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Active Protection of Endangered Species of Peat Bog Flora (*Drosera intermedia*, *D. anglica*) in the Łęczna-Włodawa Lake District

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Abstract: Protecting endangered plant species is crucial to maintaining biodiversity. Currently, there is a rapid decline in the populations of many moisture-loving plant species throughout Poland. These include the entire genus *Drosera*, so this paper attempts to determine the main reasons for the decline of *Drosera intermedia* and *Drosera anglica* in the Łęczna-Włodawa Lake District. For this purpose, the habitat conditions, climatic factors of the sites, as well as the vegetation of their current and historically abundant occurrence were compared, and it was shown that an important reason for the receding of sundews may be changes associated with rising temperatures in the study area. In the case of *Drosera anglica*, a clear preference was observed for colonising sites associated with the shoreline of lakes, more hydrated and almost devoid of companion plants. For *Drosera intermedia*, on the other hand, it was revealed that it acclimatises to mid-forest peatlands, rich in magnesium, nitrogen, phosphorus, and manganese, with moderate carbon content, medium levels of groundwater and air temperature, and low concentrations of organic matter. In addition, it was noted that sundew sites are characterised by lower diversity indices but a greater number of rare and protected species and significantly lower concentrations of iron and potassium.

Keywords: *Drosera intermedia*; *Drosera anglica*; environmental factors; conservation actions; wetland

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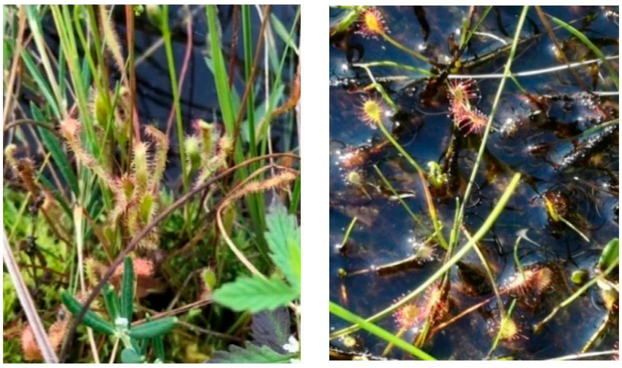
1. Introduction

The conservation of endangered plant species is crucial for maintaining biodiversity [1]. The primary factors affecting endangered species include the small size of their population, occupying small specialised habitat types, small seed size, low dispersion capacity, high vegetative reproduction, and low competitive ability [2,3].

The populations of many moisture-loving plant species in Poland are currently rapidly disappearing. These include the entire genus *Drosera*—a carnivorous species in peat bogs [4]. This genus of sundew covers approximately 90 species distributed on all continents [5] and represents the amphiatlantic element in our flora [6]. There are only three species of this genus in Poland: the round-leaved sundew *Drosera rotundifolia* L., the long-leaved sundew *Drosera anglica* L., and the rarest—the intermediate sundew *Drosera intermedia* Hayne. There are also hybrid forms of round-leaved sundew, and an intermediate sundew, oval sundew *Drosera × obovata* Mert. et Koch. Both *Drosera intermedia* and *D. anglica* belong to plants with a low number of sites (currently around 100), showing a considerable decline over the recent decades [7]. They are, therefore, the most endangered species of this genus in Poland.

The global range of these species covers the northern, western, and central parts of Europe (from northwest Russia and central Finland to northern Portugal), as well as its eastern part.

The southwestern boundary of the *Drosera intermedia* range runs through the territory of Poland [6]. The intermediate sundew is the most common in Lower Silesia, Western Pomerania, the Lublin and Lesser Poland Uplands, and Polesie Lubelskie [6]. *Drosera intermedia* is also sparse in the Kashubian and Masurian Lake District, and in the Karkonosze Mountains. It is an extremely rare element in the central part of the country [8]. Almost half of approximately 160 sites of occurrence of the species in the country are historical sites (the 1930s; [9]). It is a species characteristic of transitional mires from the *Rhynchosporion albae* association [4]. It is listed on the Red List of vascular plants of Poland in the category of dying out species (E) [10]. It is subject to strict protection in Poland [11] (Figure 1).



(**A**) (**B**)

Figure 1. Intermediate sundew (**A**), long-leaved sundew, (**B**) position by Lake Łukietek.

In Poland, *Drosera anglica* occurs at dispersed sites in lowlands, and less frequently in lower mountain locations [12]. It reaches the southern boundary of the compact range in Poland. It primarily inhabits transitional [13] and lowland [14] bogs. It is a species characteristic of the order *Scheuchzerietalia palustris* [4]. It is under strict protection and is included in the endangered category (E) [11] (Figure 1).

In the Lublin region, the long-leaved sundew only occurs in transitional fens. It never grows in large groups, but is rather dispersed, often accompanied by intermediate sundew. The long-leaved sundew is the rarest in the Lublin region and mainly occurs in the Łęczna-Włodawa Lake District and on the Forest Plain. Like throughout Poland, also in the Lublin region, more than half of the identified sundew sites are historical sites [15]. Research conducted over the last 20 years shows significant impoverishment of the number of *D. intermedia* and *D. anglica* sites in the Łęczna-Włodawa Lake District. On the other hand, *Drosera* × *obovata* is the predominant taxon compared to the others. This hybrid only produces seeds that do not mature and therefore does not reproduce generatively.

In the age of changing climatic conditions, including habitat conditions, further changes in the distribution of sundew species should be expected. They are very sensitive species (species with a narrow ecological amplitude), indicative of changes in hydration and increased fertility. Hence, the greatest threat to these species is the drainage and eutrophication of peatlands, as well as the resulting expansion of rush and shrub vegetation, and in some cases synanthropisation. The research area has been subject to very intense regional changes. It is currently covered by various forms of nature protection, limiting the direct negative anthropogenic impact as much as possible. After Poland's accession to the European Community, Poland is required by the EU nature protection law to protect habitats pursuant to Annex I of the Habitats Directive [16]. These include raised bogs and transitional bogs covered with plants of the *Oxycocco-Sphagnetea* class (7120) and *Scheuchzerio-Caricetea fuscae* (7140) and depressions on peat substrate with vegetation from the *Rhynchosporion* compound (7150).

The restoration works in peatland ecosystems in the southwestern part of the Łęczna-Włodawa Lake District launched in the 1990s primarily included treatments related to the inhibition of water outflow from these areas. The next step is the reintroduction of naturally valuable species of sundew, aimed at enriching the area's biodiversity. Similar activities have been introduced at a much smaller scale in Poland (near Radomsko). These concern *Drosera intermedia* [17]. There have been no other related attempts at literature reports.

The survival of outgoing species is only possible when the reasons for their disappearance are identified. This can be done by analysing the preferential conditions of their occurrence, i.e., the places where they are still abundant. The study objective was to make an inventory of the sites of the present and past abundant occurrences of sundew (reintroduction sites) based on the characteristics of the habitat conditions, including the physical and chemical properties of the substrate, hydration, basic weather parameters, and species of the accompanying plants. The research inspired an attempt to identify the main threats to their occurrence in the Łęczna-Włodawa Lake District. We will try to explain—what habitat, climate, and population preferences do the endangered species of sundew have?

2. Materials and Methods

2.1. Study Site

The Łęczna-Włodawa Lake District is one of the most valuable natural regions of Central and Eastern Poland. It includes more than 60 lakes, interesting in terms of limnology, surrounded by vast plains of lake accumulation and peat plains with high moisture content. According to [18], there are about 800 bogs of various sizes in the Lakeland, dominated by low bogs. The flora is dominated by humid forests and meadows, as well as unique remnants of natural peat bogs. Systematic research on nature began here in the 1950s. Several nature reserves were established as early as 1959 The first landscape parks were established in 1983. The system of protected areas of the Lake District was supplemented by the establishment of the Poleski National Park in 1990.

Despite extensive protective measures, the natural values of this region have been and are still subject to rapid degradation as a result of the intensification of various forms of human pressure, including intensive agricultural drainage, the spontaneous recreational management of lakes, and the development of coal mining. Radical changes in water conditions occurred in the second half of the 20th century with the implementation of large investments (Wieprz-Krzna canal, Chełm Cement Plant, Bogdanka mine). Over the past 50 years, the groundwater level in the central part of the Lake District has decreased by 0.81–1.6 m. The water table in some lakes has decreased (e.g., Nadrybie, Piaseczno), and most reservoirs have been strongly eutrophicated. Losses in the natural resources of peat bog vegetation are estimated at 70–80% [19]. Moreover, a feature of the Łęczna-Włodawa Lake District, disadvantageous from the point of view of water resources, is the relatively low precipitation total and the number of days with precipitation, as well as their high variability. An increase in air temperature in this area causes an increase in the intensity of evaporation, which may consequently reduce the local water resources [20].

2.2. Field Investigation

2.2.1. Obtaining Sundew and Identifying Reintroduction Sites

After obtaining relevant permits for conducting research, issued by the Regional Directorate of Environmental Protection in Lublin, seeds of sundew were collected in autumn 2019 at the site with the highest abundance of sundew in the Łęczna-Włodawa Lake District (a peat bog at Lake Łukietek). Some of the seeds were frozen at −15 degrees Celsius for approximately 3 months, and the remaining ones were not cooled. In the spring of 2020, the seeds were sown on the native peat substrate brought from their places of occurrence in 60 growbox dark tents, under constant lighting, temperature, and humidity and some in mini greenhouses under natural conditions outside the laboratory. Watering with appropriate pH or rainwater was secured.

In the spring of 2020, field research commenced with the selection of places for the reintroduction of sundews in transitional fens in the Trzy Jeziora Reserve and in mid-forest peat bogs in the Sobibór Forest District. The places were chosen because of the former abundant occurrence of sundews at the sites [21]. Moreover, places for re-introduction were prepared (the top layer of mosses and herbaceous plants was removed). Naturally exposed surfaces of peat or gyttja (lake shore, places swollen by animals) were used first. Two areas were selected for each taxon. The size of each area was 0.30 m^2 (0.5/0.8).

In late summer, sundews from sowing and vegetative breeding were introduced to new positions. Sundews were introduced in a total of 5 locations, covering 11 new sites: a peat bog by Lake Płotycze (2: Pł1, Pł2), a peat bog by Lake Orchowe (2: O1, O2), mid-forest bogs in the Sobiborskie Forests-Stulno (4: S1, S2, S3, S4), a mid-forest bog Macoszyn (2: M1, M2), and Podlaski (1: Pd). In the bogs by lakes, similarly to their current occurrence, sites were created at lake shores (marking 1) and in the central parts of the bogs (marking 2).

2.2.2. Environment Factors of the Sites

At the same time, in 2020 and 2021, peat and gyttja samples were collected from potential (11) and current sites (5 peat bog sites at Lake Łukietek: Ł1, Ł2, Ł3, Ł4, Ł5). Chemical analyses of the deposits were performed according to the method developed by Sapek and Sapek [22]. The samples were mineralised with a mixture of acids (HNO_3, d = 1.40; $HClO_4$, 60%; mixed in a 20:5 volume ratio) and then assayed for the total contents of sodium, potassium, phosphorus, calcium, magnesium, iron, and manganese using Flame Atomic Absorption Spectroscopy (FAAS). Total nitrogen was determined by the Kjeldahl method [23], and total carbon was measured by infrared spectrometry. In addition, pH was measured directly in the peat material by the potentiometric method using an Elmetron CX-731 pH meter with a compatible Ag/AgCl/KCl electrode. Ash content was determined by loss-on-ignition during the combustion of 1 g of peat sample at 550 °C.

In each patch of current and potential occurrence, the following was analysed each time: soil moisture and temperature in the root zone −0.1 m by means of a soil tester (soil pH–moisture meter, measuring range 10–80%), soil pH by means of a Hanna Gro Cinesoil pH Tester, and air humidity and temperature 0.1 m above the ground by means of a Thermo-Hygrometer by Comet. Light intensity at a height of 1 m between 2 p.m. and 4 p.m. was determined using a Sonel LXP 2 light meter. The substrate temperature was additionally measured at a depth of 0.1 m, and groundwater level in piezometers.

2.2.3. Climatic Factors

In order to learn more about the conditions of the occurrence of sundew, meteorological data from the nearest available stations (Włodawa, Chełm and Łęczna) were also analysed (rainfall, temperature). The selection of meteorological stations depended on the location of the research stations. The Chełm and Włodawa stations are at places closest to the reintroduction sites, while the Łęczna station is the closest to the sites of the present abundant occurrence of sundews.

2.2.4. Floristic Characteristics

Research on the vegetation cover involved the preparation of 50 floristic lists, along with the determination of species coverage. Phytosociological relevés were made by means of the Braun–Blanquet method [24]. The floristic lists were made in compact, physiognomically distinct vegetation patches with an area of 0.5 m^2. The designation of phytocenotic units was based on the systematic system and nomenclature of [4,25,26], and the names of bryophytes after [27]. The coverage of each species was determined based on a percentage scale (+/−1%, 1–5%, 2–25%, 3–45%, 4–65%, 5–100%), more precise and more convenient for the needs of statistical inference, and at the same time transformable at any scale, e.g., the Braun–Blanquet scale. The degree of the overgrowth of the lobes was also determined on a 0–100% scale.

The Shannon–Wiener diversity index was used to assess the species richness of plants at individual sites:

$$H = -\sum_{i=1}^{S} (p_i) ln(p_i) \quad (1)$$

p_i—numerical fraction of the plants of a given species in relation to all designated species; S—number of all species.

At current sites, only phytocoenoses with sundew coverage of at least 10% were analysed.

2.3. Statistical Analysis

Based on the two-factor analysis of variance and Tukey's posthoc tests, the climatic conditions were compared in two time periods (1980–1985 and 2010–2020). The analysis permitted the identification of key differences between the conditions in particular areas, as well as the changes that occurred over time.

The hierarchical cluster analysis (AHC) method was used, along with the CH index algorithm for determining the optimal number of clusters [28] to assess differences between areas in terms of changes in the frequency of the occurrence of particular plant species. In addition, the similarity between objects was represented by a dendrogram with construction based on the Bray–Curtis dissimilarity index to analyse the frequency of plant species between sites [29]:

$$BC_{uv} = 1 - \frac{2 \cdot \sum_{j=1}^{S} \min(x_{uj}, x_{vj})}{\sum_{j=1}^{S} x_{uj} + \sum_{j=1}^{S} x_{vj}} = \frac{\sum_{j=1}^{S} |x_{uj} - x_{vj}|}{\sum_{j=1}^{S} (x_{uj} + x_{vj})} \quad (2)$$

where x_{uj} and x_{vj} denote the abundance values of species j in objects u and v, respectively, and S is the total number of species recorded in both objects.

In order to characterise the spatial variability of the physical and chemical parameters of the surveyed sites, multi-dimensional methods of classification and ordering (hierarchical cluster analysis, AHC, and principal component analysis, PCA) were used. The original data were standardised to avoid misclassification associated with different units. Moreover, based on a Grubbs test, one outlier (Łukietek 5) was removed. The preparation of the dendrograms employed the Ward minimal variance classification algorithm with the Euclidean distance as a measure of similarity.

A non-parametric Kruskal–Wallis test was applied to compare the coverages in individual layers A, B, C, and D of the three types of sites selected for the study: potential lake sites (LP), potential wetland sites (WP), and current lake sites (LC).

Calculations and graphs were performed using the XLSTAT program (https://help.xlstat.com/tutorial-guides/statistics-guides (accessed on 20 April 2022) assuming the significance level of the tests α = 0.05.

3. Results

3.1. Long-Term Changes in Temperature and Precipitation

The analysis of precipitation values for the research area shows a decrease in the annual total by almost 50 mm compared to the 1980s, and a temperature increase of 1.7 (°C) (Table 1).

Table 1. Meteorological data from the 3 weather stations (W—Włodawa, Ch—Chełm, and Ł—Łęczna) according to meteoblu over two periods (1980–1990; 2010–2020).

Feature	Precipitation (mm)			Temperature (°C)		
Station	W	Ch	Ł	W	Ch	Ł
1980–1990	751.27	766.00	761.95	7.45	7.47	7.53
2010–2020	710.09	712.57	710.65	9.16	9.15	9.25

Average annual temperature values were very similar at individual stations, although they were the highest in the following decades in the vicinity of the Łęczna station. Average annual rainfall was slightly higher in the area of the Chełm station (Table 1).

A two-factor ANOVA showed that the temperature was significantly different in the two analysed periods (Table 2, $p < 0.05$). Figure 2 revealed that the mean temperature in the period 1980–1985 was significantly lower than in the years 2010–2020. Rainfall showed no significant difference (Table 2, $p > 0.05$).

Table 2. Results of Tukey posthoc test.

Source of Variability	Precipitation	Temperature
Period	0.1170	0.0001 *
Station	0.9729	0.9454
Period * station	0.9847	0.9972

* $p < 0.05$.

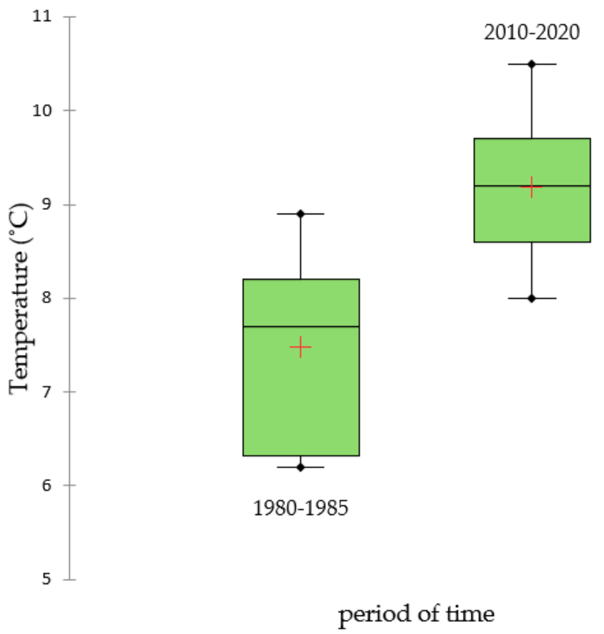


Figure 2. Box-plot of temperature in two periods of time (the averages marked with red cross).

3.2. *State of Current and Potential Habitats*

At current sites (peat bog at Lake Łukietek), sundews occurred both in patches and dispersion, particularly the long-leaved sundew. They mainly inhabited an open peat bog with a low degree of overgrowth and a shallow littoral zone (*Drosera intermedia*) (Table S5), where the water depth did not exceed 5 cm. It was open lake gyttja among reeds. *Drosera anglica* most often appeared in scattered patches at the edge of the peat bog, occupying a much smaller area (Table 3).

The potential sites (reintroductions) of *Drosera intermedia* and *D. anglica* are primarily naturally predisposed sites. Swarms of wild animals (Figure 3), natural depressions, and lake shores were selected as potential sites.

The resettlement area ranged from 0.06 m^2 (Lake Orchowe 1-O1) to 0.4 m^2 in peat bogs. The degree of the overgrowth of potential sites varied greatly, from 25% (Lake Płotycze 1-Pł1) to even 80% (Lake Płotycze 2-Pł2, Ocrchowe 2-O2 and Podlaski-Pd). There were mainly *Sphagnum*, *Carex*, *Vaccinium oxycoccos*, and *Eriophorum vaginatum*. Tree seedlings also appeared (Table 4).

Table 3. Characteristics of sundew sites. The degree of the overgrowth of reintroduction sites is prior to their preparation for planting.

Site	Stand Area (m^2)	Degree of Overgrowth (%)	Expansive and Competitive Species
		Potential lake sites (LP)	
Pł1	0.09	25	*Sphagnum, Vaccinium oxycoccos*
Pł2	0.15	80	*Sphagnum, Vaccinium oxycocco, pine seedlings, Andromeda polifonia*
O1	0.06	60	*Carex limosa, Vaccinium oxycocco*
O2	0.09	80	*Carex limosa, birch seedlings, Molinia caerulea, Vaccinium oxycocco*
		Potential wetland sites (WP)	
S1	0.25	30	*Sphagnum, Rhynchospora alba*
S2	0.12	50	*birch seedlings and pine seedlings, Carex*
S3	0.4	30	*Sphagnum, birch seedlings, Rhynchospora alba*
S4	0.09	35	*Sphagnum, Vaccinium oxycoccos, pine seedlings*
M1	0.15	35	*Sphagnum, Vaccinium oxycoccos, Eriophorum vaginatum*
M2	0.12	50	*Sphagnum, Eriophorum vaginatum, Carex lmosa, pine seedlings*
Pd	0.16	80	*Sphagnum, Eriophorum vaginatum, pine seedlings*
		Current lake sites (LC)	
Ł1	0.25	20	*Comarum palustre, Vaccinium oxycoccos, Sphagnum, Salix aurita, Vaccinium oxycocco*
Ł2	0.3	20	*Comarum palustre, Andromeda polifonia, pine seedlings*
Ł3	3.75	5	*Phragmites australis, Nymphea alba, Rhynchospora alba, Sphagnum*
Ł4	0.25	20	*Sphagnum, Rhynchospora alba, Rhododendron tomentosum*
Ł5	2	5	*Phragmites australis, Nymphea alba*

Figure 3. Places of animal activity in the mid-forest peat bog in the Sobibór Forests.

Table 4. Significance of differences in the cover of the layer of trees (A), shrubs (B), herbaceous (C), and mosses (D) at individual sites.

Layer Cover	A	B	C	D
p-value	0.5647	0.6334	0.7043	0.0670

3.3. Phytosociological Characteristics of Sundew Sites

The current and potential sundew habitats were very similar in terms of phytosociological composition. They included a total of eight plant communities:

Phragmitetea R.Tx. et Prsg 1942, *Phragmition* Koch 1926;
Phragmitetum australis (Gams 1927) Schmale 1939;
Scheuchzerio-Cariceteanigrae (Nordh. 1937) R. Tx. 1937;
Caricetum limosae Br.-Bl. 1921;
Rhynchosporetum albae Koch 1926;
Caricetum lasiocarpae Koch 1926;
Comm. *Sphagnum recurvum-Eriophorum* angustifolium Jasn. 1968 pro ass.;
Comm. with *Drosera intermedia*;
Sphagno-Caricetum rostratae (Steffen 1931) Sm. 1947;
Oxycocco-*Sphagnetea* Br.-Bl. etR.Tx. 1943, *Sphagnetalia magellanici* (Pawł. 1928) Moore (1964)1968;
Comm. *Eriophorum vaginatum-Sphagnum fallax Hueck* 1928.

The current locations of sundews showed a lower diversity of plant communities. They included from one to two plant communities, while at potential sites, there were from two to five communities (Table S6). In the case of potential objects (re-introduction), the cover of the herbaceous layer and moss was greater. The share of potentially expansive companion species was greater at the current sites. According to the assessment of the management and use of the surroundings of Lake Łukietek, it may pose a potential threat to this research object in the future (including illegal fishing grounds and trampling).

The optimum occurrence of sundew was determined in the phytocoenoses of *Rhynchosporetum albae* Koch 1926, and slightly less often in the patches of *Sphagno recurvi-Eriophoretum angustifolii* Hueck 1925.

A Kruskal–Wallis test showed no significant differences between the designated LP (potential lake sites), WP (potential wetland sites), and LC (current lake sites) sites and the degree of coverage in individual layers A, B, C, and D (Table 4, $p > 0.05$).

As a result of the AHC analysis, the data were divided into four groups (clusters). The dendrogram shows that sites Ł2 and Ł3 (value of BC = 0.0102), S2, and Ł4 (value of BC = 0.138), as well as S4 and M1 (value of BC = 0.172) are the most homogeneous in terms of vegetation. The greatest difference in the floristic composition is observed between the sites belonging to clusters C1 (marked in green) and C2 (marked in purple) (peat bogs near lakes). The former group consisted of sites located at the shoreline of the lakes, and the second group consisted of in-bog sites (Figure 4).

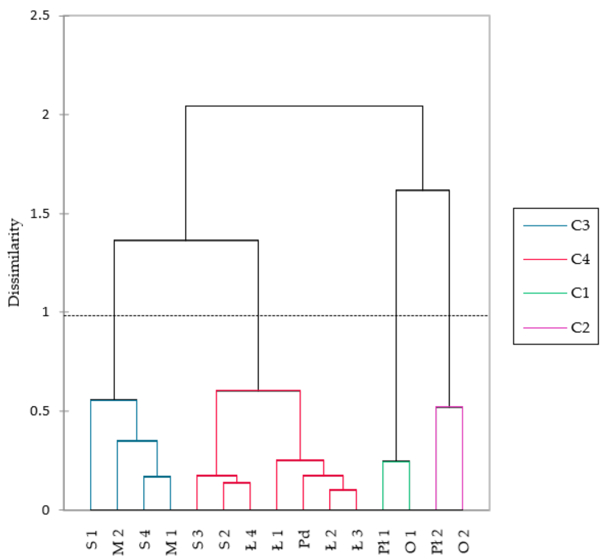


Figure 4. Cluster dendrogram of sites depending on plant composition.

The floristic diversity index was also determined for all sites. The highest values were recorded at Lake Orchowe O2 (2.26) and in the mid-forest Stulno S3 bog (2.26), and the lowest at the Macoszyn M2 bog (1.38) (Table 5). Open stands with no participation of woody vegetation achieved higher values of the analysed index.

Table 5. Index of Shannon–Wiener results.

Site	Shannon–Wiener Index
Pł1	1.74
Pł2	1.73
O1	1.92
O2	2.26
S1	2.01
S2	1.43
S3	2.26
S4	1.45
M1	1.90
M2	1.38
Pd	1.85
Ł1	1.45
Ł2	1.88
Ł3	2.04
Ł4	1.44

3.4. Rare Species

The analysed objects were characterised by a large share of rare and protected species. More than half of the 40 plant species found at the studied sites are protected species (22). The greatest number of such species was found in the bog at Lake Orchowe (11 species) and the smallest (four species) at the site at Lake Łukietek. The remaining sites were very similar in terms of colonisation by rare species. Their number ranged from five to eight (Tables S1 and S6).

3.5. Physico-Chemical Characteristics of Sundew Sites

The current occurrence of sundews (bog at Lake Łukietek) was characterised by the values of soil moisture in the root zone, similar to those at the reintroduction sites at the lakes—approximately 80%. At mid-forest bog sites, these values were slightly lower and did not exceed 78%. Air humidity was clearly correlated with ambient temperature. The light and thermal conditions were similar (Table S2). At mid-forest peat bog sites, the level of groundwater was lower (from 0.08 to 0.44). At lake sites, the groundwater level ranged from 0.005 m to 0.23 m. Sites with the lowest shade of 971.8 lx were potential sites at the lakes), while the greatest shading of 779.4 lx was found at potential sites in mid-forest bogs. Peat temperature was very stable and reached higher values in periods of low ambient temperatures (Table S2).

The concentration of carbon and nitrogen as well as the content of organic matter were very similar at the selected sites. Extremely low pH values were recorded in the mid-forest bog Stulno 2.8 (S1), while the highest was 4.94 in the bog at Lake Orchowe (O1). As a rule, slightly higher values of macro- and microelements were recorded in mid-forest bogs, as well as low values of total forms of elements (Table S3).

The PCA analysis was used to determine the spatial variability of the physico-chemical parameters. Indicators of the greatest importance for shaping the habitat conditions were determined based on the analysis. Significant axes were selected based on the Kaiser criterion, taking into account only components (PC1, PC2, PC3, PC4) with eigenvalues greater than 1 in further studies. The first two components accounted for 54.6% of the total variability of the source parameters. Ultimately, the four-factor system explained more than 78% of the total variability in the original dataset, limiting the underlying set of 17 indicators (chemical and physical) to the four factors necessary to identify the environmental conditions of sundew. Moreover, taking into account the value of factor loadings between the main components and the parameters determining the environmental conditions, the strength of the formed compounds was determined (Table S4).

Based on the PCA analysis, a clear group of objects covering mid-forest peat bogs (ellipse) was designated (Figure 5). These stands are characterised by high values of Mg, N tot, P avail, Mn, and low content of organic substances. Moreover, Ctot, groundwater level (GWL), and air temperature above ground (ATAG) reached moderately high values.

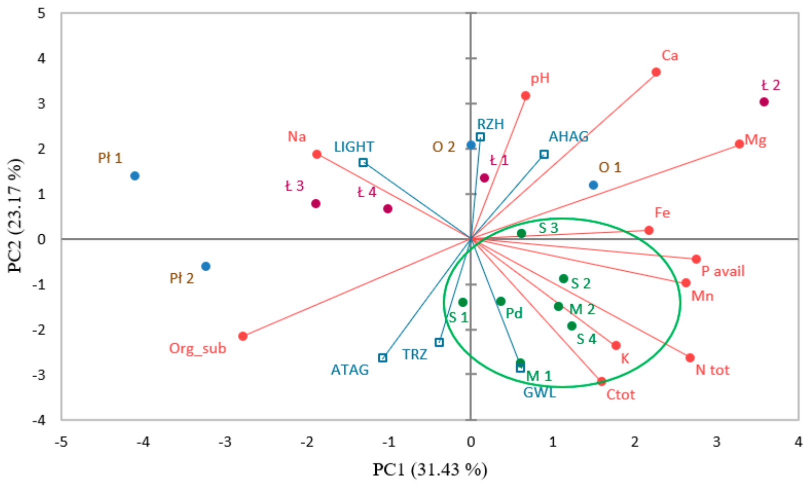


Figure 5. Results of the principal component analysis: blue—potential lake sites; green—potential wetland sites; red—current lake sites. The abbreviations of the names of the objects as they appear in the tables: RZH—root zone humidity; AHAG—air humidity above the ground; ATAG—air temperature above ground; TRZ—temperature in the root zone; GWL—groundwater level; LIGHT—light; Pł—Płotycze lake; O—Orchowe lake; S—Stulno lake; M—Macoszyn lake; Pd—Podlaski lake; Ł—Łukietek lake.

The PCA analysis also showed that Fe (PC3) and K (PC4) are factors that significantly account for the variability of the studied dataset. Fe and K are the highest for mid-forest peat bogs (average Fe = 573.7 and K average = 67.5), and the lowest for the current occurrence sites (Fe average = 459.3 and K average = 32.2). The values of Fe and K concentrations differed significantly between the positions of the current and potential occurrence of sundew, reaching higher values at potential sites and lower at current ones. Moreover, the current occurrence sites, namely the bog at Lake Łukietek and other bogs by the lakes, were characterised by higher values of Ca and pH and lower values of Ctot, GWL, and ATAG than mid-forest bogs (Figure 5).

4. Discussion

The intention of the entire project was active protection involving the restoration of the sites of *Drosera intermedia* and *D. anglica* aimed at the preservation of the population of these species that will function independently in the Łęczna-Włodawa Lake District. The success of the activities currently carried out can be verified in the perspective of several years when the next generations of plants appear. The implemented measures are of pioneer character for this region. If the effect is satisfactory, they may be continued and cover other bogs. The ecological effect is the preservation and even increase in biological diversity associated with natural habitats from Annex I of the Habitats Directive, and the maintenance of increase in the number of characteristic species, including the preservation of valuable and protected taxa of vascular flora. The very multi-threaded analysis does not seem to exhaust the issue of species recession.

Sundews have a down-to-earth rosette of leaves covered with reddish glandular hairs. They are suited to attracting insects, then holding them in with sticky secretions and digesting them. Due to their rich composition of cyanogenic compounds, various organic acids, and proteolytic enzymes, in folk medicine, sundews were used to make medicinal tinctures applied as a diuretic, expectorant, and for eye inflammation [15]. It is their invaluable healing properties and changing habitat conditions that caused the rapid decline of the population, which in turn became the basis for the species' protection.

Drosera anglica Hudson and *D. intermedia* L. are plant species with overlapping ranges in peat bogs in the peri-boreal regions of the Northern Hemisphere [30]. In boreal regions, the loss of biodiversity in peatlands occurs as a result of human activity, through changes in land development, e.g., drainage for agriculture [31]. A decline in diversity, including the population of *Drosera*, is observed even within peat bogs in various regions with no direct human impact, but where disturbances are caused by climate change [32–34]. Nutrient-poor bogs show extremely low levels of species diversity compared with other terrestrial ecosystems [35]. Consequently, the loss of an individual species from a bog may indicate the loss of an entire plant functional group [36]. The studied sites differed in terms of floristic diversity. Higher values of the diversity index were obtained in shaded places with the participation of herbaceous plants and tree seedlings. These sites included a lower number of rare and protected species.

In the 1960s in the Łęczna-Włodawa Lake District, the occurrence of *Drosera anglica* and *Drosera intermedia* was recorded in 55 bogs adjacent to the lakes, out of all 73 analysed sites. Both sundews were found in 32 peat bogs, and *Drosera intermedia* was present in another 23 [21]. Currently, the number of these objects has drastically decreased. There is no historical data on the exact number of sundews at the current site at Lake Łukietek, making it impossible to assess quantitative changes.

All places of the reintroduction of sundews are places of their abundant coexistence in the 1960s. The sites of their occurrence were documented back in the 1980s), but only as accompanying and sparse. In the case of the Łęczna-Włodawa Lake District, the withdrawal of sundew from the sites and their historically abundant occurrence were related to the works changing the hydrological regime of this region. As a rule, sundews form dense clusters, and during the melioration and embankments of lakes, they were extremely vulnerable to destruction. An additional threat is caused by water eutrophication [37]. In the 1990s, the hydrological conditions changed in many reintroduction sites. Most importantly, the outflow was discontinued [38].

Most of the peat bog plant species were included in special lists of endangered species, in a "black list" in West Europe and in a "red list" in Poland. Despite being protected, the species are systematically declining. It is probably caused by habitat conditions: water, substrate, and local climatic conditions.

Recent decades have shown that the greatest decline in biodiversity is associated with wetland habitats. Wetlands are an element increasing biodiversity, but also enriching cultural space [39]. Climate change has a direct impact on the hydrological regime of the wetland and the surrounding landscape. In recent times, climatic factors may have exceptionally contributed to changes in the rate of biological accumulation processes, fluctuations in water levels, and the activation of morphogenetic processes, resulting in slow or rapid reconstruction in the biotic structure of fens, depending on the intensity of changes. We are witnessing such changes. The abandonment of activities aimed at changes in the hydrological regime is the most important form of protection of the natural heritage of our region. The global factor contributing to an increase in temperature may prove extremely important for the species of the temperate zone. Significant thermal changes observed in the analysed area are potentially one of the reasons why sundews disappear. The research indicated the importance of the thermal effect already at the seeding stage. Cooling the seeds allowed for their greater vitality. Habitats closely related to water experience temperature changes even more, which influences the reconstruction of their plant structure [40]. Temperature also affects the processes regulating the decomposition of organic matter and all reactions of the nitrogen cycle (mineralisation, nitrification, and denitrification) [41].

Sundews most often grow among sphagnum moss. According to a study [42], *Drosera anglica* shows a low level of competition with patches created by Sphagnum. The research confirms that both *Drosera anglica* and *D. intermedia* prefer open habitats (gyttja), particularly the former one. In the case of the latter sundew, the company of several peat bog species is tolerated (*Eriophorum vaginatum* L., *Carex limosa* L., *Oxycoccus palustris* L., *Andromeda polifolia* L., *Sphagnum*). If the share of accompanying species was greater than 25% (overgrowth), the species would disappear. Such a situation occurred at potential sites with a greater degree of overgrowth.

Casper and Krausch [43] confirm that the biology and presence of *Drosera intermedia* forms are quite complex. There are forms that float in water such as Utricularia. In Drosera intermedia, floating rosettes sometimes develop as an adaptation to flooding. Such floating forms have not been found in *Drosera anglica*. Current sites have confirmed these preferences. *D. intermedia* inhabited both the peat bog and its edge and the open lake gyttja among reeds, while *D. anglica* appeared in small patches at the edge of the bog. After reintroduction, *D. anglica* survived at the lakes (by the shoreline), and *D. intermedia* at each selected site. *D. rotundifolia*, present at all analysed sites as a companion species, is much less demanding in terms of groundwater level [12,30,44,45].

The intermediate sundew, just like the long-leaved sundew, has a narrow ecological amplitude range, both in terms of substrate moisture and acidification [15,42]. According to [10], *Drosera* species prefer moderate light conditions, a moderately warm climate, high hydration conditions, and poor and moderately poor soils, acidic and moderately acidic pH < 6, but rich in organic matter. *Drosera intermedia* and *D. anglica* have even more stringent requirements for substrate pH (the pH value ranged from 2.98 to a maximum of 4.48). They also require strong hydration (the groundwater level ranged from 0.005 m to 0.43 m). The more hydrated sites had less organic matter. The PCA analysis also showed that Fe and K are factors that significantly account for the variability of the studied data set. Such a division of sites into mid-forest fens as one distinct group and the remaining ones (lake fens) could have generated processes related to decaying peat soils [46] that took place as a result of changes in the water conditions in the area.

5. Conclusions

The exact knowledge of the reasons for the disappearance of species is necessary to be able to act rationally, taking into account the need for development and nature protection.

All analysed factors more or less influence the occurrence of sundew. The main reason for the disappearance of sundews may be changes in the temperature in the studied area. Despite the fact that the loss of water was stopped, the sundews did not return to their former sites. Active conservation measures and adapting the habitats subject to succession allowed for re-populating them by sundew species. The overgrowth of sites exceeding 25% limits the possibility of their repopulation.

Clear preferences in the settlement of sites were observed. *Drosera anglica* was mainly associated with the shoreline of lakes where it showed exclusive occurrence. These sites were more hydrated and almost devoid of companion plants. *D. intermedia* appeared in larger patches, inhabiting both the more hydrated edge of the fen and its central part. For *Drosera intermedia*, on the other hand, it was revealed that it acclimatises to mid-forest peatlands, rich in magnesium, nitrogen, phosphorus, and manganese, with moderate carbon content, medium levels of groundwater and air temperature, and low concentrations of organic matter.

The sundew occurrence sites were characterised by lower diversity indexes, but a greater number of rare and protected species.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w14182775/s1, Table S1. Rare and protected species of the investigated area; Table S2. Characteristics of the habitat conditions of sundew sites; Table S3. Characteristics of the physical properties in current and potential sundew sites; Table S4. Matrix of factor loadings for PCA analysis; Table S5. Drosera transplantation effect on designated areas; Table S6. Plant communities.

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