Appendix No. 3

To an Application dated 25th September 2023

Commencement of the habilitation procedure

Summary of Professional Accomplishments

dr Zygmunt Dajdok

Department of Botany
Faculty of Biological Sciences
University of Wrocław

Wrocław 2023

1. **Name:** Zygmunt Dajdok

2. **Diplomas, degrees conferred in specific areas of science or arts, including the name of the institution which conferred the degree, year of degree conferment, title of the PhD dissertation**:

1991 – Master of Science in Biology, University of Wrocław, Faculty of Natural Sciences, majoring in biology, specialization: environmental biology. Master thesis titled "*Zbiorowiska roślinne wschodniego krańca Równiny Oleśnickiej*" (Plant communities of the eastern edge of the Oleśnica Plain)
Supervisor: prof. dr hab. Jadwiga Anioł-Kwiatkowska

1999 – PhD in biological sciences in the field of biology, University of Wrocław, Faculty of Natural Sciences. Doctoral dissertation titled "*Przestrzenne zróżnicowanie roślinności w strefach buforowych wybranych strumieni Wzgórz Lipowych*" (Spatial diversity of vegetation in buffer zones of selected streams of Wzgórza Lipowe).
Supervisor: prof. dr hab. Jadwiga Anioł-Kwiatkowska;
Reviewers: prof. dr hab. Stanisław Balcerkiewicz; prof. dr hab. Jan Sarosiek

3. **Information on employment in research institutes or faculties/departments or school of arts.**

from 16. 09. 1991 – to date University of Wrocław:

16. 09. 1991 – 2. 12. 1992 independent biologist at the Department of Plant Systematics and Phytosociology (Institute of Botany, Faculty of Natural Sciences, University of Wrocław);

2. 12. 1992 – 1. 10. 1999 assistant lecturer at the Department of Plant Systematics and Phytosociology (Institute of Botany, Faculty of Natural Sciences, University of Wrocław);

1. 10. 1999. – to date – assistant professor at the Department of Botany, Faculty of Biological Sciences, University of Wrocław (previously the Department of Plant Systematics and Phytosociology, Institute of Botany, Faculty of Natural Sciences, University of Wrocław, then Department of Biodiversity and Plant Cover Protection, Institute of Plant Biology, Faculty of Biological Sciences, University of Wrocław)

4. **Description of the achievements, set out in art. 219 para 1 point 2 of the Act.**

4.1) title of scientific achievement No. 1

Szata roślinna liniowych środowisk marginalnych w krajobrazie rolniczym w zależności od ich struktury, funkcji i cech otoczenia (*Vegetation of semi-natural field margins in relation to their structure, function and the surrounding land-use*)

4.2) A publication constituting a monograph in accordance with art. 219 para 1, point 2a of the Act,

Author: Zygmunt Dajdok

Title: Szata roślinna liniowych środowisk marginalnych w krajobrazie rolniczym w zależności od ich struktury, funkcji i cech otoczenia (*Vegetation of semi-natural field margins in relation to their structure, function and the surrounding land-use*)

Publication date: 2020

Series: Studia Naturae 63. p. 379+23 tables

Editor in Chief: prof. dr hab. Henryk Okarma

Editor of the Volume: dr hab. inż. prof. IOP PAN Andrzej Wuczyński

Publishers: Uniwersytet Wrocławski Instytut Biologii Środowiskowej & Instytut Ochrony Przyrody Polskiej Akademii Nauk, Wrocław-Kraków. ISBN-13 978-83-61191-03-2

Editorial reviewers:

1) Prof. dr hab. Maria Wojterska, Zakład Ekologii Roślin i Ochrony Środowiska Uniwersytet Adama Mickiewicza w Poznaniu, 61-614 Poznań, ul. Uniwersytetu Poznańskiego 6
2) Dr hab. Halina Ratyńska, ul. Wergiliusza 4/5, 60-461 Poznań

4.3) discussion of the scientific goal of the article mentioned above and the obtained results with the discussion of their potential use.

Justification of the selection of the research problem

Agricultural areas today are the dominant element of the landscape in many regions of the world. In Europe, their share is estimated at over 40% of the continent's area (European Environment Agency, 2019), while in Poland at about 55% (GUS data 2022 for 2021). From a natural point of view, unfavourable trends resulting from the intensification of agricultural production have been noticeable for a long time (Emmerson et al., 2016). Their manifestation, among others, is the transformation of meadows and pastures into arable land, modification of farming methods, increasing the amount of fertilisers and plant protection products used, as well as land consolidation by eliminating the boundaries between agricultural plots. These changes are accompanied by a decline in the natural diversity and abundance of organisms associated with agricultural areas, including the most widely studied group – birds (Donald et al., 2001; Stanton et al., 2018), as well as insects (Donald et al., 2001; Sánchez-Bayo & Wyckhuys, 2019) and plants (Geiger et al., 2010). The need to introduce changes into the global food production (Willett et al., 2019), among others, by radically improving fertilisation efficiency, water use, redistributing global nitrogen and phosphorus consumption, and increasing the biodiversity of agricultural systems is, therefore, indicated. It is emphasised that in order to halt the global decline of biodiversity, rigorous measures taken in the protected areas are not enough – a rational use of agricultural areas is considered necessary (Mora & Sale, 2011).

One of the key solutions contributing to the improvement of the natural environment of agricultural areas is to ensure an appropriate share of the so-called marginal habitats, i.e. landscape elements not directly used in agricultural production. These include the remains of the former natural and semi-natural ecosystems, in the form of tree lines, windbreaks, baulks, as well as strips of vegetation accompanying watercourses, roads or railway lines. Due to their natural importance, marginal environments are referred to as refugial environments (Aavik et al., 2008; Banaszak & Cierzniak, 2000; Czarnecka, 2011a; Smart et al., 2002), and linear hotspots (Croxton et al., 2005), green veining (Grashof-Bokdam & van Langevelde, 2005) or field margins (Marshall & Moonen, 2002).

Previous studies clearly indicate the great ecological importance of mid-field linear structures, although the intensity of research varies between their types, especially focusing on hedgerows (e.g. Baudry et al., 2000; Hinsley & Bellamy, 2000; Jobin et al., 1997; Wilkerson, 2014). In Poland, research on windbreaking tree lines (shelterbelts) and their functional significance in the agricultural landscape has gained a long tradition (review in: Ryszkowski, 2002). Later, interest was broadened to other types of marginal structures, with vegetation developing spontaneously, called field margins (e.g. Czarnecka, 2011b; Kujawa, 1996; Wolak & Karg, 2002; Wuczyński et al., 2011). The positive impact of shelterbelts on soil conditions (Wojewoda & Russell, 2003) and microclimatic conditions (Berezowska-Niedźwiedź et al., 2016; Górny, 1993; Woch & Borek, 2015), the functioning of these structures as biogeochemical barriers to large-scale pollution (Ryszkowski et al., 1990, 1996), as well as their role in increasing yields in neighbouring fields (Talalai, 1997; Talalai & Węgorek, 1995) have been also indicated. A fairly large number of papers on linear marginal habitats concerned flora and/or plant communities (among others Denisov & Wrzesień, 2007, 2015; Kryszak et al., 2006; Loster & Dubiel, 1985; Marciniuk, 2009; Orlowski & Nowak, 2007; Ratyńska & Szwed, 1999; Wojterska, 1990, 1992; Wróbel, 2007). However, it was still difficult to identify the importance of these habitats in a broader perspective, taking into account aspects and indicators that are now considered relevant, such as the richness of endangered species, the share of geographically alien species or those of pollinator importance. There was also a lack of analyses indicating the connection of floristic parameters with the environment, the structure of various field margin types and their function in the agricultural landscape. An attempt to fill these gaps was a comprehensive study undertaken in agricultural areas of Lower Silesia, concerning a wide spectrum of field margins, from open baulks to compact rows of trees and shrubs, taking into account indicative groups of organisms: vascular plants, bryophytes, birds and invertebrates (e.g.: Dajdok & Wuczyński, 2008; Kujawa et al., 2020; Wierzcholska et al., 2008; Wuczyński et al., 2011). The results of these studies relating to vascular plants are summarised in a monograph which is the basis of the presented scientific achievement.

Research objectives

The monographic study presented as scientific achievement No. 1 is the result of research carried out in the Sudetic Foreland, in the south-eastern part of Lower Silesia. The study covered 35 km of linear marginal habitats, divided into 70 sample plots – sections with a length of 500 m, called field margins. At individual sections, the collection of data on the composition of vascular flora was repeated several times during the growing season, and detailed characteristics of phytocenoses formed within these environments were made in transects transverse to the margin axis. In each of the transects, vegetation zones differing in structure and/or species composition were distinguished. Such a high degree of detail of the data collection was one of the features distinguishing the conducted research from previous studies. It allowed to distinguish the features of the plant cover and factors affecting its character, which were not the subject of previous research. The main objectives were:

1) indication of the parameters of marginal habitats and surroundings that determine the richness and species composition of vascular plants associated with them;
2) determining the role of mid-field, linear marginal habitats as a refuge for selected groups of vascular plants, including those covered by legal protection in Poland and/or endangered with extinction on a regional, national or European scale, as well as species classified as medicinal plants, species that are sources of nectar or pollen for insects and crop wild relatives;
3) determination of the zonal vegetation arrangement of field margins and its determinants and identification of plant communities associated with different parts (zones) of the margins, in addition, indication of the current and potential importance of these communities in biocenotic terms and their role in ecosystem services provided by marginal environments in agricultural areas;
4) formulation of guidelines for the practice of protection (management) of marginal habitats in order to optimise their biocenotic function.

Methods of data collection and analysis

The layout of the work refers to the presented objectives. The first part covers a detailed description of the site of the data collection, taking into account its location against the background of administrative and physiographic division, geological and soil conditions, hydrographic and climatic conditions. On the basis of literature data, the vegetation cover of the research area and the location of objects under legal protection were also discussed.

Field data were collected in the years 2004–2007, choosing 70 out of over 100 initially selected linear structures located in the agricultural areas of the Sudetic Foreland. In addition to the author's research on vascular plants and communities, other members of the research team collected data on birds, invertebrates and bryophytes, which in a broader context (beyond the scope of this achievement) allowed to indicate taxonomic relationships and is the first such a comprehensive study of marginal environments in Poland. An important part of the fieldwork was also measurements of the structure of the margins and their surroundings, carried out using the original GIS methodology, equipment and tools. The measurements covered several dozen parameters which, after reduction, were used in modelling the impact of environmental variables on flora features.

Detailed botanical data were collected using the transect method (Faliński, 2001), determined transversely to the axis of the field margin (three per margin). In each of the transects, the constituent zones of vegetation were determined, adopting the basic principle applicable in phytosociological research, concerning the inclusion of phytocenoses uniform in terms of floristic composition as well as vegetation structure (Dzwonko, 2007). The distribution of zones within the most frequently repeated types of field margins (with the watercourse, road, railway embankment and slope) is schematically presented in Figure 1. In the monograph, this scheme was used to illustrate the distribution of patches of plant communities, next to statistical data on the occurrence of a given community, ecological indicators of Ellenberg and Shannon-Wiener index.

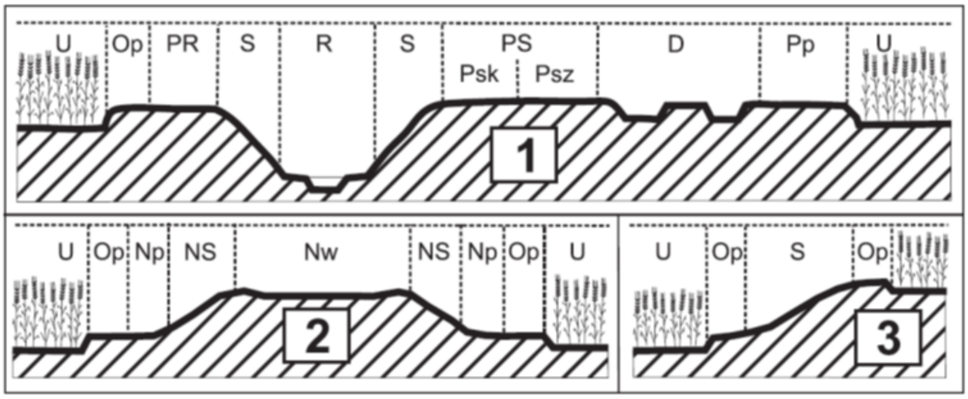

Fig. 1. Diagram of division of the basic field margins types into component zones: 1 – a margin consisting of a watercourse (stream or ditch) and a field track, 2 – a margin with a railway embankment, 3 – a margin covering balk in the form of a slope between crop fields. Zone designations: Op - extreme zone of the margin on the border with the field, PR - zone of area "next to the ditch", S – escarpments of a watercourse or a slope, PS - a strip of wide roadside from the inner side of the margin, Psz – roadside occupied by herbal plants, Psk – roadside occupied by shrubs, D – field road, Pp - roadside from the field side, Np – zone with herbaceous vegetation at the base of the embankment, NS – zone with herbaceous vegetation on the slope of the embankment, Nw – the top zone of the embankment, R – banks and riverbed of the watercourse, U – cultivation adjacent to the margin.

Data on vascular flora were obtained in two ways – from floristic lists created after the compilation of relevés made in the distinguished vegetation zones using the standard Braun-Blanquet method (Dzwonko, 2007; Westhoff & van der Maarel, 1978) and from floristic inventories made along the entire length of the margins, at different times of the growing season. Species lists formed the basis for determining the importance of linear marginal habitats for various groups of vascular plants, as well as in modelling the relationship between flora features and parameters of the margin structure. The most important of these parameters were the width of the margin, the number of crops in 200-meter buffers around the margins and the total volume of high vegetation resulting from measurements of trees and shrubs over the entire 500-meter section. On its basis, three categories of margins were distinguished: a) herbaceous – H, b) shrubby - S, c) tree lines - T. These categories reflect linear marginal habitat types present in the agricultural landscape of Poland. They were used to assess the importance of margins for different groups of plants and to indicate possible protective measures.

The numerical classification of the entire set of relevés was carried out using the modules of the JUICE package (Chytry et al., 2002; Tichý, 2002; Tichy et al., 2014). In addition, in order to characterise individual communities against the background of full diversity of field margins vegetation, the data set was subjected to the analysis of non-metric multidimensional scaling (NMDS) (Wickham, 2016) based on the species composition of communities and average values of Ellenberg indicators. Relationships were established between the dominant native expansive species, such as *Phragmites australis*, *Urtica* *dioica*, *Elymus repens* and *Prunus spinosa*, and the overall species richness of vascular plants. In the characteristics of the distinguished communities, special emphasis was placed on indicating their specific features, among others, in the context of biocenotic significance and ecosystem services (Rosin et al., 2011; Solon, 2008). The applied approach distinguishes the monograph from previous floristic and phytosociological studies, indicating the possibility of using the system of plant communities in the management of marginal habitats of agricultural areas and in the assessment of the importance of these environments for various groups of organisms.

Obtained results and the possibility of their use

In accordance with the objectives set at the beginning of the study, the results can be divided into several main aspects: 1) quantification of the parameters of the structure of mid-field marginal habitats; 2) characteristics of vascular flora, 3) specificity of plant communities, 4) guidelines for protective measures.

Ad 1. Structure and surroundings of mid-field marginal habitats.

Field measurements covered several dozen elements of the horizontal, vertical structure and the surroundings of the margins such as width, dimensions of ditches and roads, species richness and dimensions of clumps or rows of trees and shrubs, diversification of adjacent crops and soils, distances from forests and villages and others. For the purpose of statistical calculations, 16 variables were selected, which, after further reduction into collinearity, were used in numerical analyses. The following are the characteristics of the most important variables for illustrating the structure of the tested surfaces.

- the average width of the range was from 4.9 to 28.9 m. The narrowest were margins with herbaceous vegetation, stretching along ditches or streams with a bed width of about 0.5 m and baulks on slopes. The widest included linear systems covering several elements related to the former or modern function of the margins, such as railway embankments, field roads, watercourses, often in the form of rows of trees growing on the banks of watercourses;
- diversification of the vertical structure of vegetation – the total volume of dendroflora resulting from measurements of trees and shrubs over the entire 500-meter section turned out to be a useful parameter. On its basis, three of the above-mentioned categories of margins were distinguished: i) herbaceous (H, N = 21), ii) shrubby (S, N = 29) and iii) tree lines (T, N = 20);
- Structure of crops in the vicinity of the margins: the number of plots (crops) directly adjacent on both sides to the studied 500-meter sections ranged from 2 to 25 (avg. 6.3), and in the 200-meter buffer around the margins from 4 to 48 (avg. 18.0). In the analysis of the relationship between the floristic richness of the margins and the heterogeneity of the environment, Shannon–Wiener indices were calculated on the basis of area shares of individual crops in the buffer of 200 m around the margins. As has been shown, this parameter is an important predictor of the overall species richness of vascular plants of field margins and the groups distinguished among them.

Ad. 2. Characterisation of vascular flora of the studied habitats

Total number of species: contrary to popular belief about species poverty of mid-field marginal habitats, the south-western Polish margins were characterised by a relative high number of vascular plants. As many as 533 species were found in the studied margins, i.e. over 28% of the vascular flora of Lower Silesia and about 15% of the Polish flora. On one 500 m long section, there were on average almost 100 species. Perennial species dominated – almost half of the entire species composition (49.2%) was made up of hemicryptophytes, geophytes were less numerous (11.1%), mega- and nanophanerophytes were represented by over 11% of species, while therophytes accounted for 22.9% of the flora of the studied habitats.

The flora of vascular plants was analysed taking into account the belonging of individual species to different groups, which were separated for the purpose of assessing the biocenotic value of the discussed habitats. Using the model of plant life strategies according to Grime's concept (Falińska, 1996), species were classified into three basic and four intermediate groups, depending on the type of selective pressure, such as competition (C), stress (S) and disturbance (R). It has been shown that within linear marginal habitats, there is a dominance of competitors (strategy C) – over 1/3 of all species and C-S-R constituting 1/4 of the species covered by the analysis. Interestingly, the group almost completely absent among vascular plants were stress-resistant species (strategy S). Species with intermediate strategies C-R and C-S each accounted for about 15% of the flora of the margins, and the group of pioneer plants (strategy R) consisted of only 45 species (8.6%). The share of the last group, represented mainly by segetal weeds, was marked primarily in the extreme parts of the margins. This finding is important when considering the viability of endangered segetal weeds in agricultural areas and the potential importance of marginal habitats as their refuge. An important result is also the finding of dominance of species adapted to stable conditions, which proves the permanent nature of the vegetation of the studied habitats. This, in turn, is important in the context of considering the importance of margins as habitats of plant groups of specific biocenotic significance (shown below), especially in relation to the recently promoted so-called flower strips, which are only temporary solutions to improve the biodiversity of agricultural areas.

Factors influencing the species richness of herbaceous plants

Using mathematical modelling methods, the relationship of 10 environmental variables, describing the structure of the margins and their surroundings, with the total number of vascular plant species present in them was checked. All analysed variables were included in models explaining the variability of the number of plant species, indicating their relationship with the flora of marginal environments, but the importance of individual variables was uneven. The overall species richness was most positively associated with the diversity of crop fields around the range, the presence of a road and the component representing the share of the shrubby layer. The first variable means that marginal habitats located within the mosaic of fields are characterised by richer flora than the margins located between large-scale crops, which are usually characterised by a higher intensity of agrotechnical treatments. It was expected that this would be the direction of this relationship, but the demonstrated strong relationship between the mosaic of fields and the parameters of the vegetation of the margin, stronger even than, for example, the presence of a ditch or trees in its structure, is a surprising result.

The enriching impact of the presence of roads and scattered shrubs was associated with the creation of conditions for a large group of photophilous species, typical of intermediate succession stages and specific to roads and roadsides. In turn, factors negatively correlated with the richness of vascular flora turned out to be the share of open areas expressed by the number of sections of margins without trees and shrubs, as well as the increase in margin coverage by *Phragmites australis*. Such a result can be associated with the competitive properties of some plant species, such as *Phragmites australis*, which can dominate the margins with a uniform structure, reducing the species richness of phytocenoses.

Selected groups of field margin species

Protected and endangered species. Endangered species on a regional (Kącki et al., 2003), national (Kaźmierczakowa et al., 2016; Zarzycki & Szeląg, 2006) or the European continent (Allen et al., 2014; Bilz et al., 2011) scale, as well as covered by legal protection in Poland according to the Regulations of the Minister of the Environment (Regulation... 2004, 2012, 2014) have been collectively named Threatened and Conservation Concern Species (TCCS) (Wuczyński et al., 2014). They accounted for as much as one third of all taxa found within the studied habitats – 177 species (33.2%). Most of them (163) were species from the European lists, but they were mainly of least concern (LC) category. Species from the national list accounted for 2.1% of the flora of the margins, and from the Lower Silesian list – 3.6%. The analyses additionally took into account the temporal aspect, i.e. changes made to national red lists and species protection regulations over the last 20 years, in order to check how these changes translated into the assessment of the importance of the margins as a refuge for plants of special concern. The analysis showed that the update of the nationwide red list made in 2016 strengthened the arguments regarding the role of the studied environments as habitats of endangered species in Poland (increase in the number of taxa from 5 to 8). The amendments to the Regulations had the opposite effect:

the number of 17 species protected under the Regulations of 2004 and 2012 decreased to 13 species taking into account the 2014 Regulation currently in force.

With regard to species from the regional red list (Kącki et al., 2003), an additional aspect was the type of plant communities represented by individual species. Among regionally threatened taxa, species of non-forest habitats (classes *Molinio-Arrhenatheretea, Festuco-Brometea* and *Trifolio-Geranietea* and *Stellarietea mediae*) definitely prevail (80%). This result is an important argument for maintaining at least some of the discussed environments without the participation of trees and shrubs (see management guidelines).

The entire group of species of special concern at the national and regional level consisted of 31 taxa, which were recorded in 90 occurrences within 44 (62.9%) of the studied field margins. This means that almost 2/3 of the sample plots were suitable habitats for protected and endangered species. Considering the division of the margins into three categories due to the structure of high vegetation, it was found that the most margins (75.0%) with the participation of TCCS were tree lines (T), slightly less (69.0%) shrubby margins (S), and the least (42.9%) margins with the dominance of herbaceous vegetation (H). This result shows that although linear systems involving trees are the most important for TCCS, there is also a high probability of presence of special concern species among shrubby and herbaceous margins. This justifies the need to preserve or restore mid-field marginal habitats in all their variability.

These indications confirmed the results of the analysis of factors affecting the species richness of TCCS. Their occurrence was favoured by the large distance of the margins from urbanised areas, the vicinity of forest complexes, a large variety of crops in the vicinity of marginal habitats and the diversification of the vertical structure of vegetation by shrubs.

Aquatic species. Documentation of the occurrence of species from this group is important in agricultural areas in the face of increasing climate change and, consequently, deteriorating hydrological conditions. Within the studied habitats, the group consisted of 39 taxa (7.3% of all species) occurring in virtually each of the studied margins. On average, 7.9 species/margin (1-16) were recorded. In terms of life forms, the group of plants identified as hydrophytes consisted of 19 taxa recorded in 51 margins (73%).

Analysis of variables associated with the number of aquatic plant species showed, as expected, that the strongest positive impact was due to the presence of the ditch, but also to the increase in distance from the villages and the mosaic of crop fields around the margins. In turn, the increase in the share of open surfaces in the margin had a limiting impact on the species richness of the group. There was also a positive association with the presence of *Phragmites australis*, but this variable was less important, as were both components describing the development of layers of trees and shrubs.

Crop Wild Relatives (CWR). Due to their potential utility importance, this group receives much attention (Maxted, 2003; Maxted et al., 2015), even creating national strategies for their conservation (Landucci et al., 2014; Taylor et al., 2017; Weibull & Phillips, 2020). Also in our country, an extensive study of crop wild relatives was created (Dostatny et al., 2020). In the flora of the studied field margins, 40 species representing the CWR group were recorded, also included in the European Red List (Bilz et al., 2011), all with the category of least concern (LC). They account for 7.5% of the identified vascular plant species. On the scale of individual margins, the share of representatives of this group was significant – there were on average 9.7 species per margin (3-23). Most CWR species are open habitat plants, hence there has been a noticeable decrease in their number as the proportion of shrubs and trees has increased.

A number of CWR species showed an association with five variables. The strongest positive significance was the presence of a road and the share of open areas, and a strong negative relationship concerned the development of the tree layer. The share of shrubs also turned out to be important. Compared to other distinct plant groups, CWRs were least closely associated with environmental variables, of which only crop diversity around the margins appeared in one of the well-matched models. An important result of this analysis is the emphasis on the importance of dirt roads as a CWR refuge.

This applies especially to roads not used very intensively, which allows the development of vegetation referring to meadow communities.

Medicinal plants. This group was represented by 94 species, constituting 17.6% of the entire vascular flora of the studied environments, ranging from 12 to 39 species per margin (avg. 24.9). In terms of life forms, these were both herbaceous plants, shrubs and trees, hence their presence was recorded in each category of margins (H, S, T). They were most numerous within wide margins, with varied habitat conditions and a diverse share of herbaceous plants, clumps of shrubs and trees. They were least often found in the narrowest margins, with a uniform structure of vegetation, including the dominance of expansive species, primarily *Phragmites australis*. According to models explaining the variability in the richness of medicinal plant species, the expansion of the shrub layer and the presence of a road had a beneficial effect. The share of trees and crop diversification in the vicinity of the margin also had a significant positive impact, while the share of *Phragmites australis* had a negative impact.

The obtained results indicate the importance of mid-field marginal habitats as places of occurrence and potential acquisition of medicinal species, especially in areas dominated by cultivated fields. This was considered one of the basic ecosystem services provided by field margins (see below).

Insect-pollinated plants. This group consisted of 418 species, i.e. more than three-quarters (78.4%) of the entire vascular flora of the studied habitats. These species represented almost 30 categories, which are distinguished on the basis of the structure of flowers (BiolFlor database - https://wiki.ufz.de/biolflor). The most numerous group (133 species, 31.8%) were species with flowers or inflorescences with completely hidden nectar (designation B and B'). Slightly less numerous were plants with flowers with exposed (A) or partially hidden nectar (AB) – a total of 116 species (27.7%). Important categories were plants with flowers adapted to pollination by insects from the Hymenoptera order (H) – 52 species (12.4%), as well as a group of plants whose "product" that attracts insects is pollen (Po) – 28 species (7%).

Taking into account the occurrence of entomophilous species in field margins diversified in terms of the share of trees and shrubs (H, S, T), it was found that their share is not directly dependent on the vertical structure of vegetation, but their abundance is influenced by a larger spectrum of interrelated factors. Their understanding is made difficult by the fact that as the number of tree and shrub species increases, the number of nectar- and pollen-producing plants also increases. Also, after isolating only those species whose flowers are pollinated by Hymenoptera, it turned out that their share increases with the volume of shrubs and trees. However, the analysis of the percentage share indicates only a higher share of plants from this group in the flora of shruby margins (S). Also, in this case, the dependence on the volume of trees and shrubs might be apparent, and the appropriate factor determining the richness of species pollinated by Hymenoptera may be the degree of habitat diversity. This relationship is particularly evident if one considers that the smallest share of species pollinated by Hymenoptera insects was recorded in the case of narrow margins dominated by *Urtica dioica*, and the highest in the case of wide field margins, with a road, a row of shrubs and a flower roadside.

The analysis of factors affecting the richness of plant species important for insects showed the highest importance of the mosaic of crop fields around the margins, the share of shrubs and the presence of the road. The weaker, positive relationship concerned the share of trees and the distance from a village, while the negative one concerned the distance from the forest and the degree of coverage of the margin by *Phragmites australis*. The result concerning the positive impact of roads, usually with wide shoulders, which are habitats for insect-pollinated species, deserves to be highlighted again. This result provides a prerequisite for the practical management of marginal habitats, including the need to preserve existing dirt roads, which in many cases are ploughed up as a result of the consolidation of agricultural land.

Ancient woodland species. These species, distinguished on the basis of the studies by Dzwonko and Loster (2001) and Dzwonko (2007), consisted of 44 taxa, of which there were on average 4.9 per margin (range 0-20). In terms of type of dissemination, myrmecochory (36%), epizoochory (19%), gliding anemochory (17%) and light or heavy endozoochory and anemochory (12% each) dominated among species from this group. Single species (2% each) represented plants spreading by autochory and barochory. In the comparison of three groups of margins distinguished on the basis of the volume of trees and shrubs, as expected, the species of ancient woodlands were most often recorded in the margins belonging to the T category. This relationship was confirmed by regression models, which revealed the positive impact of variables reflecting the share of trees and shrubs and the presence of a ditch, which is a component of most margins with an extensive layer of trees. The distance from the forest also turned out to be marginally important – the number of species from this group decreased with the distance of the range from the nearest forest. The models also included four further variables of minor importance – field mosaicism, reed share, soil quality and number of gaps.

The obtained results may indicate that the margins with the largest share of trees and at the same time a large share of indicator species of ancient woodlands are a remnant of forest environments present in today's agricultural landscape for centuries. This is especially true of the margins along streams, where, unlike other types of margins, the probability of radical changes (e.g. ploughing) is the lowest, increasing the chances of survival of forest species. Such an eventuality also seems to be indicated by cases of even narrow structures with herbaceous vegetation, where individuals of *Anemone nemorosa* or *Galeobdolon luteum* have been recorded. At the same time, the results obtained suggest that a slightly different situation applies to margins with a large share of shrubs. Compared to the "woody" margins, they may more often be environments resulting from secondary succession that occurred within the baulks, which in the past were non-forest environments. In addition, communities with a compact layer of shrubs and limited access of light to the undergrowth may be suitable habitats for the development of forest species only at the stage of loosening of the compact structure. Often this occurs only after young trees break out above the shrub layer.

Alien and expansive species in the vascular flora of mid-field marginal habitats. The analyses paid much attention to anthropophytes, especially invasive species that may directly threaten the biodiversity of local ecosystems (Dajdok & Wuczyński, 2008). Anthropophytes accounted for 22.9% of the flora of the margins (122 species), archaeophytes dominated among them (64 species, 12% of the margins flora), and a slightly smaller share had kenophytes (49 species, 9.2%). The number of alien species was similar in the flora of all three categories of margins (H, S, T); however, in the case of archaeophytes themselves, the average percentages showed a downward trend with the increase in the volume of shrubs and trees. The average share of kenophytes was similar in the flora of the margins with the smallest (H) and the largest (T) volume of shrubs and trees, and smaller in the case of shrub (S) margins. The group of anthropophytes is associated with the problem of the presence of invasive species. Among the identified species, *Reynoutria japonica*, *Solidago gigantea* and *S. canadensis* performed the most potentially negative roles. The presence of the first of them was noted in case of only one margin. Species of the genus *Solidago* were much more often noted, but with relatively small quantities, similar to *Impatiens parviflora*. This means that at the time of data collection there was still a small proportion of the most threatening invasive species within marginal habitats. A much greater impact on the reduction of plant species diversity was the formation of almost single-species phytocenoses by several expansive native species, primarily *Phragmites australis* and *Urtica dioica*. It is important, however, that the dominant component of the studied phytocenoses were native species, and the percentage of anthropophytes, including invasive plants, turned out to be surprisingly low. It can, therefore, be concluded that the margins are refuges of native plants and so far seem to be quite resistant to invasions of the most "aggressive", alien to our flora, taxa of vascular plants.

Ad. 3. Specificity of plant communities

3.1. Zonal vegetation arrangement of field margins

The specific system of longitudinal zonality of plant communities is a little-known and characteristic feature of field margins. Its main condition are differences in function – transport, drainage, border – which make the margins strongly diverse – from narrow baulks with uniform vegetation, to linear habitats with a complex structure, including, for example, the embankment of a disused railway line with a parallel dirt road or watercourse. This makes it possible to separate one or several parallel zones covering phytocenoses of communities of a perimeter, rush, scrub or referring to meadow or regenerative forest communities. The development of a diagram of repeating spatial systems (Fig. 1) allowed to relate the distinguished plant communities to specific parts of field margins and indicate their repeatable arrangement and distinguishing features. Therefore, the presented research allowed to identify the main factors of the zonal vegetation arrangement of field margins, including: i) deposition of material extracted from the watercourse bed on banks or bank slopes as part of the maintenance of drainage ditches, ii) burning of ditches and roadsides, iii) grubbing up shrubs, undergrowth of trees and blackberries on the banks of ditches and roadsides, especially in places where they limit the mobility of agricultural machinery, iv) mowing roadsides and ditch slopes, v) application of herbicides to fields, while applying them, intentionally or accidentally (drift), to the extreme parts of the field margins.

3.2. Diversity of habitat conditions within field margins

The analysis of diversity of habitat conditions was carried out using Ellenberg's ecological indicators (light – L, thermal conditions – T, moisture – M, soil reaction – R and nutrients – N), calculated on the basis of the species composition of the patches reflected in the relevés. The following conclusions were reached: in terms of light conditions, the zones located along field roads and railway embankments stand out the most. The light indicator reaches the highest values there ($L>7.0$), and slightly lower within the herbaceous roadsides. In these three zones, the largest share of photophilous species was recorded. On the other hand, the lowest average values of this indicator ($5.0<L<5.5$) were found in riparian zones and on slopes covered with uniform vegetation with the participation of trees and/or shrubs, reflecting the share of shade-loving species. Similar trends were shown for thermal conditions. The largest share of thermophilic species ($5.5<T<6.0$) concerned embankment zones, edge of margins and roadsides, as well as the field roads themselves. In the case of the moisture index, opposite trends were shown: the most favourable moisture conditions ($8.01<M<9.0$) prevailed in parts of the margins covering the vicinity of watercourses, which was confirmed by the high share of species associated with wet soils, and in places also aquatic plants. In turn, the lowest values of the moisture index were recorded in zones with the best light conditions, i.e. roads and embankments. The nutrient index values were more uniform ($6.0<N<7.0$), but also showed a clear gradient from the poorest zone of railway embankments, through road and roadside zones, to the highest values in the zones of vegetation accompanying the watercourses. This result reflects the diversity of the share of nitrophilous species in the communities formed in these parts of the margins.

In addition to the Ellenberg indicators, differences in the species composition of vegetation zones were reflected in the values of the Shannon-Wiener (H) species diversity index. Its average values were in the range of 1.5-2.5, reaching a maximum in zones with a diverse vertical structure – shrubby roadsides and tree lines, as well as herbaceous roadsides. Lower values of this index ($H<2.0$) were obtained in the case of vegetation of the zone ""next to the ditch", slopes and edges of the margins, and the lowest in the riparian zones of watercourses. Low H values in these zones were associated with the dominance of native expansive species (*Phragmites australis* and *Urtica dioica*), which limited the growth of other plants.

3.3. Differences in species composition between the designated zones

One of the most important results of the conducted research was the indication of species distinguishing the constituent zones of the margins. For this purpose, the values of the so-called fidelity index (Φ – fidelity), calculated for individual species and tabulated, were used. The group of species showing fidelity to the distinguished zones included as many as 245 taxa (45.6%) out of 533 found within the margins. Of particular indicative importance were species with a fidelity Φ relevant only for one zone and those that showed a significant relationship with several zones, but for at least one of them the value of Φ was equal to or greater than 10. The least specific parts of the margins in terms of flora, distinguished by the smallest number of species, turned out to be the extreme zones. The distinguishing species was *Elymus repens*, and *Melandrium album* was characterised by a low but significant value of the Φ index. An interesting result was the demonstration of a large group of distinguishing species for a specific part of marginal habitats, which are field roads. High values of the fidelity index were obtained there for species typical of places exposed to mechanical factors, such as trampling or crushing by vehicles. These species include *Lolium perenne, Plantago major, Poa annua, Chamomilla suaveolens* and *Polygonum aviculare* s.l. and *Trifolium repens*. The species that distinguished both the road zone and railway embankments turned out to be *Pastinaca sativa*. Among the species associated with embankments, *Saponaria officinalis* deserves attention, it was recorded only in this zone, and *Sedum acre* and *Arenaria serpyllifolia* present only in the top part of embankments, as well as *Rubus caesius* and *Galium mollugo* with high values of the fidelity index in relation to the zone of railway embankments. *Festuca rubra* and *Galium verum* had the strongest relationship with herbaceous roadsides, but so did *Clinopodium vulgare, Tanacetum vulgare, Genista tinctoria, Cynosurus cristatus, Hieracium laevigatum* and *Trisetum flavescens*. In turn, the zone of roadside occupied by shrubs was distinguished primarily by *Malus domestica, Pyrus pyraster* and *Rubus corylifolius*. Species common to shruby roadsides and wide zones of shrubs and woody vegetation along watercourses (PRS) were *Sambucus nigra, Euonymus europaeus, Crataegus monogyna* and *Rosa canina*. The distinguishing species of the PRS zone were: *Alnus glutinosa, Salix caprea, Fraxinus excelsior, Ulmus laevis, Prunus spinosa* and *Tilia cordata*. For undergrowth plants, significant values of Φ for the PRS zone were obtained for *Poa nemoralis, Brachypodium sylvaticum, Moehringia trinervia, Stellaria holostea*, as well as *Athyrium filix-femina* and *Dryopteris filix-mas*. Typical riparian zones were distinguished by aquatic and/or rush species, such as *Berula erecta, Solanum dulcamara, Filipendula ulmaria, Symphytum officinale* or *Sparganium erectum*. On the other hand, only for individual species significant values of Φ were obtained in relation to the escarpment (mainly *Knautia arvensis*) and the zone "next to the ditch" (only *Rubus radula* and *Geranium palustre*).

In general, the analysis of the longitudinal zonality of the vegetation of the margins turned out to be an accurate direction of research. It was possible to confirm that it is an inseparable feature of field margins, often even overlooked due to the small width of the margins treated as a monolith. Extensive field data allowed to create a scientific description of the diversity of zonality and its ecological features, especially the relationship of specific species (as well as syntaxons) with specific parts of the margins or their groups. The role of vegetation zones in shaping biocenoses of margins in a broader sense, especially in maintaining the diversity of other organisms, including pollinating insects, as well as the role of man in the creation or destruction of zones in field margins was also indicated.

3.4. Quantitative characteristics of the distinguished plant communities

Within 70 sections of field margins with a total length of 35 km, 37 plant communities belonging to syntaxons of various ranks were distinguished – from groups distinguished by a specific combination of species, to incomplete communities. The most numerous, comprising 13 units, was the group of edge and ruderal communities of the class *Artemisietea*. Shrub and regenerative forest communities of the classes *Rhamno-Prunetea, Epilobietea angustifolii, Alnetea glutinosae* and *Querco-Fagetea* were represented by 10 syntaxons, while meadow communities (class *Molinio-Arrhenatheretea*) by 7, as well as rushes (*Phragmitetea*) – also by 7 syntaxons. In terms of the number of patches reflected in individual samples (relevés), the association *Convolvulo arvensis-Agropyretum repentis* performed the most important role (150 patches, 16.4% of all relevés). The next places were occupied by plant communities developing within field roads – the association *Lolio-Plantaginetum* (79 patches, 8.6% of relevés), *Phragmitetum communis*, which included 75 patches (8.2%) and phytocenoses similar to meadow communities, identified with the association *Arrhenatheretum elatioris* (73 patches, 8.0%).

In terms of the number of field margins in which patches of a specific community were found, the most numerous was also the aforementioned association *Convolvulo arvensis-Agropyretum repentis*, recorded in 54 (77.1%) field margins. Frequent groups included *Arrhenatheretum elatioris* (32 margins, 45.7%), as well as various stages of thicket development of *Euonymo-Prunetum spinosae*, recorded in 27 margins (38.6%). The next places were occupied by trampling communities included in the association *Lolio-Plantaginetum* and nitrophilous fringe communities classified as *Agropyro repentis–Aegopodietum podagrariae*, recorded in 25 (35.7%) and 24 (34.3%) margins, respectively. In more than 20 margins, patches of vegetation of the association *Ranunculo-Alopecuretum pratensis* were also found, as well as rush communities – *Phragmitetum communis* and *Phalaridetum arundinaceae* – each found within 21 margins (30.0%). Contrary to expectations, the rarest (1-3 relevés) included phytocenoses of *Typhetum latifoliae, Sparganietum ramosi* and communities from the *Sparganio-Glycerion fluitantis* alliance, and from the group of meadow communities – phytocenoses *Filipendulo-Geranietum*, communities with *Holcus lanatus*, as well as patches of *Selino carvifoliae-Molinietum caeruleae*. Among the ruderal and fringe communities, *Polygonetum cuspidati* and *Chaerophylletum bulbosi* were rare, while the least frequently found shrub and forest communities represented patches of *Euonymo-Coryletum, Saliceum cinereae* and community with *Padus avium*.

A particularly surprising result was the demonstration of only a sporadic share of phytocenoses of the above-mentioned rush communities, often forming in the beds of field watercourses. Their absence is an expression of irrational practices of maintaining watercourses (destruction of rushes through too frequent dredging and artificial shaping of banks (Dajdok & Wuczyński, 2005)), and on the other hand, the dominance of reeds and its reductive impact on other plant species. Attention is also drawn to the lack of *Typha latifolia* or *Sparganium erectum* rushes performing a positive role in the self-purification of waters (Izydorczyk et al., 2015), and thus particularly desirable in agricultural areas, which are important source of water pollution.

In terms of species richness, the most valuable were phytocenoses of the association *Ranunculo repentis-Alopecuretum pratensis* in which from 9 to 41 plant species were found (avg. 23 in one relevé), with an average Shannon-Wiener index value of 2.48. There were also phytocenoses of the ruderal association *Tanaceto-Artemisietum* (12–32 species; on average 20; H=2.33), regenerative forest communities of the class *Querco-Fagetea* (9–41 species; avg. 21; H=2.16) and *Euonymo-Prunetum spinosae* (9–33 species; avg. 18; H=2.04). On the other hand, the poorest floristic communities included *Phragmitetum communis* – an average of 11 species of vascular plants in the relevé, and in extreme cases only two (avg. H=1.38). Patches of *Convolvulo arvensis-Brometum inermis* (7–28 species, avg. 11; H=1.56), *Agropyro repentis–Aegopodietum podagrariae* (7–32 species; avg. 14; H=1.85), as well as community *Agropyron repens-Urtica dioica* (5–26 species; avg. 14; H=1.79) and association *Phalaridetum arundinaceae* (6–24 species; avg. 15; H=1.64). The obtained results allow concluding that a large part of the most widespread communities, i.e. represented by numerous patches and occurring in many field margins, belong at the same time to the poorest floristically. These were most often communities dominated by expansive grasses, such as *Phragmites australis, Elymus repens, Bromus inermis* or *Phalaris arundinacea*, and less often dicotyledonous plants – primarily *Urtica dioica*.

An important element of the characteristics of the distinguished syntaxons was to indicate their biocenotic significance and ecosystem services provided. The indication of the practical significance of plant communities distinguishes this monograph from previous studies on flora and/or vegetation of specific environments. Examples of functions performed by the analysed communities are the making an insect food base, which was emphasised in the case of 19 out of 37 discussed communities, creating bird nesting sites or shelters for various animal species (16 communities) or supporting water purification as the so-called ecological filters to reduce pollutants from running water (16 communities). For a smaller number of communities, the importance of strengthening the banks of watercourses and protecting land against erosion, the possibility of using the biomass for energy purposes, as well as the improvement of microclimatic conditions and yielding of adjacent fields were emphasised.

In the case of ecosystem services (Solon, 2008), those provided by cultivated areas are most often considered in agricultural areas. However, looking at agricultural areas in a broader context also raises awareness of the significant impact of marginal habitats on crop yield – by stimulating pollinator populations, stability of soil and microclimatic conditions or improving water quality (Haddaway et al., 2018). Using the generally accepted classification (Rosin et al. 2011), services provided by entire margins or distinguished communities include i) regulating services (among others, the impact on microclimatic conditions, water quality, erosion prevention, pollination of crops); ii) supporting services (among others, providing ecological corridors, supporting the water and element cycle, production of organic matter in the process of photosynthesis and assimilation); iii) provisioning services (e.g. supply of raw materials used in herbal medicine, genetic resources of wild species related to crops); iv) cultural services (e.g. use of margins in recreation, education, scientific research, protection of traditional landscape).

Ad. 4. Guidelines for the protection of marginal environments

Despite their important biocenotic and economic role, marginal habitats in agricultural areas are under serious threat and the current state and capacity to protect them should be considered insufficient. Among the long list of destructive actions, one can mention the common process of reducing their area (width), up to complete liquidation, grubbing of trees and shrubs, transfer (drift) of plant protection products and fertilisers used in neighbouring fields or excessive drainage treatments. In view of the prevalence of these phenomena, based on the collected results of own research and literature data, the study formulated extensive guidelines for the management of linear marginal habitats. The most important of them are:

- the need to preserve existing semi-natural marginal habitats in the full spectrum of their diversity; The protection of field margins should, therefore, take into account all their types – from narrow baulk to wide strips of vegetation accompanying watercourses, field roads or railway embankments, because the diversity of width, nature and function of these environments is associated with the diversity of habitat conditions, the richness of plant species and phytocenoses built by them and the possibility of their use by other organisms, as well as performing various application functions;
- in view of the progressive impoverishment of nature in agricultural areas, it is becoming necessary to establish new field margins; the optimal system solution would be the creation of wide zones of vegetation of a varied nature along all permanent linear landscape elements;
- while maintaining the existing field margins or creating new ones, the vertical structure of vegetation – spontaneous and deliberately shaped – should be differentiated from the simplest systems, dominated by herbaceous plants, through sections with scattered clumps of shrubs, to rows and avenues of trees;
- it is necessary to differentiate treatments for the proper maintenance of the vegetation of the field margins; These should include: (i) periodic mowing and removal of biomass, promoting floristic diversity; this is especially true of strips of vegetation along ditches and streams with predominant reeds; (ii) periodic grubbing up or pruning of selected sections of brush in order to increase the efficiency of flower and fruit production, but also (iii) leaving without any treatment of strips with an extensive vertical structure of vegetation, favouring maintaining the richness of various groups of animals.

Summary

The presented study is an extensive description of the vegetation cover of semi-natural linear marginal habitats. Field data were collected in the south-western part of Poland, but the number and selection of collection areas was carried out in such a way as to represent these environments for agricultural landscapes of the whole country or, more broadly, Central Europe. Using recognised research methods in the field of plant ecology and statistics, multifaceted characteristics of the vascular flora of field margins, selected groups of vascular plant species (including: protected and endangered, crop wild relatives, medicinal and plants constituting a source of nectar and/or pollen for insects), as well as plant communities, emphasising a little-known aspect of longitudinal zonality of margins. Considering the origin of the species, it was found that the margins perform an important role as refuge of native plants, and the share of anthropophytes in their flora is quite low. Using mathematical modelling methods, it was shown that the richness of plant species in separate groups was associated with 5-8 environmental variables.

The showcase of the research is the indication of the biocenotic and practical significance of the distinguished syntaxons and the ecosystem services provided, i.e. aspects that are most often omitted in this type of research. Among the ecosystem services included in the comparison, attention was paid to both provisioning, regulating, supporting and cultural services. Much attention was also paid to the threats to mid-field marginal habitats, which include factors noted during the research, such as those resulting from the review of an extensive list of source materials. Taking into account the results

concerning the nature of the vegetation cover of field margins, as well as their comprehensive importance for the biodiversity of agricultural areas, guidelines for the management of margins were formulated. As a result, the widest vegetation characteristics of mid-field marginal habitats made so far in Poland were presented. The monograph documents the current state of these environments and can be used as a starting material for future comparative studies.

Literature

Aavik, T., Augenstein, I., Bailey, D., Herzog, F., Zobel, M., & Liira, J. (2008). What is the role of local landscape structure in the vegetation composition of field boundaries? Applied Vegetation Science, 11(3), 375–386. https://doi.org/10.3170/2008-7-18486.

Allen, D., Bilz, M., Leaman, D. J., Miller, R. M., Timoshyna, A., & Window, J. (2014). European Red List of Medicinal Plants. Publications Office of the European Union.

Banaszak, J., & Cierzniak, T. (2000). Ocena stopnia zagrożeń i możliwości ochrony owadów w agroekosystemach. Wiadomości entomologiczne, 18(Supl. 2), 73–94.

Baudry, J., Bunce, R. G. H., & Burel, F. (2000). Hedgerows: An international perspective on their origin, function and management. Journal of Environmental Management, 60(1), 7–22. https://doi.org/10.1006/jema.2000.0358.

Berezowska-Niedźwiedź, M., Bochyńska, M., Dajdok, Z., Frankiewicz, J., Guziak, A., Jagiełło, Z., Jakubiec, Z., Józefczuk, J., Konieczny, K., Krukowska-Szopa, I., Konwerski, S., Miniewska, M., Rutkowski, T., Szulc-Guzik, D., Wojtaszyn, S., Woźnicka, J., & Wuczyński, A. (2016). Zadrzewienia dla ochrony bioróżnorodności i klimatu: Pakiet edukacyjny (K. Konieczny, I. Krukowska-Szopa, S. Szatan, M. Bochyńska, & J. Woźnicka, Eds.). Fundacja Ekologiczna „Zielona Akcja".

Bilz, M., Kell, S. P., Maxted, N., & Lansdown, R. V. (2011). European red list of vascular plants. Publications Office of the European Union. http://bot.biologia.unipi.it/listerosse/European_vascular_plants.pdf.

Chytry, M., Tichy, L., Holt, J., & Botta-Dukat, Z. (2002). Determination of diagnostic species with statistical fidelity measures. Journal of Vegetation Science, 13, 79–90.

Croxton, P. J., Hann, J. P., Greatorex-Davies, J. N., & Sparks, T. H. (2005). Linear hotspots? The floral and butterfly diversity of green lanes. Biological Conservation, 121(4), 579–584. https://doi.org/10.1016/j.biocon.2004.06.008

Czarnecka, J. (2011a). Miedze Wołynia Zachodniego jako siedliska rzadkich nawapiennych gatunków roślin. Woda-Środowisko-Obszary Wiejskie, 11(2(34)), 43–52.

Czarnecka, J. (2011b). The role of linear structures in agricultural landscape in the maitenance of xerothermic species. Acta Agrobotanica, 64(4), 151–158. https://doi.org/10.5586/aa.2011.056.

Dajdok, Z., & Wuczyński, A. (2005). Biocenotic differentiation, functions and protection problems of the small mid-field ditches. In: L. Tomiałojć & A. Drabiński (Eds.), Środowiskowe aspekty gospodarki wodnej (pp. 227–252). Komitet Ochrony Przyrody PAN, Wydział Inżynierii Kształtowania Środowiska i Geodezji AR we Wrocławiu.

Dajdok, Z., & Wuczyński, A. (2008). Alien plants of field margins and fields of southwestern Poland. Biodiversity: Research and Conservation, 9–10, 19–33.

Denisow, B., & Wrzesień, M. (2007). The anthropogenic refuge areas for bee flora in agricultural landscape. Acta Agrobotanica, 60(1), 147–157.

Denisow, B., & Wrzesień, M. (2015). The Importance of Field-Margin Location for Maintenance of Food Niches for Pollinators. Journal of Apicultural Science, 59(1), 27–37. https://doi.org/10.1515/jas-2015-0002.

Donald, P. F., Green, R. E., & Heath, M. F. (2001). Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London. Series B: Biological Sciences, 268(1462), 25–29. https://doi.org/10.1098/rspb.2000.1325.

Dostatny, D., Fu, Dajdok, Z., Nowak, A., Zalewska-Gałosz, J., Szymański, W. M., Beza, M., Michalska-Hejduk, D., Bączek, K., Węglarz, Z., Bomanowska, A., Kapler, A., Nowak, T., Kloc, G., & Podyma, W. (2020). Lista dzikich gatunków pokrewnych roślinom uprawnym występujących w Polsce. In: D. Dostatny Fu & Z. Dajdok (Eds.), Dzikie gatunki pokrewne roślinom uprawnym występujące w Polsce (pp. 21–81). Wyd. Kontekst.

Dzwonko, Z. (2007). Przewodnik do badań fitosocjologicznych. Sorus.

Dzwonko, Z. & Loster, S. (2001). Wskaźnikowe gatunki roślin starych lasów i ich znaczenie dla ochrony przyrody i kartografii roślinności. Prace Geograficzne 178, 120–132.

Emmerson, M., Morales, M. B., Oñate, J. J., Batáry, P., Berendse, F., Liira, J., Aavik, T., Guerrero, I., Bommarco, R., Eggers, S., Pärt, T., Tscharntke, T., Weisser, W., Clement, L., & Bengtsson, J. (2016). How Agricultural Intensification Affects Biodiversity and Ecosystem Services. In: Advances in Ecological Research (V. 55, pp. 43–97). Elsevier. https://doi.org/10.1016/bs.aecr.2016.08.005.

European Environment Agency. (2019). Środowisko Europy 2020—Stan i prognozy. Streszczenie. Publications Office. https://data.europa.eu/doi/10.2800/940297

Falińska, K. (1996). Ekologia roślin. Podstawy teoretyczne, populacja, zbiorowisko, procesy. Wyd. Naukowe PWN.

Faliński, J. B. (2001). Przewodnik do długoterminowych badań ekologicznych. Wyd. Naukowe PWN.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W. W., Emmerson, M., Morales, M. B., Ceryngier, P., Liira, J., Tscharntke, T., Winqvist, C., Eggers, S., Bommarco, R., Pärt, T., Bretagnolle, V., Plantegenest, M., Clement, L. W., Dennis, C., Palmer, C., Oñate, J. J., … Inchausti, P. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology, 11(2), 97–105. https://doi.org/10.1016/j.baae.2009.12.001.

Górny, M. (1993). Rola zadrzewień w krajobrazie rolniczym. In: U. Sołtysiak (Ed.), Rolnictwo ekologiczne od teorii do praktyki (p. 123–130). Stowarzyszenie Ekoland.

Grashof-Bokdam, C. J., & van Langevelde, F. (2005). Green Veining: Landscape Determinants of Biodiversity in European Agricultural Landscapes. Landscape Ecology, 20(4), 417–439. https://doi.org/10.1007/s10980-004-5646-1.

Haddaway, N. R., Brown, C., Eales, J., Eggers, S., Josefsson, J., Kronvang, B., Randall, N. P., & Uusi-Kämppä, J. (2018). The multifunctional roles of vegetated strips around and within agricultural fields. Environmental Evidence, 7(1), 1–34. https://doi.org/10.1186/s13750-018-0126-2.

Hinsley, S. A., & Bellamy, P. E. (2000). The influence of hedge structure, management and landscape context on the value of hedgerows to birds: A review. Journal of Environmental Management, 60(1), 33–49. https://doi.org/10.1006/jema.2000.0360

Izydorczyk, K., Michalska-Hejduk, D., Frątczak, W., Bednarek, A., Łapińska, M., Jarosiewicz, P., Kosińska, A., & Zalewski, M. (2015). Strefy buforowe i biotechnologie ekohydrologiczne w ograniczaniu zanieczyszczeń obszarowych. Europejskie Regionalne Centrum Ekohydrologii Polskiej Akademii Nauk.

Jobin, B., Boutin, C., & DesGranges, J.-L. (1997). Effects of agricultural practices on the flora of hedgerows and woodland edges in southern Quebec. Canadian Journal of Plant Science, 77(2), 293–299. https://doi.org/10.4141/P96-042.

Kaźmierczakowa, R., Błoch-Orłowska, J., Celka, Z., Cwener, A., Dajdok, Z., Michalska-Hejduk, D., Pawlikowski, P., Szczęśniak, E., & Ziarnek, K. (2016). Polska czerwona lista paprotników i roślin kwiatowych. Polish red list of pteridophytes and flowering plants. Instytut Ochrony Przyrody Polskiej Akademii Nauk.

Kącki, Z., Dajdok, Z., & Szczęśniak, E. (2003). Czerwona lista roślin naczyniowych Dolnego Śląska. In: Z. Kącki (Ed.), Zagrożone gatunki flory naczyniowej Dolnego Śląska. (pp. 9–65). Instytut Biologii Roślin, Uniwersytet Wrocławski, Polskie Towarzystwo Przyjaciół Przyrody „pro Natura".

Kryszak, A., Kryszak, J., Czemko, M., & Kalbarczyk, M. (2006). Roślinność nasypów wybranych szlaków kolejowych. (Plant cover of embankments of selected railway lines) Zeszyty Naukowe Uniwersytetu Przyrodniczego we Wrocławiu, 545, 157–164.

Kujawa, K. (1996). Wpływ struktury przestrzennej krajobrazu na zgrupowania ptaków lęgowych Parku Krajobrazowego im. D. Chłapowskiego. (The influence of the spatial landscape on groups of breeding birds of the D. Chłapowski landscape park) Biuletyn Parków Krajobrazowych Wielkopolski, 1(3), 83–90.

Kujawa, K., Wuczyński, A., Dajdok, Z., & Grzesiak, W. (2020). Effect of Habitat Structure and Crop Diversity on Common and Threatened Birds Breeding in Semi-Natural Field Margins. Acta Ornithologica, 54(2), 181. https://doi.org/10.3161/00016454AO2019.54.2.005.

Landucci, F., Panella, L., Lucarini, D., Gigante, D., Donnini, D., Kell, S., Maxted, N., Venanzoni, R., & Negri, V. (2014). A Prioritized Inventory of Crop Wild Relatives and Wild Harvested Plants of Italy. Crop Science, 54(4), 1628–1644. https://doi.org/10.2135/cropsci2013.05.0355.

Loster, S., & Dubiel, E. (1985). Dolina Wierzbanówki: 9. Zbiorowiska zaroślowe miedz i skarp śródpolnych. Prace Botaniczne, 13, 77–85.

Marciniuk, P. (2009). Szata roślinna śródpolnych siedlisk Podlaskiego Przełomu Bugu. Instytut Botaniki im. W. Szafera, Polska Akademia Nauk.

Marshall, E. J. P., & Moonen, A. C. (2002). Field margins in northern Europe: Their functions and interactions with agriculture. Agriculture, Ecosystems & Environment, 89(1–2), 5–21. https://doi.org/10.1016/S0167-8809(01)00315-2.

Maxted, N. (2003). Conserving the genetic resources of crop wild relatives in European Protected Areas. Biological Conservation, 113(3), 411–417. https://doi.org/10.1016/S0006-3207(03)00123-X.

Maxted, N., Avagyan, A., Frese, L., Iriondo, J., Brehm, M., Joana, Singer, A., & Kell, S. (2015). Preserving diversity: A concept for in situ conservation of crop wild relatives in Europe: Version 2. https://netzwerk-wildsellerie.julius-kuehn.de/dokumente/upload/Poster_PreservingDiversityConceptVer2.pdf.

Mora, C., & Sale, P. (2011). Ongoing global biodiversity loss and the need to move beyond protected areas: A review of the technical and practical shortcomings of protected areas on land and sea. Marine Ecology Progress Series, 434, 251–266. https://doi.org/10.3354/meps09214.

Orłowski, G., & Nowak, L. (2007). The importance of marginal habitats for the conservation of old trees in agricultural landscapes. Landscape and Urban Planning, 79(1), 77–83. https://doi.org/10.1016/j.landurbplan.2006.03.005.

Ratyńska, H., & Szwed, W. (1999). The protection of small regulated watercourses to maintain local diversity of plant cover. Roczniki Akademii Rolniczej w Poznaniu CCCX. Melioracje i Inżynieria Środowiska 20, część I, 299–314.

Rosin, Z. M., Takacs, V., Báldi, A., Banaszak-Cibicka, W., Dajdok, Z., Dolata, P. T., Kwieciński, Z., Łangowska, A., Moroń, D., Skórka, P., Tobółka, M., Tryjanowski, P., & Wuczyński, A. (2011). Koncepcja świadczeń ekosystemowych i jej znaczenie w ochronie przyrody polskiego krajobrazu rolniczego / Ecosystem services as an efficient tool of nature conservation: A view from the Polish farmland. Chrońmy Przyrodę Ojczystą, 67(1), 3–20.

Rozporządzenie Ministra Środowiska z dn. 5 stycznia 2012 r. W sprawie ochrony gatunkowej roślin. Dziennik Ustaw z 2012 r., poz. 81. (b.d.). (Regulation of the Minister of the Environment of January 5, 2012 On the protection of plant species. Journal of Laws of 2012, item 81. (n.d.))

Rozporządzenie Ministra Środowiska z dn. 9 lipca 2004 r. W sprawie gatunków dziko występujących roślin objętych ochroną. Dziennik Ustaw Nr 168, poz. 1764. (b.d.). (Regulation of the Minister of the Environment of July 9, 2004 On protected species of wild plants. Journal of Laws No. 168, item 1764. (n.d.))

Rozporządzenie Ministra Środowiska z dn. 9 października 2014 r. W sprawie ochrony gatunkowej roślin. Dziennik Ustaw z 2014 r., poz. 1409. (b.d.). (Regulation of the Minister of the Environment of October 9, 2014 On the protection of plant species. Journal of Laws of 2014, item 1409. (n.d.))

Ryszkowski, L. (Red.). (2002). Landscape Ecology in Agroecosystems Management. CRC PRESS.

Ryszkowski, L., Bartoszewicz, A., & Marcinek, J. (1990). Bariery biogeochemiczne. In: L. Ryszkowski, J. Marcinek, & A. Kędziora (Eds.), Obieg wody i bariery biogeochemiczne w krajobrazie rolniczym (pp. 167–181). Wyd. UAM.

Ryszkowski, L., Życzyńska-Baloniak, I., & Szpakowska, B. (1996). Wpływ barier biogeochemicznych na ograniczanie rozprzestrzeniania się zanieczyszczeń obszarowych. In: Oczyszczalnie Hydrobotaniczne. II Międzynarodowa Konferencja Naukowo-Techniczna, Poznań, 147–156.

Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, 232, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020.

Smart, S. M., Bunce, R. G. H., Firbank, L. G., & Coward, P. (2002). Do field boundaries act as refugia for grassland plant species diversity in intensively managed agricultural landscapes in Britain? Agriculture, Ecosystems & Environment, 91(1–3), 73–87. https://doi.org/10.1016/S0167-8809(01)00259-6.

Solon, J. (2008). Koncepcja „Ecosystem Services" i jej zastosowania w badaniach ekologiczno-krajobrazowych. In: T. J. Chmielewski (Ed.), Struktura i funkcjonowanie systemów krajobrazowych: Meta-analizy, modele, teorie i ich zastosowania (V. 21, pp. 25–44). Polska Asocjacja Ekologii Krajobrazu, Uniwersytet Przyrodniczy w Lublinie.

Stanton, R. L., Morrissey, C. A., & Clark, R. G. (2018). Analysis of trends and agricultural drivers of farmland bird declines in North America: A review. Agriculture, Ecosystems & Environment, 254, 244–254. https://doi.org/10.1016/j.agee.2017.11.028.

Tałałaj, Z. (1997). Wpływ zadrzewień na plonowanie roślin rolniczych. In: Znaczenie zadrzewień w krajobrazie rolniczym oraz aktualne problemy ich rozwoju w przyrodniczo-gospodarczych warunkach Polski (pp. 72–90).

Tałałaj, Z., & Węgorek, T. (1995). Efektywność ekologiczna zadrzewień przeciwerozyjnych oraz zasady ich zakładania i prowadzenia. Puławy.

Taylor, N. G., Kell, S. P., Holubec, V., Parra-Quijano, M., Chobot, K., & Maxted, N. (2017). A systematic conservation strategy for crop wild relatives in the Czech Republic. Diversity and Distributions, 23(4), 448–462. https://doi.org/10.1111/ddi.12539.

Tichý, L. (2002). JUICE, software for vegetation classification. Journal of Vegetation Science, 13(3), 451–453. https://doi.org/10.1111/j.1654-1103.2002.tb02069.x.

Tichy, L., Chytry, M., & Botta-Dukat, Z. (2014). Semi-supervised classification of vegetation: Preserving the good old units and searching for new ones. Journal of Vegetation Science, 25, 1504–1512.

Weibull, J., & Phillips, J. (2020). Swedish Crop Wild Relatives: Towards a national strategy for in situ conservation of CWR. Genetic Resources, 1(1), 17–24. https://doi.org/10.46265/genresj.2020.1.17-24.

Westhoff, V., & van der Maarel, E. (1978). The Braun-Blanquet approach. W R. H. Whittaker (Red.), Classification of Plant Communities (s. 287–399). W. Junk.

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag.

Wierzcholska, S., Dajdok, Z., & Wuczyński, A. (2008). Do bryophytes reflect the diversity of vascular plants and birds in marginal habitats? Environmental Changes and Biological Assessment IV, 186, 194–200.

Wilkerson, M. L. (2014). Using hedgerows as model linkages to examine non-native plant patterns. Agriculture, Ecosystems & Environment, 192, 38–46. https://doi.org/10.1016/j.agee.2014.03.044.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., De Vries, W., Majele Sibanda, L., … Murray, C. J. L. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4.

Woch, F., & Borek, R. (2015). The Role of Management of The Field-Forest Boundary in Poland's Process of Agricultural Restructuring. Papers on Global Change IGBP, 22(1), 83–100. https://doi.org/10.1515/igbp-2015-0017.

Wojewoda, D., & Russell, S. (2003). The impact of a shelterbelt on soil properties and microbial activity in an adjacent crop field. Polish Journal of Ecology, 51(3), 291–307.

Wojterska, M. (1990). Mezofilne zbiorowiska zaroślowe Wielkopolski. Prace Komisji Biologicznej PTPN, Poznań.

Wojterska, M. (1992). Dynamika wybranych zbiorowisk zaroślowych Wielkopolski. Badania Fizjograficzne nad Polską Zachodnią, 41, 115–148.

Wolak, M., & Karg, J. (2002). Pająki zimujące w zadrzewieniach śródpolnych. In: J. Banaszak (Ed.), Wyspy środowiskowe. Bioróżnorodność i próby typologii (pp. 169–179). Wydawnictwo Akademii Bydgoskiej im. Kazimierza Wielkiego.

Wróbel, M. (2007). Roślinność przydrożna w sąsiedztwie obszarów wyłączonych z użytkowania rolniczego na Nizinie Szczecińskiej. Acta Botanica Warmiae et Masuriae, 4, 361–376.

Wuczyński, A., Dajdok, Z., Wierzcholska, S., & Kujawa, K. (2014). Applying red lists to the evaluation of agricultural habitat: Regular occurrence of threatened birds, vascular plants, and bryophytes in field margins of Poland. Biodiversity and Conservation, 23(4), 999–1017. https://doi.org/10.1007/s10531-014-0649-y.

Wuczyński, A., Kujawa, K., Dajdok, Z., & Grzesiak, W. (2011). Species richness and composition of bird communities in various field margins of Poland. Agriculture, Ecosystems & Environment, 141, 202–209.

Zarzycki, K., & Szeląg, Z. (2006). Red List of the Vascular Plants in Poland. W: Z. Mirek, K. Zarzycki, W. Wojewoda, & Z. Szeląg (Eds.), Red List of plants and fungi in Poland. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

4.4) Title of scientific achievement No. 2

Koleantus delikatny *Coleanthus subtilis* (Poaceae) jako rzadki składnik efemerycznych zbiorowisk mokradłowych Polski – rozprzestrzenianie, warunki siedliskowe i ochrona (*Coleanthus subtilis (Poaceae) as a rare component of ephemeral wetland communities in Poland – spread, habitat conditions and conservation*)

4.5) List of publication comprising achievement No. 2

1. **Dajdok Z**. 2009. *Coleanthus subtilis* (Poaceae) na terenie Stawów Milickich – nowe stanowisko w Polsce. (*Coleanthus subtilis* (Poaceae) in the area of Milicz Ponds - a new site in Poland) Fragmenta Floristica et Geobotanica, Polonica 16(2): 227-236
   [MSHE points = 4; number of citations according to WoS = 0]
   I am the sole author of the publication (100%)

2. **Dajdok Z.** 2012. 1887 Koleantus delikatny *Coleanthus subtilis* (Tratt.) Seid. (Coleanthus subtilis (Tratt.) Seid.) In: J. Perzanowska (Ed.) Monitoring Gatunków roślin. Podręcznik metodyczny. Ch. 2: 112-126. GIOŚ, Warszawa
   [MSHE points = 5; number of citations according to WoS = 0]
   I am the sole author of the chapter (100%)

3. **Dajdok Z.,** Klink A., Polechońska L., Dambiec M., Pielech R. 2017. Abundance of *Coleanthus subtilis* in relation to nutrient concentrations in pond soils - A case study of localities in Poland. Flora - Morphology Distribution Functional Ecology of Plants 235: 41-50, DOI: 10.1016/j.flora.2017.08.009
[IF_{2017} = 1,365; MSHE points = 25; number of citations according to WoS = 2]
My contribution to this work consisted in preparing the concept of publication and methods of data collection, analysing source materials, taking photographs and parts of tabular lists, and cooperating with other authors in the analysis of the collected data, discussion of the obtained results, writing the manuscript and its correction after reviews. In the preparation of this publication, I acted as a corresponding author. I estimate my share at 45%.

Coleanthus subtilis (Poaceae) is a species that appeared in Poland only a quarter of a century ago. It belongs to therophytes inhabiting periodically exposed riverbanks, e.g. during the period of low flow or bottoms of overdried anthropogenic water reservoirs, including mainly breeding ponds. This species is part of a specific group of plant communities referred to as "silt", leading for the Natura 2000 habitat under the name "Brzegi lub osuszane dna zbiorników wodnych ze zbiorowiskami z *Littorelletea*, *Isoëto-Nanojuncetea* - kod 3130" (Banks or dried bottoms of water bodies with communities from *Littorelletea, Isoëto-Nanojuncetea* - code 3130).

The first finding of the Coleanthus subtilis in Poland took place in a complex of breeding ponds in the area of Borowa Oleśnica (Fabiszewski & Cebrat, 2003), near Wrocław, in the late 90s of the twentieth century. Due to its rank – a species considered rare on a global scale, protected under the Habitats Directive – Appendices II and IV (Council Directive... 1992) and the Berne Convention – Annex I (Convention... 1979), the complex of four ponds in which it was found was included in the network of Natura 2000 sites created at that time (Dajdok & Świerkosz, 2012). In 2008 I found the occurrence of individuals of the species in the area of Milicz, in the distance of around 50 km from the previously described complex of ponds. The recording of the new site in Poland was in contradiction with observations from some other European countries, where Coleanthus subtilis was disappearing. In this regard, the colonisation of a new area by this species deserved special attention. The first of the works of this cycle documents the population size and species composition of phytocenoses from the region of Milicz. As a species from the annexes of the Habitats Directive, the Coleanthus subtilis has been included in the national monitoring of Natura 2000 species and habitats and requires the preparation of reports to the European Commission. Methodological assumptions for monitoring preceded by the characteristics of the biology and ecology of the species are the subject of the second work in the series, published as a chapter in the series of methodological manuals of the General Inspectorate for Environmental Protection in Warsaw.

In the following years, the Coleanthus subtilis began to inhabit further reservoirs in the complex of Milicz Ponds, which was also noted by Poznań botanists (Czarna et al., 2013). In 2014, when the total number of occupied ponds exceeded 10, I undertook multifaceted research aimed at determining the range of habitat conditions of Coleanthus in Poland. I conducted these studies together with dr hab. A. Klink, dr L. Polechońska, dr M. Dambiec and dr hab. R. Pielech. Bottom sediments from reservoirs occupied by *Coleanthus* were subjected to a detailed analysis in terms of chemical parameters, and the obtained results were associated with the biomass of its individuals. The obtained results allowed to relate the characteristics of habitats occupied in Poland to other sites of this species known from Europe. The results of the research were published in the article constituting the third work in this series.

The results of the research of the *Coleanthus*, which I initiated and then coordinated in Lower Silesia, are the basic material for determining the status of this rare species in Poland. They are particularly important due to the strict dependence of this species on the fishing industry carried out on breeding ponds. The guidelines developed so far enable a compromise between fish farming and maintaining the population of this unique component of the national flora.

It should be added that the research, the results of which are presented in a series of three works, was continued in subsequent years. They were complemented by a paper prepared in an international team of botanists presenting the situation of the species in Europe (Richert et al., 2016).

However, the determination of the degree of threat, as well as the possibility of protecting this species in Poland was included in one of the chapters of the Polish Red Book of Plants (Fabiszewski & Dajdok, 2014). The results of recent studies on the relationship between morphological variability of species individuals and habitat conditions, as well as the determination of the chemical composition of biomass and pioneering research on the allelopathic properties of this species are the subject of work currently at the stage of review (preprint).

Scientific research on Coleanthus subtilis, which is the subject of achievement No. 2, is complemented by fieldwork on the assessment of its population, in which I have participated since the beginning of the monitoring of Natura 2000 habitats and species in Poland (in cooperation with R. Bartosz, MSc). Data on selected populations of Coleanthus subtilis in Lower Silesia and the natural habitat with which this species is associated "Brzegi lub osuszane dna zbiorników wodnych ze zbiorowiskami z *Littorelletea*, *Isoëto-Nanojuncetea* - kod 3130" (Banks or dried bottoms of water reservoirs with communities from *Littorelletea, Isoëto–Nanojuncetea* – 3130), are used in the lists of population assessments of Natura 2000 species and habitats published in the GIOŚ bulletin, as well as in the above-mentioned reports submitted to the European Commission.

Literature

Czarna, A., Maćkowiak, Ł., Woźniak, A. (2013). New localities of *Coleanthus subtilis* (Tratt.) Seid. (Poaceae) in the „Milicz Ponds" Ornithological Reserve in Wielkopolska. Steciana 17, 39–42.

Dajdok, Z., Świerkosz K. (2012). Stawy w Borowej. Specjalny Obszar Ochrony siedlisk Natura 2000 PLH020045. In: K., Świerkosz, H., Liberacka, M., Łysiak., K., Zając (Eds.) Obszary Natura 2000 na Dolnym Śląsku, pp. 261-262. Regionalna Dyrekcja Ochrony Środowiska we Wrocławiu, Wrocław.

Dyrektywa Rady 92/43/EWG z dn. 21. 05. 1992 r. w sprawie ochrony siedlisk przyrodniczych oraz dzikiej fauny i flory. (Council Directive 92/43/EEC of May 21, 1992 on the protection of natural habitats and wild fauna and flora)

Fabiszewski, J., Cebrat, J. (2003). *Coleanthus subtilis* (Tratt.) Seidel – a new species to Polish vascular flora. Acta Societatis Botanicorum Poloniae 72, 135–138.

Fabiszewski, J., Dajdok, Z. (2014). *Coleanthus subtilis* (Tratt.) Seidl - Koleantus delikatny. In: Kaźmierczakowa, R., Zarzycki, K., Mirek, Z. (Eds.) Polska Czerwona Księga Roślin. Paprotniki i rośliny kwiatowe, pp. 649-651, Instytut Ochrony Przyrody PAN, Kraków.

Konwencja o ochronie gatunków europejskich dzikich zwierząt i roślin oraz siedlisk naturalnych z 19. 09. 1979 r. (Convention on the Conservation of European Species of Wild Fauna and Plants and Natural Habitats of 19/09/1979)

Richert, E., Achtziger, R., Dajdok, Z., Günther, A., Heilmeier, H., Hübner, A., John, H., Šumberová, K. (2016). Rare wetland grass *Coleanthus subtilis* in Central and Western Europe - current distribution, habitat types, and threats. Acta Societatis Botanicorum Poloniae. 85(3) (3511): 1-16, DOI: 10.5586/asbp.3511.

5. Presentation of significant scientific or artistic activity carried out at more than one university, scientific or cultural institution, especially at foreign institutions

In order to shorten the text of this part of Appendix No. 2, the provision of full bibliographic data of the discussed publications has been abandoned in favour of numbers that are consistent with the numbering used in Appendix 4

Since the beginning of my professional career, undertaken in 1991 at the University of Wrocław, in the then Department of Systematics and Phytosociology, at the Faculty of Natural Sciences (currently the Department of Botany, Faculty of Biological Sciences), in my scientific research, I focused on issues related to vascular flora and vegetation, in the aspect of changes occurring as a result of the direct impact of human activity, as well as indirectly – as a result of succession changes. In my research, I focused primarily on two groups of species and the communities they build: species classified as rare or disappearing under the influence of anthropogenic changes in habitats, and species classified as synanthropic, which human activity favours. Developing my interest in the latter group, over time I focused my research on alien invasive plant species. The research concerned various aspects of biology, ecology, conservation and broadly understood phytogeography.

Achievements before obtaining a doctoral degree

At the initial stages of my professional career, I mainly dealt with the assessment of quantitative and qualitative changes in relation to plant cover. My goal was to get to know as much as possible the national vascular flora and the basic groups of typical plant communities and their characteristic combination of species, which was conducive to improving the research workshop. At the same time, I learned and improved my skills in using modern methods of geobotanical data analysis, which at subsequent stages of work enabled me to move freely in the matters related to the assessment of the values and degree of deformation of plant cover of specific areas. Over time, the ability to assess potential or real threats to phytocenoses of specific communities or populations of selected species became the basis for geobotanical research as well as in environmental monitoring.

In this first period of work, the experience gained during the implementation of the master's thesis under the supervision of prof. J. Anioł-Kwiatkowska and then the preparation of its results for two publications [18, 19] turned out to be fruitful. I characterised 33 plant communities and assessed the frequency of occurrence of over 440 taxa in the northern part of Opole Silesia, where no detailed studies of vegetation had been carried out before. In the next stage, these studies were extended to include research conducted in neighbouring areas together with dr hab. Z. Kącki prof. UWr, and their published results emphasised the unique natural values of the studied region [23, 114, 115]. The results concerning species that deserve special attention, such as *Leucoium vernum* and *Baeothryon alpinum*, or natural objects of unique importance, such as the "Smolnik" nature reserve, were discussed in a series of joint papers [119, 120, 122, 124]. The data contained in them complemented the picture of the distribution of populations of some species in the region or in the country, through their use in synthetic studies for the Opole region, as well as in the nationwide Atlas of vascular plant distribution – ATPOL, which appeared in 2001 edited by A. Zając and M. Zając. Floristic data collected during the first years of professional work in Opole Silesia also allowed for the preparation, in cooperation with botanists from the Universities of Wrocław and Opole, of two atlases of the distribution of vascular plants in the Opole Voivodeship: i) rare species [1] and ii) legally protected species [2]. The atlases present the distribution of 120 species, which at the end of the 90s of the twentieth century were under legal protection in Poland and 85 rare ones, included then in the red list of Opole Silesia. As a result of the analysis of historical data, as well as intensive field research, a total of over 4,000 sites were verified, distinguishing between historical and currently existing sites. An important opportunity to develop knowledge of flora and plant communities was also participation in the elaboration, together with prof. J. Anioł-Kwiatkowska and dr hab. Z. Kącki prof. UWr, of natural values of the Odra River Valley section between Oława and Wrocław, planned to be protected in the form of a landscape park [24]. The research was an opportunity to indicate the richness of vegetation in the Odra valley, but also enabled the collection of data for the elaboration on a new for Poland segetal weed association *Kickxietum spuriae* [121].

In my initial professional experience, cooperation with the dr Z. Borysławski and participation in an international project headed by him [P.1] were important to me. A trip as part of this project for a three-month internship at the Ohio State University (OSU) in Columbus, United States in 1993 [S.3.] allowed me to familiarise myself with the possibilities of using Geographic Information Systems (GIS) and start processing data using technology that was just developing in Poland at that time. Data analyses started at OSU in collaboration with prof. P. Curtis were continued after returning from the internship. They were used, among others, to prepare publications and conference presentations, in which the possibilities of using GIS in geobotany [22, Mk.25] were presented, as well as in the analysis of the degree of threat to protected plants [96, K.2, K.7, Mk.2, Mk.3]. During my stay in Columbus, it was important for me to participate in seminars conducted by OSU employees for doctoral students. Regular participation in these classes allowed me, among others, to get acquainted with the methods of preparing a data set depending on research hypotheses, as well as multifaceted analysis of source materials. The internship at OSU and cooperation with dr Borysławski also influenced the choice of the topic of the doctoral dissertation, which was closely related to the topic of the project on the possibility of reducing diffuse (area) pollution in the Oława basin – a river constituting a source of water for Wrocław. The subject of my work entitled *Spatial diversity of plant communities in buffer zones of selected streams of Lipowe Hills*, was to relate the species composition of communities developing along small mid-field watercourses (tributaries of the Oława River) with the features of the environment. The collected data were analysed using GIS methods. As a result of the conducted analyses, I proposed, among others, the use of communities with the participation of nitrophilous species as indicators of places particularly intensively enriched with nutrients runoff from crop fields. Among other things, I showed that the greater the influence of the surrounding fields on the trophic conditions of the substrate within the buffer zones of the watercourses, the greater the importance of phytocenoses with a dominance of *Urtica dioica*. This result refers primarily to open areas, where intensive sunlight and low humidity of the substrate may be factors limiting the growth of *Urtica dioica*, and the factor determining the abundant occurrence of its phytocenoses is the high abundance of nutrients in the substrate. The results concerning this aspect have been published in the form of a chapter in the monograph [89]. Continuation of research in this field and broadening the spectrum of issues and analysed habitats resulted in the development of the monograph which is the subject of this habilitation application.

At the end of the 1990s, I started research in the field of biology, ecology and biogeography of alien plant species in Poland. At this initial stage, together with dr hab. Z. Kącki prof. UWr, by organising a boat cruise on the Odra River from Skorogoszcz to Szczecin (and then supplementing the data collection on the section from the border with the Czech Republic to Skorogoszcz), we assessed the distribution of selected species in the valley of this river, which was a pioneering achievement, taking into account the scale of the research [89, K.12]. The subject of my particular interest at that time was the *Impatiens glandulifera*, which spread on a massive scale in many regions of Poland. The results documenting its distribution in the Odra River valley, habitat preferences, as well as the composition of phytocenoses with its participation were among the first materials in this field published in the country [85, 90, 116]. The results of this research were also presented at international conferences in Krakow [K.13] and Berlin [K.5]. Especially the second conference, devoted to the ecology of invasive alien plant species (Ecology and Management of Alien Plant Invasions – EMAPI, Berlin 1997), was important due to the opportunity to get acquainted with the research of such authorities as prof. J. B. Faliński, prof. H. Sukopp, prof. I. Kowarik and prof. P. Pyšek, and strengthened my interest in biological invasions.

Short internships at the Hogeschool Rotterdam & Omstreken in Rotterdam (currently: University of Applied Sciences), Masaryk University in Brno (Masarykova Univerzita v Brne) and Adam Mickiewicz University in Poznań [S.1, S.2, S.4] were important in the development of the didactic workshop, as well as the development of contacts with scientists from other research centres.

Postdoctoral achievements

After obtaining a PhD degree in biological sciences, I continued research in the field of floristic and ecological studies, expanding it with the analysis of specific types of habitats, which are broadly understood wetlands and groups of species associated with them. First of all, I continued to work on various aspects of the invasion of alien species and the threats resulting from this process and the search for countermeasures for selected representatives of the vascular flora. At the same time, in collaboration with other naturalists, I conducted research on the adaptation of IUCN criteria for assessing the threat of vascular plants to a regional scale. Another important stage in the development of my scientific path was participation in team, interdisciplinary research on the importance of mid-field marginal habitats and factors affecting the richness of organisms associated with them. Together with the scientists from the Institute of Nature Conservation of the Polish Academy of Sciences in Krakow and the Institute of Agricultural and Forest Environment of the Polish Academy of Sciences in Poznań, I was a co-organizer of this project and the person responsible for the botanical aspects.

My research problems, apart from marginal habitats, can be grouped into two thematic blocks:

1) Biology and ecology of invasive plant species in terms of impact on ecosystems and counteracting the effects of their dispersion;

2) Assessment of the current state of populations of threatened and rare vascular plant species, with particular emphasis on wetland habitats.

Ad. 1. Biology and ecology of invasive plant species in terms of impact on ecosystems and counteracting the effects of their dispersion

Research concerning the problems of the dispersion of alien plant species began to develop dynamically in our country in the 90s of the twentieth century. At that time, special attention was paid to understanding the current distribution, population size, as well as the effects of the presence of these species on ecosystems. I took up this research issue when I began studying the biology and ecology of *Impatiens glandulifera* in the early period of my scientific work. With time, the ecology of invasive species became one of the main topics of my research (as well as didactic work) at the University of Wrocław. Their result was the preparation of both "case studies" as well as synthetic studies.

As part of the case study, apart from *Impatiens glandulifera*, I subjected to a detailed analysis the least known species among American goldenrods established in Poland – *Solidago graminifolia* (cooperation with Prof. A Nowak). Studies have shown that the species is much more widespread than previously thought, and the types of habitats it occupies and the composition of phytocenoses in which it dominated were also documented. The most important achievement, however, was to show that it has as threatening impact on biodiversity as the already well-studied *S. gigantea* and *S. canadensis*. The participation of *S. graminifolia* in rush, meadow and ruderal communities was documented, thus directing attention to the colonisation potential of this species. The research results were presented at the conference Ecology and Management of Alien Plant Invasions (EMAPI) [K.16] and then published [39]. I have also carried out detailed research for other invasive species, among others, *Alopecurus myosuroides*, which can have a negative impact on field crops. I noticed its presence in the Sudetic Foreland [132]. Another species analysed was *Cyperus esculentus* known for the possibility of mass dispersal in the southern and western parts of Europe. The paper on this subject [128] is a documentation of the first site of the species in Poland. Important works in this field also include two studies prepared for the online database NOBANIS (European Network on Invasive Alien Species – https://www.nobanis.org). They concerned *Mimulus guttatus* [152] and *Spiraea tomentosa* [153] and were prepared in cooperation with botanists from Poland, and agreed upon with experts from other European countries.

Among the species that have been characterised in detail in terms of biology and ecology was *Veronica peregrina*. It is one of the few alien plants spreading within periodically dried up water banks [47]. Further studies allowed to demonstrate the allelopathic properties of this species and were the subject of a team publication [104]. The results of these studies were also presented at scientific conferences [K.45, Mk.22, Mk.23].

In 2009, I initiated the preparation of the first monographic study in Poland discussing the problems resulting from the spread of selected invasive plants within wetland ecosystems. To prepare this study, together with P. Pawlaczyk from the Naturalists' Club, we invited botanists from various scientific centres in Poland, jointly preparing the characteristics of more important species that pose a threat to the biodiversity of wetlands. In addition to co-editing the volume [91], my participation in this study consisted in the preparation of co-authored chapters: introductory – *River valleys and standing waters as habitats of invasive species* [44] and characteristics of such species as *Echinocystis lobata* [45], *Impatiens glandulifera* [46], *Veronica peregrina* [47], *Xanthium albinum* [48] and *Mimulus guttatus* [49].

I have continued my research on *Echinocystis lobata* in recent years as part of the work of an international team coordinated by dr hab. K. Kostrakiewicz-Gierałt prof AWF, dr hab. A. Stachurska-Swakoń prof. UJ and dr A. Pliszko [111]. Other analyses concerned the participation and the role of alien plant species, and in particular the group of invasive species, in the vegetation of the Opolskie Voivodeship [38], as well as mid-field marginal habitats [130]. The last study examined the most widespread species of archaeophytes and kenophytes found within 70 field margins, indicated their habitat preferences within the margins and potential impacts on plant communities of marginal habitats. Some of these results were included in a monograph presented as a scientific achievement in this aplication.

An important work of a synthesis nature is my co-authored monograph entitled "*Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem gatunków inwazyjnych"* (Alien plants in Poland with particular reference to invasive species) [4]. The work is the broadest discussion of alien vascular plants in the country to date. Its main part is a tabular list of 939 species, which are divided depending on the degree of establishment in Poland. A group of 92 invasive and potentially invasive species was subjected to detailed analyses, for which, among others, the impact on Natura 2000 habitats was indicated. Together with the co-authors, we have also prepared guidelines for practical actions necessary to be taken in Poland regarding invasive plants [135] or their selected representatives [E.21]. My participation in synthetic studies also concerned forest communities [145].

In my research on invasive species, cooperation with a team of botanists led by prof. B. Tokarska-Guzik from the Institute of Biology, Biotechnology and Environmental Protection, University of Silesia in Katowice performed a very important role. Many years of joint research have brought results in the form of publications and application studies, among others, prepared for the General Directorate for Environmental Protection in Warsaw. One of the first concerned the list of plants of foreign origin that may pose a threat to nature of Poland and the European Union [5], and the next – guidelines for the control of knotweed [E.21]. The latter was also used as a basic material for the preparation of a monograph entitled *Inwazyjne gatunki z rodzaju rdestowiec* Reynoutria *spp. w Polsce – biologia, ekologia i metody zwalczania* (Invasive species of the genus *Reynoutria* spp. in Poland – biology, ecology and methods of their eradication) [7]. In view of the growing demand for unification of the classification of invasive species, taking into account the degree of distribution and the effects and possibilities of minimising the impact of these species, I proposed, in cooperation with prof. B. Tokarska-Guzik [87], to adapt to Polish conditions the system published by Blackburn et al. The classification enables the standardisation of the evaluation of invasive species and their categorization. Its dissemination would greatly simplify the comparison of the role of specific species in different ecosystems and, above all, would allow prioritisation of actions taken at a regional and national level.

Another important synthesis in which I was involved is the recent update of the list of the most important invasive plant species in Poland [107]. The paper contains the most up-to-date statistical data on species requiring special attention, among others, when making decisions on limiting the spread of already established species, as well as preventing the occupation of new areas by species in the initial stages of invasion in Poland. In turn, cooperation with the team led by dr hab. K. Najberek prof. IOP PAN from the Institute of Nature Conservation of the Polish Academy of Sciences in Krakow resulted in participation in the study on the role of invasive species as a reservoir of pathogens [109].

Thanks to many years of experience in the field of biological invasions, I was invited to work in a team led by prof. Tokarska-Guzik as part of the project of the General Directorate for Environmental Protection entitled *Opracowanie zasad kontroli i zwalczania inwazyjnych gatunków obcych wraz z przeprowadzeniem pilotażowych działań i edukacją społeczną* (Development of rules for control and eradiacation of invasive alien species along with pilot activities and social education), financed by the European Union (Infrastructure and Environment Programme 2014-2020). In the first stage of the project, I was involved in the preparation of a methodology for assessing the invasiveness of alien plants, and then surveys of invasiveness of selected species and their cards, discussing in detail their features and possible effects of invasion on the natural environment, the economy and human health. The questionnaires and cards I co-authored [V, p.5.1] concerned nine species: 1) *Azolla filiculoides*, 2) *Bromus carinatus*, 3) *Echinocystis lobata*, 4) *Eragrostis albensis*, 5) *Impatiens capensis*, 6) *Impatiens glandulifera*, 7) *Mimulus guttatus*, 8) *Spiraea tomentosa*, 9) *Xanthium albinum*. In the second stage of the project, I participated in pilot testing of methods of combating selected invasive species. I coordinated fieldwork carried out in Lower Silesia, related to the removal of *Heracleum sosnowskyi* in the area of Łężyce (Szczytna Commune) and *Reynoutria* x*bohemica* in Koźlice (Zgorzelec Commune). I also participated in the collection of field data and the development of reports on monitoring the effects of the work carried out. In the theoretical part of the project, I also participated in the preparation of the so-called compendiums of knowledge on five invasive species (or their groups) along with guidelines for dealing with them in Poland [V, p.5.2]. These species include: 1) *Impatiens capensis* and *I. glandulifera*, 2) *Heracleum sosnowskyi* and *H. mantegazzianum*, 3) *Reynoutria japonica*, *R.* x*bohemica* and *R. sachalinensis*, 4) *Echinocystis lobata*, 5) *Spiraea tomentosa*. These studies are of significant practical importance, because the methods of dealing with invasive plant species presented in them are recommended by the General Directorate for Environmental Protection for use in the country, as part of activities aimed at control of these species.

As part of the efforts to popularize knowledge about invasive plants in our country, I took part in the preparation of a field guide [17], publications presenting the occurrence of invasive alien species in some national parks [10, 14-16] and in the region of Lower Silesia [11, 13], as well as materials addressed to farmers [41]. Problems related to the spread of invasive species were also the subject of educational projects carried out by the Lower Silesian Ecological Club, in which I co-conducted field classes, lectures or workshops on species identification. A summary of the implementation of these projects is presented in the paper [133]. Invasive species were also the subject of diploma theses prepared under my supervision. Some of them were published together with my master's students – e.g. with mgr J. Misztal [142], dr M. Czarniecka [137] and mgr M. Podżorski [146].

Ad. 2. Assessment of the current state of populations of endangered and rare vascular plant species, with particular emphasis on wetland habitats

Another field of my scientific interests is ecology and protection of selected species classified as rare or endangered on a national or Lower Silesia scale. The research undertaken by me in recent years was aimed at verifying the conservation status of their populations, assessing habitat conditions and determining real and potential threats in the context of seeking remedial actions. The analysed species included, among others: *Carex buekii*, *Arum maculatum*, *Potamogeton polygonifolius*, *Rosa gallica*, *Muscari comosum*, *Melampyrum cristatum* and *Corrigiola litoralis*.

I devoted detailed research to the *Carex buekii* – one of the less common representatives of the *Carex* genus in Poland. This species was first described for science by F. Wimmer from the area of Wrocław in 1857. In the post-war years, it was rarely reported from Lower Silesia (e.g. from the Ślęża region by Anioł-Kwiatkowska and others in 1992), and in the study from 2003, it was considered extinct in the region [37]. The research that I undertook in cooperation with mgr G. Wójcik allowed to find many sites of this species, mainly in the region of Wrocław, including the area indicated by Wimmer as the *locus classicus* of the species. The presentation of the current situation of the species in relation to the entire Polish area was possible after initiating cooperation with dr M. Zarzyka-Ryszka and dr W. Paul from the Institute of Botany of the Polish Academy of Sciences in Krakow [64, Mk.15]. Further work was undertaken in cooperation with specialists from Szczecin – dr hab. H. Więcław prof. US, dr hab. B. Bosiacka prof. US and dr J. Koopman, as well as botanists from Slovakia, the Czech Republic, Hungary and Italy. These studies enabled to prepare the publication of data on habitat preferences, phytocenoses composition and factors negatively affecting *Carex buekii* populations in Central Europe [103]. It is worth emphasising that the published results are the first, supra-regional study of the situation of this species, and in relation to Polish document the occurrence of the association *Caricetum buekii*, previously not included in national studies on plant communities. Recently, we have presented contemporary aspects concerning the morphological diversity of *Carex buekii* individuals against the background of habitat conditions [110]. An important achievement of this study is not only to indicate the range of soil variability at the sites occupied by *C. buekii*, but also to draw attention to the morphological diversity of species individuals in different habitat conditions. The importance of this work is underlined by the fact that, as with the earlier article [103], the conclusions were drawn from the perspective of Central Europe.

The subject of my detailed research was also *Arum maculatum*. I undertook research work on this species at the end of the 90s of the twentieth century, when the verification of the species sites from the southern part of the country showed the presence of only *Arum alpinum* and it became necessary to confirm whether *A. maculatum* occurs in Poland. Field verification of historical data allowed to update knowledge about the occurrence of this species in the country. It has been shown that the current coverage of *A. maculatum* includes only Western Pomerania (natural sites) and the number of its sites in our country is limited only to single sites. After verification, the first current map of the distribution of this species in Poland was published [93]. Participation in the development of the characteristics of this species in two editions of the Polish Red Book of Plants – in 2001 [26] and in 2014 [67] – allowed to determine the changes in the number that happened over 10 years within the studied populations. These changes were so unfavourable that the species was classified as a plant in the "vulnerable" category (VU), which was a prerequisite for indicating remedial actions to prevent the complete extinction of *Arum maculatum* in Poland.

Another species I studied is *Potamogeton polygonifolius*, which belongs to the group of endangered plants (EN), whose eastern border of a compact range in Europe runs through the area of Poland. In cooperation with dr hab. J. Zalewska-Gałosz prof. UJ, prof. A. Nowak and mgr W. Bena, we determined the area of the most numerous occurrence of this species, covering mainly a fragment of the Lower Silesian Forests. Taking into account the characteristics of the population, we discussed the degree to which the species is endangered in our country [139], discussed the diversity of habitat conditions in which it currently occurs [96] and indicated basic guidelines for remedial actions to maintain its population in Poland [61].

In my research, I also focused on the *Rosa gallica* – a species classified in Poland as vulnerable plants (VU), but unlike *Arum maculatum* or *Potamogeton polygonifolius*, it is showing tendencies to occupy anthropogenic habitats. The process of colonisation of these habitats (e.g. flood embankments) was recorded in Wrocław. Because such a process deserves special attention in the case of plants considered to be vulnerable, I undertook research in the area of Wrocław, first checking the potential habitats of *Rosa gallica*, and then making floristic censuses in the largest patches of vegetation with the participation of this species. In the summary of the co-authored study [141], the distribution of over 270 patches of the *Rosa gallica* was indicated, thus changing the previous belief that the species belongs to the group of plants of high category of threat in Poland.

The species whose population status I verified in the field also included: *Carex limosa*, *Rhynchospora alba*, *Scheuchzeria palustris, Dryopteris cristata, Arum alpinum, Epipactis albensis* and *E. purpurata*, *Baeothryon alpinum* and *Muscari comosum* and *Melampyrum cristatum*. Most of these species were the subject of studies prepared for the Red Data Book of Plants of the Opole Voivodeship [27-35], and the last two for the nationwide Red Data Book of Plants [25, 62, 65].

Experience from valorisation of selected species proved useful in the preparation of theoretical studies on determining species threat indicators on a regional scale. Based on the guidelines of the World Conservation Union (IUCN), a co-authored proposal for standardising the criteria for assessing the threat to plant species has been prepared. The system was used during the elaboration of the red list of vascular plants of Lower Silesia [37] and was published in the form of a chapter in the monograph devoted to "*Endangered species of vascular flora of Lower Silesia*" [37], and then in the Bulletin of the Committee for Nature Conservation of the Polish Academy of Sciences [143]. A separate list has been developed for species from the group of archaeophytes, verifying the criteria for assessing threat to them [50] and discussing in detail the situation of selected representatives of this group [51-55].

The ongoing verification and updating of data on the state of vascular flora made it possible to prepare in 2016, in cooperation with specialists from other research centres, a new Polish red list of ferns and flowering plants [6]. It includes 756 taxa (30% of the flora of vascular plants of Poland), and its main advantage is to determine the threat of individual species by assessing their situation in different regions of the country. In addition, due to the growing interest in the EU in the potential possibilities of using genetic resources of species from the group of crop wild relatives (CWR), together with dr D. F. Dostatny, we have edited the first comprehensive study on this group in Poland [92]. The main part of this book is a list of over 1400 crop wild relatives occurring in Poland [83], in the compilation of which I participated together with a team of 13 botanists from various scientific centres in the country. Also significant is chapter [82], which discusses the threats to the CWR group and urgent actions to preserve this group of plants as essential components of our country's ecosystems.

Flora and vegetation of waters and periodically dried river banks and pond bottoms

Flowing and standing water edges are one of the categories of natural habitats protected in the European Union under the Habitats Directives. One of the types of these habitats is "Brzegi lub osuszane dna zbiorników wodnych ze zbiorowiskami z *Littorelletea*, *Isoëto-Nanojuncetea* - kod 3130" (Banks or dried bottoms of water bodies with communities from *Littorelletea, Isoëto-Nanojuncetea* - code 3130), in original Interpretation Manual of European Union Habitats, from 2003 known as "Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoeto-Nanojuncetea*". In natural conditions, they are associated with river banks and depressions of land periodically filled with water, while secondarily they occupy fishponds, among others. Regulation of rivers, especially the maintenance of a constant level of water for the needs of inland navigation, have caused these habitats to be increasingly rare in river valleys, and the plant species associated with them are classified as threatened. The assessment of the situation of this group of plants on the scale of Lower Silesia is included in the form of a chapter entitled *Flora wodna i błotna Dolnego Śląska na tle zagrożeń i możliwości ochrony* (Water- and swamp-flora of Lower Silesia on the background of threats and possibilities of protection) [36]. In the case of selected species representing a group of wetland (or aquatic) habitat plants, such as *Nasturtium officinale* and *Lindernia procumbens*, I took part in separate team studies [127, 161]. As a result, the current population status of both species was presented, and in the case of *Lindernia*, the shift of the northern border of the area of occurrence of this species in Poland was additionally documented. This process was associated with the change in climatic conditions, including above all the periods of high temperature in the second half of the season. Important articles discussing the ecology and taxonomy of species associated with wetlands also include a team work prepared under the leadership of Prof. A Nowak, devoted to the occurrence of *Nymphaea candida* in Poland [94]. Thanks to the cooperation of a group of botanists from various research centres, the earlier, erroneous claim about the lack of this taxon in the southern part of the country was verified. The published data, in addition to updating the area of occurrence of *Nymphaea candida* in Poland, indicated the range of habitats in which this species has been found so far.

A completely different character than the previous work had a study prepared in cooperation with dr hab. C. Toma and dr M. Kukliński, concerning one of the most important aquatic species in Poland, which is *Trapa natans*. In Science of Nature [108] we presented the physico-mechanical properties of *Trapa natans* fruits, indicating the changes occurring in the drying process, and determining the force needed to break *Trapa natans* nuts. A practical result of the study was that the very dense material of the pericarp, after reaching maturity, slightly changes during drying, and that it can be used industrially as an extremely durable and biodegradable biological material.

In the field of wetland habitat research, in recent years I participated in a synthetic publication prepared by a team of botanists, led by prof. A. Popiela and dr hab. Z. Kącki prof. UWr, presenting the classification of vegetation of ephemeral wetlands (*Isoëto-Nanojuncetea* class) [106]. The work is a summary of knowledge about this group of communities in Poland, an important, among others, from the point of view of preserving the biodiversity of wetlands. At the same time, it is an important contribution to the knowledge concerning ecology of these communities in Europe. An important element of the study is, among others, documentation of phytocenoses of the *Coleanthus subtilis* from the area of Lower Silesia collected during research that I conducted on this species in previous years. Other studies on the biology and ecology of *Coleanthus subtilis* are discussed in the description of achievement No. 2.

10. National and international cooperation

10.1. National cooperation

Since my employment at the University of Wrocław, as part of the research topics, I have cooperated with people from my home Department of Botany (previously the Department of Systematics and Phytosociology, and then the Department of Biodiversity and Plant Cover Protection). So far, I have conducted joint research, data analysis and preparation of publications with Prof. J. Anioł-Kwiatkowska [e.g. 18-24, 85, 90], Prof. Z. Kącki [e.g. 1, 2, 12, 23, 26-29, 37], as well as dr E. Szcześniak [e.g. 37, 50, 51, 60, 105] and dr K. Reczyńska [98]. Among botanists from other units of the Faculty of Biological Sciences of the University of Wrocław, I cooperate with dr hab. K. Świerkosz prof. UWr [56-58, 125], as well as with employees of the Department of Ecology, Biogeochemistry and Environmental Protection, especially in the field of analysis of habitat conditions of selected vascular plant species. Initially, I cooperated with this Department as part of the implementation of the grant of dr Z. Borysławski [21, 22, Mk.1-3, K.2, K.3, K.7]. Currently, I conduct joint research with the employees of this Department with dr hab. A. Klink and dr L. Polechońska [3, 100, 104, Mk. 22, Mk.23, K.45]. Recently, dr hab. E. Gola prof. UWr from the Department of Plant Development Biology [Mk.22, preprint] and dr hab. R. Pielech from the Institute of Botany of the Jagiellonian University have joined the research. As part of this cooperation, we have prepared publications and conference presentations in the field of ecology, biology and morphology of *Coleanthus subtilis* and *Veronica peregrina*, and in the case of joint research with dr hab. E. Gola prof. UWr and dr E Szcześniak – on parasites of the genus *Cuscuta* [105]. From among the employees of other universities in Wrocław, I conduct joint research in the field of understanding the species diversity of mid-field marginal habitats, with dr S. Wierzcholska from the Institute of Environmental Biology of the Wrocław University of Environmental and Life Sciences [40, 97, 129, Mk.12, Mk.27, K20, K.43].

From research centres outside Wrocław, cooperation in the field of interdisciplinary research conducted with dr hab. inż. A. Wuczyński prof. IOP PAN is of fundamental importance to me. Participation in projects led by prof. Wuczyński [P.3 & P.5] enabled the preparation of several joint publications [e.g. 86, 95, 97, 102] and conference presentations [Mk.10-12, K.27, K.43] on the biodiversity of agricultural areas, and also allowed to collect material for the monograph, which is the first achievement referred to in this application. In the implementation of some of the issues in the above-mentioned thematic scope, cooperation with dr hab. K. Kujawa and prof. J. Karg from the Institute of Agricultural and Forest Environment of the Polish Academy of Sciences in Poznań, as well as with prof. P. Tryjanowski from the Department of Zoology of the Poznań University of Life Sciences [136, 138] was also of great importance. Among the employees of IOP PAS, I also cooperated with dr hab. W. Solarz prof. IOP PAN and dr hab. K. Najberek prof. IOP PAN, mainly in the implementation of projects concerning the impact of invasive species on ecosystems [107, 109, Mk.20, Mk.26, K.29, K.30]. The opportunity to cooperate with the late prof. R. Kaźmierczakowa was particularly important to me. The occasion was to prepare data for two editions of the Polish Red Data Book of Plants – from 2001 and 2014, and in 2016 the nationwide Red List of Plants [6].

In the scope of my research on invasions of alien plant species, cooperation with a team of botanists from the Institute of Biology, Biotechnology and Environmental Protection, University of Silesia in Katowice, and in particular with prof. B. Tokarska-Guzik, performs a very important role. The scope of cooperation includes participation in projects led by prof. Tokarska-Guzik, including the one implemented in recent years [P.4], under which a series of surveys of invasive species were prepared [V, p.5.1], as well as joint articles also with other members of the project team [107]. In previous years, we jointly prepared a series of publications [e.g. 4, 5, 7, 38, 87, 152, 153], as well as conference presentations [e.g. K.13, K.16, K.17, K.20] expanding the state of knowledge on the effects of the spread of invasive plants in Poland. Among them, the most important are the review works [4, 107]. The scope of this subject also includes cooperation with prof. W. Danielewicz and dr B. Wiatrowska from the Department of Botany and Habitat Science of the Poznań University of Life Sciences [e.g. 4, 135, 145, 153].

Since the beginning of my work, I have also been cooperating with botanists from the University of Opole - prof. A. Nowak, dr hab. S. Nowak prof. UO, and in the past also with dr K. Spałek. The cooperation was initiated by joint research on the distribution and ecology of selected plant species of Opole Silesia, published in the form of a monographs [1, 2] and one of the first regional red book of plants in Poland

[27-35]. The results of the cooperation also include case studies [39, 127], and more recently - species from the group of crop wild relatives [82]. Together with prof. Nowak, in a team with dr hab. J. Zalewska-Gałosz prof. UJ, we also conducted detailed research on the occurrence of *Potamogeton polygonifolius* in Poland [61, 96, 139].

My involvement in research in the field of phytogeography also allowed me to cooperate with prof. A. Zając and prof. M. Zając in the preparation of a multi-authored Atlas of the distribution of vascular plants in Poland in 2001 and an appendix to this study from 2019 [8], as well as publications on biological invasions [e.g. 4, 135].

In the field of taxonomic and ecological research on the flagship species for the area of Wrocław *(locus classicus*), which is *Carex buekii*, I cooperate with dr hab. H. Więcław prof. US and dr hab. B. Bosiacka prof. US from the University of Szczecin, as well as with dr J. Koopman, with whom we have prepared several joint publications [101, 103, 110] and conference presentations [Mk.15, K.58]. Recently, an opportunity to broaden cooperation with the employees of the University of Szczecin was the preparation of a review paper on the communities of periodically exposed water banks in a team led by prof. A. Popiela [8].

In addition, in recent years I have been pursuing a topic on a group of Crop Wild Relatives (CWR), in cooperation with dr D. F. Dostatny from the Warsaw University of Life Sciences (previously from the Institute of Plant Breeding and Acclimatization in Radzików). The result of this cooperation is a multi-author publication, which is the first comprehensive study of this group of plants in Poland [82, 83, 92].

The most important national local government units and business entities with whom I cooperated as part of the application activity include, first of all, the General Directorate for Environmental Protection in Warsaw (among others studies on the management of invasive alien plants in Poland – V, p.51 & p.5.2), the Regional Directorate for Environmental Protection in Wrocław (among others development of standard forms for Natura 2000 sites - V, p.4.7), Department of Sustainable Development in the Municipal Office of Wrocław (development of botanical values and guidelines for the protection of selected areas – E.22), Chief Inspectorate for Environmental Protection in Warsaw (monitoring of Natura 2000 habitats and species – e.g. 2), Regional Directorate of State Forests in Wrocław (verification of species and habitats in Natura 2000 areas – E.17), Forest Gene Bank Kostrzyca (implementation of didactic classes for students of the University of Wrocław in FGB), Prof. S. Białobok Forest Arboretum in Stradomia Wierzchnia (implementation of didactic classes for students of the University of Wrocław in the arboretum), directorates of national parks – Karkonosze among others (conducting research and then processing data on synanthropic species in KNP) and Wigierski (conducting research and then development of data on invasive species in WNP), Stawy Milickie SA. (monitoring of Natura 2000 species and habitats in the area of ponds in consultation with the administrator), or offices of some municipalities of the Dolnośląskie and Opolskie voivodships (nature inventories, guidelines and applications for protection of selected objects – V, p.4.4 & p.4.6). Cooperation with non-governmental organisations is also of great importance, especially in the aspect of popularisation of science through the implementation of projects addressed to young people, preparation of popular science publications and conducting lectures as part of seminars and meetings. The most important organisations with which I cooperated in this area include: the Polish Society of Friends of Nature Pro Natura, the Naturalists' Club and the Lower Silesian Ecological Club.

10.2. International cooperation

My cooperation with researchers from foreign research centres began with the participation in the project of dr Z. Borysławski [P.1], coordinated on the part of the University of Columbus, Ohio (USA) by prof. P. Curtis. An element of this cooperation was a three-month internship in Columbus in 1993 [S.3], and then conducting data analysis using GIS methods, which was possible thanks to the transfer of GIS technology to the University of Wrocław (Laboratory of Numerical Methods in Ecology, headed by dr Z. Borysławski). The effects of this cooperation include joint publication [22] and conference presentations [K.2, K.3, Mk.1, Mk.2], as well as the preparation of my doctoral dissertation.

As part of international cooperation, in the first years of my work at the University of Wrocław, I also had the opportunity to participate in shorter study visits. One of them took place in 1992 at the Masaryk University in Brno [S.2], and another one a year later at the University of Applied Sciences in Rotterdam [S.4].

After 2000, I started working with a team of German ecologists led by Prof. H. Heilmeier from the Institute of Biological Sciences (Technische Universität Bergakademie) in Freiberg (Saxony). The cooperation began with a joint visit to Saxony in 2013 together with Ms D. Chmielowiec-Tyszko from the Foundation for Sustainable Development. At that time, I presented, among others, the possibilities of undertaking joint research on the ephemeral vegetation of anthropogenic reservoirs (fishponds). The result of the initiated contacts was a return visit of prof. Heilmeier's team to the Ornithological Station of the University of Wrocław in Ruda Milicka. During its duration, we started collecting data for a publication on the current situation of the population of *Coleanthus subtilis* in Europe. The work on this issue was coordinated by dr E. Richert, and due to her experience in *Coleanthus* research in the Czech Republic, dr K. Šumberová from the Institute of Botany of the Academy of Sciences of the Czech Republic in Průhonice was invited to join the team. The result of the joint research was published in a review paper [99] in which I was a corresponding author.

Since 2022, I have been cooperating with a team of botanists led by prof. J. Pergel from the Department of Invasion Ecology, Institute of Botany of the Academy of Sciences of the Czech Republic. The cooperation is carried out as part of the project on invasive species [P.6], led on the Polish side by dr M. Stanek from the W. Szafer Institute of Botany of the Polish Academy of Sciences in Krakow. The cooperation was initiated during a two-day visit to Prague in March 2023, and as part of the next phase, the collection of field data was launched. Data analyses and publication of results are planned for the years 2024-2025.

11. Participation in conferences and seminars:

Since the beginning of my employment at the University of Wrocław, I have participated in national and international seminars and conferences, during which I delivered 18 papers (4 on international [K.1, K.2, K.10, K.11] and 14 on national [K.7, K.31-K.43] conferences) and presented 12 posters (8 on international [K.3-K.6, K.12-K.15] and 4 on national [K.8, K.9, K.44, K.45] conferences). Of these, 9 (papers or posters) I presented before obtaining my doctoral degree, and 24 after my doctorate. In addition, I am a co-author of 31 papers or posters for conferences in which I did not personally participate (14 international [K.16-K.30] and 17 national and [K.46-K.62]). Summaries of some of the presented materials were included in the conference proceedings [Mk1-Mk.27].

12. Presentation of teaching and organizational achievements as well as achievements in popularization of science or art

From the beginning of my work at the University of Wrocław, I participated in the implementation of didactic tasks, initially as an assistant in classes conducted by people with more seniority, and then conducting laboratory and field exercises. In the first years of work, these were mainly review classes in the field of systematics, biology and ecology of spore organisms and seed plants as well as plant communities. With time, I began to prepare my own scenarios of classes that were included in the curricula as obligatory or optional subjects for students of Biology, Natural Environment Management and Inter-Faculty Studies in Environmental Protection (at the bachelor's and master's level), as well as a part of postgraduate studies in Natural Environment Management "Ekoznawca" (Eco-expert). Currently, I participate in the implementation of didactic classes within 11 subjects [V, p. 2.3], both in the form of lectures and exercises, as well as field exercises. The topics discussed during their implementation concern biological invasions (three subjects – lectures, exercises and field exercises), ex situ protection and the role of botanical gardens in plant protection (two subjects – lectures, exercises and field exercises), protection and management of natural resources (three subjects – lectures, exercises and field exercises), biodiversity of urban areas (two subjects - lecture and field exercises) and improving identification skills of vascular plants and their communities (one subject – field exercises).

In addition, during my professional work, I was a supervisor (or co-supervisor) of 50 papers prepared by students of the Faculty of Biological Sciences of the University of Wrocław – majors in Biology and Natural Environment Management, as well as the Inter-Faculty Study of Environmental Protection, including 21 bachelor's theses (20 in full-time studies and one in part-time studies) and 29 master's theses (24 in full-time studies and 5 in part-time studies) [V, p. 2.1]; Three more MSc papers are currently in preparation. The results obtained as part of the implementation of some diploma theses were published [137, 142, 144, 146], and in two cases also presented at scientific conferences [K.15, K.28].

In the academic year 2018-2019, I was a scientific supervisor as part of the function of a tutor of M. Żamojda – a student of the College of Inter-Area Individual Studies (MSI) of the University of Wrocław.

As part of the popularisation of science, my activity consisted in preparing popular science publications in periodicals addressed to young people and teachers of secondary and primary schools, such as the monthly *Raj* (Paradise) – 29 articles and notes and *Zielona Planeta* (Green Planet) – 5 articles [V, p. 3.3]. I also gave several press interviews about the threats resulting from the spread of invasive species of the genus *Heracleum* spp. [V, p. 3.4]. I have given lectures many times on counteracting the spread of invasive alien species, and above all on the need to take action in the field of nature conservation. The occasion were cyclical meetings organised by societies, local governments or teacher training centres [V, p. 3.1 & 3.2]. I also took part in workshops and trainings addressed to teachers and youth of secondary schools, foresters, as well as the staff of the Integrated Monitoring of the Natural Environment [V, p. 3.2.17 & 18].

I have been awarded the Rector's Award five times for my didactic activity, and in 2022 the Medal of the National Education Commission [V, p. 1].

13. Organizational activity at the University

As part of my duties at the Faculty of Biological Sciences of the University of Wrocław, I participated in organisational work within the functions or teams appointed by His Magnificence Rector of the University of Wrocław or the Dean of the Faculty of Biological Sciences. The most important functions I performed were:

1. Deputy Director for General Affairs of the Institute of Plant Biology, in the period from 1.09.2008 to 31.03.2012
2. Head of the Laboratory of Nature Protection in the Department of Biodiversity and Protection of Plant Cover in the period from 1.09.2008 to 31.03.2012
3. Head of Postgraduate Studies in Natural Environment Management "Ekoznawca" (Eco-Expert) carried out at the Faculty of Biological Sciences of the University of Wrocław

I have participated or still participate in the work of the following university teams:

4. Member of the Faculty Team for the Evaluation of the Quality of Education (WZOJK) – since 2012 to present
5. Member of the author team established to develop an education program for the newly established field of study "Natural Environment Management"
6. Member of the Faculty Recruitment Committee for the academic year 2013/2014 for full-time second-cycle studies in biology, microbiology and biology – teaching specialisation
7. Member of the Team for the development of a system for recording and managing research infrastructure at the University of Wrocław

8. Member of the Faculty Team for the concept of the biodiversity research station in Ruda Milicka
9. Member of the Council of the Faculty of Biological Sciences UWr for the term 2020-2024
10. Supervisor of students during four study visits, in the "*Integrated Development Program of the University of Wrocław 2018-2022*" (extended until 2023), implemented by the University of Wrocław under the Operational Program Knowledge Education Development.

14. Participation in the work of expert teams outside the university and application activities for nature conservation

Conducting research on plant species and communities classified as threatened in Poland, as well as on the spread of invasive alien species, enabled me to gain knowledge conditioning the possibility of engaging in the work of expert teams outside the university [III, p. 6]. One of the most important was my work in the Committee for Nature Conservation of the Polish Academy of Sciences, in which I served as secretary in the 2003-2006 term. In 2010, I was invited by the General Director for Environmental Protection to work in a group of experts to develop the *Kodeks dobrych praktyk „Ogrodnictwo wobec roślin inwazyjnych obcego pochodzenia*" (Code of Good Practice "Horticulture towards invasive alien plants") http://projekty.gdos.gov.pl/kdpo-zalozenia. Currently, I participate, among others, in the work of the Council for Ecology and Greenery at the President of the City of Wrocław.

As part of my activities for nature conservation, together with dr hab. Z. Kącki prof. UWr, I participated, among others, in the development of Protection Plans for several nature reserves in the Opole and Lower Silesian Voivodeships, these were the following reserves: Smolnik (1998), Nowokuźnicki Pond (1998), Kanigóra (1999), Grodzisko Ryczyńskie (1999), Zwierzyniec (1999), Przylesie (2001), Przyłęk (2001). In addition, in 2004, I was a member of the team led by Prof. W. Fałtynowicz, carrying out the collection and processing of data for the Plan of Protection of the Słowiński National Park. Together with dr hab inż. A. Wuczyński prof. IOP PAN, I prepared applications for the protection of five objects in the form of ecological sites, two of which – Rozalia (Wołczyn commune, Opolskie province) and Kurka wodna (Marcinowice commune, Dolnośląskie province) were established by resolutions of municipal councils. Other objects that were established for applications prepared with my participation are the Kamieniec reserve (Opolskie Voivodeship – together with dr hab. Z. Kącki prof. UWr), the Oporowski Forest (Wrocław commune, jointly with dr I. Gottfried) [V, p. 4]. At the stage of creating the Natura 2000 network in Poland, I participated in the work of teams of naturalists to develop Standard Data Forms for five areas in the Dolnośląskie and Opolskie voivodships. Over the years of my professional career, I have also participated in the preparation of environmental impact assessments, including such important objects as flood control reservoirs on the Odra River and Nysa Kłodzka River [E.4, E.6].

In recent years, participation in the project of the General Directorate for Environmental Protection in Warsaw devoted to developing solutions to reduce the impact of invasive alien species [V, p. 5. & 5.2] has been particularly fruitful. During its implementation, in the years 2018 – 2022, I participated in the preparation of *Kart* (Cards) and *Ankiet inwazyjności* (Invasiveness Surveys) for 9 plant species, including such important from the point of view of biodiversity protection and potential impact on human health as *Heracleum* spp. and *Reynoutria* spp. In the second stage of this project, I participated in conducting supervision and monitoring of the effects of work in the field of testing methods of selected invasive species eradication. I was also a member of author teams that developed compendiums in the field of eradication of selected invasive plant species in Poland.

The work in expert teams for the preservation of the natural values of the Wrocław area as part of the preparation of *Koncepcja ochrony i zwiększenia bioróżnorodności pól irygacyjnych Wrocławia* (Concept of protection and increase in the biodiversity of irrigation fields in Wrocław) and the development of the values of selected objects planned for protection in the form of ecological sites [E.22, E.23] also translates into measurable practical effects. For many years, I have also been involved in the monitoring of selected species and habitats of Natura 2000. To date, I am involved in the dataset on

Coleanthus subtilis and habitat 3130. In addition, since 2016, I have been cooperating with the Laboratory of Natural Environment Monitoring, Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznań, in the field of monitoring changes in the share of invasive alien species in two (out of 11) stations of the Integrated Monitoring of the Natural Environment in Poland. Monitoring is carried out on a total of 24 permanent areas, designated in Wielkopolska (Różany Stream catchment, Poznań-Morasko station) and Western Pomerania (Parsęta catchment, Geoecological Station in Storkowo).

Wrocław, 25. 09. 2023

....
(Applicant's signature)