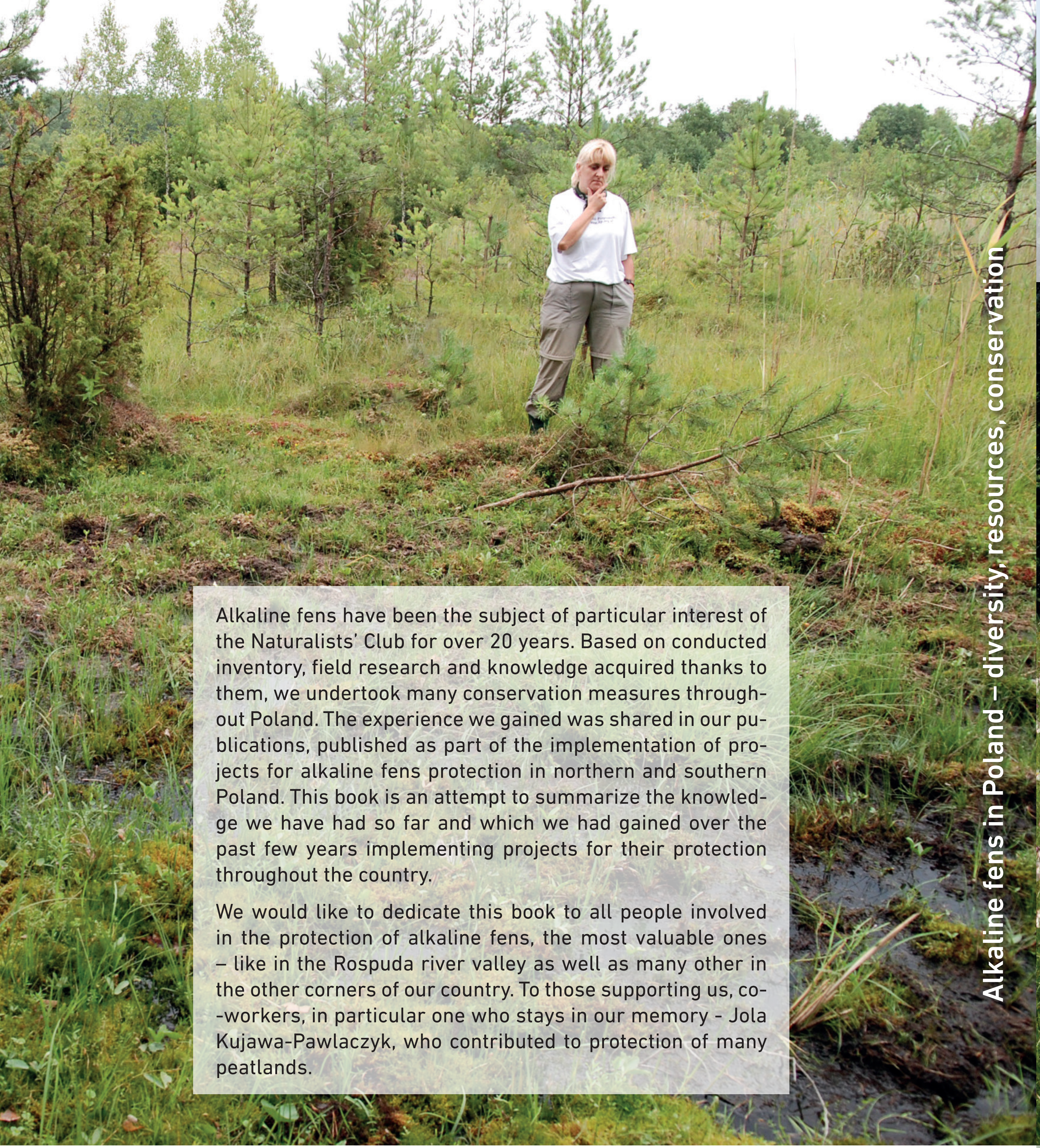

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We would like to dedicate this book to all people involved in the protection of alkaline fens, the most valuable ones – like in the Rospuda river valley as well as many other in the other corners of our country. To those supporting us, co-workers, in particular one who stays in our memory - Jola Kujawa-Pawlaczyk, who contributed to protection of many peatlands.

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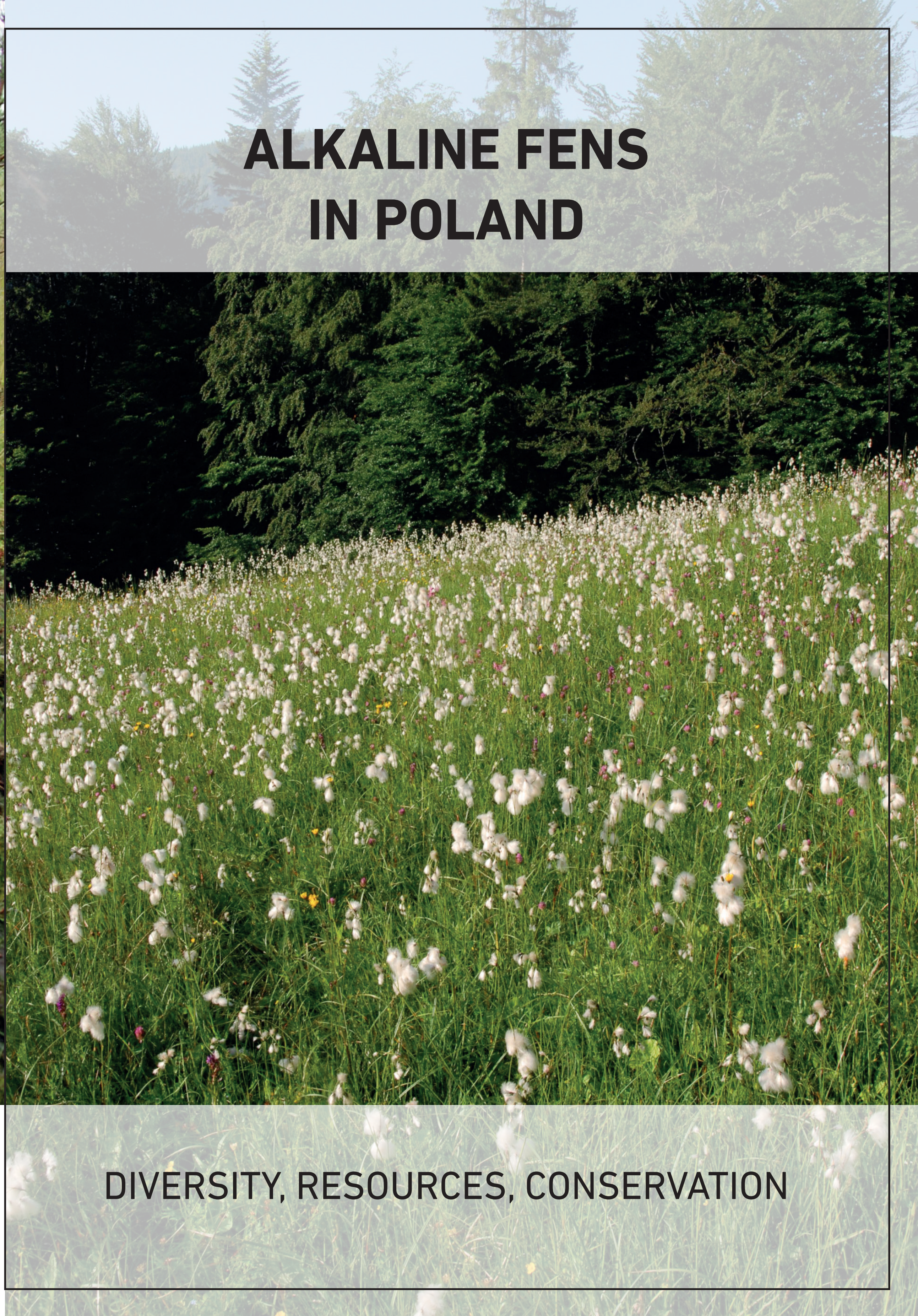
Alkaline fens in Poland – diversity, resources, conservation

# ALKALINE FENS IN POLAND

## DIVERSITY, RESOURCES, CONSERVATION



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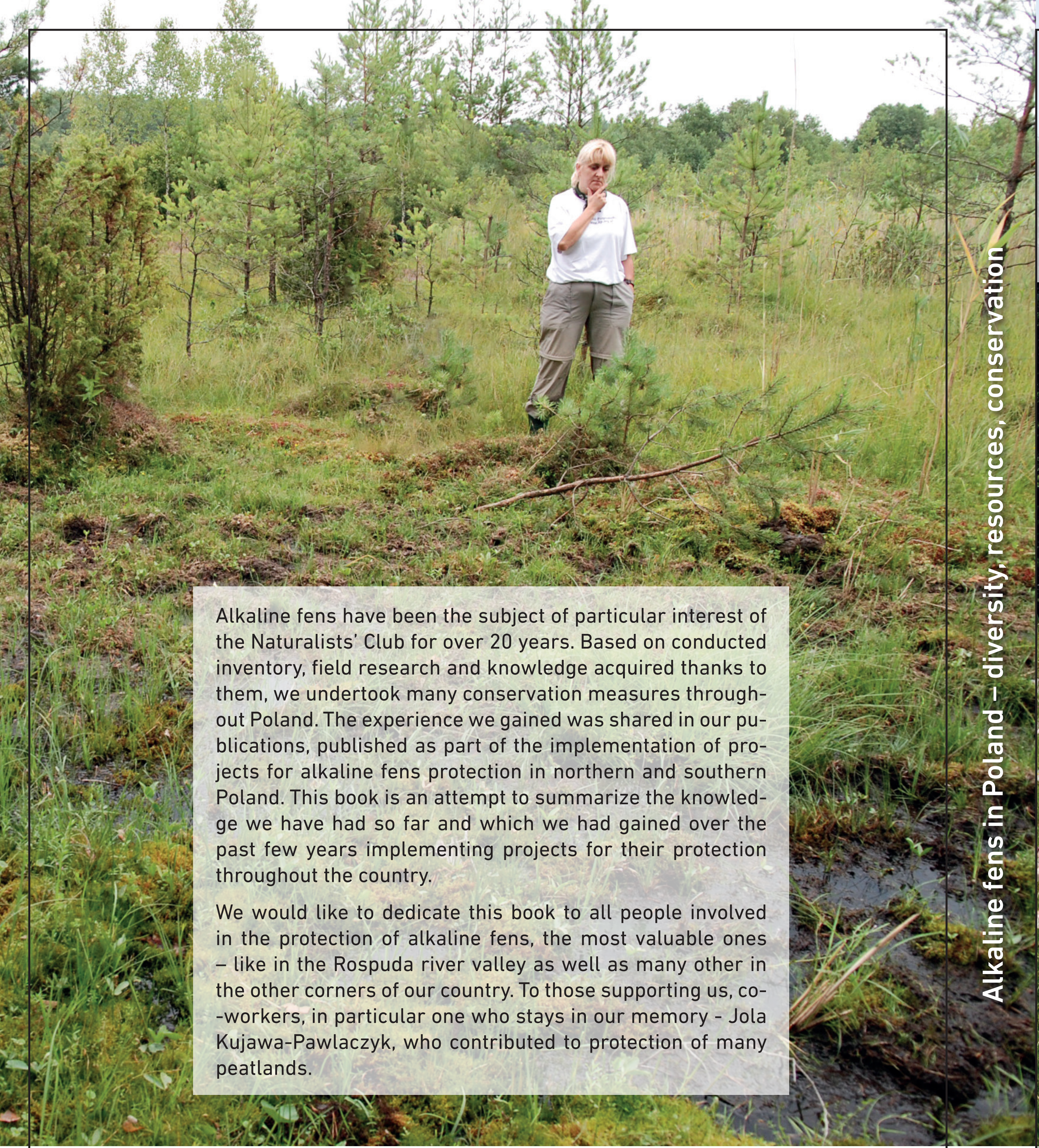

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# Alkaline fens in Poland

## – diversity, resources, conservation

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# 1. CHARACTERISTICS OF THE HABITAT TYPE

*Lesław Wołejko, Robert Stańko, Paweł Pawlaczyk*

The subject of this publication is an attempt to summarize the current knowledge about alkaline fens present in Poland compared to their situation in Europe, with particular reference to the area of the European Union. This is due to the fact that this unique, valuable and rapidly disappearing wetland ecosystem is the subject of protection under EU law (implemented in the Polish legal system). It is the so-called natural habitat 'alkaline fens', marked in the EU Habitats Directive with code 7230.

## 1.1. Definition of natural habitat 7230

Alkaline fens in the intention of the authors of the Habitat Directive, are identified (Moss & Davies 2002, European Commission 2013) by unit 54.2 in the Palearctic classification of natural habitats (Devilliers & Devilliers-Terschuren 1996), currently identical with unit D4.1 in the so-called EUNIS classification (Davies et al. 2004, European Environmental Agency 2017), matching the term *"rich fens"* which is known in paludology. This unit is described as follows: *"Wetlands and spring-mires, seasonally or permanently waterlogged, with a soligenous or topogenous base-rich, often calcareous water supply. Peat formation, when it occurs, depends on a permanently high watertable. Rich fens may be dominated by small or larger graminoids (Carex spp., Eleocharis spp., Juncus spp., Molinia caerulea, Phragmites australis, Schoenus spp., Sesleria spp.) or tall herbs (e.g. Eupatorium cannabinum). Where the water is base-rich but nutrient-poor, small sedges usually dominate the mire vegetation, together with a "brown moss" carpet. Hard-water spring mires often contain tufa cones and other tufa deposits. Excluded is the water body of hard-water springs; calcareous flushes of the alpine zone are a separate category."* The main features identifying this type of ecosystem are: peatland character, groundwater supply (shallow or deep origin) and alkalinity of supplying waters.

The central, most typical form of alkaline fens, in which its specific features are best visible, are the so-called moss fens – that is, alkaline fen with vegetation dominated by brown mosses and low sedges. The description of habitat 7230 in the EU handbook – Interpretation Manual of European Union Habitats (European Commission 2013) refers to this most typical habitat form: "*Wetlands mostly or largely occupied by peat- or tufa-producing small sedge and brown moss communities developed on soils permanently waterlogged, with a soligenous or topogenous baserich, often calcareous water supply, and with the water table at, or slightly above or below, the substratum. Peat formation, when it occurs, is infra-aquatic. Calciphile small sedges and other Cyperaceae usually dominate the mire communities, which belong to the Caricion davallianae, characterised by a usually prominent "brown moss" carpet formed by Campylium stellatum, Drepanocladus intermedius, D. revolvens, Cratoneuron commutatum, Acrocladium cuspidatum, Ctenidium molluscum, Fissidens adianthoides, Bryum pseudotriquetrum and others, a grasslike growth of Schoenus nigricans, S. ferrugineus, Eriophorum latifolium, Carex davalliana, C. flava, C. lepidocarpa, C. hostiana, C. panicea, Juncus subnodulosus, Scirpus cespitosus, Eleocharis quinqueflora, and a very rich herbaceous flora including Tofieldia calyculata, Dactylorhiza incarnata, D. traunsteineri, D. traunsteinerioides, D. russowii, D. majalis ssp.brevifolia, D. cruenta, Liparis loeselii, Herminium monorchis, Epipactis palustris, Pinguicula vulgaris, Pedicularis sceptrum-carolinum, Primula farinosa, Swertia perennis. Wet grasslands (Molinietalia caerulaea, e.g. Juncetum subnodulosi & Cirsietum rivularis), tall sedge beds (Magnocaricion), reed formations (Phragmition), fen sedge beds (Cladietum marisci), may form part of the fen system, with communities related to transition mires and amphibious or aquatic vegetation or spring communities developing in depressions*[1]. In Polish literature, a description of the natural habitat "mountain and low alkaline fens in the group of flush fens, sedge and moss fens (7230)" according to the "Handbook on Natura 2000 site and species conservation" (in Polish, Herbichowa & Wołejko 2004) also focuses on the typical character: *"meso- and meso-oligotrophic, poorly acidic, neutral and alkaline flush fens, spring-fed and percolating fens, supplied by groundwaters, abundant or very abundant in alkalia, covered by diverse, geographically diversified, peat producing moss and low sedge communities (moss fens), in part with an outstanding proportion of calcicole species,including those growing outside or near the edges of continuous geographical ranges."* However, moss fens are not the only possible form of alkaline fens and 7230 natural habitat.

A broader discussion on the differences in habitat coverage in the different European classification systems of habitats and ecosystems classified as alkaline fens is included in the "Guidebook on good practices of alkaline fen conservation" (Stańko et al. 2018). In general, in addition to typical moss fens, the 7230 habitat range includes flush fens and spring mires as well as degenerative forms of alkaline mires, e.g. fen meadows. The natural habitat shall usually identify the entire peatland with a specific ecology and not just a patch of characteristic vegetation on its surface. Earlier studies also discussed the most important criteria distinguishing

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1 In modern botanical nomenclature, also used in the rest of this book, *Drepanocladus intermedius* is named *Limprichtia cossoni*, *Cratoneuron commutatum – Palustriella commutata*, *Acrocladium cuspidatum – Calliergonella cuspidata*.

alkaline fens from Natura 2000 habitats, e.g., calcareous fens (code 7210), petrifying springs (7220), transition mires (7140) and *Molinia* meadows (6410), in the context of the identification of these ecosystems for practical purposes – mainly their effective conservation (Wołejko et al. 2012, Stańko & Wołejko 2018a, Stańko et al. 2018).

The criterion distinguishing alkaline fens from other fens supplied with surface water (EUNIS D.5, mostly not included in the Habitats Directive Annex) is underground water supply. The criterion to distinguish between alkaline and acid mires (EUNIS D.2, partly not included in the Habitats Directive Annex, and partly constituting a habitat code 7140), is the feedwater pH.

## 1.2. General characteristics of habitat 7230

Alkaline peatlands are scattered all over Europe (Šefferova-Stanová et al. 2008, Jimenez-Alfaro et al. 2014, Joosten et al. 2017, European Environmental Agency 2018), although in different biogeographical regions they may take slightly different forms and floral composition. The Alpine region is considered to be the area where they have the most typical form, bringing together numerous plant species from the *Caricion davallianae* alliance (Jimenez-Alfaro et al. 2014, Peterka et al. 2017), which is not always the case in other regions.

As mentioned above, the specificity of alkaline fens is most fully expressed in the typical form of this ecosystem type, the so-called moss fens – i.e., alkaline fens with vegetation dominated by brown mosses and low sedges. The prerequisite for the development of such a form of ecosystem is the alkalinity of feed water with its low fertility, i.e., with low availability of plant nutrients (which usually results from the limitation of this availability as a result of specific biogeochemical processes, see Chapter 2.6).

Habitat 7230 occurs throughout the entire Poland. On the uplands and in the mountains, there are numerous, although usually small, sites. The areas of their concentration include e.g., the areas of Polesie and Lubelszczyzna rich in limestones (Dobrowolski et al. 2016), Niecka Nidziańska (Przemyski & Wołejko 2011), the Western Carpathian ranges (including Hájek 1999, Koczur & Nicia 2013), including those studied in more detail within the activities of the Naturalists' Club: Czarna Orawa catchment (Kiaszewicz & Stańko 2010), Gorce (Stańko & Horabik 2015) and other Carpathian ranges (Stańko & Wołejko 2018b) and ranges of the Sudetes (Kwiatkowski et al. 2007). A more detailed description of the most important areas of alkaline peatlands presence, which are crucial for their survival in our country, is presented in Chapter 7 of this publication.

The comparability in relation to mountain and submontane alkaline peatlands of Poland is offered by well-studied – in terms of nature – alkaline and spring mires located on the Slovakian and Czech side of the Tatra Mountains (e.g., Šefferova-Stanová et al. 2008, Hájek & Hájková 2002, Hájek et al. 2002, Hájková et al. 2012, 2015, Grootjans et al. 2005, 2012, Peterka et al. 2014). The core of many of these peatlands is formed by calcareous sinters, deposited alternately with mesotrophic layers of moss peats. On their surface, in small water reservoirs, there is a process of petrification in which stoneworts and bryophytes actively participate (de Mars et al. 2016).

The smallest number of alkaline fens have survived in the central regions of Poland, which further increases their value as sites requiring effective conservation. In terms of the occupied area, the largest resources of habitat 7230 are found in the northern part of the country, especially in north-eastern Poland. These regions contain the best-developed and preserved alkaline fens, not only in Poland but also in Europe. Review descriptions of the alkaline fens presence in individual regions of the country contain studies (Wołejko et al. 2012, Stańko & Wołejko 2018a, b, Stańko et al. 2018) which are mainly a summary of projects implemented by the Naturalists' Club in 2008 – 2018. They are complemented by Chapter 7 of this study, concerning the most valuable alkaline fens of the country, also based on other sources.

The identifier of natural habitats – with numerous objections, though, as presented in more detail in a separate publication (Stańko et al. 2018) – is the vegetation and plant indicator species, with phytosociological approach.

The flora of alkaline fens as a habitat type is very rich, which distinguishes these ecosystems from other types of mires, e.g., sphagnum mires – bogs or most of the transitional ones. Floral richness and the presence of floral peculiarities is often a feature of individual patches, although it does not always have to be so. However, in the case of alkaline fens it is difficult to indicate accurate phytosociological identifiers (see Chapter 3, see Stańko et al. 2018). Because of the foregoing reasons, typical moss fens plant communities may be treated as important indicators of habitat presence but not as an entire patch of the habitat 7230. The range of a natural habitat patch should be interpreted more broadly than the range of a plant patch. Other factors such as stratigraphic structure, hydrological regime, hydrochemical parameters and the position of the peatland in the landscape, should also be taken into account when identifying it. Such an approach is important for planning and implementation of protection, ensuring that the integrity of the ecosystem – particularly of its stages transformed and disturbed by humans – is preserved.

# 2. STRUCTURE AND DEVELOPMENT OF ALKALINE FENS IN POLAND

***Lesław Wołejko, Robert Stańko***

## 2.1. Ecohydrological type

Whether or not an ecosystem qualifies for the Natura 2000 habitat type alkaline fens is only determined by it present form and this disregards the origin and further development of the ecosystem. In order to understand the operating principles of the ecosystem, its successional trends, and prospects for restoration, a proper assessment of environmental conditions of the ecosystem within the context of the surrounding is crucial. This is important for understanding the current ecosystem changes over time. Knowledge about these changes can be drived from stratigraphical analyses of wetlands supporting alkaline fens. An overview of classical methods for studying wetland ecosystems includes "Guide to the determination of peats and lake sediments" (Tobolski 2000, in Polish). Simplified analyzes, focused primarily on supporting the practical protection of alkaline fens, are summarized in the "Guidebook on good practices of alkaline fen conservation" (Stańko et al. 2018).

Tobolski (2000) also discussed the most commonly used peatland classification systems. In terms of Succow's (1988) ecological and phytocenotic typology of peatlands, which includes five units, alkaline fens are mostly found within two units: "Alkaline transitional mires (meso- and oligotrophic-subneutral mires) (*Caricetalia diandrae* order)" and "Transitional (meso- and oligotrophic-calcareous mires) (*Tofieldietalia* order)". A different hydrogeological and genetic typology (Succow and Jeschke 1986, Succow 1988) includes 8 main types of peatlands. Among them, habitat 7230 ecosystems are mainly associated with: terrestrializing fens, percolating fens, spring mires and hanging mires. This classification system, with some terminological modifications (Tobolski 2000), has also been used for years to describe peatlands in Poland, including sites covering the natural habitat 7230.

Features taken into account in the identification of peatlands and other wetlands include the intensity of water outflow, position in the landscape and the type of accumulated deposits (cf., Żurek & Tomaszewicz 1989, Pawlaczyk et al. 2002, Stańko et al. 2018). With reference to this system, Herbichowa and Wołejko (2004) proposed three regional subtypes of the 7230 habitat type for Poland:

Photo 1: Habitat 7230-1 mountain flush fens - in the Gorce National Park (photo by E. Gutowska).

Photo 2: Habitat 7230-2 alkaline fens of southern Poland (with the exception of the mountains) – cupola fen near Śniatycze (photo by E. Gutowska).

Photo 3: Habitat 7230-3 spring-fed and percolating fens of northern Poland – the Morgi fen (photo by E. Gutowska).

Photo 4: Habitat 7230-3 spring-fed and percolating fens of northern Poland – the mire in the upper Biebrza basin (photo by E. Gutowska).

– 7230-1 mountain flush fens,
– 7230-2 calcarous fens of southern Poland (excluding mountains) and central Poland,
– 7230-3 spring-fed and percolationg fens of northern Poland.

This division indicates the dominant role of a specific type of peatland in the geographical region which, however, does not exclude the presence in a given area of alkaline fens representing other hydrogeological and genetic features.

**The flush fen** is the most common variety of peatlands in mountainous areas, and with the high alkalinity of the water supplying it– the typical form of alkaline fen for the mountains. However, the occurrence of flush fens is not limited to mountains: they also develop in the lowlands, especially in the young glacial landscapes. They are usually small wetlands with characteristics between hanging mires and open springs, characterized by a superficial, unconcentrated outflow of ground water. Because they are mostly located on slopes, there are no good conditions for the formation of larger peat deposits – only shallow peaty gley soils or rather shallow peats have been formed in such areas.

Photo 5: Mountain flush fen in a small depression with
a large share of brown mosses in Gorce (photo by R. Stańko).

Photo 6: A flush fen along a small stream in the Sudetes (photo by R. Stańko).

Photo 7: A flush fens complex passing into the spring-fed fen with a large share of broad-leaved cottongrass (*Eriophorum latifolium*) (Gorce) (photo by R. Stańko).

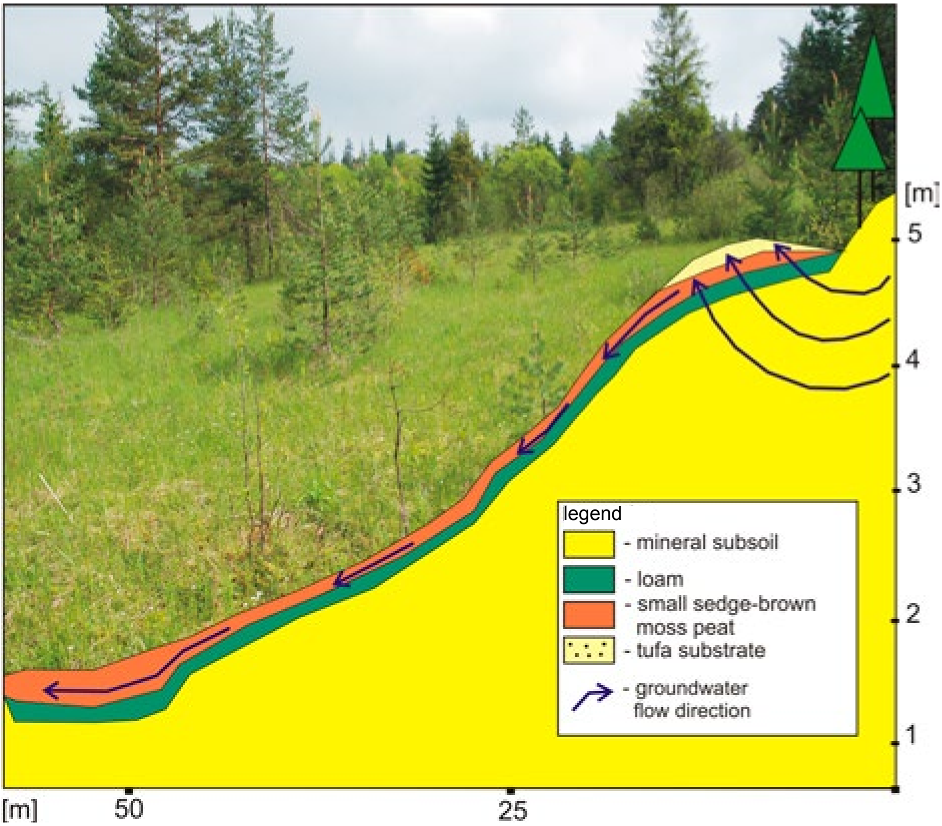



Fig. 1.The stratigraphic section with the direction of the groundwater flow within the flush fen and spring-fed mire complex in the vicinity of the Bembeński stream (Orawa).

Typical **spring-fed fens** occur in different topographical situations ensuring a long-lasting, even supply of groundwater, often under hydrostatic pressure. **Cupola** spring-fed fens have the form of cupolas or hills formed as a result of the accumulation of peat, or as a result of alternating or simultaneous deposition of peat and calcareous tufa layers. The tufa consist not only of precipitated calcium carbonate, but also of magnesium and iron compounds. This precipitation of mineral compounds from waters is called petrification and occurs around springs with a strong discharge of groundwater, which in terms of spatial coverage are quite rare in the landscape.

Alkaline **hanging** spring-fed fens are similar in terms of physiognomy and position in the landscape to mountain flush fens. They usually occur as dispersed wetlands on a slope below the outflow of groundwater, and can accumulate significant deposits of calcareous sinters and peat. A characteristic feature of well-preserved mountain flush fens with active petrification, are extremely stable and high water levels, which generally appears to be a hydrological anomaly (mountain areas are commonly known as regions with very large fluctuations in water levels, especially surface waters). Several years of groundwater level monitoring in the petrifying mires in the Orava and the Low Beskids areas show that the long-term amplitude of changes in the water table level rarely exceeds 20 cm and in most cases is even less than a few or several centimeters. In this respect, these conditions appear to be more stable than in lowland areas.

Photo 8: The cupola of a spring-fed fen with calcareous tufa in the Magura National Park (photo by D. Horabik).

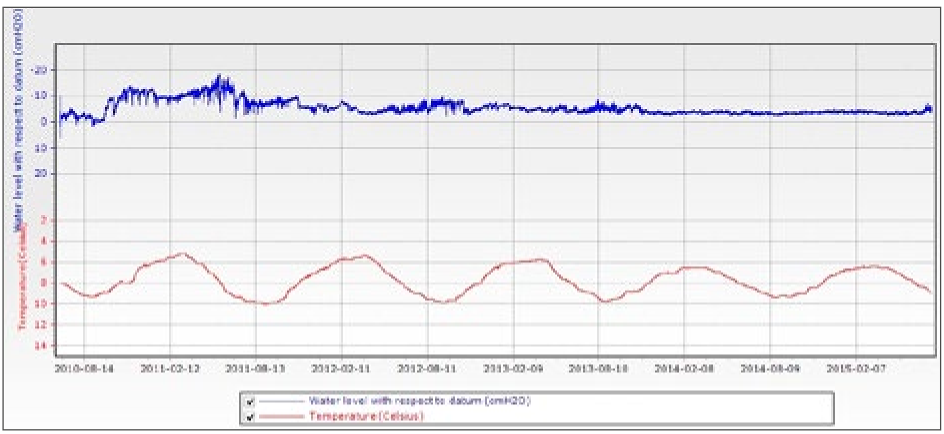



Fig. 2. Fluctuations in the water level in a mire located along the Bembeński stream (Orawa).

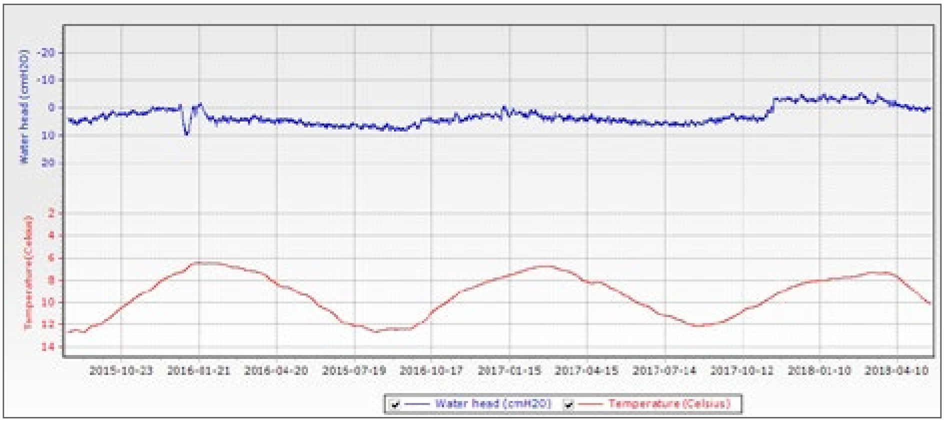



Fig. 3. Fluctuations in the water level in the mire in the Magura National Park (Beskid Niski).

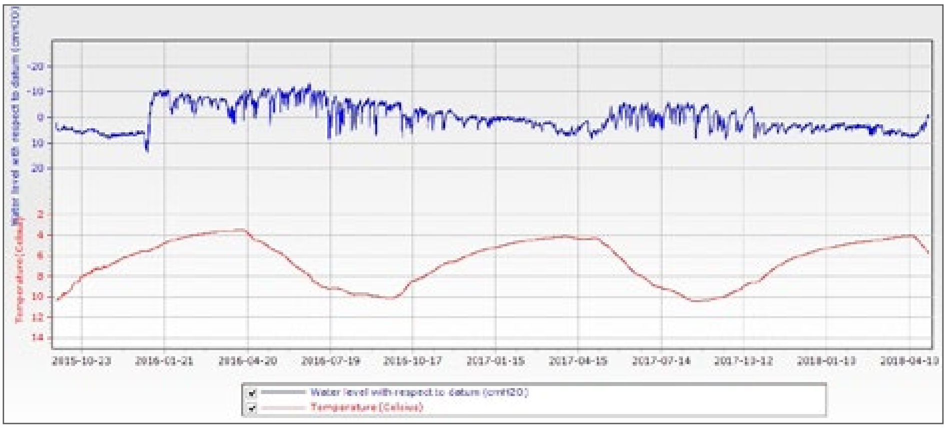



Fig. 4. Fluctuations in the water level in the mire at Hala Długa in the Gorce National Park (Gorce).

In certain geological formations, so-called hydrological windows occur, which consists of very permeable spots within less permeable geological strata. Such almost impervious strata may, for instance, consist of compact gyttjas formed earlier in open water bodies. Springs and mire ecosystems are developing intensively on the slopes of mineral hills "piercing" hydrogenic sediments. Because the resistence to groundwater flow increases in the water basins surrounding these mineral islands, the flow of groundwater is increasingly concentrated in the sandy hill. This process may be intensified by the dessication of the wetland complex. Well-documented examples come from, for example, the Drawa National Park area (Wołejko & Grootjans 2004), Gogolewko mire in the Słupia valley (Fig. 5) and from the Ilanka-, Korytnica- and Płonia river valleys.

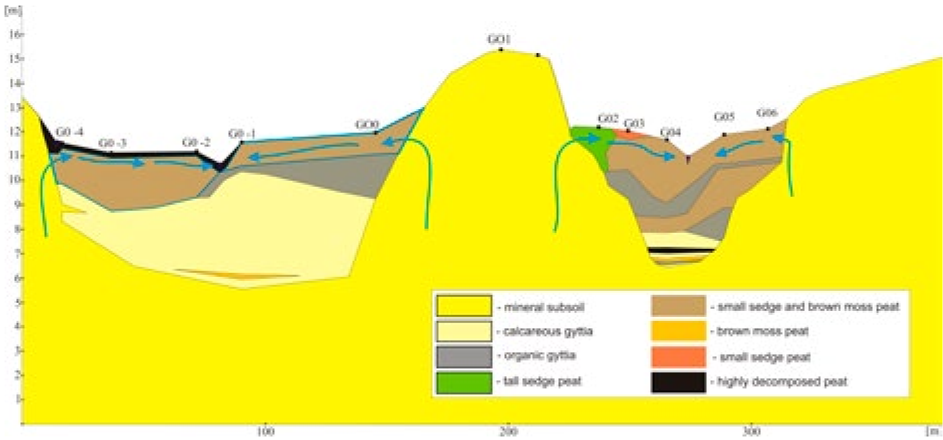



Fig. 5. The mineral island on the middle of the "Gogolewko" mire functions as a "hydrological window".

Fig. 6. Mineral island within the "Gogolewko" mire. The position of the transect shown in the figure is highlighted in yellow in Fig. 5 (photo by R. Stańko).

Cupola spring-fed fens are relatively frequent, also in the lowlandsof Poland, but nowadays almost always in more or less degraded form. "Spurgle"– the deepest known peatland of this type in north-eastern Poland– reaches a thickness of about 16 m of sediments, dominated by calcareous tufa (Łachacz 2000). In north-western Poland, a series of spring sediments with a thickness of approx. 8 m was recorded in the Chociel valley peatland (Wołejko 2001, Pidek et al. 2012, Osadowski et al. 2018).

The succession towards eutrophic vegetation types (such as reeds or alder woods) entering the spring domes is usually the result of erosion and associated eutrophication of the habitat. Due to the shape and associated ease of drainage, only a few objects of this type have survived intact until today. One of the best-known examples (Bitner 1961, Dembek 2000, Pawlikowski 2011) is the mire in the Makowlanka river valley (Fig. 7), also known as "Sidra" (studied in detail also as part of landscape ecology courses by students of Dutch universities in Utrecht and Groningen). It's core consists of alternating layers of travertine and peat. The surface layer is formed of a thin layer of peat, on which a concentric sequence of plant communities has developed (Fig. 7). At present, as a result of artificial drainage, typical sedge-moss fen vegetation (with species such as the *Carex rostrata* and *Tomentypnum nitens*) are present here only in the form of a narrow strip around the base of the dome (zone II in Fig. 7).

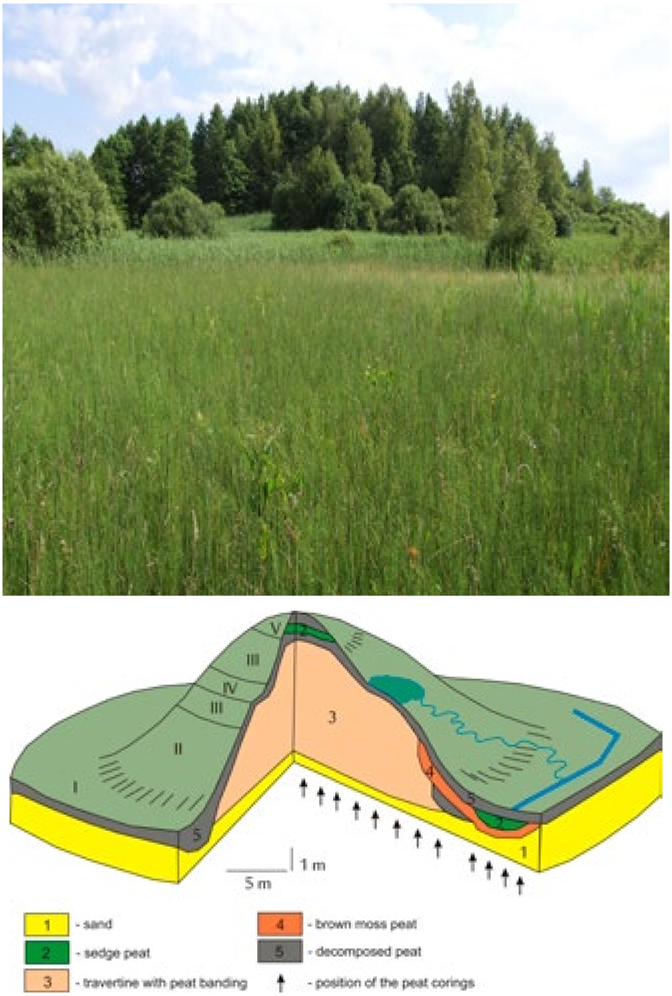



Fig. 7. The "Sidra" spring-fed fen in the Makowlanka river valley (tributary of the Biebrza river) (photo by P. Pawlikowski). After partial drainage, the vegetation of the alkaline sedge-moss fen has survived only at the base of the dome; Stratigraphy of the "Sidra" dome (Fig.– Grootjans in Pawlikowski 2011).

Well-preserved spring-fed fens with vegetation typical of alkaline fens are currently rare. Often the only trace of the earlier existence of accumulative spring domes are subfossil deposits, partly eroded away or existing at present as blocks of exposed calcareous tufa. In many regions of northern Poland, changed water conditions currently prevent the active accumulation of calcareous tufa (Grootjans et al. 2015). Similar changes have been observed in numerous spring mires of the Masurian Lake District (Łachacz 2006).

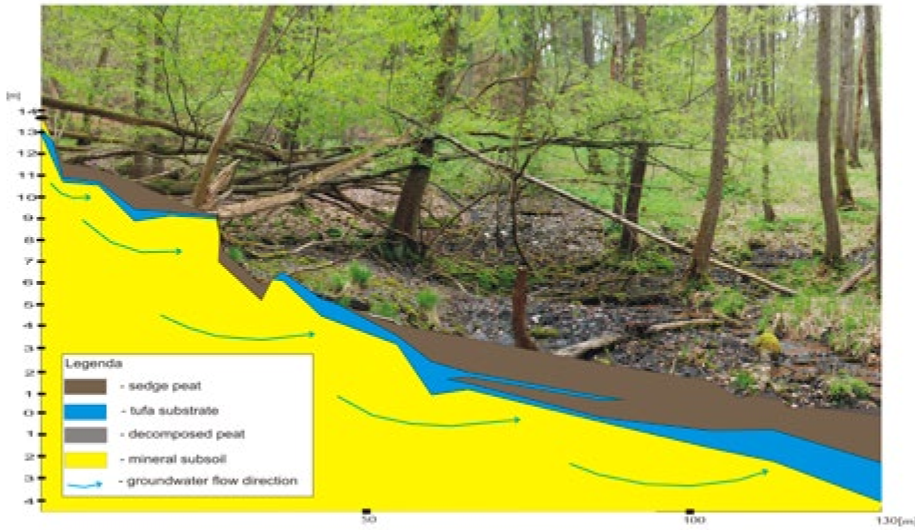



Fig. 8. Physiognomy and scheme of stratigraphic structure of a degraded spring-fed fen on the slope of the Ilanka valley.

The point outflow of a significant amount of calcareous groundwater is often related to tectonic faults, as in the Lublin region (Dobrowolski 1994) or in central Poland (Dobrowolski et al. 2017). The shifting of tectonic layers blocks the water flow within the aquifers, forcing the groundwater to discharge at the surface. Such conditions are relatively common near the southern borders of Poland, in Slovakia, e.g., in the Western Carpathians (Močiar reserve), in the Spiš region ("Siva Brada") or in the mires in the Poprad Basin

Photo 9: Fossil travertines in the Płonia valley (photo by R. Stańko).

(Grootjans et al. 2005, Hájková et al. 2012, Grootjans et al. 2012). Such phenomena probably also have a significant impact on the supply of some of the alkaline wetlands in the Polish Carpathians (cf., Gruszczyński & Mastella 1986).

**Percolating mires** are formed when groundwater from rather large aquifers discharges in a very dispersed way. It may occur at the margins of the river valleys, or within lake basins. Percolating alkaline fens develop best in areas with much relief, especially in young glacial landscape. Unlike flush fens or spring-fed fens, percolating fens are usually characterized by rather thick peat deposits, often associated with lake sediments – gyttjas. Typically, the vegetation that forms such a mire consists of small sedges and brown mosses. In mires with active peat accumulation, the water is slowly flowing slightly below the peat surface. The groundwater enters the valley at the mineral edge and leaves the mire via watercourses or lakes.The surface of the peatland is usually sloping, sometimes very clearly. In the early stages of peat development, the sedge-moss vegetation may form a floating-mat, oscillating with the water level fluctuations in adjacent rivers or lakes. In such a case, one would use the name "emersive vegetation".

In wide river valleys in the old glacial areas, the sloping of the peatland surface may be very modest. This may lead to an increased share of rainwater in the hydrological balance of the peatland. This initiates the succession of peat-forming vegetation towards sphagnum communities and may cause difficulties with the proper identification of the ecological character of the peatland and the type of natural habitat. The patches classified as habitat 7230 form a mosaic with phytocoenoses of other types of vegetation. Their current location can be reliably documented using remote-sensing techniques (Kopeć et al. 2016).

The peatlands located in the upper basin of the Biebrza valley are among the best studied mires in Poland, in terms of ecohydrological flow (Fig. 9). Also the Rospuda valley is also well-studied (e.g. Jabłońska et al. 2011, 2014), and considered one of the best preserved percolating mires in Central Europe.

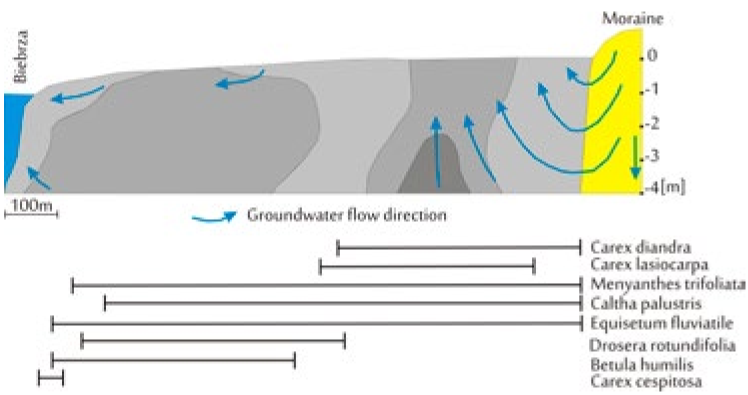



Fig. 9. The ecohydrological model of the soligenous mire in the upper basin of the Biebrza valley (according to Wassen et al. 1996).

Photo 10: Mires in the upper basin of the Biebrza valley (photo by R. Stańko).

Photo 11: One of the most valuable and the most extensive percolating fens in the Rospuda valley. Clearly visible on the photo, is the difference between rush communities (gray - adjacent to the river) and the yellowish-green sedge-moss fen communities. Forests are situated at the mineral edges (photo by R. Stańko).

In northern Poland, the most typical stratigraphic systems with a significant share of alkaline fens are those of **lake origin**, which over time, at least partially, transformed into **percolating fens**. They develop in lake basins, usually on thick layers of gyttja. In many cases, this process is also actively taking place in recent times, hence the "young" alkaline fens, growing on e.g., calcareous lakes are among the best preserved in the country. Such sites may harbor some of the rarest mire plant species in Poland such as, for example, yellow marsh saxifrage *Saxifraga hirculus*, fleshy starwort *Stellaria crassifolia* and others (Pawlikowski & Jarzombkowski 2012a, b). It can be argued that the presence of these species of "special care" can be a simple indicator of a good and stable mire ecosystem.

The relatively flat surface of the mire contributes to the accumulation of rainwater. For this reason, it is relatively easy to initiate the development of transitional mires with a significant proportion of ombrophilous sphagna. This process can be accelerated by human interference in the hydrological system of the lake itself, as well as within its surface or underground drainage basin.

Examples of well-known lake alkaline fens are, among others, fens located in the Pomeranian nature reserves Mechowisko Radość, Bagno Stawek, Dolina Kulawy and Mechowiska Sulęczyńskie. In western Poland, well-preserved (but small) alkaline fens of this type occur, for instance in the Bukowskie Bagno and Jezioro Ratno reserves. In the reserves of Chłopiny, Młodno and many other areas the fens are in a much worse condition, and require active protection.

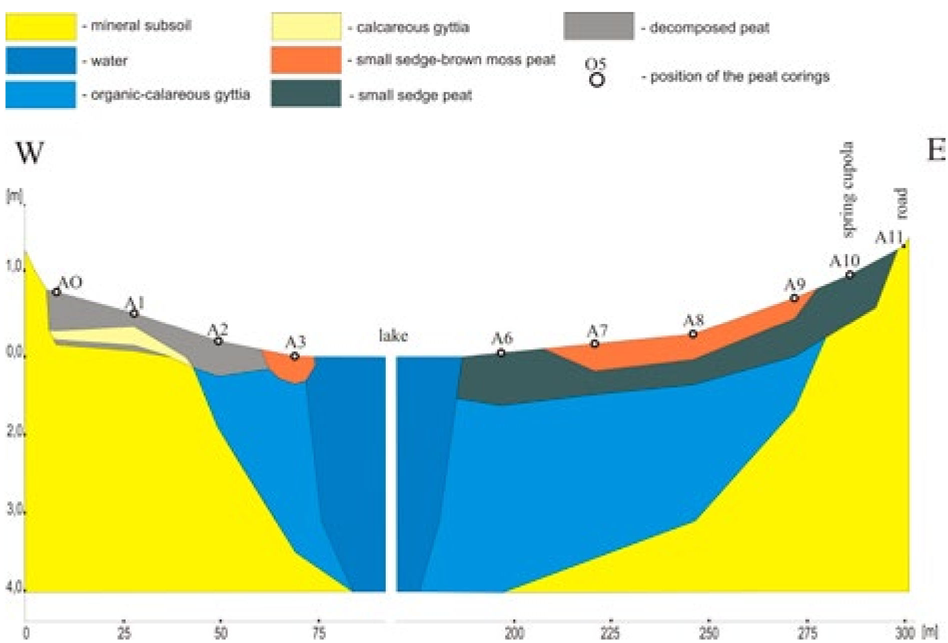



Fig. 10. Stratigraphy of alkaline fens in the Kulawa Valley reserve (Stańko & Wołejko 2018a).

Observations carried out in recent years by the Naturalists' Club as a part of alkaline fens conservation projects, indicate quite significant hydrological differences within particular sites classified as percolating fens. The observed fluctuations in the level of groundwater table were in the range of 15 to 50 cm. The largest fluctuations were recorded in the mires in the late development phases (where the terrestrialization process ended relatively long ago), while the smallest was in mires in the early stages of peat development (shallow peat deposits on gyttja) (Stańko & Wołejko 2018a, b).

Stratigraphical research in northern Poland showed that most soligenous alkaline fens originated from lakes. This is true for the fens in the Rospuda valley, for the fens in the Kulawa (Fig. 10), Słupia valleys in Northern Pomerania, for the

Photo 12: Sulęczyno fen (photo by R. Stańko).

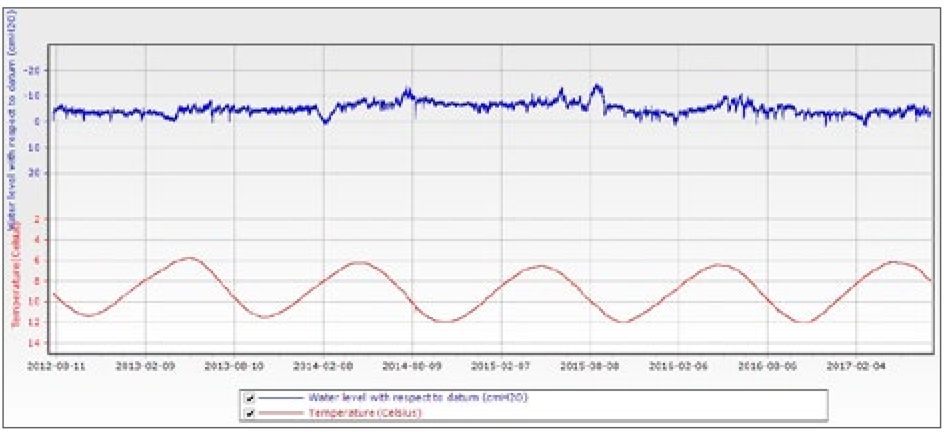



Fig. 11. Variability of the level and temperature of groundwater in the Bagno Stawek fen – site in its early stage of development.

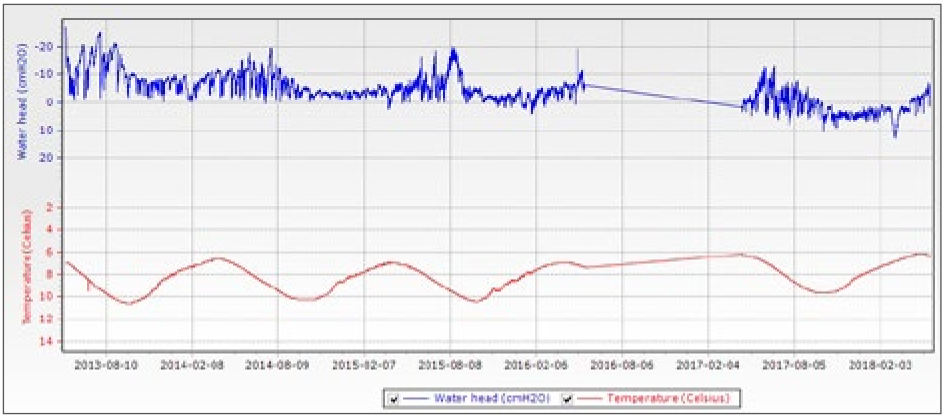



Fig. 12.Variability of groundwater level and temperature in the Kosobudki fen (Pliszka valley) – site in its final stage of development.

valleys of Debrzynka, Rurzyca, Drawa and Płonia in Western Pomerania, and for the fens in the Ilanka, Pliszka valleys in the Lubusz area. What these systems have in common is that peat formation started with the filling up of a series of elongated lakes situated in post-glacial valleys. The terrestrializing mires then developed in shallow water on top of gyttja sediments. In time these mires stabilized and gradually changed into groundwater-fed mires with water supply from higher grounds. It is worth mentioning that a real river bed in the valley developed in this stage of mire development and not before. This is indicated by the presence of gyttjas located under the more recent bottom sediments of the river.

Such sites – in addition to peat deposits underlain by lake sediments - are characterized by sloping groundwater fed mires. Unfortunately, such sloping fens are susceptable to desiccation after drainage operations, hence many of these valley mires have been preserved fragmentarily, or only in the form of degenerating deposits of peat and gyttja. Good examples of that kindof mires are located on the slopes of the West Pomeranian river valleys of Chociel (Osadowski et al. 2018), Płonia (Wołejko 2000) and Ina (Fig. 13) (Wołejko & Malinowski 2017).

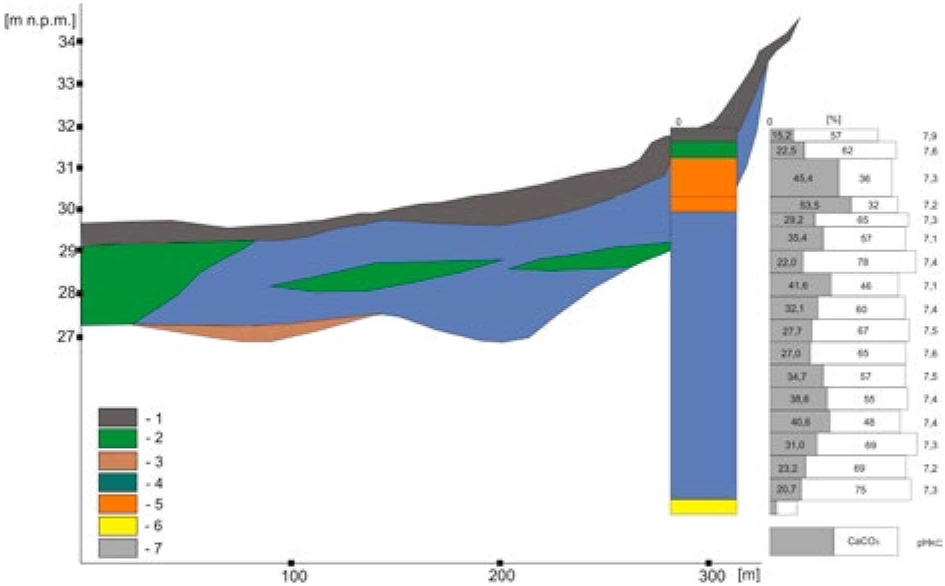



Fig. 13. Geological cross-section of the marginal zone of the Ina valley.
1 – decomposed peat, 2 – sedge peat, 3 – reed peat, 4 – aquatic and spring carbonate sediments, 5 – sedge-moss peat with carbonate precipitates, 6 – sand,
7 – content of organic matter (source: Wołejko & Malinowski 2017).

## 2.2. Genesis and age of alkaline fens

In the Western Carpathians, in the light of paleoecological analyzes, the majority of alkaline fens are relatively young; they started to grow during the last 2,500 years. Some of them developed from forested springs with species like *Carex remota*, *Carex sylvatica* and *Glyceria nemoralis*. After deforestation, the development of mires with vegetation belonging to the *Caricion davallianae* alliance started to grow in these places (Hájková et al. 2015). However, other pathways in the history of peatlands have also been documented, e.g., in an extreme case a *Sphagnum fuscum* dominated bog shifted into a calcareous fen after large scale wood felling in the Middle ages (Grootjans et al. 2005, Hájková et al. 2012, Madaras et al. 2012).

Similar results on the age of alkaline flush fens (3,500 years) were reported by Obidowicz (1996) for the Tatra National Park. Nevertheless, few older peatlands have survived until the present times. They started as open (non-forest) alkaline fens at the turn of the late Glacial and early Holocene periods. During the middle Holocene period, most of these alkaline fens were overgrown by tree vegetation (mainly alder, birch and spruce), which (temporary) eliminated heliophilic mire species – both plants and snails (Hájková et al. 2015).

Palaeoecological studies illustrating the stages of development of fens currently representing habitat 7230 on the lowlands have shown their developmental temporal and spatial relationships with other habitats, including hard-water lakes (Wołejko & Piotrowska 2011) and lakeside calcareous mires (Waloch 2012, see also description of calcareous fens in the Lublin Region, presented in Chapter 7). Sometimes the development of alkaline fens occurs in wet interdunal depressions (Gałka et al. 2016, Wołejko et al. 2019).

Peat stratigraphy studies revealed peat deposits with elements allowing to recognize the alkaline fen stage dated to the entire Holocene period, as well as analogous peat fossils from the Pleistocene period (Jasnowski 1959). A repetitive scheme is also the history of the formation of the spring cupolas with calcareous tufa, and then the development of sedge-moss and even a bog, as illustrated in the example shown in Fig. 14 (Mazurek et al. 2014).

In many areas e.g., in the Tuchola Forest and in the Drawa Forest, sedge-moss mires with brown mosses, similar to today's alkaline fens, consituted early development stage of many wetlands, that by now have reached the stage of transitional mires (Lamentowicz 2005, Kujawa-Pawlaczyk & Pawlaczyk 2014, 2015, 2017). On the other hand, based on the example of other well studied objects, such as the Stążka valley in the Tuchola Forest (Lamentowicz et al. 2013), or the mires in the Biebrza valley, the vegetation of alkaline fens can persist  for several thousand years.Many modern alkaline fens with well-developed sedge-moss vegetation are relatively young sites, with thin peat layers accumulated duringin the last 0,5–2 thousand years, usually on top of thick layers of gyttja or lake marl.

The current distribution of the rich fens may, therefore, only be a shadow of their spread a few thousand years ago, when the hydrological and climatic conditions were slightly different. Spring mires with greater thickness may have had a sedge-moss mire phase in their history, and probably were bordered by sedge-moss fens.

Many contemporarty alkaline fens, with typical mos vegetation, are relatively young, with thin peat layer accumulated by last 0,5-2 throusands years, on thick gyttja or chalk lake deposits.

There are known examples of flush fens with the vegetation typical of alkaline fens that have developed in young, anthropogenic sites, such as  former sand quaries in Silesia. Some of them  are floristically very valuable (Molenda et al. 2012, 2013, Hałabowski et al. 2016a; see also Chapters 7 and 8).

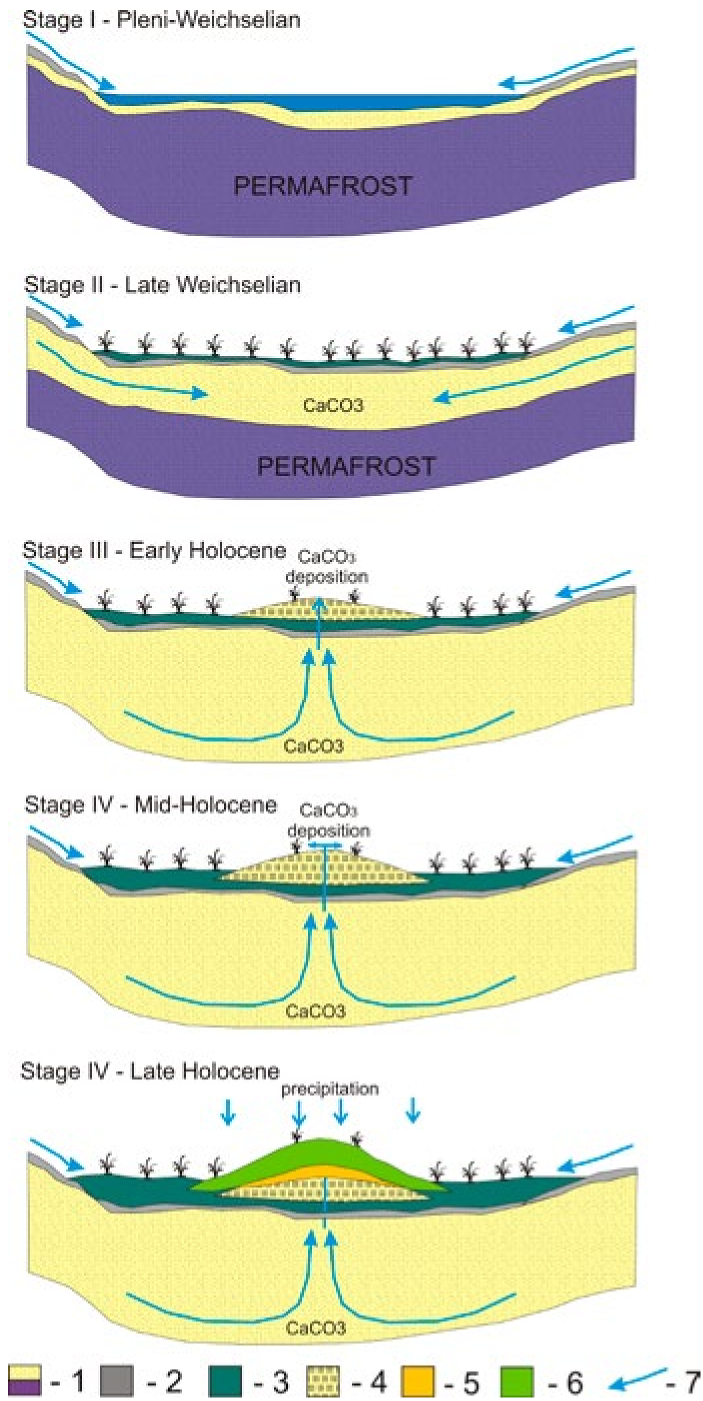



Fig. 14. Model of spring-fed fen evolution in Western Pomerania. 1–varigrained sand, 2–silty sand, 3–sedge peat, 4–moss-sedge peat, 5–calcareous tufa, 6–Sphagnum peat, 7–direction of overland and subsurface and/or groundwater flow (source: Mazurek et al. 2014).

## 2.3. Stratigraphic components of alkaline fens

Taking into account the diversity of sedimentary and sedentary environments in which alkaline fens develop, it is necessary to consider substrates of different origin. These are underwater sediments (gyttjas), peats (mainly of fen and transitional types) and spring water precipitates. A separate issue – presented in the next subsection – is the classification of soils formed from these substrates as a result of their spontaneous or human-induced transformations.

The most frequently used classification of **gyttja** is based primarily on the analysis of the percentage of the main components such as calcium carbonate, organic matter and clay parts (Markowski 1980). In addition to this approach, Tobolski (2000) also discusses other ways of identification and description of aquatic sediments, in particular the Troels-Smith method. It provides, among others, a description of the tested soils in accordance with the international code system.

The so-called genetic classification of **peat** (Tołpa et al. 1967) has been used for more than 50 years. Details of this classification system are presented in textbooks on peat science (e.g., Tobolski 2000, Ilnicki 2002). An extensive range of different types and kinds of peat has been identified in the profiles of alkaline fens. However, from the point of view of the relationship of these formations with peat-forming plant communities of typical alkaline fens, the most important are sedge-moss, (brown) moss, and (tall) sedge peats. This does not exclude the occurrence of other peat types and kinds in peat profiles, which reflects the diverse origins and multiple paths of development of the current alkaline fens. Table 1 presents a part of the classification system (Tołpa et al. 1967) covering the types and species of peat most often recognized in the profiles of alkaline fens.

Moss peats, which reflect the early, mesotrophic stages of fens development, deserve special attention. They were characterized in Poland as a result of M. Jasnowski's pioneer work (1959). The distinction of moss peat by definition means that it contains more than 60% of the remnants of a specific brown moss species (*Bryales*). Moss peat mainly consist of moss species that are considered glacial relics (Szafran 1948, Czubiński 1950). Based on their dominance in the peat, Jasnowski (1959) distinguished 7 kinds of moss peat named after the moss species forming them: *Drepanocladus sendtneri*, *Calliergon giganteum*, *Calliergon trifarium* ( =*Pseudocalliergon trifarium*), *Scorpidium scorpioides*, *Camptothecium nitens* (=*Tomentypnum nitens*), *Meesea* (=*Meesia*) and *Paludella squarrosa*. These peats are very often used as traces of the initial developmental stages of mires of lake origin, especially those situated in landscapes with a higher abundance of calcium compounds. These are usually not very thick layers; they are rather quickly replaced by other types of peat, and reflect subsequent succession stages within the terrestrializing process in mesotrophic and eutrophic water bodies (cf., Kowalewski 2014).

Photo 13: Moss peat with a low degree of decomposition (about 30%) and a characteristic light brown color – Bagno Stawek nature reserve (photo by K. Barańska).

Photo 14: Very poorly decomposed moss peat (about 20–30%) with macroscopically identifiable bryophytes of the genera *Drepanocladus* and *Pseudocalliergon* – Jezioro Ciche nature reserve (photo by R. Stańko).

Table 1. Genetic relationship between peat-forming plant communities and peat units most commonly found in the profiles of alkaline fens. The original naming of syntaxa has been maintained. Based on Tołpa et al. (1967) according to Tobolski (2000), modified.

| Peats | Peat-forming communities |
|---|---|
| **Type Kind** | **Association and order<br>Association, sub-association, variant, facies** |
| Magnocaricioni - tall sedge<br>Cariceti - sedge<br><br><br><br>Cladieti - sawgrass | *Magnocaricion*<br>*Caricetum rostrato-vesicariae*<br>*Caricetum hudsoni*<br>*Caricetum paniculatae*<br>*Caricetum gracilis caricosum acutiformis*<br>*Cladietum marisci* |
| Bryalo-Parvocaricioni -moss-sedge<br>Bryaleti - mossy<br><br><br><br><br>Carici-Bryaleti - sedge-moss<br><br><br><br><br>Gramino-Cariceti - grassy-sedge | *Caricetalia fuscae et davallianae*<br>*Caricetum diandrae camptotheciosum*<br>*Caricetum diandrae paludellosum*<br>*Caricetum rostratae calliergonosum*<br>*Scorpidium scorpioides Com.*<br>*Caricetum diandrae typicum*<br>*Caricetum canescentis-Agrostidetum caninae*<br>*Caricetum lasiocarpae*<br>*Caricetum fuscae*<br>*Caricetum flavae*<br>*Calamagrostidetum neglectae*<br>*Caricetum paniceae* |

Since the introduction of the genetic classification of peat both in the range of identified peat types and in the systematics of peat-forming plant communities, numerous significant modifications have been introduced. Also, various proposals for additions and changes have been submitted (see: Tobolski 2000, Drzymulska 2018). Nevertheless, the genetic classification and the Polish Standard PN-85/G-02500 developed based on it, constitute the only coherent and widely used system of identification and naming of peat components of alkaline fens.

In addition to well characterised peat types alkaline fens may contain peats, that can not be part of the genetic classification system. This is a case of amorphous peat often found in surface layer of fens. Such material has been described inconsistently in peat profiles, for instance as a “humopeat”, a mineralized super-


Fig. 15. Selected elements of alkaline fen stratigraphy (photo by D. Horabik).

I. Bukowskie Bagno reserve. A: moss sedge peat B: moss – sedge peat
II. Fen near Mielęcin (Drawa Forest). A: sedge-moss peat with a small amount of alder wood, passing into a sedge peat B: sedge peat with alder wood and *Menyanthes* seeds, C: sedge peat (*Magnocaricion*) with a small amount of willow wood – strongly hydrated;
III. Fen near Mielęcin (Drawa Forest). A: fine-grain organic gyttja with a small amount of sedge.

Photo 15: Vertical exposure of the calcareous peat, Slitere, Latvia (photo by A. Szafnagel-Wołejko).

ficial layer (Polish "wierzchnica") or as strongly decomposed peat. We prefer the term strongly decomposed peat.

In the neighboring countries, peat deposits with a high calcium carbonate content are also distinguished, for example, in Germany as "Kalktorf"- Calcareous peat – (Succow & Jeschke 1986).

Photo 16: Calcareous tufa formed on the surface of the spring mire in the Magura National Park (photo by D. Horabik).

Photo 17: Calcareous tufa precipitation around *Equisetum variegatum*. Močiar Reserve in Slovakia (photo by A. Szafnagel-Wołejko).

Dobrowolski (2011) attempted to sort the nomenclature related to carbonate **spring deposits**. According to this author, autogenous calcareous sediments precipitated from flowing fresh water include **calcareous tufa** (light, highly porous carbonate sediments, undiagenized or poorly diagenized, formed in the vicinity of springs supplied with groundwater with $CO_2$ originating from percolating rain water (meteogene), **travertines** (hard, highly diagenized, carbonate deposits building large calcareous terraces and/or barriers in streams with high flow dynamics), and **sinters** (hard, concise and non-porous calcite coatings precipitated mainly in thermogenic conditions).

Alternating peat layers and mineral precipitations are called peat-sinter rhythmites (Dobrowolski 2011). Full stratigraphic profiles of peatlands with rhythmites, other types of sinters, peats, gyttjas and mineral sediments are an interesting subject of numerous paleoecological studies in Poland (Dobrowolski et al. 2002, Lamentowicz et al. 2013, Apolinarska & Gałka 2017, Osadowski et al. 2018, Pietruczuk et al. 2018) as well as neighboring countries (Hájková et al. 2012, Jamrichova et al. 2018, Šolcová et al. 2018). These studies, in addition to reconstructing the history of ecosystem development, relate to the transformations of vegetation, changes in ecological and climatic conditions, and the history of human influence. Studies on the chemism of peatland formations allow for the reconstruction of the history of landscape development (Borówka et al. 2015).

Photo 18: Layered rhythmite from the "Wierzchołek" alkaline fen, near Złotów (photo by R. Stańko).


Fig. 16. Calcareous sediments – drilling in a mountain flush fen in the Magura National Park. A: sedge peat, decomposition 4, B: amorphous calcareous tufa (photo by D. Horabik).

## 2.4. Soils of alkaline fens

The surface layer of alkaline fens is shaped during peat-forming and soil-forming processes. In areas with a much relief, the role of slope denudation and erosive processes may play a significant role, resulting both from the functioning of natural geomorphological conditions and those generated by human activity. In northern Poland, the surface layer of actively growing alkaline fens may form various layers of fen peat and transitional peat. Such soil types are traditionally classified on the basis peat characteristics described in accordance with the current soil system of Polish soils (Systematyka gleb Polski 2011). Drainage in peatlands initiates degradation processes of the peat substrate, eventually leading to the disappearance of that peat deposit. The consequences of these changes, to habitat 7230, are discussed in the Chapter 5.2.

Another type of soil may develop in the contact zone of alkaline fens with other ecosystems. When, for instance, carbonate deposits have been formed downslope of the alkaline fens, spring pararendzinas can occur (Wanic 2010, Wołejko & Malinowski 2017). These soils require further pedological research enabling future determination of their relationship with the functioning of alkaline fens.

In south Poland, studies on the so-called "eutrophic" mountain flush fens were carried out in the Pieniny National Park, the Babia Góra National Park and the Orawa-Nowy Targ Basin (Nicia & Miechówka 2004, Nicia 2009, Koczur & Nicia 2013). In most cases, the investigated fens were small and the peat layer was thin. Thicker peat layer had been formed on relatively flat slopes, but peat thickness did not exceed 2 m. Often the peat is highly decomposed or it is absent. The average thickness of the organic layer of 18 alkaline fens of the Gorce National Park studied by Stańko and Horabik (2015) was 32,5 cm.

In the study on the soils of the Pieniny National Park (Niemyska-Łukaszuk et al. 2002) soils of alkaline fens were classified as semihydrogenic soils (including various types of gley soils) and hydrogenic soils (mud and peat soils).

**Semihydrogenic soils** are moist along the entire profile, and periodically even waterlogged or muddy. Hydrophilic vegetation develops on such sites, but no peat is actually formed. In hydrological conditions of mountainous areas, the water from the upper rock horizons play a decisive role in directing the soil-forming process in these soils.

**Hydrogenic soils** occur in the Pieniny National Park, but they are very rare. Soils that are classified as hydrogenic soils here consist of mud and peat soils. Peaty soils are characterized by the accumulation of both peat and mud. Fen peat soils include soils in which peat layers are present, with a thickness of more than 30 cm.

From the perspective of the current Systematics of Polish soils (2011), alkaline fen soils can be assigned to the following soil units:

Order 8. Gley soils
Type 8.1. Gley soils
Subtype 8.1.1. Proper gley soils
Subtype 8.1.2. Peat-like gley soils
Subtype 8.1.3. Peaty-gley soils
Subtype 8.1.4. Mud-gley soils
Subtype 8.1.5. Muck-gley soils

Order 10. Organic soils
Type 10.1. Fibric peat soils
Subtype 10.1.1. Proper fibric peat soils
Subtype 10.1.2. Hemic-fibric peat soils
Type 10.2. Hemic peat soils
Subtype 10.2.1. Proper hemic peat soils
Subtype 10.2.2. Sapric-hemic peat soils
Subtype 10.2.3. Fibric-hemic peat soils
Subtype 10.2.5. Muddy hemic peat soils
Subtype 10.2.6. Shallow hemic peat soils
Type 10.3. Sapric peat soils
Subtype 10.3.1. Proper sapric peat soils
Subtype 10.3.2. Fibric-sapric peat soils
Subtype 10.3.3. Hemic-sapric peat soils
Subtype 10.3.5. Muddy sapric peat soils
Subtype 10.3.6. Shallow sapric peat soils

The stratigraphic structure and soil profile structure within the most important types of vegetation have been presented in the studies of the best-preserved and rather large alkaline fens in Slovakia. They are located in the region of the Belianske Tatras and the Poprad Basin neighboring Poland (Grootjans et al. 2005, Madaras et al. 2012). Figs. 17–19 present the physiognomy of several characteristic fragments of these peatlands in connection with the associated soil profiles. In small, cascading water bodies (pools) forming natural reservoirs on the peatland dome (Fig. 17), active precipitation of travertine/tufa occurs. The vegetation of the pools consists of pioneer communities (including *Eleocharitetum pauciflorae*), as well as brown moss and moss-sedge communities. Fig. 18 illustrates the situation within the peat forming moss-sedge vegetation, while Fig. 19 – within a patch of meadow vegetation with organic and mineral soil.

The phenomena and processes observed during these studies require further in-depth analyzes, also in the area of alkaline fens in Poland.

Fig. 17. Soil profile and physiognomy of pool systems at the top of the Štrba mire's dome (Slovakia). On the right side, calcium carbonate deposition and precipitation of ferrous hydroxide are visible (source: Grootjans et al. 2005, photo by M. Madaras).


Fig. 18. Soil profile within the moss-sedge vegetation from the *Caricion davallianae* alliance on the Štrba peatland (Slovakia). The surface layer of the profile consists of slightly decomposed moss peat. The dark-colored peat at the bottom of the profile consists of decomposed peat with significant amounts of iron sulphide (FeS) (source: Grootjans et al. 2005, photo by B. Van Delft).


Fig. 19. Soil profile within the vegetation of wet meadows from the *Calthion* alliance in the alkaline fen complex Belianske Luky (Slovakia). The surface part of the soil profile is a strongly decomposed peat, underlain by organic-rich mineral layers on clay (source: Grootjans et al. 2005, photo by B. Van Delft).

## 2.5. Alkaline fens in the system of ecological gradients

Ecological gradients have been used for many decades to classify and describe peatlands, especially in Northern and Western Europe. The two most important ecological gradients relevant for understanding the functioning of peat ecosystems are the trophic gradient and the pH gradient. In the scientific literature and practice, there is a Polish term "torfowisko alkaliczne" (alkaline fen), which relates to the variations in pH. The Polish term is usually translated into English as "rich fen". However, the variety in ecosystems within the habitat type 7230 is much wider and includes both peatland and meadow ecosystems (Hájek et al. 2006). The term "rich fens" – (in dissolved minerals, mainly carbonates) also includes moss and sedge-moss fens, with considerable participation of *Sphagnum* (vegetation of *Sphagno warnstorfiani-Tomentypnion* alliance). For the habitat type 7230 the central position of the gradient is occupied by "extremely rich fens", for which we propose the Polish name "wybitnie zasobne w węglany" ("extremely rich in carbonates"). The spectrum of alkaline fens also includes "calcareous fens" – the proposed Polish name is "torfowiska petryfikujące" ("petrifying mires").

The diagram presented on Fig. 20 shows the position of typical alkaline fen ecosystems against the background of related ecosystems, such as moss and sedge-moss fens and related wet meadows (Hájek et al. 2006). Presented here are the ranges of occurrence: hydroecological processes (precipitation of carbonates), and characteristic biotic components: vegetation (in the rank of associations), calciphilous flora and snails. Attention is drawn to the thresholds for the characteristic components of these ecosystems: occurrence of snails, calciphilous plants, *Sphagnum* species and the precipitation of calcium carbonate.

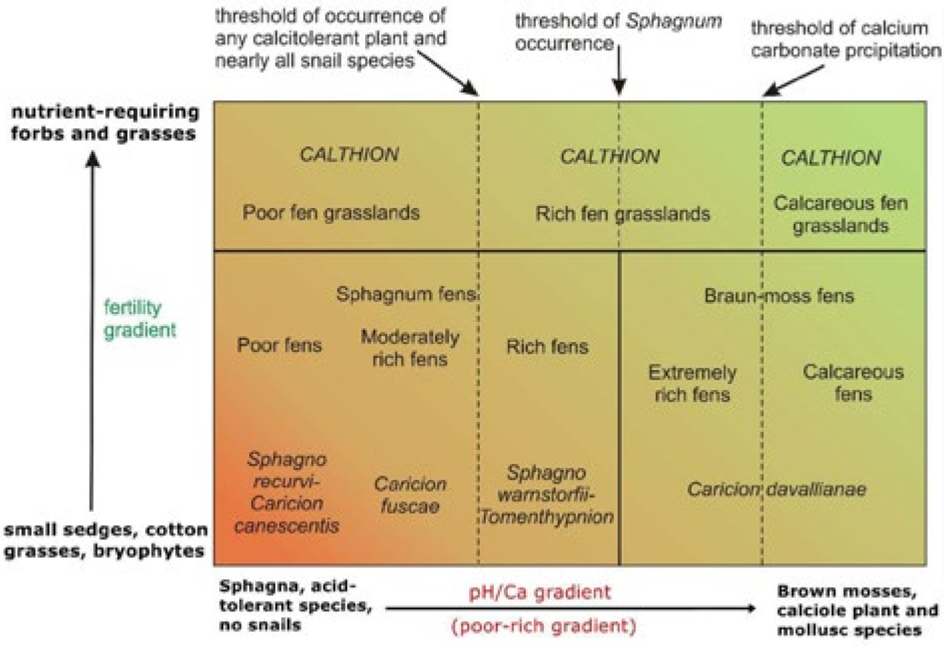



Fig. 20. Relationship between typological diversity of low peatlands with a gradient of pH and fertility, syntaxonomic position and main functional and structural boundaries (according to Hájek et al. 2006).

## 2.6. Physicochemical factors decisive for diversity of vegetation in alkaline fens

***Paweł Pawlikowski, Łukasz Kozub***

**Fens as ecosystems particularly dependent on a wide spectrum of habitat conditions**

Mire ecosystems are dependent on many interlinked and interacting environmental factors (hydrological, geochemical, climatic, biological and others) (Wheeler, Proctor 2000). The origin of feeding waters, determining their chemical composition, and the water table dynamics are decisive factors for differentiating between alkaline fens and other types of mires, such as acidic *Sphagnum*-dominated mires and fertile eutrophic tall-sedge and reed mires (Grootjans et al. 2006). Waters supplying the fens are influenced by biochemical processes governed by living organisms, particularly microorganisms (bacteria), and physical factors (Lamers et al. 2012, Rydin et al. 2006). It should be emphasized that the habitat conditions within fens are very variable: saturation with water, temperature, evaporation, origin of water and microorganisms communities composition change in annual (Hájek et al. 2005) and even diurnal cycles. These cycles affect the chemical composition of fen waters, oxygen availability in the surface layers of peat and interspecific competition determining species composition of fen communities.

**pH**

Alkaline fens, despite their name, are not always characterized by alkaline pH. Their pH depends predominantly on the amount of dissolved minerals, mostly calcium carbonates. In typical alkaline fens, fed by highly mineralized groundwater, calcium is abundant (usually over 50 mg/l; Sjörs, Gunnarsson 2002). In uplands and some mountain ranges of southern Poland, where peatlands develop on substratum built of carbonate rocks or ones that are very rich in calcium and magnesium, indeed the pH value within alkaline fens is usually slightly basic (Koczur, Nicia 2013, Schenková et al. 2014). In lowland Poland, calcium concentrations most often range from 20 to 90 mg/l (Wołejko 2002, Pawlikowski 2010, Pawlikowski et al. 2010, 2013), while pH values are often a little lower than 7 (Wołejko 2002, Pawlikowski 2006, 2010, Pawlikowski et al. 2010, Jabłońska et al. 2011).

However, what was already proven by studies by the famous Swedish peatland ecologist H. Sjörs (1950) – fundamental for the development of knowledge on peatland ecosystems – vegetation typical of alkaline fens with a dominance of brown mosses, i.e. sedge-brown-moss fen vegetation, can develop at pH values lower than 7 but almost always higher than 6, while the pH value of raised bogs dominated by *Sphagnum* mosses and without "calciphilous" species is almost always lower than 5. It is because pH values between 5 and 6 are very rarely encountered in natural ecosystems since solutions of pH above 6 are buffered by dissolved minerals, mostly carbonates, while those below pH 5 – by organic acids, especially humic acids (Gorham et al. 1984, Vitt 2000, Wheeler & Proctor 2000). This clearcut difference resulting from chemical properties of solutions provides a simple way to distinguish alkaline fens from acidic mires (acidic minerotrophic *Spaghnum*-mires and raised bogs).

Nonetheless, alkaline fens in which, for different reasons, the pH values of the surface waters are relatively low (around a borderline value of pH 6) and which, instead of brown mosses, are dominated by specific species of *Sphagnum* mosses, especially by those, which tolerate higher calcium concentrations (which are toxic to a majority of *Sphagna*, Vicherová et al. 2015), e.g., *Sphagnum teres* and *Sphagnum warnstorfii* (Hájková, Hájek 2004, Pawlikowski 2010, Pawlikowski et al. 2010, Vicherová et al. 2017), exist. Such fens are often included into the *Sphag-*

*no-Tomentypnion* alliance (Peterka et al. 2017) and they can show similarities in terms of species composition and chemical characteristics to acidic minerotrophic fens (often called transition mires, habitat type 7140) in which they can develop if acidification processes will continiue.

Despite all of the above, according to the methodology of the State Environmental Monitoring, if the conservation status of alkaline fens (habitat 7230) is assesed, the index "pH" (treated as "cardinal" so decisive for the whole parameter) can be assessed as favourable (FV) only when the pH value is equal or higher than 7; any value below pH 7 requires lower index assessment. As a consequence, even highly valuable and natural but insufficiently mineral-rich alkaline fens can be assessed as being in unfavourable-inadequate (U1) conservation status, which seems unjustified and in contradiction with the knowledge about the diversity and ecology of these ecosystems. This problem will be addressed further (see Chapter 11.1.3).

**Electrolytic conductivity (EC)**

Apart from high pH value, groundwater supplying alkaline fens is usually characterized by relatively high mineral content. It is because waters circulating for months or years in bedrock dissolve its components and, in the processes of chemical weathering, they are concomitantly enriched in substances leached inward to the soil profile. The main cations dissolved in fen-feeding waters include (in decreasing order from the most to the least abundant): calcium, magnesium, iron, potassium, sodium, manganese and aluminum, while carbonates dominate among anions. The presence of other anions (most often sulfates and chlorides) can be an indicator of groundwater pollution by human activity or can result from natural circumstances such as specific geological structure (presence of halite or gypsum) or climatic conditions (very dry climate or proximity of an ocean). The mineralization of waters supplying alkaline fens, expressed with the most commonly used measure, i.e., electrolytic conductivity (EC) of solution, usually amounts to several hundred μS/cm (Wołejko 2002, Hájek et al. 2005, Pawlikowski 2010, Pawlikowski et al. 2010). In alkaline fens, EC usually ranges from 200 to 800 μS/cm (Wołejko 2002, Pawlikowski 2010, Pawlikowski et al. 2010, 2013). However, there are alkaline fens characterized by relatively soft waters (electrolytic conductivity even slightly lower than 100 μS/cm) with a pH value being slightly acidic or close to neutral. In Poland, such situations are unique, but those oligotrophic sites are refuges for rare species, relics of colder periods and those associated with oligotrophic habitats, e.g., *Pseudocalliergon trifarium* and *Scorpidium scorpioides*. Such fens are preserved almost exclusively in the young-glacial landscape of northern Poland (mostly in the Suwałki area) though there are known from the Carpathians, where they are regarded as relict. Such fens were recently classified into *Stygio-Caricion limosae* alliance (Peterka et al. 2017, 2018).

On the other hand, if mineral content of water supplying the fen will be particularly high (electrolytic conductivity above 1000 μS/cm), which is possible when besides carbonates, which have low solubility and cannot cause too high solution mineralization, sulfates and chlorides appear, then species, such as *Triglochin maritima* or *Glaux maritima* (which was observed in the Slovak Carpathians, Háberová & Hájek 2001), typical for saline habitats can develop within alkaline fens. Such sites are at the same time characterised by reduced moss cover. Sufficiently high mineralization or fast water flow is also a condition for calcite precipitation and tufa deposition. This process is connected with a reduction of carbonate solubility due to: 1) an increase in the temperature of the water flowing out to the surface (for this reason it is very rare in the boreal zone), 2) the "escape" of carbonates from the water in form of $CO_2$ and the resulting increase in pH value (physical phenomenon in carbonate-rich waters), and 3) a pH rise due to the intake of bicarbonates from the water by the moss layer during photosynthesis (Boyer & Wheeler 1989, de Mars et al. 2016). The latter process appears to be the most significant cause of calcite precipitation in relatively cold climatic conditions, i.e., in our climate zone, especially in northern Poland (Grootjans et al. 2015, de Mars et al. 2016).

**Nutrients**

Undistorted, natural, peat-forming alkaline fens are mezotrophic or even oligotrophic but never eutrophic ecosystems. It is because under eutrophic conditions competitive species of vascular plants, like reed or tall sedges eliminate short-growing highly specialized fen vascular plants (small and medium sedges and related species, herbs, orchids, carnivorous plants, etc.) and, most importantly, often hamper possibilitis of moss layer development, which is a key component of low-productive, mossy mires, including alkaline fens. Groundwater supplying fens is usually naturally poor in nutrients (if not polluted from anthropogenic sources). In addition, peat formation leads to a natural reduction of available nutrients.

In mires, contrary to other terrestrial ecosystems, a fraction of biomass produced every year is not fully decomposed but is accumulated in peat. That fraction is estimated to be up to a few percent per year (Moore 1989). Thus, some nutrients are naturally withdrawn from the cycling and the fertility of the fens is limited. Nevertheless, the persistence of this withdrawal and its effectiveness are strongly dependent on water conditions. Only a stable water supply, with a water level close to the fen surface throughout the year, ensures the prevalence of anaerobic conditions already several centimeters below the soil surface, which strongly suppresses the decomposition of organic matter.

Fluctuations of the water level, natural or often resulting from human activity, first of all limit the amout of nutrients that can be stored in a particular year and, what is more, they can lead do peat mineralization, i.e., the release of nutrients (in the form of ammonium and phosphate ions) accumulated in previous years and to an abrupt increase of fertility which is a threat to the survival of species typical of alkaline fens (Cusell et al. 2013, Mettrop et al. 2015). A greater availability of nutrients in fens often leads to moss layer becoming dominated by the ubiquitous species – *Calliergonella cuspidata*. The increased availability of phosphorus (Kooijman, Paulissen 2006) or potassium (Vicherová et al. 2015) can also facilitate the expansion of *Sphagnum*-mosses.

**Nutrient limitation**

Primary productivity in ecosystems on Earth can be limited by the deficit of any from the major nutrients, including phosphorus, nitrogen and potassium. According to the Liebig's law of the minimum, (Liebig & Playfair 1847), the deficit of any nutrient (e.g. phosphorus), even if other nutrients (nitrogen, potassium are abundant, restricts ecosystem productivity and conserves it in the mesotrophic or oligotrophic state, which are typical for alkaline fens. In alkaline fens it is phosphorus and nitrogen, which can limit primary production. The former one is mostly present in a form of phosphates. Their solubility, i.e., availability for plants, depends on redox potential and on the presence of cations, with which they can form insoluble compounds (i. e. calcium, iron). Nitrogen is available, in reduced fen environment, in the form of ammonium ions, and even though it is stored at large amounts in peat, it is not released under stable water supply, thus remaining unavailable to producers (Koerselman et al. 1990). The third, potentially most important nutrient, i.e., potassium, as we already mentioned, is relatively abundant in groundwater, so it rarely limits primary productivity in undisturbed fens but often in meadows resulting from their deep drainage (de Mars et al. 1996).

Until recently, it was believed that phosphorus aviliability was the main productivity-limiting factor in alkaline fens, as in other calcium-rich ecosystems. It was related to the formation of insoluble compounds of calcium with phosphates resulting in phosphorus deficit and reduced fertility and productivity (Boyer, Wheeler 1989, Wassen et al. 2005). Indeed, under such conditions typical alkaline fen vegetation of the *Caricion davallianae* alliance develops (Peterka et al. 2017). However, the results of studies in Poland demonstrated that some types of fen vegetation, with dominating slender green feather moss *Hamatocaulis vernicosus* (Olde Venterlink & Vittoz 2008, Peterka et al. 2017), and also other continental, initial, species rich sedge-moss fens of the *Saxifrago-Tomentypnion* alliance (Olde Venterlink & Vittoz 2008, Peterka et al. 2017) could have primary productivity controlled by limited availability of nitrogen. It seems that the gradient of relative phosphorus and nitrogen availability is one of the most important drivers of species composition within alkaline fens having a comparable level of fertility, pH and cation availability (Pawlikowski et al. 2013, Cusell et al. 2014, Schenková et al. 2014 and *Øien* et al. 2018).

Photo 19: An example of a phosphorus-limited alkaline fen (photo by Ł. Kozub).

Photo 20: An example of a nitrogen-limited alkaline fen (photo by I. Dembicz).

Distinct groups of species can be associated with alkaline fens, primary production of which is limited either by phosphorus or nitrogen deficit. The first group comprises of species considered to be calcicole, occurying also within litter meadows of *Molinion* alliance, such as *Carex lepidocarpa*, *Carex flava*, *Eleocharis quiqueflora*, *Eriophorum latifolium*, *Limprichtia cossoni* or *Campyllium stellatum* (Photo 19 – a sedge-moss fen with species indicating phosphorus limitation). The second group, apart from the already mentioned yellow marsh saxifrage *Saxifraga hirculus* and slender green feather moss *Hamatocaulis vernicosus*, also comprises species occurying, apart from fens, also within wet meadows of the *Calthion* alliance, such as *Rumex acetosa*, *Lychnis flos-cuculi* or *Poa pratensis*, and of mosses, a fen form of *Marchantia polymorpha* (Photo 20 – a sedge-moss fen with species indicating nitrogen limitation) (Pawlikowski et al. 2013, Schenková et al. 2014, Øien et al. 2018).

Calcium and iron ions can additionally influence the availability of phosphorus and nitrogen and thus determine which of these elements will become a factor limiting primary productivity. Mettrop et al. (2018) found correlations between a high content of calcium and limitation by phosphorus deficit and between a high iron content and limitation by nitrogen deficit (see also below).

**The role of iron**

As it was already mentioned, it seems that iron is an element the abundance of which can strongly modify species composition or ecological processes within alkaline fens. Since this element can occur in two oxidation states, dependent upon redox potential, and ferric and ferrous salts differ in solubility, iron strongly influences the above-described factors determining phosphorus and nitrogen availability (Mettrop et al. 2018) and thus the fertility of alkaline fens, especially under conditions of unstable water supply. First of all, oxidized iron exposed to even a short drought episode can be a source of electrons for aerobic microorganisms even after water level rise and can accelerate the decomposition of organic matter (including peat). It leads to the release of both phosphate and ammonium ions, which increases the general fertility of iron-rich locations and slows down peat-forming processes there (Aggenbach et al. 2013, Emsens et al. 2016, 2017).

Moreover, iron forms complexes with phosphates, the solubility of which is very sensitive to fluctuations of redox potential. Thus, it functions as a phosphorus trap during drought, causing phosprorous accumulation in the fen (preventing for example its leaching into surface waters) to release it in large amounts during flooding (Aggenbach et al. 2013, Emsens et al. 2016, 2017, Zak et al. 2004). For this reason, contrary to previously prevailing views, primary production in iron-rich fens is usually limited by nitrogen, which makes them more vulnerable and prone to degradation as a result of, e.g., airborne nitrogen deposition (Olde Venterlink & Vittoz 2008) or hydrological disturbances (leading to peat mineralization) (Emsens et al. 2017). Apart from the above, it should be emphasized that high iron concentrations can influence fen vegetation by the iron's direct toxicity, to which some plant and moss species are less sensitive (e.g., *Menyanthes trifoliata*, *Carex rostra-*

*ta*, *Equisetum fluviatile*) (Snowden & Wheeler 1993, Wheeler et al. 1985, Hájek et al. 2005). Slightly disturbed iron-rich fens are also more difficult to restore because implementation of restorative measures aimed at rewetting and stabilisation of high water levels (e.g., by damming or removal of drainage network) increases their fertility via the above-described mechanism of phosphorus release from unstable compounds with iron, which can lead to the retreat of typical alkaline fen vegetation in favour of tall-sedge communities (Stańko et al. 2018, Aggenbach et al. 2013, Emsens et al. 2017).

Photo 21: Ferruginuous seepage in an alkaline fen (photo by Ł. Kozub).

# 3. PLANT COVER

***Lesław Wołejko, Robert Stańko***

## 3.1. Plant communities specific for alkaline fens

The vegetation cover of alkaline fens can be built by very different plant communities (see wider discussion of the possible vegetation of this type of habitat in Stańko et al. 2018). However, several plant associations are specific to this ecosystem. These associations were included by most authors in two orders: *Caricetalia davallianae* and *Scheuchzerietalia palustris*. The first order includes the *Caricion davallianae* alliance, as well as the recently distinguished *Sphagno warnstorfiani-Tomenthypnion* alliance (Hájek et al. 2006, Šefferová-Stanová et al. 2008). Plant associations from these orders are key components of the vegetation of some alkaline wetlands, and some of them exhibit a close (or sometimes even exclusive) relationship with these ecosystems. Related carbonate ecosystems are petrifying -, calcarous - and alkaline fen types.

The vegetation belonging to the *Caricetalia davallianae* order has been the subject of many publications. In the mountain and upland areas vegatation of alkaline fens consists of the following plant associations: *Valeriano-Caricetum flavae*, *Caricetum davallianae*, *Ctenidio mollusci-Seslerietum uliginosae*, *Lipario-Schoenetum ferruginei* and *Sphagno warnstorfiani-Eriophoretum latifolii* (e.g., Fijałkowski 1959, Pawłowski et al. 1960, Kornaś & Medwecka-Kornaś 1967, Stuchlikowa 1967, Hereźniak 1972, Grodzińska 1975, Jargiełło 1976, Głazek 1984, 1992, Fijałkowski & Chojnacka-Fijałkowska 1990, Pisarek 1996, Hájek 1999, Jutrzenka-Trzebiatowski & Szarejko 2001, Towpasz & Stachurska-Swakoń 2009 and Koczur & Nicia 2013). A more complete review of the literature sources, including unpublished materials, can be found in the monograph of Vončina (2017).

From the fens found in the lowland situated in the northern and north-western part of Poland, the following associations have been reported: *Eleocharitetum pauciflorae (=Eleocharitetum quinqueflorae), Campylio-Caricetum dioicae*, *Caricetum paniceo-lepidocarpae*, *Juncetum subnodulosi*, *Orchido-Schoenetum nigricantis*, *Campylio-Trichophoretum alpini, Helodium blandowii-Carex acutiformis* community, *Carex buxbaumii* community, *Schoenus ferrugineus* community and many others (Steffen 1931, Kaczmarek 1960, 1962, Jasnowski 1962, Pałczyński 1975, Głowacki & Wilczyńska 1979, Jasnowska & Jasnowski 1983, Herbich & Herbichowa 1984, Sokołowski 1986-1987, 1988, 1996, Tyszkowski 1993, Kucharski 1998, Kwiatkowski 1999, Wołejko 2000b, Wojterska et al. 2001, Pawlikowski 2000, Herbich 2017).

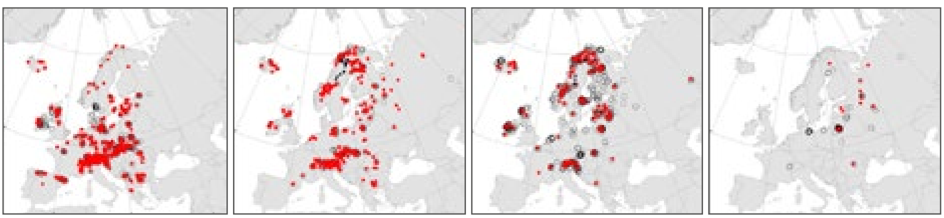
Photo 22: *Menyantho-Sphagnetum teretis* (photo by R. Stańko).

Photo 23: *Eleocharitetum pauciflorae (=Eleocharitetum quinqueflorae)* (photo by R. Stańko).

The order *Scheuchzerietalia palustris* essentially consists of plant associations typical of other peatland habitats (such as sub-neutral and transitional mires). However, for northern Poland in particular, two additional associations have been included in this order, i.e., *Menyantho-Sphagnetum teretis* and *Scorpidio-Caricetum diandrae* (= *Caricetum diandrae*), constituting the dominant element of undrained alkaline fens, classified as habitat type 7230, as defined in Chapter 1. Within these phytocoenoses, peatland species with a wider ecological amplitude are supplemented by less numerous species characteristic of the *Caricion davallianae* alliance.

Figures 22-31 show the most recent distribution of the most important indicator associations for alkaline fens in Poland. The source of this information is the updated database on alkaline fens, available at the webpage of the Naturalists Club. The dissemination image was supplemented with verified phytosociological data from scientific publications. The nomenclature of the associations follows Ratyńska et al. (2010).

In the light of new knowledge (Peterka et al. 2017), the inclusion of some of these associations in higher syntaxonomic units (especially in the rank of alliance) needs revision. This applies mostly to associations previously included in the *Caricion lasiocarpae* alliance. As a result of the recent analysis of abundant phytosociological records from Europe, vegetation of fen and transitional mires has been regrouped into 13 units in the rank of alliance (Peterka et al. 2017). In view of this new classification, the vegetation of the best preserved Polish alkaline fens contains floristic elements representing mainly 4 vegetation alliances: *Caricion davallianae* Klika 1934, *Stygio-Caricion limosae* Nordhagen 1943, *Sphagno warnstorfii-Tomentypnion nitentis* Dahl 1956 and *Saxifrago-Tomentypnion* Lapshina 2010, which partly have different geographical ranges (Fig. 21).



*Caricion davallianae* *Sphagno-Tomentypnion* *Stygio-Caricion limosae* *Saxiftrago-Tomentypnion*

Fig. 21. Distribution of four natural alkaline fen communities (in the rank of alliance) in Europe (Peterka et al. 2017).

The *Caricion davallianae* alliance includes the vegetation of petrifying spring and alkaline fens supplied with calcareous groundwater. The dominating species in the herbaceous layer are mainly calcitrophic sedge plants (including *Carex davalliana, Carex hostiana, Eleocharis quinqueflora, Eriophorum latifolium, Schoenus ferrugineus*) and herbs, such as *Parnassia palustris, Pinguicula vulgaris, Primula farinosa* and *Tofieldia calyculata*. In the layer of bryophytes, there is *Campylium stellatum* s.l., *Limprichtia cossonii*, *Palustriella commutata* s.l. and *Philonotis calcarea*. *Caricion davallianae* phytocoenoses are widespread in Europe, but the

Fig. 22. Distribution of the *Valeriano-Caricetum flavae.*

Fig. 23. Distribution of the *Caricetum davallianae.*

Photo 24: *Caricetum davallianae* (photo by R. Stańko).

centers of their occurrence are situated in the Alps and the Carpathians. In Poland some of these species are currently extremely rare. An examples is *Primula farinosa* with only one site. In Poland, associations belonging to the *Caricion davallianae* alliance are best developed within the alkaline flush fens. The *Valeriano-Caricetum flavae* association Pawłowski 1949 ex 1960 is present almost exclusively (but frequently) in the mountains and foothills. The second of the frequent associations – *Caricetum davallianae* Dutoit 1924 – has a wider range and can be found throughout southern Poland.

Photo 25: *Valeriano-Caricetum flavae* (photo by D.Horabik).

Two other associations belonging to the *Caricion davallianae* alliance are the *Ctenidio mollusci-Seslerietum uliginosae* Klika 1943 em. Głazek 1984 and the *Schoenetum ferruginei* Du Rietz 1925, which are both concentrated in specific regions of Poland only (Fig. 24 and Fig. 25). The *Ctenidio mollusci-Seslerietum uliginosae* has a very limited distribution and is almost exclusively found in the Nida Basin and in the Świętokrzyskie Mountains. The occurrence of *Schoenetum ferruginei* is mainly limited to south-eastern Poland, where it is a component of alkaline fen developed in the complex of specific calcareous mires, that have been formed on top of the chalk deposits (Buczek & Buczek 1993, see also chapter 7.2).

Fig. 24. Distribution of the *Schoenetum ferruginei.*

Fig. 25. Distribution of the *Ctenidio mollusci-Seslerietum uliginosae.*

Photo 26: *Schoenetum ferruginei* on the dome of a spring fen with travertine deposits (Śniatycze-Komarów near Zamość) with a large share of *Swertia perennis* and *Molinia caerulea***.** In the background, the *Cladietum marisci* association covering the top of the cupola (photo by D. Horabik).

The association *Caricetum paniceo-lepidocarpae* (Steffen 1931) W. Braun 1968 occurs all over the country, but is the most frequent *Caricion davallianae* association of the north-eastern Poland. The rarer, pioneer community *Eleocharitetum pauciflorae* Lüdi 1921 also has a wide distribution pattern in Poland.

The *Juncetum subnodulosi* (Allorge 1922) W. Koch 1926 association is restricted to north-western Poland, which is probably related to the sub-Atlantic character of *Juncus subnodulosus* (Markowski & Stasiak 1988).

Photo 27: *Caricetum paniceo-lepidocarpae* (photo by R. Stańko).

Photo 28: *Juncetum subnodulosi* (photo by R. Stańko).

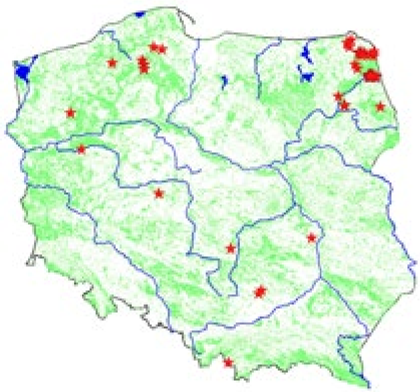


Fig. 26. Distribution of the *Caricetum paniceo-lepidocarpae.*

Fig. 27. Distribution of the *Eleocharitetum pauciflorae.*

Fig. 28. Distribution of the *Juncetum subnodulosi.*

The alliance of *Sphagno warnstorfii-Tomentypnion nitentis* is characterized by the presence of calcium-tolerant *Sphagnum* mosses (such as *Sphagnum contortum*, *Sphagnum subnitens*, *Sphagnum teres* and *Sphagnum warnstorfii*) and also by brown mosses occupying higher positions in microtopography (e.g., *Aulacomnium palustre*, *Paludella squarrosa* and *Tomentypnum nitens*). Typical species of alkaline fens are also numerous here: *Campylium stellatum* s.l., *Limprichtia revolvens agg.*, *Carex davalliana, Eleocharis quinqueflora, Eriophorum latifolium, Parnassia palustris* etc. Acidophilous plants with shallow roots (e.g., *Drosera rotundifolia*) can be found on elevated hummocks formed by bryophytes, constituting favourable conditions. The large diversity of micro-habitats causes the mire vegetation of this alliance to be one of the richest in floristic terms. It is spread throughout Europe, but more often found in mountainous and upland areas. Also in Poland, the generally rare localities of the communities belonging to the alliance have been mainly found in mountainous and sub-mountainous areas: in the Carpathians (Hájek 1999), the Sudety Mountains (e.g., Orlicke Mountains: Smoczyk & Karakula 2016), and even within the limits of Kraków municipality– as a *Sphagno warnstorfii-Eriophoretum latifolii* association, Rybníček 1974 (Koczur 2014).

Proposals to include some phytocenoses of alkaline fens of northern Poland in the *Sphagno warnstorfii-Tomentypnion* alliance, require a critical analysis. In the light of available phytosociological records, the floristic affinities of the previously recognized communities from the *Sphagno warnstorfii-Tomentypnion* alliance with the flush fen associations *Valeriano-Caricetum flavae* and *Caricetum davallianae* are visible.

Fig. 29. Distribution of the *Sphagno warnstorfii-Tomentypnion nitentis.*

Phytocoenoses belonging to the *Stygio-Caricion limosae* alliance are often found in strongly hydrated peatlands with a topogenic water supply type. The vegetation consists of small sedges (e.g., *Carex chordorrhiza*, *Carex lasiocarpa*, *Carex limosa*) and brown mosses forming loose turfs (e.g., *Pseudocalliergon trifarium*, *Scorpidium scorpioides*) and a few *Sphagnum* mosses (e.g., *Sphagnum contortum* and *Sphagnum platyphyllum*). The communities of this alliance are widespread in northern Europe, reaching southward to the British Isles and Ireland and north-eastward to the Baltic Republics. It is also found in the Alps and, less often, in the Carpathians and the Balkans. Many of the foregoing species are floristic peculiarities in Poland, found mainly on the best-preserved alkaline and subneutrial fens of northern Poland. To date, no specific plant associations have been assigned to this alliance. Initial vegetation analysis carried out for the purpose of this study suggests that it should include the most-common Polish sedge-moss associations, especially those occurring in the north of the country: *Menyantho-Sphagnetum* *teretis* Warén 1926 and *Scorpidio-Caricetum diandrae* Osvald 1926 nom. inverse. et nom. mut. Until now, these associations were most often included in the alliance *Caricion lasiocarpae* Vanden Berghen in Lebrun et al. 1949 or *Caricion nigrae*, however the legitimacy of distinguishing this first alliance is currently being questioned (Peterka et al. 2017).

Fig. 30. Distribution of the *Menyantho-Sphagnetum teretis.*

Fig. 31. Distribution of the *Scorpidio-Caricetum diandrae.*

The *Saxifrago-Tomentypnion* alliance includes fens rich in calcium (but no accumulation of calcareous tufas). In addition to species typical of the alkaline fen plants described above, there are bryophyte species with higher trophic requirements. These are wetland species with a wider ecological spectrum (such as *Brachythecium mildeanum*, *Drepanocladus aduncus* agg., *Marchantia polymorpha*) or specialized brown mosses with a higher demand for phosphorus (such as *Hamatocaulis vernicosus*; c.f., Hájek et al. 2014). A characteristic feature of the herbaceous layer is the coexistence of marsh and water plants (*Cicuta virosa*, *Ranunculus lingua, Thelypteris palustris*), meadow species (such as *Poa pratensis* agg., *Rumex acetosa* s.l.), and sometimes rare species of nutrient-poor boreo-continental habitats (*Saxifraga hirculus, Stellaria crassifolia*, *Triglochin maritima*). The alliance, originally described from western Siberia, occurs in the north-eastern part of the European Lowlands and in isolated positions of the Romanian Carpathians. It was also found at several positions in Germany (Peterka et al. 2017). Within Poland, most of the sites with the vegetation of this alliance is probably related to the presence of specific subneutral mires, which are frequent in the Suwałki Lake District (Pawlikowski et al. 2013).

It is worth noting that all plant associations specific for alkaline fens are rare or very rare in Poland, and their threat condition is defined as "directly threatened with extinction" or "vulnerable" (Ratyńska et al. 2010).

## 3.2. Indicative plant species

The flora of alkaline fens is very rich, which distinguishes these ecosystems from other types of peatlands, e.g., moss mires – bogs or most of the transitional mires. Over 400 species of vascular plants and about 80 species of mosses (Herbichowa & Wołejko 2004) occur on alkaline fens. Most species that are considered typical (representative) for this habitat are protected species in Poland. Some of them are species with a narrow ecological amplitude and almost absent outside of this type of habitat. Particularly noteworthy species include: many species of brown mosses, orchids and species from Annex II of the Habitats Directive (Wołejko et al. 2012, in Polish). Alkaline fens belong to the richest habitats in rare, protected and endangered plant species in the Polish landscape (Krajewski et al. 2017).

According to previous studies (Wołejko et al. 2012, Stańko et al. 2018) species that are characteristic of the alliance *Caricion davallianae* should be considered as species typical for alkaline fens. These include, for example: *Carex buxbaumii*, *Carex davalliana, Carex flava, Carex lepidocarpa, Carex panicea, Gentianella uliginosa*, *Polygala amarella, Eriophorum latifolium*, *Valeriana simplicifolia*, *Juncus subnodulosus, Schoenus ferrugineus*, *Eleocharis quinqueflora*, *Equisetum variegatum* and *Juncus alpino-articulatus* (= *J. alpinus*). The characteristic species of the alliance, occurring (at least theoretically) in a larger number of associations, include: *Bryum pseudotriquetrum, Campylium stellatum*, sedges: *Carex flacca*, *Carex hostiana* and *Carex pulicaris,Dactylorhiza incarnata*, *Dactylorhiza majalis*, *Epipactis palustris*, *Fissidens adianthoides*, *Limprichtia cossonii*, *Liparis loeselii*, *Parnassia palustris*, *Pinguicula vulgaris*, *Primula farinosa, Scorpidium scorpioides*, *Sesleria caerulea* (=*S. uliginosa*), *Swertia perennis*, *Tofieldia calyculata* and *Valeriana dioica.* The presence of these species usually indicates a good condition of ecosystems (Stańko et al. 2018). Due to the rich and widely available literature (identification keys, atlases, including electronic ones), we present only photographs of selected plant species here, partly presented also in the Guidebook on alkaline fens conservation (Stańko et al. 2018).

Typical species, yet obviously non-exclusive for alkaline fens, also include species that are characteristic of higher syntaxa like the class *Scheuchzerio-Caricetea fuscae*, e.g.: *Baeothryon alpinum, Calliergon giganteum, Carex dioica, Carex chordorrhiza, Carex diandra, Carex lasiocarpa, Carex limosa, Cinclidium stygium, Eriophorum gracile, Hamatocaulis vernicosus, Helodium blandowii, Limprichtia revol-*

Photo 29: *Tofieldia calyculata* (photo by R. Stańko).

Photo 30: *Carex davalliana* (with *Dactylorhiza majalis* in the background) (photo by R. Stańko).

Photo 31: *Carex lepidocarpa* (photo by K. Kiaszewicz).

Photo 32: *Carex panicea* (photo by K. Kiaszewicz).

Photo 33: *Carex pulicaris* (photo by R. Stańko).

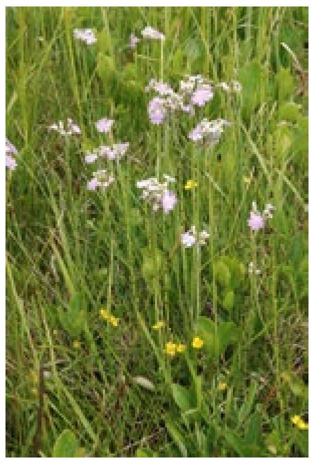


Photo 34: *Primula farinosa* (photo by R. Stańko).

Photo 35: *Schoenus ferrugineus* (photo by E. Gutowska).

Photo 36: Flowering fen orchid *Liparis loeselii* on a sedge moss fen dominated by *Paludella squarrosa* (photo by R. Stańko).

Photo 37: *Saxifraga hirculus* (photo by R. Stańko).

Photo 38: *Eleocharis quinqueflora* (photo by R. Stańko).

Photo 39: *Juncus subnodulosus* (photo by R. Stańko).

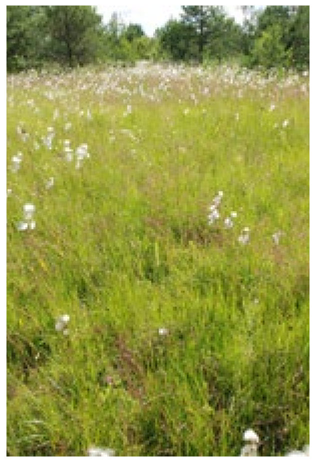


Photo 40: *Eriophorum latifolium* (photo by R. Stańko).

*vens, Meesia triquetra, Menyanthes trifoliata, Paludella squarrosa, Pseudocalliergon trifarium, Saxifraga hirculus, Sphagnum teres, Sphagnum warnstorfii, Sphagnum contortum, Stellaria crassifolia, Tomentypnum nitens, Pedicularis palustris, Pedicularis sceptrum-carolinum, Triglochin palustre* and *Warnstorfia exannulata.*

Photo 41: *Swertia perennis* (photo by R. Stańko).

Photo 42: *Pedicularis palustris* (with *Dactylorhiza majalis* in the background) on one of the flush fens upstream of the Bembeński stream (Czarna Orawa) (photo by R. Stańko).

Photo 43: Flowering *Triglichin palustris* (photo by R. Stańko).

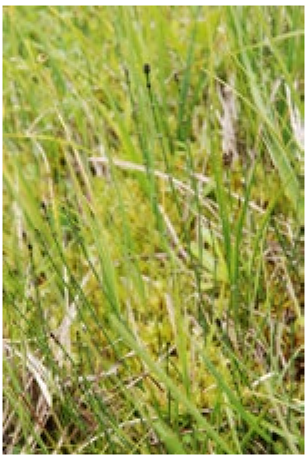


Photo 44: *Equisetum variegatum* (photo by R. Stańko).

Photo 45: Postglacial relict - *Betula humilis* (photo by E. Gutowska).

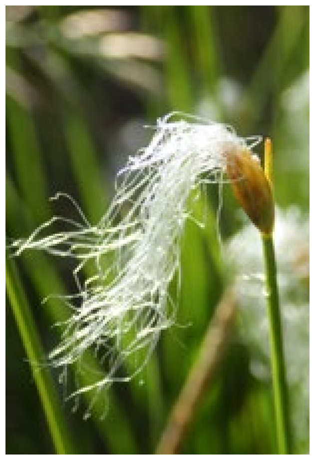


Photo 46: Postglacial relict –*Baeothryon alpinum* (photo by E. Gutowska).

Typical species for mountain flush fens include *Carex flava*, *Carex panicea*, *Eriophorum latifolium*, *Epipactis palustris*, *Tofieldia calyculata*, *Carex davalliana*, *Carex dioica* and *Valeriana simplicifolia*, and the physiognomy of the fen is also determined by *Equisetopsida*, tuft-like sedges and *Crepis paludosa*.

Photo 47: *Salix lapponum* (photo by E. Gutowska).

Photo 48: *Meesia triquetra* (photo by E. Gutowska).

In general, however, it is impossible to provide good, specific floristic or phytosociological identifiers for alkaline spring fens, including flush fens. Their vegetation is usually built from species with broad ecological amplitudes, and species with *Caricion davallianae* are not always present. In these cases, to identify the natural habitat of 7230, the ecology of the ecosystem must be crucial, not its vegetation or flora alone.

It is worth mentioning that in the practice of nature conservation monitoring there are four lists of species of plants associated with the 7230 habitat, differing slightly in detail:

- list of species considered characteristic of habitat 7230 in GIOS monitoring (state environmental monitoring);
- list of species considered characteristic of habitat 7230 in ITP monitoring (monitoring of the agri-environmental program);
- a list of indicative species – qualifying parcels to aplication of the Sedge - Moss Scheme as part of the agri-environmental program from Rural Development Plan 2007–2013;
- a list of indicative species – qualifying parcels for application of the Peatland Scheme as part of the agri-environmental and climatic program of the Rural Development Plan 2014–2020 (except for species associated with the natural habitat 7230 containing species associated with other types of peatlands).

These lists are further provided in Chapter 11 on monitoring.

Lists of species typical of alkaline fens also exist in other EU countries (e.g., Chytry et al. 2001, Beutler & Beutler 2002, Verbücheln et al. 2004, Polak & Saxa 2005, Aunina 2013 and Bundesamt für Naturschutz 2017), often also constituting an element in the methodology of monitoring and assessment of the state of this natural habitat. They are similar, but may differ in detail due to the diversity of flora, sometimes different habitat preferences of species in different parts of their range, but also due to the regional history of use and transformation of alkaline fens as well because of  differences in interpretation of this type habitat in individual countries.

Photo 49: Flowering *Carex dioica* (photo by R. Stańko).

Photo 50: *Sphagnum teres* (photo by R. Stańko).

Photo 51: *Cinclidium stygium* (oval leaves) with some *Paludella squarrosa* (photo by R. Stańko).

Photo 52: *Pseudocalliergon trifarium* – a species associated with the most hydrated fragments of fens and reservoirs within them (photo by R. Stańko).

Photo 53: Blooming *Dactylorhiza majalis* and blooming *Menyanthes trifoliata* (on the right) (photo by R. Stańko).

Photo 54: Blooming *Pinguicula vulgaris* surrounded by *Limprichtia cossonii* (photo by R. Stańko).

Photo 55: *Carex chordorrhiza* (photo by R. Stańko).

Photo 56: *Carex diandra* (photo by R. Stańko).

Photo 57: *Valeriana dioica* (photo by R. Stańko).

Photo 58: *Parnassia palustris* (photo by R. Stańko).

Photo 59: *Paludella squarrosa* with *Helodium blandowii* and *Aulacomnium palustre* (photo by R. Stańko).

Photo 60: *Hamatocaulis vernicosus* (photo by R. Stańko).

Photo 61:*Tomentypnum nitens* (photo by R. Stańko).

Photo 62: *Helodium blandowii* (photo by R. Stańko).

Photo 63: *Scorpidium scorpioides* (photo by R. Stańko).

# 4. THE FAUNA OF ALKALINE FENS

## 4.1. General aspects

***Andrzej Jermaczek, Paweł Pawlaczyk, Rafał Ruta***

Most animals are capable of movement; utilizing different components of the environment they are able to actively move between them in search of food, a mate or a refuge to safely survive under disadvantageous conditions. The home territorial ranges of larger species often comprise several, sometimes very different, types of habitats. Alkaline fens occur in the landscape to – with just few exeptions in Poland - as features usually of a small, more rarely, medium-size, forming complexes or even a mosaic with other wetland, aquatic, or forest habitats. Thus, it is difficult to describe fauna specific for such a type of habitat as alkaline fens, i.e., habitat 7230 in a narrow sense, with the exemption of animals of a small size, relatively less mobile. They inhabit microbiotopes of an area of several or a dozen or so square kilometers, and usually are highly specialized, e.g., some snails, of which alkaline fens-specific fauna is described later on in a separate section of this chapter.

Typical well-developed alkaline fens account only for a small fraction of one percent of the land area in Poland. The largest and the only truly vast complex of alkaline fens in our country encompasses the Biebrza Marshes. Over significant areas, these fens are the dominating habitat type in the landscape, and this is why they play an unquestionable role as the main refuge for many species in Poland. Thus, fauna typical of alkaline fens can be identified exactly in this area along with several other locations in northeastern Poland.

The elk *Alces alces* is undoubtedly the largest animal belonging to the specificity of landscapes dominated by alkaline fens. Although it lives in a mosaic of environments comprised mostly of complexes of alder swamp forests and shrubs, and also large forest-wetland complexes (with seasonally changing fluctuations of occurrence sites). At least in some parts of the year it prefers to feed in open or semi-open fen areas. It is commonly stated that by foraging on suckers of trees and shrubs' sprouts it undoubtedly contributes to the preservation of an open character of the habitat and succession retardation. This mechanism may be important, for example, in the preservation of alkaline fens in the Biebrza valley (Bokdam et al. 2002, Middleton et al. 2006). In the documentation of Conservation Measures Plan prepared for the Natura 2000 site in Biebrza valley (Weigle 2014) it was even proposed to recognize the elk as a key species for the 7230 habitat. It was noted there that loose willow thickets, arising on the Biebrza alkaline fens as a result of

Photo 64: The elk *Alces alces* in the fen landscape on the Biebrza River (photo by Ł. Łukasik).

secondary succession, only in case of elk presence, may represent a stable form of vegetation in the natural habitat 7230, still supporting the diversity of plant species (although not birds) typical of open mires. However, this issue is not unequivocal: other studies from the Biebrza (Devriendt 2012) suggest, however, that gnawing shoots and the flow of nutrients generated by elks can even accelerate the expansion of willows.

The beaver *Castor fiber* is the second mammal influencing the condition of alkaline fens, especially in complexes of habitats transformed by humans. The impact of the beaver on the peatland includes the biting and cutting trees and shrubs, but above all changing the water conditions by building dams there. In many cases, such damming is beneficial for peatlands. The authors of the documentation for the Conservation Measures Plan for this Natura 2000 site (Weigle 2014) point to the positive role of beavers in maintaining the proper hydration of alkaline fens in the Biebrza valley. From the Bieszczady National Park, cases of improving flush fens hydrology were described as a result of beaver activity (J. Korzeniak in Institute of Nature Conservation... 2018). Positive effects of beaver dams on hydration of spring mires were recorded on the Żytkiejmska Struga in Puszcza Notecka (Pawlikowski & Jarzombkowski 2010), as well as in the Ilanka valley in Lubusz (central-western part of Poland), where beavers additionally built up on wooden partitions (built for mire conservation purposes)  and in the Lubowo mire in Radew valley, where thanks to the beavers the construction of artificial dams on ditches was unnecessary at all. A similar impact of beavers blocking ditches was recorded on the Głógno mire in Ostoja Piska, on Zocie mire, in the "Jeziorko koło Drozdowa" nature reserve and on several mires in the Augustów Forest (Stańko & Wołejko 2018a). Beaver dams on Luciąża (river) favor the conservation of the Bęczkowice mire near Łódź, and dams on ditches stabilize the water conditions of the Śniatycze mire in the Lublin region (Stańko & Wołejko 2018b).

On the other hand, some alkaline fens may be flooded as a result of blocking the outflow through the beaver dam, which may transform the vegetation - usually by disappearance of valuable phytocoenoses and moss fen's species in favor of common rushes. The total flooding and destruction of the moss fen, on the place of which an open water table was developed, was described in the Ilanka valley. Flooding causing the transformation of the vegetation (expansion of rushes, including reed beds), was described in the Pliszka valley and Młodno nature reserve. In the Bagno Parchacz in the upper Rospuda valley after flooding by beavers, the depletion of the moss layer was noted (Stańko & Wołejko 2018a). Alkaline fens, from which - as a result of spring water feed - short streams with relatively large flows often outflow, are above-average impacted, because the same topographical conditions favor the location of beaver dams there.

The reaction of the mire to water accumulation caused by beavers can, however, be varied. Kujawa-Pawlaczyk and Pawlaczyk (2014) described in the Drawa Forest an example of an alkaline fen, Storczykowe Mechowisko, which was flooded by beavers, but the characteristic vegetation survived as a result of the fen surface raising, a few months after the flooding. Such emersive reactions of alkaline fens to the beaver damming may be more frequent. On one of the mires in the Szeszupa valley, beavers' damming caused the fen to rise, not flood, although other patches in similar conditions were flooded and degraded, and reed communities developed in their place.

The varied reactions of the moss fens on the water raising by beavers were recorded in the Czarna Hańcza valley: on some sites, the moss fen was degraded and replaced by reeds' rush, but on other sites the highly hydrated moss fens (Stańko & Wołejko 2018a) remained. It seems that the condition of the site plays a crucial role: well-preserved have a much greater ability to respond to raising the water level with vertical movements of their surface – the flooding of the surface is then less probable. It is also important what kind of water is being raised. Submerging and flooding alkaline fens with eutrophic river water usually results in significant changes in vegetation and loss of fen specific species. On the other hand, when the blocked ditch or the river supports the mesotrophic soligenous waters that filter through the fen, the functioning of the alkaline fen ecosystem can be preserved.

The flooding by beavers was indicated as a threat to 7230 natural habitat in established conservation measures plans for Natura 2000 sites: Ostoja Lidzbarska PLH280012 and Dolina Kakaju PLH280036. As part of the protection of alkaline fens, the installation of overflow devices (so called Clemson Beaver Pond Leveler) limiting the beavers damming was necessary, for example, in the Pliszka and Ilanka valleys in Lubusz Region, by the lake Wierzchołek in Wielkopolska, in the

Dłużnica valley in Tuchola Forest, in the Bukowskie Bagno in the Drawa Forest (Stańko & Wołejko 2018a). The installation of pipes regulating the water level on the beaver dams was included as a conservation measure for habitat 7230 in the conservation measures plan for the Natura 2000 sites: Dolina Górnej Rospudy PLH200022, Dolina Pliszki PLH080011, and in the already mentioned Ostoja Lidzbarska PLH280012 and Dolina Kakaju PLH280036. For Natura 2000 sites: Pojezierze Sejneńskie PLH200007 and Dolina Szeszupy PLH200016 such solution was proposed. Further such examples from nature reserves are quoted in Chapter 8.

The impact of beavers on alkaline fens is generally more complex and is only an element of the broader issue of the impact of this species on the functioning of entire catchments and landscapes (see, for example, Biały & Załuski 1994, Collen & Gibson 2001, Kobojek 2005, Janiszewski et al. 2014, Campbell-Palmer et al. 2016, Putock et al. 2017). For alkaline fens, the following phenomena may be particularly important:

1. inhibiting and slowing down the drainage of fen, as a result of modification of fluvial processes and rising the water table in watercourses in the vicinity, constituting the hydrological basis of such drainage;
2. groundwater supply from wetlands and beaver flooding (pools), which in the long term may stabilize underground water outflows at the catchment scale, crucial for alkaline fens;
3. the impact of beaver feeding on tree and herbal vegetation of fens.In particular, it seems that in strongly transformed landscapes where mires are present, the activity of beavers can be an important factor in the restoration of the landscape together with the mechanisms of its functioning, improving at the same time also the conditions for the functioning of peatlands of all types, including alkaline fens. However, knowledge about such consequences of beavers' activities is so far poor, and the possibilities of accurate prediction of such effects - very limited. It seems, however, that across a wider spatial and time scale, beavers have played a positive role in the shaping and restoration of conditions promoting the development of alkaline fens.

Birds typical of wetland complexes comprising alkaline fens are represented by at least a dozen or so species, mostly rare and endangered. Among them, the common snipe *Gallinago gallinago* belongs to the most widely distributed all over the country and relatively least demanding, nesting even in small several-hectare forest or mid-field fen complexes. However, the structure of the vegetation is important for this bird to occur, namely it has to provide shelter for the birds and their nests but should not restrict their movements and feeding. Such small patches are often feeding grounds for the green sandpiper *Tringa ochropus* which, however, nests on the fringes, most often in abandoned thrushes' nests.

Photo 65: Common snipe *Gallinago gallinago* (photo by M. Sarat).

On the other hand, the second of the snipe species nesting in Poland, the great snipe *Gallinago media*, requires large fen complexes. For this reason, only 400 – 500 displaying males have been reported to exist in our country (Chodkiewicz et al. 2015). The most abundant breeding areas can be found only in Podlasie, most of all in the Biebrza Marshes, where 16 active tooting grounds[1] were recorded in 2017 (Chief Inspectorate of Environmental Protection data). Both tooting grounds and breeding places are concentrated most often on sedge-moss fens representing the natural habitat presented herein (Korniluk & Piec 2017).

Fens bordering open areas (croplands, meadows, pastures) are inhabited by the northern lapwing *Vanellus vanellus*, still encountered all over the country and populations of other plover birds, several decades ago present throughout Poland: the common redshank *Tringa totanus*, black-tailed godwit *Limosa limosa* and the Eurasian curlew *Numenius arquata* occur already only in a few, larger fen complexes and floodplains comprising extensively used grasslands, mostly pastures. The numbers of common redshank in Poland have been estimated at only 1 500 – 2 000 pairs, black-tailed godwit at 1 000 – 1 500 pairs, and Eurasian curlew at 250 – 300 pairs (Chodkiewicz et al. 2015). Vast areas encompassing alkaline fens in north-eastern Poland, most of all in the Biebrza Marshes, are an optimal biotope for these birds and one of their last refuges.

1 A lek is a gathering of males for the purpose of competitive mating displays that occur within a chosen communal territory called a "**tooting ground**."

Photo 66: Great snipe *Gallinago media* (photo by Ł. Łukasik).

Photo 67: Black-tailed godwit *Limosa limosa* (photo by M. Sarat).

Two factors occurring in combination are important for the whole above-described group of species, namely low vegetation during early spring and constant and stable flooding of habitats throughout the nesting season that protects them from predators and humans. For these reasons, large areas well supplied with water, incorporating alkaline fens, belong to their preferred biotopes. Due to common defense of nesting sites from predators, optimal habitats are those in which a dozen or so pairs of plovers – the northern lapwings, common redshanks, black-tailed godwits, Eurasian curlew – can nest next to each other. Such a group of birds creates a kind of "protective umbrella", discouraging predators from plundering broods. Only then is the production of young high enough to allow them to function in a long-term perspective. As the quality of birds' habitat and density deteriorates, the disintegration of this protective mechanism causes that predation destroying breeding becomes a decisive factor of shrinking populations. For many species, especially plovers, alkaline fens are an important stopover site during migration. For instance, big flocks of ruffs *Philomachus pugnax* stop, feed and toot on elevations in the midst of open sedge fens.

Also, a large group of small bird species belonging to passerines Passeroformes is associated with fens, of which the aquatic warbler *Acrocephalus paludicola*. No other bird species is so strongly associated with sedges typical of alkaline fens (Tanneberger & Kubacka 2018). Its population in Poland, estimated at 3 200 – 3 250 of singing males (Chodkiewicz et al. 2015), constituting ca. 20% of the entire global population and 95-98% of EU population, is concentrated most of all in north-eastern Poland, in the Biebrza river and Narew river valleys. Over 80%

Photo 68: Ruff *Philomachus pugnax* (photo by Ł. Łukasik).

of the Poland population nests in the Biebrza National Park, exactly in complexes dominated by alkaline fens.

Natural, stable, mesotrophic alkaline fens, with low and loose sedge-moss vegetation, are the only permanent habitats for aquatic warbler with no need for human intervention. In all other habitats, this species can survive only on condition of mowing, with the need for active conservation measures the higher the more eutrophic - and therefore the less alkaline – is the fen covered with rushes (Lachman 2013, Tanneberger & Kubacka 2018).

Habitat complexes, including alkaline fens, also harbor many other bird species. Even small patches with high sedges and willow trees scattered here and there are inhabited by the sedge warbler *Acrocephalus schoenobaenus,* reed bunting *Emberiza schoeniclus*, common grasshopper-warbler *Locustella naevia*, and meadow pipit *Anthus pratensis*. Larger complexes of sedge fens are biotopes of the corncrake *Crex crex*, spotted crake *Porzana porzana*, garganey *Anas querquedula,* northern showeler *Anas clypeata,* white-winged tern *Chlidonias leucopterus*, and many others. Mires, especially those in forests, are often breeding biotopes for crane *Grus grus* None of the aforementioned species is closely tied to alkaline fens, they also colonize flooded areas, valleys of large rivers, some can be found on transition mires, calcareous mires and other more or less open wetlands; however, for many of them complexes involving alkaline fens are close to optimal habitats and key to their population survival. In many cases, especially in western and central Poland, a lot of these complexes have vanished due to ill-conceived artificial drainage or abandoning of agricultural land use which contributed to the preservation of the open character of these habitats.

The needs of birds can be a significant factor in the protection of alkaline fens, especially when it comes to shaping the structure of their vegetation. In the majority of cases, the optimal condition of the mire means also the optimal habitat condition for the most valuable species of birds, and the threats to mires and their birds are similar (see e.g., Wojtak & Kitowski 2001). Sometimes, however, there are some differences in the needs of conservation objectives, but rather no conflicts between them. If, for example, the presence of loose willow thickets often does not significantly affect the alkaline fen flora (species typical for habitat may sometimes survive even in loose bushes), but for birds are a very important factor because some peatland's species do not tolerate trees and shrubs in their habitat and for others such a mosaic is even preffered.

Fauna of alkaline fens' invertebrates abounds in rare, endangered and protected species, and may result from the wetland nature of these habitats, and not necessarily from the specifity of alkaline fen itself. In the case of most invertebrate groups, we do not know whether their populations on alkaline fens have their specificity corresponding to the specific features of this type of habitat, or are these bands typical of all sedge wetlands. This is due to the small number of faunistic studies so far, in which alkaline fens were separated as a separately studied habi-

Photo 69: Sedge warbler *Acrocephalus schoenobaenus* (photo by Ł. Łukasik).

Photo 70: Reed bunting *Emberiza schoeniclus* (photo by Ł. Łukasik).


Photo 71: Corncrake *Crex crex* (photo by Ł. Łukasik).

tat, distinguishing them from other, similarly physiognomic wetlands. More data comes from Chełm calcarous fens - specific alkaline topogenic fens formed on a substrate rich in calcium carbonate.

In the complexes with alkaline fens, you can meet most of the national species of dragonflies, but none of them are characteristif for this habitat. The diversity of mire odonatofauna is usually positively influenced by the presence of open waters - on the mire itself or in its vicinity, eg lakes, streams, or larger rivers, and even ditches. In the alkaline fen, due to, usually occurring, underground water supply, such micro-habitats are quite frequent what result in numerous dragonfly fauna. For example, on a small mire in Prosna river valley, Pawlak & Wilżak (2012) found 20 species of dragonflies, Gutowska et al. (2016) in the Rospuda valley - similarly 20 species, Rekowska et al. (2014) on the Pomeranian Mechowisko Radość - 14 species, Wołejko et al. (2015) on Bukowskie Bagno in the Drawa Forest - 18 species, and Bociąg et al. (2014) in the Kruszynek moss fen in Bory Tucholskie - as many as 23 species. Relatively often, the Large white-faced darter *Leucorrhinia pectoralis* (species included in Annex II of the Habitats Directive) was found on the alkaline fens, although Buczyński (2008) pointed out the small population of this species on the calcareous fen near Chełm. The occurrence of species such as the yellow-spotted emeral *Somatochlora flavomaculata* and the northern emerald *Somatochlora arctica* is also repeatable. Among the valuable components of odonatofauna recurring on alkaline fens are also: moorland hawker *Aeshna juncea* and subarctic darner *Aeshna subarctica*, dark whiteface *Leucorrhinia albifrons*, lilypad whiteface *Leucorrhinia caudalis*, banded darter *Sympetrum pedemontanum* and black meadowhawk *Sympetrum danae*. For example, on alkaline fens in the Rospuda river valley, the strictly protected norfolk damselfly *Coenagrion armatum* was noted. The presence of ornate bluet *Coenagrion ornatum* (Bernard & Michalczuk 2012) can be connected with the moss fens and small, spring-like watercourses within them, although it is extremely rare in Poland.

Among insect species, butterflies are a relatively well-studied group. Among butterfly taxons linked with mires, more species are typical of transitory mires foraging on species occurring therein – cranberry and bog bilberry. One of the species of this group - cranberry blue *Plebejus optilete* - is often also found in moss fens, which sometimes adjoin with pine forests and birch bogs. Especially large copper *Lycaena dispar* can be considered as a species preferring alkaline fens and related wetland environments (Sielezniew 2015). It has a wide distribution spectrum, but fringes of alkaline fens with vegetation including large rumex species (*Rumex hydrolapatum, Rumex crispus*) are undoubtedly their optimal habitat. Meadow and fen edges and dried mown alkaline fens with abundant bistort *Polygonum bistorta* growth are an optimal biotope for the violet copper *Lycaena helle*. Both species are protected by Polish and European law (Habitat Directive Annex II and IV).

Alkaline fens are also a typical biotope of another butterfly species from Annexes II and IV of the Directive - false ringlet (*Coenonympha oedippus*), currently

Photo 72: Yellow spotted *Leucorhinia pectoralis* (photo by Ł. Łukasik).

occurring in these habitats in the Narew National Park, in the Biebrza valley, on the Chełm marshes and in the Zamość region (Sielezniew 2012).

On alkaline fens, the protected common ringlet *Coenonympha tullia*, whose caterpillars feed on cotton grass and sedges, are relatively common. On several moss fens, both in eastern and western Poland, there was a rare, peatland butterfly species - false heath fritillary *Melitaea diamina*. A species typical for sedges is the large chequered skipper *Heteropterus morpheus*. Of the more interesting species also recorded in the moss fens were: scarce heat *Cohenonympha hero*, Pallas' fritillary *Argynnis laodice* and cranberry fritillary *Boloria aquilonaris*. For butterflies occurring, among others on the calcareous fens near Chełm belongs a representative of the owlet moths - *Diachrysa zosimi* and *Chariaspilates formosaria*. Both species, threatened with extinction, are noted in the Polish Red Book of Animals (Głowaciński & Nowacki 2004).

On the Pomeranian moss fens (Rekowska et al. 2014, Bociąg et al. 2014, Bociąg et al. 2015), ants - European fire ant *Myrmica rubra* and *Myrmica scabrinodis*, as well as narrow-headed ant *Formica exsecta* and and oligotermic and hygrophilous *Formica picea* (usually found in boreal and mountain regions) – are noted regularly.

Among the beetle species on the mires, some are species with a broad ecological spectrum, preferring various types of wetlands. Many species, however, show distinct, though often poorly identified, preferences towards specific types of mires, including alkaline fens. Studies of beetles from *Carabidae* in the New

Photo 73: Large copper *Lycaena dispar* (photo Ł. Łukasik).

York area (Liebherr & Song 2002) indicated their distinctive selectivity - the groups on acid peat bogs and alkaline fens were diametrically different from each other.These dependencies probably concern other geographical areas and other groups of beetles, which can be deduced from partial data available from the Polish mires. Among *Staphylinidae* the species regularly observed on alkaline fens is *Acylophorus glaberrimus*, known among others from Bukowskie Bagno in the Drawa Forest (Wołejko et al. 2015). The related *Acylophorus wagenschieberi* species is an indicator of the good conservation status of the transitional mires (Ruta 2009), but sometimes - for example in the Mechowiska Sulęczyńskie in Pomerania (Bociąg et al. 2015) - it also occurs on alkaline fens. Other *Staphylinidae* associated with the discussed habitat are the common *Pselaphus heisei*, known among others from Mechowiska Sulęczyńskie and *Atanygnathus terminalis, Erichsonius cinerascens, Euconnus rutilipennis, Eusphalerum minutum, Stenus boops, Stenus crassus, Tetartopeus sphagnetorum*, known from the Bukowskie Bagno. With the mentioned *Staphylinidae* coexist higrophilous Carabidae, e.g. *Oodes helopioides. Spercheus emarginatus* and *Bagous lutulentus* was observed on a small mire in the Drawa Forest. In detritus on the border of the moss fen and the water table, for example in the Bukowskie Bagno and Kuźnik Olsowy lake, there is *Sphaerius acaroides*, less than a millimeter long - the only representative of the suborder *Myxophaga* in the national coleopterofauna. Not much is known about water beetles accompanying alkaline fens. Data from Chełm calcareous mires (Buczynski & Przewoźny 2010) indicate a higher number of species, such as, for example, *Hydroporus angustatus, H. notatus, H. tristis, H. umbrosus, Enochrus ochropterus* and *Limnebius parvulus*, within mires, than in neighboring water basins. Some beetles are associated with microhabitats that form within alkaline fens. Observations of the *Laccornis oblongus* from the United Kingdom indicate that it is tied to small, shallow, moss-covered depressions in mires (Foster 2010). The small Bladderwort flea beetle, *Longitarsus nigerrimus*, develops on common bladderwort growing in water-filled mire's depressions. A strong population of this species occurs in the Bukowskie Bagno nature reserve. Also, habitats associated with alkaline fens, such as the outflow of calcium-rich waters, are naturally valuable for beetles, eg *Eubria palustris* - the only European representative of the *Psephenidae* family, widespread in the tropics (Ruta et al. 2011). This beetle is regularly found on mountain flush fens, much less frequent on the lowlands.

From the Orthoptera order, on the alkaline fens, the following are regularly found: large marsh grasshopper *Stethophyma grossum* and the *Conocephalus dorsalis*. In Germany, (Beutler & Beutler 2002) *Pseudochorthippus montanus, Chrysochraon dispar*, *Euthystira brachyptera* and *Metrioptera brachyptera* were also considered to be species associated with the discussed peatlands.

Other groups of insects associated with alkaline fens are poorly recognized in Poland. In Germany, species associated with the described habitats are considered to be, among others, flies from the hoverflies family (*Syrphidae*) - *Parthelophilus frutetorum* and *Tropida scita* (Beutler & Beutler 2002).

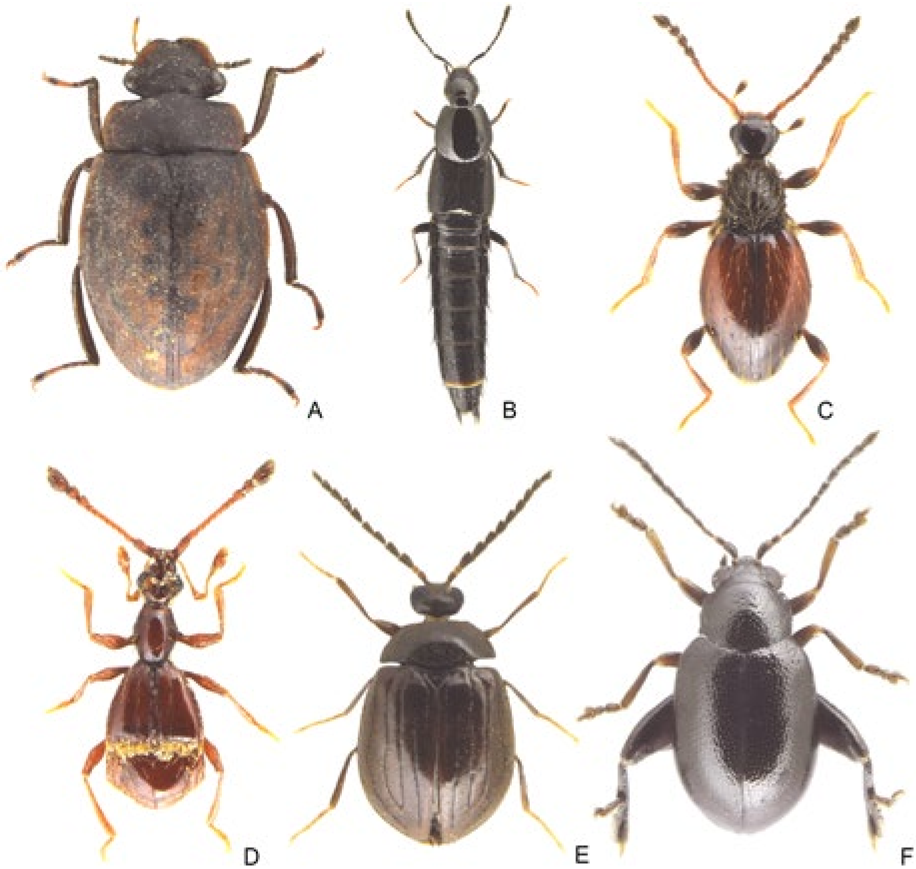



Fig. 32. Beetles of alkaline fens: A – *Spercheus emarginatus* (body length: 5,5 mm), B – *Acylophorus glaberrimus* (8 mm), C – *Euconnus rutilipennis* (1,8 mm), D – *Pselaphus heisei* (1,7 mm), E – *Eubria palustris* (3 mm), F – *Longitarsus nigerrimus* (2 mm).

Only a few alkaline fens have been studied in terms of arachnofauna, though it can also be interesting. For example, in the Mechowiska Sulęczyńskie nature reserve in Pomerania, (Bociąg et al. 2015) 39 rare, on the national and European scale, species of spiders were found, of which as many as 14 are bioindicators and even tyrfobionts. *Silometopoides sphagnicola* is a species relatively recently scientifically described from the Taimyr peninsula in northern Siberia, and its position in the reserve turned out to be the first in Europe. *Thermidion hemerobium* is a new species in the fauna of Poland. Until now, *Satilatlas britteni* was known only from the Świętokrzyskie Mountains and from the Biebrza river valley, this is the third stand of this spider in Poland. Likewise, known earlier only from the Biebrza valley. Very rare and endangered species in the country include *Trichopterna thorelli* and *Gnaphosa nigerrima*, as well as *Scotina palliardi*, *Robertus ungulatus* and *Silometopus elegans*. In turn, *Sitticus caricis*, *Pirata tenuitarsis*, *Notioscopus sarcinatus, Hypselistes jacksoni* and *Agyneta cauta* are hydrophilous species found almost exclusively on mires. Many groups of animals linked with watercourses and water bodies (e.g., dragonflies, caddis-flies, mayflies) live in a mosaic of environments, however at different stages of the life cycle, utilizing also the surrounding or neighboring fen complexes. Patches of permanently waterlogged land, such as peat bogs, beaver backwaters or overgrowing oxbow lakes, support the occurrence of many groups of organisms within fens, especially amphibians, mollusks and many groups of insects (caddis-flies, dragonflies, mayflies, water beetles, and others). In this context, most often fauna of fens with more diverse structure are richer, also in endangered species despite that, paradoxically, the heterogeneity of habitats has often been caused by anthropogenic factors, i.e., different forms of former use. In a similar way, beavers contribute to increased species diversity and the occurrence of many rare and endangered species, while eliminating others and sometimes worsening the condition of the plant communities typical of this habitat, by transforming environment to satisfy their needs.

## 4.2. Terrestrial snails of alkaline fens

***Zofia Książkiewicz-Parulska***

The high constant humidity and basic pH of alkaline fens make them a favourable environment for terrestrial snails. They are inhabited, for instance, by 3 species of protected snails of the genus *Vertigo* (Vertiginidae family): Desmoulin's whorl snail *Vertigo moulinsiana* (Dupuy, 1849) (Fig. 33A), the narrow-mouthed whorl snail *Vertigo angustior* Jeffreys, 1830 (Fig. 33B), and Geyer's whorl snail *Vertigo geyeri* Lindholm, 1925 (Fig. 33C). They have been included in the Habitat Directive Annex II (EEC 1992) and also in the IUCN Red List of Threatened Species (IUCN 2014). Moreover, Desmoulin's whorl snail and the narrow-mouthed whorl snail are under strict species protection in Poland (The Act of April 16, 2004 on the Nature Conservation – Dziennik Ustaw of 2004, No 92, item 880). According to the IUCN Red List, of the above-mentioned three snail species, only Geyer's whorl snail shows a stable population trend in Europe (Killeen et al. 2011), while a declining number of localities was evidenced for Desmoulin's whorl snail and the narrow-mouthed whorl snail (Killeen et al. 2012, Moorkens et al. 2012) in Ireland, Germany, France, Belgium and The Netherlands. It is believed that such situation is caused, for instance, by changes in habitat's hydrology (mostly decreasing of water level), fragmentation, transformation of habitats due to succession and improper active protection (e.g., cessation of extensive land use) or incorrect land use (e.g., intensive grazing) (Killeen et al. 2012, Moorkens et al. 2012). On the other hand, in some countries (also in Poland) the number of known stands of these species is higher than few years ago. It is, however, a result of better recognition of the species' distribution rather than an actual increase of the species' localities.

The small size of the terrestrial snails (their shell does not exceed 3 mm in height) and the type of their habitats (usually wetlands which are difficult to explore by humans) have contributed to insufficient knowledge of the distribution of these snails in Poland. For instance, in 2004 Geyer's whorl snail was not found in Poland, though it was suspected to occur in the area of Białowieża (Pokryszko 1990). In addition, only 3 localities for Desmoulin's whorl snail and ca. 30 localities for the narrow-mouthed whorl snail have been known (Pokryszko 2004a, b). Poland's accession to the European Union in 2004 involved a countrywide inventory of natural resources within the Natura 2000 network. The field inventory in the areas of State Forests was conducted in 2007, later, the surveys were carried out also on other areas. These studies contributed to the description of new localities of vertiginid snails (e.g., Książkiewicz 2010). Currently, the literature contains description of ca. 30 localities for Geyer's whorl snail (e.g., Horsák & Hájek 2005, Schenková et al. 2012, Zając et al. 2012, Książkiewicz et al. 2015, Pokryszko et al. 2016, Gawroński et al. 2016), over 50 localities for Desmoulin's whorl snail (e.g., Myzyk 2005, Książkiewicz 2010, Lipińska et al. 2012, Sulikowska-Drozd 2014, 2015, Książkiewicz et al. 2015, Szlauer-Łukaszewska et al. 2015, Przybylska 2016), and more than 100 localities for the narrow-mouthed whorl snail (e.g., Książkiewicz 2010, Książkiewicz et al. 2012, Książkiewicz et al. 2015, Szlauer-Łukaszewska et al. 2015) in Poland. In recent years, knowledge of the biology and ecology of the whorl snails and their microhabitat requirements has increased (e.g., Kuczyńska & Moorkens 2010, Myzyk 2011, Hettenbergerová et al. 2013, Książkiewicz-Parulska et al. 2018).

Wet alkaline habitats also host other representatives of the *Vertigo* genus, e.g., the marsh whorl snail *Vertigo antivertigo* (Fig. 33D) and striated whorl snail *Vertigo substriata* (Fig. 33E). Both these species can be found on lowland alkaline fens and montane spring fens (e.g., Książkiewicz 2010, Książkiewicz – unpublished data). On the other hand, *Vertigo pygmaea* can be found in habitats characterized by different levels of humidity (from dry to wet) (Pokryszko 1990). In addition, a whorl snail of the *Columella* genus, *Columella edentula,* may also occur in alkaline fens (Książkiewicz 2010).

The above-described whorl snails are sometimes accompanied by *Pupilla pratensis* (Fig. 33F), a representative of the *Pupilidae* family. The shell of this species is barrel-shaped and its height reaches ca. 4.5 mm (von Proschwitz et al. 2009). Not much is known about the occurrence of this species in Poland; it is probably due to incorrect description/recognition of this species – wrongly described as *Pupilla muscorum* - a similar to *P. pratensis* and very common in Poland *Pupilla* species. Currently, six localities for *P. pratensis* are known in the country. One of them, in Upper Silesia, was described in 1883 (Goldfuss 1883), but modern data on the occurrence of *P. pratensis* in this area are lacking. Other localities have been reported in the Lubusz region, Great Poland (Książkiewicz & Gołdyn 2013) and the Podlaskie Province (Horsák et al. 2012, Książkiewicz-Parulska et al. 2015). In Norvay von Proschwitz (2010) discribed this species on wet alkaline habitats.

The other species that occur in alkaline fens is *Vallonia enniensis* (Fig. 33G). Its shell is flattened, while the spire is slightly elevated, and the shell width reaches 2.5 mm (Wiktor 2004). It is thought that *V. enniensis* is endangered with extinction, although its distribution within its range is poorly recognized (Wiktor 2004). The species has been included in the IUCN Red List of Threatened Species with DD category (data deficient – status difficult to assess due to the lack of data, Mollusk Specialist Group, 1996) and in the Red List of Threatened Animals in Poland (category NT, Wiktor & Riedel 2002). In Poland, it is known from a few localities in the Lubusz region, Greater Poland, Mazovia, Podlasie, Lublin Upland and Lesser Poland (Wiktor 2004, Książkiewicz-Parulska & Pawlak 2016). Two other representatives of the grass snail family (Valloniidae) that can also be found in habitat 7230, are the ribbed grass snail *Vallonia costata* (O. F. Müller 1774) and smooth grass snail *Vallonia pulchella*; however the first mentioned species may also be foud in a drier environments (e.g., Wiktor 2004, Welter-Schultes 2012).

Two representatives of the Ellobiidae family may be found in alkaline fens in Polnd: the herald thorn *Carychium minimum* and dentate thorn *Carychium tridentatum*. Both species are very common in the country and frequently coexist in the same habitat. *Carychium minimum*, however, is found more often in wetter microhabitats than *C. tridentatum* (e.g., Książkiewicz-Parulska & Ablett 2017) Both species have a similar *Carychium tridentatum*whitish, tower-shaped shell reaching 2.2 mm in height (Wiktor 2004). These species are often found with the dwarf snail *Punctum pygmaeum*, a member of the Endodontid family (Endodontidae) having a flattened shell with a slightly elevated spire; its shell width reaches 1.6 mm and height 0.8 mm which makes them the smallest terrestrial snails in Poland (Wiktor 2004). This tiny snail is often found on the acid base of beech forests, although larger populations form on alkaline habitats (Welter-Schultes 2012).

Habitat 7230 also hosts other common snail species, e.g., the crystal snail *Vitrea crystallina*, pellucid glass snail *Vitrina pellucida*, rayed glass snail *Nesovitrea hammonis*, black gloss snail *Zonitoides nitidus*, glossy pillar snail *Cochlicopa lubrica* and brown slug *Deroceras laeve*. You can also find there species of snails tolerating acidic substrate, e.g. pellucid glass snail *Vitrina pellucida* or rayed glass snail *Nesovitrea hammonis* (Welter-Schultes 2012). Also, some less common species may be found in Polish fens, such as the robust pillar snail *Cochlicopa nitens* or the shiny hive *Euconulus alderi* as well as the Roman snail *Helix pomatia*, which is (although common but commercially harvested) under partial protection in Poland.

## Characteristics of whorl snails species occurring in Poland, included in the Habitats Directive Annex II

### Desmoulin's whorl snail *Vertigo moulinsiana*

Desmoulin's whorl snail (Fig. 33A) is a calcicole species. Its native range is the Atlantic to Mediterranean Sea. (Pokryszko 1990). In Poland, its distribution is limited to the lowland part of the country, included into the continental biogeographic region (Lipińska et al. 2012). Desmoulin's whorl snail occurs mostly in young-glacial landscape and habitats accompanying early stages of lake succession (Książkiewicz & Gołdyn 2015).

High groundwater level seems to be one of the most important factors influencing the distribution of Desmoulin's whorl snail (Killeen 2003). Representatives of this species are most abundant in the microhabitats where the water level oscillates around the ground surface (Tattersfield & McInnes 2003). For this reason, alkaline fens and sedge meadows are favourable for the occurrence of this species (e.g., Książkiewicz 2010). Localities for this species very often are scattered along river valleys, which seems to be associated with both the availability of convenient habitats (Książkiewicz 2010) and also with the possibility of passive dispersion with stream current (Myzyk 2005, Killeen 2003).

Desmoulin's whorl snail can be relatively easily observed in natural habitats because it shows a tendency to climb plants (even to the height of 2 m; Cameron 2003). Individuals of this species can be observed most abundantly on leaves and stems of monocotyledons in summer and late autumn (Killeen 2003). Adult snails more often than juvenile ones remain on plants also over winter (Książkiewicz-Parulska et al. 2018). Desmoulin's whorl snail can be active till November if the weather conditions are favourable (Myzyk 2011). In localities near Sępolno (The Pomerania Province), Myzyk (2011) recorded the beginning of the breeding season in April/May and its end in July/August. The dynamics of this species population reveals fluctuations. Desmoulin's whorl snail reaches the highest population densities usually in August – October, depending on the habitat and weather conditions (Książkiewicz-Parulska & Ablett 2016). Duration of embryonic development depends on the temperature, and can last 10 – 67 days (related with the presence of fully developed shell); these snails reach maturity after 70 – 119 days, while their lifespan is 422 – 508 days (Myzyk 2011).

**Narrow-mouthed whorl snail *Vertigo angustior***

The narrow-mouthed whorl snail (Fig. 33B) has a European range (Pokryszko 1990); it is a calcicole species with climate-dependent changing preferences for humidity (Pokryszko 2004a). In Poland, it has only not been found at higher altitudes in the mountains (Karkonosze Mts., Babia Mt., Tatra Mts., Książkiewicz et al. 2012). The localities for this whorl snail in Poland are open ones (e.g., Książkiewicz 2010). In the lowlands, it occurs in microhabitats of a moderate humidity, and most often it can be observed in sedge meadows or ridges of alkaline fens (e.g., Książkiewicz 2010, Książkiewicz et al. 2015). In the mountains, it prefers more humid microenvironments and abundantly colonizes spring fens with valerian-sedge vegetation (e.g., Książkiewicz et al. 2012).

The narrow-mouthed whorl snail lives within the litter layer and rarely climbs up vegetation. It can be found at the sedge leaf base in late autumn where it climbs up to a height of 10 – 15 cm (Cameron 2003). In Poland, this snail begins reproduction in March and ends it in July/August (Myzyk 2011). It reaches the highest density (even over 1 200 individuals/m²) usually in September or October, depending on habitat type and weather conditions (Książkiewicz-Parulska & Ablett 2016). Depending on the temperature, its embryonic development lasts from 11 to 16 days, it reaches sexual maturity (associated with fully developed shell) after 40 – 55 days, and its lifespan is 200 days (Myzyk 2011). The narrow-mouthed whorl snail (both adult and juvenile) spends the winter in microhabitats rich in mosses and litter (Książkiewicz-Parulska et al. 2018).

**Geyer's whorl snail *Vertigo geyeri***

Geyer's whorl snail (Fig. 33C) is a Boreal-Alpine species probably endemic to Europe (Kerney 1999). This species has been recorded in humid and wetland habitats, including alkaline fens, calcareous fens with *Cladium mariscus*, and transition mires (e.g., Cameron et al. 2003; Horsák & Hájek 2005, Książkiewicz-Parulska et al. 2015). It is linked with microhabitats with high relative humidity (over 80%) and a high level of groundwater (ca. 0.1 m below ground surface) (Kuczyńska & Moorkens 2010). This snail lives among mosses and at the base of sedges (Cameron et al. 2003). The biology of Geyer's whorl snail is not known. Until recently, in Poland, it was only known from subfossil positions, later it was thought to occur only in eastern Poland, but recently it was also found in Bukowskie Bagno in the Drawa Forest (Pokryszko et al. 2016) and in the Mechowisko Krąg reserve in Pomerania (Gawroński et al. 2016).

## Protection of whorl snails on alkaline fens: practical aspects

The implementation of proper conservation measures is based on an assessment of species distribution, monitoring of population condition and habitat status, among other things. At present, knowledge of the distribution of Desmoulin's, narrow-mouthed and Geyer's whorl snails in Poland is decidedly better than even 15 years ago, though still incomplete. However, countrywide monitoring is limited to some specific areas occupied by these species. Of course, increasing the number of sites surveyed within the monitoring program remains difficult due to financial and personnel constraints. However, since a decline in the number of localities for Desmoulin's and narrow-mouthed whorl snails has been noted throughout its whole distribution range (due to, for example, improper land use) (Killeen et al. 2012, Moorkens et al. 2012), it is recommended to increase the number of sites where the populations and habitats of these species are surveyed.

Moreover, the currently used monitoring methods comprise (especially in the case of the narrow-mouthed whorl snail) a time-consuming analysis of samples collected during field study. Moreover, the sample collection is connected with the killing of snails (not only those under examination) and interference with the environment, often protected (e.g., Książkiewicz et al. 2012, Lipińska et al. 2012). Recent studies have demonstrated that it is possible to apply decidedly less invasive methodology that is more beneficial for the whorl snails (and other co-occurring species). These new methods are based on counting snails in the field, by which reliable results can be obtained (Książkiewicz-Parulska & Gołdyn 2017). Such a method was tested for Desmoulin's and narrow-mouthed whorl snails. Therefore, the implementation of such a live and more efficient monitoring procedure would be worth considering in the future.

The implementation of measures aiming to actively protect whorl snails is still rare in our country. Usually they involve the realization of well-considered schedules of extensive mowing programs (taking into account, for example, snail species and habitat size). Such actions improve both the condition of the snail population and their habitat (Książkiewicz 2014). At present, such programs are in progress, with a satisfactory outcome at several localities for Desmoulin's and narrow-mouthed whorl snails in the valleys of the Ilanka River and Pliszka River (Lubuskie voievodship). However, the significance of appropriate mowing plan, its intensity (delineation of correct habitat parts), frequency (i.e. mowing of chosen fragment of the habitat once every 2-3 years), and schedule determined by type of habitat as well as snail species, should be stressed. Such procedures carried out in an incorrect way (i.e. intensive mowing with heavy equipment) can worsen the status of the protected molluskan population.

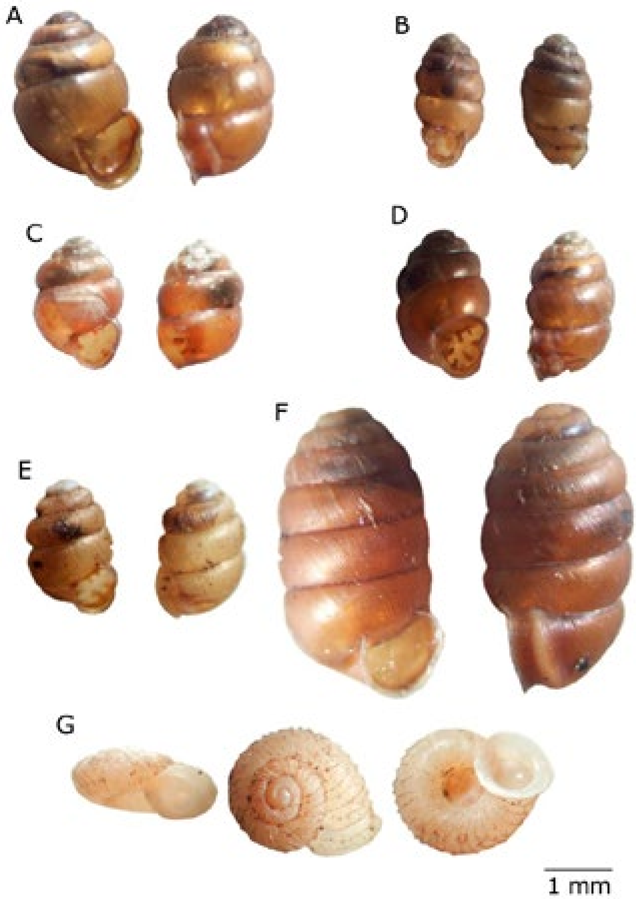



Fig. 33. Presentation of terrestrial species: Desmoulin's whorl snail *Vertigo moulinsiana* – *A*; narrow-mouthed whorl snail *Vertigo angustior* – *B*; Geyer's whorl snail *Vertigo geyeri* – *C;* marsh whorl snail *Vertigo antivertigo* – *D*; striated whorl snail *Vertigo substriata – E; Pupilla pratensis – F; Vallonia enniensis* – *G* (source: Z. Książkiewicz - Parulska).

# 5. ECOSYSTEM ECOLOGY

***Filip Jarzombkowski, Ewa Gutowska, Katarzyna Kotowska***

## 5.1. Ecology of an ecosystem with favourable conservation status

The character of each ecosystem mostly depends on a combination of plant, animal and microorganism populations and the abiotic habitat they change (Tansley 1935). Elements composing a biocenosis were described in Chapters 3 and 4, therefore attention will be focused here on the biotope.

Each live alkaline fen has two layers: the lower permanently waterlogged, called the catotelm, and the upper named acrotelm (Ivanow 1953). The catotelm is a dead peat bed underlying the acrotelm, which besides constant waterlogging, is characterized by a lack of oxygen and aerobic microorganisms and the presence of a few anaerobic organisms (Ilnicki 2002). The acrotelm is a layer at fen surface ca. 0.5 m deep composed of living organisms (plants, animals and microorganisms) which is characterized by fluctuations of water level connected with aeration of peat depositing therein. An alkaline fen can remain alive and constantly grow if the water balance is positive (i.e., the water inflow has to be equal or greater than the outflow) because only in such a situation do accumulation processes surpass decomposition processes. An appropriate water balance to ensure ecosystem stability significantly depends on a proper groundwater level which, in undisturbed fens, annually fluctuates within the range of a dozen or so centimeters as a maximum (Jabłońska et al. 2011). In practice, even if the water level subsides by a dozen or so centimeters due to capillary rise, the surface peat layer is permanently humid and water is available to plants. Such conditions are favourable for the accumulation of peat containing dead plant residues sometimes with tufa deposition (Ilnicki 2002). These deposits can form in exceptional situations when fen-feeding water has appropriate chemical composition (high content of calcium carbonate), and cyanobacteria, chlorophyta, stoneworts and special species of mosses grow at water outlets, which is conducive to the deposition process (Szulc 1983, see also Chapter 2.6). In properly conserved fens, owning to the presence of water, the peat bed is preserved in the whole profile and the surface layer does not show signs of decay.

Photo 74: A habitat properly saturated with water with well-developed moss layer (photo by E. Gutowska).

Photo 75: A habitat properly saturated with water with well-developed moss layer (photo by E. Gutowska).

Hence, an appropriate amount of water with specific composition is one of the most significant factors determining the existence of alkaline fens (Sjörs 1950). A considerable supply of water rich in calcium and magnesium ions assures an alkaline pH of the fens (pH ranging from 5.5 to 8.5). At the same time, sedge-moss fen-supplying waters contain limited amounts of biogenes, like nitrogen and phosphorus, which, due to binding with calcium or iron hydroxide ions, precipitate yielding salts unavailable to plants (Olde Venterink et al. 2003, Grootjans et al. 2006). The vegetation of sedge-moss fens may differ depending on the quantitative N:P ratio (Pawlikowski et al. 2013).

Alkaline fens can develop gradually both around lakes having appropriate chemical composition of water (topogenous type of fens) and in river valleys or other geomorphological systems where groundwaters discharge at the surface within soligenous percolating fens (Dembek & Oświt 1992). Alkaline fens of topogenous type are supplied by lake waters while sedge-moss fens most often develop in the shallowing parts of a water body. Soligenous fens use groundwater which is often discharged to the surface under pressure and then percolates through the peat bed, securing appropriate conditions for vegetation development.

The type of water supply to fens is reflected by vegetation contributing to development of its different zones, which can be observed for instance in the Rospuda river valley. Most often riparian forests, wet pine-birch forests or corresponding forest types connected with the water flow develop along its mineral edge, followed by a sedge-moss fen zone, which the closer to the river assume a more rush-like character (due to the impact of flooding), and they transition into reeds or alder forests (Jabłońska et al. 2011). The development of such a system is possible only in undisturbed ecosystems; however, due to overwhelming human impact, model examples of favorably conserved fens are very scanty in Poland.

Therefore, the conservation status of an alkaline fen can be judged as favourable when:

1. supply by waters with appropriate chemical composition (see Chapter 2.6) is preserved and undisturbed,
2. peat forming process is in progress,
3. ecological processes typical of fens are preserved and undisturbed (including those leading to limitation of biogene availability which results in preservation of vegetation specific for this type of fens).

Detailed indices of such status, which were proposed to be used in monitoring of the natural environment, are presented in Chapter 11.

## 5.2. Ecosystem ecology during degradation and regeneration

The degeneration processes of alkaline fens in Poland can be natural, but more often they are triggered by human activity (Ilnicki 2002). Most frequently they result from distortion of hydrological conditions, agricultural land use and the fragmentation of habitats (Herbichowa & Wołejko 2004). The remaining disturbances, e.g., succession, changes in species composition or eutrophication, are secondary to those mentioned above but no less important and lead to serious consequences for sedge-moss fen vegetation.

Favourable conservation status of alkaline fens, by definition, excludes the existence of drainage systems. No drainage ditches existed in natural sedge-moss fens and natural drainage system, if existing, developed freely. In some situations (especially in the mountains or more sloped areas), water erosion processes in undisturbed fens progressed spontaneously without any human impact, leading either to worsening of habitat status or even to its disappearance. It is also visible in many lowland fens where the habitat disappears along the water outlet (most often the river) but remains properly developed in the central or edge parts (e.g., Jabłońska et al. 2011). In spite of this, in a majority of cases humans were responsible for the degradation of the alkaline fens. Most of all it was caused by the need to increase plant production, and the drainage infrastructure was the principal way to achieve this goal (Ilnicki 2002, van der Linden 1982, van Diggelen et al. 2006).

Photo 76: Drainage ditch in the mire near the Księże Lake (photo by E. Gutowska).

The subsidence of the water table is dependent on the distance between the ditches and their depth (Braekke 1983). If the drainage system facilities are present in the fen, by definition the habitat status should be considered as distorted. The impact zone of the drainage ditches extends from several to several tens of meters, which is determined by the ecological conditions (Okruszko 1969a, Ilnicki 2002). For instance, if a network of drainage ditches is present in the alkaline fen, even when the ditches are several hundred meters apart, the water table will be lowered and the drainage will be accelerated, especially along the ditches and channels. It can be manifested by development of tall herb communities or rush type vegetation along the ditch and a reduction of the contribution of characteristic habitat 7230 species. Moreover, due to the availability of oxygen (Mannerkoski 1985) and biogenes from decomposed peat, such areas often began to be overgrown by shrubs or trees (Jeglum 1974).

Overgrowth of drainage ditches does not always eliminate their impact. The peat structure in overgrown ditches is very often less compact than in the remaining parts of the peat bed, which results from the fact that peat depositing over several tens of years will be more permeable than that accumulated over hundreds or thousands of years (see Baden & Eggelsman 1963, Ilnicki 2002). As a result, despite ditch overgrowth, the water will still be able to flow faster to the outflow than through the remaining part of the peat bed.

Photo 77: Willow thickets in Pakosław Mire (photo by E. Gutowska).

The hydrological conditions can be changed not only by the increased outflow but also by a reduced groundwater inflow to alkaline fens. The most common cause of this situation is a significant groundwater abstraction in the catchment where the fen is located. If in the fen catchment area there are, for instance, greenhouses utilizing large amounts of water abstracted from the groundwater, or if the fen is located within the reach of a cone of depression, such as a large city or a mine, it can lead to reduced water supply to the fen. As a consequence, the fen lacks an adequate amount of water to remain sufficiently hydrated and consequently the peat surface layers dry out.

Draining of the peat bed changes the air and water conditions of the upper peat layer (Ilnicki 2002). The availability of oxygen triggers peat decomposition and its transformation into moorsh which is accompanied by a release of nutrients to the environment. Moorsh, which has an aggregated structure, unlike peat having a fibrous structure, cannot transmit water by capillary rise as efficiently as undecomposed peat (Ilnicki 2002), which aggravates water deficit in the upper peat bed layer and prevents the development of species specialized at living at low oxygen availability (plants, animals, fungi and other microorganisms). As a result, the vegetation changes, and sedges and species that need wet and basic soil to grow disappear while – depending on the ecosystem characteristics – rush or meadow species emerge and, if agricultural use has been abandoned, shrub and tree species also follow (van Diggelen et al. 2006). All of them can function only

Photo 78: Changes in fen vegetation structure caused by dewatering: encroachment of meadow species (photo by E. Gutowska).

when the soil fertility is greater than that found in alkaline fens, which additionally limits the availability of light at the fen bottom. Next, low species typical of alkaline fen withdraw (e.g., *Liparis loeselii*, *Carex limosa*, *Carex lasiocarpa*), and the moss layer almost completely perishes (Kotowski & van Diggelen 2004).

Examples of complete damage of alkaline fens due to drainage have been described. The Wizna fen was overgrown by mossy sedge communities with *Herminium monorchis* before drainage only a half a century ago, while now it is covered by birch forest with nettle undergrowth (Kołos 2004). Tomaszewski (1998) described the destruction of a spring fen near Gostyń in Wielkopolska. In recent years, habitat 7230 on the Całowanie fen in the Mazovia has vanished despite conservation attempts (see Chapter 8.2.2). Hundreds of other alkaline fens were destroyed without any documentation of this process.

Another impact which significantly affects the status of alkaline fens is related to their use. In the natural state, owing to the ecological conditions, these ecosystems did not need agricultural use for maintenance. However, after artificial drainage systems were constructed in fens in order to improve management of wetlands and increase crop production, without extensive use, especially mowing, habitat 7230 disappears as a result of succession. Pratotechnical measures have positive effect on the vegetation but they cause compaction of peat (Schipper et al. 2007), sometimes they can also damage sward and unify the fen surface structure, which happens especially when heavy equipment is used (e.g. adapted groomer-like equipment) (Kotowski et

Photo 79: Changes in vegetation structure caused by peat soil degradation: encroachment of nitrophilous plants (photo by E. Gutowska).

al. 2013). Peat compaction during land use can lead to the formation of the compressed layer which in some cases can disturb the chemistry of the water available to plants (Schot et al. 2004). It hinders access of alkali-rich underground water to surface peat layers, and it is replaced by nutrient-poor precipitation water. This is followed by oligotrophization and acidification processes which can be aggravated by the presence of drainage ditches lowering the groundwater table.

The next phenomenon contributing to the degeneration of alkaline fens is related to habitat fragmentation. Apart from the physical damage of parts of sedge moss fens, habitat fragmentation facilitates the penetration of undesired species (including alien ones) and is important for proper fen hydrology. For instance, the construction of a road through the Rospuda river valley mires would cause irreversible habitat damage along the road, and would additionally alter water flow directions within the whole ecosystem which could lead to disadvantageous changes in the sedge moss vegetation.

The above-described phenomena lead to the degradation of habitat 7230. Subsequent implementation of conservation measures is very difficult and requires vast knowledge on the functioning of a particular ecosystem. As mentioned above, the disruption of the hydrological relations is of key importance to disturbances in sedge moss fens, and it primarily should be remedied because it can even disarrange the effect of agricultural use (Kołos & Banaszuk 2018). Habitats only slightly transformed, where sedge moss vegetation still exists, require an im-

Photo 80: Ruts resulting from mowing with heavy equipment – the Upper Biebrza River Basin (photo by E. Gutowska).

Photo 81: Fen mowing with light equipment prevents sward damage
– the Upper Biebrza River Basin (photo by E. Gutowska).

provement of the hydrological conditions by, for instance, blockage of ditches and removal of trees and shrubs every several years and/or the elimination of undesired species (Mälson et al. 2010). If conservation measures are properly chosen, disadvantageous phenomena should fade in parallel with an improvement of the conservation status of the habitat. In heavily degraded habitats, such measures are insuffcent and, in addition to improvement of hydrological conditions, it will probably be necessary to remove the surface moorsh layer and decomposed peat that are a source of biogenes hindering the development of low, light-preferring species associated with alkaline fens (Stańko et al. 2018 and references cited therein). It appears that it is required to remove the decomposed peat from the whole fen area because otherwise problems with eutrophication in the surrounding areas can affect the restored patch. Such a situation can be described as a "reset" of the fen development and a restoration of its status from several hundred years ago. Unfortunately, this procedure is very expensive and not always successful.

# 6. HABITAT 7230 IN THE EUROPEAN UNION

*Paweł Pawlaczyk*

The EU Habitats Directive, as one of its tools, imposes on Member States an obligation of surveillance of their resources of protected natural habitats and species, and periodical preparation of reports regarding their status in accordance with the unified European format. The most recent reports were submitted in 2013 and cover the period from 2007 to 2012. One has to be aware that the data contained therein are biased by often uneven interpretation of particular natural habitats in different countries and imprecise evaluation of habitat area. Nevertheless, data collected in this way provide an interesting picture

According to the reports submitted by EU Member States for 2007 – 2012, the total area of habitat 7230 in the whole European Union was estimated at 534 600 ha. The resources in Sweden (222 000 ha) and Finland (160 000) contribute most to this area. In this classification, France ranks third with 35 600 ha and Poland fourth – declaring 25 600 ha. Little Estonia declared only slightly smaller resources amounting to 23 900 ha (Tab. 2).

However, if the assessment of the Polish resources of the habitat were realistically set at about 10 100 ha (see Chapter 7.1), Poland would fall to the sixth place in the European Union, overtaken by Estonia and Ireland.

According to the declared data, in boreal countries (Estonia, Finland and Sweden) ca. 50 ha is covered by alkaline fens per each 100 $km^2$, although in the Scandinavian mountains this number rises to 162 ha (Fig. 34). In Poland, this indicator amounts to ca. 8 ha/100 $km^2$ which, however, is twice as high as in Lithuania and Slovenia, four times greater than Germany, and five times higher than in Latvia. Even if the Polish estimate of habitat 7230 area were reduced to a more probable value of 10 100 ha (see Chapter 7.1), the mentioned indicator would amount to 3,3 ha/100 $km^2$, which is still a relatively high value, though in European ranking Poland still would be worse that France and Latvia (Tab. 2).

Table 2. Resources of alkaline fens (habitat 7230) declared by EU Member States according to Article 17 of the Habitats Directive for 2007 - 2012. Source: author's compilation based on EIONET data https://nature-art17.eionet.europa.eu/article17/reports2012

| Member State | EU Member State area, thousands km$^2$ | Declared area of alkaline fens (7230), ha | Alkaline fens in landscape ha/100km$^2$ |
|---|---|---|---|
| Estonia | 45,3 | 23 900 | 52,7 |
| Finland | 337,5 | 167 000 | 49,5 |
| Sweden | 449,7 | 222 250 | 49,4 |
| Denmark | 43,2 | 9 000 | 20,8 |
| Ireland | 69,9 | 13 020 | 18,6 |
| Austria | 83,9 | 8 500 | 10,1 |
| Poland | 311,9 | 25 600 | 8,2 |
| France | 638,4 | 35 950 | 5,6 |
| Lithuania | 64,9 | 3 000 | 4,6 |
| Hungry | 93,0 | 2 500 | 2,7 |
| Slovakia | 49,0 | 992 | 2,0 |
| Germany | 358,0 | 6 802 | 1,9 |
| Italy | 300,7 | 5 573 | 1,9 |
| Latvia | 64,6 | 900 | 1,4 |
| United Kingdom | 244,5 | 3 330 | 1,4 |
| Slovenia | 20,3 | 230 | 1,1 |
| Spain | 506,0 | 5 377 | 1,1 |
| Bulgaria | 111,0 | 221 | 0,2 |
| Romania | 238,4 | 285 | 0,1 |
| Greece | 132,1 | 150 | 0,1 |
| Belgium | 30,7 | 19 | 0,1 |
| Czech Republic | 78,9 | 42 | 0,1 |
| The Netherlands | 37,4 | 11 | 0,0 |

For the purpose of environmental statistics, the Council of Europe and subsequently the European Union adopted the division into the so-called biogeographical regions: Alpine, Atlantic, Boreal, Black Sea, Continental, Macaronesian, Pannonian, Steppic and Mediterranean (outside Europe, also Anatolian and Arctic). Most alkaline fens (259 000 ha) are located in the Boreal region. Resources in the

Alpine region are also considerable (178 000 ha)[2]. The third in terms of the 7230 habitat resources ranks the Continental region (57 800 ha) and the fourth – the Atlantic region (32 000 ha). The whole Mediterranean region was reported to harbor 3 000 ha of the habitat, and the Pannonian region 2 500 ha.

A majority of the Poland's territory is located in the Continental region; only the Carpathians belong to the Alpine region.

The 7230 habitat resources in the Alpine region in Poland are estimated at ca. 600 ha (see Chapter 7.1), which may be (see chapter 7.1) about three times overstated. Either way, on a European scale this number is not significant, representing only 0,3% of alkaline fens in this region.

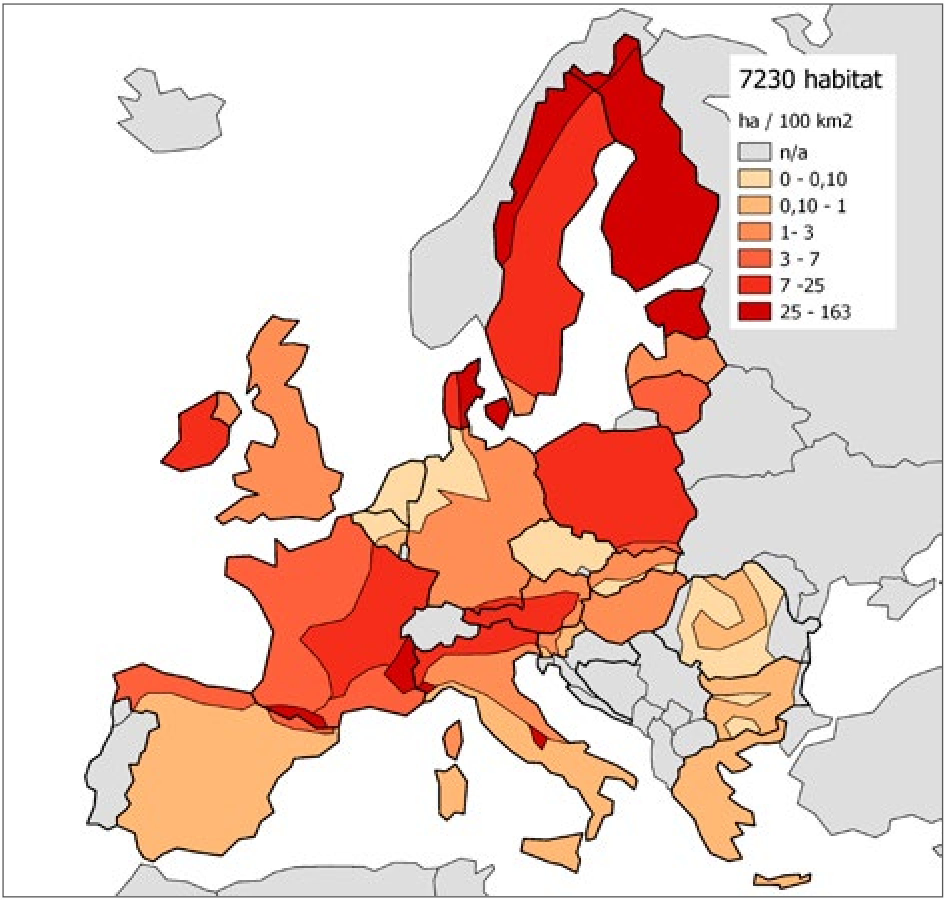



Fig. 34. Occurrence areas of habitat 7230 in the European Union, as declared by Member States in reports submitted according to Article 17 of the Habitats Directive for 2007 – 2012. Source: author's compilation based on EIONET data: https://nature-art17.eionet.europa.eu/article17/reports2012

2 The Alpine biogeographical region, despite its name, encompasses not only the Alps but also insular parts in the Pyrenees, Carpathians, Dinaric Alps, Scandinavian Mts. and small parts of the Apennine Mts.

However, in the Continental region, Poland, with the declared area of alkaline fens of ca. 25 000 ha, would be the country with the largest resources of this habitat in the European Union, with resposnsibility for 42,5% of habitat resources in this region. Even if the Polish estimate of alkaline fen area were reduced to 15 000 ha, it would correspond to 31% of European resources in this region, although in this case Poland would be outranked by France – reporting 18 600 ha of this habitat.

The unfavourable conservation status of alkaline fens in Poland is not an exemption in Europe. In the whole European Union, only Sweden and Finland declared favourable conservation status of habitat 7230 for their mountain fens (Alpine region), but not in lowlands (Boreal region), and Greece – for its 150 ha of alkaline fens in the Mediterranean region (Fig. 35).

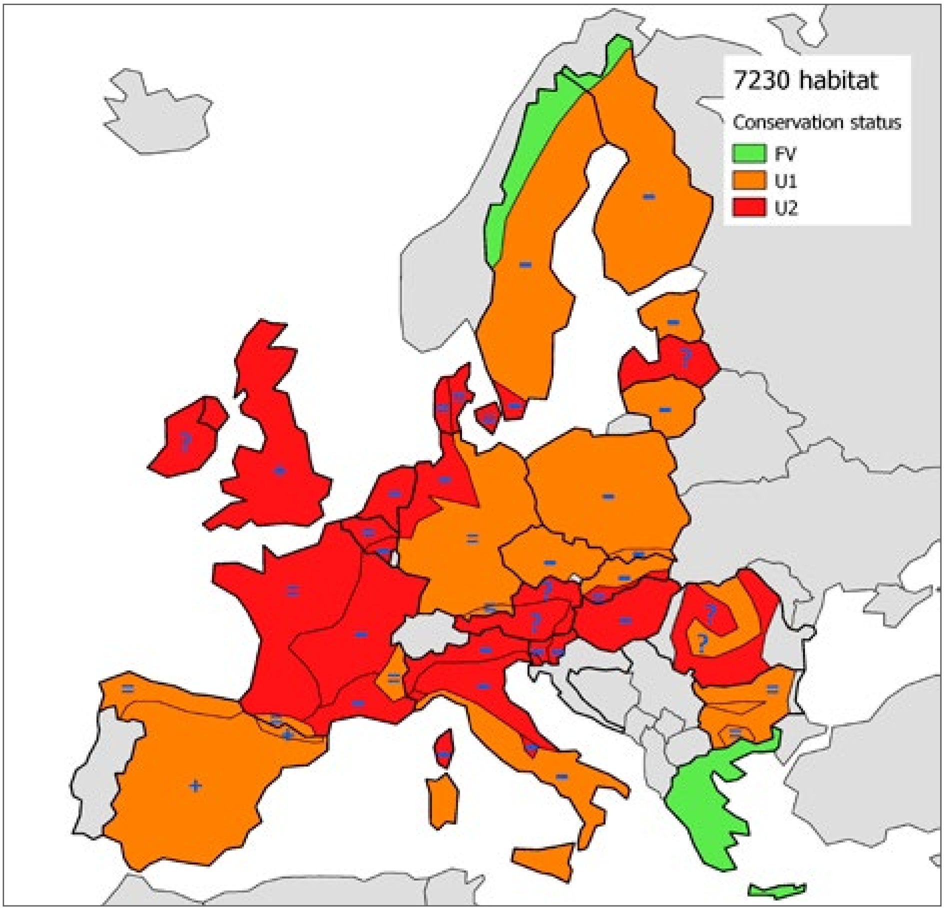



Fig. 35. Conservation status of habitat 7230 in the European Union and its trends (- deterioration, = stability, + improvement) as declared by Member States in reports according to Article 17 of the Habitats Directive for 2007 – 2012. Source: author's compilation based on EIONET data: https://nature-art17.eionet.europa.eu/article17/reports2012

# 7. THE CURRENT OCCURRENCE AND DISTRIBUTION OF ALKALINE FENS IN POLAND

## 7.1. General characteristics of alkaline fen resources in Poland

The first attempt to carry out inventory of alkaline fens in Poland made by the Naturalists' Club (Wołejko et al. 2012) resulted in mapping 872 sites with the total area of ca. 1410 ha. Since then, the catalog of alkaline fens has been systematically extended and updated both using our data and data obtained from nature conservation services resulting from preparation of conservation plans and plans of conservative measures for particular subjects of nature conservation.

At the time of publication of this book, the database comprised 1425 sites, i.e., by 63% more than in 2012. However, their total area was revised to 10 173 ha. It is a result of more detailed mapping of the range of particular habitat patches, especially the range of habitat 7230 patches in its most important Polish refuge, i.e., the Biebrza river valley within the framework of preparation of the plan of conservative measures for Natura 2000 site Dolina Biebrzy PLH200008 (Weigle 2016).

As many as 592 sites are located in the Alpine biogeographical region, i.e., in the Carpathians. However, they are mostly tiny fens and their total area is ca. 210 ha; the largest alkaline fen in this region covers ca. 19 ha and the size of only 40 of them is greater than 1 ha.

The remaining 833 sites covering a total area of 9 960 ha belong to the Continental biogeographical region.

Since the catalog includes also partially degraded fens, the area resulting from this listing is significantly greater than the area of patches with typical vegetation of this habitat.

The database of alkaline fens in Poland is made available by the Naturalists' Club at http://alkfens.kp.org.pl/o-torfowiskach/ogolnopolska-baza-mechowisk/.

## 7.2. Areas and centers of occurrence of habitat 7230 of key significance to its conservation in Poland: characteristics of regional resources.

An overview of vital areas for the conservation of alkaline fens in Poland has been presented in the report: "Krajowy program ochrony…" (Wołejko et al. 2012, in Polish). The territory of Poland was divided into 6 large units reflecting the diverse origin and character of the landscape. If necessary, smaller units (of mesoregion rank) were defined within them and characterized (Kondracki 2011, Solon et al. 2018).

In the present publication, we present an updated version of an overview of key areas of concentration of alkaline fens. Many sites have been a focus of detailed studies and evaluations in recent years. The present listing aims mainly to facilitate access to these resources and also to update knowledge on their conservation (or restitution) status.

The main body of detailed data was obtained in the course of projects realized by the Naturalists' Club. More detailed characterization of particular fens examined within these projects was published by Stańko and Wołejko (2018a, 2018b).

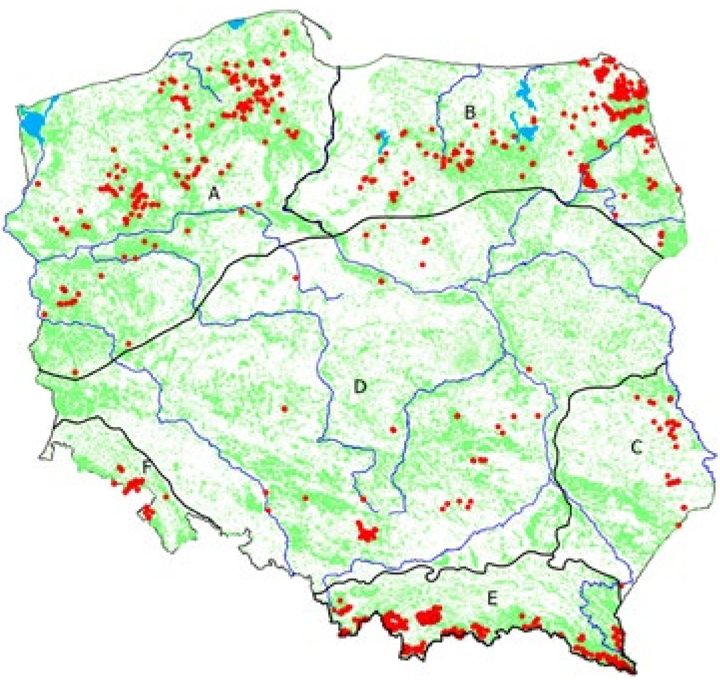



Fig. 36. Areas of concentration of alkaline fens in Poland (Wołejko et al. 2012, updated) within 6 regions of Poland: Northwestern Poland (A), Northeastern Poland (B), South-Eastern Poland with exclusion of Carpathians (C), Central Poland (D), Carpathians (E) and Sudetes (F).

Results of regional projects (Jermaczek et al. 2009, Kujawa-Pawlaczyk & Pawlaczyk 2014, 2015) and other numerous papers and documentations have been also included.

For practical reasons, in the present publication the territorial division of Poland into 6 main units was maintained: Northwestern Poland (A), Northeastern Poland (B), Southeastern Poland with exclusion of Carpathians (C), Central Poland (D), Carpathians (E) and Sudetes (F).

## Northwestern Poland

This region is conventionally bounded on the west and on the east by valleys of the Oder River and the Vistula River. The Baltic Sea coastline constitutes its northern border, while the southern border is delineated by the S line of maximal extent of Vistulian/Würm glaciation marked by marginal landforms of the Leszno Phase (Kondracki 2011, Solon et al. 2018). However, in practice, regions of the Pomerania Lakelands are the most important. In particular, river valleys, primarily formed in the deglaciation process, and depressions of different origin, most often with lakes currently at different stages of terrestrialization, played a significant role in the development of alkaline fens. Variable geological landforms dominated by moraine glacial till and sorted sands and gravels of sandurs are essential for the chemical character and composition of groundwater supporting the fens (Herbich 1994, Wołejko 2000, Osadowski 2010).

In terms of the administrative division of Poland, this area occupies the Zachodniopomorskie Voivodeship and parts of the Pomorskie Voivodeship and Kujawsko-Pomorskie Voivodeship located west of the Vistula River and northern parts of the Lubuskie Voivodeship and Wielkopolskie Voivodeship. According to data from the Naturalists' Club database, 235 patches of habitat 7230 in this region cover an area of ca. 1450 ha in total. Several distinct areas of alkaline fen concentration can be distinguished. They are situated in the following mesoregions (Kondracki 2011, Solon et al. 2018): Białogard Plain, Słupsk Plain, Polanów Heights, Choszczno Lakeland, Drawsko Lakeland, Bytów Lakeland, Cassubian Lakeland, Gorzów Plain, Drawa Plain, Wałcz Lakeland, Szczecinek Lakeland, Gwda river valley, Southern Krajna Lakeland, Charzykowy Plain and in the Tuchola Forest. A few but important sites were preserved in the Lubuskie Lakeland, especially in the Torzym Plain. Several fens have also been recorded in the Toruń-Eberswalde Ice Marginal Valley.

### Alkaline fens in the northern part of the Tuchola Forest

*Robert Stańko*

The Tuchola Forest is an expanse of large sandur plains having an area of over 3 000 km$^2$ covered by a complex of oligotrophic pine forests, one of the largest in western Poland, situated in two mesoregions: the Charzykowy Plain and the Tuchola Forest. These are terrains with relatively diverse young-glacial landforms, interwoven by well-developed hydrographic grid and numerous water bodies, including many hard-water lakes dominated by *Chara* spp. More than 50 alkaline fens have been reported to be located mostly in the northern part of the complex.

Alkaline fens are encountered here most often in the vicinity of the lakes located in vast, relatively shallow kettle depressions and also in narrow deep subglacial tunnel valleys. Diverse, concave landforms usually filled with sediments are the primary basis for development of alkaline fens gaining over time also hydrological support from groundwater. The hydrological relations of this area are determined by special geomorphological configuration. Waters supplying the alkaline fens originate from vast sand outwash plain. Usually they form one main water-bearing horizon, while in the tunnel valleys located in the neighboring Cassubian Lakeland, several inter-moraine horizons are present (Herbich 1998a).

It is also noteworthy that carbonate formations are locally exposed, as near the source of the Kulawa river where alkaline mires are located in a nature reserve Dolina Kulawy established, among others, for their conservation (see Chapter 8). The geological structure of this river valley is partially associated with a broken natural barrier maintaining an earlier water level in postglacial reservoirs. In a part of the valley, erosion processes have uncovered the layers of calcareous gyttja and carbonate tufa (of spring origin) lining bottoms of old reservoirs and the seeping edges of river valleys (Prusinkiewicz & Noryśkiewicz 1975). Apart from alkaline mires, the localities of many calciphilous mesophilic species can be identified in this area. Small patches of interesting calciphilous vegetation regenerate also at locations of former excavation works, like in the former chalk mine near Zapceń village.

This area is distinguished by the highest concentration of sedge-moss fens in all of northwestern Poland (ca. 7,5 fen/100km$^2$) and by the best conservation status and diversity of flora, especially in the fens located close to the lakes since they were not so easy to dewater. Special geomorphological features (biogene-poor sandur landscape, less suitable for agricultural use but rich in calcium carbonate limiting natural and anthropogenic eutrophication processes) and probably historical factors enabled the survival here of the several best developed and conserved sites in the western Poland. The following are worth mentioning: Mechowisko Radość, Bagno Stawek, Krąg lake, Księże lake, Kruszynek, Zielona Chocina, Polgoszcz, Wieck, Zdrójno, Cypel, Kulawa river valley, Lipczynka river valley, and Dłużnica river valley. Most of these mires developed as a result of lake terrestrialization which is confirmed by their shallow peat beds directly overlying, mostly carbonate, gyttjas. It is also worth noting that these mires have huge potential for further stable development and expansion in size due to constant overgrowing of adjacent water bodies.

The vegetation of the alkaline fens in this area is often presented as a reference for sedge-fens of northwestern Poland while these sites are mentioned among the most dazzling natural sites (Stańko & Wołejko 2018a). At the best preserved sites, for example Bagno Stawek or Mechowisko Radość, relative large areas are occupied by already exceptionally rare in lowlands associations: *Eleocharitetum pauciflorae, Caricetum paniceo-lepidocarpae* and *Scorpidio-Caricetum diandrae.* The mosaic of moss-low-sedge vegetation is complemented by the most common of lowland sedge-moss associations, namely *Menyantho-Sphagnetum teretis*. All the aforementioned associations are distinguished by the highest concentration of species in this part of Poland considered to be characteristic of the *Caricion davallianae* alliance and exceptionally rare species. Alkaline fens of the northern part of the Tuchola Forest are the largest refuge of *Saxifraga hirculus* in western Poland. In addition, these areas harbor probably the most abundant populations in western Poland of such species as: *Liparis loeselii*, *Carex dioca*, *C. chordorrhiza*, mosses: *Cinclidium stygium, Hamatocaulis vernicosus, Scorpidium scorpioides*, *Limprichtia cossonii*, *Tomentypnum nitens*, *Helodium blandowii*, *Paludella squarrosa* and species of the genus *Campylium spp.* Rarities of this area also include species occurring sporadically and increasingly rarely recorded in Poland: *Pseudocaliergon trifarium* and *Meesia triquetra*. Sedge-moss fens are also overgrown by characteristic peat mosses: *Sphagnum warnstorfii, Sph. subnitens* and *Sph. teres.* A majority of fens harbor abundant orchid populations: *Dactylorhiza majalis, D. incarnata, D. fuchsii* and the most abundant *Epipactis palustris.* Low sedge vegetation and excellent water conditions of the best preserved fens (valleys) provide favourable conditions for growth of bladderworts including *Utricularia australis, U. intermedia, U. minor*, *U. ochroleuca*.

Some sites located in this area have been long known and are thoroughly described in scientific literature, e.g., Bagno Stawek (Lisowski et al. 1965), however the majority of them have been identified and described in recent years (Gdaniec 2010, Gdaniec & Markowski 2010, Gdaniec & Schutz 2010, Stańko et al. 2015, Kozub & Dembicz 2018). Mechowisko Radość, adjacent to the Luboń village, can be mentioned here as a specific case as it was discovered in 2008 and first described as late as in 2009 as one of the most valuable alkaline fens in western Poland (Kujawa-Pawlaczyk et al. 2009, Stańko et al. 2015).

Observations and surveys carried out in recent years indicate that other still unknown alkaline fens can be discovered in this area.

Knowledge on the alkaline fens in the Tuchola Forest was significantly extended and updated during documentation of valuable fens and drafting projects of their conservation realized by the Naturalists' Club and Regional Directorate of Environmental Protection (RDOŚ) in Gdańsk in recent years. A synthetic description of the natural conditions of the most important sites and references to

Photo 82: Mechowisko Radość nature reserve of terrestrialization origin, is a locality of yellow marsh saxifrage (photo by J. Kujawa-Pawlaczyk).

unpublished materials can be found in the following publications: Kiaszewicz & Stańko (2011a), Wołejko et al. (2012), Stańko & Wołejko (2018a).

The alkaline fens of this area are protected in Natura 2000 sites: Sandr Brdy PLH220026, Ostoja Zapceńska PLH220057, Jezioro Krąg PLH220070, Jezioro Księże w Lipuszu PLH220104, Rynna Dłużnicy PLH220081 and Jeziora Wdzydzkie PLH220034; while those located at the site Nowa Brda PLH220078 still require inclusion in the list of protected sites (see Chapter 8). Until the end of the last century, only one nature reserve protecting alkaline fens was established there, i.e., Bagno Stawek, created in 1977. The Dolina Kulawy nature reserve was established in 2009 (enlarged in 2009) while the next nature reserves created in the period 2014 – 2018 most of all to protect alkaline fens include: Mechowisko Radość, Kruszynek and Mechowisko Krąg covering a total area of ca. 22 ha (Makowska et al. 2018). Their management was planned in parallel (Rekowska et al. 2014, Bociąg et al. 2014, Gawroński et al. 2016). It is still necessary to establish the Zdrójno nature reserve and Jezioro Trawnickie nature reserve and to perform corrections of boundaries of Natura 2000 sites (see Chapter 8).

**Alkaline fens in the Kaszuby moraine landscape**

*Robert Stańko, Paweł Pawlaczyk*

A concentration of alkaline fens is situated in three mesoregions: the Cassubian Lakeland and the Żarnowiec Height split by the Reda-Łeba Progracial Valley. The moraine part of the Kaszuby region, unlike the adjacent sandur areas, is characterized by the presence of a few scattered alkaline fens, most of which are in bad shape.

On the slope of Żarnowiec Height and on the bank of Reda-Łeba Progracial Valley, Orle mire is located. Alkaline fens have been preserved here in the edge mineral zone of a very large wetland complex surrounding the lake. They originated from lake terrestrialization but at present they are situated 1 – 1,5 m above the water level; they are supplied by groundwater flowing from the northern and northeastern edge of the Żarnowiec Heights. Habitat 7230 at this location covers a coherent area of ca. 36 ha, which is rather exceptional in western Poland, and is characterized by the occurrence of an almost complete set of regional typical species, e.g., *Liparis loeselii, Dactylorhiza fuchsii, D. incarnata, D. maculata, D. majalis, Epipactis palustris, Polemonium coeruleum* and bryophytes: *Paludella squarrosa, Helodium blandowii, Tomentypnum nitens* and *Hamatocaulis vernicosus*.

The fen is overgrown by vast patches of blunt-flowered rush *Juncus subnodulosus*, the population of which belongs to the largest in this region. Unfortunately, almost all resources of well-preserved alkaline fens are privately owned and the owners do not agree to the implementation of necessary conservation measures (Stańko 2011).

The sedge moss fen at the Bukowina River mouth to the Kamienieckie lake in the Sierakowice municipality is long known (Herbich 1994) and given the signifying name of either Jezioro Święte or Jezioro Kamienieckie. The mire fills the terrestrialized bay of this lake. The dominant communities include the *Menyantho-Sphagnetum teretis* and the *Caricetum diandrae*, harboring, e.g., *Helodium blandowii*, *Tomentypnum nitens* and numerous orchids *Dactylorhiza spp.* (Utracka-Minko, unpublished).

The alkaline fen located in the area of the Zęblewo village in the Szemud municipality is now occupied predominantly by meadows where only four patches of typical vegetation (*Menyantho-Sphagnetum teretis*, sedge-moss fen form of the *Caricetum rostratae*) were preserved and called the Mechowiska Zęblewskie. This habitat developed into several small patches in the edge zone of a small stream valley. The central part of this area is covered by heavily flooded rushes, mostly reeds and tall sedges, surrounding a few ponds created probably by beaver dams. The plant communities representing the habitat are characterized by a significant proportion of meadow species, which are now heavily saturated with water due to beaver activity. In spite of this, they are increasingly overgrown by willows and black alders.

The fen developed as a result of lake terrestrialization processes. Drilling showed a shallow sedge-moss peat layer (to a depth of 40 cm) underlain by organic gyttja.

Several alkaline fens are concentrated in the Ostrzyca Tunnel Valley in the Stężyca municipality. In the past, sedge-moss fens were reported to be situated in a narrow strip of land between the Lubowisko lake and Dąbrowskie lake (Herbich 1994) and at the edge of the Potulskie ribbon lake near the Gołubie village. At the latter site, even today the *Menyantho-Sphagnetum teretis* was confirmed with abundant population of the marsh helleborine *Epipactis palustris*. The most interesting site, i.e., Gołubie mire located in the side tunnel valley south of the Dąbrowskie Lake is overgrown by a mosaic of communities: Scorpidio-*Caricetum diandrae, Caricetum lepidocarpae* and *Menyantho-Sphagnetum teretis*, with a well-developed brown moss layer comprising *Paludella squarossa*, *Tomentypnum nitens* and *Helodium blandowii*, with a locality for *Liparis loeselii* (Utracka-Minko, unpublished).

Several small alkaline fens can be found in the western part of this area at the upper Łupawa river and its tributary – the Bukowina river. The sites on the Bukowina river are heavily degraded but the interesting Dąbie fen was preserved along a short Łupawa tributary west of the Rokitki village. It is covered by a com-

Photo 83: Dąbie fen in the Łupawa river valley (photo by J. Kujawa-Pawlaczyk).

plex of communities *Menyantho-Sphagnetum teretis, Caricetum appropinquatae* and *Scorpidio-Caricetum diandrae* with carpets of moss *Helodium blandowii* and *Cinclidium stygium*; orchids are very abundant: *Epipactis palustris*, *Dactylorhiza incarnata*, *D. majalis*, *D. fuchsii* (Kujawa-Pawlaczyk, unpublished).

The fen in the southern part of this area in the Wierzyca river valley north of the Wielki Klincz village is strongly degraded and practically transformed into a wet meadow, but it is known as a site where interesting studies were conducted to determine the effect of mowing on alkaline fen vegetation (Kozub et al. 2019).

**Alkaline fens in the Upper Słupia River catchment area**

*Robert Stańko*

This complex of alkaline fens is located in the western parts of the mesoregions: Bytów Lakeland and Polanów Heights. The landscape is dominated by moraine high plains with relatively numerous lakes in tunnel valleys. The Słupia River with plentiful small tributaries is the main axis of this area.

Alkaline mires in the Upper Słupia river catchment area occupy both terrestrialized lake basins (with dominating percolating water supply) and the edges of river valleys where the water supply from springs prevails. They widely differ in hydrological relations which is associated with peculiar geomorphological features of their groundwater catchment area. Waters supporting alkaline fens can originate both from one water-bearing horizon (sites located in close proximity or on vast sandur plains) and from many water-bearing layers in the case of tunnel valleys cracking through moraine landforms.

The distribution and natural values of the fens in this area are well recognized. It was possible owning to realization of the project "Valorization of natural resources and preliminary characterization of hydroecological conditions of wetland ecosystems in the Słupia River Valley Landscape Park" carried out by the Landscape Park in 2001 – 2002 (Stańko et al. 2002, in Polish).

To date, a dozen or so sites of different sizes have been preserved in this area; they are usually in bad shape due to draining and transformation into meadows and pastures. Also a lot of hydrotechnical transformations, like the construction of watermills and small hydropower plants either on the Słupia river of its tributaries, have contributed to fen degradation. A hydropower plant system and related historical infrastructure have been in operation until today to the detriment of the alkaline fens. It is harmful for spring fens situated along the so-called Old Słupia river, i.e., the original river-bed, presently carrying only a slight amount of water. The remaining water flow was diverted to the new river channel, several kilometers long, to supply the hydropower plant.

Consequently, characteristic vegetation of alkaline fens, especially typical sedge-moss fens, has been preserved in a residual form. The only exemption is a remarkably well-preserved fen in the Mechowiska Sulęczyńskie nature reserve (Herbichowa & Herbich 2015, Herbich 2017). It is a very young terrestrialized mire on deep calcareous gyttja bed with a few traces of exploitation. Its most important floristic components include such species as the *Liparis loeselii*, *Hammarbya paludosa*, *Carex dioica*, *Stellaria crassifolia* and rare in the northern part of the country *Eriophorum latifolium*. Moreover, orchid species have developed there very large populations comprising thousands of individuals: *Epipactis palustris* while *Dactylorhiza majalis* and *D. incarnata* are less abundant. Of the bryophytes, the following are worth mentioning: *Cinclidium stygium*, *Hamatocaulis vernicosus*, *Scorpidium scorpioides* and huge populations of *Paludella squarrosa*, *Tomentypnum nitens* and *Helodium blandowii*.

The nature reserve, postulated for several years, was established as late as in 2014, among other things thanks to a land purchase by the Naturalists' Club. Almost immediately thereafter, a conservation plan for this area was prepared and a thorough scientific monograph was published (Herbich 2017), concluding many years of interdisciplinary studies.

Among the terrestrialization mires of the Upper Słupia river catchment area, also two other sites protected as nature reserves – Gogolewko and Skotawskie Łąki – are worthy of notice. These sites were heavily transformed in the past. Although the major part of their area was changed into meadows, they have been undergoing slow spontaneous renaturation and regeneration as a result of implementation of conservation measures (blockading of ditches and restoration of extensive mowing). The characteristic vegetation of alkaline fens was preserved only in small and scanty patches (e.g., an excellently preserved *Scorpidio-Caricetum diandrae* patch of several ares with copious appearance of *Hamatocaulis vernicosus* in the Skotawskie Łąki nature reserve), but these sites are interesting as examples of spontaneous renaturation processes.

The Gogolewko nature reserve was probably the first where an example of spontaneous sedge-moss fen regeneration in shallow peat hollows was described (Stańko et al. 2003). This process has been observed already for over ten years and the vegetation identified in 2001 still preserves its character.

The Mechowiska Czaple nature reserve is a representative of the second group of alkaline fens of the Upper Słupia River catchment area, formerly more widespread, developing in systems of transverse river valleys. In the past almost the entire side valley of a tributary of the Słupia river was covered by alkaline fens. On the steepest edges, typical spring fens including cupola springs developed, often transforming into percolating fens in the lowest parts of the valley. A part of the mires was irreversibly transformed into meadows. However, those receiving ample groundwater supply, survived. The vegetation is diverse; vegetation of the cupola springs heavily saturated with water is dominated by lesser pond sedge

*Carex acutiformis* with copious representation of *Equisetum fluviatile* and *E. palustre*. In the neighborhood, shallow peats (ca. 30 – 40 cm deep) are also covered by typical sedge-moss fen vegetation represented by the *Menyantho-Spahagnetum teretis* association. The conducted stratygraphic studies confirmed the presence of moss and sedge-moss peats with tufa interbeddings in the central part of the valley.

Small but valuable alkaline spring fens are also preserved along the Słupia River near the Parchów village. Unfortunately, floristic elements characteristic of sedge-moss vegetation are scanty, but an abundance of orchids is a hallmark of these sites. In respect of landscape, the cupola fens of the so-called Old Słupia river are worth special attention, especially considering the significant height differences. Unfortunately, due to drainage works in the past, the typical sedge-moss vegetation almost disappeared. Several meter-high cupolas and their slopes are overgrown mostly by sedges.

Alkaline fens of the Upper Słupia river catchment area were included in the Natura 2000 network. Mechowiska Sulęczyńskie PLH220017 alone constitutes one Natura 2000 site. All of other fens are situated within the boundaries of the Natura 2000 site Dolina Słupi PLH220052. The most valuable of them are protected as nature reserves. The Mechowiska Czaple nature reserve and Skotawskie Łąki nature reserves were created in 2018, and the Mechowiska Sulęczyńskie nature reserve in 2014. The establishment of the Gogolewko nature reserve in 2018 was made possible thanks to an earlier purchase of the mires by the Słupia River Valley Landscape Park. Conservation plans were prepared for all these nature reserves and for several years conservation measures have been regularly implemented with the aim to preserve the alkaline fens. Even before establishing the nature reserves, at the beginning of 21st century, the Słupia River Valley Landscape Park built several tens of ditch blocking structures at the Skotawskie Łąki and Mechowiska Czaple. They were restored by the Naturalists' Club in 2017 within the framework of the program of conservation of alkaline fens in northern Poland. Within this project, shrubs and trees overgrowing the fen were removed from the area of ca. 30 ha in the Gogolewko nature reserve. The conservation works are currently continued by the Pomeranian Complex of Landscape Parks and by Forest District Bytów.

### Alkaline fens of the Bobolice-Koszalin area

*Lesław Wołejko*

A complex of alkaline fens is situated at the southern boundary of the Southern Baltic Coastland and Pomerania Lakeland at the interface of four mesoregions: the Białogard Plain, Słupsk Plain, Polanów Heights and Bytów Lakeland. This location has contributed to the variability of landforms and geomorphological structure, which encompasses flat and wavy plains, edges of moraine plateaus, post-glacial formations and a fragment of ice marginal valley and created beneficial conditions for development of different types of groundwater-fed wetlands. Sixteen sites with vegetation typical of alkaline fens with a total area of 110,8 ha were identified. At present, these fens are drained by water courses of the upper Parsęta river catchment area (Radew, Chociel and Chotla), Dzierżęcinka and Uniesta, and streams belonging to the Wieprza River catchment – the Grabowa River and its tributary the Bielawa River. A more detailed description of the most important sites, their status and conservation measures have been presented in the articles by Stańko (2011), Wołejko et al. (2012), Stańko & Wołejko (2018a). Some of them were also a focus of international ecological studies (Aggenbach et al. 2013).

The alkaline fens of the Koszalin region were a subject of earlier geobotanical studies (Osadowski & Sobisz 1998, Osadowski 1999, 2000, Osadowski & Fudali 2001, Osadowski & Wołejko 1997). These areas harbor significant populations of valuable species associated with fens, e.g., *Hamatocaulis vernicosus, Paludella squarrosa, Tomentypnum nitens, Helodium blandowii, Limprichtia cossoni, L. revolvens, Sphagnum warnstorfii, Sph. teres, Juncus subnodulosus, Epipactis palustris, Dactylorhiza majalis, D. maculata, D. incarnata, Carex lepidocarpa, Carex diandra, Carex pulicaris, Eleocharis quinqueflora, Eriophorum latifolium, Juncus alpinus* and *Gymnadenia conopsea.*

The alkaline fen located in the nature reserve and Natura 2000 site Mechowisko Manowo PLH320057 covering 55,47 ha is the largest and best-preserved site in this area. The *Scorpidio-Caricetum diandrae* and *Menyantho-Sphagnetum teretis* associations dominate its vegetation with significant populations of *Liparis loeselii* (ca. 100 individuals) and *Hamatocaulis vernicosus.* Moreover, the following species are abundantly represented: *Eriophorum latifolium, Carex limosa, Paludella squarrosa*, *Tomentypnum nitens*, *Helodium blandowii, Limprichtia cossonii, Dactylorhiza majalis, D. incarnata, Pedicularis palustris* et al. In addition, the interesting acidic fens developing in this area represent the early stages of transition mires.

The tiny alkaline fens in the upper section of the Radew river are situated principally on seeping slopes of valleys and spring sections of its tributaries. Among the 8 fens of this group, 5 with a total area of ca. 21 ha are subjected to conservation works within the project LIFE (detailed descriptions can be found in the publication by Stańko & Wołejko 2018a). The fens of the Łęczna and Drzewiana river valleys belong to the most valuable mires in terms of floristic and phytocenotic composition. In spite of negative changes associated principally with abandoning their use as meadows, patches of communities belonging to the *Caricion davallianae* alliance have been preserved with a whole range of floristic rarities. One of the largest populations of *Juncus subnodulosus* in Poland was discovered in the fen in the Zgniła Struga river valley (a Radew river tributary).

In the surroundings of the Kwiecko lake, besides several better preserved fens worthy of legal protection, such as the proposed Kwiecko nature reserve (see Chapter 8 and Makowska et al. 2018) and Wietrzno mire, there are also other sites that are evidence of the past intense activity of calcium-rich groundwaters. Soils in this area are of pararendzina character and are overgrown by unique orchid beech forests (Wanic 2010, Osadowski 2010). This ecosystem is protected as the Wapienny Las nature reserve, established in 2018. The complex of mires in the Chociela river valley, situated near the village of Bobolice, is also worthy of notice. Due to anthropogenic pressure the contemporary vegetation of this site contains only scanty elements typical of live alkaline fens, however it is rich in spectacular wet meadow communities with mass occurrence of *Trollius europaeus*. Features of alkaline fen vegetation were preserved only in small seepage areas along gulleys cutting through the slopes of the valley. It is also a key area for paleoecological studies due to the preservation of deep and complete Holocene deposits of spring and peat sediments (e.g., Osadowski 2000a, b, Mazurek et al. 2014).

The above-described fens are protected as the Natura 2000 site Dolina Radwi, Chocieli i Chotli PLH320022.

Besides the fens hydrologically linked with the Radew/Parsęta river catchment area, the picture of alkaline fen distribution in this region is complemented by fens in valleys of other costal rivers. The floristically interesting but quickly overgrown by forest Jacinki mire is situated in the Grabowa river valley (a tributary of the Wieprza river) (Braun et al. 2009). In the same catchment area, there is the soligenous Ratajki fen with sedge-moss vegetation (*Juncetum subnodulosi, Menyantho-Sphagnetum teretis*) and wet sedge-moss meadows (Kujawa-Pawlaczyk et al. 2018). These sites are not the subject of any form of nature protection that they deserve.

### Alkaline fens of the Drawa Forest

*Paweł Pawlaczyk*

The forest complex of the Drawa Forest (Puszcza Drawska) covering an area of 3 000 km$^2$ and overgrowing the Drawa Plain composed mostly of fluvioglacial sands shelters ca. 40 sites with typical of or related to alkaline fen vegetation comprising a total area of 100 ha. In some parts of the forest, the concentration of alkaline fens reaches 5 sites/100 km$^2$. However, they represent only 1,7% of all mires in the forest (Kujawa-Pawlaczyk & Pawlaczyk 2017).

The landscape is conspicuous for complex trains of tunnel valleys and fractures carved by meltwater from the retreating ice sheet, currently used by the Drawa river and its tributaries, and also for kame forms and kettle depressions, often with ribbon lakes. The alkaline fens occurring in this area most often belong to young terrestrialization mires with a relatively shallow peat layer and thicker gyttja bed. They are frequently located in widenings of postglacial tunnel valleys, thus being usually situated either on the sides of river valleys or in extensions of lakes filling tunnel valleys. The history of many other fens, at present transformed into raised bogs, went through the sedge-moss type vegetation phase.

Only a slight portion of alkaline fens in this region assumes the form of typical sedge moss fens. Larger typical patches of loose, low sedge vegetation with a dense carpet of brown mosses occur only at a few sites (e.g., Mnica, Zgnilec River Valley, Bukowo fen), but even here the proportion of typical calciphilous species is minor. A majority of fens is rather dominated by rush vegetation with *Carex acutiformis, C. rostrata*, *Cladium mariscus*; also with numerous patches of wet meadows of the *Calthion* alliance with more or less clear relations to sedge moss fens. Small patches of the *Menyantho-Sphagnetum teretis* and *Scorpidio-Caricetum diandrae* communities are more common as components of rush vegetation complexes. The alkaline character of the fens is usually expressed by the presence of indicator species of peat mosses and brown mosses, with the most common in this region *Sphagnum teres* and *Limprichtia cossoni*, and the quite common: *Tomentypnum nitens* and *Helodium blandowii*. *Paludella squarrosa* creates carpets covering an area of several tens of square meters but only in the best preserved sites (Mnica, Zgnilec river valley, Nowa Studnica, Bukowo fen, Storczykowe Bagno and Osowiec mire). Also, *Cinclidium stygium* and *Hamatocaulis vernicosus* can be found at better preserved sites. Locally, *Scorpidium scorpioides* is a unique species, confirmed nowadays only in the Bukowo fen and Zgnilec river valley, although it was observed in several other sites in the past.

At the Mnica mire, patches of a few-flowered spike rush community of the *Eleocharitetum pauciflorae* have been preserved at least since 2009. In the past, this community was recorded also at other sites, e.g., in the Kłocie Ostrowieckie mire, however it has disappeared there till the present. A dozen or so localities for *Liparis loeselii* have been found but its populations are tiny, represented only from several to several tens of individuals. On the other hand, *Epipactis palustris* occurs in more than 20 sites. A location for *Tofieldia calyculata* is a rarity, found only on a tiny patch of sedge-moss fen vegetation on a mid-forest Molinia meadow near Nowa Studnica village (F. Jarzombkowski, unpublished). *Juncus subnodulosus* develops compact fields in one of the fens on the Drawsko military training ground but is not common in other sites. The populations of orchids are rich, comprising *Dactylorhiza majalis, D. incarnata* and *D. fuchsii*. For *Parnassia palustris* and *Valeriana dioica*, alkaline fens provide local optimum conditions.

Fens in the present Drawa National Park (Drawieński Park Narodowy) have long been a focus of study (Jasnowski et al. 1986, Kujawa-Pawlaczyk & Pawlaczyk 2015, and references cited therein). The present state of knowledge on fens of the southern and central part of this area within the boundaries of the Natura 2000 site Uroczyska Puszczy Drawskiej PLH320046 was presented in a book by Kujawa-Pawlaczyk & Pawlaczyk (2014). Updated detailed data reported by these authors on fens in the northern part of this area, i.e., in the Drawsko military training ground, still remain unpublished though an outline of general knowledge on the fens of this region has already been published (Kujawa-Pawlaczyk & Pawlaczyk 2017).

The Kłocie Ostrowieckie mire harboring an interesting mosaic of sedge-moss fen, sedge rushes and fen sedge beds was a focus of thorough floristic and ecological analyses, repeated ten or so years later (Jasnowska & Jasnowski 1991, Jasnowska & Wróbel 2010) and a stratygraphic and historical study (Gałka & Tobolski 2011). The Miradz and Łunoczka mires in the Drawa National Park were examined in detail by Wołejko et al. (2001), Wołejko & Grootjans (2004). Descriptions of several other sites subject to conservation measures implemented by the Naturalists' Club were published in relevant reports (Stańko & Wołejko 2018a, b).

The alkaline fens of this area are protected in the Natura 2000 sites: Uroczyska Puszczy Drawskiej PLH320046, and Jezioro Lubie i Dolina Drawy PLH320023). Bukowskie Bagno nature reserve was established in 2009 (22 ha) for protection Bukowo fen. Osowiec mire, covered by a patch of sedge-moss fen adjacent to fen sedge beds, becoming heavily overgrown by reeds, is protected in the Torfowisko Osowiec nature reserve (established in 2003, 18 ha). Other alkaline fens protected in the Drawa National Park (created in 1990) include: Północne Łąki, Miradz, Nad Jeziorem Zdroje, Łunoczka, Kłocie Ostrowieckie and Głuskie Ostępy. Several other sites also deserve to be protected as nature reserves, e.g., Mnica mire, Storczykowe Mechowisko k. Drawna, and the sedge moss fens in the Korytnica river valley near the Nowa Studnica village. Conservation of alkaline fens in the Drawa Forest has been thoroughly analyzed and planned during the preparation of a conservation plan for the Drawa National Park and nature reserves, and plans of conservation measures for the above-mentioned Natura 2000 sites, and the needed conservation measures have been implemented by the Drawa National Park and were also carried out within several projects of the Naturalists' Club; however, the conservation status of the majority of these sites is still judged as inadequate or bad.

Photo 84: Mechowisko Storczykowe near the town of Drawno (photo by P. Pawlaczyk).

Photo 85: Fields of blunt-flowered rush *Juncus subnodulosus* in the fen on the Drawsko military training ground (photo by J. Kujawa-Pawlaczyk).

## Alkaline fens in the Middle Gwda River catchment area

*Lesław Wołejko, Robert Stańko*

A group of alkaline fens is concentrated in the Middle Gwda river catchment area in the central part of the Western Pomerania Lakeland. The central part of the Western Pomerania Lakeland takes the shape of a wide belt of sandur landforms of the Gwda river valley and Wałcz Plain, and adjacent moraine fragments of the Szczecinek Lakeland and Krajna Lakeland (Kondracki 2011, Solon et al. 2018). This flat landscape is covered mostly by forests: Puszcza nad Gwdą and Lasy Kujańskie was found to comprise 29 sites representing habitat 7230 with the total area of 110 ha. They are situated mostly in valleys that eroded through post-glacial landforms and at present are occupied by the Gwda river and its numerous tributaries. Several of them show above-average values on a national scale. Comprehensive descriptions of the most important sites are presented in the reports by Stańko (2011), Wołejko et al. (2012) and Stańko & Wołejko (2018a). Some of these fens were also a focus of international ecological studies (Aggenbach et al. 2013, Grootjans et al. 2015a, b).

Alkaline fens concentrate in this area primarily in the Rurzyca river valley, which is a post-glacial tunnel valley abundantly supplied by groundwater, with many, already partially terrestrialized water bodies. Alkaline fens in the Rurzyca river valley comprise 12 patches covering the total area of ca. 60 ha. This complex belongs to the unique areas in Poland where emmersive riverside sedge-moss fens have been preserved relatively well. In terms of hydrological relations, their functioning depends on sub-slope mineralized groundwater discharge and on the stable flow of the Rurzyca river throughout the year (stabilized by lakes). Alkaline fens of the valley harbor significant populations of *Liparis loeselii* (ca. 1000 individuals) and *Hamatocaulis vernicosus,* and other typical species: *Carex diandra, C. dioica, C. limosa, Dactylorhiza incarnata, Eleocharis quinqueflora, Epipactis palustris, Eriophorum latifolium,* and also a number of rare and threatened species, e.g., bryophytes: *Meesia triquetra, Cinclidium stygium*, *Paludella squarrosa, Limprichtia cossonii, Helodium blandowii, Tomentypnum nitens* and *Sphagnum teres.*

The fens of the Rurzyca river valley were described in a number of publications, for example by Jasnowska et al. (1993), Grootjans et al. (1999), Wołejko (2000, 2015) and Wołejko & Piotrowska (2011). Nature in the Rurzyca river valley is almost completely protected in a coherent complex of four adjacent nature reserves (Diabli Skok, Dolina Rurzycy, Wielkopolska Dolina Rurzycy and Smolary with the total area of 1614.91 ha) and the Natura 2000 site Dolina Rurzycy PLH300017. Only small fens located in the lower course of the Rurzyca river remain outside of this system.

The bottom of the Debrzynka river valley deeply incised in landforms of the Gwda sandur, ca. 5 km upstream of its confluence with the Gwda river, is filled with sediments of a recently terrestrialized lake basin. Groundwater discharge from water-bearing horizons on relatively steep sandy slopes of the valley supplies numerous spring cupolas and fens. It is one of the largest compact complexes of soligenous fens in northwestern Poland. The total area of habitat 7230 patches is over 60 ha. Apart from scattered typical phytocenoses and elements of alkaline fen flora occurring in this area, worth noting is one of the scarce in western Poland populations of *Saxifraga hirculus*. Other valuable species include, e.g., *Hamatocaulis vernicosus vernicosus* (large population), *Paludella squarrosa*, *Tomentypnum nitens, Limprichtia cossoni, Sphagnum teres, Epipactis palustris* and *Carex diandra*.

Description of this site and survey results were presented, among others, by Wołejko et al. (2012) and Aggenbach et al. (2013). The river is a border between voivodeships, and a Natura 2000 site was established in the Wielkopolskie Voivodeship, but it should be extended also to the Pomorskie Voivodeship. This valley also deserves to be protected as a nature reserve (see Chapter 8).

Wierzchołek mire is situated within the Natura 2000 site Uroczyska Kujańskie PLH300052 in the headwater area of the Skicka Struga river, a tributary of the Głomia/Gwda river, in a terrestrializing bay of the Wierzchołek Lake. Among the rich flora at this site, it is worth mentioning the abundant populations of *Epipactis palustris* and *Dactylorhiza incarnata*, along with the bryophytes: *Hamatocaulis vernicosus, Helodium blandowii* and *Tomentypnum nitens*. Vegetation characteristic of habitat 7230 is represented mostly by the *Scorpidio-Caricetum diandrae* and *Menyantho-Sphagnetum teretis*. The center of the fen harbors a floating fen which is capable of quite substantial vertical movement with the changing water level. It features all the peculiarities of alkaline fen vegetation. Comparative studies carried out for many years revealed only negligible changes in its vegetation structure. The Wierzchołek mire is distinctive for an active process of tufa accumulation within the peat-producing layer. This phenomenon, once common (which was recorded in stratigraphic profiles of many fens) currently is very rare in lowlands (Grootjans et al. 2015a). It was proposed to establish a nature reserve to protect this site (Chapter 8).

A complex of several riverside percolating fens was also preserved by the Gwda River which is protected as an ecological area. They are slightly more degraded, but valuable flora components have still been preserved: *Helodium blandowii, Tomentypnum nitens*, *Epipactis palustris* and numerous orchids of *Dactylorhiza spp.*

## Alkaline fens of the Noteć Forest

*Paweł Pawlaczyk*

The Warta-Noteć interfluve (part of the Gorzów Basin. Kondracki 2011, Solon et al. 2018), is covered by a huge forest complex called the Puszcza Notecka (Notecka Forest, ca. 1 300 km$^2$), commonly known as an area of riverine sand dunes and one of the largest European dune fields. At first sight, the occurrence of alkaline fens in this landscape can seem surprising; however, the actual geology and relief of this area is much more complex. In its northern part, outcrops still emerge from beneath the sands while even Tertiary formations, including lignite, are deposited relatively shallowly. Kettle depressions are conspicuous in the landscape. A post-glacial tunnel valley latitudinally crossing the forest forms the Miała river valley. Numerous longitudinal tunnel valleys at the northern and southern edge of the forest are filled with lakes. In such conditions, springs are seen relatively frequently. Moreover, several alkaline fens have developed in this area, although they do not bear typical sedge-moss fen characteristics (except for the Okonino mire).

The Makąty mire located in the area of the Międzychód town fills a short seeping water-fed valley constituting the source of the stream emptying into the Szenińskie lake, and is protected as an ecological site. It developed as a terrestrialization mire (two small lakes are still present) but is now overgrown by alder forest, reeds and sedge rushes (*Thelypteridi-Phragmiteum, Caricetum lasiocarpae, Caricetum paniculatae*), and communities characteristic of transition mires (*Sphagno-Caricetum rostratae*).

However, scattered carpets of *Sphagnum teres* and *Helodium blandowii* and spots with *Paludella squarrosa* are still retained in this complex. Localities for *Hamatocaulis vernicosus* were also noted, and in general bryoflora at this site is characterized by exceptional biodiversity (Rusińska et al. 2009).

In the area of the town of Sieraków, a section of the tunnel valley at the southern end of the Mnich lake is occupied by a mire complex comprising moss mires and fen sedge *Cladium mariscus* beds surrounding a small lake dominated by *Chara spp*., and reeds and sedge rushes with moss undergrowth and with elements indicative of alkaline fens. This area harbors the most abundant population of *Cinclidium stygium* in the central Wielkopolska Voivodeship. There occur also *Helodium blandowii*, *Paludella squarrosa,* a small patch of *Hamatocaulis vernicosus* and a tiny population of *Liparis loeselii* (Rusińska & Gąbka 2008). This site protected as the Mszar nad Jeziorem Mnich nature reserve and Natura 2000 site Jezioro Mnich PLH300029 has long been known (Dąmbska 1962, Lisowski & Szafrański 1964).

Another interesting peatlands complex, Rzecin mire, is protected as a Natura 2000 site Torfowisko Rzecińskie PLH302019 and covers a ca. 90 ha area situated in a vast dune slack. The lake dominated by *Chara spp.*, a remnant of a larger water body, is surrounded by spacious transition mire, meadows, rushes and willow thickets with scattered patches of the *Menyantho-Sphagnetum teretis* association (interestingly, this is the site where this association was first described in Polish scientific literature). Patches of moss mires with *Sphagnum teres* are partially overgrown by reeds, intertwining with rushes of the *Caricetum lasiocarpae* and *Thelypteridi-Phragmitetum*, alternating and transforming into transition mires of moss bog type with *Sphanum fallax,* and the whole mosaic is an intermediate stage between alkaline fen and transition mire. It seems that succession leads towards the latter. A locality for *Hamatocaulis vernicosus* was confirmed there (Rusińska 2008, Kujawa-Pawlaczyk 2017, unpublished), while the literature also reports the occurrence of *Liparis loeselii, Paludella squarrosa*, *Helodium blandowii, Scorpidium scorpioides* and *Cinclidium stygium* (Wojterska et al. 2001, Stachnowicz & Wojterska 2006). The history of this site is exceptionally well known based on old maps and aerial photographs (Barabach 2012, Barabach & Milecka 2013 and Milecka et al. 2017). Moreover, different aspects of the balance of greenhouse gasses have been investigated here for over ten years. Currently, a monitoring station of the University of Life Sciences in Poznań installed at this site also automatically carries out such measurements in order to realize a manipulation experiment involving the use

Photo 86: A sedge-moss fen with *Sphagnum teres* in Rzecin mire
(photo by J. Kujawa-Pawlaczyk).

Photo 87: An automatic measuring station for the balance of greenhouse gasses, a manipulation experiment in Rzecin mire (photo by J. Kujawa-Pawlaczyk).

Photo 88: Okonino mire in early spring (photo by P. Pawlaczyk).

of rain shelters and heating a fragment of bog surface (Chojnicki et al. 2017, and references cited therein).

Mires related to alkaline fens of the *Menyantho-Sphagnetum teretis* association, with *Carex diandra*, *Epipactis palustris*, *Eleocharis quinqueflora*, *Sphagnum teres* and *Sph. warnstorfii*, were reported to occur in the wetland complex by the Święte Lake near the Miały village at the Natura 2000 site Dolina Miały PLH300042, although they occupied only a tiny area in this complex (Gąbka et al. 2008).

Okonino mire near the Miały village, filling a shallow post-glacial tunnel valley parallel to the Miała river valley, is most closely related to alkaline fens. It is overgrown by vast treeless sedge fen vegetation with peat moss and brown moss undergrowth and dominating *Sphagnum teres* and *Sph. fallax*. Particularly in the central part most abundantly saturated with water, a moss carpet is created by *Helodium blandowii*, *Tomentypnum nitens* and *Paludella squarrosa* (S. Rosadziński, unpublished). This site is not protected by any form of nature protection but deserves to be declared a nature reserve and included in the Natura 2000 site Dolina Miały PLH300042) (see Chapter 8).

## Alkaline fens of the Gorzów Sandur

*Robert Stańko*

The Gorzów sandur in terms of physiographic regionalization is called the Gorzów Plain, extending between the Warta river valley in the south, the Odra river valley in the west, and the moraine landscape of the Myślibórz, Choszczno and Dobiegniew Lakelands in the north and east. This area is characterized by a high forest cover (one of the highest in Poland). The forest complexes are dominated by pine woods with small enclaves of beech forest and oak-hornbeam forest overgrowing mostly slopes of river valleys and lake basins. A small river the Myśla, an Oder river tributary, is the main hydrological axis of this area.

To date, only 4 alkaline fens have been discovered within the boundaries of the Gorzów sandur, which are located in its central and western part. Considering the fen area and natural values, the Bagno Chłopiny nature reserve and the fen complex by the Kozie lake deserve particular attention.

The Bagno Chłopiny nature reserve was established in 1963 and then enlarged in 2000; currently it is included in a slightly larger Natura 2000 site Bagno Chłopiny PLH080004. Its values have been long known (Jasnowska & Jasnowski 1977). In spite of formal legal protection, it was almost destroyed by the construction of a drainage system carried out both in the nature reserve and its direct neighborhood in the 1980s. Alkaline fens developed and survived until today in the north-western deepest part of a former lake, currently filled with calcerous gyttja and peat. Its remnants in the form of a small pond were recorded in a historical map from 1930. At present, the entire surface of the old reservoir is covered by a floating fen with sedge-moss and moss fen vegetation. In the past, this reserve attracted the special interest of botanists due to rich flora of rare and threatened species but most of all for ample orchid populations of which a dozen or so species were identified. Currently, the most important rarities of the reserve include the following species: *Corallorhiza trifida*, *Hammarbya paludo*sa and *Liparis loeselii*. Also *Dactylorhiza* species developed copious populations, of which the most abundant are: *D. majalis*, *D. maculata*, *D. incarnata*, *D. fuchsii* and *D. traunsteineri*, and their hybrids probably dominating in numbers.

Undoubtedly, *Epipactis palustris* is the most abundant of all orchid species. The nature reserve is also characterized by rich bryophyte flora. The populations of *Paludella squarrosa*, *Tomentypnum nitens* or *Limprichtia cossonii* belong to the most copious in the Lubuskie Voivodeship. Vegetation characteristic of alkaline fens is represented by the associations: *Menyantho-Sphagnetum teretis, Eleocharitetum pauciflorae, Caricetum paniceo-lepidocarpae* and *Scorpidio-Caricetum diandrae.* In recent years, several protective measures have been implemented at this site which aimed to improve the water conditions and to suppress tree and shrub expansion into the open fen. The blockading of existing drainage ditches resulted in significant elevation of the water table. Moreover, due to the construction of the S3 expressway in the neighborhood and the so-called compensation measures (renovation and construction of additional dams) undertaken, the water table in the central part of the complex increased again by several tens of centimeters. These changes contributed to a partial flooding of the fen edges overgrown by forest, while in the open part the floating fen rose with the water table. In spite of such substantial hydrological changes (the level of the water table in the open fen increased by ca. 70 cm!), a significant suppression of tree expansion was not observed.

Another important site encompassing patches of alkaline fens is the Kozie lake, protected as a Natura 2000 site, Jezioro Kozie PLH320010 (Pluciński 2014) situated only several kilometers north-westwards from the Bagno Chłopiny nature reserve. The best preserved patches of sedge-moss fen can be found near mineral edges constituting in the past the western bank of a water body. The values of this site have been discovered relatively recently, during field surveys necessary for the preparation of a plan of protective measures for *Liparis loeselii.* The presence of *Cladium mariscus* is the hallmark of alkaline fens of this area. In this respect, this area seems to be related to similar terrestrialized systems in the neighboring Myślibórz Lakeland where numerous calciphilous species have also been identified. In respect of habitat, these systems are related to calcerous fens encountered most often at the edges of lake basins. Such complexes frequently comprise also Molinia meadows characterized by a significant concentration of calcareous plants. Presumably their development is associated with a practice of partial drying of lakes used in the past to increase area of meadows This process was accompanied by exposure of calcerous gyttja deposited under the water. This situation created advantageous conditions for calciphilous plant communities.

### Alkaline fens in the Lubusz Forest

*Robert Stańko*

The Lubusz Forest (Bory Lubuskie), in terms of physiographic regionalization, occupies the whole area of the sandur Torzym Plain and small sandur fields in foreland moraine, and the highest terraces of the Odra river valley. In the south and west, the Torzym Plain is bounded by the Middle Odra river valley, in the west and north by moraine ridges of the Łagów Lakeland. This area is characterized by one of the highest forest covers in Poland and by relatively unvaried relief. Water bodies and small rivers and streams are fed by water from the first aquifer located, depending on the depth of sandur landforms, from several to several tens of meters below ground level. The plain is cut by a dozen or so tunnel valleys of which the largest are the Ilanka river valley and Pliszka river valley, protected as Natura 2000 sites Dolina Ilanki PLH080009 and Dolina Pliszki PLH080011. Alkaline fens developed along their ridges at the intersection of the aquifers. They assume different forms, however usually forming complexes of intertwining spring and percolating fens. A majority of percolating fens are of terrestrialization origin. Their total primary area is estimated at 110 ha (50 ha in the Ilanka and Pliszka river valley each, and ca. 10 ha in the Młodno nature reserve).

Alkaline fens rarely assume the form of typical sedge-moss fens. Only slender patches, measuring up to a dozen or so ares are characterized by dominance of low sedges and brown mosses. The most valuable fens of this type are preserved in the Pliszka river valley in the area of the Kosobudki and Pliszka villages. The largest area is occupied by *Caricetum acutiformis* community in at least several variants: from typical *Caricetum acutiformis* to phytocenoses dominated by *Caricetum acutiformis* with ample contribution of, e.g., *Thelypteris palustris* and *Juncus subnodulosus*. *Cladium mariscus* was recorded very rarely only on the most water-saturated patches. *Caricetum acutiformi* association was described to occur in the Ilanka river valley as a variant with *Helodium blandowii* (Wołejko & Stańko 1998). Phytocenoses dominating in the valleys contain uncommonly scanty populations of species considered to be indicators of habitat 7230, in particular bryophytes. Nevertheless, their “alkalinity” is confirmed, for instance, by the presence of moss and sedge-moss peats in the upper layers of the peat bed and the pH of the groundwater feeding this fen (in many cases higher than pH 7.5). A unique feature of the Ilanka and Pliszka fen is related to the presence of large sometimes almost single-species patches of *Juncus subnodulosus*. The Ilanka and Pliszka valleys are of key significance for the population of this species in the whole of Poland. Among the remaining valuable species, the following are worth mentioning: *Paludella squarrosa* (small patches 1 – 3 $m^2$ in the area of Kosobudki village), more abundant *Helodium blandowii* and *Tomentypnum nitens*. Small but regionally important populations of orchid species are represented by *Epipactis palistris*, *Dactylorhiza incarnata*, *D. majalis* and *D. fuchsii*. A patch of *Eleocharis quinqueflora,* (a dozen or so $m^2$) composing there its own association *Eleocharitetum pauciflorae* has been preserved in the Pliszka river valley in the area of Kijewo for many years. In addition, a small population of orchid fen *Liparis loeselii* by the Ratno lake belongs to the most valuable components of the Pliszka river valley flora. It was discovered around 2000 when only 3 individuals were identified, then reported to be extinct, and rediscovered in 2013 as represented by 60 individuals on a newly developing floating matt built of *Thelypteris palustris* (Stańko et al. 2013).

Młodno mire situated at the southern boundary of the Lubusz Forest next to the Oder river valley is protected as a nature reserve and Natura 2000 site Młodno PLH PLH080005. It is located in the melt-out basin. The terrestrialization process has been progressing up till now and vegetation characteristic of alkaline fens has developed concentrically around the remaining open water body. Due to the elevated level of the water table (by beaver activity) by ca. 40 cm, development of sedge-moss communities in the central part of the fen was suppressed for several years, and sedge moss fens also withdrew from the mineral edges of the fen. Several years later, the water table subsided again. These ongoing vegetation changes were described in a separate publication (Stańko & Wołejko 2018a).

The Lubusz Forest fens, apart from small fragments, show signs of many years of agricultural use and drastic hydrological changes. First heavily drained, sometimes covered with sand to facilitate access of mechanical equipment, finally flooded and abandoned, they have been undergoing dynamic changes. The majority of the fens have been subject to conservation works for many years. These brought expected results in most of the patches but in others they were not able to prevent substitution of sedge-moss vegetation in by sedge-reed rushes. Improvement of water conditions and mowing was insufficient to eliminate the alder from the fens, which still produces new suckers. From fen protection perspective, it is interesting to note an excellent status of *Juncus subnodulosus* persisting for many years in spite of the absence of any conservation endeavors. The alkaline fens of the Lubusz Forests have probably the best documentation of vegetation changes in relation to dynamics of hydrological conditions and implemented conservation measures throughout the last 20 years across the whole of Poland. Detailed characteristics of particular sites and conclusions from the conducted studies were published in "The report from realization of projects: Alkaline fen conservation …" (Stańko & Wołejko 2018a).

All patches of alkaline fens in the Ilanka river valley are protected in nature reserves. The Dolina Ilanki nature reserve was established in 2000 and the Dolina Ilanki II nature reserve in 2016. In 2017, on the initiative of the Naturalists' Club, a part of the fens in the Pliszka river valley was protected as the Mechowisko Kosobudki nature reserve and the Jezioro Ratno nature reserve. Unfortunately, attempts to create nature reserves to protect other most valuable sedge-moss fens and springs in the Pliszka river valley (see Jermaczek & Maciantowicz 2018) have not been successful to date because of the objections of some property managers.

## Northeastern Poland

*Filip Jarzombkowski, Ewa Gutowska, Katarzyna Kotowska*

For the purpose of this article, northeastern Poland has been arbitrarily defined as the area of Poland delimited by the Vistula River to the west and the Vistula River and Bug River to the south (except for fens in the Płock Basin which are located in the southern part of the river valley). The northern and eastern edges of this area are delineated by the state borders with Kaliningrad Oblast, Lithuania and Belarus.

These areas were covered by ice sheet during the Saale/Riss and Vistulian/ Würm Glaciation, and are particularly important for biodiversity of sedge moss fens associated with young-glacial landscape and the Eastern Baltic Lake District (Kondracki 2011, Solon et al. 2018). However, the largest resources in terms of habitat 7230 area are comprised in the Biebrza Basin belonging to the Northern Podlasie Plain (Kondracki 2011, Solon et al. 2018).

In terms of administrative division of the country, this area encompasses the Warmińsko-Mazurskie, Podlaskie Voivodeships and a part of Mazowieckie Voivodeship. The database contains 462 patches of habitat 7230 in this area covering a total area more than 5300 ha. Several zones of concentration of alkaline fens in northeastern Poland can be distinguished, which are situated in mesoregions: Biebrza Basin, Augustów Plain, Lithuanian Lakeland (most of all in the Eastern Suwałki Lakeland and Romincka Forest in the Augustów Plain) and all mesoregions of the Masurian Lakeland. Moreover, less abundant sites – but important from a nature conservation perspective – were preserved in the Sokółka Hills where several patches of spring fens still exist in the Biebrza river headwater area.

## Alkaline fens in the Biebrza Basin

The Biebrza Basin belonging to the Northern Podlasie Plain (Kondracki 2011, Solon et al. 2018) is a part of an ice marginal valley discharging meltwater from glacier stagnating in the north during the last glaciation (Pałczyński 1975), but it is not uniform. Three so-called basins were distinguished in this valley differing in morphological and spatial features in terms of longitudinal (Okruszko 1969a, Okruszko & Oświt 1969, Pałczyński 1975) and transversal (Oświt 1968, 1973, Pałczyński 1975) zonation. In some places (especially in the northern basin) the peat layers are underlain by gyttja bed which indicates the sedimentary character of this valley in the past. The Biebrza river is a tributary of the Narew river and is situated in the Vistula river catchment area, however it is also connected with the Niemen river catchment area through the Augustów Channel built in the 19th century.

Vegetation of the Biebrza river valley is most of all characterized by transversal zonation resulting from the manner of fen supply with groundwater, namely groundwater is discharged at mineral edges and flows towards the river which can also periodically flood areas situated next to the river channel (Oświt 1968, 1973, Okruszko & Oświt 1969, Pałczyński 1975). Among three distinguished zones – immersion, immersion-emersion and emersion (Pałczyński 1975; see. Oświt 1965, 1968, 1973) – the latter is characterized by the most stable hydrological conditions which can support the development of sedge-moss fens.

Significant non-flooded areas of the Biebrza Basin are covered by diverse forms of mossy sedge fens, however a part of them has currently disappeared and some other have undergone transformation due to the construction of artificial drainage systems. Nevertheless, the Biebrza Marshes comprise the largest resources of habitat 7230 in Poland (almost 4 200 ha). They also belong to the largest compact complexes of alkaline fens in Europe. Currently, vast patches of sedge moss fens are located in the lower basin, in Bagno Ławki and in the upper basin, in the area of the Szuszalewo and Nowy Lipsk villages. In connection with the described transversal zonal plant distribution pattern, vegetation in particular basins differs; namely sedge moss fens in Bagno Ławki (lower basin) are to a much greater extent of tall sedge rush character while more typical sedge moss fens develop near the Szuszalewo and Nowy Lipsk villages.

Phytocenoses of habitat 7230 from the lower basin, partially transformed by drainage, at present represent the communities of both the *Caricion davallianae* and *Caricion canescenti-nigrae* alliances, and related ones. Moreover, communities with considerable proportion of *Calamagrostis canescens* are also present. Habitat 7230 in the lower basin is relatively species-poor, but the share of groundwater feeding-dependent species is constant. Usually sedges dominate, most of all *Carex elata*, and to a lesser extent *C. gracilis*, *C. appropinquata*, *C. rostrata* and *C. lasiocarpa*, but species of the *Molinio-Arrhenatheretea* class are also constantly present. In addition, *Calliergonella cuspidata*, *Menyanthes trifoliata*, *Phragmites australis,* *Equisetum fluviatile* and *Agrostis stolonifera* can be found in phytocenoses. The character of the plant communities in the lower basin can change depending on the humidity conditions in a particular year. When water saturation is moderate without a strong impact of flooding, these communities are colonized by bryophytes and the dominance structure of herbaceous plants slightly shifts, whereas high water saturation favors the development of rushes with sparse moss layer.

The best preserved patches of sedge-moss fens in the Biebrza river valley can be found in the upper (northern) basin, where the supply of calcium-rich groundwater still plays a crucial role (Pałczyński 1975, Wassen et al. 1990, 1992, Wassen & Joosten 1996).

Unfortunately, a considerable part of this area was also transformed into grasslands but extensive patches of sedge moss fens have been preserved near the Szuszalewo and Nowy Lipsk villages.

Sedge moss fens of this area are composed mostly of brown mosses (e.g., *Hamatocaulis vernicosus*, *Campylium stellatum*, *Limprichtia cossonii* and *Calliergonella cuspidata*) and sedge species (*Carex lasiocarpa*, *C. rostrata*, *C. diandra*, *C. flava*, *C. lepidocarpa*, *C. limosa* and *Eriophorum angustifolium*) (Jarzombkowski 2010). Apart from these species, *Menyanthes trifoliata*, *Comarum palustre* and *Parnassia palustris* are frequent. A substantial share is also provided by meadow and rush species, such as *Festuca rubra*, *Poa pratensis*, *Agrostis stolonifera*, *Lychnis flos-cuculi*, *Cardamine pratensis*, *Carex appropinquata* and *C. elata*, *Rumex acetosa* and bedstraws: *Galium uliginosum* and *G. palustre* also occur. Of the rare and threatened species, the following should be mentioned: *Liparis loeselii*, *Epipactis palustris* and *Dactylorhiza incarnata* (including its subspecies ssp. *ochroleuca*).

Close to the source of the Biebrza river (Sokółka Hills), spring fens unique on a national scale were preserved scattered over a small area, including the fen next to the Sidra village (see Chapter 2) which reaches a relative height of several meters.

In the central basin, sedge moss fens almost entirely disappeared and were replaced by post-bog wet meadows, Molinia meadows and their degraded forms, often in a very intense use. Small-size patches of the habitat within the boundaries of the Czerwone Bagno strict protection area and in its neighborhood are the only exemption.

The Biebrza Basin sedge moss fens are currently protected in the Biebrza National Park and the Natura 2000 site Dolina Biebrzy PLH200008, larger than the park (see Chapters 8, 10). Several sites are situated in the adjacent Natura 2000 site Ostoja Augustowska PLH200005. Sedge moss fens at the source of the Biebrza river are protected as Natura 2000 site Źródliska Wzgórz Sokólskich PLH200026.

**Alkaline fens of the Lithuanian Lakeland**

The Lithuanian Lakeland comprises the Augustów Plain, Eastern Suwałki Lakeland, Western Suwałki Lakeland and Romincka Forest (Kondracki 2011, Solon et al. 2018). The former two are the most important in terms of quantitative resources of fens.

A large area of the Augustów Plain is covered by the Augustów Forest. It is situated at the borderline of the Niemen and Vistula river catchment areas, and the Czarna Hańcza river, and the Augustów Channel constituting hydrological axes of the Polish part of the Augustów Forest are considered to be tributaries of the Niemen river. The Augustów Plain is a flat sandur plain built of sands and gravel deposited by meltwater outwash from the glacier during the last glaciation. It is crossed by river valleys and scattered with kettle lakes created from melted chunks of dead ice. Fens fed by calcium-rich waters developed in some river valleys (e.g., in the Czarna Hańcza catchment area), by some lakes (e.g., those located along the Augustów Channel) and in some lake basins where lakes have already disappeared. The development of soligenous fens is contingent upon a long-term groundwater discharge from below valley bluffs or from the lake basin, and also on sealing its bottom by gyttja deposits.

The fen flora is relatively diverse and comprised most of all of sedge moss vegetation of the *Caricetum paniceo-lepidocarpae, Scorpidio-Caricetum diandrae* and *Caricetum lasiocarpae* associations, and also sedge moss fen phytocenoses with *Limprichtia cossonii*, *Campylium stellatum*, *Carex lasiocarpa*, *Carex panicea*, *Carex limosa* and *Baeothryon alpinum*. Within these communities there are patches of subneutral moss mires of the *Menyantho-Sphagnetum teretis* association, and complexes with f *Eleocharis quinqueflora*. Phytocenoses with *Carex elata* prevail on some fens. Fen sedge beds *Cladietum marisci* and different transition forms towards tall sedge rushes (mostly with *Carex acutiformis*) or thickets communities (e.g., with dwarf birch and willows) are locally encountered. Moreover, phytocenoses dominated by *Carex rostrata, Festuca rubra*, *Aulacomnium palustre*, *Tomentypnum nitens* prevail in some fens with numerous meadow species. Smaller areas are occupied by rushes with mosses *Caricetum appropinquatae* and *C. paniculatae.*

The most important sites in this area include the soligenous fens of Rospuda river valley and a number of smaller fens (both soligenous and topogenous), situated along the Augustów Channel and related lakes (e.g., Borsuki mire and Kobyla Biel mire).

The Rospuda river valley was a channel crossing the sandur plain which was discharging glacial meltwaters during the last glaciation. After the glacier had receded, a lake was formed in its lower segment which was becoming increasingly shallower and finally was overgrown by wetland vegetation. The fen encompasses an area of almost 600 ha and a little less than a half of the valley area is occupied by non-forest wetland vegetation composed mostly of moss-sedge (ca. 100 ha) and rush (ca. 100 ha) communities. In fact the area of these fens is smaller than those of the Biebrza Marshes, however their natural character (without any traces of drainage) and size makes the alkaline fens of the Rospuda river valley a unique wetland complex on a European scale. The Rospuda river valley was subdivided into two basins. The lower basin is lined with a 4-m deep bed of well-preserved moss-sedge peat underlain by over a 20-m deep clayey gyttja layer. On the other hand, the upper basin lacks gyttja while the depth of the peat layer reaches up to 3 m (Pawlikowski et al. 2010). Just as with the Biebrza fens, the fens in this area are characterized by a transversal (from mineral edge to the river) and longitudinal (from the upper to lower basin) zonal vegetation distribution pattern (Jabłońska et al. 2011). A narrow marginal zone harbors spring alder forest *Cardamino-Alnetum glutinosae*, and locally spruce forest growing on peat *Sphagno*

Photo 89: Lower Rospuda valley mire – complex of the species indicates limitation of primary production by nitrogen (photo by P. Pawlikowski)

*girgensohnii-Piceetum* and transition communities between them. Valley shoulders along the mineral edge are occupied by wet pine-birch forests of the *Thelypteridi-Betuletum pubescentis* followed by typical sedge moss fens, most often with dominant *Carex rostrata* in complexes with subneutral moss mires related to the *Menyantho-Sphagnetum teretis* association.

Sedge moss fens, apart from a significant contribution of the *Scheuchzerio-Caricetea fuscae* class, are characterized by an admixture of many meadow and rush species. The latter community harbors the threatened *Saxifraga hirculus*, whereas the *Liparis loeselii* population is the most abundant in Poland (more than 10 000 individuals, Pawlikowski 2008b). The next zone closer to the river is composed of sedge rushes of the *Caricetum appropinquatae* flooded partially by surface water and partially by groundwater, characterized by diverse brown moss cover but built of both sedge-moss fen and rush species. Next to the river, tall sedge beds of the *Magnocaricion* alliance dominate but *Carex acutiformis* and reeds *Phragmites australis* are also present. A narrow strip right next to the river is covered by the community *Phalaridetum argundinaceae* flooded every year with the presence of *Phragmites australis*, more rarely alder forests *Carici elongatae-Alnetum* with *Carex acutiformis*. Since the 1980s, a nature reserve has been planned to be established to protect this area. (Sokołowski 1988, 1988 (1989), 1996, see Makowska et al. 2018 and Chapter 8 herein).

Sedge-moss fen vegetation also developed on the already filled bay of the Białe lake near Augustów, as Kobyla Biel mire. This fen is not as well-known as the Rospuda river valley wetlands but represents outstanding natural values. Apart from *Liparis loeselii* in communities of the *Caricion davallianae* alliance, other identified species include: *Baeothryon alpinum*, *Eriophorum gracile*, *Carex chordorrhiza*, *C. dioica*, *C. limosa*, and orchids: *Dactylorhiza fuchsii*, *D. incarnata* ssp. *ochroleuca* and *Epipactis palustris*, and also two species of sundew: *Drosera rotundifolia* and *D. anglica*, *Pedicularis palustris*, *Ranunculus lingua*, *Viola epipsila*, bladderworts: *Utricularia intermedia* and *U. minor* and numerous brown mosses: *Bryum neodamense*, *Cinclidium stygium*, *Hamatocaulis vernicosus*, *Paludella squarrosa* and *Pseudocalliegon trifarium*, *Scorpidium scorpioides*, *Splachnum ampullaceum*, *Tomentypnum nitens* and peat mosses: *Sphagnum fuscum* and *Sph. balticum*. Moreover, it is a locality for Greyer's whorl snail *Vertigo geyeri*. This site also is waiting to be established as a nature reserve (Makowska et al. 2018 and Chapter 8 therein).

The Eastern Suwałki Lakeland, neighboring the Augustów Plain, constitutes the northeastern part of the Lithuanian Lakeland (Kondracki 2011, Solon et al. 2018). This area is characterized by young-glacial landscape created during the last glaciation. The landscape is variable with many moraines, drumlins, eskers, kames and tunnel valleys occupied by rivers and lakes. The terrain is elevated above sea level reaching an altitude of ca. 300 m a.s.l. Vegetation of fens which developed most of all around lakes and in river valleys is relatively diverse and, due to proximity of the Augustów Plain, closely resembles it. Most often fens assume the form of sedge moss complexes situated by lakes or rivers and on terrestrialized lakes with significant contribution of soligenous water supply. They are composed of sedge moss vegetation with elements of the *Caricetalia davallianae* order (phytocenoses of traditionally defined association *Caricetum lasiocarpae campylietosum stellatti*, patches similar to *Eleocharitetum pauciflorae* and *Caricetum paniceo-lepidocarpae*), fen sedge beds *Cladietum marisci* with mosses, rushes of *Carex elata* with mosses, communities of the *Caricetum diandrae* and fragments of subneutral moss mires with *Sphagnum teres – Menyantho-Sphagnetum teretis*. Besides these communities, complexes with dominant *Limprichtia cossonii* and very diverse species composition of herbaceous plants can also be found. This area also harbors dryer forms of sedge-moss fens with copious meadow species and communities developed as a result of haymaking and/or drainage.

The most important sites of this area include soligenous fens in the Szeszupa (Rudawka) river valley shoulder, fens in the Czarna Hańcza valley and a number of smaller fens (both soligenous and topogenous) scattered all over the lakeland. These sites are usually tiny but floristically very interesting and valuable (Pawlikowski 2008a, 2008b, 2010, Pawlikowski et al. 2009, Pawlikowski & Wołkowycki

Photo 90: Sarnetki mire in Augustów Forest – an example of mire with primary production limitation by phosphorus (photo by P. Pawlikowski).

2010, Pawlikowski & Wołkowycki 2010, Pawlikowski & Jarzombkowski 2010a, and references cited therein).

The vegetation of Rudawka mire is principally represented by vast soligenous sedge-moss fens with *Carex rostrata*, *Menyanthes trifoliata*, *Festuca rubra*, *Aulacomnium palustre* and *Tomentypnum nitens*, with significant participation of meadow species. A part of this fen area is occupied by rushes with an admixture of mosses of the *Caricetum acutiformis* or *C. elatae*, but sedge-moss fens are also present with *Carex lasiocarpa*. In addition, the following species occur: *Helodium blandowii*, *Liparis loeselii*, *Saxifraga hirculus*, *Stellaria crassifolia*, *Swertia perennis*, *Carex dioica*, *Dactylorhiza incarnata*, *D. baltica*, *D. rutei* and *Epipactis palustris*. The fens developed here on deep peat beds with interbeddings of tufa layers, underlain by lacustrine deposits. They are located on steep slopes which increases the value of this site.

The development of the fens in the Czarna Hańcza river valley (e.g., Rutka, Morgi, Czarnakowizna, Stara Pawłówka) is dependent on characteristic landscape formations created by meltwater outwash from a retreating glacier. The meltwater stream that flew through the Suwałki outwash plain was ca. 1 km wide and eroded the Czarna Hańcza valley. At subsequent stages of the valley development, water streams incised deeper and deeper. The presence of soligenous sedge-moss fens in this valley is connected with special conditions of the water supply, in particular with the constant long-term discharge of calcium-rich groundwater. Such conditions are created in the sub-slope part of the main Czarna Hańcza river valley and some of its shoulders. Vegetation in the above-mentioned sites assumes the form of a mosaic of patches representing the *Scheuchzerio-Caricetea fuscae* class, related to the *Caricion davallianae* alliance (including phytocenoses with *Carex lasiocarpa*, *Carex rostrata* in the herb layer, and different species of *Drepanocladus* spp., *Calliergonella cuspidata* and *Tomentypnum nitens* in the moss layer). The dominant phytocenoses contain *Limprichtia cossonii*, *Campylium stellatum*, *Carex panicea* and *Carex lepidocarpa* (*Caricetum paniceo-lepidocarpae* association), with numerous meadow species, and also grasslands with *Eleocharis quinqueflora*. *Chara* sp. complexes occur in depressions of the terrain. In some places, tall sedges like *Carex acutiformis* or *C. elata* are more abundant.

Żytkiejmska Struga mire is located at the border with the Kaliningrad Oblat west of the Żytkiejmy village in the Żytkiejmska Struga river valley, which is a tributary of Rominta river (present name Krasnaja river). It is a mesoregion of the Romnicka Forest situated west of the Eastern Suwałki Lakeland.

Fens in this area are to considerable extent supported by groundwaters and are mostly of soligenous character. Interspersed among them are spring copulas, sometimes having a relative height of several meters, developed at outlets of groundwater with confined water table. Peats with numerous tufa intercalations are slightly decomposed in most cases and underlain by calcareous gyttja bed several meters deep (Dembek 1991, Pawlikowski & Jarzombkowski 2010b).

Due to artificial drainage, most of the spring cupolas once existing in this area have been overgrown by rushes or thickets with dwarf birch but sedge-moss fen species are still present. The moss layer is often dominated by peat mosses, especially *Sphagnum teres*, tolerant to moderately alkaline conditions. Nevertheless, properly preserved non-forest ecosystems of cupola spring fens with mossy vegetation composed of sedges and grasses still function here.

At the outlet of confined groundwater these fens occur in the form of species-poor quaking bogs with dominant *Carex rostrata* and *Agrostis stolonifera*, and with participation of *Stellaria crassifolia* and *Plagiomnium ellipticum*. Cupola slopes harbor *Carex lasiocarpa* and a number of meadow species, such as *Poa pratensis*, *Galium uliginosum*, *Festuca rubra* and *Rumex acetosa*. The moss layer features *Aulacomnium palustre*, *Tomentypnum nitens*, *Sphagnum teres*, *Calliergonella cuspidata*, *Marchantia polymorpha* and *Hamatocaulis vernicosus*.

The sedge moss fens of the Lithuanian Lakeland are protected as nature reserves: Rutka, Jezioro Kalejty and Struga Żytkiejmska in the Wigry National Park (see Chapter 8) and the related Natura 2000 site Ostoja Wigierska PLH200004, and also as the Natura 2000 sites: Ostoja Augustowska PLH200005, Pojezierze Sejneńskie PLH200007, Jeleniewo PLH200001, Ostoja Suwalska PLH200003, Dolina Szeszupy PLH200016, Torfowiska Gór Sudawskich PLH200017 and Puszcza Romincka PLH280005. Several sites (e.g., Dolina Rospudy, Kobyla Biel, Borsuki, Sawonia Mostek, Krejwlanek, Jezioro Gajlik, Dolina Kunisianki) by all means deserve to be protected as nature reserves and are awaiting this status (see Chapter 8).

### Alkaline fens of the Masurian Lakeland

The Masurian Lakeland is a vast area constituting a northwestern part of the Eastern Baltic Lake District (Kondracki 2011, Solon et al. 2018). This area is also characterized by young-glacial landforms formed during the last glaciation which is visible as hills with an altitude exceeding 300 m a.s.l. Numerous ridges and ranges of moraine hills, cut by subglacial tunnels and varied by lake basins, kames and deskers, can also be seen here. Depressions are occupied by often drainless water bodies, wetlands, lakes and rivers. A part of the terrain is of sandur origin but deposits of ground and end moraines prevail. The substrate is dominated by glacial till, and to a lesser extent by sands and gravels.

Most of the fens in the Masurian Lakeland are concentrated in the Napiwodzko-Ramucka Forest. The remaining sites are widely distributed to the south of the end moraine ridges at the borderline with sandurs and throughout the outwash plain (sandur).

The vegetation of the fens located in the Olsztyn Lakeland is formed by communities of the *Scheuchzerio-Caricetea fuscae* class of mossy sedge rush character and quaking bogs, often related to tall sedge beds of the *Magnocaricion* and *Phragmition* alliance and wet meadows. Typically developed phytocenoses of the *Caricion davallianae* alliance are not frequent, but soligenous sedge-moss fens prevail with *Carex rostrata* with a considerable proportion of meadow species. A large portion of habitat 7230 patches show signs of acidification and oligortophication which is supported by drainage facilities in operation for over 100 years in this area. These phytocenoses are classified as the *Sphagno warnstorfii-Tomentypnion nitentis* alliance. Rushes with mosses of the *Caricetum paniculatae* and *Caricetum appropinquatae* and moss forms of floating matt built by ferns of the *Thelypteridi-Phragmitetum* phytocenoses also occur in some places.

The following species prevail in phytocenoses: *Carex rostrata*, *Carex acutiformis*, *Festuca rubra*, *Galium uliginosum*, *Menyanthes trifoliata*, *Thelypteris palustris* and *Equisetum fluviatile,* and in the moss layer: *Calliergonella cuspidata*, *Marchantia polymorpha*, *Aulacomnium palustre* and *Plagiomnium ellipticum*, and more rarely *Tomentypnum nitens* and *Helodium blandowii*, or *Hamatocaulis vernicosus*.

The most valuable sites in the Masurian Lakeland include the Zocie, Trępel and Głógno mires.

Zocie mire – protected as a nature-landscape complex and Natura 2000 site Torfowisko Zocie PLH280037 – is situated in the southeastern part of a small forest within a kettle basin of a terrestrialized lake which was gradually filled with gyttja. The central part of this complex assumes the form of a strongly water saturated quagmire in transition into moss mire and then into sedge-moss communities and finally into forest communities.

The largest areas are occupied by moss mire and moss-sedge communities. They constitute a system of intermingled phytocenoses with bog moss mire physiognomy (with high species diversity) and dominating *Sphagnum teres* and *Sph. angustifolium*, partially similar to *Menyantho-Sphagnetum teretis* association, sedge-moss communities with *Carex lasiocarpa* and *C. limosa* and abundant brown mosses (mostly *Campylium stellatum* and species of the genus *Limprichtia* sp.) and strongly hydrated patches of transition communities between sedge-moss fens and mossy forms of the *Thelypteridi-Phragmitetum*. In some places there are communities of transition mire character with dominant *Carex rostrata* and

*Sphagnum fallax*. At the edges, particularly in the northern and western part, peat mosses and *Oxycoccus palustris* appear and tree species begin to spread, mostly *Betula pubescens*, more rarely *Pinus sylvestris*.

The moss layer of the fen is well-developed and shows very high diversity in species composition and spatial distribution. The dominant species among the mosses include *Campylium stellatum*, *Campylium stellatum*, *Limprichtia cossonii*, *Sphagnum teres*, and locally *Pseudocalliergon trifarium*, *Scorpidium scorpioides* and *Calliergon giganteum*. Apart from the aforementioned species, the moss layer contains *Aulacomnium palustre*, *Cinclidium stygium*, *Hamatocaulis vernicosus*, *Limprichtia revolvens*, *Splachnum ampullaceum*, *Straminergon stramineum*, *Tomentypnum nitens* and peat mosses: *Sphagnum fuscum*, *Sph. subsecundum*, *Sph. warnstorfii* and other more common species.

The mosaic character of this fen creates favourable conditions for rich flora. Over 40% of flora belongs to rare, threatened and protected species (Bloch-Orłowska & Pisarek 2005), of which the following can be mentioned: *Hammarbya paludosa*, *Liparis loeselii*, *Dactylorhiza incarnata*, *Epipactis palustris, Baeothryon alpinum*, *Drosera anglica*, *D. rotundifolia*, *Carex limosa*, *C. chordorrhiza*, *C. dioica*, *Eleocharis quinqueflora*, *Scheuchzeria palustris*, *Rhynchospora alba*, *Utricularia intermedia* and *U. minor*, *Betula humilis*, and in the neighborhood of the complex, *Empetrum nigrum*. In the past, the only locality for *Carex microglochin* in Poland was reported to occur in this area.

Trępel mire is situated at the western outskirts of the Napiwodzko-Ramucka Forest on a vast sandur extending in the southwestern part of the Olsztyn Lakeland (the so-called Olsztyn Plain). It is located between the Staw lake and Niskie lake at the extension of the Pluszne Wielkie lake. Sedge-moss fens developed in the shoulder of a former subglacial tunnel as a result of lake succession accelerated by human activity. The vegetation is composed of communities of the *Scheuchzerio-Caricetea fuscae* class of mossy sedge reeds character and quaking mire (*Scorpidio-Caricetum diandrae; Helodium blandowii-Carex acutiformis* Com.), locally related to *Magnocaricion alliance* (*Caricetum acutiformis*). Moss phytocenoses dominate with prevalent *Carex rostrata* and *C. acutiformis*, with participation of *Festuca rubra*, *Equisetum fluviatile*, *Galium uliginosum*, *Eriophorum angustifolium*, *Menyanthes trifoliata* and *Thelypteris palustris*. The moss layer comprises *Calliergonella cuspidata*, *Calliergon giganteum*, *Marchantia polymorpha* and *Plagiomnium ellipticum*, and rarer *Tomentypnum nitens*, *Helodium blandowii*, *Aulacomnium palustre* and *Hamatocaulis vernicosus*.

Głógno mire is situated in the Mrągowo Lakeland south of the Borówko Lake and north-west of the Głógno village, and developed on the overgrowing body of water that filled a kettle depression in the past. The vegetation is dominated by mossy sedge communities mostly with *Carex rostrata* and *C. lasiocarpa,* while in marginal parts of the habitat and in places where more advanced secondary succession proceeds, *Thelypteris palustris* prevails with participation of *Equisetum palustre* and *Eriophorum angustifolium*. Locally also patches with *Carex limosa, Eleocharis quinqueflora* and *Triglochin palustris* can be found. The moss layer is very well-developed, species-rich with a prevalence of brown mosses and participation of alkaline-tolerant peat mosses, built mostly of *Hamatocaulis vernicosus*, *Calliergonella cuspidata*, *Sphagnum teres* and *Tomentypnum nitens*. Phytocenoses at this site are represented by the *Caricion davallianae* alliance while in some parts of this area they transition into moss mire patches of the *Menyantho-Sphagnetum teretis*. Signs of secondary succession are visible all over the fen, especially at patch edges where this habitat transitions into initial forest community with *Alnus glutinosa* and *Betula pubescens* and further into a narrow strip of alder forest surrounding the site. Isolated *Pinus sylvestris* and *Picea abies* trees are scattered around. Of shrubs, *Salix rosmarinifolia* is fairy abundant, while *Salix cinerea* and *S. pentandra* are rarer. Slight signs of acidification can be noted in the fen, and the following species appear: *Oxycoccus palustris*, *Andromeda polifolia, Drosera rotundifolia* and alkaline-tolerant peat mosses: *Sphagnum teres* and *Sph. warnstorfii*. The habitat comprises many characteristic species for alkaline fens, including rare and protected ones, such as *Liparis loeselii, Dactylorhiza incarnata, Epipactis palustris, Eriophorum gracile, Carex chordorrhiza* and *C. dioica,* and among mosses *Campylium stellatum*, *Campylium stellatum*, *Limprichtia cossonii* and *Bryum pseudotriquetrum*.

Apart from the above-mentioned sites, this region contains many other valuable sites, e.g., mires in the Napiwodzko-Ramucka Forest deserving protection in nature reserves: Uroczysko Korea and Łaźnica Lake; in the Piska Forest: Torfowisko nad Babięcką Strugą, Torfowisko nad jeziorem Krawno); and Kosewskie Bagno situated in the agricultural landscape near the Piska Forest.

Sedge-moss fens of the Masurian Lakeland are protected in the Natura 2000 sites: Ostoja Napiwodzko-Ramucka PLH280052, Ostoja Piska PLH280048, Mazurskie Bagna PLH280054, Jonkowo-Warkały PLH280039, Mazurska Ostoja Żółwia Baranowo PLH280055, Mokradła Kolneńskie i Kurpiowskie PLH200020, and also as nature reserves: Galwica, Jeziorko koło Drozdowa, Krutynia, Małga, Nietlickie Bagno, Sołtysek and Zabrodzie.

## Southeastern Poland (excluding the Carpathians)

*Filip Jarzombkowski, Ewa Gutowska, Katarzyna Kotowska, Lesław Wołejko*

For the purpose of this overview, the area of Poland comprising the Lublin-Lviv Upland and Polesie was assumed to constitute a boundary of southeastern Poland. These are old-glacial terrains where sedge moss fens are associated with the availability of mineral-rich groundwaters, the outlets of which occur in specific geomorphological situations (Kondracki 2011, Solon et al. 2018).

In terms of administrative division of the country, this area encompasses the Lubelskie Voivodeship and a part of Podkarpackie Voivodeship. Data accumulated in the database include 35 patches of habitat 7230 covering a total area of 2,800 ha. Several of the most important regions with respect to conservation of biodiversity of alkaline fens in southeastern Poland can be distinguished, in particular they can be found in the Hrubieszów Basin and Polesie. Moreover, individual sites have been preserved south of the aforementioned area.

### Alkaline fens of the Hrubieszów Basin

The Hrubieszów Basin is a fragment of the Volhyn Upland neighboring the Lublin Upland (Kondracki 2011, Solon et al. 2018). It is located in the Vistula river catchment area in the Sieniocha and Siniocha river valleys (the latter is the Huczwa river tributary) emptying to the Bug river. The hydrographic grid of this area is composed of the regulated river and extended artificial drainage system and also a complex of fish ponds. The basin was formed in a belt of soft Upper Cretaceous layers in the eastern extension of the Zamojki valley. It is a plain of loess deposition, almost flat with small relative heights. Its surface is covered by alternating loess, marls, alluvial soils and sands.

The basin is transversely crossed by the Bug River and its tributary the Huczwa river, which divide the area into two parts differing in relief. Terrain situated south of its river channel gently rises while southern area rises more steeply towards the Horodło Ridge. This terrain is characterized by the presence of flat drainless depressions and a lack of young erosional incisions. Basic landforms include Pleistocene and Holocene terrace plains created in the course of alternating cycles of river erosion and accumulation

Alkaline fens existing in this area are remnants of vast fen complexes which formed in the Sieniocha and Siniocha river valleys and once covered vast areas whereas, at present, due to severe hydrological transformations connected with the development of agriculture and peat extraction, they are limited to relatively small patches concentrated in headwater courses of rivers. In the areas where agricultural use has been abandoned, rush, forest and willow scrub communities developed as a result of secondary succession. Sedge moss fens were preserved at better hydrated locations and in former peat hollows.

At present, the fens of this region are strongly fragmented and their vegetation constitutes a mosaic of intertwined sedge-moss, meadow and rush communities. The atypical physiognomy of fens in this area is also a consequence of specific management methods, i.e., the burning of dead organic matter accumulated due to extensive use of land less suitable for agricultural use. Spring fires limited development of shrub species, led to renewal of grasses which can be used as feed only at a young stage (with prevailing *Molinia caerulea*), but only slightly increased habitat fertility. After burning of vegetation, low-sedge loose sward developed in humid places, and patches of bare soil were colonized by specific fen species, such as *Pinguicula vulgaris*.

The fen vegetation is not uniform and develops into transition forms between communities of the *Caricion davallianae* alliance concentrating mostly in peat hollows, *Schoenetum ferruginei*, and meadows of the *Molinietalia* order (including Molinia meadows of the *Molinion caeruleae* alliance with dominance of *Molinia caerulea* and presence of *Succisa pratensis* and *Sanguisorba officinalis*), and phytocenoses of the alliance with *Carex panicea* and *C. lepidocarpa* of the *Caricetum paniceo-lepidocarpae* with a great share of Molinia meadows. Hollows produced by peat extraction are occupied by communities of the *Caricion davallianae* alliance with different proportions of sedges: *Carex panicea, C. davalliana, C.lasiocarpa*, and the rarer *C. lepidocarpa, C. hostiana* with participation of broad-leaved cottongrass and common cottongrass *Eriophorum latifolium* and *Eriophorum angustifolium* and *Schoenus ferrugineus, Salix rosmarinifolia* and meadow species of the *Molinietalia* order. The moss layer is loose, built of *Campylium stellatum*, *Bryum pseudotriquetrum*, *Plagiomnium elatum*, *Pseudocalliergon lycopodioides*, *Limprichtia revolvens*, *Limprichtia cossonii*, *Calliergon giganteum*, *Calliergonella cuspidata* and *Scorpidium scorpioides*

Among all the fen patches in this area, the most distinctive is the cupola fen Śniatycze. Due to the installation of drainage facilities, the cupola is split with a channel which divides the sedge-moss fen into two parts. *Schoenetum ferruginei* community dominates with many relations with Molinia meadows, however in the midst of them at the cupola top there is a patch with *Cladium mariscus*. It is a locality for *Swertia perennis*, *Schoenus ferrugineus, Sch. nigricans, Tofieldia calyculata*, *Carex davaliana*, *Pinguicula vulgaris* ssp. *bicolor*, *Gentianella amarella*, *Epipactis palustris* and *Gymnadenia conopsea* ssp. *densiflora*. *Chara* sp. and *Pedicularis sceptrum-carolinum* occur in old post-excavation peat pits. Moreover, the *Coenonympa oedippus* has been identified in this area.

It is a unique natural site on a European scale with regard to the dating of organic deposits (Dobrowolski et al. 2016). The well-preserved sequences of deposits from the last 10 000 years allow for a relatively precise reconstruction of past conditions, and the obtained results are comparable with reference locations for Poland and Europe.

Alkaline fens in the Hrubieszów Basin are protected as Special Areas of Conservation: Dolina Sieniochy PLH060025 and Dolina Górnej Siniochy PLH060086. Besides, the establishment of a nature reserve comprising the cupola spring fen Śniatycze was postulated (Stanicka 2010) (see Chapter 8).

Photo 91: The Śniatycze cupola fen split by a channel. The best preserved vegetation occurs to the right of the channel (at the cupola top) with great fen sedge *Cladium mariscus*. The photo also shows the channel impact on vegetation changes and the range of its strong impact (photo by R. Stańko).

### Alkaline fens in the surroundings of the city of Chełm

This area contains 8 alkaline fens in the vicinity of the city of Chełm in the Lublin Upland, within the mesoregions: Chełm Hills and Dubienka Depression (Kondracki 2011, Solon et al. 2018).

The most important sites in this area include the large-surface area complexes: Sobowice mire (known also as Zawadówka), situated west of Chełm (Pawlikowski 2011c), and a group of fens known as Chełmskie Torfowiska Węglanowe located north-west of Chełm (Buczek & Buczek 1993, Buczek 2005, Pawlikowski 2011a) and encompassing fens in the nature reserves: Brzeźno, Roskosz and Bagno Serebryskie.

These fens were formed as a result of accumulation of organic and mineral matter in karst dolines, called "werteby", eroded in calcareous rocks. They include both ecosystems of terrestrialized lakes in which the deep peat bed is sometimes underlain by gyttja deposits, and soligenous fens supplied by groundwaters. The central part of the Sobowice mire is occupied by a vast spring cupola which was a focus of detailed paleoecological studies (Dobrowolski 2000, Dobrowolski et al. 2005). In the light of these studies, development of this spring fen began ca. 9900 years ago.

These sites are unique natural habitats on a national scale. In terms of surface area, they are dominated by calcareous fens (7210) with vast areas harboring beds of *Cladietum marisci* and *Caricetum buxbaumi.* Elements of alkaline fens of habitat 7230, the area of which was estimated at ca. 570 ha (ca. 35% of the total fen area) are most often concentrated in marginal fen parts and in transition zones to meadow communities. The third important structural element of the Chełm mires, Molinia meadows (6410), is of special importance because they cover, among others, drier, carbonate hills (called "grądziki") within fens with shallow chalk deposits distinguished by a host of floristic rarities. All three types of vegetation contain plant species characteristic of the *Caricion davallianae* alliance, which sometimes is a source of serious difficulties with sharp distinguishing of habitat patches belonging to different types.

Typical vegetation of the alkaline fens is composed of associations of *Caricetum davallianae* and *Schoenetum ferruginei*. *Caricetum davallianae* is a low-sedge tuft-forming rush occurring in small patches (from several square meters to several ares) in mosaic with other sedge rushes and Molinia meadows. The largest patches of this community are located in the southwestern part of Roskosz mire and in islands scattered in the central part of the Brzeźno mire. *Schoenetum ferruginei* occurs over relatively larger areas in the Bagno Serebryskie.

Fens of the Chełm surroundings are a key refuge of valuable flora on a national scale. Alkaline fen and meadow communities of this area harbor three species mentioned in the Habitats Directive, namely *Ligularia sibirica, Liparis loeselii* and *Ostericum palustre.* Rare species characteristic of the *Caricion davallianae* alliance include, among others, *Swertia perennis*, *Carex buxbaumii, Epipactis palustris, Tofieldia calyculata*, *Pinguicula vulgaris* ssp. *bicolor*, *Pedicularis sceptrum-carolinum* and *Dactylorhiza incarnata* (ssp. *ochroleuca*). Moss layer contains: *Ctenidium molluscum*, *Tomentypnum nitens*, *Bryum neodamense* and *Bryum pseudotriquetrum*, *Scorpidium scorpioides*, *Campylium stellatum*, *Limprichtia cossonii* and *Fissidens adianthoides.* Other rarities often occurring at the borderline of fens and grasslands and meadows include: *Ophrys insectifera*, *Betula humilis, Dianthus suberbus, Gentiana pneumonanthe, Gentianella uliginosa, Senecio macrophyllus, Gladiolus imbricatus, Iris sibirica*, *Veratrum lobelianum*, *Cirsium canum, Aconitum variegatum, Trollius europaeus* and *Phyteuma orbiculare* (Kucharczyk 1996, Pawlikowski 2011a).

The survival of the alkaline fens of the Chełm neighborhood is shrouded in uncertainty in spite of different forms of legal protection. In all of the fens drainage facilities were installed as early as before WWI. At present, the abandoning of grassland use of some of their parts also poses a threat. However, the greatest risk is created by the proximity of the urban and industrial center in Chełm which is related with large-scale disturbances of water conditions, namely water intake for the city is situated within the Sobowice mire, and a cone of depression connected with limestone extraction for a cement plant poses a threat to local water relations. These problems were addressed at an international level and became the basis for the resolution of the International Mire Conservation Group (IMCG) addressed to the Polish Government in 2010 postulating that the Chełm fens should be taken under efficient – not only formal – protection. The existing forms of protection comprise nature reserves: Brzeźno, Roskosz, Bagno Serebryskie and Torfowisko Sobowice, Special Area of Conservation Torfowiska Chełmskie PLH060023, Special Protected Area Chełmskie Torfowiska Węglanowe PLB060002, Chełm Landscape Park and Chełmno Protected Landscape Area.

**Alkaline fens of the Lublin Polesie**

Polesie extends throughout a substantial area from the Bug River to the Dniepr River, but only a small part of this subprovince is located in Poland (Kondracki 2011, Solon et al. 2018). The Polish part is situated on the edge of pre-Cambrian East European Platform (Żelichowski 1974), and also along a borderline between plant-climatic zones. This area is dominated by denudation and alluvial plains with local occurrence of carbonate rocks, which favored the development of alkaline fens. This subprovince includes the mesoregion Łęczna-Włodawa Plain where several valuable fens are located. The largest and the most important of them – Bubnów mire (ca. 931 ha) and Staw mire (ca. 276 ha) – are situated in the Polesie National Park. As in the case of the Chełm fens, these fens are located in complicated wetland complexes covered by a wide spectrum of aquatic, rush, fen and meadow phytocenoses. The surface area of the alkaline fens within these sites estimated at ca. 600 ha.

Sedge-moss vegetation is represented mostly by the *Caricetum davallianae* and *Schoenetum ferruginei* associations. In these complexes there are also (often prevail) fen sedge beds and *Caricetum buxbaumii* communities. The majority of the fens are of sedge rush character with a large contribution of species of the *Scheuchzerio-Caricetea fuscae* class, and also meadow and rush species: *Carex lasiocarpa*, *C. caespitosa*, *C. appropinquata*, *C. elata* and *C. disticha* (Sugier et al. 2010, Sugier & Różycki 2010).

A vast complex of Krowie Bagno mire is located north of the border of the Polesie National Park. It is a very spacious, well-documented in terms of natural values, drained calcerous fen (Kozub 2011). At present, Krowie Bagno is not included into the list of important alkaline fens in Poland, however a comparative analysis of its vegetation structure described in the paper by Sugier et al. (2010) shows its similarity to flora of Bubnów mire.

As in the case of the Chełm fens, the greatest threat to Polesie fens is likewise posed by large-scale industrial endeavors both already realized and planned. It is particularly relevant to hard coal mining and associated disturbances in the hydrological conditions. These projects are contested by the international scientific community which was expressed by the next resolution of the International Mire Conservation Group (IMCG) of 2018 regarding plans of construction of a coal mine in the neighborhood of Torfowisko Bubnów.

The Polesie sedge-moss fens are currently protected as Natura 2000 sites Ostoja Poleska PLH060013 and Krowie Bagno PLH060011, and in the Polesie National Park.

## Central Poland

*Filip Jarzombkowski, Paweł Pawlaczyk,*
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The number of sedge-moss fens in central Poland is not high due to its geomorphological structure and centuries-long relatively intensive agricultural land use. Nevertheless, there still exist alkaline fens with sedge-moss vegetation that survived in a nearly natural state, or more often in peat hollows where peat was extracted in the past.

This area encompasses the Middle Vistula river valley, the central and eastern part of the Central Poland Lowlands with their borderline with South Baltic Lake Districts (fens of the Płock Basin, Dobrzyń Lakeland, Urszulewo Plain and Brodnica Lakeland), and the northern part of the Silesia-Kraków Upland. In most cases these are areas of old-glacial landscape dominated by post-glacial erosive and denudation landforms formed in the glacier foreland (Kondracki 2011, Solon et al. 2018).

With respect to the administrative division of the country, this area encompasses the Mazowieckie and Świętokrzyskie Voivodeships and parts of the Łódzkie, Wielkopolskie, Dolnośląskie and Śląskie Voivodeships. The database contains 68 patches of habitat 7230 covering an area of ca. 490 ha in total. They are sparsely distributed quite far from each other and form enclaves of biodiversity associated with sedge-moss fens in the intensively managed landscape of central Poland. In the Northern Masovia Lowland and its borderline areas, the Płock Basin fens (Drzezno, Nałęcin) with the largest locality for *Liparis loeselii* in Masovia, vast fen sedge beds on the Raciąż Plain (Kłocie Raciąskie), or strongly oligotrophic Serafin mire are worth mentioning. In the Central Mazovia Lowland, only one patch of sedge moss vegetation was preserved, called Torfy Orońskie with an area of 1,5 ha, which is a refuge for alkaline fen species in this area. A huge area of alkaline fens, Całowanie mire, has to be considered as entirely degraded since isolated patches related to sedge moss fens existing not long ago in recent years have disappeared, and drainage works carried out at the beginning of 2019 significantly worsened the water conditions in this area (see Chapter 8). In the Southern Masovia Hills, a number of fen patches with sedge-moss vegetation still exist, for example small areas in Pakosław mire with a locality for *Ligularia sibirica* and Stara Siekierka mire and Mierziączka mire in the Zwolenka river valley. The most important sedge-moss fens, as described below, include: Torfowiska Niecki Nidziańskiej, Bęczkowice mire, Pastwa mire and a concentration of fens in the Silesia, partly composed of natural sites (e.g., Myszków fen, sedge-moss fens in the Biała Przemsza river valley, fens in the Biała river valley near

Laski, Antoniów), and partly of unique flush fens developed in anthropogenic habitats (e.g., Kuźnica Warężyńska, Młaki nad Pogorią, Młaki w Szczakowej) (Hałabowski et al. 2016a).

**Alkaline fens of the Nida Basin**

The Nida Basin constitutes the southern edge of the Małopolska Upland neighboring the Northern Subcarpathians (Kondracki 2011, Solon et al. 2018). This area is situated in the Vistula river catchment area and its hydrographic grid is composed of the Nida river and its tributaries. The basin is filled mostly by Mesozoic and Permian deposits, most often marls, opokas and limestones. Substratum is built of Cretaceous rocks overlain by Pleistocene and Holocene deposits.

The vegetation of a few alkaline fens occurring in this area is mostly composed of phytocenoses of the *Caricetum paniceo-lepidocarpae* and *Caricetum davallianae* associations of the *Caricion davallianae* alliance, creating a mosaic of patches with *Schoenetum ferruginei* and meadow communities of the *Molinietalia* order. The best preserved patches of fen vegetation are situated in former shallow peat hollows and comprise low sedges, mostly *Carex panicea*, *C. flava*, with participation of *Potentilla erecta, Carex lepidocarpa* and *C. diandra* and *Sesleria uliginosa*. The moss layer is built of brown mosses, most of all *Limprichtia cossonii* and *Campylium stellatum*, and also *Calliergonella cuspidata, Fissidens adianthoides, Tomentypnum nitens* and *Plagiomnium ellipticum*. In addition, the following characteristic fen species can be found *Carex davalliana*, *C. flacca*, *Epipactis palustris*, *Pedicularis palustris*, *Schoenus ferrugineus* and *Valeriana simplicifolia*. In marginal patches of the fens and in places with distinct succession, the vegetation assumes the character of wet meadows of the *Calthion palustris* alliance with *Carex nigra* and many thistles: *Cirsium rivulare*, *C. canum* and *C. palustre*. Moreover, a locality for *Ligularia sibirica* has been found here.

Distinctive among all fen patches, soligenous Bełk mire is supplied by calcium-rich groundwater discharged from beneath the valley slopes. It developed in the location where the shallow valley bottom widens and its northern mineral edge becomes prominent.

The vegetation of Bełk mire comprises mostly phytocenoses of the associations *Caricetum paniceo-lepidocarpae* and *Caricetum davallianae* of the *Caricion davallianae* alliance in a mosaic with patches of meadow communities of the *Molinietalia* order. *Eleocharis quinqueflora,* and *Utricularia minor* and *U. intermedia* and *Chara* sp. occur in small depressions filled with water. Besides, the following rare and protected species can be mentioned: *Liparis loeselii*, *Dac-*

*tylorhiza incarnata* and *Epipactis palustris*, *Carex davalliana*, *C. dioica, Parnassia palustris* and *Pedicularis palustris*. *Sesleria uliginosa* occurs in small patches with meadow-grassland vegetation. Compact multispecies moss layer is built of brown mosses, mostly *Limprichtia cossoni* and *Campylium stellatum*, and also *Calliergonella cuspidata, Fissidens adianthoides, Tomentypnum nitens, Plagiomnium ellipticum*, and in more hydrated places *Limprichtia revolvens*, *Scorpidium scorpioides*, *Bryum pseudotriquetrum* and *Philonotis* sp.

Sedge-moss fens of the Nida Basin are currently protected as Natura 2000 sites Dolina Mierzawy PLH260020, Ostoja Szaniecko-Solecka PLH260034 and Ostoja Nidziańska PLH260003.

Photo 92: Bełk mire (photo by E. Gutowska).

### Torfowisko Bęczkowice

Bęczkowice mire (see Zając et al. 2012) is situated on the Radomsko Hills constituting the northern edge of the Małopolska Upland, built of Cretaceous sandstones and Jurasic limestones overlain by Quaternary sands and clays. The meadow-fen complex Bęczkowice is located at the borderline of the zone of glaciofluvial water outflow from moraines of the Warta stadium of Vistulian/Würm glaciation (Kondracki 2011, Solon et al. 2018). An alkaline fen was preserved near the edge of the Luciąża river valley and is of soligenous character. Sedge moss vegetation covers an area of ca. 10 ha and occurs in five patches, most of which developed in hollows that remained after peat extraction in the first half of the 20th century. It is represented by phytocenoses belonging to the *Caricion davallianae* alliance, *Caricetum rostratae* and *Tomentypno-Caricetum rostratae* associations and related communities of rush or meadow character. The moss layer in most of these patches is quite well-developed but, unfortunately, succession processes are also visible which is manifested by encroachment of meadow and rush species and the growth of trees and shrubs. It is one of two localities for fen orchid *Liparis loeselii* in the Łódzkie Voivodeship and for many rare species associated with sedge moss fens in this region. This area harbors inter alia the following species: *Carex davalliana*, *Epipactis palustris*, *Drosera rotundifolia*, *Dactylorhiza incarnata, D. majalis*, and in the moss layer *Helodium blandowii*, *Tomentypnum nitens*, *Sphagnum teres*, *Sph. warnstorfii*, *Hamatocaulis vernicosus*, *Limprichtia cossonii*, *Campylium stellatum*, *Bryum pseudotriquetrum* and *Aulacomnium palustre*. Bęczkowice mire is protected as a Natura 2000 site  Łąka w Bęczkowicach PLH100004.

### The Prosna river valley

In the Prosna river valley situated in the Southern Wielkopolska Lowland, lined with fluvioglacial and fluvial sands (Kondracki 2011, Solon et al. 2018), there is the soligenous Pastwa mire covering an area of 6 ha. It is located in the eastern part of the valley just under the bluff, probably in the location of past aggregate extraction. The vegetation has the mossy sedge fen character of the *Caricion davallianae* alliance with a large proportion of meadow species, while some patches are related to wet Nardus grasslands, to tall sedge beds of the *Magnocaricion* alliance and to meadows of the *Molinion* alliance. The sward is dominated by lesser *Carex diandra*, with a constant proportion of *C. rostrata* and *C. panicea*. Besides this, phytocenoses comprise *Eriophorum latifolium*, *Menyanthes trifoliata*, *Equisetum fluviatile* and *E. palustre* with constant presence of meadow species, including numerous grasses. The moss layer contains brown mosses, such as *Aulacomnium palustre*, *Fissidens adianthoides*, *Calliergonella cuspidata*, *Marchantia polymorpha* and *Plagiomnium cuspidatum*, and locally abundant peat mosses (*Sphagnum teres*, *Sph. palustre*, *Sph. magellanicum*, *Sph. fimbriatum,* among others). Other species that can be found in this area include, among others, *Eriophorum latifolium*, *Liparis loeselii*, *Dactylorhiza incarnata*, *D. majalis*, *Drosera rotundifolia, Epipactis palustris* and *Listera ovata*. Pastwa mire is protected as a Natura 2000 site Torfowiska nad Prosną PLH100037.

Photo 93: Mires on the Prosna River, PLH100037 (photo by D. Horabik).

**Silesia**

The very significantly anthropogenically transformed Silesian region, paradoxically, appears as one of the most interesting places of concentration of alkaline fens and flush fens. Most sites are concentrated in the Silesia Upland, in the mesoregions of the Katowice Upland and Tarnowskie Góry Hummock (according to Kondracki 2011, Solon et al. 2018). However, the most natural fen in this region is situated in the Warta river valley near Myszków, isolated from the above group of fens.

Myszków fen is located in a right-bank pocket of the Warta river valley and covers an area of ca. 50 ha. It is the largest – in terms of surface area – remnant of natural alkaline fens in Silesia, preserved in a nearly natural state. Habitat 7230 occurs in a mosaic with transition mires and the *Rhynchosporetum albae* association. Probably it is the locality for the most abundant population of *Liparis loeselii* in a natural environment in the Śląskie Voivodeship (ca. 250 individuals in 2012, Hałabowski & Błońska 2015) and for the most abundant population of *Hamatocaulis vernicosus* preserved in this region. Large areas are occupied by relic *Scorpidium scorpioides, Calliergon giganteum* and *Limprichtia cossonii*; peat mosses typical of alkaline fens: *Sphagnum teres*, *Sph. warnstorfii* and *Sph. contortum* are also present. Among vascular plants, boreal sedges need to be mentioned: *Carex diandra* and *C. lasiocarpa*, *C. davalliana*, which has a distribution range in southern Europe and *C. pulicaris*, associated with the western part of Europe. *Liparis loeselii* occurs principally in vast patches of *Eleocharis quinqueflora*, while in the remaining depressions, *Rhynchospora alba*, *Drosera rotundifolia*, *D. anglica* and *D. intermedia*, *Nymphaea candida*, *Chara virgata* and *Utricularia ochroleuca* (at the eastern limit of its distribution rage) can be found. There are also numerous *Epipactis palustris*, *Carex lepidocarpa*, *Valeriana simplicifolia*, *Dactylorhiza majalis*, early *D. incarnata, D. maculata*, and from the valley edge: *Ledum palustre*, *Oxycoccus palustris* and *Vaccinium uliginosum*. It is an exceptional fen on a national scale which combines well-preserved glacial, western and southern-mountain elements. A part of this complex is protected as the Przygiełka Ecological Site, but this form of protection is proving to be insufficient. (Hałabowski et al. 2016b) and the fen requires inclusion in the Natura 2000 network (see Chapter 8).

Patches of alkaline fens in the Biała river valley downstream of the Laski village are remnants of natural fens in this region. At least several hectares of well-developed sedge-moss fens occur in three patches harboring, among others: *Liparis loeselii* (at least 100 individuals in total), *Hamatocaulis vernicosus*, *Epipactis palustris*, *Carex davalliana*, *C. dioica*, *C. pulicaris*, *Valeriana simplicifolia*, *Eleocharis quinqueflora*, *Pedicularis palustris*, *Campylium stellatum*, *Meesia triquetra*, *Pseudocalliergon trifarium* and *Hypnum pratense*. These sites also deserve to be included into the Natura 2000 network (see Chapter 8).

The sedge-moss fen in the Biała Przemsza river valley in Sławków (ca. 1 ha), also proposed for inclusion in Natura 2000 network (Chapter 8), gathers many floristic rarities, which *inter alia* include: *Liparis loeselii*, *Epipactis palustris*, *Carex dioica*, *C. diandra*, *C. davalliana*, *Limprichtia cossonii*, *Campylium stellatum* and *Utricularia intermedia*.

Antoniów mire (ca. 2.5 ha), preserved in the place formerly occupied by a larger complex, on terraces of the Trzebrzyczka stream valley, is fed by groundwater outflowing from beneath a mineral scarps. Vegetation forms a complex with transition mires and those related to raised bogs. Mossy sedge communities of the *Caricion davallianae* alliance developed there contain many characteristic species. This fen is protected as a part of the Natura 2000 site Lipienniki w Dąbrowie Górniczej PLH240037.

However, a specific form of alkaline fens, i.e., floristically rich flush fens are a hallmark of this region. They developed in former sand excavation pits, in places where the pit reached aquifers with alkaline water (Błońska 2010, Molenda et al. 2012, 2013).

The site Kuźnica Warężyńska, included in the Natura 2000 site Lipienniki w Dąbrowie Górniczej PLH240037, is an example of such a situation. Habitat 7230 takes the form of initial sedge moss patches developing at the foot of the scarp of a sand pit and in places fed with alkaline groundwater. It harbors one of the most abundant populations of *Liparis loeselii* in southern Poland. Moreover, the following species are present: *Carex davalliana*, *Pinguicula vulgaris ssp. bicolor*, *Drosera anglica* and *D. intermedia* and orchids: *Malaxis monophyllos*, *Dactylorhiza majalis*, *D. incarnata* and *Epipactis palustris*. Apart of these, there are also *Parnassia palustris*, *Tofieldia calyculata*, *Eleocharis quinqueflora*, *Cladium*

Photo 94: A flush fen with *Tofieldia calyculata* in a sand excavation pit in Szczakowa (photo by Ł. Krajewski).

*mariscus*, *Equisetum variegatum*, *Eriophorum latifolium*, *Utricularia minor* and *Menyanthes trifoliata*. In the moss layer, *Hamatocaulis vernicosus*, *Pseudocalliergon trifarium*, *Limprichtia cossonii* and *L. revolvens* and peat mosses: *Sphagnum warnstorfii* and *Sph. contortum* have been identified.

In the city of Dąbrowa Górnicza, valuable sedge-moss vegetation, covering ca. 6 ha, developed also at the bottom of a former sand-pit. At present, this area is protected as an ecological site but its inclusion into the Natura 2000 network is worth considering (see Chapter 8). Flora of this site is characterized by the presence of *Pinguicula bicolor*, *Carex davalliana*, *Tofieldia calyculata*, *Epipactis palustris*, *Malaxis monophyllos*, *Drosera anglica*, *D. rotundifolia* and *D. intermedia, Equisetum variegatum*, *Utricularia minor*, *Limprichtia cossonii* and *Sphagnum teres*. Approximately 120 *Liparis loeselii* individuals were observed in this area in 2013, and a part of flush fen area was subjected to shrub removal by the Dąbrowa Górnicza Town Office (Ł. Krajewski, unpublished).

The area of former sand pits located in the Szczakowa neighborhood comprises ca. 100 ha of floristically valuable flush fens that are not subject to any protection, although they are worth inclusion into the Natura 2000 network (see Chapter 8). This area is characterized by the presence of *Tofieldia calyculata*, *Carex davalliana*, *C. lepidocarpa*, *C. appropinquata*, *Epipactis palustris*, *Equisetum variegatum*, *Eleocharis quinqueflora*, *Drosera rotundifolia*, *Pedicularis palustris*, *Sphagnum teres*, *Triglochin palustre*, moss *Hamatocaulis vernicosus*, *Drepanocladus sendtneri* and glacial relics: *Carex dioica* and *Pseudocalliergon lycopodioides.* Flush fens are related to petrifying springs – habitat 7220 -which is confirmed by the presence of *Preissia quadrata*, *Palustriella commutata* and tufa deposited on mosses. Stoneworts growing in stagnating water include: *Chara vulgaris*, *Ch. virgata, Ch. hispida* and *Ch. intermedia*, and also *Utricularia minor*. The population of *Liparis loeselii* was estimated at more than 2 000 individuals. In 2015, *Gymnadenia densiflora* and *Pinguicula bicolor* were also found in this area. The floristic richness of this site probably results from the vicinity of the already vanished fens in the Biała Przemsza river valley running just alongside the sand pits (Ł. Krajewski, unpublished).

## Carpathians

*Robert Stańko, Lesław Wołejko, Grzegorz Vončina*

The Carpathians are one of the youngest mountain ranges in Europe developed during Alpine orogeny. Their Polish part is a fragment (9,3%) of a large mountain range extending across eight European countries. Their varied geological structures, ages and folding times are the basis for distinguishing two geological structures in Poland: the Inner Carpathians (Tatra Mts., Podhale Basin and Pieniny Klippen Belt) and the Outer Carpathians, called the Flysh Carpathians (the Beskids and their foothills).

The spatial distribution of alkaline fens is correlated mostly with substrate type, therefore they are most abundant in areas built of calcareous rocks, e.g., the Pieniny and Małe Pieniny Mts. However, in practice, alkaline fens occur in all mountain ranges of the Polish Carpathians, beginning from the Silesian Beskid to the Bieszczady Mts. and also in their foothills (Wołejko et al. 2012). Analysis of the literature data (Vončina 2017, and references cited therein) indicates the largest concentration of alkaline fens in the Beskid Sądecki Mts., Bieszczady Mts., Pieniny Mts. and Gorce Mts. (within the Magura nappe). The Low Beskid Mts. are the least abundant in alkaline fens. In the remaining part of the Carpathians dominated by flysh built of conglomerates, sandstones, claystones and siltstones (Oszczypko 1995), distribution of habitat 7230 depends on the local presence of larger amounts of calcium carbonate in the rocks (in flysch mostly marls) (Wołejko et al. 2012), e.g., in the Żywiec Beskid Mts., Gorce Mts. and Bieszczady Mts. Some fens developed on former glaciofluvial deposits (Orawa-Nowy Targ Basin) (Koczur 2011). Field inventories conducted by the Naturalists' Club from 2009 to 2015 seem to confirm the above data. Based on field data collected by us, and to a lesser extent supplemented by literature data, ca. 550 sites have been recorded up till now. In total, they cover an area of ca. 200 ha which constitutes only 1,3 % of all national resources of habitat 7230. Sites dominating in this area have a small surface area from several tens of square meters to several ares. It results in often slight depth of the peat bed (or its complete absence) which is largely dependent on slope and variable topography. Frequently, there are only shallow peat-gley soil layers (Jermaczek et al. 2009). Among all the surveyed patches of habitat 7230, only a few of them exceed an area of 1 ha. The largest of the identified fens are situated in the Orawa-Nowy Targ Basin.

Since the chemical composition of waters in the Carpathians depends on groundwater contact with the bedrock, it can vary in a relatively wide range. Surface waters in alkaline fens in the Pieniny Mts. have been shown to contain very high contents of $CaCO_3$, reaching 700 g/l (Nicia 2009). Such conditions favor petrification process and accumulated biomass undergoes fast decomposition. High contents of calcium carbonate in the soils of the Pieniny flush fens results in high pH values from pH 6,7 – 8,1 (Vončina 2017).

In terms of altitude, the greatest concentration of flush fens was noted in the foothill zone and lower montane zone. Human activity is an important factor influencing the presence and size of flush fens. Most often they occur in areas without dense tree cover, for example glades, alpine meadows and pastures. The number of sites increases in areas where extensive land management involving grazing and mowing has not been abandoned (Koczur 2011).

Besides bedrock type, the occurrence of alkaline fens is strongly dependent on geomorphological features of the terrain and character of supply with groundwaters (Wilczek 2006). Mountain alkaline fens develop at seepage of groundwater with an appropriate chemical composition, which encountering semipermeable layers increases substrate hydration. Alkaline fens often develop in depressions, basins or pits, and on sub-slope and top plateaus (Pawłowski et al. 1960, Wilczek 2006, Mróz et al. 2011). They are fed by shallow groundwaters seeping from the slopes and from valley-heads and from erosive fissures and at outlets of aquifers (Łajczak 2006). Such springs in the Carpathians discharging most often from surface formations are characterized by low capacity, which usually does not exceed 5 l/s (Dynowska & Pociask-Karteczka 1999).

Conditions in the fen areas are modified by erosion processes which are particularly active at steep slopes and substrate fissures. It can lead to dehydration of a part of the fen and to leaching of amorphous particles of organic matter with precipitation waters (Jermaczek et al. 2009).

Vegetation in the majority of the surveyed alkaline fens is represented by its most important association *Valeriano-Caricetum flavae* (see, for example, Pawłowski et al. 1960, Grodzińska 1975, Pawłowski 1977, Hájek 1999). Based on the analyzed 415 phytosociological releves from the Carpathians, Vončina (2017) distinguished four sub-associations, each additionally subdivided into several variants. The paper also reported the geographical diversity of the *Valeriano-Caricetum flavae* association. The described sub-association *Valeriano-Caricetum flavae senecionetosum subalpini* occurs in the western part of the Carpathians. Sub-associations *Valeriano-Caricetum flavae typicum* and *Valeriano-Caricetum flavae caricetosum davalianae* are found mostly in the central part of the Carpathians, and sub-association *Valeriano-Caricetum flavae eleocharitetosum quinqueflorae* occurs slightly further to the east in the Beskid Niski Mts. The article also describes a specific type of flush fens of the pasture type in the easternmost part of the Carpathians (Bieszczady Mts.) characterized by the highest percent cover by *Juncus articulatus* and *Caltha laeta*. These flush fens are situated in the Bieszczady alpine pasture zone at an altitude of 1290 m a.s.l. (Vončina 2017).

In addition, the *Caricetum davallianae* association is a typical component of flush fens, while smaller areas are occupied by the *Eleocharitetum pauciflorae* (in light of the newest studies, probably as the *Valeriano-Caricetum flavae eleocharitetosum quinqueflorae* sub-association) and communities identified as the *Menyantho-Sphagnetum teretis* and *Caricetum nigrae* (Kiaszewicz & Stańko 2010). Classification of the vegetation of Poland's mountain alkaline fens (as well as lowland ones) requires further studies and critical revision. It results, among others, from the fact that other typical communities of alkaline fens and related ecosystems of the *Caricion davallianae* alliance have also been identified in adjacent mountain terrains in Slovakia and the Czech Republic (Wołejko et al. 2012). The vegetation of mixed-type mires classified into the *Sphagno-Tomenthypnion* alliance deserves special attention. Noteworthy is the *Sphagno warnstorfii-Eriophoretum latifolii* association which is a stage in plant succession in alkaline fens moderately rich in nutrients or surrounds mildly mineralized springs (Hájek 1999, Hájek & Hájková 2002).

The conservation status of habitat 7230 in the Carpathians is very diverse; both well-preserved and degraded habitats are found. In general, the conservation status of this habitat in the Alpine region is judged as unsatisfactory U1 (Koczur 2011). The basic problem is related to the legal status of most areas, which are characterized by a very fragmented ownership structure that seriously hinders the proper management of habitat resources. Most fens belong to private owners who usually are not aware of the natural values of these areas.

Due to strong, many centuries old anthropogenic pressure, a special dynamic balance developed in fens and their surroundings. Extensive grazing and mowing of larger areas favored the preservation of open habitats and even the extension of their area at the expense of forest and shrub phytocoenoses (Koczur 2011). Currently, land use is being systematically abandoned, and a considerable part of the montane glades, pastures and meadows – free of pressure in the form of grazing and mowing – undergoes natural processes of succession and the encroachment of shrubs and trees, leading to limitation of the fen area. Only the best preserved habitats of primeval character with undisturbed hydrological conditions resist the transformation, and are the source for the spread of typical vegetation.

A small area of mountain alkaline fens and their situation in hard-to-access locations has protected them from exploitation. These areas were free of peat extraction which allowed for the preservation of relatively natural relations. However, there are indirect threats associated with exploitation of other adjacent ecosystems, e.g., raised bogs in the Orawa - Nowy Targ Basin (Łajczak 2006).

Fens in the Polish Carpathians are drained by artificial structures only to a limited extent. There have been attempts to construct drainage facilities in single sites (e.g., Hala Cebulowa in the Żywiec Beskid Mts.) which, however, did not bring the expected effects and were subsequently abandoned (Koczur 2011).

Another risk emerging recently is related to trees harvesting, which affects very large areas of the Silesian Beskid Mts. and Żywiec Beskid Mts. Due to degeneration of the Beskid forests and dying out of weak spruce trees (their main component), huge tracts of forest are being felled. Before forest restoration, it leads to increased erosion and surface run-off, and consequently to alterations in water relations. Another threat is associated with mechanical fen damage and draining of the fen area due to the logging of trees. Such areas undergo fragmentation by new unpaved transport roads and furrows in the topsoil caused by skidding. It leads to undercutting of slopes and rapid draining. As such, the constant monitoring and recording of changes occurring in areas of extensive tree cuts are of crucial significance.

A few sites are located close to beaver lodges. Beaver dam construction and the resulting water damming can lead to flooding and habitat disappearance. In such cases, conservation measures should focus on minimizing the effect of beaver activities in adjacent areas. A further threat stems from construction of water intakes in flush fen areas most often for private purposes of the owners and watering of livestock. Removal of such facilities is indispensable because they quickly lead to fen dehydration.

A large portion of habitat 7230 resources is located in refuges of Natura 2000 sites Pieniny PLC120002, Tatry PLC120001, Ostoja Gorczańska PLH120018, Ostoja Jaśliska PLH180014, Beskid Śląski PLH240005, Małe Pieniny PLH120025 etc. (Mróz et al. 2011), and also in national parks (Bieszczady NP, Pieniny NP, Gorce NP etc.), landscape parks (Beskid Mały LP, Silesian Beskid LP, San River Valley LP etc.) and nature reserves (e.g., Dolina Jasiołki). However, in spite of the considerable extent of protected areas, the conservation status of the habitat has not improved and it even seemingly deteriorates. This is caused by the sparse distribution of sites and their small area (they cannot benefit from agri-environmental-climate packages).

Most of these mountain alkaline fens require active protection (Stańko et al. 2018).

The sections below characterize areas with increased concentration of flush fens and alkaline fens in the Carpathians which, according to the best knowledge of the authors of this report, are of key significance for conservation of habitat 7230 resources in Poland. The presented descriptions are very diverse depending on available knowledge.

**Torfowiska Orawskie**

This area of exceptional concentration of alkaline fens is situated within the Czarna Orawa river catchment area and covers the whole flysch Orawa Interfluve and adjacent small fragments of the Babia Góra Massif and Orawa-Nowy Targ Basin. Although, in general, alkaline fens of this area reflect the specificity of the Carpathians, in many cases they are distinguished by specific, distinctive features.

The Czarna Orawa river catchment is one of the best known areas in terms of natural features including the distribution of alkaline fens. Field surveys carried out by the Naturalists' Club in 2010 resulted in inventorying a total of ca. 50 sites in this catchment area (ca. 360 $km^2$). They differed in size, the majority covering a small area not exceeding 2 – 3 ares. Nevertheless, the area of some of them was greater than 5 hectares, which in mountain regions is undoubtedly a significant rarity (Kiaszewicz & Stańko 2010).

Small alkaline fens of flush fen character occurring in the catchment area exhibit many similarities. They are located on slopes in places of groundwater seepage or at outlets with slightly obstructed outflow, and usually do not form a peat layer (if present, it is very shallow – up to 10 cm deep). Almost all of them occur in complexes with wet thistle meadows or next to them. They are spread sparsely but quite evenly all over the whole Czarna Orawa river catchment area.

The *Valeriano-Caricetum flavae* association is the dominant phytocenosis; broad-leaved cottongrass and marsh helleborine are abundant. They are particu-

Photo 95: Flush fens transitioning into shallow mires with broad-leaved cotton grass surrounded by wet thistle meadows (photo by R. Stańko).

larly conspicuous in landscape during cottongrass fruiting, distinguishing them especially when *Cirsium rivulare* flowers.

Though very seldom, classic alkaline fens develop on slopes, covering an area sometimes exceeding 2 – 3 ha but usually not greater than 0,5 ha, with developed only shallow peat layer.

In comparison with small flush fens, they are characterized by much greater diversity of plant communities and flora. The most frequent phytocenoses include associations: *Menyantho-Sphagnetum teretis*, *Caricetum davallianae* and *Caricetum nigrae*. Flora is distinctive for the abundance of brown mosses which were found to comprise, among others, such species as *Limprichtia cossoni* or *Tomentypnum nitens*. Among vascular plants classified as rare, threatened or protected, several orchid species can be mentioned, e.g., *Listera ovata*, and representatives of *Dactylorhiza spp.*: *Dactylorhiza incarnata*, *D. majalis* and *D. fuchsii* and *Gymnadenia conopsea*. *Pedicularis palustris* is noted relatively often. A locality for *Malaxis monophyllos* was discovered in one site.

The largest concentration of alkaline fens in the Czarna Orawa is found in the Bembeński stream valley. Among them, the fen located ca. 3 km north of the Podwilk village is most valuable. It is situated on quite steep slope and is characterized by good hydrological conditions. The process of tufa deposition in the form of structural travertines from several to several tens of centimeters deep progresses at several places on the fen surface. In addition to the above-mentioned species, *Pinguicula vulgaris* is also numerous in places of carbonate precipitation.

This fen has remained in a good state throughout the last 10 years in spite of water intakes existing there since many years, the actual impact of which is not known and requires detailed analysis. It would be recommended to locally carry out tree and shrub removal in this area. The fen, like the remaining sites described in this section, is not subject to any protection and at least should be included into the Natura 2000 network (see Chapter 8).

Mires located in the Orawa-Nowy Targ Basin, commonly associated only with cupola raised bogs, make the Czarna Orawa river catchments area exceptional. A detailed survey indicated that the cases of coexistence of raised bogs and alkaline fens in these complexes were not uncommon. An example of this is with two fens located in a direct proximity of the Orawa reservoir (in the neighborhood of the Murowanica village, mires on both sides of the road from the village to the reservoir).

Fens take the shape of typical cupola on top of which there are ecosystems of transition mires and raised bogs, including fragments of bog forest. The cupola slope is occupied by vegetation characteristic of alkaline fens, represented mostly by such associations as the *Menyantho-Sphagnetum teretis* and *Caricetum davallianae.* Small patches of other associations characteristic of alkaline fens were also observed just next to the reservoir. They include, among others the *Caricetum paniceo-lepidocarpae, Eleocharitetum pauciflorae* and *Scorpidio-Caricetum diandrae.* Depending on the location (and thus potential sporadic flooding episodes),

Photo 96: One of the best preserved sedge-moss fens (habitat 7230) in the vicinity of the Bembeński Stream with clearly visible compact moss layer (photo by R. Stańko).

these communities are characterized by high variability. In the sporadic flooding zone, these phytocenoses are practically devoid of bryophyte layer in contrast to areas located higher that are occupied by the well-developed association *Menyantho-Sphagnetum teretis* with a prevalence of brown moss species characteristic of habitat 7230. In addition, in 2010 the raised bog cupola was split by a drainage ditch.

The next alkaline fens are located at the edges of raised bog cupolas in the neighborhood of the Baligówka village. It is one of the best-known – after Czerwony Bór (forest complex) – mire complexes (raised bogs!) of the Orawa-Nowy Targ Basin, which includes: Baligówka, Puścizna Rękowniańska and Bory Mires. The alkaline fen vegetation is dominated by the *Valeriano-Caricetum flavae* association with an admixture of *Caricetum paniceo-lepidocarpae*, *Eleocharitetum pauciflorae* and *Caricetum lasiocarpae.* Amon valuable flora species, the following should be mentioned: *Dactylorhiza majalis*, *D. maculata*, *Epipactis palustris* and *Pinguicula vulgaris.* Regeneration of calciphilous vegetation in the peat pits adds additional values to the whole complex. The regeneration of plant communities characteristic of alkaline fens progresses 1 – 2 m below the former mire surface (Perzanowska 2017).

One of the most interesting sites in the Czarna Orawa catchment area is located in the Chyżnik stream valley and covers an area of several hectares. It partly occupies the slope of an adjacent hill, while its central part takes the shape of a slightly elevated cupola (however, with no elements of raised bog or transition mire vegetation). This site is almost completely occupied by the *Menyantho-Sphagnetum teretis* association with well-developed brown moss layer.

In 2010, this fen showed favourable conservation status (with only isolated trees and shrubs). It was free of any traces of drainage facilities. In the same year the site was proposed to be included in the Natura 2000 network (see Chapter 8) and the establishment of a nature reserve was postulated for its protection.

Observations carried out in 2012 revealed that the fen was partially destroyed. A water treatment plant was built in its western part, and trenches were dug across the whole fen to lay sewage pipes.

Photo 97: One of the largest sedge-moss fens (habitat 7230) in the Chyżny stream valley (ca. 1 km upstream of the Orawa Reservoir) with the typically developed *Menyantho-Sphagnetum teretis* association (photo by R. Stańko).

Photo 98: The state of the fen in Chyżny stream valley after works on construction of a water treatment plant in 2012 (photo by R. Stańko).

Mires of the Czarna Orawa river valley, despite undeniable values distinctive in the region and in the whole country, belong to the least protected in Poland. None of them has been protected as a nature reserve, and only 4 sites located in the Orawa-Nowy Targ Basin have been included into the Natura 2000 network (proposals on the extension of the Natura 2000 network in the Czarna Orawa river catchment area are presented in Chapter 8.2).

**The Gorce Mts.**

The Gorce Mts., one of several mesoregions of the Outer Western Carpathians (420 km$^2$), are entirely built of flysch formations, i.e., sedimentary rocks of the Magura nappe 3 000 – 5 000 m deep. In general, flysch rocks do not belong to formations with very high calcium carbonate content, except for marls occurring across the whole range of the Magura nappe, which probably significantly influences the concentration of alkaline fens in this region.

Stratygraphic studies have shown a shallow peat layer usually less than 35 cm deep in most of the flush fens and mires. Only in a few of them, for instance in a small fen in the area of Turbacz Mt., does the peat bed depth exceed 100 cm. The peat bed is most often underlain by a silt layer lining the rock formations, e.g., sandstone. Measurements of the basic physicochemical parameters of the flush fen-feeding waters indicated their relatively low pH (around neutral) and low conductivity ranging between 200 – 300 μS/cm.

The alkaline fens and flush fens in most parts of the Gorce Mts. were inventoried in detail in 2013 for the needs of preparation of the conservation plan for the Gorce National Park and the plan of conservation measures for the Natura 2000 site Ostoja Gorczańska PLH120018. In total, 150 sites were inventoried and documented in the whole Natura 2000 site. Stratigraphic studies were also conducted in some of them.

Most of habitat patches in the Gorce Mts. are small sites covering an area from several tens of square meters to several ares. The surface area of only five of them exceeds 1 ha and only 3 are larger than 2 ha. More than 150 sites were recorded in this region, of which ca. 50 are situated in the Gorce National Park. A majority of flush fens show favourable conservation status. Analysis of the existing reports and cartographic materials carried out in 2013 indicated that the area occupied by habitat 7230 has remained at a similar level over the last 20 years.

Low sedge flush mires in the Ostoja Gorczańska clearly diverge into two types: eutrophic flush mires dominated by lush herbaceous vegetation often with dominant *Chaerophyllum hirsutum* and *Caltha laeta*, and mesotrophic low sedge flush fens with dominant *Eriophorum latifolium*, *E. angustifolium* and *Carex flava*. Most species accepted as characteristic of the habitat occur in the second type, i.e., mesotrophic flush fens, despite their generally poorer species composition. They also harbor abundant species of brown mosses. Some of them have not been listed as characteristic of the habitat (Methodological Guide, GIOŚ, see Chapter 11.1, Wołejko et al. 2012), however in this area, due to close association with flush fens, they have been treated as indicators of their favourable conservation status. *Cratoneuron filicinum* is an example of such a species. In terms of the occurrence of characteristic species, the conservation status of patches with eutrophic flush mires was judged as inadequate (U1) while those with mesotrophic flush fens as favourable (FV). Unfortunately, it is not known to what extent the richness of the herbaceous plants limiting the growth of characteristic species, especially bryophytes, and indicating an increased trophic state of the habitat reflects natural habitat conditions (water parameters), and to what extent it results from disturbances caused by former land use or its abandonment. The exceptional value of the Gorce flush fens is underlined also by the practical absence of invasive species, absence of expansive species, a good water supply, the absence of drainage facilities and scanty shrubs and tree saplings. A floristic peculiarity is the occurrence in some fens with the accumulation of calcareous tufas a rare, protected liverwort Moerckia hibernica (Stebel et al. 2016).

The abundance of flush fens in the Gorce Mts. should be related most of all with management type, mostly pastoral stockfarming. The preservation of open pastures often surrounding flush fens has favored habitat development (probably by beneficial modification of water and light conditions). Sporadic pasturing and probable biomass gathering for litter for livestock maintained this habitat in a woodless state.

Photo 99: One of the many flush fens in the Gorce Mts. (photo by D. Horabik).

The continuation of even limited traditional use of mountain pastures in the Gorce National Park allowed for the preservation of the habitat in a relatively favourable status. It should be emphasized that in the future, even after entire abandoning the use of mountain pastures, sporadic mowing will be sufficient for habitat 7230 conservation. Such measures are being implemented especially in the national park, in particular within the framework of alkaline fen conservation projects (see Chapter 9).

Undoubtedly, one of the largest and most valuable complexes of flush fens within Ostoja Gorczańska is situated on mountain pastures near the Turbacz Mt. (Gorce National Park); they are described in the chapter dealing with alkaline fens in protected areas.

**The Pieniny Mts.**

The Pieniny Mts. are located in southern Poland at the boundary of the Outer Western Carpathians built of Carpathian flysch, and the Central Western Carpathians formed with igneous, metamorphic and sedimentary rocks. The westernmost edge of the Pieniny Mts., situated in Podhale, is formed of isolated calcareous rocks transforming eastwards into a compact range of calcareous ridges and massifs ending in the Rozdziele Pass. The most spectacular group of rocks, called the Trzy Korony Massif, is situated in the middle part of the range, but the whole range culminates in the Wysokie Skałki (Wysoka) peak (1050 m a.s.l.) located to the east. The small range 30 km long and covering an area of ca. 100 km$^2$ is divided into four fragments by the Białka river and Dunajec river which, crossing the Pieniny Mts., created the deep Dunajec river Gorge (Kondracki 2011, Solon et al. 2018).

Calcareous rocks with complex geological structure form the calcium carbonate-containing bedrock which determines basic pH of the groundwater flowing through them. Since flush fens are fed by these waters, their hydrogenic soils show alkaline pH value (Nicia & Miechówka 2004). Calcium carbonate contained in water sometimes is deposited as tufa on plants, their remains or on mineral substrate.

Flush fens classified into the *Caricetalia davallianae* order, represented by the mountain flush fen association *Valeriano-Caricetum flavae*, are unevenly distributed throughout the Pieniny Mts., from the foot to the height of 940 m a.s.l. (Vončina 2017). Most best preserved flush fens occur in the Western Pieniny Mts., while they are less numerous in the Pieniny Właściwe Mts., Pieniny Spiskie Mts. and Małe Pieniny Mts. The community is formed of small several are-sized scattered patches; only in the glades Za Stronią and Kwicurki in the Western Pieniny Mts. they form a larger complex occupying an area of more than 1 ha. Flush fens are located in almost flat wet spots (Kaźmierczakowa et al. 2004). Abundant and frequent occurrence of *Carex davalliana*, which in some patches reaches even 75% cover of herbaceous plants, is a hallmark of flush fens in the Pieniny Mts. Other species distinctive for the Pieniny flush fens include *Carex flacca* and *Epipactis palustris*; moreover, other species are also constantly present: *Carex panicea*, *C. flava* s.l. and *C. nigra*. Among plants occurring in the Pieniny flush fens, the occurrence of protected orchids is noteworthy: *Dactylorhiza majalis*, *Listera ovata*, and *Gymnadenia conopsea* (sometimes very abundant). Patches of this association have well-developed moss layer sometimes covering their entire area. This layer is built of *Bryum pseudotriquetrum*, *Campylium stellatum*, *Calliergonella cuspidata*, *Cratoneuron filicinum*, *Limprichtia cossonii*, *Plagiomnium elatum* and the relic species *Tomentypnum nitens* (Vončina 2017). In combination with some of the above-listed species, the vegetation also comprises numerous protected species, e.g., *Pinguicula vulgaris*, *Tofieldia calyculata* and *Philonotis calcarea*.

The species composition of the Pieniny flush fens is internally diverse, which allowed for distinguishing three variants of the sub-association *Valeriano-Caricetum flavae caricetosum davallianae*. The variant with marsh helleborine, described on the basis of phytosociological releves taken in patches located principally on southern slopes, was defined according to the constant presence of orchid and also *Limprichtia cossonii* and *Eupatorium cannabinum*. On northern slopes, there are patches with frequently occurring *Myosotis palustris* and increased contribution of *Climacium dendroides*. The third and the rarest variant comprises the community with dominance of *Calamagrostis varia*, whose scanty patches unrelated to slope aspect were described in geobotanical sub-regions of the Pieniny Zachodnie and Pieniny Centralne Mts. (Vončina 2017).

Intensively grazed flush fens of the *Valeriano-Caricetum flavae* association in the Małe Pieniny Mts. are colonized by *Epilobium hirsutum*, *Equisetum arvense*, *Potentilla anserina* and *P. repens*

The Pieniny flush fens were first described by Kulczyński (1928) as *Caricetum davallianae*, while the list attached in that paper confirmed the significance of *Carex davalliana* as a species constantly present in the described association. Next, reports documenting the status of flush fens in the Małe Pieniny Mts. were published in the post-war period, however they focused on their practical usefulness (Kostuch 1966); also a collective phytosociological table for the Skalice Spiskie area was reported (Grodzińska 1975). More recently, the monograph published in conclusion of works on the conservation plan for the Pieniny National Park contained descriptions of syntaxons identified in the period 1998 – 1999 with original phytosociological releves (Kaźmierczakowa et al. 2004). The monograph of flush fens in the Polish Carpathians published by Vončina (2017) is a complement to the phytosociological material from the Pieniny Mts. with a description of their relations to communities in the remaining part of the Carpathians and floristically related sedge moss communities in Poland.

Mountain and lowland alkaline fens of flush fen, sedge fen and sedge-moss fen character (7230) are protected in the Pieniny Mts. within the framework of conservation measures for the Pieniny National Park (see Chapter 8). In the Małe Pieniny Mts., they are situated in Natura 2000 sites: Małe Pieniny PLH120025, where they cover an area of 1.5 ha (most of them were subject to conservation measures implemented within the project LIFE13 NAT/PL/024), and Podkowce w Szczawnicy PLH120037 (a small area of 0,26 ha). On the one hand, the abandoning of traditional land use (mowing) is a threat to the natural habitat 7230 due to succession of tree species but on the other, damage of moss layer and topsoil drying in places of intense sheep grazing and water intake for agricultural purposes have an impact on the sedge-moss fens in the Małe Pieniny Mts.

Photo 100: A view on one of the many flush fens within the Natura 2000 site Małe Pieniny PLH120025 (photo by D. Horabik).

## The Bieszczady Mts.

The Bieszczady Mts. covering an area of ca. 1500 $km^2$ are built of flysch uplifted and undulating on the turn of Oligocene and Miocene (ca. 28 mln years ago). The Western Bieszczady Mts. are formed of two nappes – the Dukla nappe and the Silesian nappe – with relatively variable geological structure. Sedimentary rocks comprise, among others, calcium carbonate-rich formations (marls).

Our studies and available literature data (Krameko 2015) confirmed the presence of more than 100 habitat 7230 patches in the area of the Bieszczady Mts. These sites occur mostly in the Bieszczady National Park in woodless mountain expanses located at higher altitudes, called "połoniny" and in stream valleys. Most of them are small-sized, occupying an area of several or a dozen or so ares. According to the confirmed data, the total area of habitat 7230 in the Bieszczady Mts. is slightly greater that 15 ha, of which ca. 11 ha are located in the Bieszczady National Park (Krameko 2015).

Considering the geological and natural hydroecological conditions, it appears that habitat 7230 in this region should occupy a much larger area. It is indicated, for instance, by a significant disproportion between the inventoried habitat area in the national park and outside of it. During preparation of the conservation plan (Krameko 2015), the conservation status in the whole Natura 2000 site was judged as inadequate (U1), with no indication about the absence of threats.

Flush fen covering an area of 0,5 ha situated in the Komańcza Forest District at the border with the Baligród Forest District, close to the Jeziorka Duszatyńskie nature reserve, was indicated as the most valuable site representing habitat 7230, which also occupies the largest area (outside of the national park). Vascular flora contained abundant species of the *Caricion davallianae* alliance and characteristic of the habitat (e.g., *Carex flava, Epipactis palustris, Valeriana simplicifolia* and *Eriophorum latifolium*). The moss layer was also relatively rich and included many characteristic species, e.g., *Sphagnum warnstorfii, Campylium stellatum, Limprichtia cossoni, Bryum pseudotriquetrum* and *Tomentypnum nitens, Philonotis sp*. (Krameko 2015).

A vast majority of the habitat 7230 patches is located within the Natura 2000 site Bieszczady PLC180001, including the Bieszczady National Park. Considering the insufficient knowledge on habitat distribution outside of the national park, it is difficult to determine the scale of the needs for the establishment of new protected areas (nature reserves) for its better protection.

**Beskid Sądecki Mts. (Ostoja Popradzka)**

The Beskid Sądecki Mts. is a range in the Western Carpathians with an area of almost 700 km$^2$, built of flysch formations undulated at the beginning of Neogene and in mid-Miocene. They are composed of undulating, alternating layers of sandstones, conglomerates and silt-clay shales, locally marly within the Magura nappe (geological unit comprising the Gorce Mts. and a prevailing part of the Czarna Orawa catchment area).

The fens develop here under identical field conditions as in the remaining part of the Carpathians.

Within the framework of field surveys carried out by the Naturalists' Club, 16 small sites were inventoried. Literature data and our studies indicate that at least 36 patches of the habitat occur in this region. They have a varied, usually small surface area, and the area of only one site exceeded 0,5 ha.

Most flush fens are located in the catchment area of the upper Poprad River and its tributary Grajcarek Stream.

The flora of the flush fens of the Sącz Beskid Mts. show similar characteristics as the flora of flush fens and alkaline fens in the rest of the Carpathians. Relatively common species include orchids, e.g., *Dactylorhiza majalis*, *Epipactis palustris* and *Listera ovata*, which is one of the most common species in this group. The *Valeriano-Caricetum flavae* association is the dominant community. Similarly as in other regions of the Carpathians, flush fens of the Beskid Sądecki Mts. are distinguished by the abundance of typical mountain species, e.g., *Senecio subalpinus* or *Veratrum lobelianum* (Bregin 2016). Thus, one of four sub-associations was distinguished there, i.e., *Valeriano-Caricetum flavae senecionetosum subalpini.* The only known locality for *Primula farinosa* in Poland was identified in the Beskid Sądecki Mts. (Gajewski et al. 2018).

Most of flush fens of the Beskid Sądecki Mts. are protected as Natura 2000 site Ostoja Popradzka PLH120019.

## The Sudety Mts.

*Lesław Wołejko, Paweł Pawlaczyk*

The Sudety Mts. belong to a few regions of Dolny Śląsk where significant resources of habitat 7230 are still preserved. They concentrate in Central Sudetes. Information on the habitat occurrence come mainly from floristic papers (*inter alia* Smoczyk & Jakubska 2004, Jakubska et al. 2005, Smoczyk 2005, 2010, 2012, Jakubska-Busse & Śliwiński 2011, Wasiak et al. 2013, Smoczyk & Karakula 2016), where alkaline flush fens of *Caricetalia davallianae* order were indicated as habitat of valuable species such as *Carex davalliana, Epipactis palustris, Pedicularis pal-*

*ustris, Pinguicula vulgaris, Trollius europaeus, Dactylorhiza majalis, Dactylorhiza fuchsii, Eriophorum latifolium, Triglochin palustre*. Calcareous flush fens in Sudety are also the habitat of many valuable moss species such as: *Tomentypnum nitens* (Smoczyk & Wierzcholska 2016), *Moerckia hibernica, Hypnum pratense, Limprichtia cossonii*. Knowledge of region's alkaline fens were supplemented, by describing in details few dozens of sites, during nationwide inventory and conservation measures implemented by Naturalists' Club (Jermaczek et al. 2012, Wołejko et al. 2012, Stańko & Wołejko 2018b). In the Naturalist's Club database in Sudety Mts. 34 sites of total area of 23 ha are included but the number of flush fens existing is most probably higher.

The alkaline flush fens of Sudetes are very small in terms of their area. Typical vegetation is related to valerian-sedge flush fen type *Valeriano-Caricetum flavae* (*Valeriana simplicifolia* is replaced often by *Valeriana dioica*) and *Caricetum davallianae* association. In some phytosociology classifications those flush fens are classified as *Valeriano dioicae-Caricetum davallianae* association (Hájek & Hájková 2011). In Orlickie Mts. flush fens with calcium-tolerant sphagna representing phytocenosis of *Sphagno warnstorfii-Tomentypnion nitentis* alliance occur (*Sphagno warnstorfii-Eriophoretum latifolii*).

Mostly however, vegetation of Sudetes' flush fens is of transition character towards moist meadows (*Calthion*), herb communities, or less common *Molinion* meadows. Commonly stages related to moss transition mires occur. They develop mostly within mountain hanging mires. This is a result of low share (and in some regions complete lack) of calcareous rocks, in comparison to the Carpathians, in geological structure of the mountains. It concerns in particular ranges of Western Sudetes where acid granites and gneisses dominate.

The conservation status of the surveyed mire complexes is much worse compared with the Carpathians, which is most probably a result of strong many centuries long anthropogenic pressure. After traditional agricultural land use was abandoned, many sites suffered due to forestation efforts. New threats are associated with the expansion of recreational infrastructure, e.g., the construction of ski lifts or ski slopes. Such examples are known, for instance, from the Zieleniec area (Smoczyk 2011). Observations carried out for many years in the Polskie Wrota Pass document the disappearance of valuable flora components. In the period from 2005 to 2011, the population of *Epipactis palustris* decreased by 70% (Jakubska-Busse & Śliwiński 2011).

A clearly visible flush fens concentration, very valuable from the floristic point of view, is on the Orlickie Mts. Foreland and in the Orlickie Mts. themselves. The flush fens with *Pinguicula vulgaris subsp. vulgaris* and *Pedicularis palustris* in Zieleniec (Smoczyk 2011, Smoczyk & Karakula 2016), flush fens with *Pinguicula vulgaris subsp. vulgaris* in the area of former village Zimne Wody (Smoczyk & Karakula 2016), flush fen with *Epipactis palustris* on the Polskie Wrota Pass (Jakubska et al. 2005, Smoczyk 2005), flush fens with *Carex davalliana* on the Polskie Wrota

Photo 101: A flush fen in the Orlickie Mts. landscape
(photo by M. Smoczyk).

Photo 102: *Pinguicula vulgaris* on a flush fen in the Orlickie Mts.
(photo by M. Smoczyk).

Pass and Zieleniec (Smoczyk 2005), flush fens on Żmijowa Łąka near Duszniki Zdroj, near Pokrzywno, in Słoszow, Czermna and Kudowa are known. Typical for this region is occurence of flush fens with *Sphagno warnstorfii-Eriophoretum latifolii*. A few – less developed – flush fens are still preserved in neighbouring Stołowe Mts, *inter alia* on Torfowisko Batorowskie and in spring area of Czerwona Woda. On some of those mires i.e. in Zieleniec, precipitation of calcarous tufa was observed (Smoczyk & Karakula 2016).

Second noticable concentration of alkaline flush fens in Sudetes is in the Kamienne Mts., Obniżenie Ścinawki, Zawory, Brama Lubawska and eastern ranges of the Karkonosze Mts. Flush fens in Niedamirow, with *Carex davalliana* and *Epipactis palustris*, are under conservation measures implemented by Naturalist's Club which are described in detail in Stańko & Wołejko 2018b. Concentration of valuable flush fens with *Carex davalliana, Epipactis palustris, Trollius europaeus, Iris sibirica*, numerous population of *Dactylorhiza majalis* is present also in the Jawiszowka river valley, near Głazy Krasnoludkow nature reserve (Jermaczek et al. 2012, Wasiak et al. 2013). Some parts of this complex were subject of conservation measures implemented in 2010-2012 in a frame of the project "Conservation and restoring of hydrogenic habitats in Central Sudetes" (Jermaczek et al. 2012, in Polish, see also Chapter 10.1); Sudety Naturalists' Association in 2013 was also removing branches left over on the flush fen area (Polskie Towarzystwo Storczykowe 2013). Flush fens on the foothill of Wielka Kopa Massif near Raszow are also interesting (Wasiak et al. 2013).

Smaller concentration of flush fens are present in the Kaczawskie Mts., Ołowiane Mts. and Rudawy Janowickie Mts. (*inter alia* Kwiatkowski 1997, 2007, Świerkosz 2006). Calcareous flush fen with *Epipactis palustris* population is found in Radomice on the Izery Foreland (Jakubska-Busse & Śliwiński 2011). In the Sowie Mts. hanging fens of sphagna moss fen type with some characteristics of spring-fed fens are found (Jermaczek et al. 2012). Some small calcareous flush fens are also present in the Krowiarki mountain range in Śnieżnik Massif i.e. near Romanów.

Not typically developed initial calcarous flush fens with high share of valuable species of vascular plants and mosses are found on bottoms of former limestone quarries in some parts of Sudetes. Those unusual habitats for flush fens, mostly dominated by moss vegetation (*Caricion davallianae* or *Cratoneuron commutati* association), are known from the Śnieżnik and Krowiarki Massifs i.e. Kleśnica river valley near Stronie Śląskie, Rogożka and also near Złoty Stok in Złote Mts. and Duszniki-Zdrój in Orlickie Mts. Flush fens of Sudetes are protected within Natura 2000 sites: Góry Orlickie PLH020060, Grodczyn i Homole k. Dusznik PLH020039, Góry Stołowe PLH020004, Góry Kamienne PLH020038, Karkonosze PLH020006, Pasmo Krowiarki PLH020019.


Photo 103: A typical flush fen in the Kamienne Mts.
(photo by R. Stańko).

# 8. ALKALINE FENS (NATURAL HABITAT 7230) IN POLISH PROTECTED AREAS NETWORK

***Paweł Pawlaczyk, Dorota Horabik***

## 8.1. Alkaline fens resources in protected areas

The database of alkaline fens maintained by the Naturalists' Club shows that only 76 (of 1425) known alkaline fens in Poland are not covered by any form of nature protection. The area of alkaline fens remaining outside the forms of nature protection is 374 ha, which is only 3,7% of national resources. Other forms of nature protection, often overlapping, include the following part of the national resources of the natural habitat 7230 (Table 3):

Table 3. National resources of the natural habitat 7230 contained in particular forms of nature protection. Source of data on forms of nature conservation: Central Register of Nature Conservation Forms http://crfop.gdos.gov.pl/ Habitat area according to the Naturalists' Club database http://alkfens.kp.org.pl/ogolnopolska-baza-mechowisk/

| Form of protection | Area | |
|---|---|---|
| | ha | % |
| Natura 2000 sites (Habitats Directive) | 9041,90 | 88,9% |
| National Parks | 5339,40 | 52,5% |
| Nature reserves | 1988,60 | 19,5% |
| Landscape parks | 1896,80 | 18,6% |
| Protected landscape areas | 1662,40 | 16,3% |
| Ecological areas | 606,60 | 6,0% |
| Nature and landscape complexes | 159,80 | 1,6% |
| Nature monuments | 0,48 | 0,005% |
| Outside of protection areas | 374,10 | 3,7% |
| **Total[3]** | **10 173,0** | **100%** |

3 The sum of individual records is higher as those protection forms may overlap.

## 8.2. Natura 2000 sites

### 8.2.1. Alkaline fens resources in the network

The area of the habitat patches included in the nationwide base of alkaline fens conducted by the Naturalists' Club, located in the habitat areas of Natura 2000, is 9041,9 ha (which constitutes approx. 89% of the total habitat area in Poland). As of the end of 2018, conservation of 7230 natural habitat is the conservation objective (i.e. the habitat it is shown with an A, B or C representativeness assessment) in 161 Polish Natura 2000 sites. The total area of the habitat declared in the Standard Data Forms (SDF) in these areas is 20 196 ha. Discrepancies between the data on habitat 7230 in SDFs and the presence of habitat patches inventoried in the nationwide base of alkaline fens are, however, very large. In, as many as 76 areas (47%!) in which habitat 7230 is the conservation objective, we do not know the location of any patches of this habitat (Table 4).

Table 4. Natura 2000 sites in which habitat 7230 is subject to protection. Data source from SDF: General Directorate of Environmental Protection. Naturalists' Club Database of Alkaline Fens as at 31/12/2018.

| Name and code of the site | Area of the habitat 7230 according to SDF, ha | General assessment of site's importance for habitat 7230 according to SDF | Area of the 7230 habitat patches in Naturalists' Club data base, ha |
|---|---|---|---|
| Bagna Orońskie PLH140023 | 1,57 | B | 1,80 |
| Beskid Mały PLH240023 | 7,19 | C | |
| Beskid Śląski PLH240005 | 26,41 | A | 0,66 |
| Beskid Żywiecki PLH240006 | 176,38 | A | 3,57 |
| Bieszczady PLC180001 | 111,52 | A | 15,95 |
| Błota Kłócieńskie PLH040031 | 1,95 | C | |
| Bobolickie Jeziora Lobeliowe PLH320001 | 53,78 | C | |
| Buczyna Szprotawsko-Piotrowicka PLH080007 | 42,70 | C | |
| Diabelskie Pustacie PLH320048 | 12,93 | B | |
| Dobromierz PLH020034 | 2,50 | C | |
| Dobromyśl PLH060033 | 0,32 | B | |
| Dolina Biebrzy PLH200008 | 3000,00 | A | 4140,03 |
| Dolina Bielawy PLH320053 | 0,78 | C | 0,58 |
| Dolina Debrzynki PLH300047 | 0,92 | A | 40,64 |
| Dolina Górnej Łeby PLH220006 | 255,01 | A | |

| | | | |
|---|---|---|---|
| Dolina Górnej Rospudy PLH200022 | 40,71 | B | 4,09 |
| Dolina Grabowej PLH320003 | 412,77 | A | |
| Dolina Ilanki PLH080009 | 47,23 | A | 48,01 |
| Dolina Iny koło Recza PLH320004 | 11,18 | B | 13,04 |
| Dolina Kakaju PLH280036 | 0,29 | B | |
| Dolina Krasnej PLH260001 | 0,48 | C | |
| Dolina Krąpieli PLH320005 | 11,64 | C | |
| Dolina Lubszy PLH080057 | 1,30 | A | |
| Dolina Łętowni PLH060040 | 5,68 | A | |
| Dolina Łobżonki PLH300040 | 47,16 | A | 43,22 |
| Dolina Łupawy PLH220036 | 170,77 | B | 4,94 |
| Dolina Małej Panwi PLH160008 | 0,19 | C | 0,49 |
| Dolina Pliszki PLH080011 | 41,70 | A | 49,10 |
| Dolina Płoni i Jezioro Miedwie PLH320006 | 20,00 | B | 23,50 |
| Dolina Prądnika PLH120004 | 18,58 | B | |
| Dolina Radwi, Chocieli i Chotli PLH320022 | 1475,66 | A | 43,20 |
| Dolina Rurzycy PLH300017 | 35,32 | A | 60,00 |
| Dolina Sieniochy PLH060025 | 13,47 | A | 24,42 |
| Dolina Słupi PLH220052 | 24,65 | B | 211,12 |
| Dolina Stropnej PLH220037 | 57,80 | A | 3,72 |
| Dolina Szczyry PLH220066 | 180,56 | C | |
| Dolina Szeszupy PLH200016 | 18,71 | A | 12,62 |
| Dolina Środkowej Wietcisy PLH220009 | 64,64 | A | |
| Dolina Wieprzy i Studnicy PLH220038 | 1957,20 | B | |
| Dolina Wierzycy PLH220094 | 0 | C | |
| Dolina Wolicy PLH060058 | 9,38 | B | |
| Dolny Wieprz PLH060051 | 163,65 | C | |
| Dorzecze Parsęty PLH320007 | 1718,04 | B | |
| Dorzecze Regi PLH320049 | 14,83 | B | 1,71 |
| Góra Świętej Anny PLH160002 | 0 | C | |
| Góry i Pogórze Kaczawskie PLH020037 | 3,50 | A | |
| Góry Kamienne PLH020038 | 2,41 | A | 8,42 |
| Góry Opawskie PLH160007 | 2,79 | C | |
| Góry Orlickie PLH020060 | 1,96 | B | |
| Góry Stołowe PLH020004 | 24,16 | C | 5,07 |
| Góry Złote PLH020096 | 0,71 | A | |

| | | | |
|---|---|---|---|
| Grądy w Dolinie Odry PLH020017 | 0 | C | |
| Grodczyn i Homole koło Dusznik PLH020039 | 2,87 | A | 0,76 |
| Jata PLH060108 | 0,95 | C | |
| Jeleniewo PLH200001 | 46,69 | A | 18,88 |
| Jeziora Szczecineckie PLH320009 | 16,20 | B | |
| Jeziora Uściwierskie PLH060009 | 82,62 | C | |
| Jeziora Wdzydzkie PLH220034 | 0 | C | 31,73 |
| Jezioro Bobięcińskie PLH320040 | 50,75 | A | |
| Jezioro Gopło PLH040007 | 6,47 | B | |
| Jezioro Kozie PLH320010 | 4,84 | B | 12,38 |
| Jezioro Krąg PLH220070 | 3,78 | A | 6,76 |
| Jezioro Księże w Lipuszu PLH220104 | 4,25 | B | 4,05 |
| Jezioro Lubie i Dolina Drawy PLH320023 | 832,08 | A | 4,42 |
| Jezioro Mnich PLH300029 | 2,16 | A | 10,44 |
| Jonkowo-Warkały PLH280039 | 2,51 | C | 2,51 |
| Kamień PLH060067 | 2,94 | A | 7,37 |
| Karkonosze PLH020006 | 18,20 | A | 1,91 |
| Kemy Rymańskie PLH320012 | 538,22 | C | |
| Krowie Bagno PLH060011 | 26,76 | B | |
| Lasy Bierzwnickie PLH320044 | 8,79 | B | |
| Lisi Kąt PLH040026 | 10,61 | C | 8,44 |
| Łąka w Bęczkowicach PLH100004 | 38,24 | A | 27,34 |
| Łąki Gór i Pogórza Izerskiego PLH020102 | 4,50 | A | |
| Łąki nad Szyszłą PLH060042 | 19,62 | A | 2,50 |
| Małe Pieniny PLH120025 | 1,48 | B | 2,44 |
| Masyw Ślęży PLH020040 | 0,51 | B | |
| Mazurska Ostoja Żółwia Baranowo PLH280055 | 9,47 | B | |
| Mazurskie Bagna PLH280054 | 9,10 | B | 9,38 |
| Mechowiska Sulęczyńskie PLH220017 | 20,52 | A | 19,07 |
| Mechowiska Zęblewskie PLH220075 | 2,68 | B | 2,92 |
| Mechowisko Manowo PLH320057 | 26,06 | B | 43,69 |
| Moczary PLH180026 | 12,65 | B | 5,86 |

| | | | |
|---|---|---|---|
| Mokradła Kolneńskie i Kurpiowskie PLH200020 | 43,40 | A | 4,86 |
| Narwiańskie Bagna PLH200002 | 90,38 | C | 45,13 |
| Nowosiółki (Julianów) PLH060064 | 0,67 | C | 17,12 |
| Orle PLH220019 | 36,11 | A | 37,05 |
| Ostoja Augustowska PLH200005 | 535,34 | A | 254,24 |
| Ostoja Babiogórska PLH120001 | 1,37 | B | |
| Ostoja Bagno Całowanie PLH140001 | 917,04 | B | |
| Ostoja Barlinecka PLH080071 | 23,94 | B | 5,30 |
| Ostoja Borzyszkowska PLH220079 | 11,25 | B | |
| Ostoja Brodnicka PLH040036 | 15,45 | B | 3,10 |
| Ostoja Goleniowska PLH320013 | 0,84 | B | |
| Ostoja Gorczańska PLH120018 | 18,00 | A | 31,37 |
| Ostoja Jaśliska PLH180014 | 8,79 | C | 0,27 |
| Ostoja Knyszyńska PLH200006 | 82,00 | B | 106,17 |
| Ostoja Lidzbarska PLH280012 | 5,32 | A | 22,86 |
| Ostoja Magurska PLH180001 | 241,01 | A | 1,40 |
| Ostoja nad Baryczą PLH020041 | 16,41 | A | |
| Ostoja Nadliwiecka PLH140032 | 2,72 | C | |
| Ostoja Nadwarciańska PLH300009 | 266,53 | C | |
| Ostoja Napiwodzko-Ramucka PLH280052 | 3,26 | A | 165,44 |
| Ostoja Nidziańska PLH260003 | 1,33 | B | 3,75 |
| Ostoja Piska PLH280048 | 2,15 | A | 27,66 |
| Ostoja Poleska PLH060013 | 711,14 | A | 1205,53 |
| Ostoja Popradzka PLH120019 | 86,90 | A | 3,86 |
| Ostoja Przemęcka PLH300041 | 1,20 | A | |
| Ostoja Przemyska PLH180012 | 594,85 | A | |
| Ostoja Radomno PLH280035 | 15,80 | A | 9,57 |
| Ostoja Szaniecko-Solecka PLH260034 | 80,73 | A | 3,82 |
| Ostoja Środkowojurajska PLH240009 | 28,84 | C | |
| Ostoja w Dolinie Górnego Nurca PLH200021 | 1,27 | B | |
| Ostoja w Dolinie Górnej Narwi PLH200010 | 7,53 | B | |
| Ostoja Welska PLH280014 | 16,58 | A | 3,37 |
| Ostoja Wełtyńska PLH320069 | 10,15 | B | 10,27 |
| Ostoja Wielkopolska PLH300010 | 84,27 | C | |

| | | | |
|---|---|---|---|
| Ostoja Zapceńska PLH220057 | 65,15 | A | 20,60 |
| Ostoja Złotopotocka PLH240020 | 2,75 | C | |
| Pasmo Krowiarki PLH020019 | 2,17 | A | |
| Pieniny PLC120002 | 8,41 | A | 0,87 |
| Płaskowyż Nałęczowski PLH060015 | 10,81 | B | |
| Pojezierze Ińskie PLH320067 | 3,07 | B | |
| Pojezierze Myśliborskie PLH320014 | 427,46 | A | |
| Pojezierze Sejneńskie PLH200007 | 27,26 | A | 22,90 |
| Polana Biały Potok PLH120026 | 1,07 | B | 9,07 |
| Poleska Dolina Bugu PLH060032 | 326,93 | C | |
| Poligon w Okonku PLH300021 | 545,05 | B | 1,09 |
| Pradolina Bzury-Neru PLH100006 | 4,38 | C | |
| Przełomowa Dolina Rzeki Wel PLH280015 | 0,25 | B | |
| Puszcza Białowieska PLC200004 | 157,87 | C | |
| Puszcza Kozienicka PLH140035 | 2,82 | C | |
| Rudawy Janowickie PLH020011 | 0,20 | B | 1,91 |
| Rynna Dłużnicy PLH220081 | 12,73 | C | 3,40 |
| Rynna Gryżyny PLH080067 | 13,50 | B | |
| Sandr Brdy PLH220026 | 3,75 | A | 12,85 |
| Sandr Wdy PLH040017 | 63,20 | B | 14,66 |
| Sawin PLH060068 | 0,29 | C | |
| Słone Łąki w Dolinie Zgłowiączki PLH040037 | 0,82 | C | |
| Struga Białośliwka PLH300054 | 1,26 | B | |
| Tatry PLC120001 | 65,16 | A | 0,09 |
| Torfowiska Chełmskie PLH060023 | 637,26 | A | 1371,91 |
| Torfowiska Gór Sudawskich PLH200017 | 1,38 | B | 0,94 |
| Torfowiska Orawsko-Nowotarskie PLH120016 | 24,74 | B | 7,71 |
| Torfowisko Mieleńskie PLH040018 | 1,45 | B | |
| Torfowisko Rzecińskie PLH300019 | 70,92 | B | 5,05 |
| Torfowisko Sobowice PLH060024 | 5,14 | A | 90,73 |
| Torfowisko Zocie PLH280037 | 3,29 | B | 2,24 |
| Trzy Młyny PLH220029 | 179,99 | A | |

| | | | |
|---|---|---|---|
| Uroczyska Borów Dolnośląskich PLH020072 | 4,84 | A | |
| Uroczyska Borów Zasieckich PLH080060 | 5,69 | A | |
| Uroczyska Płyty Krotoszyńskiej PLH300002 | 342,25 | C | |
| Uroczyska Pojezierza Kaszubskiego PLH220095 | 12,69 | B | 26,02 |
| Uroczyska Puszczy Drawskiej PLH320046 | 290,22 | A | 111,62 |
| Uroczyska Puszczy Zielonki PLH300058 | 12,38 | C | |
| Wolin i Uznam PLH320019 | 153,96 | C | |
| Zachodnie Pojezierze Krzywińskie PLH300014 | 115,39 | B | |
| Zatoka Pucka i Półwysep Helski PLH220032 | 4,00 | B | |
| Źródliska Wisłoki PLH120057 | 18,18 | B | |
| Źródliska Wzgórz Sokólskich PLH200026 | 5,06 | B | 5,08 |
| Żurawie Bagno Sławskie PLH080047 | 6,86 | A | 6,06 |

Photo 104: Calcareous flush fen (habitat 7230) with orchids in the Góry Orlickie PLH020060 Natura 2000 site (photo by M. Smoczyk).

Although during the Bilateral Biogeographical Seminar in March 2010, representation of natural habitat 7230 in the Natura 2000 network both in Continental and Alpine regions[4] was assessed as sufficient (SUF), the progress of knowledge on the occurrence of this habitat obtained in the period from 2010 to 2018 should currently be a premise for the re-opening of biogeographical analysis.

In the continental region, although a majority of alkaline fens within the whole region have been included in the network, in the light of the presently available data, two geographical gaps can be noted:

- In the Mazovian region, only 2,6 ha of alkaline fens have been included in the network which corresponds to only 1,05% of resources of this habitat in that region. It resulted from the omitting of two large fens from the network – Serafin and Kłocie Raciąskie –with an area of 95 and 137 ha, respectively. In addition, local resources of the *Liparis loeselii* on alkaline fens are poorly covered in this province.
- In the Silesian Province, although 70% of the habitat area was included, it comprises only 14% of sites. The most valuable alkaline fens of this region remain outside the network. In particular, the fen in Myszków is the largest in terms of area, a remnant of alkaline fens in this province, preserved in an almost natural state, located in the right bank pocket of the Warta river valley. Across the entire country, no other fen was preserved that would so closely combine well-preserved glacial, western, and southern (mountain) floristic components.

Photo 105. Młaka Szczakowa (flush fen Szczakowa) (photo by Ł. Krajewski).

4 Alpine biogeographical region in Poland covers Carpathians. The rest of the country is included in Continental biogeographical region.

Apart from the Myszków Fen, the most valuable patches of natural alkaline fens in the Silesian-Cracovian Upland are located in the Biała river valley. The characteristic features of this province also include also very valuable spring fens formed on anthropogenic habitats, e.g., in former sand mines. In spite of their anthropogenic origin, they are young alkaline fens with typical, unique flora. Although the spring fens in the area of Lipienniki in the city of Dąbrowa Górnicza were included in the network, the better developed and floristically richer spring fens in Szczakowa and Pogoria have not been included. All these areas are also important for the *Liparis loeselii*.

- Furthermore, although in the Pomeranian Province, distinguished in the whole country by abundance and better preservation of alkaline fens than elsewhere, 60% of alkaline fens have been included in the Natura 2000 sites since 2009, locally – in relation to individual sites – there are significant problems with the delimitation of boundaries of Natura 2000 sites and leaving of valuable patches of alkaline fens outside the Natura 2000 sites. For instance, in the Dobrzynka river valley (at the border with the Greater Poland Province), left-bank fens were included in the Natural 2000 network while the Pomeranian right-bank part of this coherent fen complex was completely omitted. In addition, in the Wda River sandurs, the most valuable alkaline fens were left outside the Natura 2000 area, theoretically designated to protect this type of natural habitat.
- In the Warmian-Masurian Province, Natura 2000 sites comprise most known patches of habitat 7230 but some gaps can be noticed in relation to the *Liparis loeselii* occurring on alkaline fens. The largest population of this species in the province (Sikory Juskie) and third largest (Kirszniter) remain outside the network.
- Also, in several other localities, the need for a slight extension of Natura 2000 sites was discovered during preparation of the conservation measures plans, in order to include valuable adjacent patches of alkaline fens.

In the Alpine region, the choice of alkaline fens included in the Natura 2000 network is not representative because the Natura 2000 network in this area was designed in 2002 – 2005, while an inventory of spring fens in 2010 – 2011, conducted before our LIFE projects, resulted in discoveries crucially changing the knowledge about alkaline fens in the Carpathians. Earlier, habitat 7230 was known to occur in the form of numerous but very small, in terms of area, spring fens, scattered in mountain complexes. However, in summer 2010 large patches of alkaline fens, with an area of several or a dozen or so hectares, were discovered in Orava, which was additionally verified in 2011. Orava occurred to be the most important aggregation of alkaline fens in the Alpine region, however they are not included into the network.

In consequence, currently only 7% of alkaline fen area is included in the Natura 2000 network in the Alpine biogeographical region. It is caused most of all by an entire lack of protection of fens in Orava in the Lesser Poland Province (where only 3,8% of the habitat area is included in the network).

Specific proposals which could fill the gaps in Natura 2000 network and solve problem are as follows:

**1. Inclusion of new sites (mires)**

**Bembeńskie moss fen,** 11,9 ha, the Lesser Poland Province, Alpine region, comprising three alkaline fens in the Bembeński stream valley in Orava. One of them belongs to the most valuable alkaline fens in the Polish Carpathians, with efflux of calcareous waters and sedimenting tufaceous limestone, travertines, and with a number of unique indicator plant species (e.g., *Pinguicula vulgaris, Carex davalliana*). This complex was discovered during a biological inventory in summer 2010 (Stańko & Kiaszewicz 2010). In 2013, Z. Książkiewicz identified there also a strong population of *Vertigo angustior* in this part of Poland linked with habitat 7230.

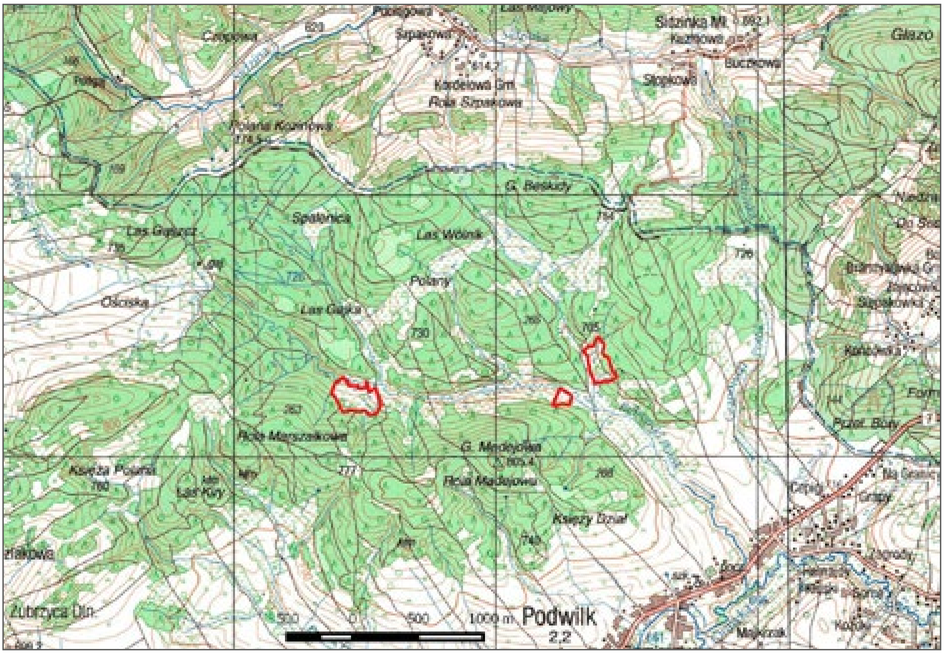


Fig. 37. Location of the Bembeńskie moss fen.

**Orava moss fens:** 79,0 ha, the Lesser Poland Province, Alpine region, three well-developed alkaline fens. These land forms were discovered during a biological inventory in the summer of 2010. One of these areas is a unique and exceptionally valuable example of a complex of co-occurring fens of different types – alkaline fen surrounding the Orava raised bog, not included yet in the Torfowiska Orawsko-Nowotarskie Natura 2000 site, comprising patches of bog forest and transition mire (although most of raised bogs, bog forests and transition mires – in Orava are included in the network (still the existence of the whole complex comprising various fen types is an ancillary argument for designation of this area). This area is characterized by the occurrence of

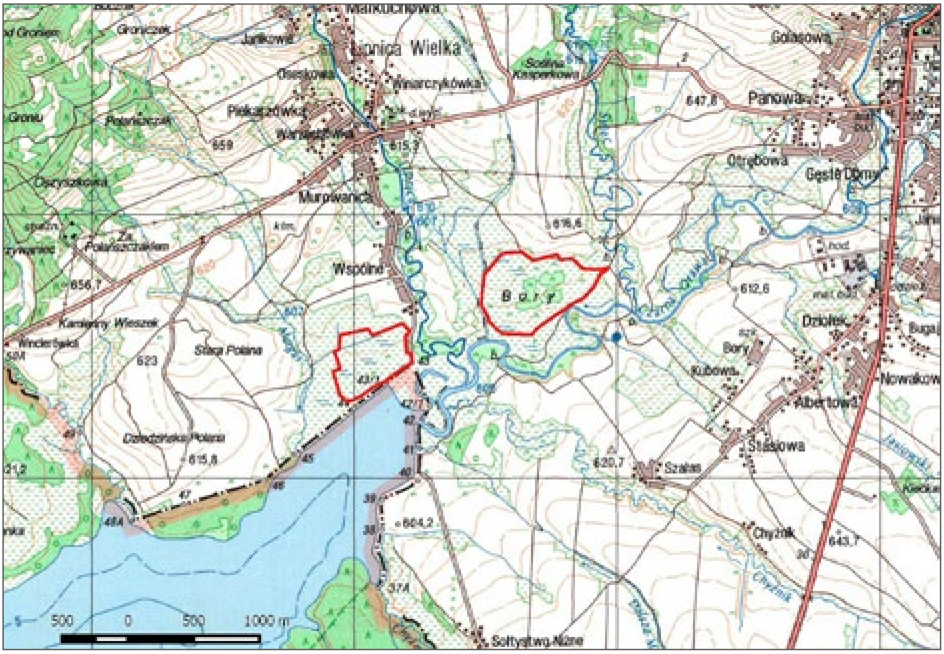


Fig. 38. Location of the Orava moss fens.

Photo 106: The Orava moss fens, essential to be included in the Natura 2000 network as a new Natura 2000 site (photo by P. Pawlaczyk).

vast patches of *Caricetum davalliane*, *Eleocharitetum pauciflorae,* and *Scorpidio-Caricetum diandrae*.
In 2013, Z. Książkiewicz identified a strong *Vertigo angustior* population in this complex in this part of Poland closely associated with alkaline fens 7230.

**Serafin fen** – 322,6 ha, the Mazovian Province, Continental region, the largest live moss fen and transition mire in the Mazovian province, the Torfowisko Serafin nature reserve is at the core of the proposed area. This moss fen is the largest in Mazovia, and the water supply is very good. The fen orchid population comprises several hundred plants, while *Hamatocaulis vernicosus* is locally very abundant. Floristically, it is the richest fen in the Mazovian Province, harboring very many threatened (13 species included in the Polish Red List) and protected species (33 species). The most valuable of them include four species of orchids: the *Liparis loeselii*, the extremely rare and endangered *Eriophorum gracile*, *Carex chordorrhiza* and very rare and endangered moss species – *Hamatocaulis vernicosus*, *Paludella squarrosa*, *Helodium blandowii*, *Tomentypnum nitens*, and *Sphagnum fuscum*. Such an accumulation of rare species in a fen is unique outside glacial extent during the last glacial period (Jarzombkowski & Kozub 2011, P. Pawlikowski, oral information).

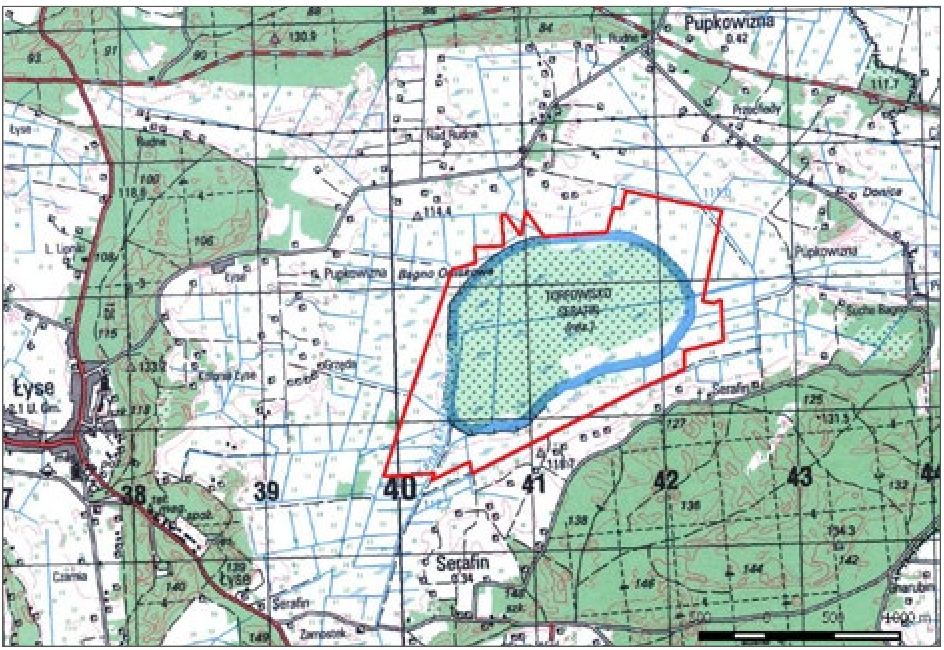


Fig. 39. Location of the Serafin fen.

**Kłocie Raciąskie** – 188,1 ha, the Mazovian province, continental region, the only and large mosaic of fen-sedge bed, moss fens (7230) and hard oligo-mesotrophic waters with benthic vegetation of *Chara* sp. (3140) in the Maziovian province, known also as the Lipa fen. The site is a patchwork of *Cladium mariscus* and tall sedge rushes and scrub communities formed in the area of an exploited fen. Moss fen communities grow in former peat mines and are dominated by *Carex elata* and sometimes *C. rostrata or C. lasiocarpa*. The moss layer is composed of *Campylium stellatum*, *Limptrichia cossoni*, and *Scorpidium scorpioides*. Open water bodies preserved in deeper pits of former peat mines are inhabited by stonewort species (*Chara spp.*), bladderwort species (*Utricularia vulgaris*, *U. minor*, *U. intermedia*), and mosses, especially *Scorpidium* moss. In their direct surroundings, they adjoin fen-sedge rushes formed by fen sedge (*Cladium mariscus*). Water supply in 2011 was moderately good. The main assets of this complex include moss fens (7230) and the only calcareous fen in the Mazovian region (Jarzombkowski & Kozub 2011).

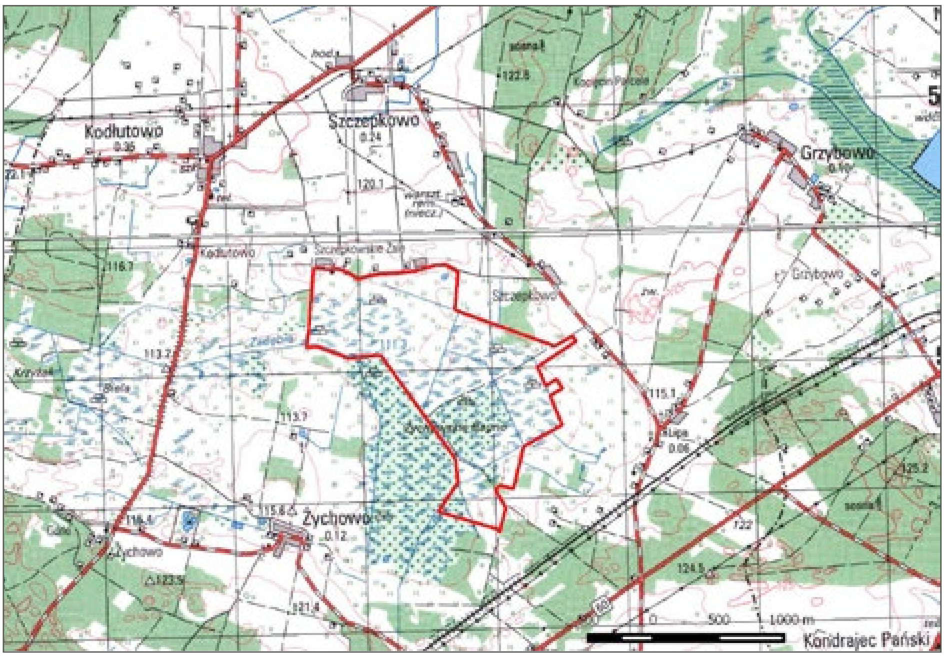


Fig. 40. Location of the Kłocie Raciąskie moss fens.

**Drzezno** – 95,3 ha, the Mazovian Province, lake and adjacent moss fen with the largest in Mazovia population of *Liparis loeselii*; a potential Natura 2000 site would include two neighbouring alkaline fens: Drzezno (nature reserve) and Nałęcin.

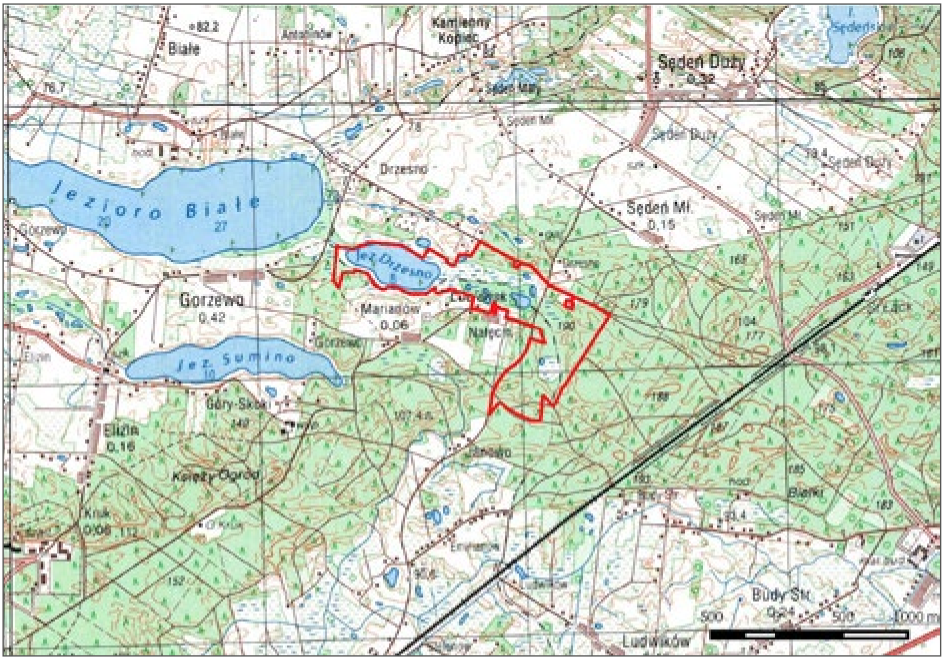


Fig. 41. Location of the Drzezno fen.

**Sikory Juskie** – 60,1 ha, the Warmian-Masurian Province, moss fen with *Liparis loeselii* population. In 2007, 1 200 fen orchid plants were found (the largest population in the Warmian-Masurian province, one of the largest in Poland (P. Pawlikowski, unpublished). This population is under surveillance of the Chief Inspectorate of Environmental Protection. Although in 2013 this population went through an abundance crisis with a reduction in several tens of plants due to a very high water level, in 2016 its abundance and area rose again. P. Pawlikowski has identified at least 165 shoots (including 45 generative and a dozen or so juvenile), so this locality still belongs to one of the richer ones in the Warmian-Masurian region. In general, wide fluctuations of shoot numbers are typical of orchids. In spite of fluctuations, the population is in all respects worth incorporation into the network.

**Kirszniter** – a small (12,0 ha) but well-developed and preserved mid-forest lake-shore moss fen with a population of several hundred *Liparis loeselii* (one of bigger ones in the Warmian-Masurian province), besides which it is a very valuable and floristically precious alkaline fen.

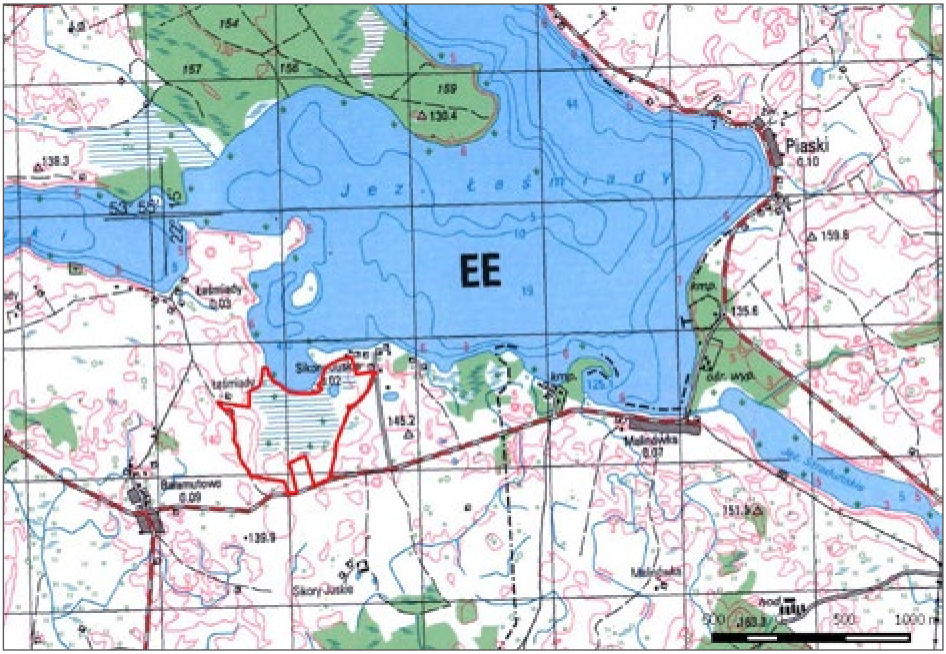


Fig. 42. Location of the Sikory Juskie fen.

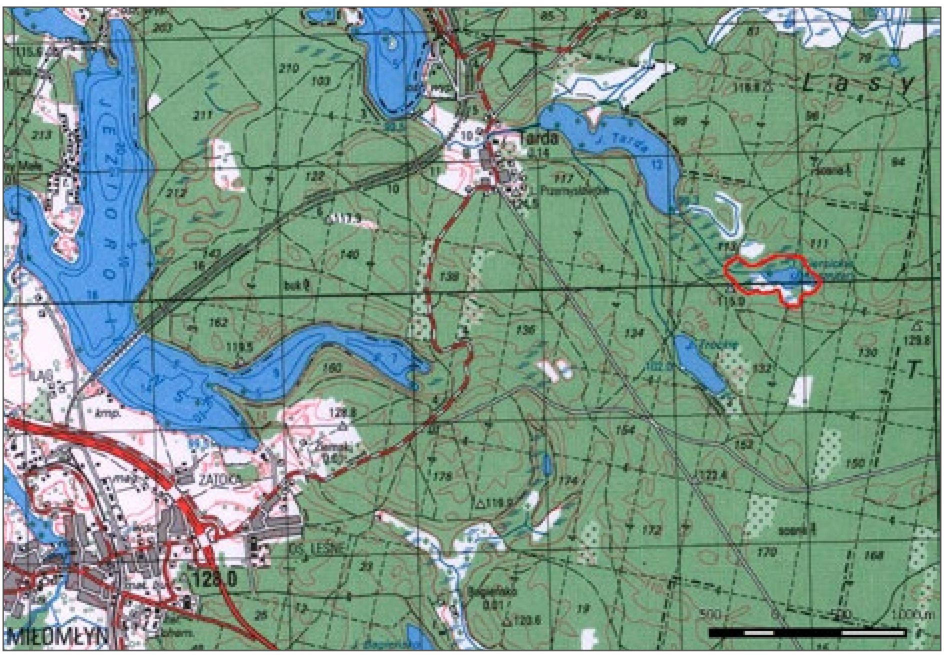


Fig. 43. Location of the Kirszniter moss fen.

Photo 107: Moss fen near Kirszniter Lake in Warmia, the area proposed to be included in the Natura 20000 network (photo by P. Pawlaczyk).

**Myszków fen** – 51 ha, Silesia, Continental region, in Warta river valley near Myszków. It is the largest area encompassing remnants of calcarous fens in good conservation status with strong populations of *Liparis loeselii* (Hałabowski & Błońska 2015) and brown moss *Hamatocaulis vernicosus,* but also with other valuable species (see Chapter 7) *inter alia* stands of *Scorpidium scorpioides*, large areas of *Eleocharis quinqueflora*, sphagna carpets: *Sphagnum teres, Sph. warnstorfii* and *Sph. contortum*. Partially protected as ecological area „Przygiełka" but this kind of protection is insufficient (Hałabowski et al. 2016b).

**Sławków** – a larger area in the Silesian Province proposed to be included in the Natura 2000 network, also known for the occurrence of bats: *Myotis emarginatus* and *Myotis myotis*, comprising in particular (apart from dispersed smaller patches) key, on the regional scale, complexes including alkaline fens, and important localities for *Liparis loeselii* **(**Ł. Krajewski, unpublished). The **Szczakowa** complex comprises ca. 100 ha of floristically valuable spring fens (habitat 7230) developed at the bottom of the former sand mine (see Chapter 7). Population of fen orchid *Liparis loeselii* counts more that 2000 plants. **Fens in the Biała river valley** comprise patches of natural alkaline fens along the valley flanks of the Biała river downstream from Laski village. It covers at least several hectare of better-preserved moss fens in three patches harboring, for

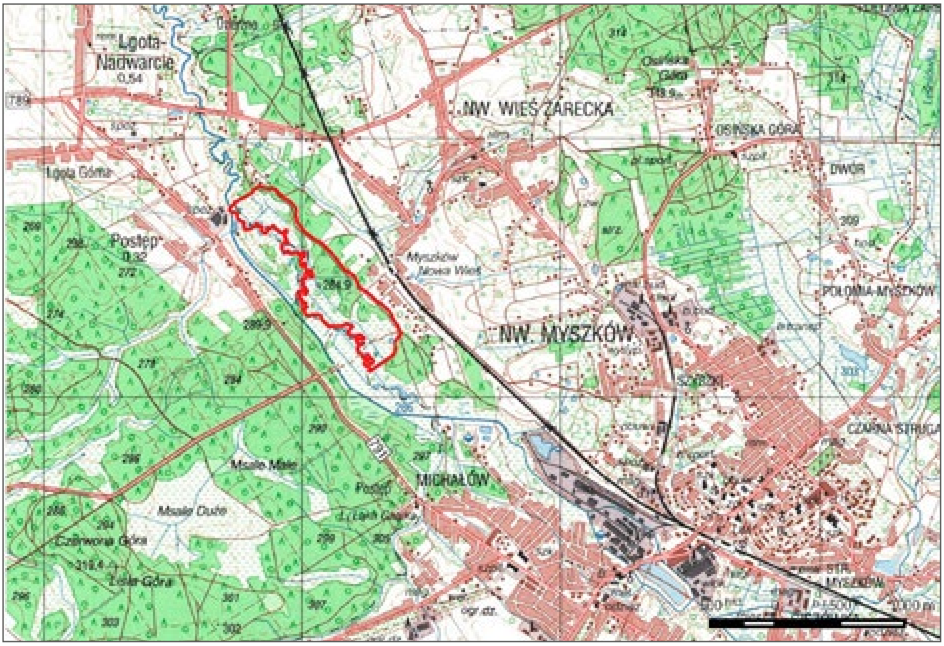


Fig. 44. Localisation of the Myszków fen.

Photo 108: Moss fen in Myszków (photo by Ł. Krajewski).

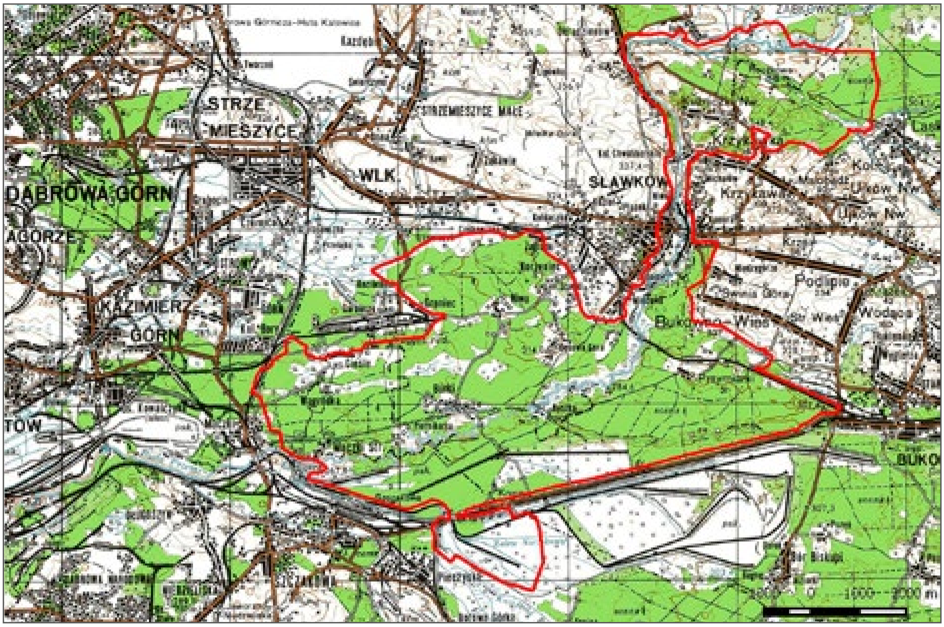


Fig. 45. Location of the Sławków area.

instance: *Liparis loeselii* (in total ca. 100 plants at 3 localities, *Hamatocaulis vernicosus* (at least 3 localities) (see Chapter 7) **The moss fen in the Biała Przemsza valley in Sławków** is a small (ca. 1 hectare) but floristically valuable natural alkaline fen with *Liparis loeselii, Epipactis palustris, Carex dioica, C. diandra, C. davalliana*, *Limprichtia cossonii, Campylium stellatum*, and *Utricularia intermedia*, found in 2015 (earlier in the 1960s, there were reports of a locality for fen orchid in this part of the Biała Przemsza river valley but until 2015 it had not been found) **(**Ł. Krajewski, unpublished).

**Spring fens near Pogoria lake** – 6,2 ha, the Silesian Province, floristically valuable spring fens developed at the bottom of a former sand mine, hosting valuable flora (see Chapter 7). A population of ca. 120 *Liparis loeselii* plants found in this complex should be included in the network also from a species conservation perspective. There are good prospects for its protection since, in 2013, shrubs were removed from a part of the spring fen area as a protective measure by a decision of the Dąbrowa Górnicza city authorities. The values of this complex were confirmed in 2016 (Ł. Krajewski, unpublished).

**2. The corrections of boundaries of Natura 2000 sites**

**Dolina Debrzynki PLH300047.** The Debrzynka river valley, situated at the border between Pomerania and Greater Poland provinces, is covered by com-

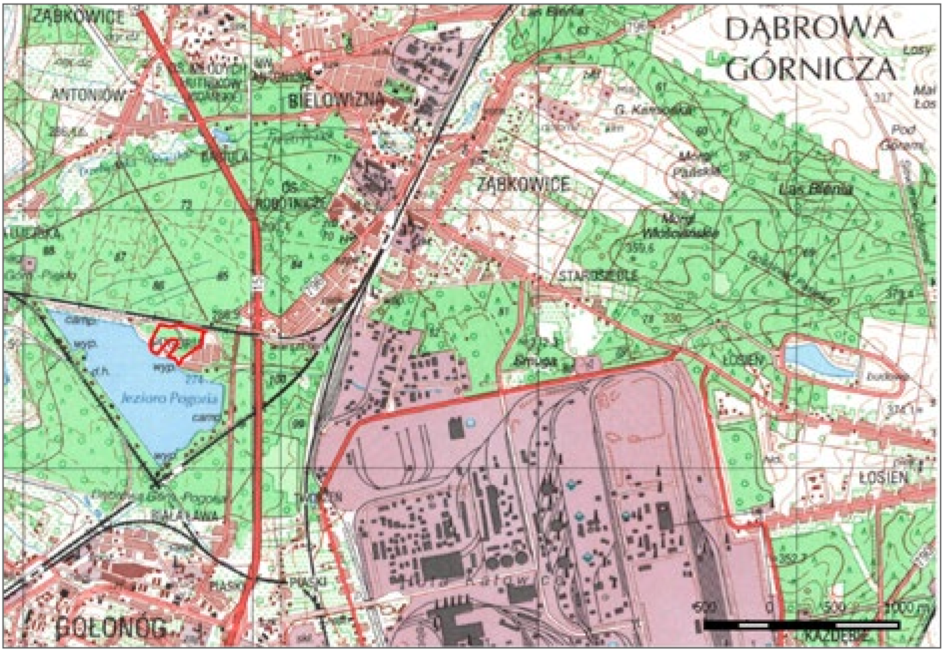


Fig. 46. Location of Spring fens near Pogoria lake.

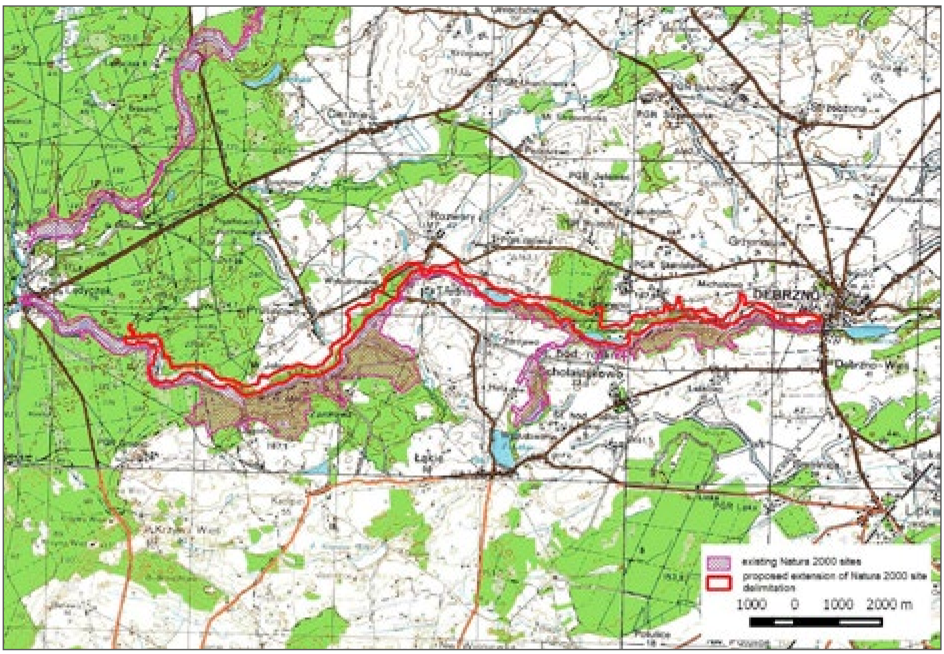


Fig. 47. The proposed enlargement of the Natura 2000 site Dolina Debrzynki PLH300047.

plexes of alkaline fens on both banks of the river. Apart from habitat 7230, abundant populations of *Vertigo angustior* and *Vertigo moulinsiana* inhabit this area not only on the Greater Poland but also on the Pomeranian side. The Natura 2000 site was delineated in this valley to protect alkaline fens, but only a half of them were included because erroneously this area encompasses only a part of this complex located in the Greater Poland Province, disregarding an equally valuable part of the fen complex stretching to the Pomeranian province.

**Sandr Wdy PLH040017.** Small valleys of the Święta Struga and Brzeźniczek streams, adjacent from north to the borders of the existing Natura 2000 site in the Pomeranian Province, near the localities of Ocypel, Mermet, and Zdrójno, and north and west from Kasparus, are covered by well-developed patches of moss fens with a large surface area, e.g., in the locality of Zdrójno, on the edge and west of Długie lake. Populations of species characteristic of alkaline fens are abundant, e.g., patches with dominant *Paludella squarrosa,* with *Hamatocaulis vernicosus*, and ample population of *Liparis loeselii* (Ł. Kozub, unpublished).

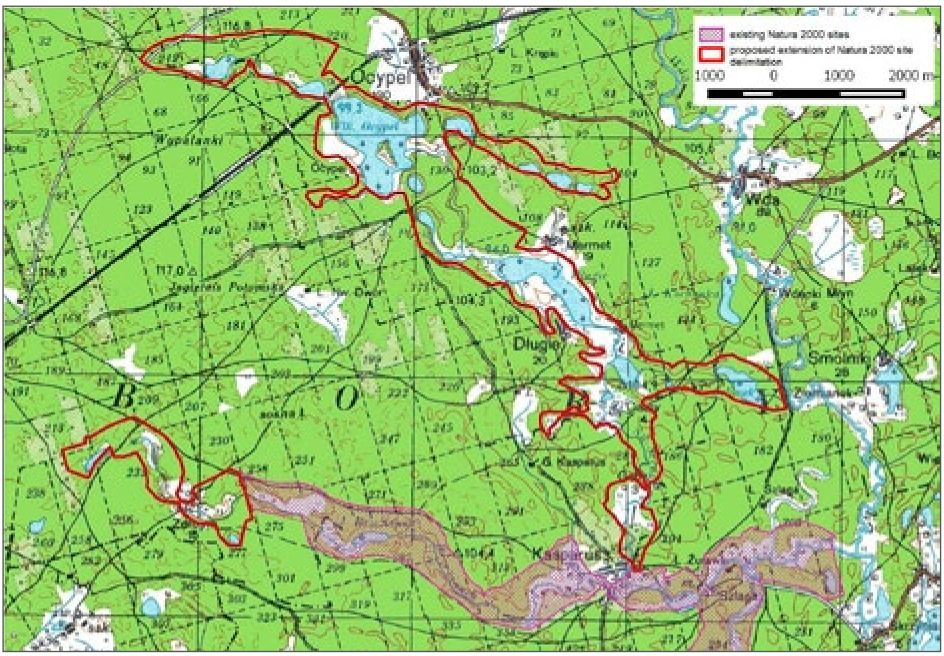


Fig. 48. The proposed enlargement of the Natura 2000 site Sandr Wdy PLH040017.

Photo 109: Moss fen near Długie Lake proposed to be included in the Natura 2000 network by enlargement of Sandr Wdy PLH040017 (photo by Ł. Kozub).

**Łąka w Bęczkowicach PLH100004**. As part of elaborating Conservation Measures Plan for this Natura 2000 site near Łódź, in the Continental biogeographic region, the need to expand the existing area was confirmed so as to include existing ecological area covering plot no. 45 (Kolonia Trzepnica, municipality Łęki Szlacheckie) with an area of over 11 hectares. It is protecting a complex of mires in the Luciąża river valley with a unique bryophyte flora and vascular plants, including the occurrence of brown moss *Hamatocaulis vernicosus* and *Liparis loeselii* population (about 80 individuals).

**Dolina Bielawy PLH320053.** During preparation of the protection plan for this Natura 2000 site in the West-Pomeranian province, the need was identified to complement the area with a side valley of the Świrnica River, a tributary of the Bielawa. The main objective for this enlargement is to include an alkaline fen located in this valley called Ratajki moss fen, where soligenous mires developed with moss-sedge vegetation (*Juncetum subnodulosi, Menyantho-Sphagnetum teretis*) and humid meadows of moss fen type (with *Tomenthypnum nitens, Helodium blandowii*), and also cupola spring mires with spring fens and rushes, which in terms of their natural values significantly exceed the alkaline fens already included in this Natura 2000 site (J. Kujawa-Pawlaczyk et al. 2018).

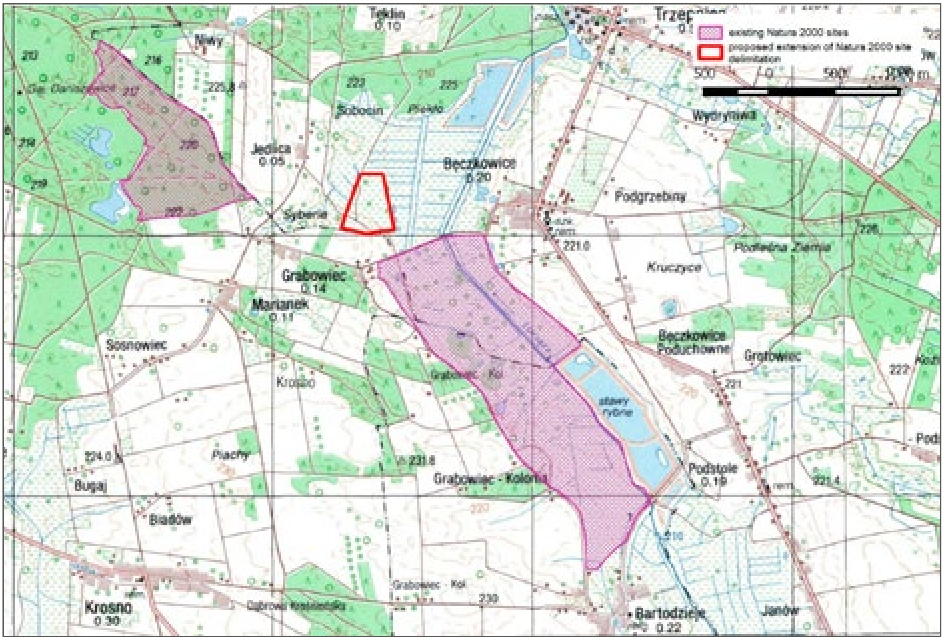


Fig. 49. Proposed change in Natura 2000 Łąka w Bęczkowicach PLH100004 site delimitation.

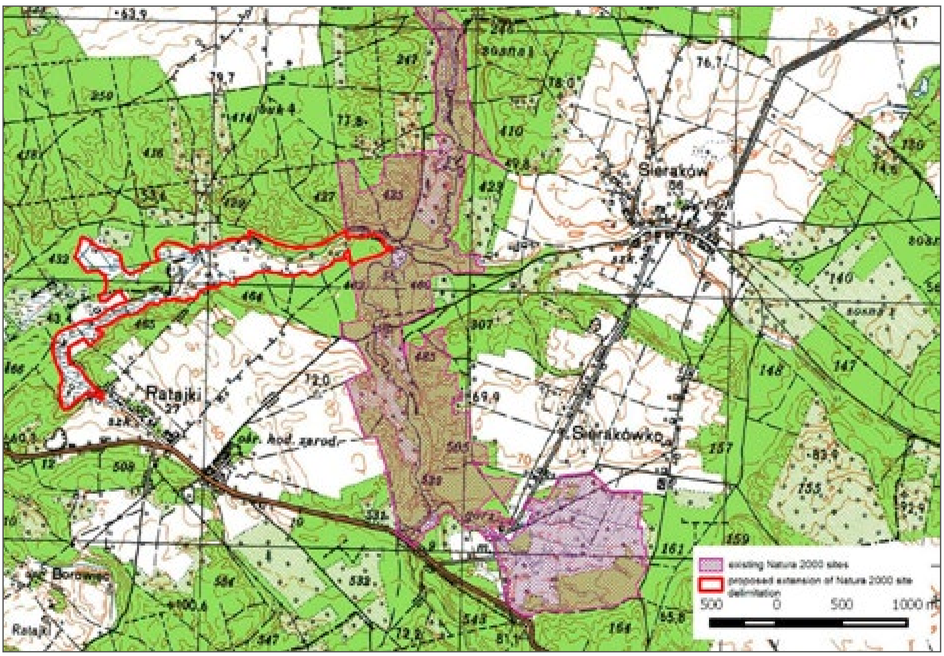


Fig. 50. The proposed enlargement of Natura 2000 site Dolina Bielawy PLH320053.

**Dolina Miały PLH300042.** In autumn 2016, S. Rozsadziński discovered the previously undescribed fen Okonino near a Natura 2000 site but outside of its borders. The fen fills a lake basin dominated by alkaline, limnogenic moss fens with the largest populations of *Paludella squarrosa* and *Helodium blandowii* in Greater Poland and occurrence of *Sphagnum teres, S. warnstorfii, S. contortum, Campylium stellatum*, and *Tomentypnum nitens* (S. Rosadziński, unpublished).This complex is more valuable than all the fens situated within the present borders of the Natura 2000 site Dolina Miały PLH300042 and should be included in this area as a compartment in order to account for the largest moss fen in this region.

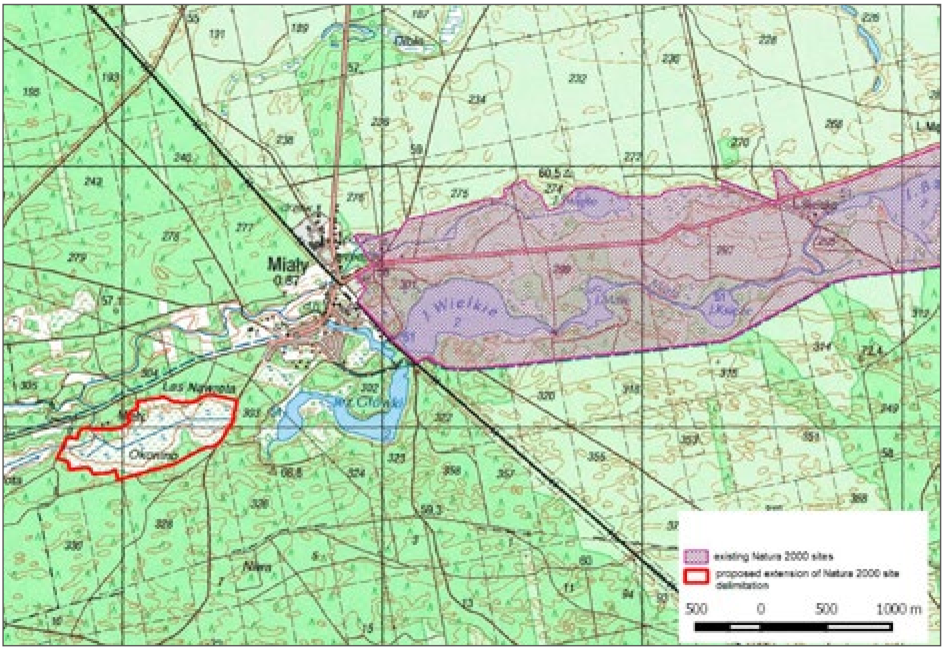


Fig. 51. The proposed enlargement of the Natura 2000 site Dolina Miały PLH300042.

**Uroczyska Puszczy Drawskiej PLH320046**. In this case, the site should include the Mszary Tuczyńskie nature reserve protecting the soligenous mire overgrown with mossy sedge rush, adjacent from the outside to the border of the Natura 2000 site and only mistakenly left outside of it.

**3. Supplementing the list of conservation objectives in existing sites**

It is necessary to supplement information about the natural habitat 7230 in the Natura 2000 site **Nowa Brda PLH220078**. So far, alkaline fens in this area are not mentioned at all in its SDF and are not subject to protection. Meanwhile, on the lake Wieczyno and in the Lipczynka stream valley, four alkaline fens are known, with a total area of approx. 30 ha. Of particular interest is the complex in the valley of Lipczynka, where in addition to the moss-sedge fen rushes and overgrown by reeds spring fen cupolas, there is also a well-formed mesotrophic moss fen with *Saxifraga hirculus* (Kozub & Dembicz 2018).

Photo 110: Moss fen with yellow marsh saxifrage *Saxifraga hirculus* in Nowa Brda PLH220078 site (photo Ł. Kozub).

## 8.2.2. Conservation of alkaline fens within Natura 2000 sites

Inclusion of an alkaline fen into a Natura 2000 site and its recognition as a subject of protection at that site is not sufficient to provide efficient protection to the fen as yet.

The Natura 2000 site Bagno Całowanie PLH140001 can be an example. This site, established to protect over 900 ha of alkaline fens, formally has existed in the Natura 2000 network up till now. However, already at the moment of its establishment (2004) this fen was heavily degraded (drainage facilities were constructed in the 1960s –1980s) and the area of 900 ha reflects rather an area of peat bed developed historically due to soligenous water supply than an area of natural habitat 7230 actually existing at that time. Nevertheless, sedge-moss meadows related to sedge-moss fens with an area of at least several tens of hectares had still been preserved in the peat pits (Klimkowska et al. 2007, Kozub 2016). In 2009, locations for the state monitoring of habitat 7230 were successfully established there although already at that time it was assessed that "*the habitat in this refuge would probably disappear soon or its status would significantly deteriorate*." This forecast proved correct in 2017 when the disappearance of these habitats was confirmed (F. Jarzombkowski in Insitute of Nature Conservation... 2018). Legal mechanisms, which theoretically should protect a Natura 2000 site, were not effectively used to prevent functioning of the drainage system. The plan of conservation measures prepared and established in 2014 was an example of helplessness since it recommended increasing the knowledge on habitat 7230 resources and causes of its disappearance as the only measure of habitat protection. In spite of the status of a Natura 2000 site, the drainage ditches were maintained and dredged while the hydrology of this area was negatively affected by groundwater abstraction in the neighborhood, as well as by illicit peat extraction and the creation of ponds. Although there were attempts to implement some conservation measures, such as construction of wooden dams in ditches, they were regularly destroyed by the local inhabitants. The disappearance of the habitat was not prevented by regular mowing of a majority of its patches.

Cases of destruction of alkaline fens and flush fens by property owners through partial filling them with rubble and soil or renovation of drainage ditches, were documented for example in Natura 2000 sites Lipienniki w Dąbrowie Górniczej PLH240037 and Ostoja Augustowska PLH200005 (Kobyla Biel Fen).

In the Natura 2000 site Jezioro Księże w Lipuszu PLH220104, the property owner, although he receives agri-environmental subsidies, not only dredges ditches but he does not even allow the environmental protection service to access the fen. Probably, there are many more such cases. In spite of the regulations which require infringers to make good the damage, enforcement of remedial actions is difficult and not fully effective.

At many other sites, alkaline fens disappear due to the lack of proper protection, e.g., because long existing drainage systems are in operation or because fens are overgrown by trees, shrubs and reeds. Theoretically regulations require environmental protection services to undertake appropriate actions in each of such cases, but in practice the remedies differ widely.

For instance, in the Natura 2000 site Jeziora Szczecineckie PLH320009, relatively large patches of habitat 7230 with vegetation of mossy sedge character, e.g., with *Carex diandra* and *Helodium blandowii* were observed by the Płociczno, Drężno and Małe Lakes in 2003 though already at that time heavy overgrowth by willow thickets and urgent need for active protection were signaled. After a 10-year delay in protection planning, the only conclusion that remained to be drawn was that "*formerly recorded fen patches currently show the character of tall herbs, willow thickets or young alder forests, at most with some contribution of Menyanthes trifoliata (...). It is proposed to indicate in the SDF that the habitat has disappeared*."

The insufficient effectiveness of alkaline fen protection in Natura 2000 sites in Poland is confirmed by results of the State Environmental Monitoring. At 120 monitoring locations established in 2009 in Natura 2000 sites (located according to expert's decision mostly in better preserved habitat patches), and then reexamined in 2017, the proportion of those with bad conservation status (U2) increased from 24% to 54% while the percentage of sites with favourable conservation status (FV) dropped from 17% to 10%.

On a national scale, the preparation of plans of conservation measures is the basic tool for conservation planning of Natura 2000 sites. They are planning documents developed and formally established for 10-year periods pursuant to the Nature Conservation Act. It is assumed that they will be prepared based on available knowledge, complemented by a certainly not necessarily comprehensive field survey. Up to the end of 2018, plans of conservation measures were established for over 400 Natura 2000 sites in Poland. Among them, 93 plans were established for sites where habitat 7230, alkaline fens, is a subject of protection. In addition, this habitat type was accounted for in the conservation plan for the Pieniny National Park (see below) containing also an outline of the plan of conservation measures for the Natura 2000 site.

In as many as 19 of those 93 sites, the plan mentions only an unsuccessful attempt to find the habitat within the site and proposes to withdraw it from the list of subjects of protection. Probably in a majority of these cases, the SDF entry is actually erroneous and indeed alkaline fens presently do not occur at these sites. However, it happens that questioning of the existence of alkaline fens results from incorrect preparation of the plan and neglecting that such fens not only exist in the site under examination but are known and described. Such situation happened, for instance, in the Natura 2000 site Jeziora Wdzydzkie PLH220034, where the established plan of conservation measures for habitat 7230 recommended "*Analysis and verification of data on the habitat in the site and change in the SDF in order to possibly remove the habitat from the catalog of subjects of protection*", while this site is known to harbor 10 alkaline fens with the total area of ca. 32 ha.

In the next 19 sites, in spite of preparation of plans of conservation measures and appropriate documentation, sufficient information for protection of alkaline fens could not be gathered, thus the completion of knowledge was recommended as the only conservation measure while actual protective actions were postponed until more comprehensive knowledge is available.

However, most often only basic knowledge on habitat distribution and physiognomy-based assessment of its status are expected to be completed. Only one plan suggested examination of fen stratigraphy, while several others sometimes recommended preparation of "hydrological expert opinions" to be able to plan in detail the location of dams in ditches. No document was deemed necessary to conduct thorough ecohydrological studies, e.g., including biochemical aspects.

Consequently, in nearly 40% of cases, the conservation management plans established for the Natura 2000 sites did not ensure effective protection of alkaline fens declared as a subject of protection at these sites. Hence, out of the 97 established plans, 57 actually defined measures for habitat 7230 conservation.

In 93% of sites possessing plans of conservation measures, succession of vegetation, usually expressed as expansion of rush, tall herb species or expansion of trees and shrubs, has been identified as hazardous for habitat 7230. It was usually caused by the abandoning of extensive mowing. Almost always it was recognized as an existing not only potential hazard. In 55% of plans, it was considered necessary to remove trees and shrubs. In most cases complete removal was suggested although in two sites "*junipers and dwarf pines were suggested to be left*" while in several other plans, the retention of 10% tree cover was accepted. Eighty percent of plans recommended the restoration of mowing. However, only 34 % of these plans specified mowing conditions (e.g., its frequency, height, seasons, mowing methods, leaving of unmown plots). In the remaining 46% of plans, the recommendations were limited to a standard statement that the habitat should be "*used in compliance with recommendations of an appropriate agri-environmental package within the framework of the valid RDP aimed at conservation of habitat 7230*", which is bizarre in so far as the valid RDP for 2014 – 2020 does not contain any package dedicated specifically to habitat 7230[5]. About one third of plans (34%) contained a statement allowing for a free choice of management methods when using fens for haymaking, pasture-based farming or their combination. Only one plan excluded grazing in alkaline fens.

In 46% of 57 plans specifying conservation measures, actual threats to water conditions in the fens were noted, while in a further 36% of the plans such concerns were expressed as potential. They were usually associated with dredging and maintenance of ditches, maintenance works in neighboring water courses and groundwater abstraction within the site or nearby. However, in nearly three-quarters of such situations, this diagnosis was not followed by the suggestion of any conservation measures or even recommendation of fen hydration monitoring. Only 10 plans specified some measures aimed to counteract the threats to water conditions in the fen, such as the construction of dams or other water control facilities, or allowing for natural build-up of slime and ditch overgrowth. Only 5 plans provided for recording of water level in the fens as one of the monitoring objectives.

Two plans proposed placing licks in the fen to attract deer (to stimulate vegetation trampling which sometimes favors the growth of sedge and moss species). Five plans underlined the need to leave a 25 – 30 m wide zone protected from

5 Alkaline fens can be protected within the framework of a wider variant "fens" under a basic subvariant assuming only removal of tree and shrub suckers or under an extended subvariant assuming extensive mowing. However, adjustment of details of fen use to the requirements of a particular fen can be made only in the form of the additional recommendations of an expert preparing documentation for the farmer. See also Chapter 9

complete felling in the adjacent forest. Conservation objectives set in plans of conservation measures for habitat 7230 are not very ambitious. No plan established so far has assumed restoration or enlargement of the area of this natural habitat. In a majority of cases, the plans concentrate on preservation of undeteriorated current status (even if it is unfavourable) or, at most, improvement of some indices regarding vegetation.

In essence, conservation measures prepared and established for Natura 2000 sites clearly depend on recommendations of the General Directorate for Environmental Protection which are developed at the central level and are not always substantively correct. The statement that fens should be "*used in compliance with recommendations of an appropriate agri-environmental package within the framework of the valid Rural Development Plan aimed at conservation of habitat 7230*" repeatedly included in planning documents instead of a detailed description of mowing schemes, corresponding to local specificity, has just that origin. However, it is worth noting that such a statement does not even comply with the rules of legislative technique because it shifts the burden of responsibility from the authority in charge of the site authorized to preparation of the plan of nature conservation to the central authority competent in matters of rural economy. An equally unfortunate but routinely used statement allowing all forms of haymaking and pasture farming and their combinations, even in fens never used for grazing and where grazing is undesirable, is also a result of recommendations established at the central level resulting from political decision not to restrict freedom of farmers and not to provide an opportunity for their control.

An impact of the nationwide standards of habitat monitoring and assessment of its conservation status (Koczur 2012, see also hereinafter, Chapter 11.1) on the contents of plans of conservation measures is also conspicuous, which sometimes results in insufficient accounting for local specificity. Stringent criteria as to the presence of trees and shrubs in the fen proposed by Koczur (2012) result in massive and routine planning of removal of trees and shrubs, although actually not always and not everywhere is it necessary for the conservation of habitat biodiversity. An unwillingness to incorporate more detailed monitoring of water conditions in the fens or monitoring of any biogeochemical characteristics into the plans of conservation measures should be associated with the fact that the state monitoring does not survey these parameters.

In spite of these limitations, at least several plans of conservative measures (e.g., for the following Natura 2000 sites: Dolina Górnej Rospudy PLH200022, Źródliska Wzgórz Sokólskich PLH200026, Mechowiska Sulęczyńskie PLH220017, Jonkowo-Warkały PLH280039, Mechowisko Manowo PLH320057) appear to be correct and well captured, and their implementation would provide an opportunity for the reversal of current negative trends at least in those sites.

## 8.3. National Parks

According to the database of alkaline fens in Poland maintained by the Naturalists' Club, over a half of the area covered by these fens in our country is protected in National Parks, although it corresponds only to 24% of patches. However, in two parks harboring the largest areas of alkaline fens, i.e., the Biebrza National Park and the Polesie National Park, separation of habitat 7230 from other types of mires is not clear, which results in considerable differences in estimates of habitat areas reported by different sources.

The largest alkaline fens in Poland are situated in the Biebrza river valley and they are protected in the **Biebrza National Park**. According to the plan of conservation measures for the larger Natura 2000 site Dolina Biebrzy PLH200008 (with borders similar to the national park buffer zone) developed by the park (Weigle 2016), the whole site encompasses 4,136 ha of alkaline fens, of which 3,661 ha are located in the national park. Typical mezotrophic sedge moss fens have developed most of all in the Upper Biebrza river basin, especially in the area of the villages Szuszalewo and Nowy Lipsk. The Lower Basin is covered mostly by tall sedge beds with participation of sedge-moss fen species, of transition character between soligenous fens and fluviogenic mires. The Middle Biebrza river basin comprises the smallest proportion of these habitats (226 ha) (see Chapter 7).

An up-to-date conservation plan has not been developed for this national park until now, and conservation measures are implemented based on plans of conservation measures established for 1 – 5-year periods. However, the conservation needs of alkaline fens were defined in the above-mentioned plan of conservation measures of the Natura 2000 site. Some patches of habitat 7230 are relatively stable even under passive protection either as open fens or loose thickets maintained in this form due to high hydration and pressure of elks (Weigle 2014). Nevertheless, most of patches of sedge moss fens require actions aimed at curbing succession, especially expansion of trees and shrubs, and also reeds. The National Park has implemented such measures either alone (also during realization of the project LIFE11 NAT/PL/422 "Conservation of wetland habitats in the Upper Biebrza River Valley") or partially by leasing surfaces for controlled mowing within the framework of the program of multiannual leases for nature protection. Lessees receive agri-environmental subsidies. Within the RDP for the period 2007 – 2013, 350 ha of alkaline fens were subjected to conservation for 5 years under the variant "sedge-moss fens" optimal for alkaline fens. Less optimal variants, e.g., "tall sedge beds" and "bird habitat conservation" were also used.

However, the fen area subjected to extensive mowing is still too small. In the most valuable sites, mainly in the Upper Basin of Biebrza River, small-scale hand mowing is practiced (which is best suited for conservation of sedge moss fens which are in the process of being overgrown, and concomitantly allows for preservation of community structure). Mowing attempts with the use of conventional agricultural tractors resulted in the formation of deep ruts and destruction of fen surface. The problems with the use of traditional tractors were thought to be overcome by the use of tracked groomers more widely applied since about 2005 in the Lower and Middle Biebrza river basin; however, this method also is not devoid of negative impact on fens, namely the vehicles can press sedge and moss hummocks into the peat bed leading to unification of the fen surface and consequently to a reduction of the abundance of rare plant species which inhabit those hummocks (Kotowski et al. 2013). For this reason, since 2014 the park has avoided using tracked groomers for mowing of communities characterized by a hummocks' structure. The implemented conservation measures allow for preservation of the open character of the Biebrza fens, however some their details are not adjusted to so delicate and sensitive habitats as alkaline fens. Mowing of many hectares of land at the same date leads to unification of vegetation structure, while the vehicles used for this work cause sward damage. Experts underline the formation of ruts, numerous maneuvering areas, too low mowing, excessive shrub removal resulting in homogenization of phytocenoses, procedures performed at inappropriate times, i.e., during heavy hydration, compaction of the habitat with too heavy equipment, and suggest mosaic-like mowing with leaving greater patches unmown, use of lighter equipment or hand mowing (F. Jarzombkowski, in Institute of Nature Conservation... 2018, unpublished). However, so far no better method has been found. Hand mowing in not cost-effective and it is difficult to find contractors due to the challenging conditions of the field work. Moreover, severe winters are increasingly rarer which creates serious problems with biomass removal.

Photo 111: Hay harvesting from the fens in the Biebrza National Park with the use of a tracked groomer (photo by M. Marczakiewicz).

The identified protection needs include also counteracting drainage, including prevention of silt removal and ditch dredging on numerous privately owned plots in this park, which is not always successful.

The **Polesie National Park** comprises two large topogenous-soligenous fens – Bagno Bubnów and Bagno Staw (see Pietruczuk 2015, 2016) – developed in depressions on chalk substrate. In the database held by the Naturalists' Club, both these sites covering a total area of 1,205 ha were included as a whole into alkaline fens. Their vegetation comprises sedge fen complexes, wet Molinia meadows and (less abundant) reed beds with a greater or smaller contribution of calcicole species, with patches of the *Caricetum davallianae* and *Caricetum buxbaumii.* In the data of the national park, only patches of sedge fen vegetation of the *Caricetum davallianae* and *Schoenetum ferruginei* are identified as habitat 7230, which results in area estimation at 32.6 ha. In spite of awareness of the need for active protection and relevant measures implemented up till now (removal of shrubs, mowing of reed beds, mowing of rushes, mostly to protect bird habitats), from an alkaline fen perspective the protection is insufficient. Monitoring data from four representative locations of the State Environmental Monitoring in the period 2009 – 2017 demonstrated progression of disadvantageous succession and worsening of the conservation status from unfavourable/inadequate (U1) to unfavourable/bad (U2). The conservation plan for the national park, which is awaiting approval[6], and temporarily established conservation measures for consecutive years, require the removal of trees and shrubs and "*damming up water during its scarcity in the habitat as needed in drought years*" as conservation measures for this habitat.

In the **Narew National Park**, according to the Naturalists' Club database, one patch of alkaline fen with an area of ca. 45 ha is situated in the Uroczysko Rynki. Wołkowycki (2013) and Wołkowycki et al. (2016) described distribution of habitat 7230 in the park in more detail and estimated its total area at ca. 90 ha. This habitat type in the park comprises low sedge flush fens mostly with *Carex nigra* (a form of the *Caricetum paniceo-lepidocarpae* association), *Calamagrostietum neglectae* community, mossy variant of *Caricetum rostratae*, and some forms of *Caricetum appropinquatae* association. The habitat covers an area of ca. 90 ha and is scattered along almost the full length of the Narew river valley within the borders of the national park, encompassing, besides Uroczysko Rynki, also areas near the villages of Radule, Kruszewo, Kurowo, Jeńki, Baciuty, Kolonia Bojary, and north of the towns of Łapy and Suraż. It is threatened by being overgrown by alder and willow (including *Salix rosmarinifolia*), by succession-related changes

6 Projects of conservation plans were prepared for the majority of Polish national parks but they have been waiting for formal establishment by the Minister of the Environment for several years, which is contrary to the Act requiring approval of a conservation plan within 6 months from submission. Such legislative helplessness of the Minister of the Environment in establishing conservation plans for national parks has lasted unceasingly since 1990s. However, in practice, the prepared projects are the basis for implementation of conservation measures by the parks which is formalized as "provisional plans" in the form of conservation measures established for 1 – 5-year periods

due to abandonment of mowing, and also by drying (when water supply from groundwater seepage declined, low sedge vegetation was noted to transition into Nardus grasslands). At present, a portion of the patches remains unutilized while others are mown within a mowing program of larger rush and meadow complexes either by the park or by private property owners. The national park conservation plan, which is currently awaiting approval, envisages active protection of the habitat by removal of trees and shrubs and mowing with an objective to conserve the habitat over the whole area of its occurrence, i.e., ca. 90 ha.

The **Wigry National Park** is known to harbor more than 20 alkaline fens with an area of ca. 30 ha. They develop in river valleys (Wiatrołuża, Czarna Hańcza) along the banks of lakes (Białe Piertańskie, Leszczewek, Samle, Widne, Wigry, Muliczne). Their vegetation often assumes the form of mossy beds of beaked sedge *Carex rostrata* and bogbean *Menyanthes trifoliata*, with a high proportion of meadow species and orchids, sometimes lesser tussock sedge *Carex diandra* beds, patches of the *Menyantho-Sphagnetum teretis* with peat mosses, mossy forms of sedge fens (*Caricetum paniculatae, Caricetum acutiformis* and *Caricetum appropinquatae*) (Sikorski et al. 2013). The habitat is thought to be the most valuable flora refuge in the Wigry National Park (Pawlikowski & Romański 2014); it harbors *Saxifraga hirculus*, *Liparis loeselii*, numerous orchid species and unique moss species. The majority of patches require active protection tailored according to the needs of protection of valuable floral components. The park has longer experience with active protection of some fens, mostly in the Wiatrołuża river valley, where shrubs were removed and the area was mown with an objective of orchid conservation. Experience indicates that it is necessary to apply different procedures depending on the threat of reed expansion (if reed is present, the area should be mown every year, if it is absent mowing every 2 – 3 years in an optimum), it is beneficial to apply hand mowing and it is required to carefully remove the cut biomass. Many patches even in the national park are privately owned. The documentation of the draft national park conservation plan (Sikorski et al. 2013) contains a suggestion to purchase habitat patches from private property owners, and concomitantly indicates that it is possible and needed to be purchased by the park and to protect other alkaline fens outside the borders of the Wigry National Park - by the Perty lake and Czarna Hańcza river in the area of the villages of Mikołajewo, Buda Ruska and Gremzdówka. Several fens are situated in the non-intervention zone. Nevertheless in most of fens active protection measures are planned to be implemented, which involves one operation of tree and shrub removal (leaving dwarf pines with structure typical of fens and all junipers), mowing with biomass removal (every year in patches with reeds and other tall perennials and every 2 – 3 years in late summer for the remaining patches). The draft conservation plan is awaiting approval.

Photo 112: One of many dams constructed within the area occupied by flush fens in the Gorce National Park (photo by D. Horabik).

In the **Gorce National Park**, alkaline fens occur in the form of small flush fens with the *Valeriano-Caricetum flavae* type vegetation. More than 50 such fens were identified in the park with the total area of ca. 16 ha. The distribution of the flush fens is well known. In the area of the Turbacz Mt., the concentration of flush fens reaches 5 sites/km$^2$, which belongs to the highest values in the Polish Carpathians. Conservation measures (removal of trees and shrubs, mowing, slight damming of water in outflows) were applied at 15 sites within the framework of the project "Protection of alkaline fens in southern Poland" (LIFE 13 NAT/PL/024) implemented in the period 2014 – 2018 by the Park in partnership with the Naturalists' Club (Stańko & Wołejko 2018b). Under this project, plots with the 4 most valuable flush fens were purchased from private owners for the benefit of the national park. The conservation plan for the national park, which currently is awaiting authorization, provides for the continuation of similar conservation measures. Some problems are created by the fact that many patches are private property. The draft plan envisages land purchase whenever possible. Other flush fen conservation measures, in case of area grazing, include exclusion of waterlogged areas from grazing and mowing it only, as well as location of drinkers for animals and night animals enclosures outside flush fen areas.

In the **Drawa National Park**, alkaline fens are represented by 12 sites covering an area of ca. 11 ha in total. Sedge moss fens formed of sedge beds with *Carex rostrata*, *C. lasiocarpa*, *C. caespitosa* and *C. appropinquata* as the most common form of vegetation. Several sites are occupied by more typical moss-sedge communities with *C. nigra* and *C. diandra*, and moss-peat moss communities of the *Menyantho-Sphagnetum* type (Pawlaczyk et al. 2013, Kujawa-Pawlaczyk & Pawlaczyk

Photo 113: Moss sedge fen Łunoczka in the Drawa National Park mown every year (photo by J. Kujawa-Pawlaczyk).

2014, 2015). Well hydrated fens connected with lakes are stable even under passive protection, while fens traditionally used as meadows require mowing which has been consistently realized in the park since the 1990s, which has contributed to the maintenance of the floristic diversity and character of these ecosystems (Pawlaczyk 2014). The conservation plan currently awaiting approval intends to continue this approach.

In the **Bieszczady National Park**, alkaline fens are represented by almost 100 flush fens with the *Valeriano-Caricetum flavae* type vegetation, covering an area of 11 ha in total. Most often they are flush fens in the midst of meadow communities, sometimes small mid-forest glades, always in spring areas, sometimes on the fringes of raised bogs and acidic flush fens. Some patches are stable even without implementation of any conservation measures, while others are maintained by conservation actions such as tree and shrub removal and mowing together with larger complexes of non-forest vegetation. At some sites, water conditions are improved by beaver dams constructed on adjacent ditches (J. Korzeniak in Institute of Nature Conservation... 2018). The conservation plan for the national park, which currently is awaiting approval, assumes the habitat conservation by preservation of the optimum groundwater level, implementation of conservation measures related to haymaking (e.g., one of the sites in the park was mown within the project LIFE13 NAT/PL/024), and the counteracting secondary forest succession.

Photo 114: A mown flush fen in the Pieniny National Park
(photo by G. Vončina, Archives of the Pieniny NP).

In the **Pieniny National Park** alkaline fens are represented by type *Valeriano-Caricetum flavae* flush fens developing at local seeping outlets of calcium carbonate-rich water, relatively well-developed and preserved. A high content of carbonates in the water in the Pieniny Mts. causes precipitation of tufas on mosses and in soil. Studies conducted at the end of the 20$^{th}$ century revealed over 100 flush fens with their highest concentration in the Western Pieniny Mts. The concentrations exceeding 5 flush fens/km$^2$ belong to the highest in the Carpathians. The conservation plan established in 2014 identifies 8 ha of habitat 7230 in total. Conservation measures include, wherever possible, mowing with biomass harvesting which prevents succession of tree species and eutrophication, and removal of shrubs and tree saplings. However, some problems result from the fact that most of the flush fens are private property and, although the patches are located in the national park, their management rests with the owners who most often do not conduct any works. The conservation plan recommends removal of trees and shrubs, removing of undesirable species whenever needed, periodical mowing with biomass removal, elimination of water outflows and reduction of water abstraction, fencing to prevent sheep trampling, land purchase. On the privately owned plots all these actions depend on the consent of the property owners.

In the **Ojców National Park,** habitat 7230 it thought to be associated (which seems a little doubtful) with the thistle association *Cirsietum rivulare,* occurring at the bottom of river valleys; it is threatened by overgrowth by nettle and other nitrophilous plants after abandonment of use, thus requiring mowing. The conservation plan, which is awaiting authorization, records the existence of 6 ha of the habitat but aims to conserve only 2 ha. It assumes hand mowing in June/July every year, with biomass harvesting and removal of trees or shrubs that develop as a result of secondary succession.

In the **Tatra National Park,** ca. 20 flush fens of the *Valeriano-Caricetum flavae* were mapped, covering an area of almost 2 ha (Mirek et al. 2013). Their conservation status was assessed as favourable but they are threatened by forest succession. The conservation plan awaiting approval did not distinguish any special actions, in particular habitat patches, but recommended removal of trees from some flush fens and mowing planned for larger meadow complexes.

The **Magura National Park** is known to comprise almost 40 flush fens of the *Valeriano- Caricetum flavae* type. According to the park's estimate, habitat 7230 covers an area of 3,4 ha. The currently prepared draft conservation plan assumes obligatory extensive use of the flush fen areas for haymaking, and optionally: autumn mowing every 2-5 years, shrub removal every 3 – 5 years (in early spring), assuring proper water conditions and enlargement of habitat area by shrub removal. These measures (mowing and shrub removal) were implemented in 6 patches by the Naturalists' Club within the project LIFE13 NAT/PL/024 and will be continued by the park in the following years.

In the **Babia Góra National Park,** a dozen or so flush fens of the *Valeriano-Caricetum flavae* type occupying a total area of ca. 1,5 ha are known to be scattered mostly in the northern part of the park and to a lesser extent also in its western part. The draft conservation plan awaiting approval envisages their active protection by maintaining extensive use of the areas for haymaking. No specific conservation measures were defined for alkaline fens, but they were included in a common package of actions together with other meadow ecosystems, which includes the purchase of private plots in the park area, in enclaves within the park and in its neighborhood, removal of trees and shrubs, and mowing with biomass harvesting or grazing.

In the **Stołowe Mts. National Park**, small flush fens with vegetation of the *Valeriano - Caricetum flavae* and *Caricetum davallianae* were reported to occur even at the beginning of the 21$^{st}$ century in the Małe Torfowisko Batorowskie and near the Pasterka village, while a group of spring fens and flush fens heavily overgrown by spruces and alders was described near the Karłów village. However, in 2013 – 2018 this habitat was not identified in the complex of meadows near the Pasterka village and no species that could suggest its existence were found. At present, only the flush fen in the Małe Torfowisko Batorowskie represents habitat 7230 though it also undergoes transition into a wet meadow. It is hand mown which restricts threatening reed expansion (M. Smoczyk, unpublished information, Institute of Nature Conservation.. 2018). The draft conservation plan for the national park awaiting approval does not mention alkaline fens, and active protection of Małe Torfowisko Batorowskie is realized as conservation of habitat 7140.

In the **Świętokrzyski National Park,** two small flush fens of minor significance were identified in the Czarna Woda river valley near the Święta Katarzyna village, with vegetation of the degenerated *Valeriano-Caricetum flavae* type and a total area not exceeding 0.1 ha. The draft conservation plan does not mention alkaline fens.

In general, the conservation of alkaline fens in national parks appears to be correctly and professionally planned and implemented, with only a few exemptions. In spite of this, trends of changes in habitat 7230 conservation status, even in national parks, are worrying. The State Environmental Monitoring collects data from 15 monitoring locations in national parks. It appears to be too small sample for drawing final conclusions, however it is striking that the conservation status estimated in 2017 in none of these locations was assessed as better than in 2009, whereas in 8 locations, i.e., more than a half, it was judged to be worse than 8 years ago.

## 8.4. Nature reserves

### 8.4.1. Representation of alkaline fens in the nature reserve network

According to the database of alkaline fens in Poland, maintained by the Naturalists' Club, the occurrence of habitat 7230 can be identified in 53 existing nature reserves, which are listed below in an alphabetical order.

Table 5. Occurrence of habitat 7230 in nature reserves. Source of data on nature reserves: the Central Register of Forms of Environmental Protection: http://crfop.gdos.gov.pl/CRFOP/. Habitat patches according to Naturalists' Club Database of Alkaline Fens: http://alkfens.kp.org.pl/ogolnopolska-baza-mechowisk/.

| Name of nature reserve | Official area of nature reserve, ha | Geometric area of habitat 7230 in the nature reserve, ha | % of nature reserve occupied by habitat 7230 | Official type of nature reserve | Protection objective of the nature reserve according to the law establishing the nature reserve |
|---|---|---|---|---|---|
| **Bagno Chłopiny** | 118,99 | 21,04 | 17,7% | peatland | Protection objective is defined as conservation of a diverse complex of peatland ecosystems and bog forests with a transition mire situated in the central part and characteristic vegetation and fauna, for didactic and scientific reasons. |

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| **Bagno Serebryskie** | 376,62 | 282,38 | 75,0%[7] | peatland | Protection objective is to conserve a calcareous fen which is the refuge for very rare species of birds and plants. |
| **Bagno Stawek** | 40,8 | 7,2 | 17,6% | peatland | Protection objective is to conserve a complex of alkaline fens distinguished by outstanding phytocenotic and floristic values. |
| **Bahno w Borkach** | 289,87 | 0,19 | 0,1% | peatland | Protection objective is to conserve valuable, well-developed boreal fen communities, distinguished by rich flora of vascular plants and bryophytes and a large number of protected species. |
| **Biała Woda** | 33,71 | 0,1 | 0,3% | landscape | Conservation of a fragment of the Biała river valley in the Małe Pieniny Mts., distinguished by exceptional beauty of the landscape and harboring many rarities of animate and unanimate nature, for didactic and touristic reasons. |
| **Brzeźno** | 157,78 | 151,99 | 96,3%[8] | peatland | The nature reserve was created to conserve a carbonate fen with rare plant species, for scientific and didactic reasons. |

7 This area as a whole is covered by a difficult to separate complex of communities of the so-called carbonate fen developed in a large karst depression, comprising fen sedge beds, *Schoenetum ferruginei* communities, calcareous sedge fens, peat excavations, and calcareous elevations ("grądziki"), difficult both to unequivocally classify as a whole and to separate into different types of natural habitats.

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| **Bukowskie Bagno** | 22,41 | 8,53 | 38,1% | peatland | Protection objective it to conserve a site comprising sedge moss spring fens and moss bogs with rare fauna and flora, including locations for relic bryophyte species (*Helodium blandowii, Paludella squarrosa, Tomenthypnum nitens*) and rare orchids (*Liparis loeselii* and *Epipactis palustris*), and also to protect the Bukowo Małe lake dominated by *Chara* spp., and an overmature oak, beech and hornbeam forest complex in the fen catchment area. |
| **Diabli Skok** | 20,97 | 1,98 | 9,4% | forest | The nature reserve was created to conserve, for scientific and didactic reasons, forest, rush and spring ecosystems developed on the slopes of moraine hills and the adjacent bank of the Krąpskie Małe lake. |
| **Dolina Ilanki** | 239,53 | 32,72 | 13,7% | peatland | Protection objective in the nature reserve is to conserve, for scientific and didactic reasons, different types of peatlands, spring complexes within natural and seminatural landscape distinguished by rich flora, fauna and characteristic, rare phytocenoses. |
| **Dolina Ilanki II** | 11,32 | 6,28 | 55,5% | peatland | Conservation of the site harboring especially soligenous spring fens, and forest and non-forest meadow and aquatic ecosystems with biocenoses characteristic of these ecosystems. |
| **Dolina Kulawy** | 154,55 | 4,65 | 3,0% | peatland | Protection objective in this nature reserve is to conserve a complex of soligenous fens, springs, lakes, and forest and non-forest terrestrial ecosystems with biocenoses characteristic of these ecosystems. |

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| **Dolina Rurzycy** | 554,68 | 0,46 | 0,1% | land-scape | Protection objective in the nature reserve is to conserve rare plant communities, rare and protected plant and animal species and unique natural landscapes together with variable relief, i.e., natural forests growing on steep slopes, clean lakes forming long chains of channel valleys, and hilly terrains with meandering river in a deep valley. |
| **Galwica** | 94,58 | 45,65 | 48,3% | peatland | The nature reserve was created for conservation of an alkaline fen with locations for endangered species of fen plants. |
| **Gogolewko** | 37,51 | 36,01 | 96,0% | peatland | Protection objective of this nature reserve is to conserve a complex of soligenous fens and meadows together with biocenoses characteristic of these ecosystems. |
| **Jeziorko koło Drozdowa** | 10,01 | 4,91 | 49,1% | peatland | Protection objective is to conserve, for landscape, didactic and scientific reasons, a natural fragment of quaking bog with plant communities comprising rare and threatened plant species. |
| **Jezioro Drzezno** | 30,36 | 1,04 | 3,4% | aquatic | Protection objective of this nature reserve is to conserve a lacustrine ecosystem with natural zonal structure of communities. |
| **Jezioro Kalejty** | 763,3 | 1,37 | 0,2% | land-scape | Protection objective of the nature reserve is to conserve natural values of a lake and valuable landscape features. |
| **Jezioro Ratno** | 48,72 | 0,41 | 0,8% | aquatic | Conservation of an aquatic-mire complex of natural eutrophic communities and fens, particularly soligenous, springs, and forest and non-forest terrestrial and aquatic ecosystems with biocenoses characteristic of these ecosystems. |

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| **Klonowo** | 32,77 | 0 | 0,0% | forest | Protection objective is to conserve a fragment of mixed forest with nature monuments of pine trees until its biological death. |
| **Kruszynek** | 8,42 | 4,41 | 52,4% | peatland | Protection objective in this nature reserve is to conserve the alkaline fen ecosystem with unique bryophyte and vascular plant flora. |
| **Krutynia** | 969,33 | 4,88 | 0,5% | forest | Protection objective is to conserve the natural postglacial landscape, natural aquatic ecosystems and unique richness of fauna and flora. |
| **Łempis** | 132,34 | 1,32 | 1,0% | forest | Protection objective in this nature reserve is to conserve natural forest, aquatic and peatland ecosystems with rare and protected plant and animal species characteristic of the Suwałki-Augustów Lakeland. |
| **Małga** | 163,92 | 1,36 | 0,8% | faunistic | Protection objective is to conserve wetlands which are crane roosts and waterbird habitats. |
| **Mechowiska Czaple** | 9,36 | 8,04 | 85,9% | peatland | Protection objective in this nature reserve is to conserve a soligenous fen complex in a valley of a small water course, and valuable aquatic, wetland, meadow and terrestrial ecosystems. |
| **Mechowiska Sulęczyńskie** | 25,2 | 17,8 | 70,6% | peatland | Protection objective in this nature reserve is to conserve an alkaline fen ecosystem with unique bryophyte and vascular plant flora. |
| **Mechowisko Kosobudki** | 12,47 | 7,64 | 61,3% | peatland | Conservation of the site harboring especially soligenous, spring fens, and forest and non-forest terrestrial and aquatic ecosystems with biocenoses characteristic of these ecosystems. |

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| **Mechowisko Krąg** | 3,81 | 2,17 | 57,0% | peatland | Protection objective in this nature reserve is to conserve the alkaline fen ecosystem with unique bryophyte and vascular plant flora. |
| **Mechowisko Manowo** | 55,47 | 42,85 | 77,2% | peatland | Protection objective in this nature reserve is to conserve a lake terrestrialization mire complex, especially a soligenous alkaline fen in a complex with transition mires, riparian forests and bog forests, together with characteristic phytocenoses distinguished by rich flora and fauna. |
| **Mechowisko Radość** | 9,59 | 8,41 | 87,7% | peatland | Protection objective in this nature reserve is to conserve an alkaline fen ecosystem with unique bryophyte and vascular plant flora. |
| **Młodno** | 92,91 | 33,08 | 35,6% | peatland | Protection objective is to conserve, for scientific and didactic reasons, a fen and a fragment of meadows with characteristic plant associations and localities for protected plant and animal species. |
| **Mszar nad Jeziorem Mnich** | 6,04 | 4,86 | 80,5% | peatland | Protection objective in the nature reserve is to conserve habitats and vegetation of transition mire, sedge fen beds and sedge-moss fens developed along the banks of the humus lake with dominance of *Chara spp*. and relic flora of cryptogamous plants. |
| **Mszary Tuczyńskie** | 7,22 | 0,9 | 12,5% | peatland | Conservation of a mosaic of habitats and ecosystems of wet meadows and tall herbs, wetland communities, bog forests and spring complexes together with processes of their natural dynamics and valuable flora in fauna associated with them. |

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| **Nietlickie Bagno** | 1 132,91 | 4,5 | 0,4% | faunistic | Protection objective is to conserve natural and landscape values of the Nietlickie Bagno with rush vegetation dominating in landscape, adjacent forests and non-forest areas with numerous swamps, and rare and protected plant and animal species. |
| **Perkuć** | 209,82 | 9,09 | 4,3% | Not specified in the legal act | Protection objective of this nature reserve is to conserve natural plant communities associated with a water body in the process of terrestrialization. |
| **Roskosz** | 472,79 | 475,26 | 100%[9] | peatland | Protection objective is to conserve unique communities of carbonate fens and refuges of protected and rare bird species. |
| **Rutka** | 49,06 | 0,5 | 1,0% | Not specified in the legal act | The nature reserve was created to conserve in natural state a unique post-glacial pavement of the Linówek lake together with adjacent transition mire, constituting significant value for natural, scientific and didactic reasons. |
| **Skotawskie Łąki** | 54,78 | 51,37 | 93,8% | peatland | Protection objective in this nature reserve is to conserve a complex of soligenous and topogenous fens in the headwater area of the Skotawa river and valuable aquatic, meadow and forest ecosystems. |

9 This area as a whole is covered by a difficult to separate complex of communities of the so-called carbonate fen developed in a large karst depression, comprising fen sedge beds, communities, calcareous sedge fens, peat excavations, and calcareous elevations ("grądziki"), difficult both to unequivocally classify as a whole and to separate into different types of natural habitats.

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| **Smolary** | 143,2 | 0,93 | 0,6% | peatland | Protection objective of the nature reserve is to conserve natural sedge moss fen vegetation rich in rare bryophyte species. |
| **Sołtysek** | 38,6 | 2,49 | 6,5% | floristic | Protection objective of the nature reserve is to conserve a raised bog with adjacent coniferous forests, bog forests and localities for *Chamaedaphne calyculata, Betula humilis, Hamatocaulis vernicosus* and other endangered fen plant species. |
| **Stare Biele** | 256,2 | 54,49 | 21,3% | forest | Protection objective of the nature reserve is to conserve valuable fragments of the Knyszyńska Forest comprising well-developed plant communities with a number of protected and rare plants and conservation of complexes of bogs and meadows in the process of terrestrialization, which are a refuge for animals. |
| **Struga Żytkiejmska** | 471,04 | 1,78 | 0,4% | forest | Protection objective is to conserve natural ecological processes occurring in forest communities characteristic of the Romincka Forest and to conserve natural hydrological systems, including underground and surface water resources. |
| **Torfowisko Osowiec** | 18,24 | 1,15 | 6,3% | peatland | Protection objective is to conserve a terrestrialization carbonate mire with sedge moss vegetation and fen sedge bed together with characteristic, rare and protected species of vascular plants and bryophytes. |
| **Torfowisko Serafin** | 184,92 | 127,6 | 69,0% | peatland | Protection objective is to conserve, for scientific, didactic and sightseeing reasons, a fen with rich fauna and flora, including rare and protected species. |

| | | | | | |
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| **Torfowisko Sobowice** | 95,46 | 63,34 | 66,4% | peatland | Protection objective is to conserve, for scientific and didactic reasons, the unique spring cupola fens with characteristic sequence of peat-carbonate deposits and a mosaic of thermophilic fen vegetation with numerous protected and rare flora and fauna species. |
| **Torfy Orońskie** | 12,61 | 1,8 | 14,3% | peatland | Protection objective is to conserve, for scientific and didactic reasons, rare and protected plant species, occurring in natural fen and forest communities. |
| **Wąwóz Homole** | 58,64 | 0,2 | 0,3% | land-scape | Conservation, for scientific reasons, a rocky gorge in the Małe Pieniny Mts., distinguished by exceptionally beautiful landscape and comprising many rarities of animate and inanimate nature. |
| **Wielkopolska Dolina Rurzycy** | 896,06 | 6,58 | 0,7% | land-scape | Protection objective is to conserve valuable plant communities, rare and protected plant, animal and fungal species and unique natural landscapes, together with variable relief, i.e., natural forests growing on steep slopes, clean lakes forming long chains of channel valleys and hilly terrain with a meandering river in a deep valley. |
| **Wisła** | 17,61 | 0 | 0,0% | Not specified in the legal act | The nature reserve was created to protect trout in the most natural habitat conditions. |
| **Zabrodzie** | 27,01 | 0,34 | 1,3% | peatland | Protection objective is to conserve ecological processes in the wetland ecosystems. |

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| **Zaskalskie--Bodnarówka** | 19,02 | 0,06 | 0,3% | landscape | Conservation, for scientific, didactic and touristic reasons, of a rocky gorge in the Małe Pieniny Mts., overgrown by deciduous forest distinguished by exceptional beauty of the landscape and many rarities of animate and inanimate nature, and also conservation of the breeding site of eagle-owl (*Bubo bubo* L.). |
| **Zdrójno** | 168,97 | 2,05 | 1,2% | forest | Protection objective in the nature reserve is to conserve ecosystems of the Brzezianek lake and river and surrounding forests which harbor many rare plant and animal species, mostly beavers and birds. |
| **Źródliska Flinty** | 44,83 | 0,03 | 0,1% | forest | Protection objective of the nature reserve is to conserve the undisturbed course of processes progressing in forest, shrub, swamp, aquatic and fen ecosystems with their entire richness and biodiversity, in particular the conservation of the spring character of the Niewiemko lake and localities for protected plant species. |
| **Źródliska Jasiołki** | 1 585,01 | 0,27 | 0,0% | landscape | Protection objective is to conserve, for scientific, didactic and landscape reasons, natural communities comprising headwater areas of the Wisłoka and Jasiołka rivers. |

Only in 16 (30%) of the above-mentioned nature reserves, was the alkalinity, carbonate content, spring water supply or soligenicity of fens situated therein declared as the formal protection objective of the nature reserve.

Noteworthy, almost all alkaline fens protected in nature reserves are situated also in Natura 2000 sites. Exemptions include the mires Serafin, Drzezno and Mszary Tuczyńskie, which, as indicated above, we have proposed to include into the Natura 2000 network, and also the Zabrodzie and Źródliska Flinty nature reserves where habitat 7230 patches are poorly developed and heavily degraded.

Issues related to the protection of alkaline fens in nature reserves, including justification of the creation of a nature reserve even within Natura 2000 sites, were presented in a separate article (Makowska et al. 2018). It was also indicated in that paper that the Polish network of nature reserves protecting alkaline fens should be supplemented at least by the following sites:

1. **Torfowisko Pliszka** (Pliszka mire) in the Lubuskie Voivodeship: a complex of fluviogenic, soligenous, spring and terrestrialization mires;
2. **Jezioro Wierzchołek** (Wierzchołek lake) in the Wielkopolskie Voivodeship: the lake with adjacent soligenous fen where, at present, tufa accumulation can be macroscopically observed;
3. **Jezioro Małe Długie** (Małe Długie lake) in the Pomorskie Voivodeship, in the Tuchola Forest: alkaline fen in a narrow and deep terrestrialized tunnel valley, earlier a bay of the Małe Długie lake, with *Saxifraga hirculus*, *Liparis loeselii* and *Epipactis palustris*;
4. **Kwiecko** in the Zachodniopomorskie Voivodeship: a drainless depression filled with a fen with *Carex diandra*, *Epipactis palustris*, *Hamatocaulis vernicosus*, *Paludella squarrosa* and *Helodium blandowii*;
5. **Nowa Studnica** in the Zachodniopomorskie Voivodeship: cupola spring fens and alkaline fens in the Korytnica river valley, harboring, among others, *Epipactis palustris, Paludella squarrosa* and *Helodium blandowii*;
6. **Dolina Płoni** (Płonia river valley) in the Zachodniopomorskie Voivodeship: spring fen with *Juncus subnodulosus* and *Trollius europaeus*;
7. **Kobyla Biel** in the Podlaskie Voivodeship, in the Augustów Forest: a complex of well-developed sedge moss fens and bog forests situated by the lake;
8. **Borsuki** in the Podlaskie Voivodeship, in the Augustów Forest: soligenous fen with a complex of moss-sedge and moss bog-sedge moss fen communities, with valuable flora of vascular plants and mosses, among others, with *Liparis loeselii* and *Saxifraga hirculus*;
9. **Sawonia Mostek** in the Podlaskie Voivodeship, in the Augustów Forest: soligenous fen with a complex of moss-sedge and moss bog-sedge fen communities, with valuable flora of vascular plants and mosses, among others, with *Liparis loeselii* and *Saxifraga hirculus*;
10. **Bagienna Dolina Rospudy** (Marshy Rospuda river valley) in the Podlaskie Voivodeship: a famous complex comprising alkaline fens with patches of sedge moss fens preserved in a natural state, saved from destruction by the construction of the Augustów bypass across this area - to be regarded as a nature reserve ready for establishment; some land was purchased by the Naturalists' Club and some is managed by the State Forests

11. **Torfowisko Mnica** (Mnica mire) in the Zachodniopomorskie Voivodeship, in the Drawsko Pomorskie Military Training Area: a site comprising *Cladium mariscus* and a beautiful sedge moss fen with *Eleocharis quinqueflora*, and a population of *Liparis loeselii*;

Photo 115: Botanical studies on the Mnica mire in the Drawsko Pomorskie Military Training Area (photo by P. Pawlaczyk).

12. **Jezioro Trawnickie** (Trawnickie lake) in the Pomorskie Voivodeship, in the Tuchola Forest: a sedge-moss fen with *Liparis loeselii, Scorpidium scorpioides*, and very abundant *Cinclidium stygium,* situated by the lake;
13. **Zdrójno** in the Pomorskie Voivodeship, in the Tuchola Forest: enlargement of the existing nature reserve by adjacent very well-developed typical sedge moss fen with a full set of typical moss species, *Liparis loeselii*, and a large population of *Epipactis palustris*;
14. **Okonino** in the Wielkopolskie Voivodeship, in the Notecka Forest: a terrestrialization mire overgrown by sedge fen vegetation with large populations of mosses typical of alkaline fens (*Paludella squarrosa*, *Helodium blandowii*, *Tomentypnum nitens*).

More detailed descriptions of these reserves were presented in the paper by Makowska et al. (2018).

In addition to the above list, the following sites should be declared as nature reserves:

1. **Dolina Debrzynki**, at the border of the Pomorskie and Wielkopolskie Voivodeships: a large and well preserved complex of soligenous fens with the only population in the Wielkopolskie Voivodeship of *Saxifraga hirculus* (see also above about the need for enlargement of the Natura 2000 site).
2. **Gwdziańskie Mechowiska**, the Wielkopolskie Voivodeship. Currently protected as ecological sites, spring fens in the Gwda river valley, slightly degraded but still valuable and unique in the landscape of this part of the country, with a rich population of *Helodium blandowii*, *Epipactis palustris*, many populations of *Dactylorhiza incaranata* and *D. maculata.*
3. **Uroczysko Korea**, the Warmińsko-Mazurskie Voivodeship. A vast (ca. 40 ha including 15 ha of sedge moss fens) soligenous fen, with one of the largest populations of *Hamatocaulis vernicosus* in the voivodeship and one of the most abundant in Poland, with extensive initial sedge moss fen with *Carex diandra, C. limosa* and *Menyanthes trifoliata* in the southern part and with *Carex rostrata, Sphagnum teres* and *Schoenoplectus tabernaemontani* in the northern part. A locality for orchids, including *Liparis loeselii* and *Epipactis palustris*. One of the larger soligenous fens in the voivodship, a part of which is excellently conserved.

Photo 116: Planned nature reserve Korea (photo by P. Pawlikowski)

4. **Jezioro Łaźnica**, the Warmińsko-Mazurskie Voivodeship. A huge, very heavily hydrated sedge moss fen developing in the form of quaking bog, overgrowing the Łaźnica and Koziołek lakes with *Carex rostrata, C. diandra, Hamatocaulis vernicosus, Menyanthes trifoliata,* and localities for rare species: *Liparis loeselii* and *Stellaria crassifolia*.
5. **Torfowisko nad Babięcką Strugą**, the Warmińsko-Mazurskie Voivodeship. The richest soligenous, spring fen in the area of the Piska Forest, dominated by *Carex rostrata* and *Sphagnum teres*, with *Liparis loeselii*, *Stellaria crassifolia*, *Paludella squarrosa* and *Hamatocaulis vernicosus*. Strongly hydrated, with preserved spring and spring riparian forest.

Photo 117: Torfowisko nad Babięcką Strugą (photo by Ł. Kozub).

6. **Torfowisko nad Jeziorem Krawno**, the Warmińsko-Mazurskie Voivodeship. Alkaline fens with diverse vegetation in a complex of bog forests (spruce forest on peat, pine-birch forests, and spring alder forests and on a quaking bog by the Krawno Lake with *Liparis loeselii*, *Stellaria crassifolia*, *Paludella squarrosa* and *Hamatocaulis vernicosus*.

7. **Kosewskie Bagno**, in the Warmińsko-Mazurskie Voivodeship, developing in the field landscape with very diverse vegetation typical of mezo- and oligotrophic habitats with a number of rare and endangered mosses and vascular plants, such as *Liparis loeselii*, creeping sedge *Carex chordorrhiza* and *Hamatocaulis vernicosus*.
8. **Jezioro Krejwelanek,** the Podlaskie Voivodeship. Sedge moss fen developing over a spring area at the northwestern edge of the Krejwelanek lake. The surroundings of the lake are dominated by bog forests and moss bogs with *Sphagnum teres*, however a small sedge moss fen harbors a unique group of endangered species, such as *Saxifraga hirculus*, *Liparis loeselii*, *Aldrovanda vesiculosa*, *Malaxis monophyllos*, *Stellaria crassifolia*, *Paludella squarrosa*, *Hamatocaulis vernicosus* and many others. It was described in detail by Tyszkowski (1992) and has still preserved its values.
9. **Jezioro Gajlik**, the Podlaskie Voivodeship. Sedge moss fen developing on gyttja bed by the Gajlik lake. In the drier southern part, phytocenosis of the *Caricion davallianae* alliance dominates with *Carex lepidocarpa*, *C. panicea*, *Limprichtia cossonii* and others, whereas the northern part is of quaking bog character with phytocenoses of the *Eleocharitetum quinqueflorae*, *Caricetum diandrae* and *Menyantho-Sphagnetum teretis*. This site harbors a number of endangered species, including seven taxons of carnivorous plants, many other rare vascular plants, such as *Liparis loeselii*, *Stellaria crassifolia*, *Pinguicula vulgaris, Dactylorhiza baltica, Drosera anglica, D. intermedia*, and a number of relic mosses (*Cinclidium stygium* and *Paludella squarrosa* in masses; moreover, among others, *Meesia triquetra, Scorpidium scorpioides* and *Hamatocaulis vernicosus*) (Jabłońska 2005, Pawlikowski 2010).
10. **Dolina Kunisianki**, the Podlaskie Voivodeship. Peat-rich valley of the small Kunisianka river with a system of soligenous fens. The landscape of the valley is dominated by forest and shrub communities but enclaves of non-forest fen vegetation harbor a number of rare and endangered species of vascular plants, such as *Saxifraga hirculus*, *Liparis loeselii*, *Stellaria crassifolia*, *Malaxis monophyllos*, *Dactylorhiza baltica*, *Meesia triquetra*, *Paludella squarrosa*, *Hamatocaulis vernicosus* and others (Pawlikowski 2008a).

11. **Torfowisko Chyżnik**, the Małopolskie Voivodeship. Alkaline fen in the Chyżnik stream valley, about 2.4 km northwest of the Chyżne village (at the border with Slovakia). As for mountain conditions, it is a large-sized site covering ca. 9 ha. Its central part is slightly elevated. The vegetation is dominated by the *Menyantho-Sphagnetum teretis* association with abundant *Dactylorhiza majalis, Carex diandra*, *C. panicea*, *Menyanthes trifoliata*, and *Tomentypnum nitens*.

Photo 118: Chyżnik mire (photo by Ł. Kozub).

12. **Kopułowe Torfowisko Śniatycze**, the Lubelskie Voivodeship. It is located in the Sieniocha river valley with a man-made drainage system and comprises 2 patches split by the artificially dug river channel. It harbors many rare and endangered plant species, among others, *Cladium mariscus*, *Swertia perennis ssp. perennis*, *Schoenus ferrugineus*, *Sch. nigricans*, *Tofieldia calyculata*, *Carex davalliana*, *Pinguicula vulgaris* ssp. *bicolor*, *Gentianella amarella*, *Epipactis palustris* and *Gymnadenia conopsea ssp. densiflora*. In peat pits, *Chara* sp. and *Pedicularis sceptrum-carolinumare* present. Moreover, *Coenonympha oedippus*, a butterfly species rare in Poland, was found in this area.

Photo 119: The Śniatycze cupola fen (photo by D. Horabik).

## 8.4.2. Conservation of alkaline fens in nature reserves

In 18 of the above-mentioned nature reserves protecting alkaline fens, no actions for the benefit of this habitat type have been undertaken so far. In the remaining nature reserves, some form of active protection was implemented. At 32 sites the fen area was mown (Bagno Chłopiny, Bagno Stawek, Biała Woda, Brzeźno, Diabli Skok, Dolina Ilanki, Dolina Ilanki II, Dolina Kulawy, Dolina Rurzycy, Gogolewko, Kruszynek, Mechowiska Czaple, Mechowiska Sulęczyńskie, Mechowisko Manowo, Mechowisko Radość, Młodno, Mszary Tuczyńskie, Nietlickie Bagno, Perkuć, Roskosz, Rutka, Skotawskie Łąki, Smolary, Struga Żytkiejmska, Torfowisko Osowiec, Torfowisko Serafin, Torfowisko Sobowice, Torfy Orońskie, Wąwóz Homole, Wielkopolska Dolina Rurzycy, Zaskalskie-Bodnarówka, Źródliska Jasiołki). In 26 nature reserves trees were removed (Roskosz, Brzeźno, Torfowisko Serafin, Torfowisko Sobowice, Galwica, Mechowisko Manowo, Gogolewko, Młodno, Dolina Ilanki, Bagno Chłopiny, Mechowiska Sulęczyńskie, Perkuć, Mechowisko Radość, Bagno Stawek, Wielkopolska Dolina Rurzycy, Dolina Kulawy, Kruszynek, Diabli Skok, Torfy Orońskie, Smolary, Rutka, Dolina Rurzycy, Źródliska Jasiołki, Wąwóz Homole, Biała Woda, Zaskalskie-Bodnarówka). In 10 nature reserves, dams blocking water outflow were constructed (Skotawskie Łąki, Galwica, Mechowisko Manowo, Gogolewko, Młodno, Bagno Chłopiny, Mechowiska Czaple, Dolina Ilanki II, Dolina Kulawy, Torfowisko Osowiec), and at two sites (Młodno, Bukowskie Bagno) pipes stabilizing the water level resulting from water damming by beavers were installed. Notably, most of these actions were realized by subjects under no formal obligation to do so, i.e., by the landscape park, forest district or non-governmental organization interested in fen conservation, namely the Naturalists' Club.

Moreover, in two nature reserves (Dolina Kulawy, Mechowiska Sulęczyńskie), within the framework of the project "Protection of alkaline fens (7230) in young glacial landscape of northern Poland" (LIFE 11/NAT/PL/423), the Naturalists' Club introduced *Saxifraga hirculus,* while individuals of this species, cultivated in vitro from local populations, were introduced in the sites Bagno Stawek, Mechowisko Krąg, Mechowisko Radość and Struga Żytkiejmska nature reserves (Bloch-Orłowska et al. 2018).

39 of 53 of the above-listed nature reserves protecting alkaline fens have currently valid planning documents in the form of either conservation plans established for 20 years or plans of conservation measures covering periods of 1 – 5 years. For three other nature reserves in the Lubuskie Voivodeship, draft conservation plans were developed by the end of 2018. The conservation of Mechowisko Manowo nature reserve was partially planned within a plan of conservation measures for the Natura 2000 site, both of which cover the same area. However, 10 nature reserves have no plans whatsoever.

In 15 of 43 documents (35%), the existence of an alkaline fen was not recognized. Often alkaline fens were erroneously described as transition mires. However, it not always led to mistakes in conservation planning. For instance, in the Roskosz and Brzeźno nature reserves, conservation measures were planned to protect the habitat of the aquatic warbler *Acrocephalus paludicola* but they will probably be beneficial also for fens situated at this site. Mowing and shrub removal in the Serafin mire can improve the conservation status of this site in spite of incorrect recognition of the mire type. However, for instance, the alkaline fen in the Stare Biele nature reserves in the Knyszyńska Forest remained unnoticed while it would probably require active and not passive protection (ditch blocking, shrub removal, mowing).

In 27 plans, habitat 7230 identification is correct.

At three sites, passive protection was planned: in the Bukowskie Bagno nature reserve; it was decided that the alkaline fen present at this site requires only monitoring (however, earlier, a tube stabilizing water level in a beaver pond was installed). In the Jeziorko koło Drozdowa nature reserve, a potential threat of fen overgrowth by trees was noted, but it was decided that no intervention was required at that time. In the Mszary Tuczyńskie nature reserve, only monitoring was planned, although earlier mowing was carried out at this site.

However, in the majority of nature reserves active conservation was recommended: tree and shrub removal (Biała Woda, Bagno Stawek, Dolina Ilanki, Dolina Ilanki II, Dolina Kulawy, Dolina Rurzycy, Jezioro Drzezno, Kruszynek, Młodno, Mechowiska Sulęczyńskie, Mechowisko Radość, Smolary, Torfowisko Sobowice, Źródliska Jasiołki), mowing (Bagno Stawek, Dolina Ilanki II, Dolina Kulawy, Gogolewko, Jezioro Drzezno, Jezioro Kalejty, Mechowiska Sulęczyńskie, Mechowisko Krąg, Mechowisko Radość, Skotawskie Łąki, Smolary, Torfowisko Osowiec, Torfowisko Sobowice, Wąwóz Homole, Zaskalskie-Bodnarówka, Źródliska Jasiołki, the construction of dams regulating water outflow (Mechowiska Sulęczyńskie), and water level control in beaver's dams (Dolina Kulawy, Gogolewko).

## 8.5. Other protected areas

In 26 of 124 landscape parks in Poland, alkaline fens are a component of the landscape. The greatest resources of this habitat are located in the **Chełmski Park Krajobrazowy** (Chełm Landscape Park), in the southern part of which the vast mires Bagno Serebryskie, Brzeźno and Roskosz are situated in depressions on chalk substrate which covers a total area of 1,300 ha. The second largest complex in Poland is located in the **Park Krajobrazowy Dolina Słupi** with 8 fens and a total area of over 200 ha. Six alkaline fens covering a total area of 83 ha are known to occur in the **Park Krajobrazowy Puszczy Knyszyńskiej im. Witolda Sławińskiego**. 11 sites occupying more than 50 ha are concentrated in the **Kaszubski Park Krajobrazowy**. The remaining landscape parks harboring alkaline fens and flush fens include (in decreasing order in terms of habitat 7230 resources): **Barlinecko-Gorzowski, Wdzydzki, Górznieńsko-Lidzbarski, Zaborski, Mazurski, Sierakowski, Suwalski, Szaniecki, Brodnicki, Ciśniańsko-Wetliński, Popradzki, Żywiecki, Puszczy Rominckiej, Welski, Rudawski, Pojezierza Iławskiego, Południoworoztoczański, Beskidu Śląskiego, Jaśliski, Sobiborski, Łagowsko-Sulęciński** and **Sudetów Wałbrzyskich**. The fens located in these landscape parks can also have the status of a nature reserve or ecological area; in addition, landscape parks largely overlap with Natura 2000 sites, in particular, 94% of alkaline fens occurring in landscape parks are also located in respective Natura 2000 habitat site.

Of the aforementioned landscape parks, in the following conservation plans were established: Chełmski, Dolina Słupi, Puszczy Knyszyńskiej, Wdzydzki, Mazurski, Suwalski, Ciśniańsko-Wetliński, Popradzki, Rudawski, Południoworoztoczański and Jaśliski. In the remaining parks, the law establishing the park is the only document outlining its protection program with minor changes and amendments. Due to the special character of the landscape parks, conservation plans usually do not regulate directly the protection of particular fens, but can contain statements favoring such protection when they, in general, require, for instance, protection of water conditions, conservation and renaturation of fens, conservation of wetlands, renaturation of the hydrographic system, protection of biodiversity refuges, identification of particularly valuable components and the postulation to create other, individual forms of protection for the most valuable subjects.

Landscape park management bodies, either in the form of directorates of individual parks or complexes of parks, are accountable to voivodeship self-governments. These institutions may or may not take initiatives aimed at protection of particular natural features in landscape parks. With regard to alkaline fens, such actions have been undertaken so far by Park Krajobrazowy Doliny Słupi in the Pomorskie Voivodeship and Zespół Parków Krajobrazowych Województwa Śląskiego (in the Żywiec Beskid Mts. and Silesian Beskid Mts.), namely they have implemented such protection measures as tree and shrub removal, mowing, and the blocking of water outflow is some fens under their authority.

Alkaline fens occur also in 61 of 407 protected landscape areas (PLA) existing in Poland, among others in: **Chełmski, Doliny Biebrzy, Puszcza Napiwodzko-Ramucka, Poludniowomałopolski, Dolina Rospudy, Nadwkrzański, Lasy Taborskie, Pojezierze Sejneńskie, Puszcza nad Drawą, Puszcza nad Pliszką, Dolina Ilanki, Puszcza i Jeziora Augustowskie, Bory Tucholskie** and **Pojezierza Północnej Suwalszczyzny**. However, the legal status of this form of protection provides no tools to directly protect fens. Nonetheless, the Act permits the inclusion of recommendations as to active protection of ecosystems under the law establishing a protected landscape area, which in some voivodeships and areas has been used to define relatively wide packages of measures regarding, for instance, the conservation of wetlands or natural water conditions, which creates a legal environment favoring the conservation of fens.

Landscape-nature complex (LNC) provides protection to, e.g., **Torfowisko Zocie** (Kalinowo municipality, Warmińsko-Mazurskie Voivodeship), a well-known terrestrialization mire with moss sedge-moss fen vegetation and unique flora. Mechowisko **Jezioro Święte** in the Kaszuby region is situated within the boundaries of the **Rynna Kamienicka Landscape-Nature Complex** (Sierakowice municipality, Pomorskie Voivodeship). The **Pólka-Raciąż Landscape-Nature Complex** comprises the valuable mire Lipa (Kłocie Raciąskie) with a mosaic of fen sedge beds and sedge-moss fens (Raciąż municipality, Mazowieckie).

There are 50 ecological areas (EA) in Poland harboring alkaline fens. For instance, **Torfowisko Sikora** Ecological Area (38,5 ha, Stare Juchy municipality, Warmińsko-Mazurskie Voivodeship) protects sedge moss fens (known as Sikory Juskie) by the Łaśmiady lake, with a large population of *Liparis loeselii*, *Carex chordorrhiza* and *Scorpidium scorpioides*.

Beautiful sedge-moss fens with *Liparis loeselii* are protected in the ecological area by the **Kurzyny lake** (61 ha, Zbiczno municipality, Kujawsko-Pomorskie Voievodship). **Dolina Zgnilca** in the Drawa Forest is an ecological area (22 ha, Kalisz Pomorski municipality, Zachodniopomorskie Voievodship) with valuable sedge moss fen with carpets of *Paludella squarrosa* and *Scorpidium scorpioides*. Sedge moss fens with near the Podgaje village are protected as **Gwdziańskie Mechowiska** Ecological Area (20 ha, Okonek municipality, Wielkopolskie Voievodship), while the sedge-moss fen near the town of Jastrowie composes **Uroczysko nad Gwdą** Ecological Area (6 ha, Jastrowie municipality, Wielkopolskie Voievodship). The **Grzęzawisko** (12 ha, Torzym municipality, Lubuskie Voievodship) and **Kijewo** Ecological Areas (9 ha, Łagów municipality, Lubuskie Voievodship) protect valuable sedge-moss fens on the Pliszka river. A beautiful, rich sedge-moss fen with orchids is protected by the **Bagno Wietrzno** Ecological Area (9 ha, Polanów municipality, Zachodniopomorskie Voievodship). In the Notecka Forest, **Mąkąty** mire with valuable moss flora (9 ha, Międzychód municipality, Wielkopolskie Voievodship) and **Bagno i Jezioro Rzecińskie** (56 ha, Wronki municipality, Wielkopolskie Voievodship) are protected as ecological areas. Protection to the Torfowisko k. Myszkowa in the Silesia is provided by the **Przygiełka** Ecological Area (3 ha, Myszków municipality). Patches of the *Caricetum davallianae* with localities for *Dianthus superbus* in the city of Opole are protected as the **Łąki w Nowej Wsi Królewskiej** Ecological Area (3 ha). The northern enclava of the site **Łąka w Bęczkowicach**, with localities for *Liparis loeselii* and *Hamatocaulis vernicosus* (11 ha, Łęki Szlacheckie municipality, Łódzkie) has also an ecological area status. Protection to the **Purwin lake** with an adjacent sedge moss fen (2

Photo 120: Nature Monument established to protect the Złatna Huta alkaline fen, especially a locality for orchids, just after execution of conservation measures (mowing, shrub removal) (photo by T. Bąkowski).

ha, Rutka-Tartak municipality, Podlaskie Voievodship) is provided by ecological area status. In addition, ecological area status was given to the alps **Hala Miziowa** and **Hala Cebulowa** with mountain flush fens in the Żywiec Beskid Mts. (5 ha and 3 ha, respectively, Jeleśnia municipality, Śląskie Voievodship). Flush fens and sedge-moss fens developing in former sand pits in the Silesia have been granted protection as the **Młaki nad Pogorią I** (7 ha, Dąbrowa Górnicza municipality) and **Torfowisko Bory** (Sosnowiec municipality) Ecological Areas.

There is also in Poland one nature monument protecting an alkaline fen, established in 2009, namely a locality for orchids in **Złatna Huta** in the Żywiec Beskid Mts. (Ujsoły municipality, Śląskie Voivodeship), where a flush fen harbors orchids: *Orchis mascula*, *Dactylorhiza fuchsii*, *D. sambucina*, *Traunsteinera globosa*, *Platanthera bifolia*, *Platanthera chlorantha*, common twayblade *Listera ovata*, *Gymnadenia conopsea*, *Epipactis palustris*, *E. helleborine*. Conservation measures (mowing, shrub removal in the alkaline fen) in this nature monument were carried out by the Naturalists' Club within the above-mentioned project LIFE13 NAT/PL/024.

Landscape-nature complexes, ecological areas and nature monuments are the means by which the places with exceptional natural values can be identified, that increases awareness of the local community and at least to some extent protects them from destruction. Theoretically, the Nature Conservation Act allows for defining, if needed, the active conservation measures for each of these forms of nature protection. However, we do not know of any examples of implementing such measures for the protection of alkaline fens in ecological areas by responsible nature conservation services – in this case at the municipal level. At several such sites, protection is provided by third parties (forest district, landscape park, non-governmental organization).

# 9. ECOSYSTEM SERVICES

***Magdalena Makowska***

In principle, alkaline fens can be attributed the same functions as widely understood wetlands, described in detail in the literature (e.g., Oleszczuk & Brandyk 1997, Lipka and Stabryła 2012, Makles et al. 2014). These include, first of all, shaping the water balance through retention and then a slow release of water resources, improvement of water quality and a reduction of soil erosion. From the point of view of nature protection, peatlands (one of the types of wetland ecosystems) are perceived as biodiversity refuges and the last elements of natural ecosystems. Not always in accordance with nature conservation, they can also play a significant role in agriculture. Regardless of their size, they enhance the value of the landscape. They also play an invaluable role in science and education. Due to numerous studies on this subject, there is only a short review of the alkaline fens functions compared to other peatland ecosystems in Poland in the further part of this chapter.

**Retention**

Hydrological aspects of peatlands functioning and their natural significance in this context were described in the first half of the 20th century (Kulczyński, 1939, 1940). Peatlands play the role of natural retention reservoirs, which on the one hand store flow and rain water, and on the other hand inhibit and regulate the outflow of water in rivers and the groundwater outflow of soil adjacent to the peatlands. Having considered the foregoing, they form hydrological and biocenotic links with the surrounding area, automatically adjusting them to the ecological situation. Mioduszewski (1995) points out that a 30% share of peatlands in the catchment area may reduce the flood wave by 60 – 80% (both in terms of speed and height). Lipka (2000) showed that the lowest flow in dry years is significantly higher in watercourses in valleys of high share of peatlands, as compared to the lowest flow in "non-peatland" valleys. For example, the Rurzyca river in western Poland (see Chapter 7) has a very even flow precisely because it is fed with groundwater flowing through the alkaline percolating fen.

Peatlands with undisturbed or close to natural hydrological conditions have the best retention properties. Disturbances in hydrology, especially when they trigger at least partial peat decomposition, cause impairment of this function, and even the conservation and renaturalization of the peatland may only partially restore the retention function.

Soligenic feeding of alkaline fens, requiring a specific geological system (e.g., a hydrological window in impermeable layers) and chemism of water supplying the mire, makes them sensitive to any disturbances in the hydrological system. Maintaining water conditions appropriate for alkaline fens is also a key element in maintaining their retention properties.

Photo 121: The Rurzyca valley is fed mainly from aquifers. The stable river level all year round enables mires on the bottom of the valley to function (photo by J. Ramucki).

In this respect, alkaline fens stand out from other types of peatlands. Their hydrological specificity (see Chapter 2.1) makes the water circulation route one of the longest observed in all wetlands. Depending on the geological structure of the catchment and terrain form, precipitation water often leaves the fen after several decades. This demonstrates great importance not only in terms of natural values, but also from an economic point of view, as it limits the effects not only of short-term droughts but also of long droughts. Alkaline fens in mountain areas play a special role in the context of water retention. Fens and flush fens located on the mountain slopes inhibit sudden outflow (and also prevent erosion as a side effect) and retain water used in dry periods.

For example, Grygoruk et al. (2013) estimated that the peatlands of the Biebrza valley – in which alkaline fens constitute a significant part – retain 10,4 million $m^3$ of water annually, which corresponds to a service worth EUR 5,5 million per year.

**Filtration and protection of water quality**

Due to their role in the process of water purification from nutrients and pollutants, peatlands are often called natural water treatment plants or the kidneys of the landscape. Peats have high filtration properties for vertically and horizontally moving waters. Reduction of nutrients in waters flowing from the surrounding fields and flowing through mire to the river can range from 60 to 100% (Kiryluk 2013).

In this case, the role of the alkaline fens themselves is limited, as they naturally develop outside the surface water floodplain zone, and their survival depends on the naturally "clean" groundwater. However, during sporadic floods, alkaline fens are sometimes also flooded and then can also play a filtration role. However, it is worth mentioning at this point that too frequent or permanent floods may contribute to their degradation.

Nevertheless, the passage of water, which feeds mires through underground aquifers, is of great importance. As already mentioned, it can last for many years, and over its course water is purified and changes its physical and chemical properties.

**Role in the carbon balance**

Due to natural conditions, peatlands of all types are among the few ecosystems capable of accumulating organic matter, and thus permanently excluding it from the carbon cycle. By applying the averaged value of peat deposit growth at the level of approx. 1 mm/year, theoretically, in the entire peatlands in Poland (a total area of approx. 1 million ha), there should be an approx. 10 000 000 $m^3$ of peat increase! Unfortunately, only 10% of them are living mires (with peat-forming process taking place). Alkaline fens have a significant share in this process.

On a global scale, their role is increasing in areas with continental climate, where natural moss fens are characterized by faster deposit growth and more intensive carbon sequestration (accumulation) than bogs. In addition, alkaline fens play a special role in the process of carbon capture and withdrawal from the carbon cycle due to the frequent precipitation of the so-called calcareous tufa (a specific form of calcium carbonate, see Chapter 2) permanently deposited in the peat deposit. This issue has not been the subject of quantitative analyses, though. Nevertheless, from a carbon balance point of view, peatland protection appears to be one of the key elements in climate protection.

Maintaining peatlands in good condition (undisturbed peat-forming process) is of key importance in terms of inhibiting the global warming process, as degraded peatlands emit huge amounts of carbon dioxide ($CO_2$) – estimated at about 1,3 – 5 x $10^9$ tonnes per year on a global scale (according to Pawlaczyk 2018), out of which 1 – 4 x $10^6$ tonnes per year would be in Poland (Global Peatland Database, 2019).

There is no data on $CO_2$ and other greenhouse gas emissions which would refer specifically and unambiguously to alkaline fens – i.e., natural habitat 7230. Estimates of $CO_2$ emissions from particular types of peatlands vary considerably depending on the author's location and the method being used. There is also insufficient data to explain this variation in field conditions. In particular, there is not enough data to link the emission values with the eco-hydrological type of the peatland. However, the dependence of $CO_2$ emissions on the conservation status of peatlands is clear. Well-preserved peatlands are characterized by $CO_2$ accumulation. The more drained and degraded the peatland, the higher the emissions from it are. For example, Oleszczuk (2012) quotes literature stating that maintaining the water table at a depth of 50 cm below the ground surface (conditions unfavourable for the development of peatlands), in the case of peatlands in the Netherlands, causes $CO_2$ emissions at the level of 10 t/ha. According to our own calculations (although very rough because they are based only on the so-called GEST[10] approach), the implementation of the LIFE11 NAT/PL/423 project (conservation of alkaline fens in northern Poland) through the implementation of active conservation measures on an area of several hundred ha contributed to the reduction of the Global Warming Potential by the equivalent of 317.6 tonnes of $CO_2$ per year, i.e., by 0.51 tonnes of $CO_2$/ha per year (Pawlaczyk 2018).

**Protection of biodiversity**

More than half of the species and natural habitats considered rare or threatened with extinction are associated with wetland ecosystems, peatlands in particular. Some of them were on the "red" lists and books of species threatened by extinction, among others the "Polish Red Book of Plants". Alkaline fens, especially

10 The method for estimating emissions and absorption of greenhouse gases by peatland is based on vegetation on its area – the individual vegetation units are assigned an appropriate emission or absorption coefficient (Couwenberg et al. 2008, 2011).

in the landscape of lowland Poland, undoubtedly lead the way in this respect. The list of protected, rare and endangered plant species includes dozens of taxons. Among the vascular plants, orchids are one of the most numerous groups. The group of bryophyte is also equally numerous, including those indicated as so-called glacial relics. Most of them, considered to be species characteristic for natural habitat 7230, are presented in Chapter 3 – devoted to alkaline fens vegetation.

The importance of alkaline fens for biodiversity is greater (especially for fauna) when they occur in large complexes and complex landscapes, e.g., in a mosaic with "non-wetland" forest areas. On the other hand, in a landscape under strong traditional agricultural pressure, e.g., in the foothills and mountains, flush fens, as small and difficult to drain, are permanent enclaves of "wild" nature. Therefore, the systems of wetlands – river valleys, lakes, peatlands of various origins, marshes and ponds – are at the same time a place of life and an element of the network of ecological corridors for the movement of animals – both locally (for insects, amphibians), regionally (for larger predators) and supra-regionally (e.g., for birds).

Peatland ecosystems, including alkaline fens characterized by diverse, often extreme conditions – which makes it possible for them to be inhabited by highly specialized species and thus with very narrow habitat requirements (the so-called stenotopic species); this feature refers mainly to flora. However, in case of large complexes (e.g., Biebrza Marshes), it may also apply to animals, e.g., birds (see Chapter 4 – devoted to fauna). The world of peatland invertebrates (especially alkaline fens) is rich and specific, but most often unknown; it is possible to find several thousand individuals representing several dozen orders and several dozen species (see Chapter 4) per 1m$^2$ of peatland.

### Scientific and cultural role

Alkaline peatlands, like other types of peatlands, are very interesting research objects, not only because of the complexity of structure, genesis or hydrological conditions. Palinological studies often reveal surprising information on climate change (Dobrowolski et al. 2016) and related changes in the vegetation of adjacent areas. Peatlands are an invaluable source of knowledge in the field of archaeology. Due to the specific oxygen conditions, the decomposition of organic matter is very slow, which leads to the accumulation of significant amounts of identifiable organic matter (identification of the remains of most species occurring in the peatland is possible for several or even a dozen or more thousand years back); it is possible to restore the full genesis of the peatland, as well as the vegetation changes in its vicinity. Due to the longevity of peatlands, they have been accompanied for thousands of years by various forms of construction, especially settlements, as well as wooden communication routes lying under the peat layers, but above all by numerous so-called loose monuments, e.g., sacrificial gifts (Tobolski 2007).

Peatlands also have their place in literature and literature studies, as well as history. Formerly associated as a link between the "earthly" world and the "nether world", they were often the subject of literary works, numerous legends and stories (hence the names in the Slavic Bestiary, i.e., *wodnice*, *utopce*, *topielice*, *rusałki*, *mamuny* and *syreny*[11] – "mermaids") (Zych & Vargas 2018). Marshes and related adjacent areas (rivers, lakes, wetland forests) in history usually had their own local terms, which have often survived to this day, e.g., in the names of villages or towns such as Topielec, Bagienna, Topikoń and Trzęsawiska[12].

For these reasons, in 2004 the International Peat Society set up a new commission: Commission VIII – Cultural aspects of peat and peatlands. Its main function and aim is to promote and consolidate knowledge about peatlands and their cultural role.

**Tourism based on natural values**

Tourism, as such, inherently includes making use of the natural values in the visited areas. Natural tourism – a fast-growing trend in recent decades – as a type of qualified tourism is assumed to be a service of a tourist who has a certain amount of nature-related knowledge and is aware of the natural values of the visited area.

Birdwatching, i.e., excursions of ornithologists to the areas of occurrence (clusters) of valuable bird species and their observation, is a recognizable branch. In this respect, over the last years the aquatic warbler (*Acrocephalus paludicola*), the protection of which e.g. in Biebrza Marshes consumed a lot of time and energy, has become a valuable alkaline fen species on an EU scale. Another example is the Rospuda river valley and its alkaline fens, one of the most valuable in the EU, which thanks to the struggle not only of ecologists but also the general public, have been preserved from destruction by the construction of the Augustów bypass on their territory. The intensity of the canoe movement on the Rospuda River increased significantly after the matter became famous in the media.

However, peatlands, including alkaline fens, find their admirers and attract crowds of tourists not only in such dramatic circumstances. In many Polish national parks, including the Polesie, Biebrza and Bieszczady National Parks, as well as in reserves where peatlands are present – including alkaline fens – there are natural paths being developed, including educational paths often in the form of footbridges stretching deep into the peatland, showing its natural, visual and landscape qualities and educating the public about their values and ways of protection. Interesting examples of using the educational value of peatlands as such i.e footbridges in peatlands: Oidrema-Tuhu in Estonia, Virco and Flambro in Italy

11 Those names are very hard to translate to show their linguistic relation to wetland.

12 As above

and Belianske Luky in Slovakia, are described in the "A Guidebook of Good Practices in Alkaline Fens Conservation" (Stańko et al. 2018).

**Use of geological formations**

Compared to the 19th century, the economic importance of peat is much smaller today. In the pre-war and post-war period, peat was used as a fuel (approximately 2 million tonnes were extracted annually in Poland; Kiryluk, 2013). Currently, peat is practically not mined for heating purposes in Poland. Peat accumulated in alkaline fens, due to its physicochemical properties, was never well-suited to be a fuel and was thus not more widely used for this purpose.

However, peat extraction for other purposes had – and still has – some importance. In the past, peat in some parts of Poland was used as animal litter. Nowadays, peat mining for horticultural purposes dominates. In 2016, peat was officially mined in 64 mines in Poland, and 1 157 000 $m^3$ was extracted annually (which accounts for 0,007% of domestic peat resources; according to unpublished data of the Polish Geological Institute). Industrial extraction concerned mostly Sphagnum peats; no official mine exploiting an alkaline fen could be identified. The scale of peat mining in Poland is negligible from the economic perspective, yet mines are important for specific peatlands where they are located, usually causing their deep degradation. Minor illegal peat mining for individual own purposes or on a local scale, often carried out under the pretext of digging ponds, is not registered. This practice is already an important threat to alkaline fens.

Among the less known ways of using peat, the more interesting ones include the paper industry (production of cardboard and inferior paper grades), metallurgical industry (additives for moulding masses), production of insulation materials (thermal and acoustic), chemical industry (peat coke, gas, activated coal), food industry (flavor enhancers for whisky production, water filters, absorbents), textile industry (fiber production using *Eriophorum vaginatum*, characterized by better thermal properties than sheep's wool), cosmetology (cosmetics additive, dressing material) and also biostimulators used in agriculture and medicine. In addition to hydrolysis products used in medicine, properly prepared peat is used for balneological purposes (medicinal baths) (Kiryluk 2013, Joosten and Clarke 2002). The foregoing applications also apply to peat from fens and sometimes also gyttjas.

Calcareous tufa, including travertines[13], used to be an important building material. Many Roman buildings have been built of travertine, such as the Colosseum, the façade of St. Peter's Basilica, the Bernini Colonnade in front of this Basilica, as well as the Fountain of the Four Rivers on Piazza Navona (Pentecost 2005),

13 There is some confusion introduced by using the term "travertine" to refer to porous limestones in masonry, regardless of their actual origin. For example, "Polish travertine" excavated in the quarry in Raciszyn near Działoszyn in the Łódź Voivodeship is not, in fact, a travertine in the geological and petrographic sense.

as well as the façade of the Romanesque Sacré-Cœur Basilica in Paris. Travertines obtained in Slovakia, near Bešeňova and Drevenik, as well as near Levice, are numerously represented in the architecture of Bratislava and are also present in the architecture of Kraków (Rajchel 2009). In Poland, calcareous tufas originating from the vicinity of Trląg, near Inowrocław, were used in early medieval churches in Ostrów Lednicki, Gniezno, Mogilno, Trzemeszno and Poznań (Kaszubkiewicz 2000, Skoczylas 2013), and Holocene tufas from the valleys near Kraków – used for making tomb sculptures and the constructing of several chapels in Kraków. Due to its low specific weight, tufa was also supposed to be used to build the dome of the St. Andrew's Church in Kraków (Rajchel 2009). In XX and XXI century travertines are used in architecture as a decorative material (for example "Kameleon" store in Wrocław, numerous contemporary arrangments with imported travertines (mainly from Italy and Iran).

Late carboniferous calcareous tufas in the vicinity of Karniowice, near Kraków, are a geotourist attraction these days, as a unique "freshwater limestone" – similar to the travertine craters in Vyšné Ružbachy in the Slovak Spiš region, travertines in Schwabisch Jura, spring Waldbillig in Luxembuorg, reserve Močiar or the travertine hill in Levice in Slovakia.

**Agricultural use of peatlands**

The majority of Polish peatlands, mainly fens (including alkaline), have been transformed in various ways. Out of these approximately 14% are uncultivated land, and approximately 70% are permanent grasslands. The agricultural use of peatlands was accompanied by drainage operations, the intention of which was to "regulate air-water relations in peat soil". However, as it turned out, and on a mass scale, degradation processes always take place after the melioration of peatlands. In Poland, the largest programs of peatland drainage were carried out between 1950 – 1970, during the development of large state-owned farms involved in cattle breeding.

A spectacular example of alkaline fen destruction is the Wizna Marsh, east of Łomża, which as late as in the 1960s was still as valuable in terms of nature as the Biebrza Marshes, and the thickness of the local peats reached 11 meters. These areas were transformed into pastures and hay meadows, leading to the complete mineralization of the peat. As a result of these activities, the entire area of meadows surrounding the Wizna river is decreasing every year. The dryness of the peat resulted in once species-rich, valuable peatland becoming monotonous and poor grassy meadows (Życie a klimat, accessed in 12/2018). During peak drainage works, two nature reserves were established on the peatland, hoping that this will enable to *"preserve the most valuable fragments of the fen with sites of rare plant species: musk orchid (Herminium monorchis), rusty bogrush (Schoenus ferrugineus), star swertia (Swertia perennis), moor-king (Pedicularis sceptrum-carolinum), creeping sedge (Carex chordorrhiza), bog-sedge (Carex limosa), shrubby birch (Betula* *humilis) and downy willow (Salix lapponum)"* – this attempt at partial protection, however, was completely unsuccessful, and today both reserves are completely overgrown with birchwood and nettle forest (*Betula pubescens-Urtica dioica*) (Kolos 2004).

The yielding of cultivated plants on peatlands is unstable, as influenced by the strong development of nitrophilous weeds, pests and excessive dryness and hydrophobicity of the upper, decomposing soil layer. Deep sand-providing ploughing was used as a countermeasure, improving the physical water conditions of the profile and reducing evapotranspiration which, however, additionally increased soil aeration and accelerated the decession process. Drainage of peat agricultural land has led to irreversible changes in peatland ecosystems, depriving them of all the aforementioned functions.

It is now well-known that the value of ecological services provided by undrained peatlands is much higher than the value of agricultural production that can be obtained from them. Currently, the only form of their agricultural use acceptable in terms of protection of the function of alkaline fens is their extensive meadow-related use (and this applies only to part of previously drained and used sites). This use must be carried out in such a way as not to start the process of peat decomposition, which requires a specific "marsh pratotechnics" (e.g., the application of an appropriate schedule and manner of use during the year, and the type of equipment used), because only full saturation of the peat profile with water throughout the year can prevent the decomposition of peat.

Agriculture in peatlands is sometimes practiced in the form of hay economy, supported by EU Common Agricultural Policy instruments to maintain the open nature of habitats. The basic instrument of this kind are so-called agri-environmental schemes, transformed in 2014 into so-called agri-environmental-climate schemes (see also Chapter 10.2), precisely in recognition of the need to protect peat under agricultural land in view of the greenhouse gas balance. In the 2018 campaign, payments for mowing in the "Peatlands" variant (see Chapter 10.2) covered about 7.2 thousand ha in Poland and approx. 400 farmers benefited from them. On the other hand, peat drainage (desirable, for example, from the farmers' point of view) cannot accommodate the demand for other peatland ecosystem services. Taking this into consideration, it is even more inappropriate for peat soils to have large-scale agriculture using heavy agricultural equipment (e.g., destroying the undergrowth, microrelief, peat compacting).

At present, due to the departure from fossil fuel combustion, the use of biomass from agricultural peatland use for heating purposes is currently being researched. Research on the combustibility of biomass from peatlands, e.g., alkaline fens in Belarus (Wichtmann et al. 2014) has demonstrated that the potential yield and combustibility of biomass from wet and rewetted fens could be an alternative to other fuels, while at the same time protecting the habitats. International studies (see Link 2013) show that the role of peatlands as a source of biomass may be significant in the future.

The world is developing a trend of biomass production (but also other specific products, e.g., Sphagnum for horticultural purposes) using wetland ecosystems, while fully maintaining their marshy character, called "paludiculture" (Schröder et al. 2015, Wichtmann et al. 2010, 2016, Biancalani and Avagyan 2014, Wichmann 2018, Greifswald Moore Centre 2018). This probably represents the future of agriculture on peat soils as it optimizes the total value of the ecosystem services thus obtained, which are not reduced to the value of agricultural production itself.

**Valuation and balance of services**

Some naturalists and economists believe that the value of ecosystem services can be expressed in monetary terms, and such a valuation can be a premise for decisions on wetland management. Such valuations are being attempted (see: interesting practical attempts for Polish river valleys in the publication by Biedroń et al. 2018).

As a rule, such valuations lead to the conclusion that peatland ecosystem services that are preserved in their natural state are of greater value than the production that can be obtained from them (e.g., peat or agricultural produce). The valuation of, for example, water retention in the flooded Biebrza river valley, exceeding the economic inconvenience that the spring flood of the valley creates for agriculture, has already been mentioned previously.

Few such studies, however, concern alkaline fens. One of the few is the publication by Peh et al. (2014) on the renaturalization of wetlands in the Wicken Fen alkaline fen complex in Cambridgeshire, England. Even incomplete renaturalization of wetlands at the expense of agricultural land has turned out to be economically more advantageous than the continuation of intensive agricultural use. In this balance sheet, it is also important that the accessibility of these areas to the public has increased significantly.

# 10. NATURE PROTECTION PRACTICE

Issues related to alkaline fen conservation were discussed in other articles (Šefferova-Stanová et al. 2008, McBride et al. 2011, Nilsson 2015, Priede 2017, Stańko et al. 2018). Conservation of habitat 7230 in Polish forms of nature protection and function of these forms were described in Chapter 8 of this publication. Therefore, we will address here only several additional problems.

## 10.1. Projects aimed at protection of alkaline fens in Poland

***Dorota Horabik, Anna Smolarska***

Alkaline fen conservation in Poland has been carried out over several decades, both by institutions legally responsible for conservation of natural habitats (regional directorates of nature protection and national parks, the State Forests, National Forest Holding), and by subjects voluntarily engaging in nature protection (landscape parks, municipalities, non-governmental organizations). Most of the realized projects have already been described in many publications (e.g., Makles et al. 2014, Stańko & Wołejko 2018b). However, only a few of them have dealt with alkaline fens.

The Naturalists' Club, since the beginning of its activity (1983), has been engaged in the realization of diverse projects aimed at conservation of habitats and species, however the majority of them concentrated on the protection of fens. Active protection measures were implemented, among others, in the Drawa Forest ("Comprehensive conservation of wetlands in the Drawa Forest"; "Continuation of conservation of wetland ecosystems in the Drawa Forest", see Kujawa-Pawlaczyk & Pawlaczyk 2014, in Polish), where reeds were mown in a fragment of sedge moss fen in the Torfowisko Osowiec nature reserve. Alkaline fens were also one of subjects of protection in the project realized in the Sudety Mts. ("Conservation and restoration of endangered hydrogenic habitats in the Central Sudety Mts.", see Jermaczek et al. 2012, in Polish). Measures implemented at that time demonstrated that the installation of a large number of micro-dams was the most efficient method for blocking excessive water outflow in the mountains. These micro-dams were constructed of wood harvested during removal of tree saplings. Experiences from realization of this project and its results were presented in a publication by Jermaczek et al. (2012), and the same method was used to perform protective actions in other projects in mountain areas (e.g., conservation of mountain flush fens within the project LIFE13 NAT/PL/024).

In recent years, activities for the benefit of alkaline fens on a larger scale have been realized thanks to financial support from the European Union, including the EU's funding instrument LIFE. A part of them was allocated to conservation of Nature 2000 habitat and a part for conservation of valuable species of animals or plants associated with the habitat. Nevertheless, all these projects are guided by one goal, i.e. to conserve what is the most valuable in our nature. Every project is a source of new experiences, methods and approaches to nature protection. Particular projects are based on similar habitat and species conservation methods, while slight differences result from unique features of the region and conditions of habitat functioning. Other methods of implementation of protection measures should be considered in large-sized fen habitats, i.e., in the Biebrza river valley, and others are necessary to protect small-area patches situated in difficult-to-access locations, e.g., flush fens in mountains.

Alkaline fens have been the focus of large, countrywide projects of the Naturalists' Club: "Management plans for habitat 7230 and endangered plant species: *Saxifraga hirculus, Liparis loeselii, Stellaria crassifolia* and *Herminium monorchis*" (partially supported by the European Regional Development Fund within the framework of the Operational Programme Infrastructure and Environment 2008 – 2011), "Conservation of alkaline fens (7230) in young-glacial landscape of northern Poland" (partially supported as the project LIFE11 NAT/PL/423, 2012 – 2018) and "Conservation of alkaline fens (7230) in southern Poland" (partially supported as the project LIFE13 NAT/PL/024, 2014 – 2018). The first project resulted, among others, in preparation of an inventory of alkaline fens in Poland and development of conservation programs (Wołejko et al. 2012, Pawlikowski & Jarzombkowski 2012a, 2012b, Jarzombkowski & Pawlikowski 2012, Jarzombkowski 2012, all in Polish). The other two projects (Stańko & Wołejko 2018a, 2018b) were devoted to implementation of active protection measures in more than 200 alkaline fens located in 54 Natura 2000 sites. The following works were performed, among others: preparatory mowing of 327 ha of fen area (making them ready for continuous conservation by mowing), shrub removal from an area of ca. 265 ha, construction of 195 dams and other facilities aimed at improving water conditions. Ca. 65 ha of the most valuable alkaline fens were purchased, 9 nature reserves were established, and 12 draft conservation plans for nature reserves were developed.

Conservation of wetland habitats in the Biebrza National Park has been realized within the framework of two projects (Preservation of wetland habitats in the Upper Biebrza valley LIFE11 NAT/PL/422: 2012 – 2019 and LIFE13 NAT/PL/050 Restoration of hydrological system in the Middle Basin of the Biebrza Valley, Stage II: 2014 – 2018) thus only the first one covered measures targeted directly to alkaline fens. The former project was directly focused on the conservation of alkaline fens. The main actions within this project included: land purchase, shrub removal from fen habitats (including ca. 108 ha of alkaline fens), mowing (ca. 92 ha of

Photo 122: Protective actions carried out at one of the sites (Łąka w Bęczkowicach) under the project LIFE13 NAT/PL/024 (photo by T. Bąkowski).

alkaline fens) and also restoration of proper water conditions by elimination of drainage systems (construction of dams). Within the framework of this project, considerable effort was made to encourage local farmers to restore extensive use of wetland areas that was abandoned several years ago. In addition, application of remote sensing methods was tested in order to identify habitat 7230 and threats to it (see Kopeć et al. 2016), at least in the Biebrza river valley. Moreover, local populations of *Liparis loeselii* and *Saxifraga hirculus* were evaluated and monitored. At the final stage of this project realization, the works that could not be contracted or that were not carried out by contractors were voluntarily performed by employees of the Biebrza National Park! (LIFE11 NAT/PL/422).

Photo 123: Protective actions carried out in the Kropiwno alkaline fens within the project LIFE11 NAT/PL/422 (photo by P. Pawłowski).

Photo 124: Conservation actions carried out in the Szuszalewo alkaline fens within the project LIFE11 NAT/PL/422 (photo by J. Pińkowska).

Mountain flush fens were protected also within the project "Protection of non-forest habitats  in the Beskid's Landscape Parks" (LIFE12 NAT/PL/081; 2013 – 2018; LIFE "Beskidy") realized by the Complex of Landscape Parks of the Śląskie Voivodeship in two Natura 2000 sites: Beskid Śląski PLH240005 and Beskid Żywiecki PLH240006. Although this project was mostly focused on protection of non-fen habitats – Nardus grasslands (habitat code 6230*) and mountain hay meadows (habitat code 6520) – through restoration of their use by herding, removal of tree and shrub saplings, mowing the meadow and grassland vegetation and mowing the compact patches of *Rumex alpinus*, these protective procedures indirectly influence the conservation status of fen patches occurring within the glades

Photo 125: Preparation to the mowing of the alp Hala Cudzichowa in order to remove *Rumex alpinus* within the project LIFE12 NAT/PL/000081 (photo by A. Smolarska).

Photo 126: The alp Hala Cudzichowa with a zone of unmown vegetation left after mowing *Rumex alpinus* (photo by A. Smolarska).

subjected to these actions. The alp Hala Cudzichowa situated in the Pilska Massif in the Żywiec Beskid Mts. is an example of an interesting mosaic of such habitats, comprising patches of Nardus grasslands with different conservation status and a small patch of alkaline fen with beautifully blooming *Allium sibiricum*. In this alp, mowing *Rumex alpinus* was an especially important protective action because it is an expansive species with wide adaptability which started to encroach also into wet areas. Monitoring studies revealed that restriction of *Rumex alpinus* growth resulting in reduction of its flower production and fruit setting had a positive impact on the conservation status of all the valuable types of habitats located in the glades under extensive use, including fens. The Complex of Landscape Parks of the Śląskie Voivodeship plans to continue the implemented measures after completion of the project, contributing to improvement of natural and landscape values of the Beskidy Mts. and to preservation of the ecological effect of the actions carried out under this project.

Alkaline fens harbor many valuable plant and animal species. Aquatic warbler *Acrocephalus paludicola* can be an illustrative example because it is an umbrella species representing fen habitats, preferring particularly mesotrophic alkaline fens which are an optimal biotope for this species (Tannenberger & Kubacka 2018). Protection of the aquatic warbler was carried out by the Polish Society for the Protection of Birds within the framework of the project "Conserving *Acrocephalus paludicola* in Poland and Germany LIFE05 NAT/PL/000101 (2005 – 2012). The greatest threat to this species is posed by the loss of habitat, therefore, protection of habitat was the aim of the protective actions. These mostly involved preservation of an open character of the habitat by removal of reeds, shrubs and trees and then restoration of extensive use of these areas for haymaking, abandoned long time ago. For this purpose, a special prototype of a mower was designed on the basis of a snow groomer. This vehicle was used to mow very large areas where hand mowing was too labor intensive and uneconomical. However, monitoring revealed that although mowing with the use of groomers restored the aquatic warbler's biotope, it was not optimal for alkaline fens and their flora. Based on monitoring data, the conditions of the use of each habitat patch were defined separately. For smaller areas, it was decided to recommend grazing, and for larger – mowing. Long-term actions were mostly determined by hydrological conditions prevailing in a particular area. In the areas where property owners were not interested in restoration of proper habitat management, ca. 1000 ha was purchased within the project, of which 650 was purchased from private owners in the Biebrza National Park, while the remaining 350 ha was the property of the PSPB and three "private nature reserves" were created: Ławki-Szorce, Mścichy and Laskowiec-Zajki (Zadrąg et al. 2011).

The second PSPB project "Facilitating Aquatic Warbler (*Acrocephalus paludicola*) habitat management through sustainable systems of biomass use" LIFE09 NAT/PL/000260 (2010 – 2015) concentrated on a solution to the problem of management of biomass created during the mowing of fens and marshy meadows. For this purpose, a pelleting plant was built in Trzcianne in the Podlaskie Voivodeship, whereas in the Lubelszczyzna region, biomass is utilized by three plants (two pelleting plants and one cement factory). Thanks to identification of customers ensuring biomass reception and use, it ceased to be a problem hindering implementation of the protective measures (Gatkowski 2015).

## 10.2. Support for agricultural management protecting alkaline fens

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The protection of valuable habitats, including alkaline fens, by management of these areas with the use of extensive farming methods (especially mowing) is supported by instruments of the Common Agricultural Policy (CAP) of the European Union.

One of the actions within the framework of the Rural Development Programme 2007 – 2013, namely the agri-environmental program, offered support in two packages: "4. Protection of valuable habitats within Natura 2000 sites" and "5. Protection of valuable habitats outside Natura 2000 sites". Both packages contained the variant "Sedge moss fens" (variant 4.2 and 5.2, respectively). It ensured subsidies to agricultural plots in which a habitat expert identified habitat 7230 with sedge-moss fen vegetation of the *Caricion davallianae*, *Caricion nigrae* alliances, a part of *Caricion lasiocarpae* alliance or other related communities by confirming the occurrence of the required number of indicator species (see the list in Chapter 11.2).

General requirements, valid irrespective of the variant, included the ban on some pratotechnical procedures such as plowing, rolling, reseeding or dragging in the period from April 1 to September 1. In addition, it was not allowed to use wastewater and sewage sludge. The general prohibition on construction and enlargement of drainage facilities did not apply to investments aimed at conservation or elevation of natural values (e.g., ditches with dams, impoundments or other types of damming barriers). It was also claimed that this prohibition did not apply to the so-called on-going maintenance[14]. The last general requirement was related to the ban on the use of plant protection products, except for (after consultation of an agri-environmental expert) selective and local destruction of onerous weeds with the use of appropriate equipment (e.g., herbicide applicators).

Additional requirements applicable only to sedge moss fens, most of all defined a mowing schedule (grazing is prohibited). The area should be mown from July 15 to September 30, at a height of 5 – 15 cm, without destruction of

14 Unfortunately, in practice, this "on-going maintenance" of drainage ditches often contributed to a worsening of water conditions in hydrogenic habitats (including alkaline fens).

sward or topsoil, in a manner allowing animals to escape (in some other way than from the outside to the center of the mown area). Three mowing schemes were permitted, of which an expert chose the most beneficial for a particular plot. It was possible to leave a half of the area unmown every year (alternating), to leave the whole plot unmown and mowing the whole area in the next year, or to leave a half of the plot unmown alternating with mowing the whole plot in the next year. It was also obligatory to remove or deposit into haystack the biomass within two weeks after the cut (in justified cases later). Apart the mowing issues, additional requirements also prohibited fertilization.

The "Mechowiska" (segde-moss mires) variant was implemented at approx. 600 ha. In almost 80%, these were plots in Natura 2000 sites. More than half of the area of implementation of this variant was located in the Biebrza valley, mostly in the Biebrza National Park (see Chapter 8).

In the next edition of the Rural Development Program for the years 2014-2020, guidelines on the use of alkaline fens were included together with the requirements for other peatland habitats (such as: 7110, 7120, 7140, 7150, 7210, 7220 and 4010) in options 4.6.1 and 5.6.1 "Peatlands - mandatory requirements" and 4.6.2 and 5.6.2 "Peatlands - mandatory and complementary requirements". These variants are part of the agri-environmental-climate scheme, which is a continuation of the agri-environmental program implemented earlier. As before, package 4 is for Natura 2000 sites, and package 5 for other areas. A greater role was assigned to the decision of an expert, whose task is to precisely identify the needs of the habitat and to select from the available pool of conservation measures those appropriate ones to be carried out by the user. Both habitats that do not require systematic mowing are subsidized (on which only mandatory requirements are implemented), as well as those on which regular mowing is necessary to maintain or improve their conservation status (additionally complementary requirements are implemented here). As a result, payments under the agri-environmental-climate commitments under discussion are differentiated - higher for options 4.6.2 and 5.6.2, where the scope of activities is wider.

Qualification of individual plots for one of the "Torfowiska" ("Peatlands") variants (similar to the case for the "Mechowiska" ("Sedge-moss mires") variant as part of ERDF 2007-2013) is based on the so-called habitat expertise. It should confirm the occurrence of certain plant communities and qualifying species listed on the list common for various types of peatlands (compare the list in section 11.2).

Similarly to the previously implemented agri-environmental program, a set of requirements common for all habitat variants (not only peatlands) applies. Some of the bans remained unchanged (e.g., regarding the sowing or application of sewage sludge), other provisions were modified, for example, the period without the ban on rolling in upland and mountain areas was extended until 15 April; the ban on drainage systems was reformulated, emphasizing the possibility of creating new, expanding and reconstructing devices adjusting the water level to the requirements of habitats being the subject of activities in a given variant (using existing drainage systems). In addition, the scope of permitted use of plant protection products has been narrowed, limiting them only to onerous invasive species. A ban on biomass storage was also introduced among the clumps of trees and shrubs, in ditches, ravines and other depressions of land located on plots declared for agri-environmental-climate payments.

Mandatory requirements specified for all types of peatlands (including habitat 7230) also include the ban on peat extraction, afforestation, fertilization, liming, mechanical destruction of soil structure (including harrowing and plowing), the use of mechanical equipment causing disturbance of the topsoil and the leaving of fragmented biomass. The removal of anthropogenic waste is also obligatory here. The implementation of other basic requirements depends on the specifics of a given patch of habitat as well as local conditions and recommendations of a habitat expert. In the case of plots being subject to secondary succession of trees and shrubs (caused by, for example, overdrying or cessation of use), it will be mandatory to cut out the selected trees or undergrowth in the first year of implementation of the variant from August 15$^{th}$ to February 15$^{th}$ of the following year, and in subsequent years if necessary mowing the area where there are tree and bush growths or cutting out these shoots every year or every two years, also from August 15$^{th}$ to February 15$^{th}$ of the following year. Cut or mown biomass must in these cases be collected and removed from the surface within two weeks after the cut or laid in piles, stacks or temporary hay sheds and removed from the surface no later than March 1$^{st}$ of the following year.

In the case of options 4.6.2 and 5.6.2, apart from the actions indicated in the part concerning mandatory requirements, it is necessary to plan mowing. Depending on the needs of the habitat, it may take place once, twice or three times within 5 years of commitment, and at the same time not more often than every two years. In relation to the previous approach (under RDP 2007-2013), the period in which mowing is allowed was extended until February 15$^{th}$. In addition, the expert may impose an obligation to leave up to 20% of the unmown area. The unmown parts determined in this way can not be repeated in two subsequent cuttings. As in the case of removing trees and shrubs, and mowing sprouts, it is necessary to collect and remove the biomass (the same rules apply as in the case of mandatory requirements).

As of 2018, the “Torfowiska” (“Peatlands”) variant is implemented on an area of 7,8 thousand ha, of which approx. 5,7 thousand ha are located in Natura 2000 sites. 92% of this area is an extended variant, i.e. with mowing. The entire “Torfowiska” package is only about 1% of the habitat packages of the agri-environmental-climatic program. It is not known how much of the peatlands subsidized in this way are alkaline fens, but on the basis of monitoring of plots samples, it can be estimated that it is about 6-10%.

Shaping the vegetation of some alkaline fens can be additionally supported as part of variants for the protection of bird habitats, e.g. aquatic warbler. However, there is no data that would allow estimating the scale of such support.

The implementation of agri-environmental programs has been subject to monitoring by the Institute of Technology and Life Sciences (see also Chapter 11.2). On the sample of plots covered by the program, the identification of the habitat is verified and its condition is assessed at the beginning and at the end of the implementation of the agri-environmental commitment. The results of this monitoring, apart from the report from 2014 (Jarzombkowski et al. 2015a), have not been made public.

Observations suggest that the activities carried out under the appropriate variants of the agri-environmental or agri-environment-climate package actually prevent the most serious threat to the habitat, which is overgrowing as a result of abandonment of use. Sometimes, however, problems resulting from careless or improper implementation were observed (e.g. damage to the fen surface by agricultural equipment, leaving biomass on a plot, mulching, violating the prohibition of changing water relations by dredging and deepening ditches), combined with poorly functioning mechanisms of control such specific recommendations.

The results of independent studies on the impact of mowing alkaline fens (Kotowski et al. 2013, Kozub et al. 2019) suggest that mowing may improve the vegetation condition of degraded peatlands, but they deteriorate the condition of the best preserved ones.

# 11. MONITORING

## 11.1. State Environmental Monitoring

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### 11.1.1. Chief Inspectorate of Environment Protection (GIOŚ) Methodology

Monitoring of natural habitats listed in Annex I to the Habitats Directive is carried out in all EU Member States, which results from the obligation for continuous surveillance of resources of these habitats (Article 11 of the Habitats Directive) and preparation of reports on their conservation status every 6 years (Article 17 of the Habitats Directive, see Chapter 6) (Habitats Directive 1992). Methods of field monitoring are not standardized and left to the decision of every country, making the results difficult to compare. However, in a majority of countries, basic assumptions are similar (Ellwanger et al. 2018), and the core of habitat monitoring is to assure periodical field assessment of the chosen indices of "structure and function" in particular habitat patches (in all patches for rare habitats and on representative sample of patches for more widespread habitats).

In Poland, the method of habitat 7230 monitoring adopted by the Chief Inspectorate of Environmental Protection (GIOŚ) (Koczur 2012, 2013) within the framework of the so-called State Environmental Monitoring (Państwowy Monitoring Środowiska, PMŚ) assumes the investigation of an average of 4 locations chosen within each Natura 2000 site. The choice of the location is left to the decision of an expert who performs the first observation. A location is generally defined as a patch of natural habitat. At each location in a patch of habitat, a transect measuring 200 x 10 m is delineated according to the expert's decision (modifications of transect size are possible if necessary, e.g., when the patch is smaller). Three phytosociological relevés are taken on plots measuring 5 x 5 m using the classical Braun-Blanquet scale: at the beginning, in the middle and at the end of transect. The coordinates are obtained using a GPS receiver. The methodology does not specify the positioning precision, but in practice GPS receivers of a tourist class are used.

The idea of conservation status assessment relies on the description and evaluation of some chosen aspects of ecosystem structure and function – called structure and function indices – according to a three-point scale: favourable (FV), unfavourable-inadequate (U1) and unfavourable-bad (U2). The following indices are evaluated in the whole transect:

1. Percentage of area occupied by the habitat in the transect (if the habitat is preserved only as mosaic of patches with other ecosystems). 80 – 100% is assessed as FV, 50 – 80% as U1, and < 50% as U2;
2. The number of characteristic species. If 9 of more characteristic species are present or the total cover by characteristic species exceeds 50% the conservation status is rated as FV, 4 – 8 characteristic species and total cover 20 – 50% is assessed as U1 and lower values are rated as U2. The following characteristic species for this habitat were listed: *Bryum pseudotriquetrum var. bimum, Campylium stellatum, Carex davalliana, Carex dioica, Carex flava, Carex hostiana, Carex lepidocarpa, Carex panicea, Carex pulicaulis, Ctenidium molluscum, Dactylorhiza incarnata, Dactylorhiza majalis, Drepanocladus aduncus, Eleocharis quinqueflora, Epipactis palustris, Eriophorum latifolium, Fissidens adianthoides, Hamatocaulis vernicosus, Helodium blandowii, Juncus alpino-articulatus, Limptrichia cossoni, Liparis loeselii, Orchis palustris, Paludella squarrosa, Parnassia palustris, Pedicularis palustris, Pedicularis sceptrum-carolinum, Pinguicula vulgaris, Primula farinosa, Scorpidium scorpioides, Schoenus ferrugineus, Schoenus nigricans, Swertia penernnis, Sphagnum teres, Sphagnum warnstorfiii, Tofieldia calyculata, Tomentypnum nitens, Triglochin palustre, Valeriana simplicifolia, Warnstorfia exannulata, Warstoria fluitans, Warnstorfia sarmentosa*;
3. Dominance structure (dominance of characteristic species for the habitat is rated as FV, dominance of species not included among characteristic species as U2);
4. Cover and structure of moss layer. Total cover exceeding 50% with more than 70% of brown mosses is rated as FV, total cover 20 – 50% with 20 – 70% of brown mosses as U1, and lower parameter values, including lack of brown mosses or dominating sphagnum mosses, as U2;
5. Possible presence of alien invasive species. Lack of these species is evaluated as FV, 5% of invasive species as U1, and greater percentage as U2.
6. Presence of expansive herbaceous plant species. Their lack is evaluated as FV, 5% share as U1, and a higher percentage as U2;
7. pH value of surface peat layer, measured at 5 points along the transect with the use of field pH-meter or estimated colorimetrically by Hellig's method; pH>7 is rated as FV, pH between 6 and 7 – as U1, lower than 6 – as U2;
8. Overgrowth by trees and shrubs. Lack or single trees is rated as FV, 15% cover by trees and shrubs as U1, and a higher percentage as U2.
9. Water conditions on the day of observation, at 5 points on the transect. Water table between 10 cm below and 2 cm above fen surface level is judged as FV, between 20 cm below and 10 cm above ground level as U1, and values more distant from peat surface as U2. The practical criterion of FV status is that "water is always visible during walking on the fen at least up to the height of the sole".

10. Historical and current peat extraction. Traces of historical extraction up to 5% without current works can be rated as FV, contemporary sporadic small-scale extraction or historical larger-scale extraction reduce the rating to U1, while a larger scale of current extraction further reduces rating to U2;
11. Presence of artificial drainage system (no ditches or their fully neutralized impact is evaluated as FV, ditches filled with vegetation or blocked enough to have only slight impact – as U1, ditches visibly worsening water conditions - as U2).

Based on the above-listed indices, an expert makes an assessment of the synthetic status of the parameter "structure and function" on a three point scale: FV-U1-U2. The indices: characteristic species, cover and species structure of mosses, pH range, expansive herbaceous plant species, encroachment of shrubs and saplings, water conditions (underlined in the above listing) are considered to be cardinal, i.e., synthetic rating of structure and function cannot be better than the worse of these indices. Interpretation of the remaining indices is left to the discretion of the expert.

Besides the above-described assessment of structure and function of the habitat, the expert also evaluates two parameters at the location:

- Habitat area at the site. The whole patch, not only the transect, is evaluated: when the area is stable or increases in comparison with earlier studies, or the status is rated as FV, slowly decreasing area is rated as U1 while distinctly decreasing as U2.
- Conservation prospects, i.e., chances for existence, conservation of the studied patch, considering both the existing threats and undertaken protective measures.

The overall rating of the conservation status at a location is determined by the lowest rating of these three parameters[15]. In practice, it is usually determined by assessment of the parameter "structure and function" because it first reflects area shrinkage and prospects for efficient protection.

Basic assumptions of this method are similar to the methods used in many EU countries (see e.g., Verbücheln et al. 2004, Joint Nature Conservation Committee 2004, Polak & Saxa 2005, Ellmauer & Essl 2005, Zingstra et al. 2009, Bundesamt für Naturschutz 2017). Almost everywhere assessments refer to the list of plants typical of the habitat, to the presence of expansive species (usually with a distinction between native and alien species of trees and shrubs) and crude assessment

15 In the original paper by Koczur (2012, 2013), it was proposed that the overall assessment should be based on the dominating assessments of parameters, e.g., two parameters FV and one U1 were recommended to be given the overall assessment FV, whereas two U1 and one U2 – the overall assessment U1. However, GIOŚ verified this recommendation in erratum posted online, in order to adjust the procedure to unified assessment scheme for all habitat types: http://siedliska.gios.gov.pl/images/pliki_pdf/publikacje/Erraty_i_modyfikacje_metodyk_monitoringu/Errata-do-przewodnikw-metodycznych-Cz-I-Cz-II-Cz-III-Cz-IV.pdf

Photo 127: State Environmental Monitoring (PMŚ) on moss fen meadow in Łupawa river valley (photo by P. Pawlaczyk).

of quality of water conditions. However, detailed indices and methods of their recording and interpretation differ slightly. In some countries, floristic lists limited to indicator species but encompassing the whole patch are an alternative to phytosociological relevés. Almost everywhere the results are assessed according to a three-point scale. In some countries it is the same as in Poland (FV-U1-U2), in others conservation status is assessed as A-B-C, while the scale FV-U1-U2 is preferred during data aggregation at the level of country or biogeographical region.

In Poland, in planning of conservation of Natura 2000 sites either by preparation of plans of conservation measures or conservation plans[16], *"evaluation of structure and function of a natural habitat is based on sets of* indices*, applicable to a particular Natura 2000 site, adopted according to scientific knowledge for the purpose of monitoring, referred to in Art. 112, item 2 of the Act, and reports, referred to in Art. 38 of the Act, supplemented if needed with* indices *specific for a particular Natura 2000 site."* It indicates that for management planning the conservation sta-

16 In practice, planning of protection of Natura 2000 sites in Poland is almost completely carried out by preparation and establishing of plans of conservation measures. Until 2018, more than 400 such plans were established. Although the Act provides the option to prepare and establish a more refined planning tool, namely the conservation plan for Natura 2000 site or its fragments, until 2018 this solution had not once been used.

tus of natural habitats is generally assessed, for management planning, based on the same parameters (habitat area, structure and function, protection prospects), while the structure and function of natural habitats are assessed according to the same set of indices as the set accepted by the State Environmental Monitoring (Regulation of 2010a, Regulation of 2010b). The option to add indices "specific for a particular Natura 2000 site" as well as to omit indices "inapplicable to a particular Natura 2000 site" was introduced to the regulations as late as in November 2017, while the set of indices used earlier had to strictly comply with the set of indices specified in the GIOŚ method.

As a consequence, the above-mentioned indices were used not only for assessments within the framework of the State Environmental Monitoring but also for assessments used to prepare plans of conservation measures in many areas. These indices were also the basis for setting the objectives of conservation tasks in these plans and for defining the concept of local monitoring of conservation status of protected features at Natura 2000 sites. In many cases, an explicit obligation *"to monitor conservation status of habitat 7230 using the PMŚ method"* was introduced as one of conservation measures in monitoring programs (despite this – as we will demonstrate below – such a solution is incorrect).

It is worth noting that the procedure of conservation planning for Natura 2000 sites requires using an analogical set of indices as in GIOŚ methodology for assessment of conservations status, but stipulates no requirement for using identical methods for evaluation of these indices.

### 11.1.2. GIOŚ monitoring results obtained to date

The above-described methodology of monitoring and assessment of conservation status of habitat 7320 was applied in practice in the State Environmental Monitoring. In 2009, 121 locations in Poland were examined with this method and, in 2017, 115 of them plus one new location were reexamined (Institute of Nature Conservation... 2018). A report summarizing the monitoring data obtained to date was published (Vončina 2018).

Only 2 study locations were situated outside Natura 2000 sites, which, does not drastically deviate from the distribution of known habitat patches. 12% of locations were placed in National Parks (clearly an insufficient representation in relation to habitat distribution), and 15% in nature reserves (less than a proportional representation).

In 2017, 10 locations were proposed to be withdrawn from further monitoring, mostly due to habitat disappearance. The structure of overall assessments of conservation status was as follows:

Table 6. Overall assessment of conservation status of habitat 7230 at PMŚ locations in 2009 and 2017.

| Conservation status | Favourable (FV) | Unfavourable –inadequate (U1) | Unfavourable – bad (U2), but existence of habitat was confirmed | Habitat disappearance (U2, XX) |
|---|---|---|---|---|
| 2009 | 20 (16,5%) | 71 (58,7%) | 30 (24,8%) | |
| 2017 | 12 (10,3%) | 37 (31,6%) | 58 (49,6%) | 10 (8,5%) |

Positive differences between the assessment in 2009 and in 2017 were noted only at 3 locations in all of Poland. Conservation status in 2017 was rated worse than in 2009 at over a half of the locations.

These results would indicate a dramatic deterioration of the habitat status in Poland. Negative differences between the conservation status assessment in 2017 and its earlier rating in 2009 could be seen even at locations in National Parks. Negative changes were attributable most of all to indices describing succession (expansive species, dominant species) and water conditions. Demonstration of some changes may be biased by increasing experts' awareness of threats to the habitat, however the scale of negative differences is greater than that explainable by this factor.

## 11.1.3. Practical experiences with implementation of GIOŚ methodology and postulates for method improvements

Our field experiences with habitat 7230 monitoring using GIOŚ methodology (both for the State Environmental Monitoring and for conservation planning for Natura 2000 sites) leads to the following reflections:

**Representativeness.** The adopted rule that an expert makes the decision as to the choice of locations and the assumption that ca. 4 locations are to be selected in each Natura 2000 site, where alkaline fens are protected features, causes that better developed and preserved patches are over-represented. At the level of Natura 2000 site, no expert – who can choose only several locations for monitoring – will omit "the best" locations in the area, consequently no sites will be left for representative presentation of less typical, doubtful, more deformed locations. In the same way, the choice of transect location at each location by an expert usually leads to transect positioning in a better developed and preserved part of the patch.

As a consequence, the method used in the State Environmental Monitoring allows for following the pathways of changes and fate of alkaline fens, especially with respect to their better preserved and developed patches that are most important for biodiversity. It is valuable that the changes will be captured and documented at least in such better preserved patches. However, the structure of the conservation status of a habitat at monitoring locations cannot be considered to be a correct indicator of the structure of the conservation status of the country's resources of the habitat. It is well reflected by a comparison of monitoring results from 2009 and results of detailed inventory of this habitat in a similar period (2008 – 2011): the structure of conservation status assessments at the locations of the State Monitoring was significantly overestimated in relation to the actual structure of conservation status of habitat patches, assessed by full field inventory (Tab. 7). Yet a comparison of assessments of PMŚ locations with assessments resulting from inventory of patches where these locations were situated demonstrated that these assessments were similar. Therefore, the differences in the structure of results do not stem from divergent interpretation of indices but overrepresentation of better preserved patches among PMŚ sites.

Table 7. Structure of conservation status of habitat 7230 in Poland estimated in different surveys. Sources of data: Database of alkaline fens of the Naturalists' Club:
1. [http://alkfens.kp.org.pl/o-torfowiskach/ogolnopolska-baza-mechowisk/] as of 2011.
2. Data from the State Environmental Monitoring, observations from 2009: Instytut... 2018 [http://www.iop.krakow.pl/cn2000/Monitoring/ZestawienieWynikow.aspx

| Survey | Conservation status | | |
|---|---|---|---|
| | Favourable – FV | Unfavourable inadequate – U1 | Unfavourable – bad (U2) |
| Database of alkaline fens of the Naturalists' Club based on field inventory in 2008 – 2011. Field assessment of each patch based on GIOŚ indices with the option to select fragments of different status. | 4,96% of habitat area | 44,08% of habitat area | 50,96% of habitat area |
| State Environmental Monitoring, survey from 2009, assessment at 121 locations. | 16,5% of the total number of locations | 58,7% of the total number of locations | 14,8% of the total number of locations |
| State Environmental Monitoring, survey from 2017, assessment at 117 locations, the same as in 2009. | 10,3% of the number of locations | 31,6% of the number of locations | 53,8% of the number of locations |

**Repeatability.** Assessment of changes that have occurred at a given location requires, as a rule, repetition of observation, including phytosociological relevés exactly at the same location.

The GIOŚ methodology, which assumes using GPS receivers for positioning of the location, transect and relevé plots, does not fulfill this requirement. The experts usually used GPS receivers of a tourist class, guaranteeing a mean theoretical error of positioning at the level of 2 – 6 m. This error of course doubles when exactly the same point with a previously determined position has to be spotted and the values 2 – 6 m refer only to the mean. Consequently, characteristic points of transect, and thus the relevé plots, are not necessarily identical with the locations chosen during the first observation.

In alkaline fens characterized often by mosaic vegetation patterns, it is a serious problem. A several-meter difference in location positioning can shift observation from a patch of open moss fen to a patch of reeds or willow thickets. Consequently, the differences between observations are difficult to interpret since we do not know whether they result from changes having occurred at the location or they are artifacts caused by imprecise positioning.

This problem disappears when the aim of the survey is to assess the conservation status of a habitat at the level of the country, i.e., when data from a large number of locations are averaged, and it is how the GIOŚ methodology is optimized (also in terms of cost-effectiveness). Then, it can be expected that such averaging will eliminate the effect of small differences in positioning, and the differences observed after averaging between two surveys will represent an actual trend of changes in particular indices. Comparison of synthetic data of the State Environmental Monitoring from 2009 and 2017 (Tab. 6) reveals such a clear trend towards the worsening of conservation status of the habitat (see above).

However, this problem becomes vital when we aim to interpret changes at a particular location or Natura 2000 site in which only several locations are studied. Partially, it can be solved by the application of more precise positioning techniques (e.g., GNSS, EGNOS, RTK corrections) which, however, requires using much more advanced and expensive equipment that will affect the cost of surveying a single location. However, the application of such solutions is hindered by the situation of some locations outside of mobile network coverage, making RTK correction impossible. Post-processing does not address the need to "hit a defined point in the field". More precise positioning often requires also prolongation of the measurements time – in this way the coordinates of a study location can be measured precisely but it is not possible to efficiently look for the very place with known coordinates.

Apparently the only way which could ensure full repeatability of monitoring location positioning would be to mark characteristic points on the transect, for instance using stakes with an underground metal tracer, positioned additionally in reference to characteristic land features. GIOŚ methodology does not require such marking because it is not necessary for proper interpretation of the data at a national level. However, in local monitoring it is indispensable for efficient investigation of the changes progressing at each location.

**Assessment of habitat area and its possible changes.** This is practically impossible during field observation. Firstly, even interpretation of the habitat area is usually doubtful: should it include only the area of patches of typical vegetation, and if so where would be their borders? How should tree and shrub overgrowth inside a patch be treated? Secondly, even if the interpretation is clear, a visual assessment of the area within which one is standing is usually affected by a several hundred percent error. It seems that only remote-sensing techniques based on a once developed algorithm of identification creates an opportunity for reliable monitoring of the changes on the habitat surface (see e.g., Kopeć et al. 2016). Even if this algorithm is not perfect, at least it will assure repeatability of assessments. However, these methods can be used only for some fens because remote sensing can only distinguish patches of vegetation differing in appearance, while in the case of many alkaline fens moss forms of sedge rushes look identical as non-moss-type rushes.

**Assessment of water conditions.** Although water conditions are a key factor for each fen, GIOŚ methodology recommends using only one parameter for its characterization, namely the location of groundwater table in relation to fen surface, which is assessed on the observation date, i.e., once in several years on a randomly chosen day. If no piezometers are available for measurement in the fen (which usually is the case), this assessment is performed with an estimated organoleptic method (estimation criterion is specified as rising of water to the surface during walking on the fen "at least to a height of the sole"). It is a consequence of the general assumption made by the State Environmental Monitoring to base the whole monitoring of habitats on single visits of experts at monitoring locations once every few years.

However, such a method of assessment of water conditions is insufficient for the monitoring of any fen (see Pawlaczyk & Kujawa-Pawlaczyk 2017). This problem is essential particularly for alkaline fens because their status depends rather on the stability of the water level in peat than the height of the water level during a single observation (see also below).

Efficient monitoring of any fen, and especially alkaline fens, requires the assessment of water conditions on the basis of continuous monitoring, not only on the basis of an arbitrary, random observation. As a technical solution, it should be recommended to carry out continuous (at least once a day) recording of water level in observation pits using automatic recorders (Divers). Detailed recommendations regarding this issue are listed in a later chapter. It should be remembered that even the measurement organized in this way has some methodological limitations (see Pawlaczyk & Kujawa-Pawlaczyk 2017).

In alkaline fens it would be advisable to monitor not only water level alone but also its characteristics, e.g., chemical and physicochemical parameters. Only such information makes it possible to interpret the hydrology and ecology of groundwater-fed alkaline fens (Wołejko & Grootjans 2004, Grootjans et al. 2015), to reveal the directions of water inflow and disclose the changes threatening the fen.

**Assessment of overgrowth by trees and shrubs.** Overgrowth by woody vegetation is a serious conservational problem in many alkaline fens. Therefore, a proper monitoring should allow for identification of even slight, unobvious changes which, however, follow a particular trend, including a reliable measurement of overgrowth rate. The only method proposed by GIOŚ methodology for the assessment of this parameter relies on a visual examination by an expert of the compactness of the trees and shrubs in a transect. Usually the transect is located in the center of the fen, therefore the changes in tree cover at its edges remain outside the scope of monitoring, at least until they have not led to the complete disappearance of the habitat 7230 from the edges, i.e., to shrinkage of its area. Visual evaluation by an expert, especially for a transect measuring 200 x 20 m which cannot be grasped at one glance, is also quite imprecise. The error of such assessment (including that between assessments made by different observers) is much greater than the changes it should identify.

This problem can be partially overcome by assuring that consecutive surveys at the location will be carried out by the same observer, who remembers the extent of overgrowth from the previous survey and is able to directly assess the changes; however, it is not always possible.

An effective assessment of the changes in the tree and shrub overgrowth would require reproducible photographic recording or like, most desirable both in the form of standardized, reproducible photographic documentation of the transect and aerial or satellite documentation of the tree cover in the whole patch (drone, aerial or satellite photos or LIDAR data). Such documentation could be used for quantitative measurements of tree cover and shrub cover of the study area and its changes.

**Phenology of vegetation.** PMŚ methodology requires only that the studies should be performed in the period from mid-June to mid-August when most species are at peak bloom, allowing even "works in a later vegetation season" warning, however, that at that time "problems with identification of some species (sedges, grasses, orchids) and their cover can be encountered." Practical experiences indicate that some species of vascular plants, e.g., *Saxifraga hirculus* are surprisingly difficult to notice outside the blooming season. Hence, the assessment of their cover by an observer performed at the beginning of August can significantly differ from an assessment in mid-August. Moreover, cover of different species of mosses can undergo striking changes throughout the year (Šoltes et al. 2015).

**Subjectivity of assessments and methodological ambiguities in some indices.** Experiences resulting from repetition of the State Environmental Monitoring survey in 2017 at monitoring locations previously assessed in 2009 and also cross-sectional analyses of observation dataset suggest that data interpretation by experts or details of these assessments were not fully uniform for several indices. In particular:

1. The index *"The presence of expansive herbaceous plant species"* is variously treated by experts with respect to the choice of species that have to be considered "expansive". For instance, there were differences in approach to nettle, reed and massively occurring sedges, especially in cases of their dominance in the studied phytocenosis. Usually, an expert does not have enough data for assessment as to whether such dominance results from "expansion" or it is a natural stable phenomenon, thus, his/her assessment is based rather on intuition which leads to considerable subjectivity of assessment. It strongly affects synthetic assessment of structure and function status.
2. The index *"pH value of surface peat layer"* heavily depends on the measurement method which has not been standardized. A field pH-meter measures pH of liquid phase, i.e., water; if it is taken at the peat surface, it can be strongly affected by e.g., precipitation water. Colorimetric pH estimation with the use of a Hellig soil pH-meter is based on measurement of the pH of an ad hoc prepared solution washed out from a peat sample with Hellig liquid. Regardless, the impact of this problem on synthetic assessment of structure and function status is not vital because the criterion is defined only as a pH value below or above 7. However, this problem becomes significant when data from consecutive observations at the same location have to be compared, especially when the methods used for previous pH measurements were not recorded.
3. Although GIOŚ methodology contains lists of "characteristic species for the habitat", interpretations of this aspect are not always uniform, especially considering doubts the composition of the list can raise. For instance, experts differently treated *Calliergon stramineum, Carex diandra, Cinclidium stygium, Cratoneuron spp., Drepanocladus spp., Juncus subnodulosus, Meesia triquetra, Menyanthes trifoliata, Valeriana dioica* and *Saxifraga hirculus*, which are undoubtedly important species, characteristic of at least some forms of alkaline fens that should be but are not included in this list (see also problem of Gorce Mountain flush fens described in Chapter 7). It also appeared misleading to experts that parallel to the list of characteristic species published by Koczur (2012, 2013), there is also another list of characteristic species used in ITP monitoring, and still another list of indicator species qualifying for appropriate variant of the agri-environmental program (see below).

4. Some subjectivity is inherent to taking phytosociological relevés. It is known that differences between relevés made by different observers at the same plot can be significant (Pawlaczyk, Kujawa-Pawlaczyk 2017 and references cited therein). This subjectivity cannot be completely eliminated because it stems from the very method of phytosociological relevés and unsurpassable phytosociological and psychological circumstances of observers. However, this influence could be reduced by, for example, inter-calibration exercises or assuring that observations at the same plot are taken by the same observer.
5. The observer's competence in bryological studies is also very important since in alkaline fens the best indicator species and also their most interesting peculiarities often belong to mosses, not to vascular plants. Thus, it is important that the expert who performs the survey should have proper skills and experience. Looking for mosses requires concentration and time, bending over, searching through herbaceous vegetation while their spotting requires experience. Ordinary botanical knowledge is insufficient.
6. The estimated Braun-Blanquet cover-abundance scale is very useful for a description and comparison of vegetation, but its use for investigation of changes in species cover over constant plots leads to the loss of some information which need not have to be lost. In cover classes 1 and 2, even a five-fold change in species cover (clearly noticeable by an observer) may not be reflected by changes in cover classes. Besides, no mathematical operations can be carried out on classes of the Braun-Blanquet scale, so the change cannot be measured. Some, though not all of these limitations could be reduced by the Barkman modification splitting class 2 of the Braun-Blanquet scale into subclasses 2a, 2b and 2m. In addition, decimal Londo scale would have many advantages for monitoring studies because it allows for measuring the differences between relevés as mathematical differences of assessments (Pawlaczyk & Kujawa-Pawlaczyk 2017 and references cited therein).

**Calibration of some indices.** Calibration of assessments of some indices in GIOŚ methodology appears to be based on an idea of ideal and, at the same time, specific patches of alkaline fens and is not entirely correct for considering the diversity of such ecosystems in Poland. In particular:

1. The index *"overgrowth by trees and shrubs"* was calibrated very rigidly. In practice, it is difficult to distinguish "single trees and shrubs" (FV) from "tree and shrub cover to 15%". In many natural and well-preserved fens tree and shrub cover of 10 – 20% is normal and natural, and such a share remains stable. It was highlighted that in the Biebrza Marshes, overgrowth by shrubs and trees not always has to mean habitat damage: loose thickets maintained in this form by high water level (as a result of beaver activity) and browsing by elks, can still preserve biodiversity typical of the habitat (Weigle 2014). However, GIOŚ methodology requires U2 assessment when the threshold of 15% tree and shrub cover has been exceeded, and this rating cannot be worsened more when this cover increases.

2. Several indices, e.g., *"cover and structure of moss layer"* and "pH *value of surface peat layer"* are well calibrated for measurement of progress of surface acidification of alkaline fens. Indeed, in natural conditions this process is significant. However, in the current situation of alkaline fens in Poland, other trends are creating a much more serious threat. Many actual patches of this habitat at present assume the form of "peat-based meadows with moss fen elements" and a real threat to them is related to the disappearance of the moss fen component due to incorrect mowing regimen (e.g., leaving biomass on surface, too early or too low mowing). However, calibration of the above-mentioned GIOŚ indices (also the index *"the number of characteristic species"*) causes that the status of such patches is initially assessed as poor (U2) and further worsening of their condition cannot be properly underlined.
3. The cardinal pH indicator is calibrated adequately to surveys from calcareous hydroecological systems of southern Poland and Slovakia. But, typical moss vegetation can also develop at pH 6-7 (Sjörs 1950), and in northern Poland these situations are quite typical (compare eg data from Rospuda valley: Pawlikowski et al. 2010, Jabłońska et al. 2011, Chapter 2.6 in this publication). Perfectly developed and preserved moss mires will receive an unfair unfavourable (U1) status score.

If the status of each index is described in detail and not only the assessments are recorded, then this problem does not hinder monitoring. However, improper and cursory interpretation of monitoring results can suggest the need for implementation of conservative measures (e.g., tree removal) where they are not legitimate or can mask negative changes and the need for action (e.g., correction of the mowing scheme or introduction or return to mowing) at other patches.

### 11.1.4. GIOŚ methodology as the basis for planning and organization of local monitoring

In spite of some above-mentioned problems, GIOŚ methodology has a great advantage in that it sets a nationwide standard for habitat 7230 monitoring, which additionally is coherent with the conservation planning approach. For this reason, this method can be recommended as the core of local monitoring organized in every Natura 2000 site. However, the objective of local monitoring is slightly different to the objective of a nationwide survey within the State Environmental Monitoring, namely we wish to possibly quickly identify changes occurring at individual locations, and not only to obtain synthetic assessment of conservation status of the habitat in the country. For this reason, the mere implementation of GIOŚ methodology in local monitoring is insufficient. Efficient monitoring at a location(s) in a Natura 2000 site requires, in accordance with general assumptions of GIOŚ methodology and monitoring of a set of indices, at least the following extension modifications:

1. Permanent marking of the beginning, middle and end of each transect in the field.
2. Using extended quantitative scales in the description of vegetation (phytosociological relevés) which will assure that information about discernible cover changes is not lost.
3. Additional continuous monitoring of water level with the use of a probe(s) (Divers) placed in observation pits, at least at one point on the transect (see also, hereinafter, the chapter about monitoring of water conditions).
4. Complementary monitoring of tree canopy cover all over the habitat patch, based on photographic data interpretation (drone photographs or comparison of aerial or satellite photos and LIDAR representations from data for Poland in different timeframes), and also the use of remote sensing techniques for assessment of changes in the habitat area.
5. A detailed description of the value of each index, and not only recording the assessment itself, in-field assessment of the changes having occurred from the last survey, if possible assuring that consecutive surveys are performed by the same researcher.

Monitoring organized in this way will be slightly more expensive but will provide much better and more useful information for planning on each of the monitored fens, at the same time preserving compliance with nationwide GIOŚ methodology.

## 11.2. Monitoring of effects of agri-environmental and agri-environment-climate programs

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### 11.2.1. ITP methodology

Monitoring of the status of alkaline fens in Poland, besides the State Environmental Monitoring, is also carried out by the Institute of Technology and Life Sciences (Instytut Technologiczno-Przyrodniczy, ITP) within the program "Monitoring of environmental effects of agri-environment program" which is a part of the Multiannual Program entitled "Standardization and monitoring of environment-oriented endeavors, agricultural technology and infrastructural solutions towards safety and sustainable development of agriculture and rural areas." It is continued within the program "Technological and environmental endeavors towards innovative, efficient and low-emission management of rural areas 2016 – 2020" as the task "Monitoring of environmental effects of some tools of the Common Agricultural Policy implemented in 2014 – 2020 with special emphasis on agri-environment-climate measures."

The monitoring has been carried out from 2012 (with a one-year break in 2016) and encompasses habitats in agricultural use and wildlife refuges in agricultural landscape used sporadically or under strict protection. The basic aim of the surveys is to assess the impact of pratotechnical actions defined by requirements of agri-environment and agri-environment-climate program variants on the status of selected natural habitats, including alkaline fens (Jarzombkowski et al. 2015, 2017).

Monitoring is carried out on agri-environmental parcels declared for subsidy under Package 4 – "Protection of threatened bird species and habitats outside Natura 2000 areas." and Package 5 – "Protection of threatened bird species and habitats within Natura 2000 areas." Each variant of environmental packages imposes certain requirements as to the manner and frequency of habitat use. Alkaline fens are included in variant 4.2/5.2 Moss fens, 4.10./5.10 Lands of ecological use (agri-environment program within Rural Develpment Plan 2007-2013), and 4.6/5.6 Peatlands (agri-environment-climate task within Rural Development Plan 2014-2020).

Study parcels are randomly selected from among a pool of parcels declared each year by beneficiaries, whereof environmental documentation was submitted by experts to the Ministry of Agriculture and Rural Development or to the Institute of Technology and Life Sciences. Within the framework of Rural Development Plan 2007-2013, all parcels submitted every year declared as the habitat 7230 were monitored, while within Rural Development Plan 2014-2020, due to financial constraints, the majority of them were monitored.

Photo 128: Field observation on an agri-environmental parcel: a fen near Sarnetki village (Podlaskie region, NE Poland) (photo by E. Gutowska).

Monitoring surveys are repeated every 4 years, and observation begins after the first year of implementation of agri-environmental or agri-environment-climate measures, and ends in the following year after the agri-environmental commitment expired. Within the borders of an agri-environmental parcel selected for monitoring, three study plots, circular in shape with a 14.6 m radius and total area of 0,2 ha, are chosen in patches representative of the habitat. The centers of the study plots are not permanently marked in the field but they are positioned with the use of a GPS receiver (measurements are taken when PDOP < 2,5). If a parcel is smaller than 0,2 ha, its whole area is surveyed. If the shape of the parcel does not allow for delineation of circles of a 14,6 m radius, it is permissible to delineate atypical study plots the shape of which is left to decision of the expert in the field (Jarzombkowski et al. 2015, 2017). In the central part of the study plot, a phytosociological relevé is taken on the relevé plot measuring 5 x 5 m with the Braun-Blanquet method. Photographic documentation of habitat vegetation structure is prepared for the study plots and for the whole agri-environmental parcel.

As in the State Environmental Monitoring (see Chapter 11.1), the assessment of habitat status entails a description of habitat conservation prospects and assessment of the structure and function of certain components of the ecosystem using indices and parameters rated according to a three-point scale: FV – favourable, U1 – unsatisfactory and U2 – bad. The status of each of the three study plots is rated and these assessments are averaged to obtain the overall assessment for the whole study parcel, therefore each index and parameter is characterized by one value for the whole study parcel. Assessment of all indices and parameters should be carried out within the area of study plots, treated jointly, such as a description of the plant characteristics; abundance of all species is assessed using the Tansley scale (Tansley 1946) i.e., by classifying each species to one of the following categories:

- dominant,
- local dominant,
- co-dominant,
- common,
- common locally,
- abundant,
- abundant locally,
- occasional, scattered (single plants occurring all over the plot or on a majority of its area),
- rare (several to a dozen or so representatives),
- sporadic (1 – 2 representatives).

Some of the analyzed indices are considered to be cardinal, which means that their assessments have a crucial impact on structure and function of the habitat. They include: "characteristic species", "expansive herbaceous plant species", "presence of trees and tree saplings", "cover and species structure of mosses and liverworts", and "water supply". The remaining indices are of an auxiliary character.

The status of alkaline fens is assessed based on the following indices (Jarzombkowski et al. 2015, 2017):

**1. Characteristic species**

It is a cardinal index. The criterion for assessment of this index is defined by the presence of a characteristic floristic combination of plant communities representative of habitat 7230. The study plots are surveyed within the outlined study area, and if a characteristic species occurs outside the study plot, its presence is recorded but does not influence the assessment. The presence of 7 or more characteristic species is rated as FV, 4 – 6 as U1 and 2 – 3 as U2. The following species are considered as characteristic: *Baeothryon alpinum*, *Bryum pseudotriquetrum, Bryum neodamense, Bryum subneodamense, Calliergon giganteum, Campylium stellatum, Carex buekii, Carex buxbaumii, Carex chordorrhiza, Carex davalliana, Carex diandra, Carex dioica, Carex flava, Carex lasiocarpa, Carex lepidocarpa, Carex limosa, Carex rostrata, Chara vulgaris, Cinclidium stygium, Dactylorhiza incarnata, Eleocharis quinqueflora, Epipactis palustris, Equisetum variegatum, Eriophorum gracile, Eriophorum latifolium, Fissidens adianthoides, Gentianella uliginosa, Hamatocaulis vernicosus, Helodium blandowii, Juncus alpino-articulatus, Juncus subnodulosus, Limprichtia cossoni, Limprichtia revolvens, Liparis loeselii, Meesia triquetra, Menyanthes trifoliata, Orchis palustris, Paludella squarrosa, Parnassia palustris, Pedicularis palustris, Pedicularis sceptrum-carolinum, Philonotis fontana, Pinuicula vulgaris, Polygala amarella, Primula farinosa, Pseudocalliergon lycopodioides, Pseudocalliergon trifarium, Saxifraga hirculus, Schoenus ferrugineus, Schoenus nigricans, Scorpidium scorpioides, Sphagnum contortum, Sphagnum teres, Sphagnum warnstorfii, Stellaria crassifolia, Swertia perennis, Tofieldia calyculata, Tomentypnum nitens, Triglochin palustre, Utricularia intermedia, Utricularia minor, Valeriana dioica, Valeriana simplicifolia* and *Warnstorfia exannulata.* Abundance of all species is determined according to the Tansley scale. It is worth noting that both the list of species and scaling of this index are slightly different than in the State Environmental Monitoring (Koczur 2012). Moreover, the list of characteristic species adopted for monitoring of environmental impact of PRŚ and PRŚK is somewhat wider, but omits the following species: *Dactylorhiza majalis*, *Drepanocladus aduncus*, *Carex panicea*, *Carex pulicaris* and *Ctenidium molliuscum*.

**2. Dominant species**

This index characterizes the structure of plant communities. Dominance of characteristic species for the habitat among herbaceous plants and lack of dominance of expansive species is judged as FV, co-dominance of typical and other species and abundance or local dominance of expansive species is assessed as U1, while predominance of species that are not typical of the habitat gives it U2 status. Abundance of all species is determined according to the Tansley scale. This index is similar to that used in the State Environmental Monitoring.

**3. Expansive herbaceous plant species**

It is a cardinal index. This index characterizes the presence of expansive species in alkaline fens. Expansive species are defined as native taxons considerably widespread in the ecosystem and distorting its species structure. Whether or not a given species should be defined as expansive is left every time to the decision of an expert. The following species are often classified as expansive: *Phragmites australis*, *Filipendula ulmaria*, *Molinia caerulea*, *Mentha longifolia*, *Typha latifolia*, *Lysimachia vulgaris* and others. The lack or sporadic occurrence of expansive species is indicative of FV status, frequent occurrence or local domination is taken as U1, and their common occurrence or dominance all over the plot as U2. Abundance of all species is determined according to the Tansley scale. Valorization of this index is similar to that used in the State Environmental Monitoring, though it uses another scale.

**4. Invasive alien species**

This index characterizes the presence of invasive alien species in alkaline fens. Invasive alien species are defined as those listed by Tokarska-Guzik (2012). Lack or sporadic occurrence of invasive alien species is rated as FV, their occasional presence as U1, and more common occurrence or dominance all over the plot as U2. Abundance of all species is determined according to the Tansley scale. This index is similar to that used by the State Environmental Monitoring, although it uses another scale and more liberally treats sporadic occurrence of alien species.

**5. Indicator species**

The criterion of this index is defined as occurrence of characteristic species accepted by agri-environmental and agri-environment-climate programs as qualifying for inclusion into the variant "Moss fens" or "Peatlands" (e.g., Documentation 2014, Methodology 2015, see Tab. 8). The occurrence of 3 or more characteristic species, or 2 or more protected species, is assessed as FV, 1 – 2 as U1, and lack of these species as U2. Abundance of all species is determined according to the Tansley scale. This index has no equivalent in the State Environmental Monitoring.

Table 8. Lists of agri-environmental indicator species

| |
|---|
| **Indicator species for the variant "Moss fens" Rural Development Plan 2007 – 2013:** *Calamagrostis stricta, Carex buxbaumii, Carex canescens (curta), Carex chordorrhiza, Carex davalliana, Carex diandra, Carex dioica, Carex echinata, Carex flava, Calex lepidocarpa, Carex panicea, Carex pulicaris, Dactylorhiza spp., Drepanocladus spp., Epipactis palustris, Eriophorum angustifolium, Eriophorum latifolium, Helodium blandowii, Juncus filiformis, Juncus subnodulosus, Liparis loeselii, Menyanthes trifoliata, Paludella squarrosa, Parnassia palustris, Pedicularis palustris, Pedicularis sceptrum-carolinum, Pinguicula vulgaris, Polemonium coeruleum, Saxifraga hirculus, Scorpidium scorpioides, Sphagnum teres, Stellaria palustris, Tofieldia calyculata, Tomentypnum nitens, Triglochin palustre, Valeriana dioica, Valeriana simplicifolia.* |
| **Indicator species for the variant "Peatlands" Rural Development Plan 2014 – 2020:** *Andromeda polifolia, Aulacomnium palustre, Baeothryon alpinum, Baeothryon cespitosum, Calla palustris, Campylium stellatum, Carex buxbaumii, Carex canescens, Carex chordorrhiza, Carex davalliana, Carex diandra, Carex dioica, Carex echinata, Carex flava s.l., Carex heleonastes, Carex hostiana, Carex lasiocarpa, Carex limosa, Carex pauciflora, Carex rostrata, Chamaedaphne calyculata, Chara spp., Cinclidium stygium, Cladium mariscus, Comarum palustre, Cratoneuron filicinum, Dactylorhiza spp., Drepanocladus sendtneri, Drosera spp., Eleocharis quinqueflora, Empetrum spp., Epipactis palustris, Erica tetralix, Eriophorum spp., Fissidens adianthoides, Hamatocaulis vernicosus, Hammarbya paludosa, Helodium blandowii, Juncus alpino-articulatus, Juncus filiformis, Juncus subnodulosus, Ledum palustre, Ligularia sibirica, Limprichtia spp., Liparis loeselii, Lycopodiella inundata, Meesia spp., Menyanthes trifoliata, Orchis palustris, Oxycoccus palustris, Paludella squarrosa, Palustriella spp., Parnassia palustris, Pedicularis palustris, Pedicularis sceptrum-carolinum, Philonotis spp,. Pinguicula vulgaris, Pseudocalliergon spp,. Rhynchospora spp,. Saxifraga hirculus, Scheuchzeria palustris, Schoenus spp., Scorpidium scorpioides, Sesleria spp., Sphagnum spp., Stellaria crassifolia, Straminergon stramineum, Swertia perennis, Tofieldia calyculata, Tomentypnum nitens, Triglochin palustre, Utricularia spp., Vaccinium uliginosum, Valeriana dioica s.l., Viola epipsila, Warnstorfia spp.* |

**6. Dead organic matter (plant litter)**

This index describes the presence or absence of plant litter in the habitat which may be indicative of disadvantageous processes connected with the accumulation of dead organic matter. It allows for assessment of extensive use measures implemented in agri-environmental parcels. The lack of plant litter is advantageous for development of light-loving plants, and for this reason thickness of the accumulated biomass is measured without pressing it to the level of the fen. The lack of plant litter or its presence as a loose structure is judged as FV, layer thickness of 0,5 – 2 cm as U1, and plant litter thicker than 2 cm requires a classification of the index's status as U2. This index has no equivalent in the State Environmental Monitoring for habitat 7230, although it is used, for example, in monitoring of species linked with the habitat, such as *Liparis loeselii* or *Saxifraga hirculus*.

**7. Sward damage**

This index describes mechanical sward damage caused both by animals and human actions, and outlines its causes. Sward damaged over up to 5% of study plot area is rated as FV, over 5 – 10% as U1, and over more than 10% of the plot area as U2. This index has no equivalent in the State Environmental Monitoring, however it is important for monitoring of parcels in agricultural use because most often sward is damaged by agricultural measures implemented with the use of improperly chosen equipment.

**8. Artificial drainage systems**

Artificial drainage systems have an unequivocally negative impact on the status of alkaline fens, worsen water conditions and lower the groundwater table. This index describes the presence or absence of a drainage system on agri-environmental parcels and in their direct vicinity. Assessment of this index includes characterization of not only the drainage system but also its impact on water conditions in moss fens. No drainage ditches in the plot and within 50 m from it, and plot location outside of a drained complex, is judged as FV. If ditches up to 50 cm deep or deeper are present in the plot and within a distance of 50 m from it, but sluices and dams are functional or there are no ditches in the plot but it is located in a drained complex, the status is assessed as U1. When ditches deeper than 50 cm occur in the plot or it is located near a patch with the regulated river, the status needs to be judged as U2. This index is similar to that used in the State Environmental monitoring, but its valorization is different.

**9. Overgrowth of trees and tree saplings**

It is a cardinal index which is used for assessment of succession rate in the monitored habitat patch. Its assessment requires preparation of a list of trees and shrubs identified in the study plots and their distribution is characterized according to the Tensley scale. This index does not comprise *Juniperus communis*, while dwarf forms of *Pinus sylvestris* are treated liberally, which distinguishes this valorization from the methodology used in the State Environmental Monitoring. A lack or sporadic occurrence of trees and shrubs is taken as FV, their common occurrence or local dominance as U1, and copious occurrence or dominance are judged as U2. This index is similar to the one used in the State Environmental Monitoring, although its valorization is different.

**10. Cover and species structure of mosses and liverworts**

It is a cardinal index describing the degree of development of moss layer, which is a crucial element for peat formation. Moreover, the moss layer is a good index of changes in hydrological and hydrochemical conditions of the peat layer, and of light availability near the fen surface. To assess this index, it is required to evaluate moss cover specifying separately the cover of characteristic brown mosses (and alkaline-tolerant sphagnum mosses are included into this group, e.g., *Sphagnum teres*) (see Daniels & Eddy 1990, Dierssen 2001), sphagnum mosses and liverworts. If the moss layer covers more than 50% of the study areas, with over 70% of this layer occupied by brown mosses and alkali-tolerant sphagnum mosses, the status is classified as FV. Moss cover of 20 – 50% of study area and/or 20 – 70% contribution of brown mosses to the moss layer is judged as U1. Habitat patches where the moss cover is smaller than 20% and/or brown mosses cover 0 – 20% of study area are rated as U2. In addition, abundance of all species is determined according to the Tensley scale. A similar index is used in the State Environmental Monitoring, though its detailed scaling differs (e.g., inclusion of alkaline-tolerant sphagnum mosses).

**11. Habitat area in study plots**

This index describes the alkaline fen structure and characterizes its coherence by evaluation of the area occupied by index vegetation for this habitat. Values of this index can differ both between different habitat patches and between monitoring years. Its assessment is useful for observation of the entirety of changes resulting from alterations in habitat conditions and habitat 7230 disappearance. Parcels where the value of this index estimated over the study plots amounts to 80% or more are judged as FV, where this area ranges from 50 – 79% as U1, and the remaining parcels as U2. This index is equivalent to the index "Percent area occupied by the habitat in transect" adopted by the State Environmental Monitoring.

**12. Water conditions**

It is a cardinal index which is based on a single measurement of the level of water table on relevé plots (if the level is below ground level, a pit is dug to a depth of 50 cm). Before assessment, the results are averaged. In spite of the low precision of this method, it provides an opportunity for evaluation of the hydrological conditions in the fen. Water level ranging from +2 to -10 cm from ground level is judged as FV; slight flooding or groundwater table from -10 to -20 cm below ground level is rated as U1; flooding higher than 10 cm or a water table more than 20 cm below ground level is classified as U2. It is a cardinal index, analogical to that used in the State Environmental Monitoring.

**13. Structure of fen surface**

This index describes the spatial structure of the fen, in which tussocks may develop due to succession processes disadvantageous for the fen. The valorization distinguishes alkaline fens with low sedges, with tall sedges and post-bog meadows. This index is assessed as FV when there are no tussocks (habitat with low sedges and post-bog meadows) or if they occur over less than 40% of the study plot area while moss layer is well-developed (habitat with tall sedges). If low tussocks occupy less than 10% of the area of moss fen with low sedges or of post-bog meadows, then the status is judged as U1. In the case of fens with tall sedges, the status U1 is given when tussocks are tall and cover 40 – 70% of the area, and mosses of alkaline fens or *Calliergonella cuspidata* sporadically occur within them. The remaining cases (tussocks occupy more than 10% and 70% of area, respectively, and scarce moss layer occurs between them) are assessed as U2. This index is not included in the State Environmental Monitoring.

**14. pH range**

pH value indicates the alkaline character of fen waters which is crucial for the development of specific plant species. A low pH value is indicative of disadvantageous processes progressing in the habitat that may be connected, for instance, with hydrological disturbances. Water for analyses is collected either from the fen surface or it is squeezed from the moss layer. Three measurements are carried out in an agri-environmental parcel. If the pH value of at least two water samples is higher than 7, the status is judged as FV, while if it is lower than 6 as U2. The remaining cases are assigned to the U1 class. This index is equivalent to that used by the State Environmental Monitoring where, however, it is a cardinal index.

In addition, the State Environmental Monitoring contains the indices "Historic and present peat extraction" and "Habitat area at the site" which are not assessed in the monitoring of biological effects of agri-environmental and agri-environment-climate program.

The parameter "structure and function of habitat" is assessed using the above-described indices, according to a three point scale. "Conservation prospects of habitat" are also evaluated. Overall assessment based on these premises is equal to the lowest assessment ascribed to individual parameters.

Apart from the aforementioned indices and parameters, the monitored patches of habitat 7230 are also characterized by the identification of interactions, additional natural values and vegetation features. Reports on habitat status are provided by the Institute of Technology and Life Sciences, which carries out monitoring to the contracting authority, i.e., the Ministry of Agriculture and Rural Development.

### 11.2.2. Practical experiences

The basic assumption of monitoring of biological effects of the agri-environmental (PRŚ) and agri-environment-climate (PRŚK) program was to assure its compatibility with habitat monitoring within the State Environmental Monitoring. Therefore, the methodological frame of these programs was grounded on GIOŚ methodology (see Chapter 11.1.1), which is expressed in its similar structure and methods of habitat status assessment by evaluation of indices, parameters and interactions. Nevertheless, there are differences between these systems which results from the special character of the monitoring carried out by the Institute of Technology and Life Sciences

The most important difference relates to the **representativeness** of the habitat patches covered by the monitoring. Monitoring of environmental effects of PRŚ and PRŚK is carried out in parcels in agricultural use which are declared at the Agency for Restructuring and Modernization of Agriculture for agri-environmental subsidies. These parcels do not always comprise the whole patch of the habitat; most often only its part is included, while the vegetation development pattern depends of the parcel location. Monitoring covers both well-developed patches comprising the best preserved fen parts, patches situated at the edges of alkaline fens where vegetation to a different degree agrees with habitat 7230 characteristics, and also patches located in varied landscapes where moss phytocenoses form a mosaic with reeds, meadows and others or have a transient character.

The agri-environmental parcels declared for subsidies are not always located in Natura 2000 sites, thus this monitoring covers not only the best developed habitat patches but also atypical, degrades and isolated ones.

When selecting the monitoring sites, an expert is required to choose such places which are representative of habitats present on the parcel, both in terms of floristic composition and spatial distribution. However, this requirement is not always met as in many cases the habitat area limited to the agricultural parcel hinders a subjective approach to the assessment.

In consequence, monitoring of habitat 7230 status carried out by the Institute of Technology and Life Science encompasses an array of different forms of the habitat, thus it seems to provide a better insight into the status of moss fens than in the State Environmental Monitoring (see Chapter 11.1.1). On the other hand, it bypasses the forms of alkaline fens that do not qualify for agricultural use, e.g., small areal spring fens, forest swamps or all mires possessed by owners not interested in agri-environmental subsidies; for instance there are no monitoring sites in western Poland.

Issues related to **repeatability** are similar here as in the State Environmental Monitoring. Since the aim of the monitoring was to collect data from all over the country there was no need for permanent marking of the monitoring sites. The used equipment assured accuracy of about several meters which in certain cases precluded precise positioning of earlier study sites. Moreover, due to agricultural land use, it sometimes happened (haystack, rutted road) that to repeat an observation, the study site had to be moved and located nearby. Nevertheless the accepted procedure is useful for drawing conclusions about the whole country, which should be borne in mind while analyzing datasets.

Assessment of **water conditions** in the State Environmental Monitoring has been thoroughly discussed in Chapter 11.1. The ITP monitoring of environmental effects of PRŚ and PRŚK required reading of the water table in soil pits and to express them in centimeters; however, due to shortage of financial resources, the essence of the survey, as in PMŚ, is that single measurements are carried out which provide only a snapshot of the status at the time of the expert's visit. The obtained information is insufficient for assessment of most of the habitat 7230 patches, however it can warn about disturbances in some of them. If the measurement results demonstrate a significant lowering of the water table below the fen surface, it can suggest that water conditions of the fen have been distorted (see Chapter 5 on ecosystem ecology).

**Habitat overgrowth by trees and shrubs** is assessed by visual estimation also in the monitoring of environmental effects of PRŚ and PRŚK, however another method of site location compared with the State Environmental Monitoring, which often limits subjective assessment, could influence the obtained results.

In spite of the low precision of this method, the obtained information was sufficient for evaluation of protective measures which had to be implemented in the variant comprising moss fens and peatlands. Analysis of the data collected for an individual agri-environmental plots seems to be unfounded, but drawing conclusions for the whole country based on the used procedure can bring tangible effects.

Both monitoring of natural habitats in the State Environmental Monitoring and monitoring of the environmental effects of agri-environmental and agri-environment-climate schemes carry a risk of a subjective approach to the assessments of the indices. Similar problems are encountered, including: the lack of a closed list of expansive species, for obvious reasons, which leaves room for unequivocal interpretation of the index describing these species, the index of water level is measured only once during the expert's visit, and all areas are not actually measured but estimated. Moreover, a three-point scale used for assessment in some cases appears to be insufficient for proper characterization of the habitat status, however it is a compromise between the needs and the resources allocated for monitoring.

Regarding the Braun-Blanquet scale, it was proposed to introduce in the future the Barkman correction which divides class 2 of the scale into subclasses 2a, 2b and 2m, which would significantly improve data quality; however, realization of this postulate is not certain, yet (Jarzmbkowski F. – oral information).

On the other hand, in terms of a limited number of experts who carry out habitat 7230 monitoring, the use of standardized equipment and the application precluding the inclusion of data from outside the lists, no problems were encountered with pH measurements (lack of some data resulted from an inability to perform measurements due to e.g., draught) or with the possible addition of characteristic species not included in the methodology.

The monitoring program also included methodological training conducted every year aimed at a unified approach to different issues. However, such training was not organized in the last two years due to financial constraints. Therefore, there still remains a problem with subjectivism connected with knowledge and accuracy in performing the tasks by different experts. However, in the case of habitat 7230, a vast majority of sites were heretofore assessed by a limited group of specialists particularly proficient in examining this habitat, which contributed to obtaining a rather uniform dataset regarding alkaline fens.

## 11.3. Monitoring of water conditions

***Filip Jarzombkowski, Ewa Gutowska, Katarzyna Kotowska***

Hydrological conditions are of particular importance for the functioning of alkaline fens (Sjörs 1950). Therefore, they should be monitored both when conservation measures are planned to be implemented and during every-day management and control of individual habitat patches.

Alkaline fens are fed by groundwaters flowing out of impermeable aquifers, most often through layers cracked by ridges of river valleys or through the so-called "hydrological windows" (Godwin et al. 2002, Dembek & Oświt 1992). In some cases water comes out under pressure, which is termed a confined water table, sometimes the pressure is high enough that for hundreds of years cupola mires, even up to several meters high, can form around water outflows (Okruszko 1982, Dembek 1993, Dembek 2000). In addition, water is supplied to alkaline fens also from precipitation, including runoff from surrounding terrains, and in some cases also from rivers or lakes which periodically flood adjacent ecosystems (Dembek & Oświt 1992). Therefore, waters percolating through the fen, called unconfined groundwater, are a mixture of groundwater, precipitation water and others, but in the case of moss fens, prevailing mineralized groundwater supports the development of calciphilous vegetation.

The level of the groundwater table in fens is variable and can fluctuate by even 1 meter depending on atmospheric conditions, type of water supply, type of peat, presence of drainage systems and use type (Ilnicki 2002). Information about the depth of the water table is very significant (but not solely) for evaluation of water availability to plants; however, for reasons of simplicity, we will use this value. In practice, if the groundwater table is at 20 cm below the fen surface, then due to capillary rise facilitated by specific fibrous structure of peat, the entire peat profile could be saturated with water which is available to plants. Capillary rise rates are variable and depend on, for example, peat type and degree of decomposition (Szuniewicz 1975, Ilnicki 2002), thus, humidity of the surface layer of soil is usually different than might be deduced from the groundwater level.

It should be remembered that different plant species have diverse requirements for water availability, roots at different depths and variable resistance to drought stress (e.g., Ellenberg 1991). Periodical subsidence of the groundwater table usually does not create problems for a majority of fen plants, but the recurrence of such a situation or permanent lowering of the water table can significantly affect the floristic composition of phytocenoses (Jeglum 1974, Ilnicki 2002, van Diggelen et al. 2006).

When conservation measures for habitat 7230 are planned to be implemented, understanding of the hydrogeological conditions will further their better adjustment; however, if the situation is obvious or when there are drainage ditches in the moss fen, it is not necessary to postpone conservation measures until hydrological results become available. As mentioned in Chapter 5, the presence of drainage ditches in the fen indicates habitat disturbance and is not a natural feature, thus improvement of fen status should be a priority. However, it is always advisable to monitor the effect of the conservation measures.

Hydrological monitoring on alkaline fens should be based primarily on regular measurements of the groundwater table position. The one-off studies are not enough for understanding hydrological circumstances. It is crucial to know how the water level in peat changes both in the annual cycle and in response to hydrological events, e.g., precipitation. Stable water level measured relative to the mire surface is usually a good indicator of the condition of the mire. That is why as more significant unsatisfactory should be considered the research methods described above used in State Environmental Monitoring and monitoring of ecological effects of agri-environmental and agri-environmental-climatic programs, which only assume a rough assessment of the position of the water table once every few years.

In hydrology, it is assumed that the "hydrological year" begins on November 1st of the previous calendar year and ends on October 31st. This approach is linked with retention of snow and ice which in the form of melt water become available usually not earlier than in the next year. In order to understand hydrological condition in a fen, it is needed to carry out a series of observations spanning over at least a hydrological year. Longer surveys provide more complete data and show, for instance, how a fen functions in dry and wet years, which allows for averaging hydrological conditions for a given ecosystem, and to obtain data independent of differences in the annual precipitation in consecutive years. Moreover, such data demonstrate in which way and how fast the fen responds to dry and wet years.

Observations can be carried out throughout the year and their frequency should be chosen according to information needs. When we use automatic measuring devices of a "Diver" type, recording the frequency of parameters can be freely programed; however, at too high a frequency, too much data are generated and wear of the device and battery power consumption increase. Often data are recorded once per 24 h at a constant hour which can provide a good overview of long-term changes. More detailed data can be obtained with recording of the water level every 6 h, e.g., at 0.00, 6.00, 12.00 and 18.00, while data recording every hour allows for measurement of, for instance, evapotranspiration of water by vegetation (Grygoruk et al. 2011) (of course, it is valid only if we observe a dry period and a piezometer is built appropriately for such a task, i.e., with shallow piezometer screen depth).

In the case of manual measurements, it would be most beneficial to carry them out every day at the same time, but if it is not possible due to financial shortages, a 10-day cycle is an indispensable minimum. However, in this case important information about diurnal changes is lost, e.g., about fen response to precipitation episodes. A survey should be as long as possible because of changeable weather conditions in different hydrological years.

Measurements are best performed using piezometers, which are pipes perforated at an appropriate depth, isolated from the peat by a membrane. They are set vertically in the peat to accumulate water at a depth corresponding to actual water table. An automatic device of "Diver" type installed inside the piezometer measures the pressure of the water above it and ambient atmospheric pressure. It is also indispensable to install a second device measuring only atmospheric pressure (the so-called "Barodiver") to be able to calculate water pressure which is indicative of groundwater table depth. Depending on the device manufacturer, the Barodiver can be combined with Diver or can be a separate device. The device records data according to the programed rhythm and saves them in its memory; they can be read at longer intervals, e.g., once a year, but due to a risk of equipment failure, a read-out is recommended at six-monthly intervals.

Manual measurements are carried out with a level indicator (a simple device lowered on a line to the piezometer tube which signals with a sound when the probe touches the water surface), while with a shallow water table, estimation can be made visually using a measuring tape.

The greatest accuracy of results can be achieved when measurements are taken automatically, in which case we also avoid treading on the fen surface in close vicinity of the piezometer, which can sometimes contribute to distortion of the obtained data in relation to actual values.

The method of piezometer installation has to be planned in accordance with the kind of information that is to be collected. Most often piezometers are set in peat in such a way as to allow the piezometer to move with the vertical movement of the fen surface. Piezometers of this kind measure water table depth in relation to fen surface (the height of the piezometer riser above the peat surface should be periodically controlled) which well characterizes e.g., conditions for plant growth, but cannot provide information about the absolute ordinate of water level. If piezometers are set in the mineral substratum underlying the peat to prevent its vertical movement, then the obtained results will reflect the absolute level of the water table but we will have no information about water depth in relation to fen surface (Pawlaczyk & Kujawa-Pawlaczyk 2017).

The results of piezometric measurements sometimes depend on piezometer screen depth in peat. It is connected with water movement within the fen which can be especially important for ecosystems fed by groundwaters. In such a situation, it happens that deeply set piezometers can be affected by artesian and subartesian wells. Observation of this phenomenon requires using, for instance, double piezometers set at different depths (Pawlaczyk & Kujawa-Pawlaczyk 2017): deep piezometers reflect most of all groundwater feeding from the fen bottom, while shallow ones are useful for e.g., evapotranspiration studies (Grygoruk et al. 2011).

Proper planning of measurements requires also designation of measurements sites in the field. The number of sites should depend on fen type and size, available financial resources and the endpoints we plan to achieve. It would be best if the choice of piezometer locations could be preceded by preliminary visual examination – from where water flows out, where it appears and where and how fast it flows out. Initial exploration of the field should be repeated in different seasons, taking account of both dry and rainy periods. In this way the main water outflow patterns can be discovered, like for instance drainage ditches creating the greatest risk to the fen. Places of groundwater discharge can be identified with the same way e.g., springs or constant seepage from beneath scarps. In all those methods, the stability of these phenomena throughout the year and in different weather conditions can be evaluated.

In a best case scenario, the water level should be measured in the whole ecosystem with surroundings so as to be able to efficiently understand ongoing ecological processes. The location of measurement points should create a coherent network either based on transects or forming a regular network covering the fen. The transects, if possible, should be positioned along a straight line from the fen edge to its center where the moss fen patches under investigation have developed, and if there exists a water receiver (river, lake, common ditch), also perpendicularly to it. However, if due to financial constraints it is not possible to maintain constant distances between the measurement points, then it would be optimal to set at least one measurement point in each identified vegetation type. The measurements of the water table with piezometers should be accompanied by observations of the water table in neighboring ditches, water courses and lakes, which can

Photo 129: Installation of a piezometer with a measuring device
(photo by E. Gutowska).

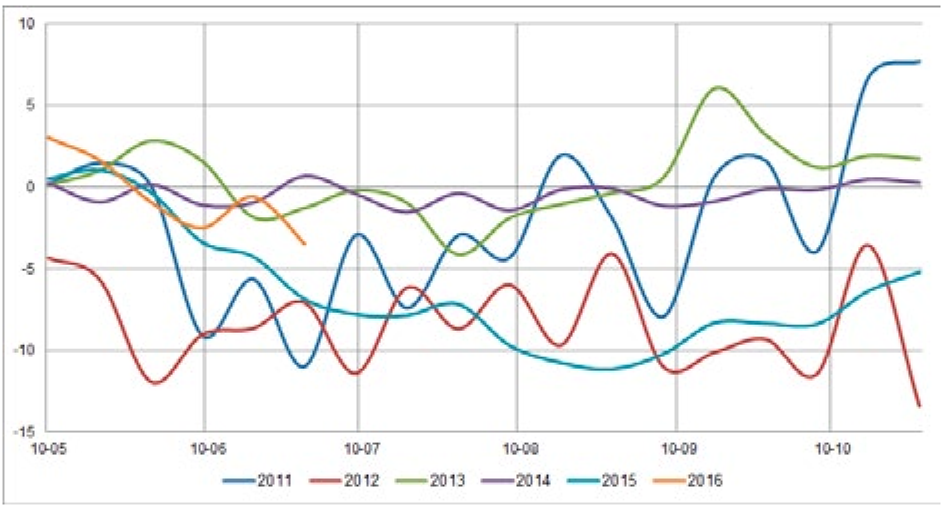


Fig. 52. Annual average results of a hydrological survey during the vegetation season in the alkaline fen in the Rospuda river valley. Different colors mark consecutive hydrological years.

also be performed with the use of automatic measuring devices. It is also useful to periodically measure water flow in ditches and water courses since this provides important information on water outflow from the fen; they are usually carried out manually or using different flow meters several times a year.

In the case of an equipment shortage, studies can be limited only to surveyed patches of habitat 7230; however, limitations related to incompleteness of the information obtained in this way should be borne in mind.

If the aims of observations include, besides hydrological monitoring, a full understanding of the water balance in the fen, it is needed to extend observations by other components of the water cycle. In addition to the network of piezometers – which allow for determination of water inflow and outflow – precipitation and evapotranspiration should also be estimated. These data are best collected with the use of research stations located as close to the fen as possible or directly in the fen. Currently, research stations can receive energy supply from batteries or from photovoltaic panels which practically do not require attendance. They can be used for measurement of precipitation, temperature, atmospheric pressure, solar radiation intensity, soil temperature and humidity or evapotranspiration. Lacking an own station, data can be used from the nearest station of the National Hydrological & Meteorological Service measurement-observation network[17], although they are usually available as archival data and posted with some delay.

The obtained data can be analyzed in different ways. Both short-term variability of the level of the water table and trends averaged for decades are significant (Fig. 52) Analysis of the collected data, depending on the measurement network, should involve the creation of maps of the averaged levels of the groundwater table for different periods, or at least a graphical presentation of the variability of the water table in the hydrological year. These data should be combined with the bulk of precipitation recorded for this area and analyzed in connection with them. It can also be attempted to create maps of slopes and surface run-off directions, which in some situations will be helpful in management of the moss fen resources.

In alkaline fens, it is also deemed advisable not only to monitor water level but also water characteristics, e.g., chemical and physicochemical parameters (see also Chapter 2.6 and Chapter 11.3). The frequency of these studies does not need be high – several times a year as a maximum is sufficient. The water for analyses should be collected from the upper groundwater of the fen; best it can be collected from piezometers (that are preferably made of inert materials). Before the procedure, stagnating water should be pumped out of the piezometer and samples should be collected after its refilling. As an auxiliary measure, water samples from groundwater discharge, water from drainage ditches or from streams flowing out of the fen can also be analyzed. However, analyses of water stagnating in puddles appear to be of limited use, since they usually contain precipitation water.

17 https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne/

Photo 130: Measurement station with evapotranspiration measuring container (photo by E. Gutowska).

Basic parameters that should be measured in the field with an appropriate device include: temperature, pH and electrolytic conductivity (reflecting the contents of ions). This basic information allows for initial identification of the sources of water inflow to the fen while knowledge of the changes in these parameters may hint at the dynamics of water supply. Permanently low water temperature throughout the year can suggest its groundwater origin, like high pH (often connected with the presence of calcium ions). On the other hand, acidic pH value suggests progression of acidification processes, disadvantageous for vegetation typical of alkaline fens. Low electrolytic conductivity is characteristic of precipitation water, while its level exceeding 400 – 500 μS/cm suggests strong mineralization typical of groundwaters.

Analysis of the remaining water characteristics usually requires sample collection and their laboratory analysis. Water parameters vital for alkaline fen functioning include the level of calcium and magnesium ions, content and proportions of potential biogenes: nitrogen and phosphorus and concentration of potassium, iron and aluminum ions. The character and peculiarities of alkaline fen vegetation can be strongly determined by geochemical features (see e.g., Chapter 2.6 and literature cited therein), therefore monitoring of trends and changes in abiotic conditions seems also to be meaningful.

Ecohydrological evaluation of alkaline fens can be broadened in many ways, and each of them provides valuable information useful for the most appropriate planning of its conservation. Such evaluation ideally should encompass not only the fen but also its landscape context, which requires groundwater probing in the catchment. Monitoring of water temperature or calcium and sulfate ion contents at different depths in the fen surroundings informs of the intensity of groundwater discharge to the fen (Grootjans et al. 2006, Wołejko & Grootjans 2004); this helps understand the fen functioning and to plan conservation measures. In some situations, these parameters may be indispensable for the choice of proper conservation schemes, and their changes may warn us against threatening hazards.

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