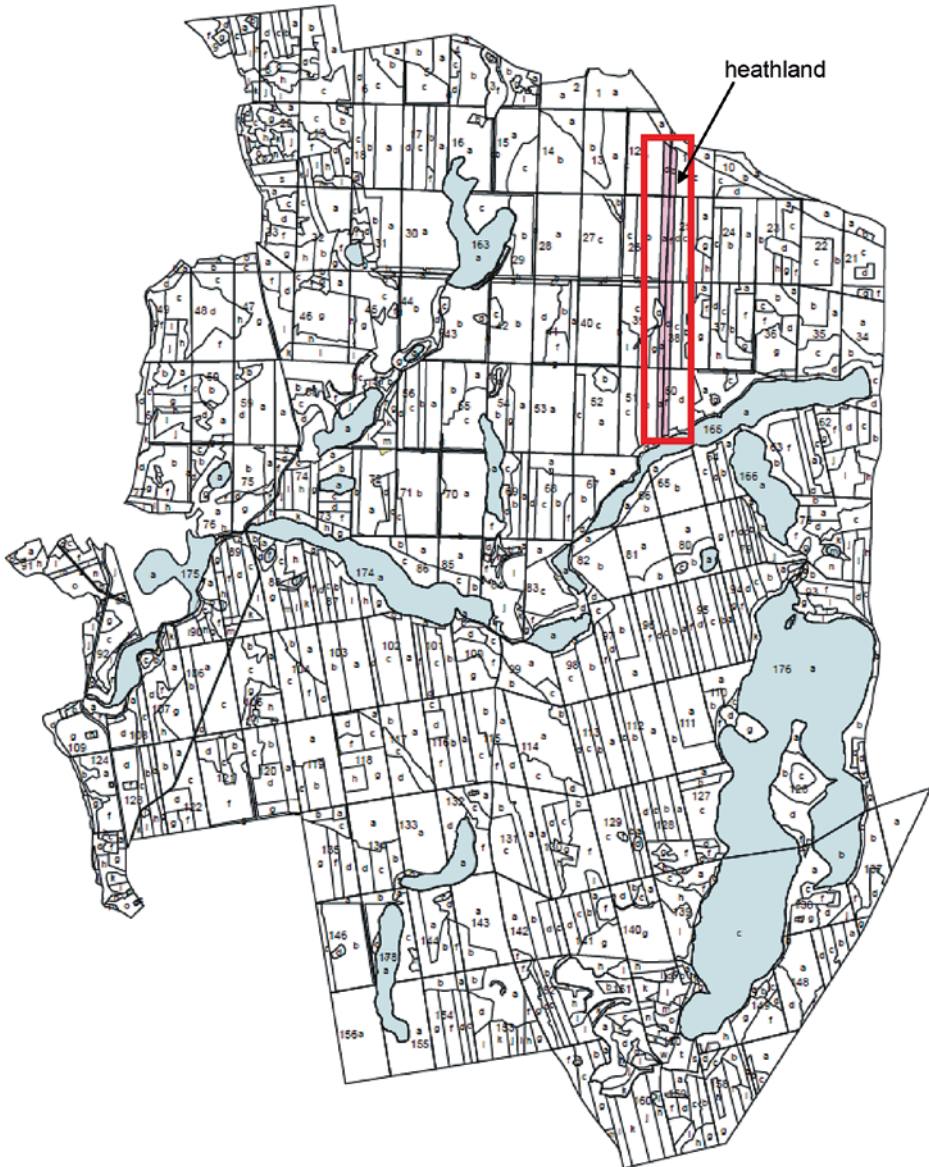


Figure 5. Location of the former firebreak at the eastern boundary of the national park



Figure 6. Heath in the firebreak (photo by K. Lubińska)

Lipnicki (2012) recommends the following actions to preserve lichens at the described study site:

- mowing of heather to prevent the expansion of this species, which should be carried out every 3–5 years. The heather must be immediately collected after mowing and removed from the heath area,
- removal of excessive trees and shrubs (*Betula pendula*, *Pinus sylvestris*, *Juniperus communis*) by cutting them down and grubbing.
- burning in accordance with the following recommendations):
 - a) before the commencement of work – consultations with experts in fauna of invertebrates, in particular entomologists,
 - b) implementation of treatments in late winter and early spring after melting of snow and drying of vegetation cover, and before the beginning of the growing season,
 - c) full protection against flame spread to neighbouring areas, particularly in forest,
 - d) only a single fragment of a heath can be burnt, not the entire area,
 - e) burning may not be repeated more often than every 8–10 years.
 - f) before setting a fire, a site with *Stereocaulon* lichens must be secured, in particular if rare *S. tomentosum* occurs.

According to Lipnicki (2012), grazing by Wrzosówka sheep seems unreal in the conditions of Tuchola Forest National Park, at least at present.

In the near future, a research will be undertaken on the impact of herbaceous vegetation and litter raking on the occurrence and the growth of lichens in the heath area and its vicinity. The experiment is intended to determine the extent to which this treatment used in the past by the local community affects the sustainability of the heath and dry pine forest *Cladonio-Pinetum*; the latter becomes increasingly rare in Poland.

2.6. Nature reserve and Natura 2000 Conservation Site on the former military training grounds near Okonek

2.6.1. Location and general description of the “Wrzosowiska w Okonku” (Heaths in Okonek) Nature Reserve

The reserve near Okonek is one of the largest dry heathlands in Poland. It is located in the Okonek commune, Złotów district and Wielkopolska province. According to Kondracki's geomorphological division of Poland (2001), the site is located in the Szczecinek Lakeland mesoregion (314.66) which is part of the South Pomeranian Lakeland macroregion (314.6/7), which in turn is contained in the South Baltic Coast subprovince (314/315).

The reserve covers an area of 204.13 ha and is entirely located within the limits of the former military training area, i.e. the exercise field (Figs 1 and 2). Once the military stopped using the site, it was transferred to the State Forests, Polish National Forest Holding, and is now managed by the Okonek Forest District as part of the Marianowo Forest District (www.okonek.pila.lasy.gov.pl/rezerwaty-przyrody). The nature reserve owes its present characteristics to human activity. The military use of this land with the exercises, including terrain deformation, missile explosions, and fires, produced an ecosystem with the dominance of common heather, *Calluna vulgaris*. The nature reserve requires constant active protection to keep its status of reserve. Therefore, in 2012, the Okonek Forest District removed trees and shrubs that overgrew the heathlands and grasslands within its jurisdiction. The work was funded by the European Union under the “Land Rehabilitation



Figure 2. Location of "Wrzosowiska w Okonku" (Heaths in Okonek) nature reserve on the orthophotomap

2.6.2. Natura 2000 Conservation Site PLH300021 “Poligon w Okonku” (Okonek Military Training Area)

The conservation site covers an area of 2,180.21 ha. According to the site entry in the database kept by the Polish Ministry of the Environment, it is a vast deforested area covered with heaths and calcareous grasslands. Part of the area was re-forested, however, considerable areas of heathlands are consciously and actively protected by the forest administration (including the removal of encroaching trees and shrubs). The site is one of the best preserved open and extensive heathlands in Poland. This area is also important to protection of invertebrates (locality of *Dytiscus latissimus* diving beetle). Eleven types of habitats and 4 species listed in Appendix I and Appendix II to Council Directive 92/43/EEC, respectively, were identified at this site. The habitats are ecological systems with the following codes and size: 2330 – inland dunes with psammophilous grasslands, 43.6 ha; 3160 – natural dystrophic lakes and ponds, 21.8 ha; 3260 – water courses of plain to montane levels with the *Ranunculion fluitantis* communities, 10.9 ha; 4030 – European dry heaths (*Calluno-Genistion*, *Pohlio-Callunion*, *Calluno-Arctostaphyilion*), 436.04 ha (Figs 3 and 4); 6120 – xerothermic psammophilous (*Koelerion glaucae*) grasslands, 2.18 ha; 6230 – species-rich *Nardus* grassland in mountain and lowland areas (*Nardion* – species-rich phytocoenoses), 10.9 ha; 6410 – *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*), 21.8 ha; 7140 – transition mires and quaking bogs (mostly with *Scheuchzerio-Caricetea nigrae* vegetation), 2.18 ha; 7150 – depressions on peat substrates of the *Rhynchosporion* alliance, 1.09 ha; 7230 – mountain and lowland alkaline peat bogs, sedge meadows and fens, 545.05 ha; and 91E0 – alluvial forests with willows, poplars, alders and common ash (*Salicetum albae*, *Populetum albae*, *Alnenion glutinoso-incanae*, alder forests on percolating mires), 106.39 ha. Furthermore, *Carlina acaulis* (stemless carline thistle) occurs on Mt Egipska, there are gorges of the Czarna river with headwaters phenomena, a large peat bog is located in the Czarna Valley (with fen components) west of Okonek, and fragmentary old alder forest (obszary.natura2000.org.pl).



Figure 3. The view of the road crossing the “Wrzosowiska w Okonku” (Heaths in Okonek) nature reserve (photo by Przemysław Szczawiński)



Figure 4. *Calluna vulgaris* in the „Wrzosowiska w Okonku” (Heaths in Okonek) nature reserve (photo by Przemysław Szczawiński)

The species listed in Article 4 of Directive 2009/147/ EC and Annex II to Directive 92/43/EEC are invertebrates: *Dytiscus latissimus* and *Leucorrhinia pectoralis*; birds: *Anthus campestris*, *Caprimulgus europaeus*, *Lanius collurio*, *Lanius minor* and *Lullula arborea*; and mammals: *Canis lupus*, *Castor fiber* and *Lutra Lutra*.

The site is managed by the Poznań Regional Directorate for Environmental Protection.

2.6.3. Okonek Forest Division

The land is owned by the Okonek Forest Inspectorate. According to natural forest regionalisation by Trampler et al. (1989), the forest division is located in the region of Wielkopolska and Pomerania (III), the District of Krajna Lakeland (III.2), the mesoregion of Krajna Highland (III.2.b) with a small fragment in the mesoregion of Wałcz Plain (III.2.a).

The Okonek Forest Division consists of two subdistricts: Lędyczek and Okonek. They used to be two independent inspectorates until 1975 (www.okonek.pila.lasy.gov.pl).

Lędyczek was a former inspectorate with the same name, which was established in October 1946. It included forests of the former German state-owned Landeck Forest Inspectorate and those of former estates: Vangerov and Lümzov. The total area of that forest division was 8,385 ha.

The Okonek Subdistrict used to be a separate forest division called Racibórz, which was established in 1945. The area of the then forest division was 5,274 ha. The forest division consisted of former estate, farmer and urban forests. Their structure was heterogeneous due to different management methods practised in the said forest properties. Some of the forests were established through afforestation of lands no longer suitable for farming. In 1975, the Okonek division was submitted under the authority of Lędyczek Inspectorate as the Okonek subdistrict and incorporated into the Toruń Forestry Board. When the Forestry Board was established in Piła on 1 January 1978, the Lędyczek division, including the Okonek Subdistrict was administratively submitted under their jurisdiction. By the directive of the Chief Executive Officer of the National Forest Holding, the inspectorate name was changed to Okonek with effect from 1 November 1979 (www.okonek.pila.lasy.gov.pl).

The forest division is a very interesting area in terms of natural resources. It is located in lowlands with typical flat and undulating scenery with some hilly terrains (Fig. 5). The heterogeneous terrain relief

with numerous river valleys and peat bogs supports natural diversity of both flora and fauna. This relief with such geological formations as sands and boulder clays (or glacial tills) and sandur sands is a result of the Baltic glaciation. The soils are primarily rusty (72%) and podzolic (6%), but also peaty, marshy, brown, lessive and muck.



Figure 5. The view of heaths with *Sarothamnus scoparius* from the hill near the boundary of the nature reserve (photo by Anna Lewandowska-Czarnecka)

The Okonek Inspectorate (Fig. 6) manages over 16,000 ha of forest. Fertile soils are good habitats for forests with species rich vegetation. Coniferous habitats are less fertile and their biotic composition is simpler but completely different, and hence equally interesting and fascinating. All coniferous forest habitats are dominated by pine stands. The habitats of fresh forests are also dominated by pine stands with beech and oak.

In the shrub and undergrowth layers of local forest, there are tens of protected species. The most interesting are: *Daphne mezereum*, early marsh and broad-leaved marsh orchids (*Dactylorhiza incarnata* and *D. majalis*), *Anacamptis palustris*, lesser butterfly orchid (*Platanthera bifolia*), stemless carline thistle (*Carlina acaulis*), marsh saxifrage (*Saxifraga hirculus*), snowdrop (*Galanthus nivalis*), wolf's-foot and interrupted club moss (*Lycopodium clavatum* and *L. annotinum*).

Localities of these plants require active protection, i.e. pruning and removal of shrubs. The magnificent specimens are also protected as nature monuments.



Figure 6. The main building of Okonek Forest Inspectorate (photo by Przemysław Szczawiński)

The fauna of the Okonek Forest Division is as rich as its flora. The mammals are represented by common game species: red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), hare (*Lepus europaeus*), red fox (*Vulpes vulpes*), raccoon dog (*Nyctereutes procyonoides*), European badger (*Meles meles*) and European polecat (*Mustela putorius*). As to some more interesting protected animals, the presence of wolf, beaver, otter, brown long-eared bat and Natterer's bat (*Myotis nattereri*) was also reported. The birds are represented by many protected species: lesser spotted eagle (*Clanga pomarina*), crane, woodlark (*Lullula arborea*), common buzzard (*Buteo buteo*) and goldeneye.

Reptiles are represented by: European adder (*Vipera berus*), sand lizard (*Lacerta agilis*) and slow worm, (*Anguis fragilis*) and grass snake (*Natrix natrix*). Amphibians are represented by: fire-bellied toad, smooth newt (*Lissotriton vulgaris*) and great crested newt (*Triturus cristatus*), common spadefoot (*Pelobates fuscus*), European tree frog (*Hyla arborea*), natterjack (*Epidalea calamita*) and common toads (*Bufo bufo*); and

insects: large white-faced darter *Leucorrhinia pectoralis*), purple emperor (*Apatura iris*) and lesser purple emperor (*Apatura ilia*), large copper (*Lycaena dispar*), *Dytiscus latissimus* and numerous representatives of ground beetles of the *Carabidae* family.

The Okonek Forest Division is dominated by coniferous habitats with pine mainly. The average age of forest stands in this area is 60 years and the average stand density exceeds 230 cubic meters/ha.

The percentage of forest habitats is as follows: 54% – coniferous, or stands with the dominance of coniferous species, mostly pine and spruce; 40% – deciduous forests, or stands with the dominance of broadleaved species; 6% – alder forests, or forests growing on fertile, swampy areas.

The percentage distribution of forest tree species is as follows: 77% – pine, larch; 7% – birch; 5% – oak, maple (acer), sycamore maple, elm, ash; 5% – alder; 4% – beech; 1% – spruce; 1% – other.

Tree stands by age classes: 23% – class I (up to 20 years old trees); 15% – class II (21–40 years); 24% – class III (41–60 years); 12% – class IV (61–80 years); 12% – class V (81–100 years); 14% – class VI and older (over 100 years).

The stand density is as follows: pine – 278 c.m/ha; larch – 171 c.m/ha; spruce – 256 c.m/ha; beech – 273 c.m/ha; birch – 176 c.m/ha (www.okonek.pila.lasy.gov.pl).

The Okonek Forest District renovates about 115 ha of forests every year. The inspectorate also participates in the programme to increase the forest cover in Poland by assisting private owners in the development of their afforestation plans for farmlands.

The Inspectorate cultivates about 235 ha per annum of forest plantations. Their activities encompass: weed mowing among the trees and loosening the soil around the trees with a special forest hoe. At the same time, the Inspectorate performs pruning: early pruning during cultivation, late pruning in young forests, early thinning on mature trees and late thinning in mature forest stands.

Early pruning is performed annually over an area of about 52 ha on average, late pruning – 151 ha, early thinning – 212 ha, and late thinning – ca. 715 ha.

Another operation consists in introducing seedlings of such tree and shrub species that would increase the stand productivity. Oak and beech are introduced under the canopy of the existing stands on fertile habitats (in the past forested mainly with pine).

The nature reserve “Wrzosowiska w Okonku” and the “Pojezierze Wałęckie i Dolina Gwdy” (Wałcz Lakeland and the Gwda Valley)

Protected Landscape Site are legally protected areas located in the Okonek Forest Division. Only a fragment of this site is located within the boundaries of the Okonek Forest Division, with an area of 5,900 ha. It is situated in eastern part of the Forest Division, within the Lędyczek subdistrict and the Racibórz Forest District.

The site includes areas where unique landscape is protected with diversified ecosystems whose value derives from their ability to meet both tourist and recreational needs, and their role of wildlife corridors.

There are also three Natura 2000 sites designated within the Okonek Forest Division, including Special Area of Conservation PLH300021 of the Natura 2000 network, referred to as "Poligon w Okonku" (Okonek Military Training Area) described above.

The second is the "Dolina Debrzynki" (Debrzynka Valley) Special Area of Conservation PLH300047. Only 100 ha of this site are located within the Okonek Forest Division. The site includes a section of a small river – the Debrzynka – a tributary of the Gwda with habitats important to Natura 2000s. Many valuable natural habitats are located in this area: well-preserved resources of alkaline fens and fens with meadows, fragments of riparian forests along riversides and on percolating mires, and a complex of beech and Sub-Atlantic oak and hornbeam forest with beech stands on the slopes of the river valley.

The third site is Natura 2000 Special Area of Conservation PLH220066 called "Dolina Szczyry" (the Szczyra Valley). Only a small part of this area is located within the Okonek Forest Division, i.e. 30 ha. The Szczyra river is a right tributary of the Gwda river. The protected habitats within this site are mostly concentrated at the bottom of the river valley. A partially well-preserved beech stand grows on the valley slopes in the eastern part of the valley. The area is an important refugium for alkaline peat-bogs and precious entomofauna and plant species.

There are 4 nature monuments in the forest division, including 2 oaks (Czesław and Łukasz), 1 common beech (Mieczysław) and 1 boulder rock.

A plot of organically cultivated land, referred to as "Żurawina" (Cranberry), is also established in the area. It was created in 2000 with a goal to preserve the prevailing water conditions and enable the development of the existing vegetation and soil complex. This organic plot is situated in the Ciosaniec Forest District with an area of 48.73 ha. It is a wetland site with bog vegetation and small ponds. Quite large patches of common cranberry (*Oxycoccus palustris*) are also interesting.

Foresters of the Okonek Forest Inspectorate provide also advice and assistance in forest management to private forest owners. They provide information on silviculture and forest protection, supply seedlings of forest trees and shrubs; carry out pest control and protective treatments in private forests at the expense of the inspectorate when harmful organisms that could threaten forest sustainability are detected; they perform forest management tasks (including the sale of timber) based on agreements with forest owners; take large-area audits of forest condition and keep a forest data bank.

Private forests within the Okonek Forest Division are supervised by the local authority in Złotów.

The Piła Regional Directorate of Polish State Forests which the Okonek Forest Inspectorate accounts to is a proud holder of the PEFC and FSC Forest Management and Product certifications. The certificates confirm that Piła forests are managed in accordance with international standards and criteria, and in compliance with indicators of sustainable forest management.

The FSC certification was granted in 2013 after an audit completed by SGS. The certificate covers all forest inspectorates of the Piła Directorate, including the Okonek one.

The Piła Regional Directorate of Polish State Forests is also PEFC certified. This certificate confirms that their forests are managed in compliance with the criteria and indicators for sustainable forest management required to obtain forest certification defined in Document No. 4 of the PEFC Council Poland. The certificate is valid from 30 January 2015 to 29 January 2018 (www.okonek.pila.lasy.gov.pl).

The land relief and habitat diversity of the Okonek Forest Division, a relatively dense river network and remnants of the former military training ground provide good conditions for an interesting educational infrastructure. This infrastructure consists of: the viewpoint in the "Wrzosowiska w Okonku" nature reserve, the forest path "W Dolinie Pięciu Rzek" (Across the Valley of Five Rivers) and a forest school.

The lookout in the "Wrzosowiska w Okonku" nature reserve was established in 2012 to provide local community the access to the former training area. Since the military training area was closed, the interest in this site has been growing every year. For many years now, it has been a favourite destination of hiking and cycling trips for residents of Okonek and other nearby towns. They pick berries and mushrooms. Using the infrastructure left by the military, i.e. roads, parking lots, a hill with stairs, the Okonek Inspectorate provided this beautiful

place with some elements of architecture which made it even more attractive. Every nature enthusiast can get here not only by bicycle (7 km from Okonek) but also by car taking a road open to car traffic from the villages of Brokęcino or Okonek located at national road 11. The Inspectorate set up parking lots below the lookout for motorized tourists, and on its top – for handicapped tourists. The heathland can be observed from the viewpoint. From the texts posted on bulletin boards, visitors can learn about the history of the military training area and how it was restored, about characteristics of the forest division and nature conservation.

The forest educational path called “W Dolinie Pięciu Rzek” (Across the Valley of Five Rivers) allows to meet the beauty and natural diversity of the forest at the Gwda river. The trail owes its name to tributaries which flow into the Gwda river within the radius of 500 m. The Szczyra with the Chrzastawa and Debrzynka rivers on the left and the Czarna river on the right. The trail runs next to Lędyczek that used to be the smallest town in Poland. Lędyczek is located on the road from Gorzów to Gdańsk in the northern part of the Wielkopolska province. The entrance onto the trail is indicated with a symbolic gate and a bulletin board, and its route is marked with direction signs placed on boulder rocks. The trail is about 3.5 km long and it takes 2.5 hours to walk from one end to the other. Sixteen educational stops with information panels are located along the trail.

Forest School was established in 2000; it offers educational classes to children and youth, holds competitions and meetings to promote the information on forests. It is equipped with numerous teaching aids and multimedia devices, natural collections and a rich library. A small arboretum was established around the school building with a large collection of tree and shrub species, and a playground for children.

In 2004, close to the offices of the Okonek Forest Inspectorate, another educational trail was created. It consists of 9 stops with information panels to assist classes on various topics offered around the Forest School.

Clean Lake Leśne (also referred to as Borowe or Trzecie) is located in a beautiful place of the Okonek Forest Division. To enable access to this area to the enthusiasts of nature, tourism and active recreation, the Okonek Forest Inspectorate established a walking and cycling path called “Nad Jeziorem Leśnym” (Upon Forest Lake). It runs along the lake shores where tourists can take a rest and read about the secrets of nature at educational stops.

A district cycling trail called "Rowerem przez lasy powiatu złotowskiego" (Cycling through the Forests of the Złotów District) with a length of 180 km runs across the Okonek Forest Division. Its establishment was a joint initiative of Jastrów, Lipka, Okonek, Płytnica and Złotów forest inspectorates. About 20 km of this trail runs across the Okonek Forest Division. The trail is well marked and provided with resting areas with tables and benches. The trail was established to allow a visit to the educational path. The "Nad Czarną" (at the Czarna River) walking and cycling trail with a length of 8 km from Okonek to Łędyczek was incorporated into the larger trail. The forest divisions located along the district trail organize the "Forest Bicycle Expedition" (www.okonek.pila.lasy.gov.pl).

2.7. Heaths in the nature reserve and Habitat Conservation Site "Diabelskie Pustacie" ("Devil's Wastelands")

2.7.1. Description of the reserve and the Natura 2000 conservation site

The nature reserve "Diabelskie Pustacie" covers an area of 932.04 ha. It was created based on the Regulation No. 45/2008 of the Governor of West Pomerania Province on 14 November, 2008. It is located in the West Pomerania Province, Szczecinek district, Borne Sulinowo commune. According to physico-geographical classification of Poland developed by Kondracki (2001), the area belongs to subprovince 314/315 of the South Baltic seashore, macroregion 314.6/7 of the South Baltic Lakeland and mesoregion 314.65 of Wałcz Lakeland.

The nature reserve includes: – part of the Borne Sulinowo Forest Division with an area of 637.63 ha (including afforested and non-afforested forest lands 40.77 ha, lands associated with forest management – 24.74 ha, non-forest lands 572.12 ha), and part of the Czarnobór Forest Division with an area of 294.41 ha. The objective of nature conservation in this nature reserve is protection of biocenotic systems and landscape of two outwash plains – the younger outwash plain and the Płytnica plain featuring kettle depressions and inliers. According to the Regulation of the Minister of the Environment dated 30 March 2005 on the types and subtypes of nature reserves (Dz. U. No. 60, item. 533),

the nature reserve “Diabelskie Pustacie” was classified as: I. Category – floristic reserve (Fl); II. Type and subtype: a) as per dominant object of protection: – type – biocenotic and phytocenotic (Pbf); – subtype – natural and semi-natural biocenoses (bp); b) as per major ecosystem type: – type – other ecosystems (EE); – subtype – a mosaic of different ecosystems (me), mainly heaths.

“Diabelskie Pustacie” is part of Natura 2000 – SAC “Diabelskie Pustacie” with an area of 3,232.08 hectares. The site includes former military training grounds “Borne Sulinowo” and the adjacent Płytnica riverbed and lakes. The first wildlife survey of the area performed by IUCN Poland (Górski and Adamski, 1995) reported 376 species of vascular plants belonging to 73 families. Strictly protected plant species included: *Lycopodium annotinum*, *Lycopodiella innumdata*, *Polypodium vulgare*, *Drosera rotundifolia*, *Nuphar luteum*, *N. pumilum*. Partially protected species included: *Cetraria islandica*, *Helichrysum arenarium*, *Ononis spinosa*, *Digitalis purpurea*, *Ribes nigrum*, *Viburnum opulus*, *Frangula alnus*, *Convallaria majalis*, *Ledum palustre*. In 1994, plant communities represented 15 classes and 22 alliances. The authors confirmed the presence of 5 amphibian species and 5 reptile species. Sixteen avian species endangered on the global or European scale were identified. The list of breeding and probably breeding species included 107 birds. The mammals listed at that time in the Polish Red Data Book of Animals (Głowaciński, 2002) included the European beaver (*Castor fiber*) and otter (*Lutra lutra*). The identified species of wild game included the European hare (*Lepus capensis*), fox (*Vulpes vulpes*), moose (*Alces alces*), racoon dog (*Nyctereutes procyonoides*), boar (*Sus strofa*), roe deer (*Capreolus capreolus*), and deer (*Cervus elaphus*).

A total of 66 lichen species were identified during the designation of “Diabelskie Pustacie” (Ciaciura et al., 2006), including 22 species growing on different substrates and 44 growing only on a specific type of substrate. Nine species were listed as vulnerable in Poland. They included: *Bryoria subcana* classified as critically endangered (CR), *Pycnothelia papillaria* – endangered (EN), *Usnea hirta*, *U. subfloridana*, *Cetraria chlorophylla*, *C. islandica* and *Peltigera canina* – vulnerable (VU), and *Hypogymnia tubulosa* and *Vulpicida pinastris* – near threatened (NT).

The former military training ground Borne Sulinowo features vast treeless and heath covered areas. Part of the ground has been afforested, however, large heath areas have been purposely and actively protected by the forest administration by removing trees and shrubs.

The Płytnica channel includes the Płytnica valley with Przełęg and Kniewo lakes, as well as the biocenotic systems of surrounding outwash plains of the older and, to a small degree, younger plain called the Płytnica plain. There are numerous kettle-holes of oval or oblong shape, filled with peat deposits. The Płytnica channel is characterized by natural morphology and it features many small and larger basins and bays. The uneven bottom is covered with a thick layer of bottom sediments providing abundant microhabitats. The lakes located along the course of the river are of eutrophic type.

Dry heaths in this area belong mainly to the *Genisto-Callunion* alliance. On the other hand, the following transitional and raised-bog phytocenoses have developed in the wetland areas: the raised bog of *Sphagno-Caricetum rostratae* (the largest area), the raised bog of *Sphagno-Eriophoretum angustifoliae*, the raised bog with bog cranberry *Sphagnetum magellanicum*, young forms of marshy pine forest *Vaccinio uliginosi-Pinetum*, willow thickets *Salicetum auritae*, the raised bog of *Sphagno-Eriophoretum vaginatum*, the raised bog of *Menyanthes-Sphagnetum teretis* with sites of *Drosera rotundifolia*, and *Caricetum lasiocarpae* and *Sphagno-Juncetum bulbosi* associations and bent grass-sedge moor community of *Carici-Agrostietum caninae*.

The heaths covering the former military training ground are well-preserved large-area heaths in the Western Pomerania and the only heaths that can be currently protected, because the heaths located south of Drawsko Pomorskie are still intensively used as a military training ground. Heaths, forest bogs and humid pine forests in the Wrzosiec Forest District, the Czarnobór Forest Division, in the southern part of the Natura 2000 site, forms a unique character. The Płytnica Valley is a unique sequence of aquatic and bog ecosystems in the belt of Pomeranian Lake Districts, associated with a tunnel valley in the outwash plain characterized by outstanding biodiversity.

The "Diabelskie Pustacie" Natura 2000 area harbour 13 types of habitats listed in Annex I of Directive 92/43/EEC and 5 species from Appendix II. These habitats are ecological systems with the following codes and area: 2330 – inland dunes with open *Corynephorus* and *Agrostis* grasslands, 0.32 ha; 3140 – oligo-mesotrophic waters with benthic vegetation of *Chara* spp. with *Charion fragilis*, 129.28 ha; 3150 – oxbow lakes and natural eutrophic lakes with communities of *Nympheion*, *Potamnion*, 193.93 ha; 3160 – natural dystrophic lakes and ponds, 3.23 ha; 4030 – European dry heaths (*Calluno-Geniston*, *Pohlio-Callunion*, *Calluno-Arctostaphylion*), 646.42 ha; 6230 – species-rich

lowland *Nardus* grasslands (*Nardion* – species-rich patches), 3.23 ha; 7110 – active raised bogs, 6.46 ha; 7140 – transition mires and quaking bogs (mostly covered with *Scheuchzerio-Caricetea nigrae* association), 32.32 ha; 7230 – blanket bogs (mountain and lowland basic bogs), 12.93 ha; 9160 – Subatlantic oak-hornbeam forests (*Stellario-Carpinetum*), 0.97 ha; 91D0 – bog woodland, 64.64 ha.

The species listed in Article 4 of Directive 2009/147/EC and Annex II to Directive 92/43/EEC include: invertebrates: *Dytiscus latissimus*, amphibians: *Bombina bombina* and *Triturus cristatus*, birds: *Anthus campestris*, *Caprimulgus europaeus*, *Lanius colluria*, *L. minor* and *Lullula arborea*, mammals: *Castor fiber* and *Lutra lutra*.

2.7.2. Borne Sulinowo Forest Division in the restoration of degraded lands and former military training grounds

The Borne Sulinowo Forest Division is one of the youngest forest divisions in Poland. Its history began when the Russian Federation Army left the Borne Sulinowo military training grounds.

The Borne Sulinowo Forest Division was created on 1 January 1993 as per Regulation No. 64 of the Minister of Environmental Protection, Natural Resources and Forestry of 31 December 1992. Today, the Borne Sulinowo Forest Division with an area of 20,432 ha consists of two forest districts, i.e. Borne Sulinowo with an area of 7,893.47 ha and Broczyno with an area of 12,538.53 hectares. The Division encompasses 11 districts and a nursery farm.

The forest district of Borne Sulinowo was partially created from the previous forest district of Borne. Until World War I, the areas currently belonging to the Borne Sulinowo district were included in larger farmlands and forest properties. After the war, part of the forest area was bought by the German state and the Freierswald State Forest Division based in Marianowo was created. In 1935, German authorities displaced the local population and earmarked the area for an artillery training ground. A school for Artillery Officers was opened in Linde. This training ground was used by F. Guderian armoured forces before the attack on Poland in 1939 and by E. Rommel for Afrikakorps training. During World War II, a few prisoner-of-war camps were located in the area, including Oflag IID Gross Born. After WWII, the area was taken over by the Soviet army that used it as a training ground for

mechanized infantry and missile troops until August 21st, 1992. In 1992, fires of tree crowns destroyed over 3,000 ha of forests and heaths. After the fire, a long-term process of forest restoration has begun. In the first two years, foresters cleaned up, reclaimed 600 ha of burnt areas, and acquire 35,000 m³ of partly burnt and charred wood. Then, 327 nurseries with preserves were established, as well as 5 km of a fire belt (Borne Sulinowo Forest Division).

The Broczyno forest district was created within the Broczyno Forest Division established based on an administrative order in 1945. The Broczyno Forest Division incorporated former state forests, forests of former estates, and small areas of former peasant forests. Archival documentation and the forest condition after WWII indicate that the western sector of the district belonged to the state forests and was part of the Linichen Forest Division before 1945. Valuable pine stands covering this area reflected good conditions for pine development and proper forest management.

LOCATION AND AFFILIATION TO NATURE-FOREST REGIONS. The Borne Sulinowo Forest Division is located in the eastern part of the West Pomerania province and the northern part of the Wielkopolska province. In the north, it borders on the area of Szczecinek and Czaplnek Forest Divisions, in the east – on the Czarnobór Forest Division, in the south – on Jastrowie, Wałcz, and Mirosławiec Forest Divisions, and in the west – on the Świerczyna Forest Division (www.borne-sulinowo.szczecinek.lasy.gov.pl).

According to the classification based on nature-forest regions, the forests of the Borne Sulinowo Forest Division belong to: Baltic Region I, mesoregion 12 – the Drawsko Lakeland (I.12) – a small area in the north-western part of the Broczyno district near Czaplnek, and Region III – Wielkopolska – Pomerania, mesoregions: 7 – the Wałcz Plain (III.7) – most of the Forest Division; 8 – the Krajna Lakeland (III.8) – the south-eastern part of the Borne Sulinowo district (near Kłomino).

SPATIAL AND ADMINISTRATIVE DIVISION. Borne Sulinowo Forest Division is located in two provinces (West Pomerania 19,848.33 ha and Wielkopolska 583.28 ha, three districts (Szczecinek, Drawsko and Złotów) and four communes (Borne Sulinowo, Czaplnek, Wierzchowo and Jastrowie).

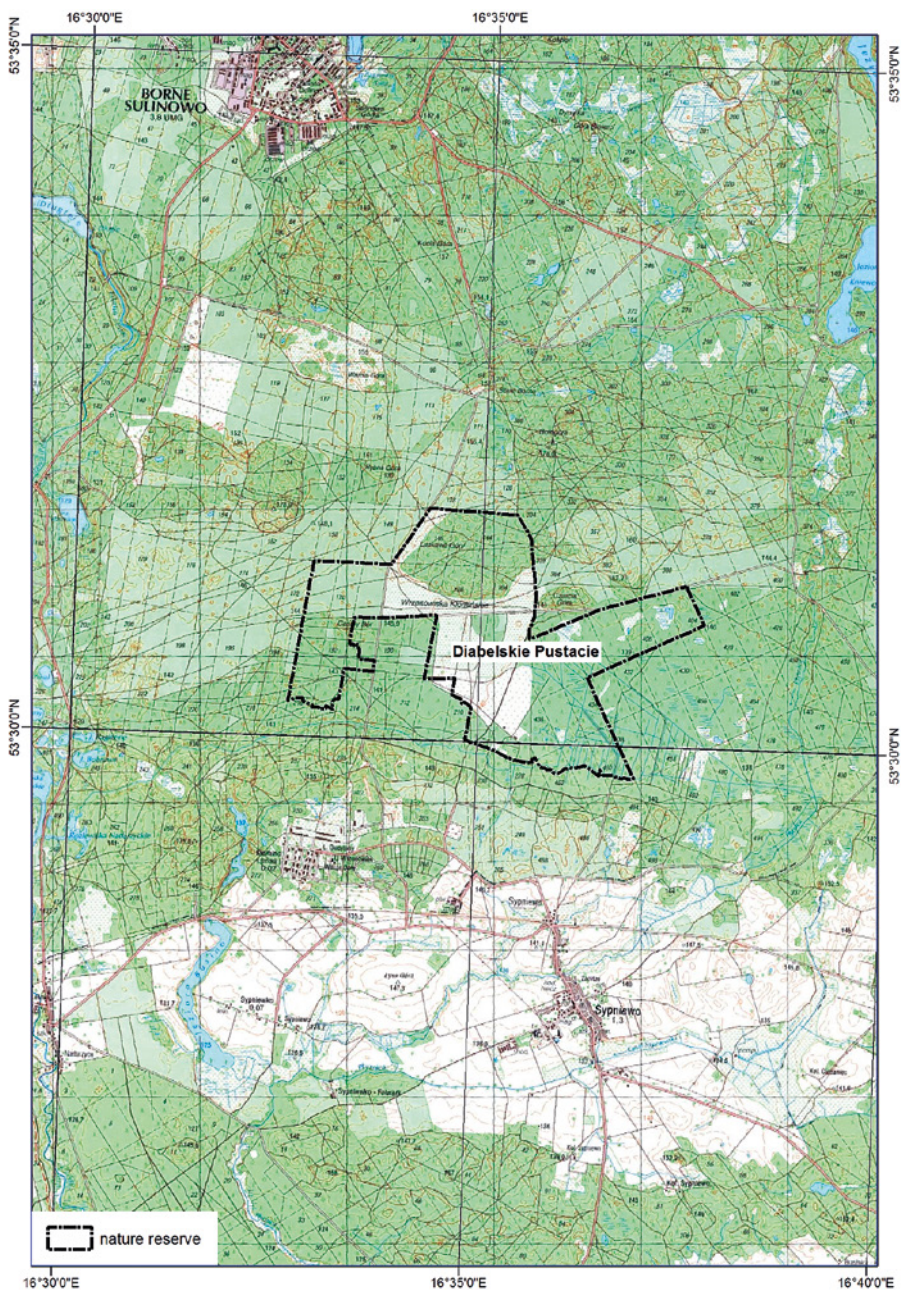


Figure 1. Location of the nature reserve "Diabelskie Pustacie" ("Devil's Wastelands") on the topographic map



Figure 2. Location of the nature reserve "Diabelskie Pustacie" on the orthophotomap

CLIMATIC DATA. According to the environmental and climatic regional division, the Borne Sulinowo Forest Division was classified into Zone B – Central European, macroregion 1 – Pomeranian Lake District. Climate of this area is affected by polar air masses dominated by maritime polar air, and it is classified as a temperate, transitory between mild Baltic climate with a relatively higher rainfall rate and more severe lakeland climate with less precipitation. It is characterized by moderate summer and winter temperatures and a relatively high precipitation rate.

Climatic data for this area are as follows: the duration of the growing season – about 200 days; average temperature in the growing season – 12.9°C; total precipitation in the growing season – ca. 400 mm; average monthly precipitation in the growing season – ca. 60 mm.

FOREST HABITAT TYPES. The Borne Sulinowo Forest Division administers the State Forests with an area of 20,431.61 ha, including 18,190.06 ha of the forest area and 2,241.55 ha of the non-forest area. The forest area includes 12,671.12 ha of timber (production) forest and 5,518.94 ha of protection forests.

The Forest Division is dominated by two types of pine forest habitats: fresh coniferous forest – 11,273.20 ha (64.5% of the forest lands) and fresh mixed coniferous forest – 5,061.10 ha (28.9%). The other habitats (wet mixed coniferous forest, marshy mixed coniferous forest, fresh mixed broadleaved forest, wet mixed broadleaved forest, marshy mixed broadleaved forest, fresh broadleaved forest, wet broadleaved forest, alder woodland) cover a total area of 6.6%.

The contribution of individual forest-forming tree species in the Borne Sulinowo forest district is as follows: pine 90.46%, birch 3.62%, oak 2.69%, alder 1.66%, beech 1.26%. In the Broczyno forest district, pine accounts for 96.89% of tree species, birch – 1.31%, alder – 1.17%, beech – 0.23%, spruce – 0.20%, larch – 0.09%, and oak – 0.07%.

The Forest Division encompasses 7.33 ha of conservation pine seed stands and 59.27 ha of commercial pine seed stands. They provide pine seed yield fulfilling the needs of a nursery farm.

Forest management procedures implemented each year in the Forest Division include: restocking (121 ha), early cleaning (147 ha), late cleaning (347 ha), and early thinning (201 ha).

In 1995–2009, afforestation in the Borne Sulinowo Forest Division encompassed 2,588.0 ha of wastelands, representing mainly the former Soviet military training grounds. The most common problems faced during reclamation of this former Soviet military base are soil profiles destroyed

by heavy fighting equipment (tanks, armoured vehicles), substrate compacted up to 60 cm, almost to a concrete hardness level, and all kinds of military residues. The average annual afforestation rate in the recent years was over 200 ha. The forest plantations established on the poorest soils in 1998 and 1999 were fertilized over a total area of 600 ha. In 2004, fertilization was carried out over an area of 82 ha, and in 2005 – 72 ha.

Each year the forests of the Borne Sulinowo Forest Division are threatened by primary and secondary insect pests. The forests are carefully monitored and the pests are eliminated by standard traps, pheromone traps, cutting or decortication of infested trees and eventually chemical agents. In recent years, nun moth gradations were a serious problem. Biological elimination of fungal pathogens is implemented by protection of tree stumps with PgIBL formulation and occasionally by mechanical removal of infested trees. A series of implemented management procedures represent an approach of local and comprehensive forest protection. The main purpose of this approach is to improve the biological resistance of forest stands by artificial thickening of the populations of organisms antagonistic towards harmful organisms and by transformations of the forest stands representing a potential gradation area.



Figure 3. General view of heaths from the observatory point near the Borne Sulinowo town (photo by Katarzyna Żółkoś)



Figure 4. Heathland at the former military grounds in Borne Sulinowo shortly after afforestation (photo by Katarzyna Żółkoś)

FIRE PROTECTION. Since 2012, all forests in the Borne Sulinowo Forest Division belonged to the second class of the fire risk. Thanks to collective effort of the Forest Division employees, the monitoring system, and ground and aerial patrols, fires are pretty rare and biological damage is low. In 2008–2013, there were 31 fires within a total area of 20.30 ha.

IMPLEMENTATION OF THE PROJECT “RESTORATION OF DEGRADED, POST-MILITARY AND POST-TRAINING GROUNDS MANAGED BY THE STATE FORESTS”. The Borne Sulinowo Forest Division participates in the project “Restoration of degraded, post-military and post-training grounds managed by the State Forests”. The project is implemented under Priority Axis II of the EU Operational Programme Infrastructure and Environment under Measure 2.2. Restoration of degraded sites and sea-shore protection. The total cost of the project is 130M PLN. It is implemented across Poland in 58 forest divisions covering over 30 000 ha.

The aim of the project is to restore natural values of the areas managed by the State Forests destroyed as a result of military activities. The first step is to find any explosives and dangerous materials and to clear the forest area by removing these materials. Further steps

consists in demolition or securing the former military facilities, removal of ground pollution and ground reclamation, as well as restoration and reconstruction of forest stands involving the adaptation of their species composition to habitat conditions.



Figure 5. Young patches of *Calluna vulgaris* growing on the former burnt area (photo by Katarzyna Żółkoś)



Figure 6. Patch of *Calluna vulgaris* at former military grounds in Borne Sulinowo (photo by Edyta Adamska)

By January 2015, sappers from P.P.H Telkaz and Uni Saper companies, who executed tasks I–IV, removed a total of 57 429 pieces of hazardous materials. In January 2015, the Borne Sulnowo Forest Division signed another contract for localization and removal of explosives from the former military training grounds. Until 30 September 2015, the GISAP company from Nysa will carry out the agreed works under task Va over a total area of 316.60 ha.

HUNTING (GAME MANAGEMENT). Game management in the Borne Sulnowo Forest Division is carried out over 6 hunting grounds. Four of them, i.e. grounds No. 168, 171, 172 and 174 are leased by Hunting Clubs of the Polish Hunting Association, and the other two, i.e. grounds No. 168 and 170 constitute the State Forests Game Breeding Centre managed by the Czarnobór Forest Division. Four clubs of the Polish Hunting Association lease a total of 23,596.95 hectares.

According to data from the wildlife inventory as of March 10, 2014, the Forest Division harbour the following number of species within individual hunting grounds: deer (72; 95; 255; 30), roe deer (218; 260; 270; 134); fallow deer (0, 8, 0, 0), boar (85; 180; 90; 70), and wolf (3, 8, 3, 2).

NATURE CONSERVATION. In addition to the nature reserve “Diabelskie Pustacie” and Natura 2000 PLH320048 area “Diabelskie Pustacie”, the Borne Sulnowo Forest Division includes two protected landscape areas “Piława Valley” and “Drawsko Lakeland”.

The protected landscape area “Piława Valley” was established by Resolution No. XIII/143/2004 of the City Council in Borne Sulnowo of 28 February, 2004, on the designation of protected landscape areas in the Borne Sulnowo commune. The whole area encompasses 2,197.95 ha and includes the valley of Piława along with the Nadarzyce Reservoir and Lake Długie, and the surrounding forests and peat bogs. The elements under protection include vegetation and the landscape of the Piława river valley. Characteristic natural features of this area include: characteristic landscapes with exceptional natural, cultural, scientific and education values; marshes, wetlands, small kettle lakes and lakes near Nadarzyce Reservoirs; the whole area is very valuable in landscape terms, protected habitats; breeding sites and habitats of rare and endangered animals, including birds: bittern, marsh harrier, Savi’s warbler, garganey, black and green woodpecker, common goldeneye, common moorhen, gadwall, common snipe, mute swan, little grebe, Eurasian penduline-tit, common merganser, great reed warbler, kingfisher, crane, as well as white-tailed

eagle, black stork, lesser spotted eagle, eagle owl and osprey (www.borne-sulinowo.szczecinek.lasy.gov.pl).

“DRAWSKO LAKELAND” PROTECTED LANDSCAPE AREA. The first protection efforts in this area were undertaken as early as in 1975 in the form of protected landscape zone. The whole area is 92,616.40 ha, including 1,484.45 ha within the territory of the Borne Sulinowo Forest Division and 223.64 ha located within the Forest Division grounds. The area is located in the north-western part of the Borne Sulinowo forest district. It was created to protect the landscape and nature of the Drawsko Lakeland.

The most valuable features of this area include: varied terrain with compact forest complexes; picturesque landscape of fertile Pomeranian beech forests; a large number of lakes and watercourses located in depressions and valleys, decalcified lobelia lakes, raised bogs and marshy coniferous forests on peat bogs, protected natural habitats, breeding sites and habitats of rare and endangered animals, including such birds as bittern, white-tailed eagle, marsh harrier and Montagu’s harrier, common goldeneye, fieldfare, Eurasian penduline-tit, goosander, and flocking sites and migration routes of cranes, geese and ducks.

NATURA 2000 AREAS. As of 1 January 2012, the territory of the Borne Sulinowo Forest Division includes two Special Areas of Conservation (Natura 2000 areas of importance to the Community – “the Piława Valley” (code: PLH320025) and “Diabelskie Pustacie” (PLH320048), and two Special Protection Areas – “Gwda Forest” (PLB300012) and “Drawsko Refugium” (PLB300019).

PLH320025 SAC “THE PIŁAWA VALLEY”. An area of 2,204.30 ha encompasses part of the former military training grounds in Borne Sulinowo and the valley of the Piława river along the section of Nadarzyce Reservoirs (artificial reservoirs created before World War II as part of the Pomeranian Wall fortifications, high natural and landscape values). This is a unique sequence of aquatic and bog ecosystems in the Pomeranian Lakelands, associated with the tunnel valley deeply cutting into the outwash of the older Piława plain and thus significantly improving the landscape values of the refugium. Abundant and well-preserved peat bogs are highly heterogeneous due to diverse morphology of glacial depressions they developed from. They differ in the form, ranging from small, flat-bottomed and fairly shallow

depressions to deep valley lakes. Numerous glacial depressions are large lakes, such as Młyńskie, Brzeźno, Kowal, Dudylany, Bagienne, and Rybnik. Bunkers that formed the Pomeranian Wall fortifications are now bat hibernacula. The area harbour 15 types of natural habitats listed in Annex I to Council Directive 92/43/EEC, including 10 types of general importance A, B or C are under protection. The area is important for the protection of otter, beaver, greater mouse-eared bat, northern crested newt, thick shelled river mussel, green snaketail, *Dytiscus latissimus*, *Graphoderus bilineatus* and 2 fish species listed in Appendix II of the Habitats Directive.

PLB300012 SAC "PUSZCZA NAD GWDA" (GWDA PRIMEVAL FOREST).

The area of 77,678.90 ha covers a vast forest complex including mostly pine forests and deciduous and mixed forests at the bottom and on valley slopes. Highly diversified, post-glacial terrain determines a high diversity of habitats. The lakes, ranging in size from a few to several dozen hectares, are surrounded by vast fens, transitional mires, raised bogs and wetlands. It is also a seepage spring area of several rivers. The area features numerous meadow patches but the contribution of arable lands is small. There are former fortifications of the Pomeranian Wall from 1934–1945 (Nadarzyce, Szwecja, Jastrowie) serving as potential bat hibernacula. The area encompasses the following forms of nature conservation: 7 nature reserves and two protected landscape areas – "Wałcz Lakeland and the Gwda Valley" and "the Noteć Valley". The protected species include: black kite, red kite, white-tailed eagle, osprey, eagle owl, nightjar, black woodpecker, woodlark, common goldeneye and merganser. "Gwda Forest" within the territorial range of the Borne Sulinowo Forest Division covers 38.32 hectares, i.e. 0.1% of the entire territorial range of the Forest Division and 0.05% of its area. It is located in the southern part of the Forest Division near Busino Wielkie Lake.

PLB320019 SCA "OSTOJA DRAWSKA" (DRAWSKO REFUGIUM).

The whole area embraces 153,906.10 hectares. It includes a large part of Drawsko Lakeland with more than 50 lakes (ca. 6% of the area) of all types. Forests, mostly the coniferous ones, cover approx. 45% of the area. The remaining part is mostly used as farmlands. The area encompasses the following forms of nature conservation: 7 nature reserves, Drawsko Landscape Park, the protected landscape area "Drawsko Lakeland", 8 SAC Natura 2000 areas, ecological lands and a complex of landscape parks. Protected bird species include: bittern, black stork, white stork,

honey buzzard, black kite, red kite, white-tailed eagle, marsh harrier, lesser spotted eagle, corn crake, crane, black tern, eagle owl, kingfisher, tawny pipit. The "Drawsko Refugium" within the territorial range of the Borne Sulinowo Forest Division covers 729.48 hectares, i.e. 2.4% of the entire territorial range of the Forest Division and 0.5% of its area. It is located in the north-western part of the Forest Division, outside the lands used by the Forest Division.

FORESTS WITH SPECIAL QUALITIES. The Borne Sulinowo Forest Division includes forests of outstanding natural values, identified according to the criteria of HCVF (High Conservation Value Forests), adapted to Polish conditions by the Union of Associations "FSC-Poland Working Group".

The Borne Sulinowo Forest Division held public consultations concerning the forests crucial for the cultural identity of local communities (category 6A). Results of these consultations were considered while determining the forest areas in this category, including year-round bird protection areas (10.32 ha), forest stands related to the protection of cultural heritage (3.42 ha), forest stands similar to natural forests (21.09 ha), forest stands with trees burnt during military and training operations (41.95 ha), manor parks, particularly forest parks (0.97 ha), forest stands in areas with difficult conditions for logging, such as slopes, ravines, flooded areas and floodplains (5.01 ha), forest stands in coastal ecotone zones, i.e. growing at swamps, lakes, rivers, bogs and other bodies of water (226.01 ha), forest stands in seepage spring areas (10.40 ha). The total area of these forests is 319.17 ha, representing 1.76% of the Forest Division area (www.borne-sulinowo.szczecinek.lasy.gov.pl).

TOURISM AND RECREATION. Since Borne Sulinowo Forest Division is an interesting area in natural and historical terms, it is popular among tourists, especially mushroom pickers. To meet the expectations of tourists and local communities, the Forest Division created numerous tourist routes and constructed 2 beauty spots, parking places for tourists and anglers, and camping sites.

Tourists can take one of the following routes: black "Kraina Małych Jezior" (Small lakes trail), blue "Kraina Odwróconego Krzyża" (Land of Inverted Cross), red "Nad Jezioro Ciemino" (Towards Ciemino Lake), yellow "Wrzosa" (Heathers), orange "Wodny" (Aquatic) (along the southern shore of Pile Lake), pink "Bunkry" (Bunkers), and green "Dobrzyca" (Dobrzyca). There is also a canoe trail and a horse riding path.

The paths and trails cross the most interesting places, such as unique vast heaths or remnants of military facilities. Cemeteries and former POW camps for the soldiers of Polish, Allied and Red Army are located in the Borne Sulinowo Forest Division – Stalag 302 Gross Born – Rederitz and Oflag II D Gross Born from World War II. Oflag II D was located near the road joining Sypniewo and Nadarzyce, on the border of Wielkopolska and Western Pomerania provinces. The camp consisted of two parts, the upper camp called by prisoners “Dog Hill” and the lower camp. Both camps were situated on the edge of the largest military training ground, from which Guderian’s Panzer army attacked Poland in September 1939. The upper camp consisted of wooden barracks built before the war for the German Labour service. In 1939, it was transformed into a POW camp.

The upper camp occupied about 18 ha and held up to 8,000 prisoners. During the war, a larger lower camp was erected, with an area of ca. 26 ha. Finally, this huge prison complex was used as a containment site for tens of thousands of prisoners of different nationalities. It hosted soldiers fighting in the September campaign and civilians from the Western Pomerania, then French, British and Soviet officers and privates, and from May 1942 also Polish officers previously detained in Oflag II B Armswalde (Choszczno). In 1944, the camp received Polish officers transferred from Oflag II E Neubrandenburg. Later on, about 1150 officers who fought in the Warsaw Uprising were imprisoned there. At the end of the war, a group of Yugoslavian officers was held in the camp.

Over the entire WWII, the Gross Born camp complex was a containment site for about 50,000 to 60,000 prisoners. According to German records, about 20,000 soldiers and officers were buried at the camp cemeteries. Exhumation and investigation works carried out since 2002 by the archaeologists from the Nicolaus Copernicus University in Toruń under the supervision of professor Andrzej Kola revealed that at least 12,000 prisoners were buried at these cemeteries.

Many of the prisoners were foresters, e.g. graduates of the Warsaw University of Life Sciences, and post-war employees of the Forest Research Institute. On 15 October 2004, a plaque dedicated to the memory of foresters held in POW camps was unveiled in the Borne Sulinowo Forest Division and a cross was erected at the site of the chapel in the Oflag II D Gross Born camp (Borne Sulinowo Forest Division).

FOREST EDUCATION. The Borne Sulinowo Forest Division is involved in the forest education and cooperates with primary and secondary

schools, kindergartens and the local Environmental Education Centre in Borne Sulinowo. The educational activity was particularly intense in 2011 which was the International Year of Forests. In 2011, the Forest Division employees organized outdoor classes, school and out-of-school educational meetings with foresters, forest competitions (knowledge, art, literature, etc.), special activities and events. In total, the events were attended by 845 people (701 from primary schools, 29 from junior secondary schools, 25 from senior secondary schools and 90 adults). The most important educational event of 2011 was a special meeting at the Environmental Education Centre in Borne Sulinowo "International Year of Forests – Forests around us". During that event, the foresters discussed the idea of the International Year of Forests and talked about their everyday work and natural values of the local forests. The highlight of the year was a photo contest "Forests around us", aimed at all enthusiasts of forests around Borne Sulinowo.

2.7.3. Czarnobór Forest Division and its contribution to conservation of heathlands

Czarnobór Forest Division was established on the same day as Borne Sulinowo Forest Division, i.e. 1 January 1993, in the area of the former German and Soviet military training grounds. Until 2012, it administered the area of 13,383.33 ha. On 1 January 2012, by Regulation No. 59 of the Director General of State Forests of 2 December 2010, it was enlarged by incorporating parts of the neighbouring Forest Divisions and its present area is 17,732.32 ha (www.czarnobor.szczecinek.lasy.gov.pl).

Czarnobór Forest Division consists of one forest district (Czarnobór) divided into 10 forest subdistricts with an area of 1,504.68 ha (Płytnica) to 2,344.82 ha (Kniewo).

Czarnobór Forest Division is dominated by coniferous habitats with pine as the main species. The average age of forests in this area is 51 years, and average resources exceed 179 cubic meters per hectare.

Approximately 75.15% of the area is covered with coniferous habitats, i.e. forest stands dominated by conifers, mostly pine and spruce. Forest habitats, i.e. forest stands dominated by deciduous species, occupy 23.84% of the area, and alder forests growing on fertile wetlands account for 1.01%.

The contribution of forest-forming tree species is as follows: 78.63% – pine, larch; 1.89% – spruce; 2.81% – oak, ash; 9.18% – birch; 5.36% – beech; 0.07% – fir; 2.07% – other.

The range of forest management procedures is outlined below. In 2014, afforestation and restoration were conducted over 117.68 ha of the Czarnobór Forest Division. The plan for 2015 assumes a restoration of 96.62 hectares, while a 10-year plan – afforestation and restoration over a total area of 1552.68 ha, both outdoors and under cover. The main species planted is Scots pine and birch, sessile oak, and beech. Nurseries and preserves are also planted with valuable species improving the diversity, e.g. hornbeam, common pear, cherry plum, linden and mountain ash.

In 2014, the following techniques were used in nurseries and young forest stands: soil cultivation: 369.88 ha, early cleaning 28.38 ha, late cleaning: 74.79 ha.

The forest management plan for 2015–2024 assumes silviculture over an area of 3,928.22 ha (www.czarnobor.szczecinek.lasy.gov.pl).

SEED PRODUCTION AND SELECTION. Seed production in the Czarnobór Forest Division includes: 34 commercial pine seed stands with a total area of 135.53 ha, three commercial beech seed stand with a total area of 17.68 ha, one commercial seed stand of Douglas fir with a total area of 2.06 ha, ten parent trees, including eight larch trees and two Douglas firs, a block of pine trees grown from locally produced and selected seeds over an area of 17.71 ha, and a block of beech trees over an area of 22.08 ha, as well as pine plantations and beech and oak and linden crops over a total area of 32.37 ha.

FOREST PROTECTION. A specific problem of forests in Czarnobór Forest Division are fungal diseases affecting the stands planted on former farmlands. The most persistent one is annosum root rot, causing ring decay of pine stands.

The most significant injuries to nurseries and young stands are tree browsing and bark stripping by deer and roe deer.

Preventive measures aimed at limiting the game-induced damage involve mesh fencing, mechanical scarring, tube protectors, chemical protection, planting trees for browsing, protection by dense nets or beech tree bandaging against bark stripping by deer.

The most effective form of protection is fencing. In 2014, a mesh fence was used to secure 23.45 ha, and the largest area of 110.55 ha was fenced in 2007. Another common method protecting the trees against browsing is the use of chemical repellents. In 2014, they were used to protect the area of 153 ha. In the same year, 825 ha were planted with trees intended for browsing.

IMPLEMENTATION OF THE PROJECT “RESTORATION OF DEGRADED, POST-MILITARY AND POST-TRAINING GROUNDS MANAGED BY THE STATE FORESTS”. Czarnobór Forest Division takes up activities aimed at: localization of any explosives and dangerous materials and clearing the forest area by removing them, environmental valuation of the reclaimed areas and geo-environmental assessment of the areas. The project covers 455 ha of lands in Czarnobór Forest Division.



Figure 7. *Cladonia coccifera* in a heath patch (photo by Katarzyna Żółkoś)



Figure 8. Clusters of *Genista tinctoria* in a *Calluna vulgaris* patch (photo by Katarzyna Żółkoś)

FOREST MANAGEMENT. Logging in Czarnobór Forest Division is carried out based on the Forest Management Plan for the years 2015–2024. The average annual timber yield is 86.000 m³.

Felling, aimed at forest restoration and reconstruction, yields 52% of the timber, and improvement cutting (cleaning and thinning) – 48%, resulting in a forest stand of the best possible quality and high biodiversity.

The main species harvested in Czarnobór Forest Division is pine (72% of the timber harvesting plan for 2015). Pine wood harvest planned for 2015 is 60.452 m³. Other species included in the timber harvesting plan for 2015 include silver birch (approx. 12%), common beech (7%), Norway spruce (3%), or aspen (3%).

Each year timber harvest is lower than the stand increment and hence the wood supply in the stands increases.

The forests of Czarnobór Forest Division are also used by the local communities who pick up mushrooms and various berries, such as blueberries, raspberries or blackberries. In addition, some forest districts, especially those created on the former artillery range, feature vast patches of heaths. When the shrubs are flowering, beekeepers may use their apiaries to produce heather honey with a strong aroma and distinctive taste. In the Christmas season, the Forest Division offers pine or spruce trees for sale.

HUNTING. Czarnobór Forest Division administers three hunting grounds with Game Breeding Centres No. 167, 168 and 170. The total area of the hunting grounds is 20,565.0 ha, including 19,770.0 ha of the forest area.

When the Czarnobór Forest Division was created, 9165 ha of its grounds were designated for a Game Breeding Centre that was handed over to the State Forests in 1993. The first wildlife inventory revealed the presence of 3 elks, 14 deer, 55 roe deer, 20 boars and lack of any hunting facilities, buffer strips or wildlife food plots.

The newly created Game Breeding Centre soon was followed by the construction of new hunting facilities, improvement of game living conditions by creating proper refugium sites and providing food resources. The first wildlife food plots, buffer strips and hunting meadows were established.

According to an assessment of game breeding centres carried out in 2007, the Czarnobór centre (including ground 167) was classified within group I, i.e. the most effectively managed centres.

The successful management of the hunting grounds, and mainly the positive outcomes of the efforts aimed at improving the game living conditions were further corroborated by the growing population of beaver, otter and wolf. Today, marshes and beaver lodges are not exceptions but permanent elements of the landscape. The area is also a refugium for a pack of wolves, whose tracks have been reported for several years.

On 30 April 2012, by the ordinance of the Director of the Regional Directorate of State Forests in Szczecinek as of 16 April, 2012, the Czarnobór Forest Division took over the Game Breeding Station with grounds no. 168 and 170, previously included in the Borne Sulinowo Forest Division.

NATURE CONSERVATION

NATURE RESERVES.

There are two nature reserves in the Czarnobór Forest Division: "Ciemino Quagmire" and "Diabelskie Pustacie".

"BAGNO CIEMINO" (CIEMINO QUAGMIRE) NATURE RESERVE.

The nature reserve "Ciemino Quagmire" was established by the ordinance of the Minister of Environmental Protection, Natural Resources and Forestry of 25 July, 1997 and Regulation No. 12/2004 of the Governor of Western Pomerania province of 5 May, 2004.

The reserve encompasses 400.43 ha, including 382.57 ha of the forest area and 17.86 ha of the non-forest area.

The purpose of protection is to preserve valuable forest and peat bog ecosystems, typical of Drawsko Lakeland, for scientific and educational reasons. This is implemented by preserving valuable and protected species of vascular plants and bryophytes.

The southern border of the nature reserve (Ciemino Lake shore) is marked with bunkers of the Pomeranian Wall. In the western part of the reserve, the black bike trail "Nizica" is located (a circular trail with the beginning and the end in Szczecinek).

"DIABELSKIE PUSTACIE" NATURE RESERVE. The nature reserve "Diabelskie Pustacie" was created by Regulation No. 45/2008 of 14 November 2008, of the Governor of the West Pomeranian province (Dz. Urz. No. 96, item 2076). As stated in the description of Borne Sulinowo Forest Division, its total area is 932.04 ha, including 294.41 ha

belonging to the Czarnobór Forest Division: 229.62 ha of the forest area and 64.79 ha of the non-forest area.

Landscape protection areas

The administrative range of Czarnobór Forest Division includes three areas with such a status: "the Płytnica Valley", "Drawsko Lake" and "Wałcz Lake and the Gwda Valley".

"THE PŁYTNICA VALLEY". The area covers 1,305.60 ha in Czarnobór Forest Division and was established by a resolution No. XXI/136/2004 of the Szczecinek Commune Council of 24 June 2004, on the designation of the protected landscape area "the Płytnica Valley", and resolution No. XVII/194/2004 of the Borne Sulinowo City Council of 26 August 2004 on the designation of the protected landscape area "the Płytnica Valley".

The area is located in the Western Pomerania province, Szczecinek district, communes of Borne Sulinowo and Szczecinek. It includes the Płytnica river valley with three ribbon lakes: Przełęg (69.30 ha), Kniewo (53.50 ha) and Rymierowo (97.04 ha). The main objective of this area was to protect the diverse, mosaic and rich natural landscape.

"POJEZIERZE DRAWSKIE" (DRAWSKO LAKELAND). The lakeland encompasses 1,237.30 ha of Czarnobór Forest Division. The current legal provisions for this area were set out in the resolution of the Provincial National Council in Koszalin No. X/46/75 of 17 November 1975 on protected landscape areas, as amended by Resolution No. XXXII/375/09 of the Western Pomeranian Provincial Assembly of 15 September 2009 on protected landscape areas. It is located in the communes of Drawsko Pomorskie, Ostrowice, Złocieniec, Brzeżno, Szczecinek and Wierzchowo, and its total area is ca. 68,450.00 ha.

"POJEZIERZE WAŁECKIE I DOLINA RZEKI GWDY" (WAŁCZ LAKELAND AND THE GWDA VALLEY). The area encompasses 165.15 ha of Czarnobór Forest Division. It was created by Resolution No. IX/56/89 of the Provincial National Council in Piła in 31 May 1989. Current legal provisions for this area in the Wielkopolska province were set out in Regulation No. 5/98 of the Piła Governor of 15 May 1998, and in the Western Pomeranian province in Resolution No. XXXII/375/9 of the Western Pomeranian Provincial Assembly of 15 September 2009 on the protected landscape areas.

Natura 2000 areas

PLH 320048 “DIABELSKIE PUSTACIE”. The special area of conservation “Diabelskie Pustacie” with a total area of 3,232.08 ha is administered by Borne Sulinowo and Czarnobór forests divisions. In total, 2,361.57 ha of the area are located in the Czarnobór Forest Division. The area was described in detail in the section on the Borne Sulinowo Forest Division.

The former military training ground in the Czarnobór Forest Division is an interesting object of scientific research. Since 2005, an intensive research has been conducted by scientists from the Department of Entomology and Environmental Protection and Management of the Faculty of Horticulture and Landscape Architecture of Poznań University of Life Sciences.

The observations carried out since 2005 in the area of the former Soviet military training ground of Borne Sulinowo focused on larger butterflies *Macrolepidoptera*. Until the 1990s, no such observations were possible within this site. The hunting methods include night catching using a screen or light traps, and day observations or hunting with a net. In some habitats, pre-imago forms (mostly caterpillars were searched for). By the end of the 2013 season, over 400 species of *Macrolepidoptera* were identified, i.e. about 30% of the country’ fauna of larger butterflies. Since 2008, the research has covered also some species of smaller moths, flies and net-winged insects.

PLH 320036 “BAGNO I JEZIORO CIEMINO” (CIEMINO LAKE AND QUAGMIRE). The area of 787.35 ha include a former peat bog covered with marshy coniferous forest and adjacent Ciemino Lake. The area includes also the nature reserve “Ciemino Quagmire”. The area is located in the Czarnobór Forest Division. In total, 503.00 ha of SAC is managed by the Forest Division.

PLH 320042 “JEZIORO ŚMIADOWO” (ŚMIADOWO LAKE). The site includes Śmiadowo Lake and its immediate surroundings, with a total area of 213.43 ha. Śmiadowo Lake with an area of 132.70 ha is an oligotrophic lobelia lake. It features six picturesque islands. The area is located in the Czarnobór Forest Division. The grounds managed by the Forest Division cover 48.52 ha.

Nature monuments

The grounds of Czarnobór Forest Division harbour 12 objects classified as nature monuments, including 7 single trees and 5 groups

of trees. These 12 monuments include 58 trees: 43 common oaks, 11 common beeches, 2 ashes, 1 linden and 1 European larch.

FORESTS WITH SPECIAL QUALITIES. Some forests of the Czarnobór Forest Division were classified as High Conservation Value Forests (HCVF). Such nature objects are identified based on the “Criteria for identifying forests of outstanding natural values”, adapted to Polish conditions in July 2006, prepared by the Union of Associations “FSC-Poland Working Group”.

Taking into account the results of the public consultations, the Czarnobór Forest Division identified also forests crucial for the cultural identity of local communities. They include year-round bird protection areas (14.93 ha), forest stands on marshy habitats (107.73 ha), groups of nature monuments (385.61 ha), forest stands related to the protection of cultural heritage (2.02 ha), forest stands with trees burnt during military operations and training (13.37 ha), forest stands with damage caused by beavers (2.33 ha), islands (7.70 hectares), forest stands in areas with difficult conditions for logging, such as slopes, ravines, flooded areas and floodplains (70.01 ha), forest stands in coastal ecotone zones, i.e. growing at swamps, lakes, rivers, bogs and other water bodies (316.34 ha), forest stands in seepage spring areas (29.58 hectares).

HCV forests cover an area of 995.76 ha, representing 6.54% of the forest area within the Czarnobór Forest Division.

CERTIFICATES OF QUALITY MANAGEMENT. Certificates of good forestry FSC No. SGS-FM/COC-000008 and PEFC No. PL PEFC-11/0033 awarded to the Regional Directorate of State Forests in Szczecinek confirm that Czarnobór and Borne Sulinowo Forest Divisions, as well as all the other forest divisions within this Directorate, are properly managed, with particular emphasis on conservation and social aspects.

FOREST EDUCATION. The Forest Division headquarters at Forest Lake runs a small educational centre called “Dziupla Ekologiczna” (Ecological Hole) where foresters offer 60 min classes for groups of children and teenagers of up to 25 people (www.czarnobor.szczecinek.lasy.gov.pl).

The Forest Division prepared two educational paths – “Jezioro Leśne” (Forest Lake) and “Na dawnym poligonie” (On the former training ground).

“JEZIORO LEŚNE” (FOREST LAKE). 2 km forest nature trail. Hiking – 1.5 h, by bike – 40 min.

The trail runs through the forest, along the southern, western and northern shore of Forest Lake (143.8 m above sea level, 17.7 ha, depth 5 m). The path is marked with information boards, providing a lot of interesting information on forest development and protection, forest life cycle, protected plants and animals, and reasons for tree felling. The shores are dotted with old oaks, beeches, larches, alders and abundant aquatic and littoral plants.

“NA DAWNYM POLIGONIE” (ON THE FORMER TRAINING GROUND).

About 9 km forest nature trail. Method of transport: on foot or by bike.

The path begins in the vicinity of the former Soviet cemetery in Borne Sulinowo and leads to a forester’s lodge at Przełęg Lake. The path is recommended as a trekking or bike trail. Details on local species of fauna and flora and explanations of works carried out by foresters are provided on the educational boards placed along the trail.



Figure 9. Flowers of *Genista tinctoria* (photo by Katarzyna Żółkoś)



Figure 10. Monument at the Soviet cemetery in Borne Sulinowo (photo by Katarzyna Żółkoś)

2.8. Afforestation of heathlands in Zaborski Landscape Park in the 19th and 20th centuries

2.8.1. General description of Zaborski Landscape Park

Zaborski Landscape Park was established pursuant to resolution No. XI/68/90 of the Provincial National Council in Bydgoszcz dated February 28, 1990 (www.zaborskipark.pl/o-nas-6/). It is located in the communes of Brusy and Chojnice. Initially it was referred to as Chojnice Landscape Park included in the administration range of Tuchola Landscape Park with the registered office in Tuchola. In 1991,

the name was changed to include the historical reference of Zaborska Land, which is the southern part of the Kashubia region (Regulation No. 1/91 of the Governor of Bydgoszcz of 12 January 1991). The area of the park was 31,279 ha and the protection zone was 7,536 ha. The Park was established to protect and promote the natural heritage and cultural landscape of the north-western part of Tuchola Forest.

In 1996, part of the Zaborski Landscape Park located in the region of Struga Siedmiu Jezior (Stream of Seven Lakes) was included in the Tuchola Forest National Park, which was established over an area of 4,613 ha. Since the National Park was established, the area of Zaborski Landscape Park was 26,490 ha, and the buffer zone was 7,536 ha. Regulation No. 30/98 issued by the Governor of the Kujawy-Pomerania Province on 31 August 1998 changed the boundaries of Zaborski Landscape Park – a buffer zone was added. Since that time, the Landscape Park area did not change in a significant way, except for a small border adjustments in the area of Charzykowy in 2006. The current description of the Zaborski Landscape Park boundaries and conservation objectives are defined by resolution No. 144/VII/11 issued by the Pomerania Regional Council on May 27, 2011. Currently the Zaborski Landscape Park area is 34,026 ha, including 60% located in the commune of Brusy, and 40% in the commune of Chojnice (Fig. 1). The land-use structure of Zaborski Landscape Park is dominated by forests – 71%, arable lands – 6.8%, grasslands – 4.8%, lakes and rivers – 13.1% and wastelands – 4.3% of the total park area. The forest areas are managed by Forest Inspectorates of Przymuszewo, Rytel and Czersk. From June 2 2010, Zaborski Landscape Park is part of the largest Polish Tuchola Forest Biosphere Reserve. From 1 July 2010 by virtue of Resolution No. 1185/XLVIII/10 issued by the Pomerania Regional Council on 31 May 2010, landscape parks of the Pomeranian province (seven parks), including Zaborski Landscape Park, were merged into a complex of Pomeranian Landscape Parks with headquarters in Słupsk (www.zaborskipark.pl/o-nas-6/). Zaborski landscape park covers the middle course of the Brda River. The landscape is diversified by the Zbrzyca River – a tributary of the Brda River, and the Kulawa River and the Kłonecznica River – tributaries of the Zbrzyca River. There are about 50 lakes within the limits of the Park. The largest one is Lake Charzykowskie. Together with Lake Długie, Karsińskie, Witoczno, Kosobudno and Łackie, Lake Charzykowskie represents ribbon (usually open) lakes. In Zaborski Landscape Park, there are oligotrophic lobelia lakes with crystal clear water characteristic of this area, and small

dystrophic lakes, nutritionally poor but rich in humic compounds. The park is dominated by pine forests, except for soils developed from boulder clay overgrown with oak-hornbeam natural forests with rich undergrowth. In addition, rich vegetation with relics of glacial origin occurs, e.g. string sedge, black crowberry, marsh saxifrage, twinflower and several species of bryophytes. Lobelia lakes are home to rare aquatic plants: water lobelia, lake quillwort, floating water-plantain, narrow leaf bur-reed.

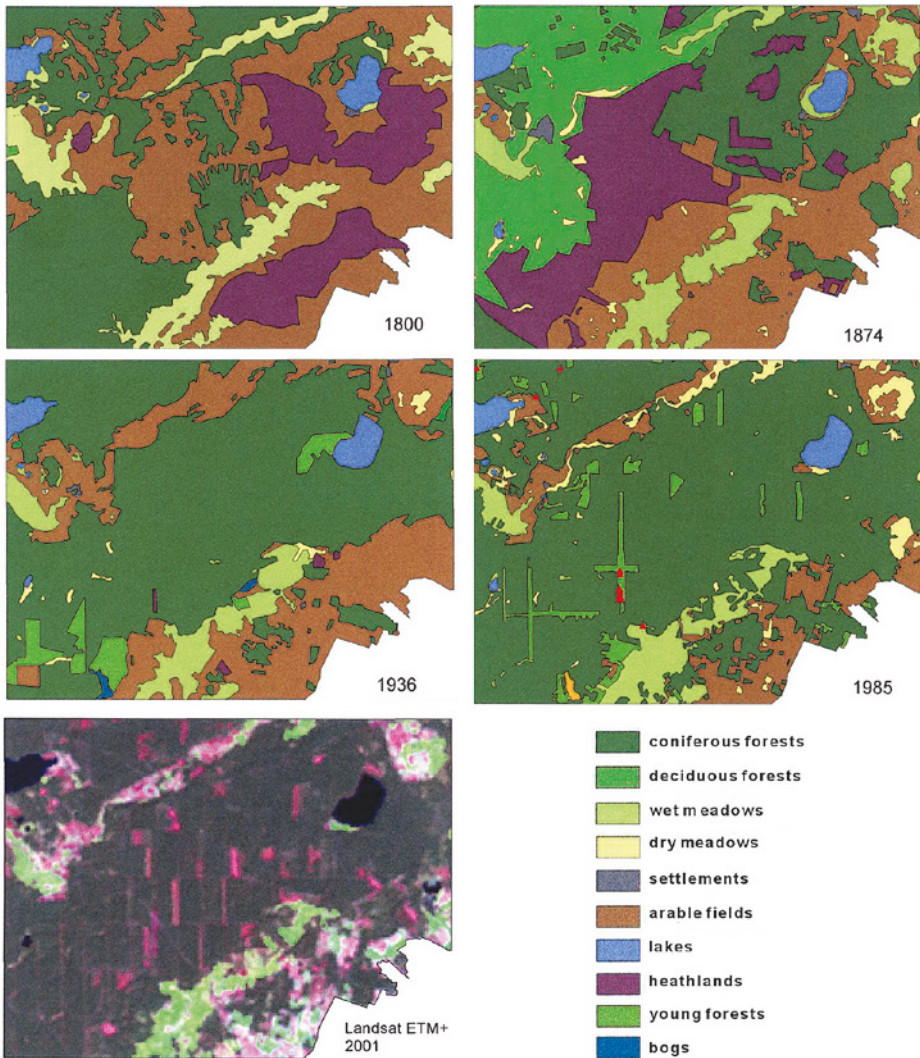


Figure 1. Plan of the Zaborski Landscape Park with the location of the study area

To protect the most valuable fragments of nature, 7 nature reserves were established in the Park (Nawionek, Lake Laska, Piecki, Bagno Stawek, Kulawa Valley, Małe Łowne, Kruszynek), and 4 more are planned (“Buczyna Charzykowska”, “Buczyna nad Jeziorem Milachowo”, “Dolina Jezior Rynnowych”, “Jezioro Moczadło”). Furthermore, 83 natural monuments and 95 ecological sites were established. The area of Zaborski Landscape Park includes Natura 2000 sites: Special Protection Areas – PLB220001 “Wielki Sandr Brdy” and PLB220009 “Bory Tucholskie” and Special Areas of Conservation – PLH220026 “Sandr Brdy”, PLH220056 “Czerwona Woda pod Babilonem”, PLH220058 “Doliny Brdy i Chociny”, PLH220060 “Las Wolność”. Furthermore, the Park is adjacent to Natura 2000 site PLH220057 “Ostoja Zapceńska” (www.zaborskipark.pl/o-nas-6/).

Nature of Zaborski Landscape Park can be explored along 9 tourist routes: Julian Rydzkowski Kashubian trail, Struga Siedmiu Jezior trail, Jan Karnowski trail, Józef Bruski trail, Brda trail, Zaborski trail, Zbrzyca trail and two short trails connecting long routes. In addition, 5 cycling routes were established: Blue, Black, Anna Łajming Literary Tourist Trail, Naszyjnik Północny, “Kołowe Ścieżki Gochów” and three canoe routes on the Brda, Zbrzyca and Chocina rivers. Fifteen nature paths serve environmental education (www.zaborskipark.pl/o-nas-6/).

2.8.2. Changes in the heathland range

In the 19th century, a large part of Pomerania (i.e. the region located in north-western Poland between the Oder River in the west, the Vistula River in the east and the Noteć River in the south, adjacent to the southern coast of the Baltic Sea) was covered by heaths. Changes in the range of forests in the entire region in the last millennium were presented by Ślaski (1951) who used the cartographic method, while the range of forests at the turn of the 18th and 19th century in the eastern part, referred to as Gdańsk Pomerania – by Zaborski (1935). The formed author created a map based on written historical sources, the latter – based on Schrötter-Engelhardt’s maps from 1796–1802, under the regulation of Frederick II the Great for new territories incorporated into Prussia, including areas seized by Prussia in the three Partitions of Poland. A small forest range presented on Schrötter-Engelhardt’s map does not represent the maximum deforestation range as further reduction in the forest area followed during the Napoleonic Wars and

later when Prussia repaid the timber contribution to France and freed the landlords from banned logging and timber sales to cover the war debts. As a result of the above political and economic processes, some of the areas were completely devoid of vegetation (Kozikowski, 1911). Sheep breeding developed in deforested areas dominated by heaths and pioneer grasslands (Wachowiak, 1993). According to historical sources, the number of sheep in Pomerania in the mid-19th century was about 3.8 million (Wielopolski, 1959). Cloth manufacture developed in towns; it supplied materials for the Prussian army and for export to Russia.

In the second half of the 19th century, after seeing the extent of the destruction and taking into account the decline in the demand for wool as a result of imports from Argentina and Australia, the Prussian government began to reconstruct the forest by creating new forest divisions in non-forest areas. This was largely done in the course of anti-Polish policy *Kulturkampf* of Chancellor Bismarck by purchasing indebted Polish estates and handing them over into the hands of the so-called "Green expropriator", i.e. the Prussian state forests. In the area of Gdańsk Pomerania, included in the reborn Polish state after World War I by the Treaty of Versailles, the restoration of forests was continued by the Polish forest divisions. Further extensive afforestation of former agricultural lands and heathlands took place after World War II when these lands were handed over to the Polish state forests as a result of the nationalization of landed estates conducted by the Polish communist government. In the post-war period, the forests of Pomerania were restored from the war damage.

The afforestation took place mostly in the north-western part of Tuchola Forest where the current Zaborski Landscape Park is located. The large part of the park overlaps with the territory of the Przymuszewo Forest Division. Today, the area of the park and the Przymuszewo Forest Division is covered mainly with the monoculture of Scots pine, *Pinus sylvestris*, which is a buffer for many lobelia lakes and peat bogs. At present, heaths cover a small area of the landscape park and the forest division. However, they occur mainly within the fire belts and on margins of forest complexes. They make the landscape more mosaic, just like aquatic ecosystems do.

Former maps of forest stands and inventory books of forest divisions have been preserved for this area, including description of land cover, the main tree layer and species composition of understory and undergrowth.

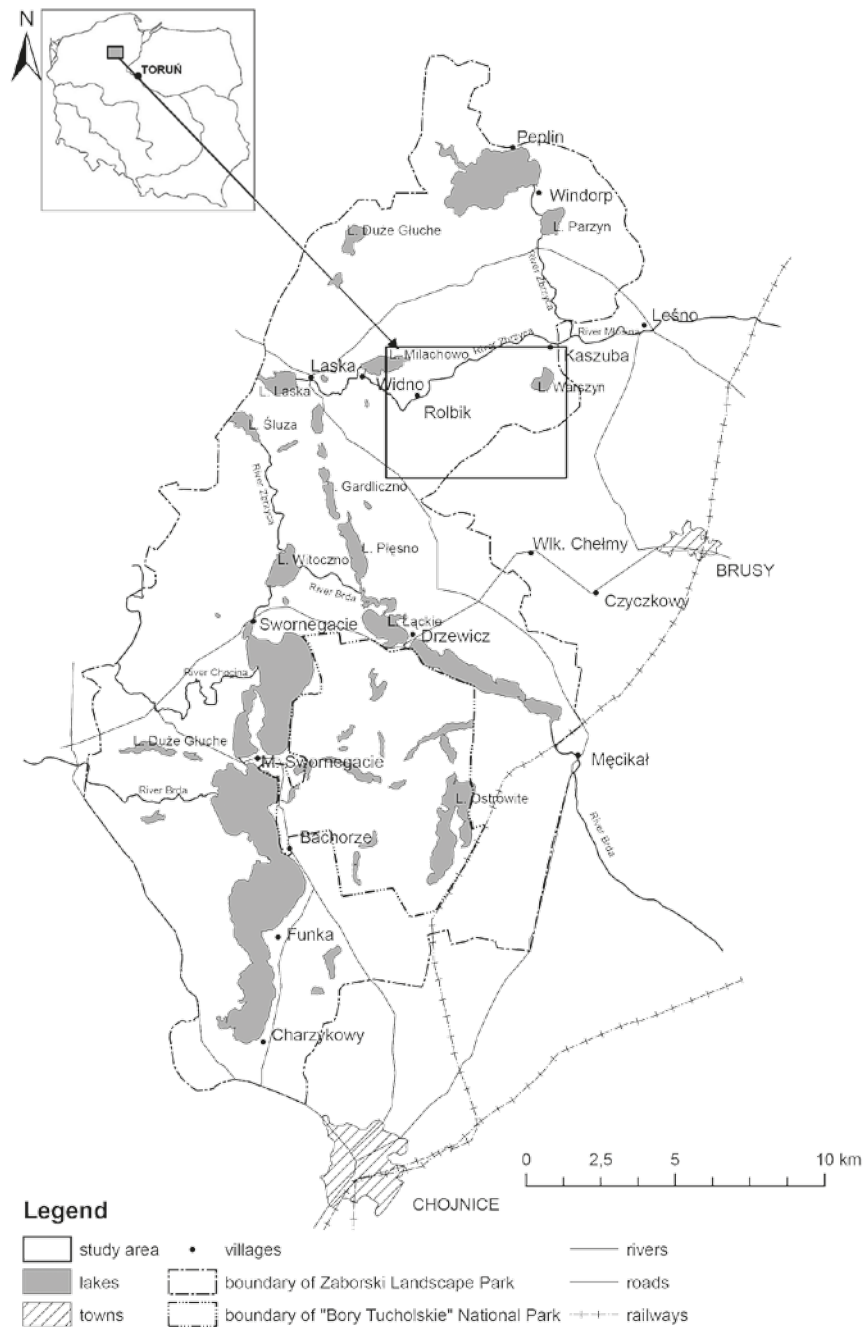


Figure 2. Landcover/landuse in the northern part of Zaborski Landscape Park in 1800–2001 (according to Mizgalska, 2006; Kunz et al. 2008a, b, c)

This chapter presents changes in the spatial distribution of heaths in the northern part of Zaborski Landscape Park in 1800–2003. The analysis was based on available cartographic materials and Landsat ETM+ satellite imagery (Mizgalska, 2006; Kunz et al., 2008a, b, c). Due to the fact that collected materials did not cover the whole area of Zaborski Landscape Park, the area of 3,156 ha located in the northern part of the park was selected for comparative analysis (Fig. 1). It has been assumed that former heathlands were transformed into infertile arable lands. This assumption was based on the fact that heathlands started to develop on infertile sandy soils and available data prove that infertile sheep grazing lands were located in the past in this part of Zaborski Landscape Park (Dziadowiec and Bednarek, 1993). This type of land cover is not included on contemporary topographic maps. The contribution of heathlands in the landscape was 14.4% in 1800, 19.0% in 1874 and 0.3% in 1936. Contemporary heathlands cover less than 0.1% of the area. Changes in the range and the area of heathlands in the study area are presented in Figure 2.

Small areas of heaths were found in the landscape park in the course of fieldwork. Their existence in the northern part of the park is connected with the heather-pine forest *Calluno – Pinetum*. Moreover, heaths have good habitat conditions along fire belts (ploughing and fires guarantee good conditions for the dominance of heather in phytocenoses), sandy roadsides, and forest margins.

2.9. The current area and distribution of heathlands in Przymuszewo Forest Division and in the region of Pomerania

2.9.1. General description of the Przymuszewo Forest Division

LOCATION AND STRUCTURE. Przymuszewo is the northernmost forest division of the Regional Directorate of State Forests in Toruń. The area is located in the Pomerania province, in the Chojnice district, and the communes of Brusy and Chojnice (Fig. 1). According to the natural forest regionalisation, it is located in forest region III – Wielkopolska and Pomerania and district I – Tuchola Coniferous Forests.



Figure 1. Location of the Przymuszewo Forest Division on the topographic map

Brusy is the only city in the forest division. The nearest towns are Bytów, Chojnice, Czersk and Kościerzyna.

The area of the Przymuszewo Forest Division (PFD) is 18,584 ha, including 17,636 ha of forest area. It consists of two forest districts: Przymuszewo and Laska. The area of the whole forest division is divided into 14 subdistricts. The Forest Division includes also a plant nursery which is located in the Dąbrowa subdistrict.

Employees of the Przymuszewo Forest Inspectorate are responsible for supervising the private forests in 16 districts.

HISTORY. Until 1973, the districts Przymuszewo and Laska represented separate forest divisions. The Polish Przymuszewo Division was established after 1920 in the former Prussian Foresterei Zwanshof. The latter was established in 1890 from the land that Count Koenigsmarck from Kamienica sold to the Prussian government. Lands purchased by the Prussian authorities from the owners of the following villages: Wielkie Chełmy, Leśno, Widno, Giełdon, Drzewicz, Broda, Okręglik, as well as Kruszyna, Nowa Laska, Widna, Małe Chełmy, Lubnia, Czernica, Męcikał and Giełdon, were incorporated into the area of the former estate. On the lands purchased in 1890, the Forest Division Laska was created and the Prussian Forest Divisions Giełdon and Chociński Młyn. The Laska Division was established in 1894 over an area of 6,222 ha (www.przymuszewo.torun.lasy.gov.pl).

GEOLOGICAL STRUCTURE AND HYDROLOGY. The Przymuszewo Forest Division has a very varied land relief, which is a result of the Baltic glaciation. Numerous ribbon lakes are located on the outwash plain (e.g. Duże Głuche, Małe Głuche, Skąpe, Dybrzk, Zmarłe, Nawionek, Płesno). There are also large and shallow lakes of the ground moraine (e.g. Somińskie, Laska and the largest one – Kruszyńskie with an area of 461 ha). In addition, many rivers flow through the area, including the largest one – the Brda river (in a deep, up to 50 m, valley with outwash deposits), which is also the south-western border of the Forest Division. The following rivers: Zbrzyca, Młosina, Kulawa, Kłonecznica, Chocina and Orla Struga are tributaries of the Brda. The basic form of land relief are gravel and sandy outwash plains sloping slightly southwards. The basic geological and soil formations are fluvio-glacial sands and gravels, i.e. outwash plains covering a large part of the Forest Division – Wielki Sandr Brdy Natura 2000 site with an area of almost 14,000 ha.

THE VEGETATION. Several dozen species of strictly and partially protected species occur in the Przymuszewo Forest Division. The most interesting species are: *Isoëtes lacustris*, *Viola epipsila*, *Lobelia dortmanna*, *Lycopodium clavatum* and *Lycopodium annotinum*, *Drosera anglica* and *Drosera rotundifolia*, *Daphne mezereum*.

Habitats of coniferous forest dominate in the area of Przymuszewo Forest Division. They cover 62% of the total area, mixed coniferous forests cover 30%, mixed forests – 7%, and other forests – 1%. *Pinus sylvestris* is the dominant tree species. Pine stands cover 95.5% of the forest area. Birch stands cover 2.0% of the total area, oak forest stands – 0.8%, alder – 0.6%, spruce – 0.6% and other species, including *Fagus sylvatica* – 0.5% (www.przymuszewo.torun.lasy.gov.pl).

The area of Przymuszewo Forest Division is dominated by fresh (mesic) *Leucobryo-Pinetum* and dry pine coniferous forests *Cladonio-Pinetum* (Fig. 2). Moist coniferous forests *Molinio-Pinetum* and marshy coniferous forests *Vaccinio uliginosi-Pinetum* occur near the lakes and ground depressions. Deciduous forests cover much smaller areas. These are mainly riparian forests in the valleys of the rivers: Zbrzyca, Konecznica and Kulawa, i.e. tributaries of the 1st and the 2nd order of the Brda River. On the northern shore of Lake Milachowo (on the slope of the lake channel), small areas of oak-hornbeam forest and acidophilous beech forest occur, classified by Sokolowski (1965) as associations *Galio-Carpinetum typicum* and *Luzulo pilosae-Fagetum*.

Heather patches used, in the past as sheep pastures occur especially on division lines on small areas (Figs 3 and 4).

More information on the vegetation can be found in the descriptions of nature reserves and Natura 2000 sites located in the Przymuszewo Forest Division.

FAUNA. The fauna is as rich as the flora. The following species of mammals occur: wild boar, elk, roe deer, red deer, hare and common rabbit. Rodents are the most abundant group of mammals – 14 species, including beaver, muskrat, squirrel, bank vole. The basic predators include: fox, badger, raccoon, marten forest and wolf (in small numbers). Avifauna includes 125 breeding species and 20 regularly migrating species. Strictly protected species include: white-tailed eagle *Haliaeetus albicilla*, Eurasian eagle-owl *Bubo bubo* and red kite *Milvus milvus*.

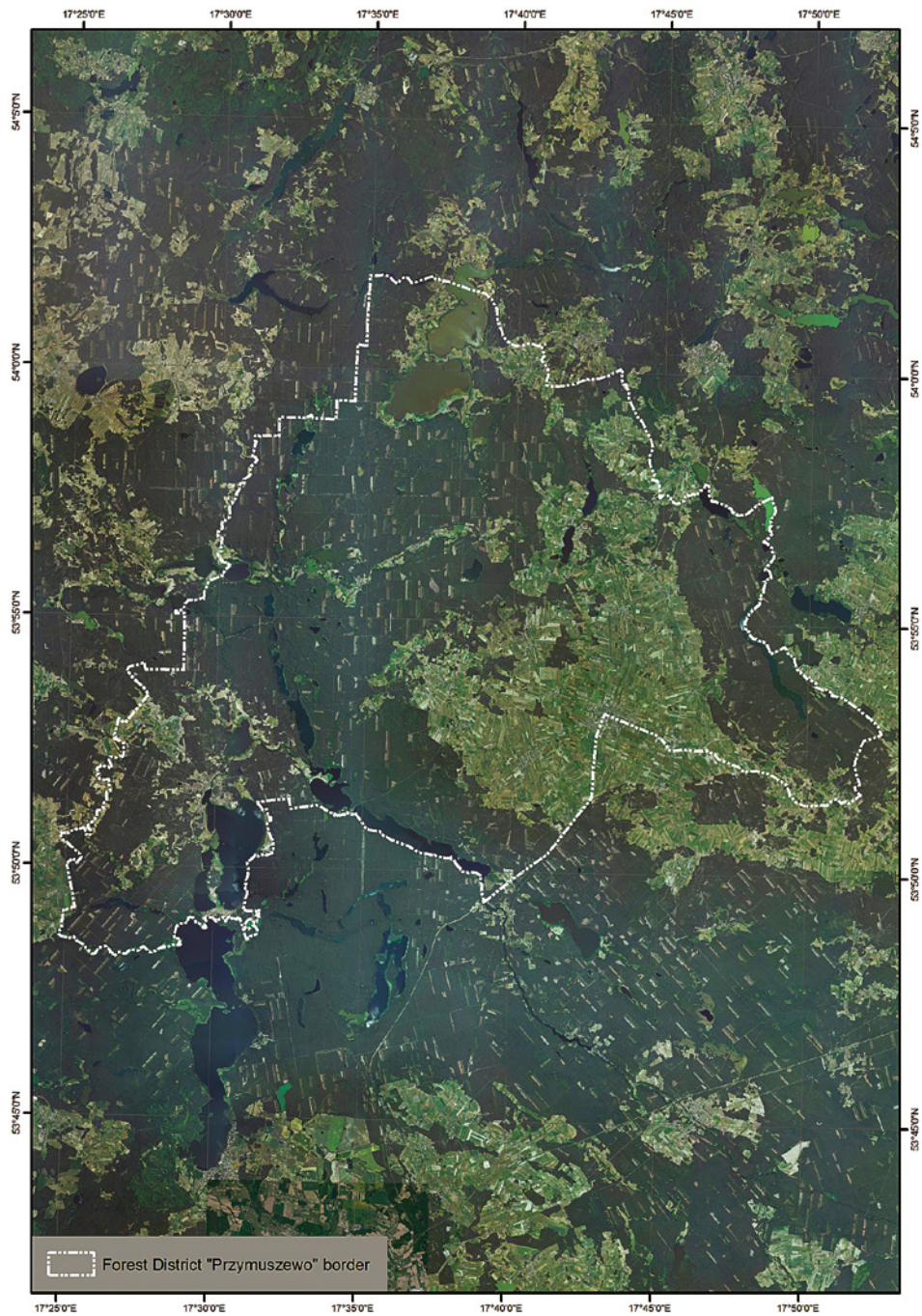


Figure 2. Location of the Przymuszewo Forest Division on the orthophotomap



Figure. 3. Dry pine forest in the Przymuszewo Forest Division



Figure 4. Heath with *Calluna vulgaris* and *Juniperus communis* on fire protection belt (photo by Marian Boinski)

2.9.2. Silviculture, exploitation and protection of forest

SILVICULTURE. Each year, foresters from the Przymuszewo Forest Inspectorate restore forest areas and afforest former farmlands over an area of about 150 ha. Forest tree seeds are harvested from selected stands of the best quality, so-called seed tree stands. About 2 million seedlings are obtained each year from tree and shrub seeds sown in the forest plant nursery. The annual extent of silviculture tasks in the Przymuszewo Forest Inspectorate is as follows: restoration and afforestation – on average 193 ha; soil treatment in crops – 198 ha; early and late cleaning – 314 ha; early and late thinning – 1285 ha. In addition, planting of shrubs and deciduous trees is carried out in thinned pine wood stands.

An environmentally friendly model of forestry is currently implemented in Poland, which places the protection functions of forests above the production ones. In the Przymuszewo Forest Division, elements of the ecological model are implemented mainly through: 1) development of forest species composition adapted to local habitat conditions; 2) maintenance of high species diversity in the forest and active promotion of biodiversity in forest ecosystems; 3) supporting natural restoration of valuable forest stands of native origin instead of artificial renewal; 4) supporting natural processes occurring in forest ecosystems, including the dissemination of biological methods of forest protection.

FORESTRY. The Przymuszewo Forest Inspectorate obtains ca. 66,000 cubic meters of timber per year from an area of ca. 18,000 ha. The raw material is obtained from pruning (in younger forest stands), logging (in mature forest stands) and casual felling resulting from unexpected situations such as natural disasters. During the currently applicable forest management plan (i.e. 2009–2018), the forest inspectorate obtains on average ca. 41,000 m³ of raw material per year from mature forest stands (final crop), and ca. 25,000 m³ from pre-mature forest stands. The relatively high crop from older stands results from the fact that 25% of all tree stands in the forest division is older than 100 years (data included in the Forestry Plan from January 2009). Timber harvested in the forest division is sold mainly to companies involved in the wood processing, such as sawmills, pulp and paper factories,

furniture factories. The forest inspectorate delivers wood to 50 wood-processing companies. They are located in the provinces of Pomerania, West Pomerania, Kujawy-Pomerania and Podlasie. In addition, the forest inspectorate supplies fuel wood for the local population and sells Christmas trees during the holiday season.

HUNTING. Hunters associated in the Polish Hunting Association and foresters are involved in the management of game in accordance with the principles of ecology and rational forestry, agriculture and fishery. Two hunting grounds are located in the Przymuszewo Forest Division, with the total area of over 12,000 ha.

FAUNA. Przymuszewo Forest Division is inventoried every year. Results of the inventory from February 2014 are as follows: deer – 295 ind., fallow deer – 5 ind., roe deer – 843 ind., wild boar – 247 ind., foxes – 197 ind., raccoon dogs – 116 ind., badgers – 97 ind., martens – 143 ind., American mink – 22 ind., polecats – 85 ind., muskrats – 67 ind., otters – 160 ind., hares – 887 ind., wild rabbits – 44 ind., partridges – 57 ind., wild geese – 85 ind., ducks – 1221 ind., woodpigeons – 468 ind., woodcocks – 329 ind., coots – 223 ind., beavers – 513 ind., herons – 137 ind., wolves – 2 ind. (www.przymuszewo.torun.lasy.gov.pl).

FOREST PROTECTION AGAINST FIRE, LARGE HERBIVORES AND INSECTS. One of the tasks of the forest inspectorate is to protect forest areas against fires. Pine stands growing on infertile, coniferous habitats present a huge fire hazard due to dry and flammable undergrowth. An additional threat is posed by reckless behaviour of people in forests. Przymuszewo Forests are classified under category II of fire hazard (on a three-grade scale). In recent years, the Forest Inspectorate modernized and expanded the firefighting system, rebuilt watchtowers, installed a forest monitoring TV system, built fire tanks, and the system of access roads for firefighters.

In 2008, a new threat to forest ecosystems and people was identified – unexploded ordnance from World War II. Inspection of the area and removal of unexploded ordnance require substantial financial involvement of the forest inspectorate.

Damage to forests is also caused by large herbivores, such as red deer or deer. They eat leaves of young shoots of trees, break them and nibble their bark, trample forest plantations. In order to reduce damage to forests, foresters use very expensive fencing or lubrication of

trees with repellents, or place covers protecting against tapping. Trees weakened and suffering from drought, frost or negative effects of winds become susceptible to damage caused by insects. Primary pests which eat leaves and needles of trees, such as nun moth, pine beauty, pine-tree lappet and common pine sawflies reduce vitality and weight gain of trees. Secondary pests which feed under the bark of trees weakened by primary pests or other adverse external factors such as beetles from the genus *Tomicus* or *Phaenops cyanea*, usually lead to death of trees. The mass occurrence of harmful insects (pest gradation) may become an ecological disaster and cause serious economic losses in the woods. In 1981–82, the Przymuszewo Forest Division suffered from the nun-moth gradation. To fight the nun moth, chemicals had to be applied with the use of aircrafts. The pest gradation was brought under control, but foresters had to remove weak and ill trees over the next few years. Forests growing on lands previously used for agriculture are particularly susceptible to fungal diseases of which the most dangerous are: honey fungi and root bracket fungi. Trees heavily infested by parasitic fungi are removed in order to prevent the spreading of diseases. Reconnaissance, prevention and control of harmful insects and fungi are among the main tasks of the Forest Service.

CERTIFICATES OF QUALITY MANAGEMENT. The Przymuszewo Forest Inspectorate as the organizational unit of the Regional Directorate of State Forests in Toruń has two major forest management certificates: FSC and PEFC.

The FSC certificate is a document certifying the compliance of the standards of the Good Forest Stewardship developed by the International Forest Stewardship Council (FSC). It certifies that forests are managed properly at every stage – from seeds sowing in plant nurseries, through all silvicultural treatments and conservation efforts in the forest stands, logging and timber selling. In addition to forestry, accredited auditors evaluated issues related to conservation, access to forests for society, workers' rights, planning and documenting, relations with local society and others. The latest certificate no. SGS-FM/COC-000916 is valid from 02 January 2013 to 01 January 2018 (www.przymuszewo.torun.lasy.gov.pl).

ECOLOGICAL EDUCATION. Przymuszewo Forest Inspectorate conducts nature and forest education in educational centres in Kokoszka and Dąbrowa as well as along educational paths in the forest division and schools.

The centre of education in Kokoszka is located near the forester's lodge Kokoszka. It is equipped with a projector, educational boards, exhibits of dissected animals. A fireplace and an ornithological path are located in the vicinity.

The centre of education in the forest nursery in Dąbrowa encompasses a hall with educational materials and an "old office" where old equipment used by foresters is collected, e.g. old measuring instruments, and inventory equipment, as well as documents and maps.

The educational path in Czernica starts at the forester's lodge in Czernica and runs through forest stands. Along the path, visitors learn about tasks of foresters, both those related to nature conservation and forestry.

2.9.3. Nature conservation

The following forms of nature conservation are implemented in PFD: nature reserves, landscape park, protected landscape area, natural monuments, refuges and priority areas designated under Natura 2000. PND borders on the Tuchola Forest National Park.

NATURE RESERVES. There are seven nature reserves in the Przymuszewo Forest Division, including three entirely under the administration of Przymuszewo Forest Inspectorate: "Nawionek", "Bagno Stawek" and "Bór Chrobotkowy".

The nature reserve "Nawionek" was established by the Directive of the Minister of Forestry and Wood Industry dated 16 September 1974 in the area of Antoniewo Subdistrict. It covers a partially protected area of 10.67 ha. The purpose of protection is to preserve the lobelia lake on the southern edge of the *Lobelia dortmanna* range.

Lake Nawionek is situated among forests, including more than 150-year-old pine stands. The shores are sandy and in some places more or less silted. The slopes gently incline towards the shores of the lake, only the south-eastern slope is steeper. The depth of Lake Nawionek is about 11 m. At a depth of 0.5–2 m, the bottom of the lake is overgrown with *Lobelia dortmanna*. In a few places, the species is replaced by *Cladium mariscus* and at a depth of ca. 2 m, patches of *Lobelia dortmanna* turn into underwater meadows of *Isoëtes lacustris* which disappears at a depth of ca. 2.5 m. At greater depths, i.e. up to 8 m, dense monospecies moss patches develop.

Nature reserve “Bagno Stawek” was established under the Directive of the Minister of Forestry and Wood Industry dated 4 January 1977 in the Antoniewo Forest Subdistrict. It covers an area of 40.80 ha, including 18.18 ha of peat bogs. The purpose of this nature reserve is to preserve the natural bog vegetation. Protected plants are represented by; common sundew, great sundew, small bur-reed, stiff clubmoss, creeping sedge, marsh helleborine, broad-leaved marsh orchid, wild rosemary. The reserve encompasses crescent-like post-glacial depressions filled with peat and surrounded by undulating sandy plains formed in the Pomeranian phase of the Vistulian glaciation. The greatest altitudinal differences occur along the northern border of the reserve in district no. 162 with a fairly steep slope which is an extension of a kettle-hole. The depression covering the reserve is relatively shallow and was glaciated in the Holocene over a large area as a result of peat-forming processes. At present, a slow process of vegetation encroachment is observed at Lake Stawek located in the eastern part of the reserve.

Nature reserve “Bór Chrobotkowy” was established by the Directive of the Minister of the Environment, Natural Resources and Forestry on 31 December 1993 in the Lubnia Forest Subdistrict. It covers a partially protected area of 41.50 ha. The objective is to protect a typically developed lichen-pine forest (*Cladonio-Pinetum*), and in some places – heath forest (*Calluno-Pinetum*). Both syntaxa are characterized by a rare and unique flora of lichens. About 70 lichen species occur in this nature reserve, including 50 terrestrial species. The occurrence of *Cetraria nivalis* – a montane species – represents a unique situation. It is an Arctic-Alpine species or by some other authors defined as a Boreal-Alpine one. It is extremely rare outside the mountains. Only six sites are reported from the lowlands of Central Europe, including two in Poland: Tuchola Forest and the Vistula Spit.

Cladonia stellaris (Opiz) Brodo = *Cladonia alpestris* (L.) Rabenh is also a rare species. It is considered to be a boreal species, widespread in forests of northern Europe, Asia and North America and in high mountains. In Poland, it occurs in the mountains near the upper limit of forests, in the Alpine-forest zone, in the dwarf pine zone, usually in sunny places. The species occurs (but is quite rare) in lowlands on raised bogs, in marshy and lichen-pine forests, mostly in the northern and eastern parts of the country.

Two nature reserves: “Piecki” and “Kruszynek” are located in the territorial and, partially, administrative range of the forest inspectorate.

Nature reserve “Piecki” was established by Regulation No. 13/2001 of the Pomeranian Governor dated 21 November 2001 in the Antoniewo Forest Subdistrict. The reserve covers a partially protected area of 19.42 ha. The objective is to preserve the flora and plant communities typical of lobelia lakes, transitional bogs, fresh coniferous forests and wetland forests with protected, rare and threatened species. The reserve encompasses 5 sites surrounded by a buffer zone, i.e. three lakes: Piecki, Piecki Małe and Kaczewo, and 2 peat bogs surrounded by swamp forest. Lake Piecki is surrounded by forest along the entire shore. Southern, western and north-western shores are steep, the others are rather flat. It is a lobelia lake (the only one in the Piecki nature reserve). Lake Piecki Małe has steep shores and is surrounded by forest. In the southern part, the shores are turning into large fens, transitional and raised bogs. The northern shore of Lake Kaczewo is high and steep, the other shores are flat and peaty; the western shore turns into extensive transitional and raised peat-bogs. Five species of club-moss occur (*Lycopodium inundata*, *L. selago*, *L. clavatum*, *L. complanatum*, *L. annotinum*), three species of sundew (common sundew, great sundew and oblong-leaved sundew), and the northern and white water lily. *Isoëtes lacustris* and *Lobelia dortmanna* occur in Lake Piecki. Apart from species protected in Western Pomerania, rare species include: *Carex limosa*, *Utricularia minor*, *Utricularia intermedia*, *Sparganium minimum* and *Scheuchzeria palustris*.

Nature reserve “Kruszynek” was established by the Directive of the Regional Director for Environmental Protection in Gdańsk dated 25 February 2014. It is a peatland reserve, which protects the existing ecological site and part of Lake Kruszyńskie. The area of the reserve is 8.42 ha, and the buffer zone – 11.03 ha. It is entirely located on the land of the State Treasury, mostly under the administration of Przymuszewo Forest Inspectorate and the Regional Water Management in Gdansk (part of the lake). Also the buffer zone is located under Przymuszewo administration, and the remaining part is private.

It is a well-preserved alkaline peat-bog in the lake bay subject to a terrestrialization process. The thickness of the peat layer ranges from 80 to 45 cm on the borderline with the water table. Flora and vegetation is typical of fens. The most valuable species include: *Liparis loeselii*, *Carex dioica*, *Epipactis palustris*, *Paludella squarrosa*, *Tomenthypnum nitens*, *Helodium blandowii*, *Hamatocaulis vernicosus*. A significant part of the reserve has a well-developed and preserved natural habitat 7230 “Mountain and lowland, alkaline raised bogs, mires and fens”.

One nature reserve “Lake Laska” is located in the territorial range of Przymuszewo Forest Inspectorate, but on the lands of other owners. The reserve is adjacent to these lands and is similar in terms of nature.

The reserve “Lake Laska” was created on 21 July 1977. This is a faunistic reserve established to protect the nesting sites of aquatic birds, especially the mute swan. Its total area is 70.40 ha. The reserve encompasses Lake Laska – an eutrophic water body located at the Zbrzyca river. The water table is separated from the surrounding land by a wide zone of rush vegetation. In addition to the mute swan, also great crested grebe, coot, black-headed gull occur.

The reserve “Dolina Kulawy” is located in PFD and partly in the neighbouring Forest Division Osusznica.

Reserve “Dolina Kulawy” was established under the Directive of the Director of the Regional Directorate of Environmental Protection in Gdańsk No. 14/09 of 8 July 2009. It protects complexes of peat bogs, springs, mesotrophic water bodies, forest and non-forest terrestrial ecosystems characteristic of the spring area of the Kulawy river, with a total area of 155.41 ha. The buffer zone has an area of 346 ha.

The Kulawa River Valley is part of the river-lake hydrological system with a length of about 7 km. The river is fed by numerous springs, flows in the bottom of the valley where many rare ecosystems and habitats developed on calcareous substrate.

At the end of the 19th century, a Prussian irrigation system was built, which additionally enriched the natural habitats of the valley. In the 1970s, the maintenance of the system was ceased, which resulted in the drainage of the surrounding meadows and, consequently, reduction in the sites and population resources of rare and protected plant species. In 1999, the Przymuszewo Forest Inspectorate started to restore the historic irrigation system – a bridge with a weir was rebuilt, and ditches and gates were renovated in 2008. The environmental effect is to stop the degradation of wet meadows and to improve their quality. The Przymuszewo Forest Inspectorate received a prestigious award – Master of Ecology for the restoration of the monument and the renewal of a similar system in the Kłonecznica river valley.

THE ZABORSKI LANDSCAPE PARK. As much as 60% of the Przymuszewo Forest Division overlaps with the Zaborski Landscape Park. The description of the park is presented in the previous part of this book.

PROTECTED LANDSCAPE AREAS. In the northern part, within the PFD administration, a fragment of the Northern Protected Landscape Area is located.

It was established in accordance with Regulation of the Governor of the Bydgoszcz of 14 June 1991 in the area of 78 km². The area is a homogeneous outwash plain divided by thaw depressions and river valleys. Long and narrow finger lakes with steep shores are typical elements of the landscape. The reserve "Bor Chrobotkowy" is located in the protected landscape area.

NATURE MONUMENTS. There are 69 nature monuments: boulders (2), spring fens (4), sites of *Usnea* on a building (1), sites of the giant horsetail (2), birch alleys (5), a group of junipers and groups of trees and single trees, including *Quercus robur* (15), beech (9), Scots pine (6), elm (5), Norway maple (2), hornbeam (2), *Tilia cordata* (2), *Malus sylvestris* (1), birch (1), Norway spruce (1).

Natura 2000 site. Two Special Protection Areas for birds are located: "Wielki Sandr Brdy" and "Bory Tucholskie", and the following four areas of Special Areas of Conservation NATURA 2000: "Sandr Brdy", "Ostoja Zapceńska", "Doliny Brdy i Chociny" and "Młosino-Lubnia".

Refugium PLB220001 "Wielki Sandr Brdy" in the Przymuszewo Forest Division covers 37,106 ha in the following communes: Lipnica, Studzienice, Brusy, Chojnice and Konarzyny. The area represents a fragment of Wielki Sandr Tucholski and is located mostly in Zaborski Landscape Park.

Characteristic of this area is the water system which consists of numerous rivers and lakes. The main element of the whole system is the Brda River with many tributaries of which the largest is the Zbrzyca river. In addition, there are more than 50 lakes of which the deepest is Lake Ostrowite (43m) and the largest Charzykowskie Lake (1363 ha). Most of the lakes are oligotrophic, i.e. a low content of nutrients dissolved in water and good oxygenation. In contrast, eutrophic lakes with a high content of nutrients dissolved in water and low oxygenation occur in the smallest number. The afforestation rate is 70% and the dominant forest community are pine forests.

The following bird species are observed in the refugium area: *Actitis hypoleucos*, *Aegolius funereus*, *Alcedo atthis*, *Anas crecca*, *A. platyrhynchos*, *A. strepera*, *Aythya ferina*, *A. fuligula*, *Botaurus stellaris*, *Bubo bubo*, *Bucephala clangula*, *Caprimulgus europaeus*, *Charadrius dubius*, *Chlidonias niger*, *Ciconia nigra*, *Circus aeruginosus*,

Crex crex, *Cygnus cygnus*, *C. olor*, *Dendrocopos medius*, *Dryocopus marinus*, *Fulica atra*, *Gallinago gallinago*, *Grus grus*, *Haliaeetus albicilla*, *Lanius collurio*, *Larus minutus*, *Lullula arborea*, *Mergus merganser*, *Milvus migrans*, *M. milvus*, *Pandion haliaetus*, *Pernis apivorus*, *Podiceps cristatus*, *Scolopax rusticola*, *Tachybaptus ruficollis*, *Tringa glareola*, *T. ochropus* (obszary.natura2000.org.pl).

In addition to those species, all bird species, other taxonomic groups of animals and plant species listed in the description of PLH220026 "Sandr Brdy" occur.

Refugium PLB220009 "Bory Tucholskie" (Tuchola Forest) is one of the most valuable Polish lowland areas, situated on a vast outwash plain south of the terminal moraines of the last glaciation. The largest number of relict plant species occurs in the Tuchola Forest compared to the entire Central European lowlands. At least 28 species of birds from Annex I of the Birds Directive and 6 species from the Polish Red Book occur (white-tailed eagle, black kite, red kite, ferruginous duck, eagle owl, red-breasted merganser). In addition, at least 107 species of birds nest in the area, including black tern, common tern, kingfisher, crane, common goldeneye, goosander, marsh harrier, whooper swan. A complete list of species listed in the standard data form is provided in the chapter presenting the entire area of the Tuchola Forest Biosphere Reserve and Refugium PLB220009 Bory Tucholskie (Tuchola Forest).

Area PLH220026 "Sandr Brdy" is the largest habitat Natura 2000 area in the Przymuszewo Forest Division. The site is located in the following forest districts: Kokoszka, Młynek, Zbrzyca, Antoniewo, Laska and Bukówka, and covers the most valuable natural fragments, including those protected in nature reserves: Dolina Kulawy, Laska, Piecki, Nawionek and Bagno Stawek.

The area of Sandr Brdy is characterized by a diverse glacial relief with a well-developed hydrographic network which consists of the Brda River together with many tributaries and lakes, mainly lobelia lakes and dystrophic lakes. The landscape is dominated by forests (86%) and inland waters (10%). The area is particularly valuable in terms of natural assets. Valuable habitats occupy 30% of the total area. Many protected plant and animal species occur. There are 25 habitat types, including dry heaths, which occupy 37.46 ha.

These habitats are ecological systems with codes the following codes: 2330 – Inland dunes with psammophilous grasslands; 3110 – lobelia lakes; 3140 – charophyte communities from the alliance *Charion fragilis* in strongly mineralized, alkaline oligo-mesotrophic waters; 3150 – old

river beds and natural eutrophic water bodies with the communities of *Nymphaeion*, *Potamnion*; 3160 – natural dystrophic lakes and ponds; 4030 – dry heaths (*Calluno-Genistion*, *Pohlio-Callunion*, *Calluno-Arctostaphylion*); 6230 – floristically rich mountain and lowland *Nardus* grasslands (*Nardion* – species-rich patches); 6410 – natural and semi-natural grassland formations (*Molinion*); 6430 – Hydrophilous tall herb fringe communities (*Adenostylion alliariae*) and riverside herb communities (*Convolvuletalia sepium*); 6510 – lowland and mountain hay meadows (*Arrhenatherion elatioris*); 7110 – active raised bogs; 7120 – degraded raised peatbogs still capable of natural and stimulated regeneration; 7140 – transition mires and quaking bogs (mostly *Scheuchzerio-Caricetea nigrae* vegetation); 7150 – depressions on peat substrates of the *Rhynchosporion* alliance; 7210 – calcareous fens (*Cladietum marisci*, *Caricetum buxbaumii*, *Schoenetum nigricantis*); 7230 – alkaline fens; 9110 – acidophilous beech forest; 9160 – Sub-Atlantic and medio-European oak or oak-hornbeam forests (*Stellario-Carpinetum*); 9170 – Central European and subcontinental hornbeam forest (*Galio-Carpinetum*, *Tilio-Carpinetum*); 9190 – old acidophilous oak woods (*Betulo-Quercetum*); 91D0 – bog woodland; 91E0 – alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Salicetum albae*, *Populetum albae*, *Alnenion glutinoso-incanae*); 91F0 – oak-elm-ash riparian forests (*Ficario-Ulmetum*); 91I0 – thermophilic oak woods (*Quercetalia pubescenti-petraeae*); 91T0 – Cladonia-pine forest (obszary.natura2000.org.pl).

The following species (plants and animals) are covered by Article 4 of Directive 2009/147/EC and species listed in Annex II to Directive 92/43/EEC: *Aegolius funereus*, *Alcedo atthis*, *Bombina bombina*, *Botaurus stellaris*, *Canis lupus*, *Caprimulgus europaeus*, *Castor fiber*, *Circus aeruginosus*, *Cypripedium calceolus*, *Dendrocopos medius*, *Drepanocladus vernicosus*, *Dryocopus martius*, *Gallinago gallinago*, *Lampetra fluviatilis*, *L. planeri*, *Liparis loeselii*, *Lullula arborea*, *Lurionium natans*, *Lutra lutra*, *Lycaena dispar*, *Mergus albellus*, *Milvus migrans*, *Myotis dasycneme*, *M. myotis*, *Pulsatilla patens*, *Rhodeus sericeus amarus*, *Saxifraga hirculus*, *Triturus cristatus*, *Unio crassus* (obszary.natura2000.org.pl).

Area PLH220057 “Ostoja Zapceńska” is located mainly in the Osusznica Forest Division. Only small fragments are located in the Laska Forest Subdistrict (Przymuszewo FD), distributed along the Kłonicznica river, and in the Bukówka Forest Subdistrict.

Zapceńska Ostoja is located on the outwash plain in the north-western part of the Tuchola Forest. The landscape is dominated by

forest (66%) with some agricultural habitats (16%). There are many aquatic ecosystems and wetlands, including lobelia and charophyte lakes. Charophyte lakes are characterized by underwater plant communities dominated by charophytes forming so-called charophyte meadows. Additionally, the landscape is enriched by the Kłonecznica river, which has a rapid current in the lower reaches, typical of mountain rivers. This river is a right tributary of the Zbrzyca river, with a length of 27 km. There are 14 habitat types described in the standard description of data from the area, including dry heaths.

In the area of Ostoja Zapceńska, *Botrychium simplex* occurred in the past – one of the two last sites of this species in Poland. The newly created nature reserve “Kruszynek” is located in the area.

Area PLH220058 “Valley of the Brda and Chociny” in the Przymuszewo Forest Division is mostly located in the Młyn Chociński Forest Subdistrict. It encompasses lakes: Duże Małe, Małe Głuche, Małe Łowno, Duże Łowno, fragments of the Brda river valley and the Chociny river valley and a fragment of the outwash plain. The area is covered mainly by coniferous forests (65%) and grassland and thicket habitats (20%). There are many oligotrophic, charophyte and eutrophic lakes. *Cladonia*-pine forests are characteristic of the Tuchola Forests. There are 8 habitat types. Dry heath habitat is not mentioned in the standard data form.

Area PLH220077 “Młosino – Lubnia” is located in the north-eastern part of the Przymuszewo Forest Division, in the forest subdistricts of Lubnia and Dąbrowa. It includes a fragment of the outwash plain with numerous peat bogs and water bodies. Forests cover 79% of the area, including coniferous forests 77% and mixed forests only 2%. There many lobelia and dystrophic lakes in the area.

In addition, dune hills are overgrown with pine forests, including *Cladonia*-pine forests with numerous species of terrestrial lichens.

There are 12 habitat types listed in the standard data form for the area, including dry heaths.

2.9.4 Current number of patches with heathlands and their distribution

In the past, heaths were abundant in the area managed by the Forest Inspectorate of Przymuszewo. On the Prussian topographic map from 1874, there are large non-forest areas marked as heaths and

xerothermic grasslands. In 1890, when the Prussian Forest Division of Zwanshoff was created, they were replaced by forests. Several decades earlier, the Prussian Forest Division of Laska was created in the adjacent area. After 1920, i.e. after restoration of the Republic of Poland, further afforestation of these areas was conducted in the Polish Forest Divisions of Przymuszewo and Laska. The afforestation was continued after World War II when the communist government took over large landed estates, incorporated them into state forests and started to restore forests in areas used for agriculture.

As a result of afforestation carried out for years, forest communities currently dominate in the areas managed by the Przymuszewo Forest Division whose territory encompasses the former forest divisions of Przymuszewo and Laska merged into one entity in 1973. Heaths occur in the form of small patches along forest-section lines, former firebreaks and in fragments of forests where pine density and canopy of trees is small. According to the survey from 2007 on the distribution and the size of heathlands, there are 93 heath patches (phytocoenoses) in the Przymuszewo Forest Division, with a total area of 59.26 ha. The size of individual phytocoenoses ranges from 0.07 ha to 2.64 ha. Patches of 0.01 to 0.50 ha occur in the largest number (i.e. 62 patches). The number of patches in the subsequent five classes, with an area increasing by 0.5 ha, is up to 10. There are only 3 patches in the largest size class – from 2.51 to 3.00 ha (Fig. 5).

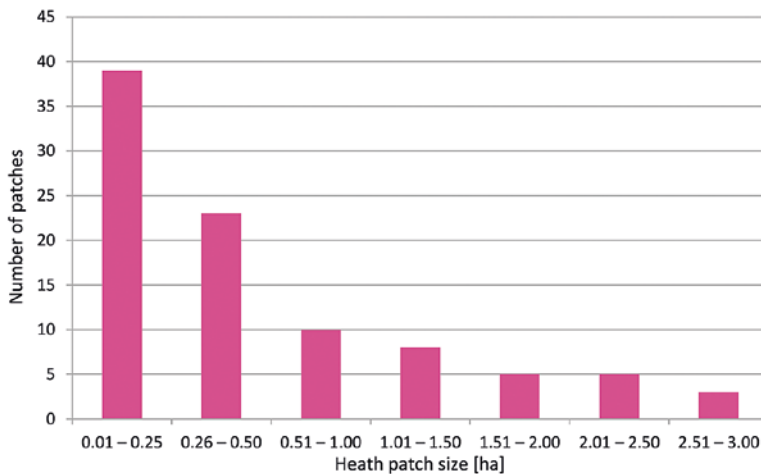


Figure 5. Structure of heathland size in the Przymuszewo Forest Division

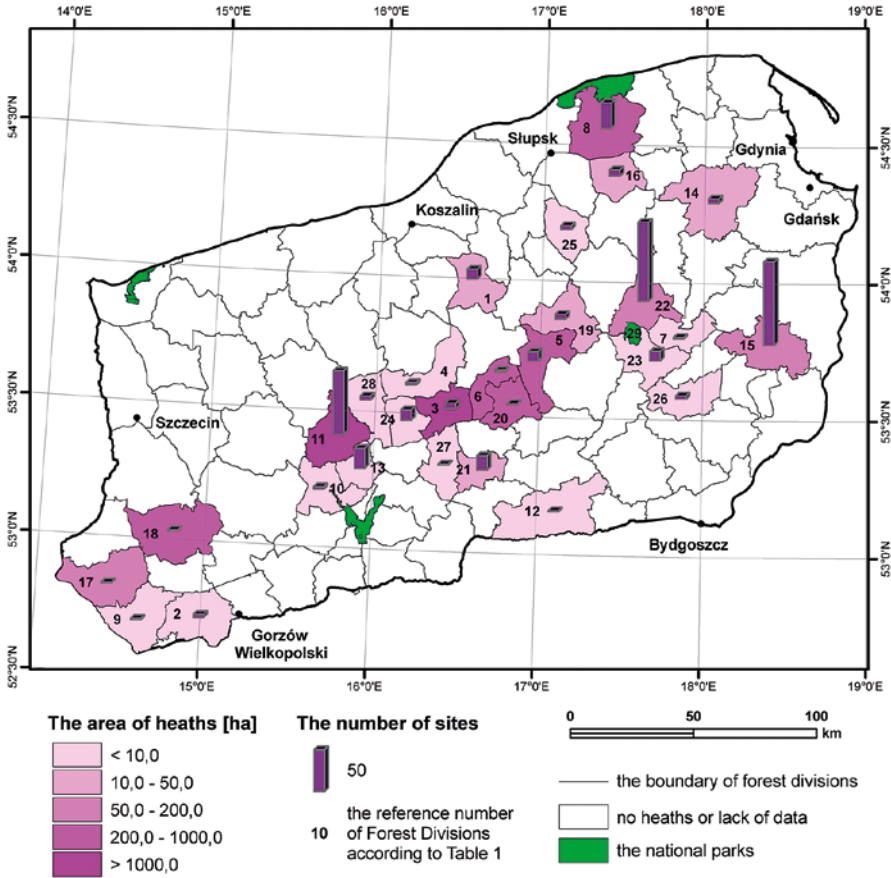


Figure 6. Spatial distribution, the total area and the number of sites in Pomerania with reference to forest divisions (according to Kunz and Nienartowicz, 2010). The numbers denote the following forest divisions: 1 – Bobolice, 2 – Bogdanic, 3 – Borne Sulino, 4 – Czaplonek, 5 – Czarne Człuchowskie, 6 – Czarnobór, 7 – Czersk, 8 – Damnica, 9 – Dębno, 10 – Drawno, 11 – Drawsko, 12 – Kaczory, 13 – Kalisz Pomorski, 14 – Kartuzy, 15 – Lubichowo, 16 – Łupawa, 17 – Mieszkowice, 18 – Myślubórz, 19 – Niedźwiady, 20 – Okonek, 21 – Płytnica, 22 – Przymuszewo, 23 – Ryteł, 24 – Świerczyna, 25 – Trzebielino, 26 – Tuchola, 27 – Wącz, 28 – Żłocieniec, 29 – “Tuchola Forest” National Park

A few years later, the heath size structure in the Przymuszewo Forest Division was compared with data for other forest divisions in Pomerania. In 2010, questionnaires were distributed in 115 forest divisions of this region and adjacent areas. Answers were obtained from 80 units (Kunz and Nienartowicz, 2010). According to the results obtained, heaths occur in 28 forest divisions and one national park (Tuchola Forest National Park). Figure 6 presents the distribution of all forest divisions with

heathlands. Altogether 4,470 ha of heaths were catalogued at 480 sites. Most of the heathlands occur in the area of: 1 – the Forest Division of Borne Sulinowo (over 1670 ha); they are classified into the so-called Kłomino heaths in the nature reserve “Diabelskie Pustacie (“Devils’ Wastelands”), 2 – the Forest Division of Drawsko (over 1370 ha), on the military training ground, 3 – the Forest Division of Czarnobór (over 240 ha), 4 – the Forest Division of Damnica (over 240 ha), 5 – the Forest Division of Okonek (over 200 ha), in the nature reserve “Wrzosowisko w Okonku” (“Heathland in Okonek”).

The largest heather patches were located in the Forest Division of Borne Sulinowo (the forest districts of Borne Sulinowo and Broczyno), the Forest Divisions of Okonek (the forest district of Okonek) and Czarnobór (the forest district of Czarnobór).

Most of the heather patches were located in the Forest Division of Lubichowo (105), the Forest Division of Przymuszewo (99 patches, i.e. six more than in the study from 2007), and the Forest Division of Drawsko (80). However, the area of these heather patches is small. In the questionnaires, *Calluna vulgaris* (in dry heaths) was quoted as the only species encountered.

2.10. Man in the heath landscape in southern Kashubia

Man is inextricably linked with tradition, culture, history and nature. The concept of landscape as a cultural and natural space storing the memories of the lives and culture of past generations encompasses various forms of nature conservation as well as regional museums whose objective is to preserve cultural heritage of local communities.

In southern Kashubia, there are: Wdzydze Landscape Park, the Kashubian Ethnographic Park Museum in Wdzydze Kiszewskie and the “Stone Circles” Archaeological and Natural Reserve in Odry (Fig. 1).

2.10.1. Wdzydze Landscape Park

Wdzydze Landscape Park (WLP) is located in the north-western part of the Tuchola Forest, in the south-western part of Pomerania Province, 70 km south-west of Gdańsk in Kościerzyna district. It was established on 15 June 1983 with an area of 17,800 ha (and a buffer zone of 15,200 ha) in order to preserve natural, cultural and landscape values.

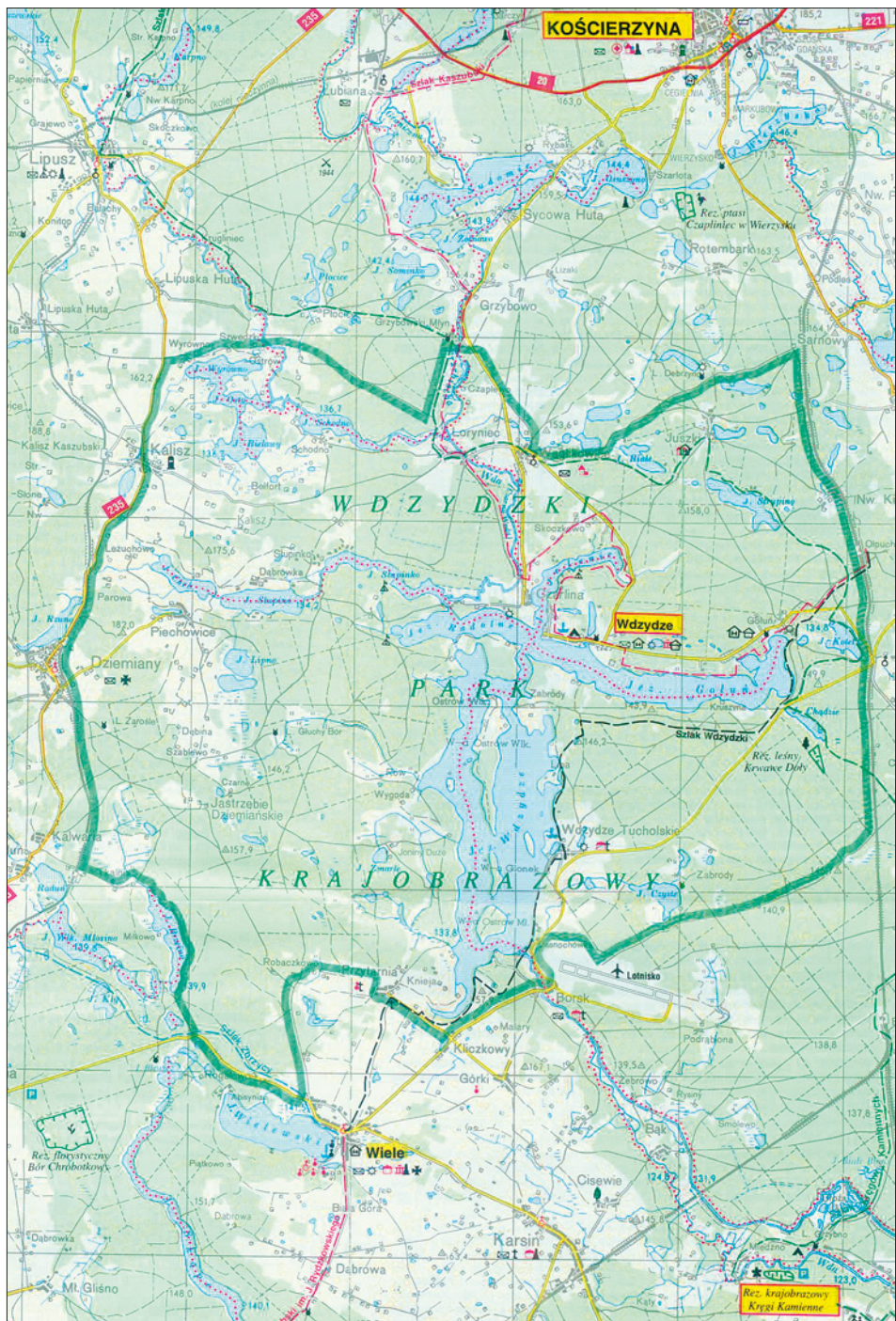


Figure 1. Location of Wdzydze Landscape Park, the Kashubian Ethnographic Park Museum in Wdzydze Kiszewskie and the „Stone Circles” Archaeological and Natural Reserve in Odry

On 1 July 2010, the Pomeranian Provincial Assembly decided to consolidate landscape parks located within that province, i.e.: Coastal LP, TriCity LP, "Słupia Valley" LP, Kashubian LP, "Vistula Spit" LP, Wdzydze LP, Zaborski LP under one administration of Pomorski Zespół Parków Krajobrazowych (Pomeranian Complex of Landscape Parks) with a seat in Słupsk (Wdzydze Landscape Park, 2011).

The dominant land relief in WLP is an outwash (sandur) plain in the form of a vast alluvial fan formed by melting waters of the continental glacier. The central part of the Park is occupied by Lake Wdzydze which is a ribbon lake. There are over 160 lakes and ponds within WLP. Waters represent 11% of the Park area. The abundance of forests and lakes connected with the Wda river and its tributaries along with its heterogeneous land relief provided this Landscape Park with unique scenic values suitable for tourism and recreation. Nature in the Park is still relatively well preserved which is owed to low population density.

The Park flora includes 820 taxa of vascular plants, representing about 50% of the flora in Western Pomerania and 23% of the Polish flora. This relatively small number of plants is compensated by the abundance of aquatic, marsh and peat species whose presence functionally derives from favourable habitat conditions. Less common plants found in the WLP forests include *Lycopodium* species: *Diphasiastrum complanatum*, *Lycopodiella inundata*, *Diphasiastrum zeilleri* (Rouy) Holub, *Lycopodium clavatum* and *Lycopodium annotinum*, as well as *Polypodium vulgare*, *Viburnum opulus*, *Arctostaphylos uva-ursi*, orchids, sundews, *Lobelia dortmanna*, *Isoetes lacustris*, *Daphne mezereum* (Wdzydze Landscape Park, 2011).

Wdzydze Landscape Park is additionally an interesting area because of its abundant lichen biota. Lichenological research conducted in this region confirmed a significant contribution of rare, endangered and protected lichen species in the flora (Kowalewska, 1999, 2002, 2010, 2012; Kukwa et al., 2013). In total, 276 lichen taxa, 38 lichenicolous fungi, 1 lichenicolous slime mould as well as 5 saprophytic fungi closely related to lichens were found in WLP (Kukwa et al., 2013). According to the authors, two lichenicolous fungi deserve special attention: *Roselliniella microthelia* and *Epigloea urosperma*. The former was found for the first time in Poland, and the latter has only one site in Poland, located in WLP. In the list of species provided by Kukwa et al. (2013), there are some new species previously not encountered in lowland Poland: *Absconditella cellata*, *Lecidea sphaerella*, *Micarea bauschiana*, *Peltigera lepidophora*, *Polycoccum peltigereae* and *Staurothele frustulenta*, while *Lichenosticta alcicornaria* and *Rinodina pityrea* were identified for the

first time in Western and Gdańsk Pomerania. It is also worth mentioning that a locality of one lichen species, *Lecidea sphaerella* – which was considered to be already extinct in Poland (cf. Cieśliński et al., 2006) – was recently identified by Kukwa et al. (2013) in WLP.

The list of lichen found in WLP encompasses as many as 69 species from the Polish red list of endangered lichens (Cieśliński et al., 2006), including 4 critically endangered (CR): *Bryoria capillaris*, *B. implexa*, *B. subcana*, *Pyrrospora quernea*. In the category of endangered (EN) species, the WLP listing of lichen species includes 14 taxa. The lichen list also includes: 27 vulnerable (VU) species, 15 near-threatened taxa (NT), 4 least concern (LC) and data deficient (DD) species (Kukwa al., 2013).

A total of 52 lichen species threatened in Gdańsk Pomerania occur in WLP according to the regional red list compiled by Fałtynowicz and Kukwa (2003), including e.g. 1 critically endangered species – *Cladonia incrassata*, 23 species in the VU category, 3 taxa in the NT category, 2 taxa in the LC category and 11 data deficient DD species.

According to the Regulation on wild fungi species occurring in Poland issued by the Minister of the Environment in 2014 (Regulation 2014), taxa identified in Wdzydze Landscape Park are represented by 40 protected lichen species, including 18 strictly protected species; the latter represented by the *Bryoria* genus (except for *B. fuscescens*).

Peat-bog vegetation associated with forest ponds, transformed by man to a lesser or greater extent, is particularly abundant in the Park. Common species in those localities include: round-leaved and English sundews (*Drosera rotundifolia* and *Drosera anglica*, respectively), bog sedge (*Carex limosa*), Rannoch-rush (*Scheuchzeria palustris*), bog rosemary (*Andromeda polifolia*), white beak sedge (*Rhynchospora alba*), bog cranberry (*Vaccinium oxycoccos*) and wild rosemary (*Rhododendron tomentosum*). One of the rarest plant species found in spring peat bogs (supplied by underground water) is marsh saxifrage (*Saxifraga hirculus*) which is a glacial relic in Poland. Its presence was reported at only a few sites in Pomerania, including two located in the Wdzydze Landscape Park.

The most common mammalian species living in the Park are: roe deer, hare, wild boar, badger, fox and raccoon dog. A large population of beavers lives in lakes, rivers and periodically in dry drainage ditches. The beaver activity is manifested in the form of lodges, dams, burrows or fallen trees (Wdzydzki Landscape Park, 2011).

The presence of ten bat species was reported from the Park, including a breeding colony of the pond bat near the Wda river – an endangered species in Europe (Ciechanowski et al., 2006).

There are about 126 species of nesting birds in the Park. The following species are frequently spotted: cranes with their breeding grounds in forest peat bogs, kingfishers found close to watercourses and lakes, mute swans, goldeneyes and tufted ducks. The most precious avifauna species is red-breasted merganser nesting on the shores of islands and in the bays of Lake Wdzydze. It is a highly endangered species in Poland.

There are 35 fish species found in the Park and its buffer zone, including many rare and protected ones. One of the most valuable is a lacustrine morph of brown trout whose local form is referred to as Wdzydze trout. It is an indigenous population of the relict morph which developed as a result of geographic isolation caused by the last glaciation (Radtke, 2008). Another valuable component of the fish fauna is lake minnow (*Rhynchocypris percniurus*) which is listed in the Polish Red Book of Animals as a critically endangered species. Noble crayfish is also an important representative of the Park fauna; this species used to be common in the Polish waters but now it is on the verge of extinction now. Since 2007, WLP has been struggling to save noble or European crayfish.

There are at least 12 different species of amphibians in Wdzydze Landscape Park, including: pool, common, marsh and European tree frogs, European fire-bellied toad, smooth newt, and common or green toads. All amphibian species are protected (Wdzydze Landscape Park, 2011).

Three types of landscape can be distinguished in WLP: 1 – landscape of large forest; 2 – water landscape, and 3 – so-called cultivated landscape created by the Kashubian farmers, associated with their material culture and cultural forms of spatial development.

The cultivated landscape of WLP is very heterogeneous: areas of infertile agricultural lands are accompanied by small woods, groves, wetlands and areas with fertile soils covered by uniform field crops. There are also quite large stretches of permanent grasslands found in the cultivated landscape extending next to or along rivers and periodically flooded areas. The above differences are followed by diverse cultural manifestations in the landscape, i.e. villages and hamlets. Two different types of cultural landscape can be distinguished: “poor” with scattered solitary homesteads and small hamlets, and “rich” with large peasant villages that have turned into settlement units in the form of small towns, such as Wiele and Dziemiany (<http://wdzydzkipark.pl/krajobraz/>).

Natural components dominate over the cultural ones in the Park landscape. Natural landscape is primarily composed of large forests and a variety of surface waters: valleys of small rivers, and lakes of varied shape and size. In the Park, you can find both large lakes whose surfaces extend toward the horizon, medium-sized lakes at the side of meadows and pastures, and quite frequently located within a village span, and finally – forest ponds. You can often see steep, high slopes rising above the water surface. A large water body of Lake Wdzydze is a unique and outstanding nature marvel on the scale of Poland, which can be observed in Kliczkowy on the road from Borsk to Wiele.

However, the components of cultural landscape, scattered and nestled in the surrounding nature, do not significantly affect the perception of the Park as a “quiet and intimate” place. This landscape is associated with material culture and cultural forms of spatial development by the Kashubian population and is manifested in the preserved network of roads and settlements, in the village buildings and accompanying landmarks such as roadside chapels and crosses (Wdzydzki Landscape Park, 2011).

The origins of historical settlements within the present area of the Park date back to as early as the 13th century when the village of Piechowice was established. At the end of the 15th century, the following villages were already in existence too: Lipusz, Kalisz and Dziemiany. Until the late 15th century, villages were mostly established under Germanic law (Chełmno and Magdeburg rights). From the late 16th to the mid-18th century, more settlements were founded. Some of them were established in the neighbourhood of tar kilns and glass works operated in the forests, others were founded close to grain and saw mills. Peasant villages developed around some of them (Olpuch, Juszeki, Szenajda, Grzybowo, Lipuska and Sycowa Huta). Such villages as Wdzydze Kiszewskie, Wdzydze Tucholskie and Czarlina were formed in the second half of the 17th at the site of the previously established fishing settlements. In the early 20th century, farm *folwarks* (granges) Kliczkowy and settlements for forest and rail road workers started to develop too (<http://wdzydzkipark.pl/historia-i-kultura/kultura/>).

Local economy and society were primarily agrarian. Until the late 18th century, cereals were the main crops, among which, rye prevailed because of habitat conditions; it was followed by oats and barley here and there. Smaller acreages were allotted to peas, buckwheat and flax. Grain milling took place in the mills of Lipusz and Kalisz (since the 15th century) and Grzybów (since the 17th century).

Draft animals dominated the animal production. They were mostly oxen, with fewer horses which were held primarily by *lemans* (i.e. vassals who had to provide knight's services in return for land), village heads (*Schulzes*, similar or equivalent to medieval sheriffs) and gentry. In addition to draft animals, sheep were raised as well as cows and pigs on a smaller scale. The deficiency of quality grassland often forced their owners to graze animals in the forests. Poultry farming was quite common judging by the tributes paid in hens by *giburo* peasants (affluent peasants) to the Teutonic Knights.

Forests were also a source of significant economic wealth. Naturally, timber was the backbone profit maker. The abundance of pine stands was conducive to the development of bee-keeping. The earliest mentions of forest apiculture are found in the documents of the Teutonic Knights' Order from the early 14th century and refer to hives located near Lake Kołpiny (entirely drained at present). The most interesting forest industry was tar production and distillery. Tar was made from resin-rich pine root wood. In addition, charcoal and resin torches were also produced.

Natural conditions fostered fishery development as an important branch of economy. Since the second half of the 15th century, all larger lakes and forests were royal property managed by *starosts* (district governors). Peasants were allowed to fish with rods and small nets but only in summer to meet their own needs. At more valuable lakes, "official" fishermen were settled permanently whose role was to supply fish to *starosts*. Moreover, the villages of Lipusz and Kalisz were granted the privilege to fish crayfish but had to pay so called crayfish fee in return.

Wdzydze Landscape Park is located in the ethnographic region called South Kashubia. The area around and north of Lake Wdzydze is inhabited by a Kashubian ethnic group referred to as *Łyczaki*, while the southern part of the Park, including *Wiele*, is occupied by *Zaboracy*. This is where the old building tradition was preserved the longest in Kashubia. A traditional homestead within the Park is a two building farm where the outbuilding (e.g. barn) faces the road with its narrower front and is positioned ahead of the façade of a wide-front dwelling house. Another typical feature of the WLP region were gentry-owned rural estates with larger homesteads and separate animal barns and crop storages. Quite common in such homesteads were separate earth cellars and bread ovens. Also mills, inns, forges, chapels and crosses were important structures in village developments.

The preserved spatial arrangements of the villages, homestead layouts and their components, traditional wooden buildings are also extremely valuable examples of the material culture. The villages with

outstanding cultural values are: Bąk, Borsk, Czarlina, Górki, Juszki, Kalisz Kaszubski, Lipusz, Loryniec, Olpuch, Piechowice, Płocice, Wąglkowice, Wdzydze Kiszewskie, Wdzydze Tucholskie and Viele.

There are two Nature 2000 sites in Wdzydze Landscape Park. The first one is a special area of conservation (SAC) established to protect the habitats at Lake Wdzydzkie (PLH220034). It covers about 80% of the Park area, including such habitats as lobelia and dystrophic lakes, fens with mosses and sedges, transitional and raised peatbogs, wet meadows, calcareous grasslands and marshy (coniferous) forest with the following protected plant and animal species:

Plants: marsh saxifrage (*Saxifraga hirculus*), floating water-plantain (*Luronium natans*), fen orchid (*Liparis loeselii*); fish: amur bitterling (*Rhodeus sericeus*), spined loach (*Cobitis taenia*), lake minnow; amphibians: northern crested newt (*Triturus cristatus*), fire-bellied toad; Mammals: pond bat, European beaver and otter.

The other site is the Tuchola Forest special protected area (SPA) for wild birds (PLB220009). It covers the entire area of the Park to ensure protection of the following avian species: red-breasted merganser, Eurasian bittern (*Botaurus stellaris*), great egret (*Ardea alba*), white stork (*Ciconia ciconia*), whooper swan (*Cygnus cygnus*), white-tailed eagle (*Haliaeetus albicilla*), western marsh harrier (*Circus aeruginosus*), black woodpecker (*Dryocopus martius*), nightjar (*Caprimulgus europaeus*), woodlark (*Lullula arborea*), red-breasted flycatcher (*Ficedula parva*), Eurasian eagle-owl (*Bubo bubo*), boreal owl (*Aegolius funereus*), kingfisher, crane, red-throated loon (*Gavia stellata*), black-throated loon (*Gavia arctica*), red kite (*Milvus milvus*) and corncrake (*Crex crex*) (<http://wdzydzkipark.pl/przyroda/formy-ochrony-przyrody/natura-2000/>).

There is one nature reserve in the Park which is called "Krwawe Doły" (Bloody Pits). It was established on 12 November 1996. It is a floristic and sylvatic reserve with an area of 13.02 ha. Its conservation goal is to preserve forest communities with rare protected plants and lichen typical of the Tuchola Forest. It is located in the Forest Division of Kościerzyna. The reserve encompasses habitats of fresh coniferous and dry forests covered with about 100-year-old pine stands of quite loose growth. The shrub layer is dominated by pine and spruce growths. Wavy hair-grass (*Deschampsia flexuosa*), heather, blueberry (*Vaccinium myrtillus*), and new pine seedlings are often found in the undergrowth. Also a parasitic plant grows in the nature reserve – Dutchman's pipe (*Monotropa hypopitys*) (<http://wdzydzkipark.pl/przyroda/formy-ochrony-przyrody/rezerwaty-3/>).

2.10.2. “The Kashubian Ethnographic Park” Museum in Wdzydze Kiszewskie

The park was founded in 1906. Its founders, Teodora and Izydor Gulgowski were the first to establish an open-air museum on the Polish soils. They arranged it in the 18th century *giburo* cottage purchased from a local farmer, Michał Hinc. The couple gathered a collection of Kashubian bonnets, glass paintings, furniture and farm equipment in the cottage. The museum burnt down in 1932 but was rebuilt after a few years thanks to Teodora Gulgowska’s endeavours. In 1948, Teodora Gulgowska donated the cottage with the surrounding ground to the state treasury. Since then, the *skansen* was expanded with additional facilities brought from Kashubian lands, and the museum was named after the founders, i.e. Teodora and Izydor Gulgowski.

The research activities and social passions of the museum founders promoted the development of local handicrafts and helped to discover the beauty of the Kashubian folk art which is inherited in elaborate woven root products and colourful Wdzydze embroideries. Currently, more than one 100-year-old museum occupies an area of 22 ha located on the banks of Lake Gołub and is built up with structures representing regional architecture. Cottages/huts, manor houses, a school building, forge, windmills, churches, outbuildings and craft workshops – 48 exhibits from Kashubia and Kociewie demonstrate the diversity of rural architecture dating back to the period from the 17th to 20th centuries. Accurately recreated interiors with authentic furnishings and temporarily operated farm and industrial machinery create unique atmosphere enhanced by the scenic location of the museum and treasures of the surrounding nature (<http://wdzydzkipark.pl/historia-i-kultura/muzea/kaszubski-park-etnograficzny/>).

2.10.3. “Kręgi Kamienne” (Stone Circles) Archaeological and Nature Reserve in Odry

The reserve with an area of 17 ha is located in the Czersk Forest Division, Odry Forest District, 44 km north-east of Chojnice and 14 km north of Czersk. It is a burial site of the Wielbark culture attributed to the Goths and Gepids’ migration from Scandinavia to the Black Sea. The

burial ground is located on the eastern bank of the Czarna Woda river near the village of Odry (Figs 2 and 3).

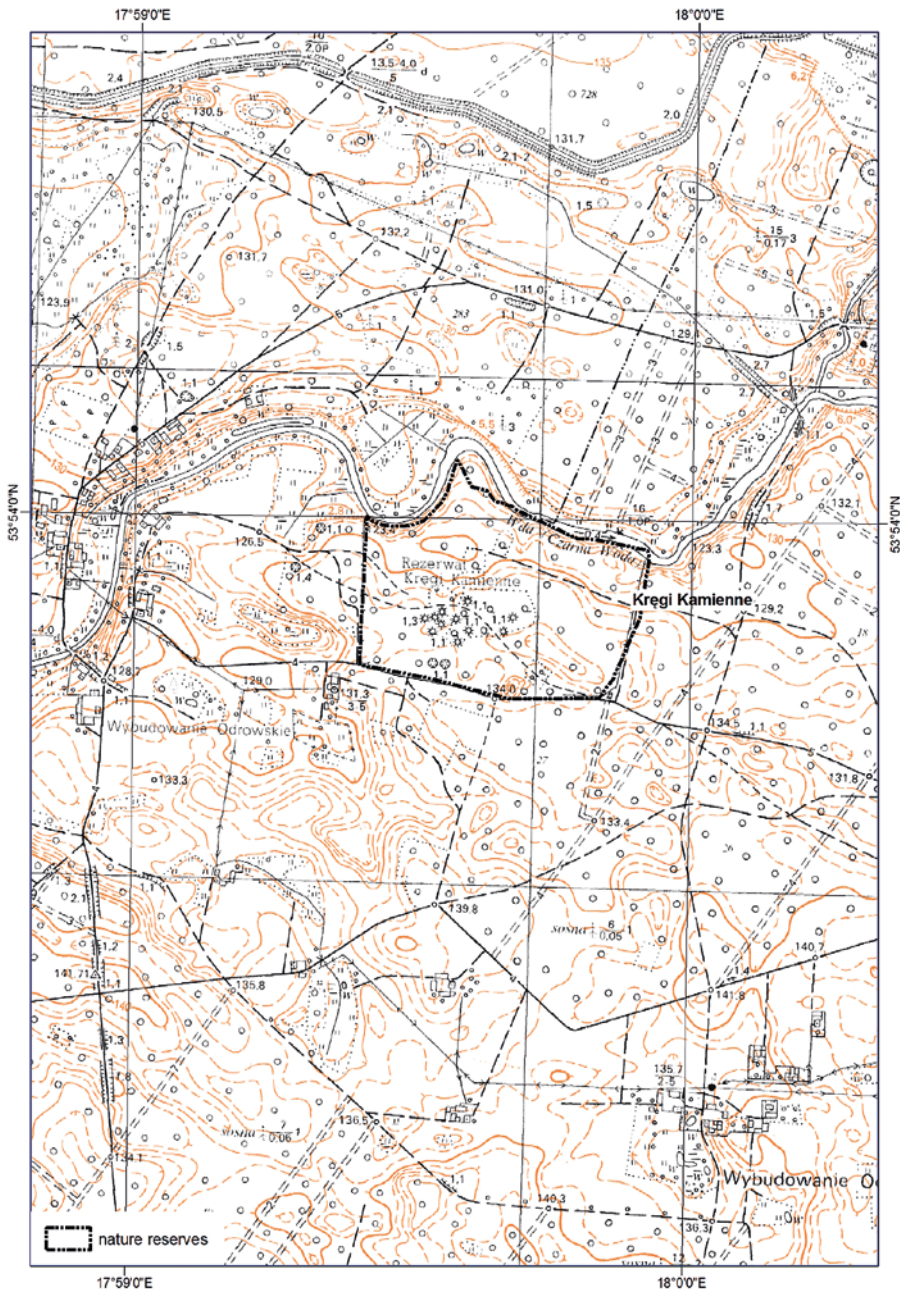


Figure 2. Location of “Kęgi Kamienne” (Stone Circles) Archaeological and Nature Reserve in Odry on the topographic map



Figure 3. Location of the „Křęgi Kamienne” (Stone Circles) Archaeological and Nature Reserve in Odry on the orthophotomap

This scenic site was declared a natural reserve in 1958. In the middle of a sparse pine forest, there is a fenced area with 10 complete and some fragmented stone circles, of which the smallest has a diameter of 15 m, and the largest one of 33 m. Stones, which protrude above the ground up to a height ranging from 20 to 70 cm, are arranged along the perimeter of the circles (Figs 4 and 5). The number of stones varies from 16 to 29 in a single circle. In the middle of each circle, one more stone is placed, or two in a few circles. There are also about 30 burial mounds in the reserve whose diameters range from 8 to 12 m ([http://pl.wikipedia.org/wiki/Rezerwat_przyrody_Kręgi_Kamienne_\(pomorskie\)](http://pl.wikipedia.org/wiki/Rezerwat_przyrody_Kręgi_Kamienne_(pomorskie))).

The site has attracted attention of many researchers for a long time. The first excavation took place there in the second half of the nineteenth century. It was first examined by William Strykowski and Abraham Lissauer. They destroyed many burial cavities, and pushed aside or moved some stones. The topographic survey of the site was taken by a surveyor from Poznań, Paul Stephan in 1915. Being a surveyor, he was mostly interested in the arrangement of the stones and circles. He put forward a thesis that the stone circles were a sort of prehistoric clocks [http://pl.wikipedia.org/wiki/Rezerwat_przyrody_Kręgi_Kamienne_\(pomorskie\)](http://pl.wikipedia.org/wiki/Rezerwat_przyrody_Kręgi_Kamienne_(pomorskie))



Figure 4. Stone circle in the reserve (photo by Ludwik Lipnicki)



Figure 5. Young lichenologist in the „Stone Circles” Archaeological and Nature Reserve (photo by Ludwik Lipnicki)

The first Polish archaeologist who became interested in the site was Prof. Józef Kostrzewski (discoverer of Biskupin). He found that the site was a graveyard used in the 1st and the 2nd century AD, and the circles and mounds were graves. During his archaeological excavations, he carried out a complete examination of three burial mounds and one circle. He found: a gold pendant, glass beads, hair pins, bronze buckle, fabric remnants, and fragments of pottery from the Roman period in the burial mounds. In addition to the ash urn graves (urn field culture), Prof. Kostrzewski found evidence of two other types of funeral rituals, based on which he put forward a hypothesis that foreign incomers from the north settled in the region next to the indigenous population who kept cremating their dead as they used to do (Kostrzewski 1928). In the 1st century AD, Germanic tribes of the Goths came to Pomerania from Scandinavia during their migration to the Black Sea. (http://pl.wikipedia.org/wiki/Odry_%28cmentarzysko%29). They left behind their graves with skeletal remnants (http://pl.wikipedia.org/wiki/Odry_%28cmentarzysko%29).

In 1962, archaeological excavations were resumed in the reserve. It was Dr. Jerzy Kmiecński of the Archaeology Institute of Łódź University who started the scientific research. He found particularly

interesting tombs in the mounds, especially women's graves. They are supplied with various rich ornaments, which suggests that a woman-mother played a very important role in the then society (breast pins, large safe pins, glass beads, bracelets, pendants, vessels that were not made locally but in the workshops operated in the Roman Empire). Men's burials were humbler because apparently it was not customary to insert tools or weapons into their graves.

The most stunning discovery was evidence of tillage, which was revealed at the boundary separating the zero datum layer from the native humus stratum. The traces of ploughing date back to the period when the area was populated by peoples of the Pomeranian culture. The discovery confirmed the rural nature of the settlers. Kmiecinski (1968) conducted excavations in 8 circles and 25 burial mounds. He discovered about 480 graves. Kmiecinski stated that the Odry cemetery was in use from the 2nd to the 4th century AD. Recently, the excavations were carried out by Tadeusz Grabarczyk who claimed that it was a Goths' graveyard. Around 70 AD, one Scandinavian group came to the banks of the Wda river. They probably settled in the immediate vicinity of the cemetery for a period of 130–150 years. The Goths buried their dead in the mounds with stone banks, in stone circles and the flat part of the cemetery where all graves were initially marked with steles. It is worth mentioning that the dead's heads were oriented toward the north in the graves with skeletal remnants. In total, more than 600 graves were discovered. The Goths' residence in the area was merely an episode in the history of this land. According to Grabarczyk (1997), the site was a graveyard since the period of Roman influence, and it was then used by the Scandinavian Goths in 70–200 AD.

Furthermore, lichenological research has been conducted in the reserve. The work was initiated by Krawiec (1938) who reported 41 epiphytic lichen species found on boulders. His studies of lichens on rock habitats were continued by Lipnicki (1990, 1998), and then by Kiszka and Lipnicki (1993, 1994).

Kiszka and Lipnicki (1993) identified about 80 lichen species on 250 rocks and about 100 larger boulders. The authors listed some new or not yet identified species in Poland: *Lepraria latebrarum*, *Stereocaulon evolutum*, *Chrysothrix chloryna*, and *Miriquidica griseoatra*, *M. leucophaea*, *Lecidea caesioatra*, *Rimularia furvella*, *Acarospora nitrophila* as rare in Poland, both in lowlands and Pomerania.

According to Lipnicki (1998), during the lichenological research conducted in the 1980s and 1990s, a total of 86 lichen species were found on the surface of boulders; these species were often very rare for Central

European Lowlands and in general, for Poland. The author analysed the process of formation of lichen biota on boulders as pioneer media.

The species found in the reserve are included on the red list of endangered lichens of Tuchola Forest, which covers 151 taxa (Lipnicki, 2003). Seven taxa that used to be found on the rocks in the reserve (Krawiec, 1938) are now considered regionally extinct (RE), and the cause of their extinction is attributed to the intensified tourist traffic. The category of endangered (EN) species also includes lichen found exclusively in the “Stone Circles” reserve, i.e. *Lecanora rupicola*, *Lecidea lapicida* and *Protoparmelia badia* (Lipnicki, 2003).

2.10.4. “Kęgi Kamienne” (Stone Circles) Archaeological and Nature Exhibition in Odry

The exhibition is set up to accompany the well-known stone circles reserve and is designed as a two-part exposition. One part shows the most valuable archaeological artefacts found during the excavations (pottery, jewellery, utensils and tools) presenting the material and spiritual culture of the Goths. It encompasses a cemetery mock-up, visual presentation charts and reconstructed graves. The nature part shows many valuable lichen species found in the reserve and in Tuchola Forest (80 species were identified in the reserve, some of which are known in Poland only from their locality in Odry) as well as the most interesting plant communities typical of the Tuchola Forest (<http://chojnicemuzeum.pl/?ekspozycja-archeologiczno-przyrodnicza-kregi-kamienne-w-odrach,54>).

2.11. Active Protection of peat bogs and forest restoration in Staniszewskie Błoto Reserve

2.11.1. Detailed Description of the Natural Reserve*

Staniszewskie Błoto – a forest and mire nature reserve – is located in the Kashubian Lakeland, in the central part of the Staniszewo Upland (Wysoczyzna Staniszevska) and in the Mirachowo Forest (Figs 1 and 2). It is part of the Kashubian Landscape Park which protects the central part

* The authors of the book are grateful to Professor Jacek Herbich from the University of Gdańsk for the information on the history and the concept of protection of the “Bielawskie Błoto” nature reserve and the method of its implementation and the observed ecological effects.

of the Kashubian Lakeland. It is also contained in two areas of the Natura 2000 network: Special Area of Conservation PLH220030 Staniszewskie Błoto, and Special Protection Area PLB220008 Mirachowo Forest.

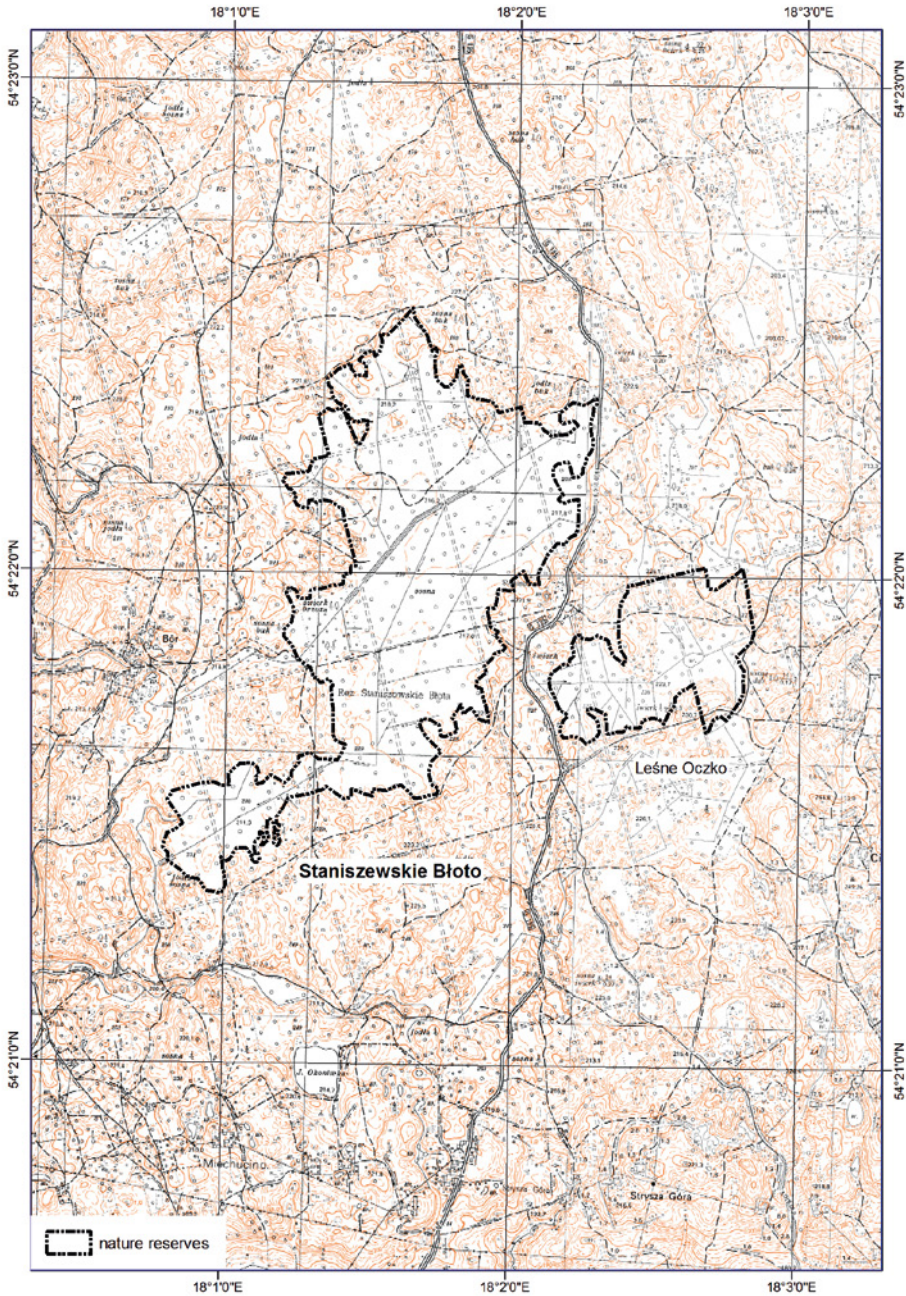


Figure 1. Location of the „Staniszewskie Błoto” nature reserve on the topographic map

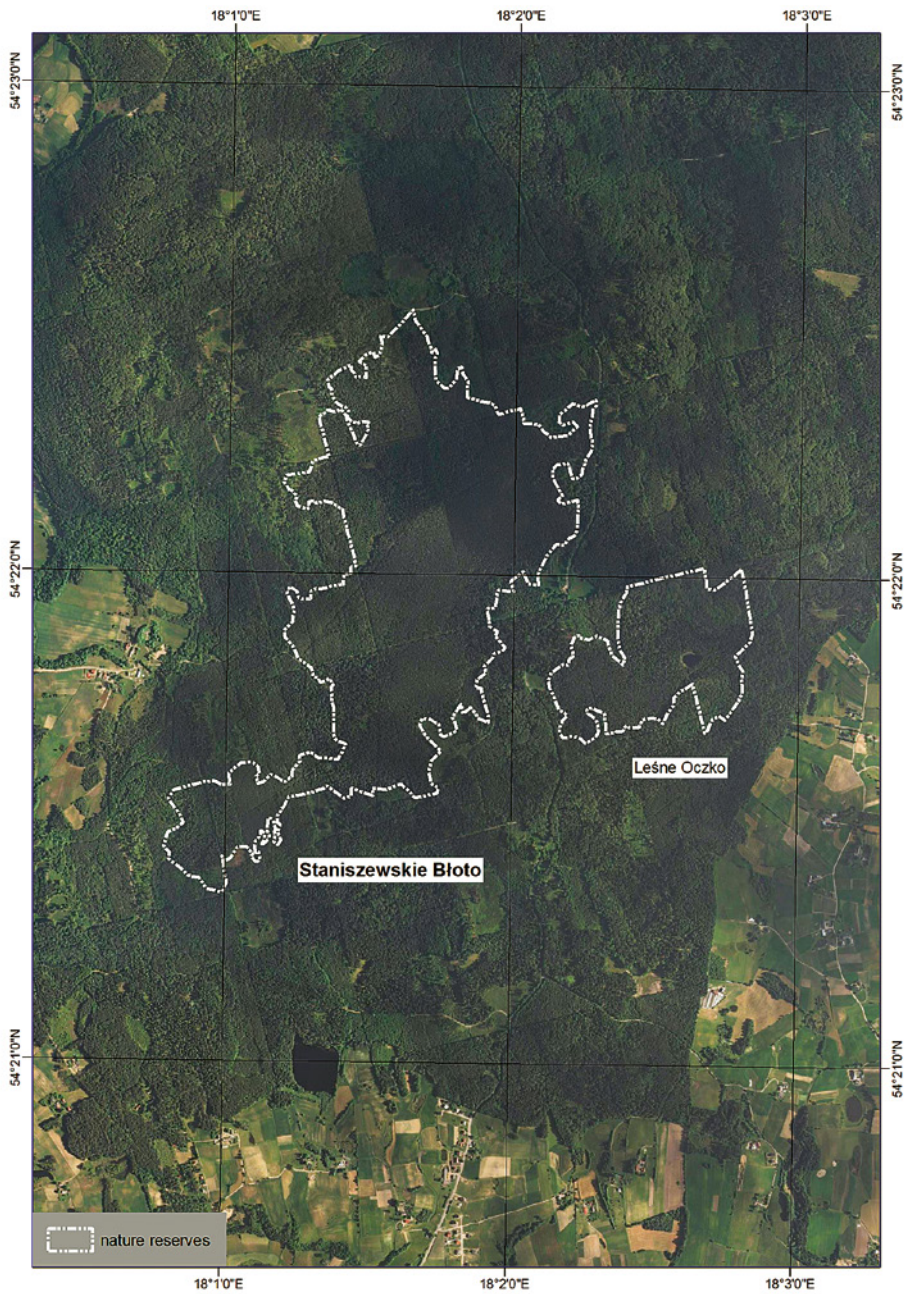


Figure 2. Location of the „Staniszewskie Błoto” nature reserve on the orthophotomap



Figure 3. Birch bog forest *Vaccinio uliginosi-Betuletum* in the “Staniszewskie Błoto” nature reserve (photo by Jacek Herbich)

The peat-bog reserve was established in 1916, endorsed in 1962 and expanded to its present area of 130.41 ha in 1989. Originally, it protected a treeless raised peat bog and the most important regional wood grouse’s (*Tetrao urogallus*) courting ground. As a result of drainage work conducted for about 150 years, the bog underwent dramatic changes.

Staniszewskie Błoto is located in a large depression within a ground moraine in the central part of the Kashubian Lakeland. Peat deposit at

the deepest point exceeds a depth of 11 m and it is a raised *Eriophorum* and *Sphagnum* peat bog along the whole profile.

The largest area is occupied by swamp pine forest *Vaccinio uliginosi-Pinetum*, built of low-grade pine, and two typical species: *Ledum palustre* and *Vaccinium uliginosum*, as well as a significant contribution of raised peat-bog vascular plants and *Sphagnum* species. Swamp birch forest grows along the peat-bog margins on dry transitional peat. The tree layer consists of birch and pine; *Lycopodium annotinum* and *Dryopteris dilatata* occur in the groundcover. The forest differs from swamp coniferous forest in the absence of species typical of raised peat bogs and the presence of plants with higher trophic requirements. Both associations correspond to Natura 2000 habitat *91D0, i.e. swamp forest (Figs 3 and 4). A moss fen of *Sphagnetum magellanicum* occupies a very small area on the top of the dome and is formed by raised-bog vascular plants and *Sphagnum* species – it is a Natura 2000 habitat *7110, i.e. raised (active) bogs (Fig. 5). Large areas of the swamp birch habitat is covered with monocultures of planted spruce. Its mineral margins are occupied by natural forests with the dominance of beech in the tree layer (9190 – acidophilous oak woods and stands of planted pine and spruce).



Figure 4. Pine bog forest *Vaccinio uliginosi-Pinetum* in the "Staniszewskie Błoto" nature reserve (photo by Jacek Herbich)

The analysis of literature, archival topographic maps and photographs, and the results of drilling show that most of the bog was treeless in the last century, and so were large parts of the central dome as late as in the 1930s. In 1835, a drainage plan was prepared for the site whose implementation probably followed soon after. As a consequence, forest communities which originally could grow on the dome slopes and its shallow peaty margins, began to expand. Consequently, non-forest moss vegetation already dominated by heather in the 1930s, but still with a significant contribution of raised peat bog plants, was gradually replaced by swamp pine forest, and its lagg zone by swamp birch wood. It should be emphasized that the composition and structure of these communities were almost natural although their development was caused by anthropogenic factors. Due to the drainage, the communities underwent major degeneration, peat subsided and declined; the rate of bog level lowering in the most desiccated areas was so fast that about 25 years ago, a significant proportion of trees growing near the main drainage ditch died due to disruption of their root systems. In the former lagg area, the peat level lowered by 50 to 70 cm. If the direction and the rate of changes had been maintained, the shallow peat deposit, a habitat of *Betuletum pubescentis* would have disappeared on the margins, while on the deposit of raised peat, *Vaccinio uliginosi-Pinetum* would have become a community with characteristics of swamp birch wood or wet coniferous forest with the dominance of *Vaccinium* genus (such trends were already observed at the site in the 1980s). However, it should be noted that negative changes in the vegetation and the threats posed by drainage were already observed in 1926 when backfilling of drainage ditches was recommended to protect the peat-bog (in the reserve established in 1916). The Directorate of State Forests agreed to do it but had never fulfilled the declaration. The issue occurred in all subsequent publications and documents, nevertheless, the ditches were regularly cleaned and deepened; the last cleaning took place in 1985 though it was banned by the provincial Nature Conservationist.

THE CONCEPT OF PEAT-BOG PROTECTION. It was formulated in the 1980s and was based on the following assumptions:

- to prevent any drainage as a pre-condition for any further forms of protection;
- to take into consideration hydrological factors as a starting point for vegetation protection;

— to expand the reserve to the peat-bog limits, including its mineral margin to protect the entire hydrological system; the reserve was expanded in 1989 from 44.58 ha to its current area of 130.41 ha.

The main problem consisted in selecting a conservation strategy and its priorities based on the assessment of current and historical status of vegetation, analysis of current and anticipated changes in the vegetation and habitats, assessment of natural values of the existing phytocoenoses and likelihood of success in rehabilitation of individual phytocoenoses and biotopes. The work at this stage produced the following results:

- full reconstruction of the pristine habitat was impossible due to irreversible changes that occurred in the peat bog;
- a significant part of forest phytocoenoses, although developed as a result of artificial drainage, demonstrated the highest natural values;
- it was very risky to attempt full restoration of water conditions in some phytocoenoses, because the existing valuable phytocoenoses could be irreversibly destroyed;
- natural values of some contemporary communities were higher than the phytocoenoses they replaced despite the natural character of the latter; the comparison refers to the contemporary swamp birch wood with swathes of *Lycopodium annotinum* with willow thickets that most likely occupied the non-drained lagg zone. Any attempts to restore the original water conditions would lead to complete destruction of this form of birch wood.

The analysis of all those premises led to the conclusion that from a theoretical and practical point of view, it seemed most advantageous to restore water and phytocoenotic conditions to the status prevailing at the site several decades ago. The restoration should lead to:

- prevention of peat deposit subsidence and further decline of peat over the entire peat-bog;
- restoration of the open bog only on the top of the dome which was forested as the last and whose habitats were transformed to the least extent;
- conservation of swamp coniferous forest along the margins and on the slopes of the raised dome, and swamp birch wood with *Lycopodium annotinum* in the former lagg zone;
- prevention of degeneration of these communities, and restoration of their status from before ca. 50 years.

The starting point for all proposed measures was a gradual formation of a new water balance in the peat-bog through a grid

of damming barriers on drainage ditches; the grid had to meet the following objectives:

- blocking of the water outflow from the dome;
- restoration of natural water retention within the dome;
- initial reduction, and then maintenance of a monitored water outflow from the former lagg zone.

IMPLEMENTATION OF ACTIVE PROTECTION. The first five gates were created in 1988–89. Their impact on adjacent segments of the mire was so positive that in 2007, under the LIFE Nature programme, 37 additional barriers were built (Fig. 6). Changes in the vegetation in the red moss fen on the top of the dome within the stable area, located in a short distance from the barrier placed on the main drainage ditch in 1988, are presented in the enclosed table. The major decrease in the heather and lichen cover is observed with an increased role of cranberries and other raised peat-bog plants. The role of bog mosses: *Sphagnum cuspidatum* and *S. fallax* (requiring inundation) significantly increased. The regeneration of raised peat-bog plants, accompanied by an essential decrease in the role of plants that indicate bog desiccation (especially *Vaccinum myrtillus*), was also observed in the swamp forest.



Figure 5. *Sphagnetum magellanici* patch on the top of the bog cupola after the water table rise (photo by Jacek Herbich)



Figure 6. Gate in the “Staniszewskie Błoto” nature reserve built in 2007 under the project of peat bog active protection (photo by Jacek Herbich)

The above concept of protection and its implementation cover: 1) peat deposits in the Staniszewskie Błoto reserve; 2) ecosystems of open moss fens; 3) part of phytocoenoses of swamp coniferous forest and swamp birch woods demonstrating the features of natural communities regardless of their origin; 4) phytocoenoses of beech and oak mixed forest; 5) accumulation of organic matter and peat sedimentation in peat-forming phytocoenoses; 6) regeneration of peat vegetation; 7) plant populations with species of particular concern (6 species of vascular plants, 10 species of brown moss and 15 *Sphagnum* species, e.g. *Andromeda polifolia*, *Drosera rotundifolia*, *Erica tetralix*, *Baeothryon caespitosum* ssp. *germanicum*, *Lycopodium annotinum*, *Sphagnum fuscum*, *S. tenellum*, *S. wulfianum*); 8) lichen populations with 25 species (*Absconditella pauxilla*, *Arthonia vinosa*, *Biatora efflorescens*, *Biatora turgidula*, *Cetraria sepincola*, *Cladonia arbuscula* subsp. *squarrosa*, *C. portentosa*, *C. stygia*, *Evernia prunastri*, *Fellhaneropsis myrtillicola*, *Graphis scripta*, *Hypogymnia farinacea*, *Imschaugia aleurites*, *Melanelixia fuliginosa*, *Micarea melaena*, *Micarea misella*, *Ochrolechia alboflavescens*, *Ochrolechia androgyna* s.l., *Opegrapha* cf. *vulgata*, *Parmelia saxatilis*, *Parmeliopsis ambigua*, *Peltigera membranacea*, *Platismatia glauca*, *Pseudevernia furfuracea*, and *Usnea*

hirta); 9) populations and nesting grounds of 45 strictly protected bird species, 8 species from the Polish Red List, 2 species from the Polish Red Book, 3 species from Annex I to the Bird Directive, 5 species from Annex IV of the Habitat Directive, 46 species from Annexes II and III to the Bern Convention, 8 species included in the Bonn Convention, in particular tyrphobiont invertebrates – stenotopic organisms typical of waters of *Sphagnum* peat bogs, especially caddisfly *Haganella clathrata*, diving beetles: *Hydroporus gyllenhalli* and *H. morio*; birds: *Aegolius funereus* and *Caprimulgus europaeus*; and forest beetle of the longicorn family: *Oxymirus cursor*.

Some lichens reported from the Staniszewskie Błoto reserve are very rare not only on a regional scale but also in Poland. One of them – *Absconditella pauxilla* is known in Poland only from the Staniszewskie Błoto and the nearby Kurze Grzędy natural reserve. Another valuable species occurring on the raised peat bogs and in well-preserved swamp pine forests is *Cladonia stygia* surviving in the reserve for decades. Some species, like *Arthonia vinosa*, *Biatora turgidula* and *Fellhaneropsis myrtillicola*, are considered to be indicators of forests with long-term ecological continuity.

In 1997, the parasitic bolete (*Pseudoboletus parasiticus*, previously known as *Xerocomus parasiticus*) was found in the reserve; the species is listed on the Polish Red List of Fungi. Rare invertebrate species include also: *Diplocephalus dentatus*, *Formica picea* and *Stenus lustrator*. One of the two sites of the biting midge *Palpomyia nigripes* is located in this reserve. The reduced diversity of the forest stands is a cause of species-poor forest fauna, which is represented by e.g. *Dendroctonus micans*.

2.11.2. Natura 2000 Special Area of Conservation PLH22027, Staniszewskie Błoto

The area covers a fragment of the Mirachowo Forest that surrounds the Staniszewskie Błota mire and Lake Leśne Oczko. It has an area of 917.17 ha. Characteristics of the area are presented below according to the corresponding entry in the Natura 2000 network data base of the Ministry of the Environment.

The peat bog is heavily drained but some areas preserved their high natural values. The dominant peat bog communities are: coniferous forest and swamp birch wood. Acidophilus oak forests occur in the neighbourhood. The remaining area is dominated by acidophilus beech forests.

Staniszewskie Błoto protects one of the largest areas of swamp coniferous forests and birch woods in the Pomerania Province with an abundant population of *Lycopodium annotinum*. Dystrophic lake Leśne Oczko also represents a significant natural value; it is surrounded by bog vegetation with a classic zonal system. Six habitat types listed in Annex I to Council Directive 92/43/EEC, were identified at this site; they cover about 90% of the site's area. The refugium is one of the southernmost locality of *Erica tetralix*, *Goodyera repens* and rare species of *Sphagnum* and lichens.

The above habitats are ecological systems with the following codes: 3160 – natural dystrophic lakes and ponds, 0.92 ha; 7110 – active raised bogs, 0.0 ha; 7120 – degraded raised bogs still capable of natural and stimulated regeneration, 4.59 ha; 7140 – transition mires and quaking bogs (mostly with *Scheuchzerio-Caricetea nigrae* vegetation), 0.92 ha; 7150 – depressions on peat substrates of the *Rhynchosporion* alliance, 0.92 ha; 9110 – acidophilous beech forests, 458.60 ha; 91D0 – bog woodland, 119.88 ha.

The following species are covered by Article 4 of Directive 2009/147/EC and listed in Annex II to Directive 92/43/EEC: shelled river mussel *Unio crassus* – a freshwater mussel species of the *Unioidea* family and the European otter *Lutra* of the *Mustelidae* predator family.

2.11.3. Natura 2000 Special Area of Protection PLH22027, Mirachowo Forest

The refuge of Mirachowo Forest covers an area of 8,232.38 ha. It covers a forest complex located in the central part of the Kashubian Lakeland on the Mirachowo Upland. It is the largest compact forest in the Kashubian Lakeland. In the central and southern part of the refuge, there are only few forests because they were previously cut down and converted into arable land.

The refuge covers also the central and the highest part of the moraine lakeland. Its landscape is distinguished by extremely mosaic land relief with typical deeply carved channels of lakes, valleys of small streams and steep slopes inclining towards the river valleys. This is also a watershed area between two large coastal rivers, Lupawa and Bukowina, and a place of their origin. In the northern part, a deep latitudinal trough is located, with Lake Lubygość and the lake complex Potęgowo. There are also many small lakes and dystrophic ponds surrounded by peat bogs, pine forests and swamp birch woods.

The habitats of mixed fresh, mixed fresh coniferous, swamp and fresh forests dominate in this area. Scots pine dominates in forest stands, representing about 58% of all trees. The contribution of spruce, beech and birch are: 17, 18 and 3%, respectively. The trees are mostly young. The oldest parts are legally protected as nature reserves. Human settlement is well developed in non-forest areas.

There are eight nature reserves, Kashubian Landscape Park and Gowidlino Protected Landscape Area within this refuge.

At least 19 species listed in Annex I of the Birds Directive, including 14 breeding species, were recorded in the refuge of the Mirachowo Forests. The population size of one of these species, i.e. *Aegolius funereus*, meets the criteria for the designation of bird refuges introduced by BirdLife International. Moreover, four species were included on the list of endangered birds in the Polish Red Book of Animals.

The species listed in Annex I of the Birds Directive include: *Aegolius funereus*, *Alcedo atthis*, *Bucephala clangula*, *Caprimulgus europaeus*, *Ciconia ciconia*, *Ciconia nigra*, *Circus aeruginosus*, *Crex crex*, *Dendrocopos medius*, *Dryocopus martius*, *Ficedula parva*, *Grus grus*, *Lanius collurio*, *Lullula arborea*, *Milvus milvus*, *Pandion haliaetus*, *Pernis aprivorus*, *Porzana porzana*, *Sterna hirundo* and *Tringa glareola*.

2.12. Active Mire Protection and Wet Heathland Development in Bielawa Nature Reserve

2.12.1. Nature Reserve Description*

Bielawskie Błota (Bielawa Wetlands), or referred to as Bielawa, is a remnant of one of the largest Baltic mires in Poland whose landscape and nature are entirely unique across Poland and Europe. The Bielawa nature reserve was established based on ordinance no. 8/2005 of 30 May 2005 by the Pomerania Governor (Dz.U. of the Pomerania Province no. 59, item 1110. It was formed by consolidating three smaller nature reserves: "Woskownica Bielawskiego Błota" and "Moroszka

* The authors of the book are grateful to Professor Maria Herbichowa from the University of Gdańsk for the information on the history and the concept of protection of the "Bielawa" nature reserve and the method of its implementation and monitoring of the ecological effects.

Bielawskiego Błota” established by the directive of the Minister of Forestry and Timber Processing of 4 April 1977 (M.P.Dz.U. of the Polish People’s Republic no. 10, item 64), and “Bielawa” established by ordinance no. 165/99 of November 1999 by the Pomerania Governor (Dz.U. of the Pomerania Province no. 122 item 1075). The first reserve called “Bielawa” was established in 1999 with an area of 680.2 ha. After the consolidation, the entire protected site under the name of “Bielawa” increased to 721.41 ha. The reserve owes its Polish name to swathes of white cotton-like seed heads of common and sheathed cotton sedges (*Eriophorum angustifolium* and *E. vaginatum* L, respectively) that used to cover the entire surface of the bog (npk.org.pl/formy-ochrony-przyrody-1/rezerwaty-przyrody-3/bielawa/).

According to Kondracki’s geomorphological division of Poland (2001), the reserve is located in the Kashubian Coastland Mesoregion, at the eastern end of the Slovincian (Słowiński) Coast which is contained in the South Baltic Coast subprovince. It is situated in the Pomerania Province between the towns of Jastrzębia Góra, Sławoszyn and Parszkowo; at a distance of 1.6–5.8 km from the Baltic coastline (Figs 1 and 2), and about 30 km from the city of Gdańsk.

The reserve preserves the remnants of an old mire complex of Bielawskie Błota whose original area was about 2,000 ha. Its central part is occupied by the Baltic type of raised peat bogs surrounded by transitional peat bogs and fens with some small mineral uplifts. The Bielawa reserve is also contained in two Natura 2000 sites established under the Habitats (Bielawa and Bory Bażynowe **Special Area of Conservation** PLH220063) and Birds Directives (Bielawskie Błota **Special Protection Area** PLB220010).

Bielawskie Błota is one of about 70 Baltic raised bogs reported from Poland. It has the form of an unevenly raised dome. The central part is flat, highly waterlogged, open (treeless) and covered with moss vegetation, while the slopes are slightly less marshy, with some trees, mostly pine. In Poland, the most common domes range from 100 to 200 ha in size. The formation of raised dome bogs is strictly associated with the prevailing climatic conditions, with their optimal development occurring in moist and cool climate. Therefore, their distribution in Poland is irregular and restricted to northern regions of the country (mainly Pomerania) which also delineate the southernmost limit of their European range. None of the bog sites preserved the entirely natural conditions; more than 50% were completely destroyed, and only 24 sites are likely to survive in Pomerania provided their conservation is efficient.

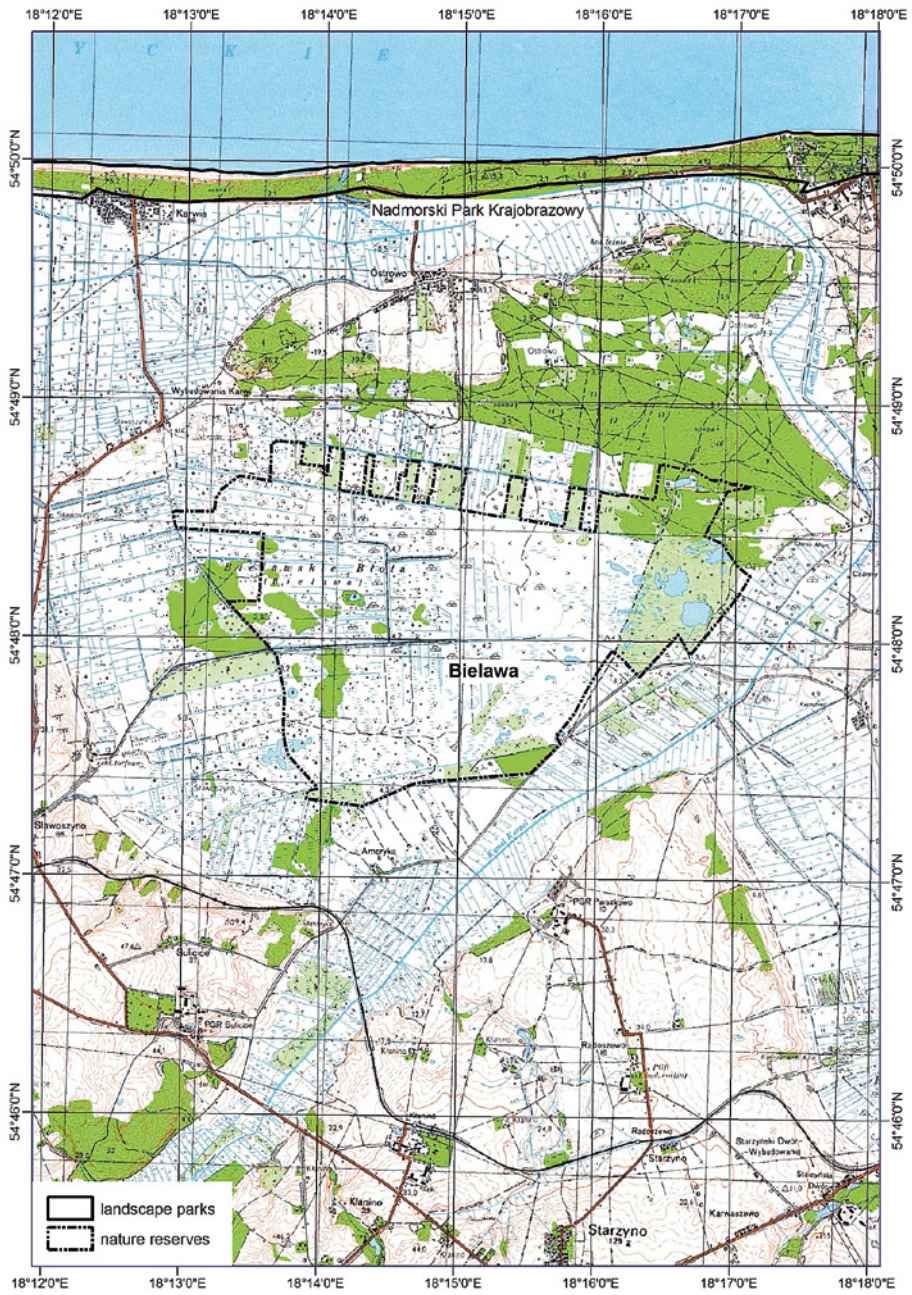


Figure 1. Location of the „Bielawa” nature reserve on the topographic map

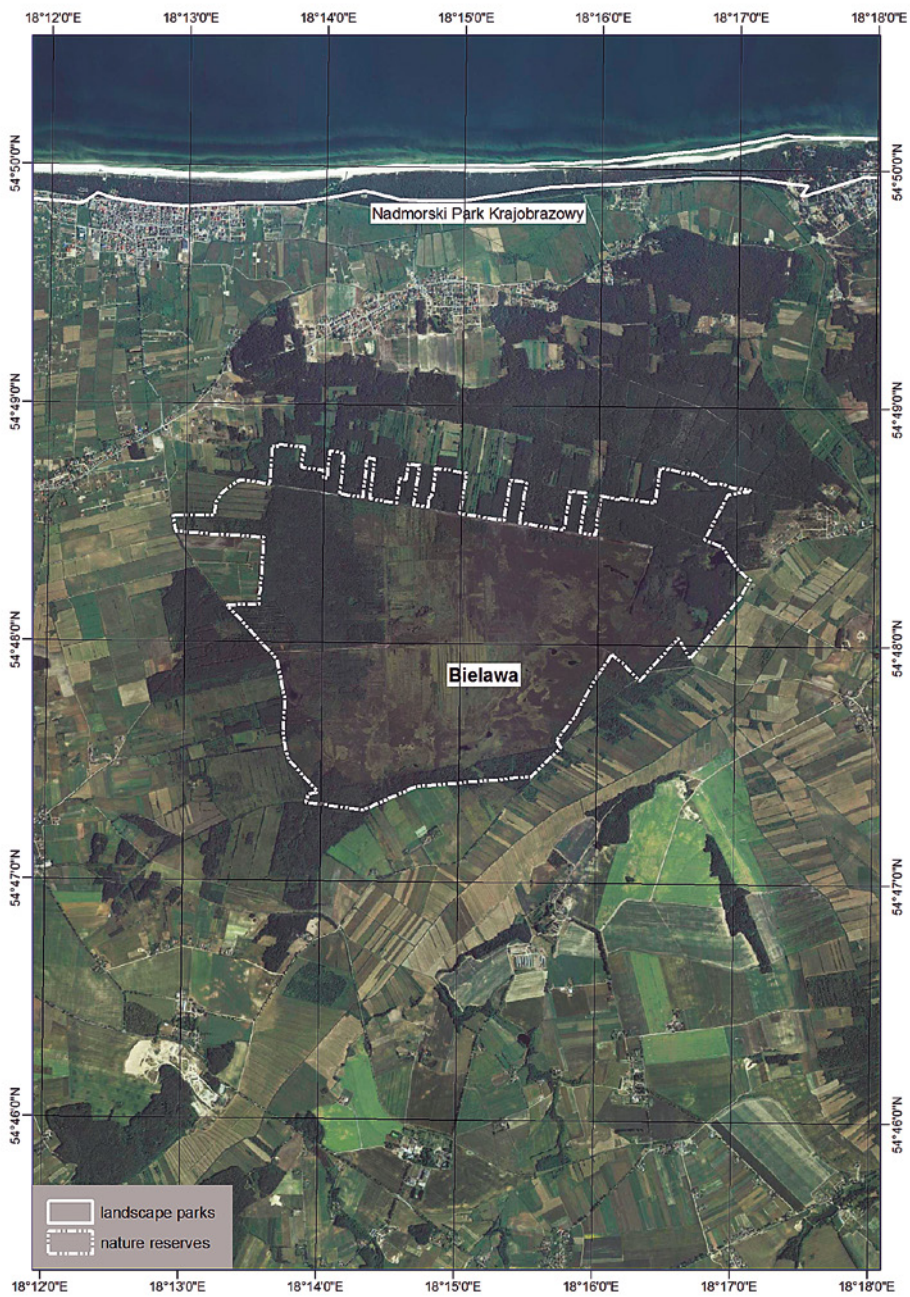


Figure 2. Location of the „Bielawa” nature reserve on the orthophotomap

The Bielawa reserve is situated approximately 3 km from the Baltic coast, in an large, shallow and originally drainless depression. The development of the bog was initiated by the process of paludification on mineral substrates composed of fine-grained leached sand. Peat started to accumulate around 6,900 years ago. During the first stage, a layer of highly decomposed transitional peat developed, which was followed by the development of a raised peat bog – *Eriophorum* and *Sphagnum* – with *Sphagnum fuscum* as the main component. The peat deposit is shallow; its total thickness was slightly above 2 m, including the layer of raised peat – 1.5 m.

Until the mid-19th century, the peat dome of Bielawskie Błota preserved the natural conditions, i.e. it was supplied by rainwater whose excess reached the adjacent wetlands. The construction of the drainage network was started in the second half of the 19th century to be expanded until the 1970s. As a consequence of the drainage development, the water table lowered in Bielawskie Błota, gradually improving the land use. Peat was extracted throughout the raised bog; farm animals were grazed and arable fields were established on organic and mineral margins, while fen margins were mostly used as meadows. Such extensive forms of land management were still implemented in the mid-20th century. The landscape of the peat bog and its organic and mineral peripheries were still almost entirely open. At the turn of the 1960s and 1970s, the last and particularly intensive drainage work was carried out, which was followed by planned afforestation of mineral habitats. Peat mining ended in the late 1970s. Intensive succession of pine and birch started on the remaining peat deposits, and both species began to encroach on the adjacent heathlands.

The efforts to protect Bielawskie Błota were resumed in the early 1970s. They were related to initiatives undertaken in the 1920s and the 1950s, which resulted in the establishment of two small floristic reserves in 1977, surrounded by areas subject to further intensive degradation.

The entire area of the present nature reserve included a spatial complex of strongly transformed habitats and rapidly changing plant communities at the time of its establishment in 1999. A mosaic of mire vegetation occurred in post peat-excitation pits, while dry levees were overgrown with trees. The following types of vegetation occurred outside the bog: 1 – spontaneously developed compact young stands of birch and pine; 2 – heaths gradually overgrown with trees; 3 – pine monocultures that replaced former heaths; 4 – spatial complex of wet heaths and periodically flooded depressions with aggregations of single mire

species; 5 – degenerated swamp forests, and 6 – two small dystrophic lakes and intermittent meso-oligotrophic ponds with wetland vegetation.

The following wildlife habitats are protected in the reserve under the Natura 2000 network: 2180 – mixed and coniferous forests on the dunes, 3160 – natural dystrophic lakes and ponds; 4010 – Northern Atlantic wet heaths with *Erica tetralix*, 4030 – European dry heaths; 7120 – Degraded raised bogs still capable of natural or stimulated regeneration, 7140 – transition mires and quaking bogs; *91D0 – bog woodland. None of the above habitats is currently in its optimal condition with degraded raised bogs, wet heathland and bog woodland occupying the largest area.

Despite profound changes in the habitats and vegetation cover, the reserve is important to the conservation of floristic and faunal resources. Over 8% of its current vascular flora is represented by protected species from the red lists and books. The most valuable species include: *Rubus chamaemorus*, *Erica tetralix* (Fig. 3), *Sparganium angustifolium*, *Myrica gale*, *Baeothryon cespitosum* subsp. *germanicum* and subsp. *austriacum*. The group of mosses is represented by: *Sphagnum molle*, *S. tenellum*, *S. compactum* and *S. papillosum*.



Figure 3. Heaths with *Calluna vulgaris* and *Erica tetralix* in the “Bielawa” nature reserve (photo by Magdalena Dąbkowska)

There are also rare, endangered and protected lichen species in the reserve. During his explorations conducted in the 1980s, Fałtynowicz (1986) observed 98 lichen species, of which 31 taxa had not been previously reported from the area. Among the lichen species reported by the author, a total of 37 lichen species are endangered and protected.

The list of lichen species compiled by Fałtynowicz for Bielawskie Błota (1986) includes species from the red lists of endangered lichens both in Poland (Cieśliński et al., 2006) and in the region of Gdańsk Pomerania (Fałtynowicz and Kukwa, 2003). There are 30 lichen species endangered in Poland found at the described site (Cieśliński et al., 2006), including 4 critically endangered (CR) species, 11 endangered (EN) and 9 vulnerable (VU) species. Particularly noteworthy are taxa that are found at the verge of extinction, such as: *Bryoria bicolor*, *Melanohalea olivacea*, *Parmelina quercina*. As many as 11 species were classified as endangered (EN), including: *Arthonia atra*, *Cladonia botrydes*, *C. incrassata*, *C. stellaris* and *Icmadophila ericetorum*.

Based on the regional red list for Gdańsk Pomerania (Fałtynowicz and Kukwa, 2003), 19 species of Bielawskie Błota are endangered in the region, including: 5 – critically endangered (CR), 3 – endangered (EN), and 11 – vulnerable (VU). For example, the above mentioned *Cladonia incrassata* is classified in Poland as (EN) but regionally is recognised as critically endangered (CR), so was *Icmadophila ericetorum*, while *Xanthoparmelia pulla* is near-threatened in Poland (NT), while in Pomerania it was classified as critically endangered (CR).

The list includes 31 protected lichen species, including 14 strictly protected and 17 partially protected (Regulation 2014). Among the protected species, the following taxa are particularly interesting: *Bryoria bicolor*, *B. crispa*, *Cladonia incrassata*, *C. stellaris*, *Melanohalea exasperata* and *M. olivacea*.

Avifauna represents particularly valuable faunal resources of the reserve. A total of 106 species of birds were identified, including 57 species nesting directly on the peat bog, and 18 nesting in its close vicinity. Particularly interesting species include: *Grus grus*, *Asio flammeus*, *Tringa glareola*, *Caprimulgus europaeus*, *Ciconia nigra* and *Aquila chrysaetos*. The reserve is a bird refugium of the European importance.

THE CONCEPT AND IMPLEMENTATION OF NATURE CONSERVATION.

The basic concept consists in active protective, covering almost the entire area of the reserve. Its strategic objective is to:

- restore and preserve a large area of open landscape in the raised bog and adjacent heathlands;
- improve the condition of all natural habitats and to restore these fragments of the reserve which currently do not have such a status. The main directions of direct conservation measures are:
 - to raise and stabilise the water level in the entire nature reserve (Fig. 4);
 - to prevent the succession of forest vegetation;
 - to amend the species composition and age structure of forest stands in forest communities.

Measures that would directly improve the water conditions were found of utmost priority. In this regard, the following methods were applied:

- construction of earthen dikes and gates in drainage ditches;
- complete backfilling of some ditches with earth;
- segmental sealing of water drainage courses by burying screens of impermeable foil in the ground (Fig. 5).



Figure 4. Small water bodies in the “Bielawa” nature reserve (photo by Magdalena Dąbkowska)

The protection measures are implemented in stages; their form and extent is adjusted to the results of hydrological monitoring conducted by

a network of automated equipment recording the condition and dynamic relations of groundwater. Hydrological monitoring is combined with the monitoring of local climate conditions.



Figure 5. Installment of screens (PCV foil) to seal the edges of the peat-bog dome (photo by Magdalena Dąbkowska)

The suppression of woody vegetation succession is accomplished by removal of birch and pine self-seedlings on the degraded raised bog (habitat 7120) and dry heathland with *Erica tetralix* (habitat 4010). Moreover, to improve the structure of phytocoenoses in wet heathland habitat, cutting of strongly developed wooded heather stems was also applied.

The improvement of species composition and structure of forest phytocoenoses consists in thinning the dense tree stands, which

would improve light conditions and consequently enable the growth of undergrowth and tree regeneration. The improvement of water conditions should be followed by an increase in the contribution of bog species, especially peat moss (*Sphagnum*) on the swamp forest habitat.

The nature conservation measures in the Bielawa reserve are accompanied by continuous observations of changes in the environment in order to adjust the conservation plan accordingly. In addition, the Coastal Landscape Park conduct fire surveillance in Bielawskie Błota. Among others, daily surveillance shifts on a fire tower (from where the entire bog can be observed) are taken daily during the summer season, i.e. periods of increased fire risk.

Conservation measures in Bielawskie Błota were financed from the Gdańsk Regional Fund for Environmental Protection and Water Management, LIFE-Nature, the National Fund for Environmental Protection and Water Management and EcoFund Foundation.

PREVIOUS RESULTS OF NATURE CONSERVATION. In terms of the water conditions improvement:

- changes in water conditions in the reserve do not occur regularly;
 - the water level in parts of the bog rises steadily;
 - outside the mire, permanent and temporary backwaters were formed;
 - in those parts of the reserve where drainage ditches reach the mineral floor, water continues to escape but the bog is periodically supplied with groundwater;
 - hydrological conditions and dynamics of changes in the water table is affected not only by hydrometeorological conditions prevailing in a given year but indirectly also by the water level in the Baltic Sea.
- Prevention of succession of trees:
- fully effective and relatively rapid effect was observed only in the backwaters formed in places where water outflow from the bog was successfully blocked (the trees died and swamp vegetation began to develop spontaneously);
 - the most economic and efficient way to reduce the expansion of birch in non-forest habitats is to remove the self-seedlings in the first year, and then remove their offshoots three times in three consecutive years;
 - once pine was removed from wet heathland, cutting of overgrown heather shoots has a positive impact on the development of *Erica tetralix* and *Baeothryon cespitosum* – a typical species of the habitat.

2.12.2. Bielawskie Błota Natura 2000 Site PLB220010

The Natura 2000 site PLB220010, which includes the “Bielawa” reserve has an area of 1,101.29 ha. The most important characteristics of the area are listed below and are based on the Natura 2000 Standard Data Form:

At least 32 bird species included in Annex I of the Birds Directive and 16 species listed in the Polish Red Book occur in the area. During the breeding season, the area is inhabited by at least 1% of the national population of wood sandpiper (*Tringa glareola*) and short-eared owl (*Asio flammeus*) (both species are listed in the Polish Red Book). During the bird flight season, the crane population occurs with a relatively high concentration. The area of Bielawskie Błota is the only breeding place of wood sandpiper in Poland. Breeding of the species is very irregular in this area, and a constant decline in the population size is observed.

The area of Bielawskie Błota and its surroundings are the refuge of waterfowl of the national importance, including the following nesting birds that are critically endangered in Europe and valuable in Gdańsk Pomerania: *Circus pygargus*, *Grus grus* (during the migration of cranes up to ca. 800 birds group together in the reserve), *Charadrius hiaticula*, *Tringa glareola*, *Streptopelia tortur*, *Asio flammeus*, *Caprimulgus europaeus*, *Jynx torquilla*, *Alauda arvensis*, *Lullula arborea*, *Anthus campestris*, *Muscicapa strata*, *Lanius collurio*, *Lanius excubitor*. The species of birds of prey that use Bielawskie Błota as their preying grounds, and probably nest in the nearby forests or in the surrounding meadows include: *Pernis apivorus*, *Milvus migrans*, *Milvus milvus*, *Haliaeetus albicilla*, *Circus aeruginosus*, *Circus cyaneus*, *Accipiter gentilis*, *Accipiter nisus*, *Buteo buteo*, *Aquila pomarina*, *Falco tinnunculus*, *Falco subbuteo*. During the spring migration, large flocks (about 30 birds) of red-footed falcons *Falco vespertinus* preying on dragonflies can be observed on the treeless heathlands, as well as single, young golden eagles *Aquila chrysaetos* arriving here regularly (obszary.natura2000.org.pl/index).

In addition to the above-mentioned bird species, the list of birds found in the reserve or its surroundings includes: *Aegolius funereus*, *Ardea purpurea*, *Botanus stellaris*, *Calidris alpina*, *Ciconia ciconia*, *Crex crex*, *Cygnus columbianus bewickii*, *Cygnus cygnus*, *Dryocopus martius*, *Falco colombarius*, *Pandion haliaetus*, *Philomachus pugnax*, *Pluvialis apricaria*, *Porzana porzana* and *Sylvia nisoria*.

2.12.3. Bielawa and Bory Bażynowe Natura 2000 Site PLH220063

The Bielawa and Bory Bażynowe Natura 2000 Site PLH220063 has an area of 1,341.51 ha. The most important characteristics of the area based on the Natura 2000 Standard Data Form are presented below.

Vascular flora of Bielawskie Błota encompasses 323 species, including 15 species of strictly protected plants, 5 species listed on the red list of endangered plants in Poland, and 21 species included on the Red List of vascular flora of Gdańsk Pomerania. One of the characteristic features of Bielawskie Błota is the coexistence of species of the Atlantic (14 species) and Boreal (13 species) range.

The large bog dome (almost 600 ha), degraded by land drainage carried out in the 1970s and fires in the 1980s and 1990s, is now dominated by wet heaths with cross-leaved heath (*Erica tetralix*) (Nature 2000 habitat code 4010): almost 17% of the total area (obszary.natura2000.org.pl/index).

Despite the fact that the reserve area was heavily damaged by long-term mining of the peat deposit, the associated drainage, and recurring extensive fires, it is still valuable and worth natural restoration.

The following Natura 2000 habitats occur in the nature reserve: 2180 – mixed and coniferous forests on coastal dunes, 59.83 ha; 3130 – banks or dried up bottoms of lakes with the communities of *Littorelletea*, *Isoëto Nanojuncetea*, 0.67 ha; 3160 – natural dystrophic lakes and ponds, 35.42 ha; 4010 – Northern Atlantic wet heaths with *Erica tetralix*, 163.66 ha; 4030 – European dry heaths (*Calluno-Genistion*, *Pohlio-Callunion*, *Calluno-Arctostaphyilion*), 3.09 ha; 6410 – *Molinia* wet quaking meadows (*Molinion*), 14.76 ha; 7120 – degraded raised bogs capable of natural and stimulated regeneration, 147.03 ha; 7140 – transition mires and quaking bogs (mostly with *Scheuchzerio-Caricetea nigrae* vegetation), 69.22 ha; 7150 – depressions on peat substrates of the *Rhynchosporion*, 0.27 ha; 9160 – Sub-Atlantic oak-hornbeam forests (*Stellario-Carpinetum*), 5.50 ha; 9190 – Pomeranian acidophilous birch and oak woods (*Betulo-Quercetum*), 30.32 ha; 91D0 – bog woodland, 106.65 ha; and 91E0 – alluvial forests with willows, poplars, alders and common ash (*Salicetum albae*, *Populetum albae*, *Alnenion glutinoso-incanae*, alder forests on percolating mires), 2.01 ha (obszary.natura2000.org.pl/index).

The following most important species occur in Bielawskie Błota: northern crested newt, *Triturus cristatus* (included in the Habitats Directive, Annex II) and valuable aquatic invertebrates: large white-faced darter dragonfly *Leucorrhinia pectoralis* (Habitats Directive, Annex II), *L. albifrons* (Bern Convention), *L. dubia* (umbrella species for mires), *Aeschna subarctica elisabethae* (trylobiton, Polish Red List), *Aeschna juncea* (Polish Red List), hemipterus *Notonecta lutea* (umbrella species for mires), the largest Polish Hydrachnidiaae – *Hydrachna geographica* (very rare in Poland). Small vertebrates are represented by *Triturus cristatus* and *Neomys anomalus*, the latter is included in the Polish Red Book of Animals.

Bielawskie Błota is an avian refuge of national importance K 05. There are at least 9 species of birds listed in Annex I of the Birds Directive, and 4 species from the Polish Red Book. During the breeding season, the area is inhabited by populations of wood sandpiper and short-eared owl (both species are listed in the Polish Red Book), as well as a large population of crane.

3. Conclusions

Data on heaths presented in the ecological literature and observations to be made along the proposed natural-historical route indicate that Polish heaths are extensively and thoroughly researched, and their phytosociological classification has been completed. A number of lower-rank units were distinguished within the main heath types, i.e. wet and dry heaths, as well as within the main associations – subassociations, variants and subvariants. Furthermore, syndynamics relationships were determined between some of these units.

Descriptions presented in the available literature and direct observations made in the field lead to the conclusion that heaths in Poland are no longer only afforested as wastelands or maintained by the military use. In the last twenty years, heaths have also been created and maintained to increase and protect the biodiversity and heterogeneity of the historical landscape as well as to preserve the cultural traditions. This is reflected in the recently created nature reserves (a few hundred hectares) and several thousand hectares of Natura 2000 heath areas. Effective conservation plans have been prepared for these areas. In the case of areas used in the recent past by military units, projects aimed at restoring their environmental values are implemented, with the possibility to use the heath areas in the economic development of regions, especially in the tourism and recreation sector. These projects are efficiently and quickly implemented over a large area.

Observations that can be made at different points of the proposed route show that honey is the main product offered by heath ecosystem services. Heaths are not used for sheep grazing, although this has been a common practice in Pomerania. Sheep grazing of heaths could be an effective form of their active protection as it brings good effects in other types of plant communities, often occurring next to heaths. The growing

interest of farmers in sheep industry, enhanced by the developing market for products of sheep breeding, may support the implementation of grazing as a form of land use and nature conservation on heaths. This form of active conservation could be implemented alongside with removal of wilding trees carried out under the supervision of State Forests. Perhaps in the distant future, monitored fires of heaths will also become one of the active protection methods. They were recently carried out in another region of the country to identify their environmental effect.

The Regional Directorates for Environmental Protection (RDOŚ) is an authority responsible for the management in newly created heath reserves. Effective management and protection, while meeting all ecosystem services attributed to heaths, require good cooperation of RDOŚ with State Forests, other economic entities, both state-owned and private, as well as NGOs.

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