RICH FENS AND POOR FENS IN THE SOUTH-EASTERN CARPATHIAN REGION OF ROMANIA – REFUGIA FOR RELICT SPECIES

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Abstract. With the exception of the oligotrophic marshes (peat bogs), the Romanian literature makes too little distinction between fens and the rest of the eutrophic wetlands in the country. Therefore, this article aims to contribute in understanding the formation, the ecological and the floristic peculiarities of the alkaline and transitional eutrophic mires, known as rich fens, respectively poor fens. At the same time, like the peat bogs, the fens have become an important refugia for many glacial relicts, found today only in the boreal and arctic-alpine regions. The paper offer some new contributions through the research of these fens regarding the postglacial refugia in the South-Eastern Carpathians and reports of new species for some areas. Eight major regions comprising rich fens and poor fens have been identified that still retain somehow their archaic character by conserving many species considered to be glacial relicts. At the same time, these regions thus became true postglacial refugia of relict species, which have managed to maintain a local microclimate favorable to the perpetuation of these plants. Fens are among the most endangered wetland ecosystems in the country. They require strict protection and reassessment of their surface, flora and vegetation, as the vast majority of them have been severely affected by human activity in recent decades.

Keywords: rich fens; poor fens; postglacial refugia; South-Eastern Carpathian region; Romania.

INTRODUCTION

The marsh is an unventilated aquatic formation in which the plant remnants transform into peat, instead of rotting or mineralizing, forming a peat deposit at the bottom of the soil [80]. These areas are constantly or frequently flooded by water, being fed by groundwater and rainfall. They are rich in minerals and nutrients, with a usually neutral pH [20].

In general, the concept of peat does not refer strictly to sediments formed from the well-known peat moss (*Sphagnum*). Eutrophic marshes have other types of peat made up of different plant species. Thus, the eutrophic peat is usually made by different types of plants. Therefore, we can distinguish the reed peat (*Phragmites*), the sedge peat (*Carex*), and other kinds of peat made mostly by species of eutrophic mosses. The oligotrophic marshes have other types of peat, including the more common *Sphagnum* peat, the *Eriophorum* peat and the *Scheuchzeria* peat. Poor fens also have different peat like the *Carex* and *Sphagnum* peat, *Polytrichum* peat and the moss based peat with wood (from pine, alder, birch) [80, 107].

The rich fen

Alkaline marshes (rich fens) receive their nutrients and water source from mineral-rich springs and through groundwater movements, less from rainfall. They have a pH higher than 6. Their main character is the formation of peat sediments. They differ from peat bogs by being less acidic and with more nutrients, which support a high diversity of organisms. Over time, the peat can separate the fen from the groundwater source, which will cause it to turn into an oligotrophic marsh. The water level is not depending on the amount of rainfall, it can fluctuate or remain constant. The woody vegetation is entirely missing. These fens are usually located away from surface waters (lakes, ponds). They are formed nearby the valleys of some rivers or above some geological faults, where, through the ruptures of the rocks and the sediments of the substrate, very cold springs of water arrive to the surface from the deep aquifer reserves. They can form also on former lakes on a calcareous substrate [33, 94, 20].

The rich fens are characteristic of a colder and very humid climate, where heavy rainfall creates large accumulations of water. The formation of these fens takes up to 10,000 years [20]. The Carpathian region is on the periphery of these ecosystems specific to the northern latitudes, being less and less encountered to the southern latitudes [33].

The calcareous springs, rich in calcium and bicarbonate, constantly deposit travertine (calcite, calcareous tuff) on the surface of the fen. The peat covered travertine, deposited above, often becomes impermeable and helps the movement of the water flow on the surface [33]. The fens that form around the mineral springs are called "borcuturi" in Szeklerland (Eastern Transylvania), where the spring often forms a cone with travertine deposits that rise above the marsh, giving it a characteristic appearance [80]. The waters are very rich in dissolved minerals and very poor in nutrients, being among the richest wetlands in terms of biodiversity. At the same time, they are among the most endangered ecosystems in Europe where rare and endangered plant communities are found [32].

Changes in the vegetation of these fens can be put to the effects of climate change, anthropogenic and natural changes in the biotope [24]. The intensely mowed and drained alkaline marsh become an alkaline meadow, which over time lose the ability to produce peat. As a consequence, these fens are also losing their biodiversity. Anthropogenic activities have led to the reduction of these rich fens in the Carpathian region. Slovakia had an area of 260 km^2 covered by such marshes in the past; now it has only 5.8 km^2 [33].

Rich fen species

The main dominant cenoses are composed of species of Cyperaceae and different types of mosses (*Bryum, Campylium, Drepanocladus, Philonotis, Scorpidium, Calliergonella* and *Meesia triquetrum*) [104, 36]. The edifying species of rich fens are: *Carex davalliana, C. dioica, C. flava, C. hostiana, C. lepidocarpa, Schoenus nigricans, S. ferrugineus, Blysmus compressus, Eriophorum latifolium, Cladium mariscus* subsp. *mariscus* and *Sesleria uliginosa*. The main indicator species are: *Tofieldia calyculata, Primula farinosa, Juncus alpinoarticulatus, Dactylorhiza incarnata, Epipactis palustris, Eleocharis quinqueflora, Equisetum variegatum, Parnassia palustris, Pinguicula vulgaris, Selaginella selaginoides, Swertia perennis, Triglochin palustris, Valeriana simplicifolia* [107, 48].

The poor fen

These wetlands are intermediate between alkaline eutrophic and acidic oligotrophic marshes. Hydrologically, they are similar to rich fens, but in terms of vegetation and chemical composition are closer to peat bogs. They are more acidic, with a pH of 5.5 to 4. The deposited peat is thicker, limiting the access of vegetation to underground mineral springs, which also can no longer influence the pH of the fen. As a result, the fen becomes dependent on atmospheric precipitation. Even with the domination of the peat mosses (*Sphagnum*), these poor fens have a much higher species richness than the typical oligotrophic peat bogs [94].

Poor fen species

Short sedges are characteristic of these marshes, while a compact carpet of moss is formed at the surface of the soil. It can sometimes consist exclusively of *Sphagnum* and *Drepanocladus* mosses. They are found in areas with constant water and few organic substances. Among the edifying species are: *Carex nigra, C. lasiocarpa, C. rostrata, C. echinata* or *Eriophorum angustifolium*, along with *Parnassia palustris, Comarum palustre, Potentilla erecta* [107]. In the Ciuc Depression, *Drosera anglica, Drosera × obovata* and *Saxifraga hirculus* appear on the cushions of *Sphagnum magellanicum* and *Tomentypnum nitens* mosses [49]. In the Carpathian depressions (Dorna, Drăgoiasa, Bilbor, Borsec, etc.), these habitats are often found in the continuation of oligotrophic peat bogs where they shelter species such as *Salix starkeana, Ligularia sibirica, Pedicularis sceptrum-carolinum* or *Valeriana simplicifolia* [80, 62].

Refugia for relict species

Archaic fens are true glacial refugia, housing a number of species adapted to rare ecological conditions. All these species have a very disjointed area along the European continent, occurring together in the island habitats of these fens [40].

According to Csergő [9], these refugia are areas where local climatic conditions, due to the environment, tend to be resistant to changes in the general climate. This climatic resistance prevents the installation and proliferation of vegetation influenced by the general climate, which helps the survival and perpetuation of species adapted to local climatic conditions, many of which are reminiscent of past periods. The plant species found here may come from very different time periods, but they have one thing in common - they are adapted to climates with particular conditions and are very uncompetitive compared to common species over a period of time. The only plants that are found here, either evolved at the same time as the environmental changes, or arrived here in certain more favorable climatic periods and due to some morphological peculiarities they managed to survive. Some emblematic species like the arcto-alpine *Tofieldia calyculata* managed to found a refugium in the rich fens of Valea Morii near Cluj-Napoca at 600 m altitude, being the only certain population in Romania [8]. The other populations mentioned in the Făgăraș Depression are now extinct due to the transformation of the fens into agricultural land, while those from Făgăraș Mts. were not confirmed [19]. The now extinct single population of the alpine species *Saxifraga mutata* subsp. *mutata* at Stupini – around 500 m altitude (near Brașov) was a reminiscent of the cold glacial periods when the high mountain species descended to lower altitudes. This species is only known from the Alps and Western Carpathians [66].

These refugia are often responsible for the formation of endemic species, with a clear correlation between the number of endemics and the age of the surrounding flora. Due to the specialization and adaptation to the particular conditions of the refugium, the populations of these species cannot expand outside the area created by the refugium, remaining isolated. Thus, the refugia presents an impressive floristic richness, correlated with their antiquity. These refugia, offering multiple ecotopes and microclimates, are considered floristic hot spots, which accumulate the flora of several historical periods, while the rest of the landscape forms that support a low number of habitats, usually reflect the vegetation of the current climate [9]. In Romania, *Armeria maritima* subsp. *barcensis*, *Allium ericetorum* subsp. *pseudosuaveolens* or *Cochlearia borzaeana* are such endemic species restricted to a number of rich fens and calcareous springs.

For today's glacial relicts, these sites are known as postglacial (e.g. interglacial) refugia [14]. The conditions in these refugia are harsher for most current temperate plants, being similar to those in the cold periods. The postglacial refugia is somewhat limited to a smaller area (scattered local microhabitats or distinct orographic units, mostly swampy plains, valleys and mountain depressions).

The long time in situ persistence of populations is determined by how long the optimal climatic conditions are kept unaltered. Unlike preglacial relicts, which are found in various geographical units that allow the survival of some species from different climatic periods, due to the landscape and altitude, the Holocene relicts are often limited to very small areas (marshes, screes). Those regions whose climatic conditions have a relative stability, have not only many climate relicts but also endemic species [42].

The topography, the peculiarities of the soil or the structure of the vegetation help to maintain optimal climatic conditions of the refugia. Marshes, lakes and springs are the main thermoregulatory elements of a refugium. The temperature in the center of the fen is often lower than its edges. Also, the height of the vegetation is another element that can reduce the temperature by a few degrees at the base of the soil. The same can be said about the humidity of the air, a high and compact vegetation preventing evapotranspiration [42].

Researched territory

The researched region completely overlaps to the area of the Carpathian region in Romania. The general name of the Carpathian region includes the Transylvanian Depression, which is a major component of the Carpathian region [50], as well as the adjacent hills and plateaus outside the Carpathian arch. This delimitation continues the acceptance of the latest scientific documents [46, 50].

MATERIALS AND METHODS

In order to identify the areas of fens and the chorology, all the available literature was researched. The plant nomenclature used in the study is based on Ciocârlan [5] and Sârbu et al. [97]. Glacial relicts are taken from the Romanian and the Carpathian region literature [80, 81, 82, 5, 71, 118, 15, 37, 4]. For more details about the relict species in the study see Table 1.

Table 1. Glacial relict species encountered in the regions dominated by rich and poor fens in Romania

Nr. crt.	Relict species	Wetland affinity in Romania	Cited as glacial relict species in
0	1	2	3
1.	*Achillea impatiens*	Marsh	[81, 118]
2.	*Adenophora liliifolia*	Marsh/Tall-herbs community	[80, 14]
3.	*Andromeda polifolia*	Bog	[81, 118, 14]
4.	*Angelica palustris*	Marsh	[81, 118, 71]
5.	*Armeria maritima* subsp. *barcensis*	Rich fen	[81]
6.	*Betula humilis*	Marsh, Rich fen	[81, 118]
7.	*Betula nana*	Bog	[81, 118, 14]
8.	*Betula pubescens*	Bog, Poor fen	[80, 14]
9.	*Calamagrostis canescens*	Marsh	[81, 14]
10.	*Calamagrostis stricta*	Marsh	[81, 118]
11.	*Calla palustris*	Marsh	[81, 14]
12.	*Carex appropinquata*	Marsh	[81, 14]
13.	*Carex capillaris*	Marsh, Rich fen, Poor fen	[4, 14] Unpublished (in press)
14.	*Carex chordorrhiza*	Marsh, Poor fen	[118, 14] Unpublished (in press)
15.	*Carex davalliana*	Rich fen	[80]
16.	*Carex diandra*	Marsh	[81, 118, 14]
17.	*Carex dioica*	Rich fen	[81, 118, 14]
18.	*Carex elongata*	Marsh, Poor fen, Bog, Alluvial forest	[81]
19.	*Carex hartmanii*	Marsh	[80, 5, 118, 14]
20.	*Carex hostiana*	Rich fen	[37] Unpublished (in press)
21.	*Carex lasiocarpa*	Bog, Poor fen	[14] Unpublished (in press)
22.	*Carex limosa*	Bog, Poor fen	[81, 118, 14]
23.	*Carex loliacea*	Poor fen, Bog	[81]
24.	*Carex magellanica* subsp. *irrigua*	Bog, Marsh	[81, 14]
25.	*Carex pauciflora*	Bog, Poor fen	[81, 14]
26.	*Carex vaginata*	Rich fen, Marsh	[15, 14]
27.	*Chimaphila umbellata*	Taiga species, occasionally in humid shrubs	[118] Unpublished (in press)
28.	*Cladium mariscus* subsp. *mariscus*	Rich fen	[78, 8, 4]
29.	*Cnidium dubium*	Marsh	[81]
30.	*Cochlearia borzaeana*	Streams	[81]
31.	*Comarum palustre*	Marsh	[118, 14] Unpublished (in press)
32.	*Crepis sibirica*	Tall-herbs community	[82, 118, 14]
33.	*Dactylorhiza lapponica*	Rich fen	Unpublished (in press)
34.	*Dactylorhiza traunsteineri*	Rich fen	Unpublished (in press)
35.	*Drosera × obovata*	Bog, Poor fen	[81]
36.	*Drosera anglica*	Bog, Poor fen	[81, 118, 14]
37.	*Drosera rotundifolia*	Bog, Poor fen	[81, 14]
38.	*Dryopteris cristata*	Marsh, Bog	[81]
39.	*Empetrum nigrum* subsp. *nigrum*	Bog	[81, 14]
40.	*Eriophorum gracile*	Marsh, Poor fen	[80, 14]
41.	*Eriophorum vaginatum*	Bog, Poor fen	[81, 14]
42.	*Euonymus nanus*	Tall-herbs community, Humid shrubs	[80, 118]
43.	*Hammarbya paludosa*	Bog, Poor fen	[118] Unpublished (in press)
44.	*Juncus alpinoarticulatus* var. *fusco-ater*	Marsh, Rich fen	[14] Unpublished (in press)
45.	*Ligularia sibirica*	Marsh, Poor fen, Rich fen	[81, 118, 14]
46.	*Liparis loeselii*	Rich fen	[82]

0	1	2	3
47.	*Lycopodiella inundata*	Bog, Marsh	[81, 118]
48.	*Lysimachia thyrsiflora*	Marsh, Poor fen, Bog	[81, 118, 14]
49.	*Malaxis monophyllos*	Bog (usually taiga species)	Unpublished (in press)
50.	*Menyanthes trifoliata*	Marsh, Poor fen, Bog	[71]
51.	*Pedicularis palustris*	Marsh	[37] Unpublished (in press)
52.	*Pedicularis sceptrum-carolinum*	Marsh, Poor fen, Rich fen	[81, 118, 14]
53.	*Polemonium caeruleum*	Marsh, Tall-herbs community	[81, 14]
54.	*Potamogeton alpinus*	Marsh, Shallow lakes, streams	[81, 14]
55.	*Primula farinosa*	Rich fen	[81, 14]
56.	*Rhynchospora alba*	Bog, Poor fen	[81, 14]
57.	*Ribes nigrum*	Marsh, Tall-herbs community	[81]
58.	*Salix pentandra*	Marsh	[22, 121] Unpublished (in press)
59.	*Salix starkeana*	Marsh, Poor fen, Tall-herbs community	[81, 118, 14]
60.	*Saxifraga hirculus*	Marsh, Poor fen	[81, 118, 14]
61.	*Saxifraga mutata* subsp. *mutata*	Rich fen	[5] after [66]
62.	*Scheuchzeria palustris*	Bog	[81, 118, 14]
63.	*Schoenus ferrugineus*	Rich fen	[4, 14] Unpublished (in press)
64.	*Schoenus nigricans*	Rich fen	[8, 4]
65.	*Sesleria uliginosa*	Rich fen	[81]
66.	*Sparganium minimum*	Marsh, Shallow lakes, streams	[81]
67.	*Spiraea salicifolia*	Marsh, Tall-herbs community, Humid shrubs	[81]
68.	*Stellaria longifolia*	Marsh, Bog, Poor fen	[81, 118, 14]
69.	*Swertia perennis*	Rich fen	[81, 14]
70.	*Tephroseris palustris*	Marsh	[118] Unpublished (in press)
71.	*Tofieldia calyculata*	Rich fen	[81]
72.	*Trientalis europaea*	Bog (usually taiga species)	[81]
73.	*Vaccinium microcarpum*	Bog	[81, 118, 14]
74.	*Vaccinium oxycoccos*	Bog	[81, 118, 14]
75.	*Vaccinium uliginosum* subsp. *uliginosum*	Bog	[80, 14]
76.	*Viola epipsila*	Marsh, Bog	[81, 118, 14]
77.	*Viola palustris*	Marsh	[81]

RESULTS

The following geographical units are the main areas of rich fens and poor fens in the Romanian Carpathian region, areas harboring a significant number of glacial relicts. In **Bold** – indicator species of rich fens.

1. Bârsa Depression

It is by far the most famous region in the country in terms of the area of rich fens and the number of preserved relict species. The region also has poor fens, alluvial forests and shrubs, non-alkaline eutrophic marshes. In total, they cover approx. 615 ha [80].

Among the important fens are: Hărman Marsh, Prejmer Marsh, the Dumbrăvița Ponds, Stupini Marsh.

All these marshes have mainly eutrophic peat of considerable age, sedimented in the Late Glacial-Preboreal.

It is an intramontane depression with a bedrock consisting of alluvial deposits and altitudes between 490 - 520 m. The mountain influences are felt from the Southern Carpathians.

Glacial relicts: *Adenophora liliifolia,* ***Armeria maritima*** **subsp.** ***barcensis*** (endemic), *Betula pubescens*, *Calamagrostis canescens*, *Calla palustris*, *Carex appropinquata*, ***C. davalliana, C. dioica,*** *C. hartmanii*, ***C. hostiana,*** *C. lasiocarpa,* ***Cladium mariscus*** **subsp.** ***mariscus****,* *Comarum palustre*, *Drosera anglica, D. rotundifolia, Ligularia sibirica,* ***Liparis loeselii****,* *Menyanthes trifoliata*, *Pedicularis palustris*, *P. sceptrum-carolinum,* ***Primula farinosa****,* *Rhynchospora alba*, *Ribes nigrum*, *Salix pentandra*, ***Saxifraga mutata*** **subsp.** ***mutata*** (EX), ***Schoenus ferrugineus*?** (not confirmed), ***S. nigricans****,* ***Sesleria uliginosa****,* ***Swertia perennis****,* *Tephroseris palustris* (EX).

* The species listed above are not growing in all the fens. EX= extinct in the area.

The endemic species *Armeria maritima* subsp. *barcensis* is considered to be derived from *Armeria alpina*, which descended during the glacial period, and when the milder climate returned, the original species retreated to the high altitude, and the remaining individuals near the cold springs differentiated themselves morphologically and ecologically in what is today the subsp. *barcensis* [13]. *Allium ericetorum* subsp. *pseudosuaveolens* is another endemic species restricted to rich fens in the region [119].

Pedicularis sceptrum-carolinum is located here in the southernmost point of its world range [80].

Counties: Brașov, Covasna

Main localities: Feldioara, Bod, Țânțari, Stupini, Sânpetru, Hărman, Prejmer, Dumbrăvița, Noua, Codlea, Vadu Roșu, Brașov, Zizin, Rotbav, Ariușd.

Selective literature: 80, 98, 63, 64, 65, 116, 7, 73.

Species bibliography: 80, 116, 70, 101, 67, 13, 68, 12, 66, 74, 111, 7, 27, 109, 63, 66, 103, 17, 100, 92, 57, 102.

2. Morii Valley (Feleacu Hills)

The area is famous for its many rare species. It has rich fens, poor fens, alluvial forests and shrubs, non-alkaline eutrophic marshes. The surface of the wetlands is approx. 3.3 ha [80].

The most important fen is the Valea Morii Reserve.

The substrate of the fen consists of eutrophic peat, whose age varies according to different authors between the Last Interglacial, Late Glacial and

Atlantic-Subboreal-Subatlantic periods. The presence of species with a disjoint area leans towards a very old fen, with peat sedimented at least in the Late Glacial.

The valley between the hills has a bedrock with coastal deposits of marine origin (sands, sandstones, conglomerates). Sand and gravel is interspersed (cemented) with calcium carbonate and rare clay intercalations. The altitude is around 600 m. The local climate is cooler and wetter than in the neighboring territories.

Glacial relicts: *Achillea impatiens* (EX), *Adenophora liliifolia*, *Betula pubescens*, *Calamagrostis canescens*, *Carex appropinquata*, ***C. hostiana***, *C. loliacea*? (not confirmed), ***Cladium mariscus* subsp. *mariscus***, *Cnidium dubium*, *Crepis sibirica* (EX), ***Dactylorhiza traunsteineri***, *Ligularia sibirica*, ***Liparis loeselii***, *Malaxis monophyllos*, *Menyanthes trifoliata* (EX), *Pedicularis palustris*, *Rhynchospora alba*, ***Schoenus ferrugineus***? (not confirmed), ***S. nigricans***, ***Swertia perennis***, ***Tofieldia calyculata***.

New species reported by the author of this paper: *Cnidium dubium, Calamagrostis canescens, Carex appropinquata,* the latter two being reported from nearby swamps; instead, *Cnidium dubium* is new to the entire region.

Dactylorhiza traunsteineri was recently discovered in these rich fens [1].

Counties: Cluj

Main localities: Feleacu, Cluj-Napoca, Vâlcele, Făget.

Selective literature: 80, 82, 10, 89, 93, 23, 25.

Species bibliography: 1, 85, 13, 69, 68, 74, 111, 101, 26, 120, 70, 82, 29, 30, 103, 93, 102, 80.

3. The marsh region of Borsec-Bilbor-Drăgoiasa Depressions

These intramontane depressions are dominated by rich fens, poor fens, alluvial forests and shrubs, non-alkaline eutrophic marshes and even some peat bogs that spread over an area of approx. 97 ha [80].

Among the important marshes are: Drăgoiasa Marsh, Dumbrava Întreită (Hármas Liget) from Borsec (which was destroyed in the past decades), the marshes Pârâul Rușilor, Sub Șașcă, Pârâul Dobreanului from Bilbor, Țâfreni Marsh (Stănești) and Tinovul de la Luncă peatland from Bilbor.

The marshes show mainly eutrophic peat, sedimented in the Late Glacial-Preboreal.

The bedrock consists of alluvial deposits and crystalline rocks, the altitude being between 820 and 1020 m. It has a pronounced continentality, with cold winters and cool summers.

Glacial relicts: *Andromeda polifolia*, ***Armeria maritima* subsp. *barcensis***? (not confirmed), *Betula humilis, B. pubescens*, *Calamagrostis stricta*, *Carex appropinquata*, *C. capillaris, C. chordorrhiza, C. diandra*, ***C. dioica***, *C. hartmanii* (EX), ***C. hostiana***, *C. lasiocarpa*, *C. limosa*, *C. loliacea, C. pauciflora*, *Chimaphila umbellata*, ***Cladium mariscus* subsp. *mariscus***, *Comarum palustre*, *Drosera rotundifolia*, *Dryopteris cristata*, *Eriophorum vaginatum*, *Ligularia sibirica, Lycopodiella inundata* (EX), *Malaxis monophyllos*, *Menyanthes trifoliata*, *Pedicularis palustris*, *P. sceptrum-carolinum, Polemonium caeruleum*, ***Primula farinosa***, *Rhynchospora alba*, *Ribes nigrum*, *Salix pentandra*, *S. starkeana, Scheuchzeria palustris*, ***Schoenus ferrugineus, S. nigricans***, *Spiraea salicifolia*, *Stellaria longifolia*, ***Swertia perennis***, *Trientalis europaea* (EX), *Vaccinium microcarpum, Vaccinium oxycoccos, Vaccinium uliginosum* subsp. *uliginosum.*

Counties: Harghita, Suceava

Main localities: Drăgoiasa, Bilbor, Borsec, Borsec-Băi.

Selective literature: 80, 105, 83.

Species bibliography: 26, 110, 80, 70, 76, 61, 112, 111, 101, 31, 100, 75, 2, 103, 77, 102, 99, 6, 83, 55, 56.

4. Ciuc Depression

This intramontane depression comprises rich fens, poor fens, alluvial forests and shrubs and non-alkaline eutrophic marshes on an area of approx. 1630 ha [80].

The most important marshes are: Borșaroș (Borsáros) Marsh, Honcioc (Honcsok), Beneș (Benes), Grădina de mesteceni (Nyirkert), Baia cu stuf (Nádas-fürdő), Valea Mijlocie (Középpatak), Csemő Marsh.

The peat is mainly eutrophic, formed in the Late Glacial-Preboreal.

The bedrock of the depression consists of alluvial deposits, the altitudes being between 640 - 850 m. It has a pronounced continentality, with cold winters and cool summers.

Glacial relicts: *Angelica palustris, Betula humilis, B. pubescens*, *Calamagrostis canescens*, *C. stricta*, *Calla palustris*, *Carex appropinquata*, ***C. davalliana***, *C. diandra*, ***C. dioica***, *C. elongata*, ***C. hostiana***, *C. limosa*, *Chimaphila umbellata*, *Cnidium dubium*, *Comarum palustre*, *Drosera anglica, D. × obovata, D. rotundifolia*, *Dryopteris cristata*, *Eriophorum gracile*, *E. vaginatum*, *Euonymus nanus*, *Ligularia sibirica, Lysimachia thyrsiflora, Menyanthes trifoliata*, *Pedicularis palustris*, *Polemonium caeruleum*, ***Primula farinosa***, *Ribes nigrum*, *Salix pentandra*, *Saxifraga hirculus*, ***Schoenus ferrugineus, Sesleria uliginosa***, *Sparganium minimum* (EX), *Spiraea salicifolia, Stellaria longifolia, Viola epipsila, Viola palustris.*

Counties: Harghita

Main localities: Mădăraș, Racu, Jigodin, Miercurea-Ciuc, Tușnad, Sâncrăieni, Sânsimion, Tușnad-Sat, Misentea, Sântimbru, Sânmartin, Vrabia, Tușnad-Băi, Tușnadul Nou.

Selective literature: 80, 87, 88, 58.

Species bibliography: 80, 70, 47, 49, 108, 113, 52, 17, 29, 51, 91.

5. Giurgeu Depression

The intramontane depression includes rich fens, poor fens, alluvial forests and shrubs, non-alkaline eutrophic marshes and even oligotrophic peat bogs over an area of approx. 476 ha [80].

Among the marshes of the territory are: După Luncă (Fenék rétláp) Marsh, Borzont (Joseni) (Nyíres) Marsh, Mlaştina cea Mare de la Remetea (Nagy rétláp) (marsh), Bogáros-Eszenyö marsh between Remetea and Ditrău, Dealul Albinelor (Méhes láp) Peatbog.

The peat substrate is mainly eutrophic, formed in the Late Glacial-Preboreal.

The bedrock of the depression consists of alluvial deposits, the altitude being between 710 - 1230 m. It has a pronounced continentality, with cold winters and cool summers.

Glacial relicts: *Achillea impatiens, Adenophora liliifolia*, *Angelica palustris*, *Betula nana*? (EX) (probably confusion), *B. humilis, B. pubescens*, *Calamagrostis canescens*, *C. stricta, Calla palustris*, *Carex appropinquata*, ***C. davalliana***, *C. diandra*, ***C. dioica***, *C. elongata*, *C. hartmanii*, *Cnidium dubium, Comarum palustre*, *Drosera rotundifolia*, *Dryopteris cristata*, *Eriophorum vaginatum*, *Euonymus nanus*, *Ligularia sibirica, Lysimachia thyrsiflora*, *Menyanthes trifoliata*, *Pedicularis palustris*, *P. sceptrum-carolinum, Polemonium caeruleum*, *Potamogeton alpinus, Ribes nigrum, Salix pentandra*, *Spiraea salicifolia, Stellaria longifolia*, *Vaccinium oxycoccos, Viola epipsila.*

Counties: Harghita

Main localities: Gheorgheni, Voşlăbeni, Joseni, Borzont, Lazărea, Remetea, Ditrău.

Selective literature: 80, 87, 88, 58, 21.

Species bibliography: 80, 70, 3, 21, 86, 13, 113, 101, 108.

6. Făgăraş and Sibiu Depressions

Most of the marshes in the two depressions have been drained over the past centuries and decades, so the existence of rich fens today is questionable. Among the types of marshes reported in the region are rich fens, peat bogs, poor fens, alluvial forests and shrubs, non-alkaline eutrophic marshes of approx. 320 ha in the past [80].

Important marshes: Poiana cu narcise Dumbrava Vadului. The peat bogs of Avrig and Arpaşul de Sus (Mlaca Tătarilor) are mostly oligotrophic but around them there are transitional – poor fens and even isolated alkaline fens according to the reported species (e.g. *Cladium mariscus*).

The peat substrate is of oligotrophic and eutrophic origin, formed in the Late Glacial-Preboreal.

The bedrock of the depression consists in alluvial deposits, the altitudes being 400 - 580 m. The climate has slight mountain influences from the Southern Carpathians.

Glacial relicts: *Adenophora liliifolia*, *Angelica palustris*, *Betula pubescens*, *Calamagrostis canescens*, *C. stricta*, *Carex appropinquata*, ***C. davalliana***, *C. diandra*, ***C. dioica***, *C. elongata*, *C. hartmanii*, ***C. hostiana***, *C. lasiocarpa*, *C. limosa*, *C. pauciflora*, *Chimaphila umbellata*, ***Cladium mariscus* subsp. *mariscus***, *Cnidium dubium*, *Comarum palustre*, *Drosera rotundifolia*, *Dryopteris cristata*, *Eriophorum gracile, E. vaginatum*, *Hammarbya paludosa*, ***Juncus alpinoarticulatus* var. *fusco-ater*** (lowest altitude), ***Liparis loeselii***, *Lysimachia thyrsiflora, Malaxis monophyllos*, *Menyanthes trifoliata*, *Pedicularis palustris*, *Polemonium caeruleum*, ***Primula farinosa*** (EX), *Rhynchospora alba, Ribes nigrum*, *Salix pentandra*, *Scheuchzeria palustris* (lowest altitude), ***Schoenus nigricans*** (EX), *Sparganium minimum*, *Spiraea salicifolia*, ***Tofieldia calyculata*** (EX), *Trientalis europaea* (EX).

Spiraea salicifolia was found by the author (together with Bogdan Hurdu) in a new remote locality between Drăguş and Staţiunea Climaterică Sâmbăta (coord. 45.69308 N, 24.74992 E, 665 m. 06 X 2020). The only population in the region was mentioned decades ago at Vad, Poiana Narciselor [96].

Counties: Braşov, Sibiu

Main localities: Comăna de Jos, Veneţia de Jos, Mândra, Şercaia, Şinca Nouă, Arpaşul de Sus, Avrig, Rupea, Făgăraş, Beclean, Sâmbăta de Sus, Arpaşul de Jos, Cârţişoara, Şura Mică, Veştem, Răşinari, Cisnădie, Sibiu, Tălmaciu, Ocna Sibiului, Dumbrava Sibiu, Boiţa, Cristian, Şelimbăr, Viile Sibiului, Guşteriţa, Vad, Merghindeal.

Selective literature: 80, 70, 18, 19.

Species bibliography: 19, 100, 70, 80, 18, 96, 74, 47, 75, 30, 101.

7. The western mountain foots of Harghita Mts. and Baraolt Mts.

Most of the marshes in the lower floors are poor fens, while those in the higher parts are peat bogs [Tăul Dracului (Ördögtó) Peat bog, Seche (Săritor) Peat bog, Luci (Lucs) Peat bog]. There are also alluvial forests and shrubs, non-alkaline eutrophic marshes, occupying approx. 159.05 ha [80].

The main marsh here is the Dumbrava Harghitei Marsh (Hargitaliget) from Vlăhiţa and smaller marshes are around Ozunca-Băi.

Their peat is both oligotrophic and eutrophic, sedimented from Preboreal to Subatlantic.

The bedrock consists of volcanic rocks. The altitudes are between 620 - 1000 m [80]. The climate has a pronounced continentality, with cold winters and cool summers.

Only the glacial relicts from the low marshes would be considered in this study, the peatland marshes from the higher altitudes in the Harghita Mts., such as the *Betula nana* populations in Luci Peat bog, will not be taken into consideration.

Glacial relicts: *Adenophora liliifolia*, *Andromeda polifolia* (EX?), *Betula humilis*, *B. pubescens*, *Calamagrostis stricta, Carex appropinquata*, ***C. davalliana***, *C. diandra*, ***C. dioica****, C. hartmanii*, ***C. hostiana***, *Chimaphila umbellata*, *Cnidium dubium*, *Comarum palustre*, *Drosera anglica, D. rotundifolia*, ***Juncus alpinoarticulatus* var. *fusco-ater***, *Ligularia sibirica, Lysimachia thyrsiflora*, *Malaxis monophyllos*, *Menyanthes trifoliata*, *Pedicularis palustris*, *P. sceptrum-carolinum, Polemonium caeruleum*, *Rhynchospora alba*, *Salix pentandra*, *Saxifraga hirculus, Sparganium minimum, Stellaria longifolia, Trientalis europaea*, *Vaccinium oxycoccos* (EX).

Counties: Covasna, Harghita

Main localities: Siculeni, Mereşti, Vlăhiţa, Lueta, Băile Harghita, Vârghiş, Ozunca-Băi, Băţani, Ozunca.

Selective literature: 80, 11.

Species bibliography: 80, 70, 11, 59.

8. Călăţele Region (Vlădeasa eastern mountain foots)

The region has both rich fens, as well as peat bogs and poor fens, but all of them are deeply affected by anthropogenic activities, with an area of approx. 24.3 ha [80].

The main marshes are: Molhaşul de la Călăţele (peat bog), Râşca Răchitiş marshes, Dâmbul Negru from Călăţele Peat bog, Molhaşul de la Râşca (peat bog), Râtul Popii (La Vălaie) (fens), Negruşul Finciului (peat bog).

The peat is mainly oligotrophic, rarely eutrophic, formed in the Late Glacial-Preboreal.

Altitude: between 916 -1100 m. The climate has oceanic influences with abundant rainfall.

Glacial relicts: *Andromeda polifolia, Betula pubescens, Carex appropinquata*, *C. hartmanii, C. limosa, C. magellanica* subsp. *irrigua, C. pauciflora*, ***Cladium mariscus* subsp. *mariscus***, *Comarum palustre,* ***Dactylorhiza lapponica***, *Drosera rotundifolia, Empetrum nigrum* subsp. *nigrum, Eriophorum vaginatum,* ***Juncus alpinoarticulatus* var. *fusco-ater***, *Menyanthes trifoliata, Pedicularis sceptrum-carolinum* (the only place outside the Eastern Carpathians and the Bârsa Depression)*, Rhynchospora alba, Salix pentandra* (the only place from Apuseni Mts.), *Sparganium minimum, Scheuchzeria palustris*, *Vaccinium oxycoccos.*

Dactylorhiza lapponica was recently confirmed for the area, being new for Romania [60].

Counties: Cluj

Main localities: Călăţele, Finciu, Văleni, Râşca.

Selective literature: 80.

Species bibliography: 80, 60, 79, 13, 112, 2, 100, 99.

Other small rich and poor mountain fens are scattered throughout the mountain areas, but are poor in species. However, two of them are worth mentioning: Sâlhoi-Zâmbroslăviile Mari in the Maramureş Mountains, where probably grows the largest population of *Cochlearia borzaena,* an endemic species considered by some authors as a glacial relict [114] and the fens near Plaiul Todirescu under Popii Rarăului in the Rarău Mountains, where *Carex vaginata* was recently discovered, being new for Romania and the fourth known population in the entire Carpathian chain. Also here, the species grows with other related fen species like: *Carex capillaris, Eriophorum vaginatum, Juncus alpinoarticulatus* var. *fusco-ater, Swertia perennis* [15].

DISCUSSION

The survival of fens in the Holocene and their role as refugia

In addition to the role of preserving a high biodiversity, eutrophic fens with alkaline springs are also considered as glacial refugia [38]. In Central Europe, most of them are protected. The main feature of these fens are the springs and groundwater rich in dissolved carbonates. Any change in water levels, whether due to climate change or human intervention, can affect the surface access of these minerals. An alternation of peat and calcareous tuff layers can be observed in the substrate of these marshes, showing the enrichment with calcium carbonate in wet periods [16]. These fens are home to a number of mollusks, which over the millennia can become good indicators of the past [40, 39].

The persistence of these fens, which are very sensitive to climate change, has recently been debated in several Central European countries. Eutrophic and alkaline marshes were dominant in the Early Holocene, but were largely eliminated by the expansion of forests from the Thermal Optimum (mid-Holocene). Sádlo [95] suggests that many heliophilous fen species survived through open water holes in the perimeter of forests and alluvial shrubs, which underwent frequent changes in water levels. Thus, the cyclicality between open fens and alluvial forests has ensured the creation of refugia along water basins and river meadows in which these species survived during the maximum period of forest expansion. These examples include: *Cladium mariscus, Schoenus nigricans, S. ferrugineus, Ligularia sibirica, Betula humilis, Calamagrostis stricta, Carex buxbaumii, Eriophorum gracile* [4].

Hájek et al. [37], studying the calcareous eutrophic fens in the Western Carpathians, shows that a large number of plant and mollusk species are closely related to these fens over several millennia. The older such a fen is, the more rare and endangered species will conserve, with a very disjointed area [45]. However, the sediments of these fens contain many contradictory elements [37]. The same authors indicate that many of them formed between the 14th and 17th centuries when massive deforestation brought many mineral springs into the open. At the same time, evidence of the existence of these species in the Maximum Glacial could not be highlighted. The sediments of these fens are also incomplete and do not preserve pollen or macrofossils. Hájková et al. [40] propose a more complex approach, analyzing several data which they then compare. Thus, for an alkaline eutrophic fen to acquire the characteristics of a refugium, must meet the following conditions: a) to be very old and with peat formation from the Late Glacial or Early Holocene; b) to favor the fossilization of plant and mollusk species; c) to house a series of glacial relict species and d) to contain in the lower sediments characteristic species of glacial periods. The main questions are whether these fens persisted throughout the Holocene in the open field, not being afforested and affected by anthropogenic activities.

Rich fens are documented from the Western Carpathians (at altitudes of 700-800 m) since the Late Glacial and Preboreal, indicating a continuous perpetuation of open field vegetation, with shrubs and trees around them. Their sediments contain a number of mollusks, vascular plants and mosses that need light for proliferation, existing in the same place from the Late Glacial until today. Although the vegetation is strongly altered after massive deforestation in the Late Holocene, it was still similar to the fens of the Middle Holocene (about 8,000 years ago) [40, 41].

Thus, Hájková et al. [40] demonstrates that alkaline fens can exist for millennia, perpetuating a number of species that have disappeared from large areas of the surrounding territories. The existence of such Late Glacial fens so far in the Western Carpathians strengthens the arguments of their relict origin in Romania, where unfortunately such complex studies are missing or very few. These marshes are much more sensitive to changes in the environment than peat bogs. Among the main factors are the climate that can affect the hydrographic network, the composition of minerals, the succession of vegetation and the organic substances from animals and humans. Thus, in the stratigraphic sediments subsequent hiatuses can appear and some processes that destroy the older sediments, which fully explains the lack of paleoecological evidence that can prove the persistence of these fens and their relict flora. Demonstrating their persistence over millennia can be achieved not only by studying sediments that have hiatuses, but also by approaching complex combined methods (pollen, macrofossils and snail shells). Therefore, in the case of the Western Carpathians, Late Glacial pollen documents the existence of open fens, while vascular plant macrofossils and mollusks from Late Glacial and Holocene clearly indicate the existence of these open fens over the millennia. Even during the massive afforestation of about 4,400 years ago, the sediments contain *Chara* oogonia, which indicate the presence of patches of water that have kept open vegetation around them. Species in need of light could thus take refuge around these puddles. The fens that were covered by forests according to the palynological evidence from sediments, are still poor in relict species today, being recolonized by them in the time of the massive anthropogenic deforestation, their macrofossils appearing only in the upper sediments [40].

Chorological results indicate a strongly disjoint distribution of species adapted to alkaline eutrophic fens. Their number increases with the size and age of the fen. The perpetuation of these fens and species is primarily related to the area occupied. The larger the area of the wet surface, the greater the diversity of the marshes that will favor a diversity of ecological conditions for the species to survive. Thus, a large and heterogeneous wetland makes it more likely that more species will survive adverse climatic conditions. Therefore, these areas mentioned above, occupied by various marshes, can be considered as refugia. In contrast, there are also small-area fens that have managed to preserve highly specialized species. Unfortunately, these are more severely degraded due to climate change and anthropogenic action [34]. The stability of these fens is maintained by the circulation of springs, groundwater and streams extremely rich in minerals, which reduce the macroclimatic fluctuations and even block the plant successions, maintaining the archaic conditions for the survival of ancient species [39, 41].

The fens from Hărman, like other similar fens in the Carpathian region, have been able to preserve glacial relicts due to the low temperature of the water soaking the substrate, as well as other ecological factors. The water temperature in June measured at 12 o'clock at the mouth of the springs was 8°C, and that of the water in the streams was 24.1°C. The differences in humidity around springs, streams, small depressions and higher parts create microhabitats where different patches of vegetation, belonging to different associations are housed [63]. The evidence of a rich fen at Valea Morii is given by the pH of the fen which is between 7.3-7.8, being rich in minerals and calcium carbonate [93]. Gałka et al. [25], through the palynological analyzes that could be taken until the appearance of hiatuses, shows the fact that at least in the last periods (part of the Atlantic, Subboreal and Subatlantic) the marshes from Valea Morii have been continuously occupied by aquatic and marshy heliophile species. The palynological analyzes from Bilbor are attesting the fact that the fens date from the Glacial period, the structure of the peat showing that at least the Dobreanu Marsh (Pârâul Dobreanului) has remained eutrophic until now due to the alkalinity of the mineral waters that ensured its continuity [83].

It can be shown that the alkaline fens richest in species in the study region are also the oldest. Thus, the marshes of Hărman, Prejmer, Valea Morii, Bilbor, Drăgoiasa, Borsec, Călățele, Ciuc, Giurgeu and Făgăraș Depressions are also the most valuable wetland ecosystems of the South-Eastern Carpathians that require strict protection and constant monitoring. These fens preserved and perpetuated species strictly adapted to certain conditions formed in the climate of the Glacial periods (e.g. *Tofieldia calyculata, Dactylorhiza traunsteineri, D. lapponica, Primula farinosa, Cladium mariscus, Armeria maritima* subsp. *barcensis, Sesleria uliginosa, Schoenus nigricans, S. ferrugineus, Swertia perennis* etc.). Unfortunately, many of them were severely damaged and some (like the fens from Borsec) were irremediably destroyed.

The importance of fens

Unlike the Arctic and northern Boreal regions, the marshes in central and southern Europe have been severely affected by anthropogenic activity [35]. Romania had an area covered with mires of only 0.03% before 1960, E. Pop estimating that the area of oligotrophic and eutrophic marshes in the country to cover about 7,078 ha [80]. The great land reclamations of the XIX-XX, even XXI centuries, destroyed about 62% of the eutrophic and oligotrophic marshes with peat formation. They now cover only 0.01% of the surface of the country. As a result of the intensification of agriculture in the 70s, 80s and even in recent decades, their area has been reduced to about 4,000 ha [72].

Oligotrophic or eutrophic marshes played an important role in the dry periods of the Ice Ages and Holocene, preserving a large number of relicts with a disjoint area [35]. Studies over the past two decades have shown that marshes are among the most important terrestrial ecosystems from which humans have unknowingly benefited. Peatlands and marshes are among the most efficient in absorbing and storing carbon and other gases responsible for climate change. At the same time, they have a beneficial effect on agriculture, not only by hosting beneficial species, but also by evaporating the water that influences the local climate. Marshes are an important reserve of the water circuit in nature, helping to stop floods, accumulate excess water and maintain springs [20].

Alkaline fens in the high mountain areas are among the richest ecosystems in Central Europe, with over 100 species in general and an average of over 30 species per $2m^2$ [77]. In Switzerland, alkaline fens are home to almost 50% of the country's endangered species [53].

Factors leading to the extinction of fens and relict species in Romania

Anthropogenic causes are by far the main factor for their extinction. First of all, the reduction, fragmentation or total disappearance of the habitat is the decisive factor in the extinction of these relicts. These species are closely related to the habitat in which they have survived or evolved over the millennia. Local microclimatic conditions no longer exist outside these refugia, which prevents these species from occupying other habitats in the general climate. For example *Cochlearia borzaeana* and *Armeria maritima* subsp. *barcensis* have evolved to adapt exclusively to the type of habitat in which they still exist today (fens with cold springs, rich in minerals). Most of the marshes in the Carpathian region do not meet the conditions listed above.

Marshes, along with sand dunes, salt marshes and other habitats without economic interest, have always been seen as being in the path of progress, having no economic benefit. Thus, the humans has systematically tried to eradicate them completely and transform them into agricultural land, pastures, forest plantations or industrial and residential areas. They were drained, plowed, mowed and grazed until the complete transformation of the archaic vegetation. Although in some cases the landscape remained unchanged (not included in the agricultural circuit), habitats are still severely affected by drainage, premature mowing or mechanized mowing, by mowers and hay harvesters destroying the soil surface, springs and sensitive plants, and especially by overgrazing with herds whose number is not supported by the vegetation of the marsh [44].

The main disappearance factor is caused by the drainage of the marshes and the construction of water drainage channels which leads to the decrease of the groundwater level and implicitly to the stopping of these springs and the drying of the streams that feed the swamps. By reducing excess mineral-rich water, opportunistic marsh vegetation quickly fills the gaps and suffocates the low associations of archaic sedges. The most eloquent example is the disappearance of the species *Primula farinosa* from the entire surface of the Hărman Marsh, remaining only through isolated patches on the edges of the drainage channels. Thus, the first species to disappear are those that need a constant amount of water specific to these springs (*Swertia perennis, Primula farinosa, Armeria maritima* subsp. *barcensis*, etc.). The case of the *Achillea impatiens* population from Valea Morii shows that a species can only survive as part of an ecosystem, as they have a threshold of adaptation, which if exceeded, leads to the total disappearance of the taxon [90]. Secondly, the decrease of the groundwater level leads to the total change of the vegetation associations, the marshy-hygrophilous species being replaced by the mesophilic and even xero-mesophilic ones. Thus the places of relict sedges (*Carex davalliana, C. dioica, C. diandra, Schoenus nigricans, S. ferrugineus*, etc.) are taken by species less sensitive to the lack of water for longer periods (*Carex riparia, Phragmites australis* etc.). As a result of the great drainage in the Ciuc Depression, the hydrophilic vegetation has almost completely disappeared. The natural successions of vegetation have been turned upside down, and the fens with tall and short sedges have been quickly occupied by *Juncus effusus, Typha* and *Schoenoplectus* species [28]. The Stupini Marsh was also drained, driving to the extinction of the only known population of *Saxifraga mutata* subsp. *mutata* in Romania.

After the drainage, the marshes are most often transformed into agricultural land. However, the usual practice is that after the groundwater level decreases, the area is immediately transformed with the remaining vegetation still present. In the rainiest years, the waters return to the surface, compromising the agricultural production [106].

Irregular mowing, but especially the transition to mechanical exploitation of mowing by machinery has led to the loss of a large number of relicts and rare species, which not only have no possibility of regeneration, but also suffer total loss of populations by effective root removal as an effect of mechanical mowing. Dwarf shrubs of *Betula humilis, Spiraea salicifolia, Ribes nigrum, Euonymus nanus and Salix* species are also mowed and destroyed to make way for Poaceae species for fodder. Mechanized mowing has sometimes led, for the first time, to the total destruction of island-like sedges formed by certain species (*Carex elata, C. paniculata, C. appropinquata, C. cespitosa*) that grew according to water level fluctuations, providing refuge for many species in the ditches between their elevations, by preventing the normal progress of mowing [106]. At the same time, mowing led to the widespread disappearance of natural tufa elevations around the springs on which the species of *Drosera anglica* or *Saxifraga hirculus* took refuge [80]. 24% of the known populations of *Swertia perennis* in Switzerland have disappeared in recent decades due to mechanized mowing and mowing at irregular intervals. The most affected were the populations at lower altitudes [53].

Grazing in swampy areas, sometimes even excessively, leads to the reduction of these relict species and the alteration of the habitat by trampling and dislocating the land. Perennial species depend not only on high seed germination to maintain populations, but also on the survival of adult individuals that guarantees the maintenance of a viable population in the future [43]. These adult individuals are no longer able to grow and bear fruit in a pasture. The vegetation of Prejmer was affected during the communist period by the establishment of a pig farm [64]. Grazing and threshing have a particularly devastating effect on wetlands [115]. *Adenophora liliifolia* has been reported in the past in over 30 localities, of which only 6 could be reconfirmed after 1990. The worst is that of the 6 populations, in recent years only one could be reconfirmed [54]. The main hazards for the survival of the species in the areas analyzed by Prausová et al. (2016) [84] is represented by overgrazing.

The burning of vegetation, especially shrubs and willows, is another contributing factor in the impoverishment of relict species. By eliminating shrub species, the protection offered by them in maintaining the humidity and nebulosity of a favorable microclimate in the summer months is eliminated. Vegetation fires in areas where groundwater has fallen sharply have ignited the exposed peat, deposited over the millennia, which has often burned to the depths, destroying the plant's roots in the region. *Cladium mariscus* habitats were often set on fire at Hărman and Valea Morii [117].

The uncontrolled exploitation of mineral or spring water reserves has led to a decrease in the necessary water flow or even to the drying of springs from the entire perimeter of archaic fens [107].

Environmental pollution is also an important factor in the extinction of some species. Pesticides and herbicides used in excess by farmers end up in the groundwater and springs of these refugia. Thus, even if the area is protected, it becomes indirectly affected by groundwater pollution. Throwing rubbish in these places also alters the environment and suffocates smaller plants. Numerous chemicals used in nitrogen and phosphorus-based agriculture seep into the groundwater of nearby fens and completely change their chemical composition. It affects species adapted to soils and waters poor in nitrogen and other organic substances. These substances also create an environment conducive to the proliferation of other invasive species, such as reeds, nettles, ruderal weeds or adventitious species: *Solidago canadensis, S. gigantea* [107]. The best example in this case is the almost complete alteration of the Hărman Marsh in recent years, the agricultural products on the marginal lands helping the proliferation of the species *Urtica dioica* which suffocated a large part of the reserve (personal observations). In the Ciuc Depression, the peat substrate of the fens began to disintegrate and rot in the absence of neutral mineral springs and the large amount of nitrogen that reaches the groundwater from the surrounding agricultural lands. As a result, species typical of alkaline fens have disappeared and replaced by nitrophilic ones (*Urtica dioica, Galium aparine*) [49].

Urbanization and construction of roads leads to habitat fragmentation and extinction of susceptible species. The transformation of marshes into recreational lakes, fish lakes, the dumping of construction materials and waste, the blocking and clogging of springs and the construction of road arteries right in the middle of the marsh are other causes of their disappearance [107]. The European road Brașov-Sf. Gheorghe passes right through the middle of the fen at Prejmer. Valea Morii near Cluj-Napoca became a residential neighborhood, being assaulted by tourist and recreation huts exactly on the site of the former archaic fens [93]. The installation of the fishery in the Hărman Marsh in the 1960s destroyed much of the archaic vegetation. It extracted the water of the streams that almost led to the extinction of the species that depended on them [117]. The ponds from Dumbrăvița were created on the site of the former archaic fens.

In order for these fens to remain active, it is necessary for the mineral springs to flow on the surface, which will prevent soil acidification and high nutrient intake, which also will stop or slow down the growth of grasses (Poaceae) and wood species. The surface of the protected area must be larger than the area of the springs, as the aquifer reserves are often enriched from the surroundings. Traditional mowing is often necessary to discourage the emergence of woody species. The ecological reconstruction of these fens is almost impossible, due to the fact that once the water disappears from the peat sediments, they compact and dry. If the water returns after a long time, it will begin to erode the lower peat sediments and lead to the disappearance of the archaic flora. Therefore, a drained alkaline fen, if it cannot regenerate on its own over time, will be completely destroyed. Their chemical composition is also affected by neighboring agricultural lands that produce a huge amount of nutrients and other chemicals that enter the aquifer and produce major imbalances in the fen [33].

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