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Terrestrial and aquatic flora along a mesotrophic lake shore remaining under increasing human impact: a case study of Lake Powidzkie (Poland)

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Abstract: Floristical investigations were carried out in 2009 in both terrestrial and littoral zones along the NW shore of the mesotrophic Lake Powidzkie (a Natura 2000 site: PLH300026). The results comprise: a general comparison of aquatic vs. terrestrial species richness; a census of 296 species of vascular plants and 7 species of charophytes; the taxonomical, biological (life forms) and geographical-historical (native vs. alien taxa) structure of vascular flora. Distribution of nationally and regionally threatened and legally protected species is presented on maps which illustrate that most of these taxa are concentrated in Lake Powidzkie and in its neighbourhood. The ongoing synanthropization of the flora is assessed and discussed considering localities of chosen alien species and their occurrence within natural plant communities: 21 of 27 aliens were recorded at least once in natural vegetation, whereas 4 of them (*Aster lanceolatus*, *Elodea canadensis*, *Impatiens parviflora* and *Rhus typhina*) formed their own, xenospontaneous communities. The main conclusion is that while the area still abounds in regionally valuable components of native biodiversity, it simultaneously is more and more threatened by increasing anthropopressure, which has already been manifested by the presence of many potentially invasive alien species.

Key words: vascular plants, Charophyceae, local distribution, endangered flora, alien species, naturalization, Natura 2000 site

1. Introduction

In Poland, as in the whole European Union, numerous, quite large sites have been recently proposed as Special Areas of Conservation (SAC) designed within the Natura 2000 network. A substantial part of them is aimed at the protection of natural lake ecosystems which are considered under the EU's Habitat Directive (92/43/EEC) as the so-called habitats of European interest. It is well known that mesotrophic, clean water reservoirs with submerged Charophyceae communities (defining the habitat No. 3140 – acc. to the Annex 1 of the 92/43/EEC directive) are particularly susceptible to eutrophication and fluctuations in water level (Piotrowicz 2004). At the same time these fragile habitats usually are highly attractive to some human activities, such as tourism, recreation, fishing etc. Thus, in such areas it seems particularly reasonable not only to recognise the diversity of native flora but also to assess current advancement of its synanthropization. Such an assessment may be very important for a successful, sustainable management of the Natura 2000 Special Areas of Conservation (SAC) which is demanded according to both European (92/43/EEC directive), as well as Polish law (The Nature Protection Act of 16th April 2004).

In this context, I would like to present floristical data recently collected in a part of a large mesotrophic lake (and its shore), containing several species of charophytes, the area which is not only included in the European Natura 2000 system, as well as in the Landscape Park – a national form of protection in Poland, but has also suffered a visible increase in anthropopressure over the last decade. The article contains results which supplement a parallel study on vegetation and cartographically summarized geobotanical values of the same area (Stachnowicz & Nagengast 2010). It is focused on a current diversity of flora along the shallow NW shore of Lake Powidzkie, an area recognised as particularly abundant in natural values (Brzeg *et al.* 1999). The investigated shore is one of the most inhabited and

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seasonally visited by tourists. The paper considers all vascular plants and charophyte species presently recorded within both aquatic, as well as terrestrial zones of ca. 4 km lakeshore. Current distribution of regionally and nationally threatened plants is presented, whereas on the other hand, the presence of locally most expansive alien taxa is examined both in space and within various plant communities of natural origin (naturalization, neophytism).

I hope that publication of this data may contribute to our understanding of the ongoing, early stages of synanthropization of the flora. The main aim of this article remains, however, both prospective and applicable (in a few-years period). I believe that floristic results collected in the potentially most threatened part of the lake ecosystem, may be a necessary starting point for a monitoring of natural resources of Lake Powidzkie in order to protect them for next generations. Such a monitoring seems to be an indispensable component of any potentially successful plan of management that is or will soon be elaborated for this (PLH300026) and many other Natura 2000 SACs.

2. Area of research

The field investigations were carried out on the NW shore of Lake Powidzkie (Fig. 1) which is situated within the Wielkopolska region, in the Gnieźnieńskie Lakeland, close to its border with the Wrzesińska Plain (Kondracki 2002). In the geobotanical division of Poland (Matuszkiewicz 1993) the area belongs to: the Powidz Subdistrict, the Gnieźnieńskie Lakeland District and the Middle-Wielkopolska Region within the Brandenburg-Wielkopolska Division.

Lake Powidzkie is a large, natural and generally well preserved, relatively clean and mesotrophic water body (Stachnowicz & Nagengast 2010). Considering its morphometric features (Jańczak 1996), it belongs to the largest reservoirs in Wielkopolska. It covers an area of ca. 1036 ha, although considerable fluctuations in water level have been observed (Jańczak 1996), which is probably also reflected in current vegetation structure of the border zone (which is relatively wide in some sections) between land and littoral (Stachnowicz & Nagengast 2010). The lake's maximal depth is quite impressive (45.4 m), as well as the shore line (almost 34 km) and total water volume (ca. 131.28 mln m^3). The water chemistry in Lake Powidzkie, measured in 1981 is characterised by: a basic reaction and distinctly high amounts of: oxygen, calcium and sulphates, even when compared to other large lakes with charophyte vegetation in Wielkopolska (Table 1; Jańczak 1996).

The investigated shore belongs the most inhabited, so particularly within the villages of Powidz and

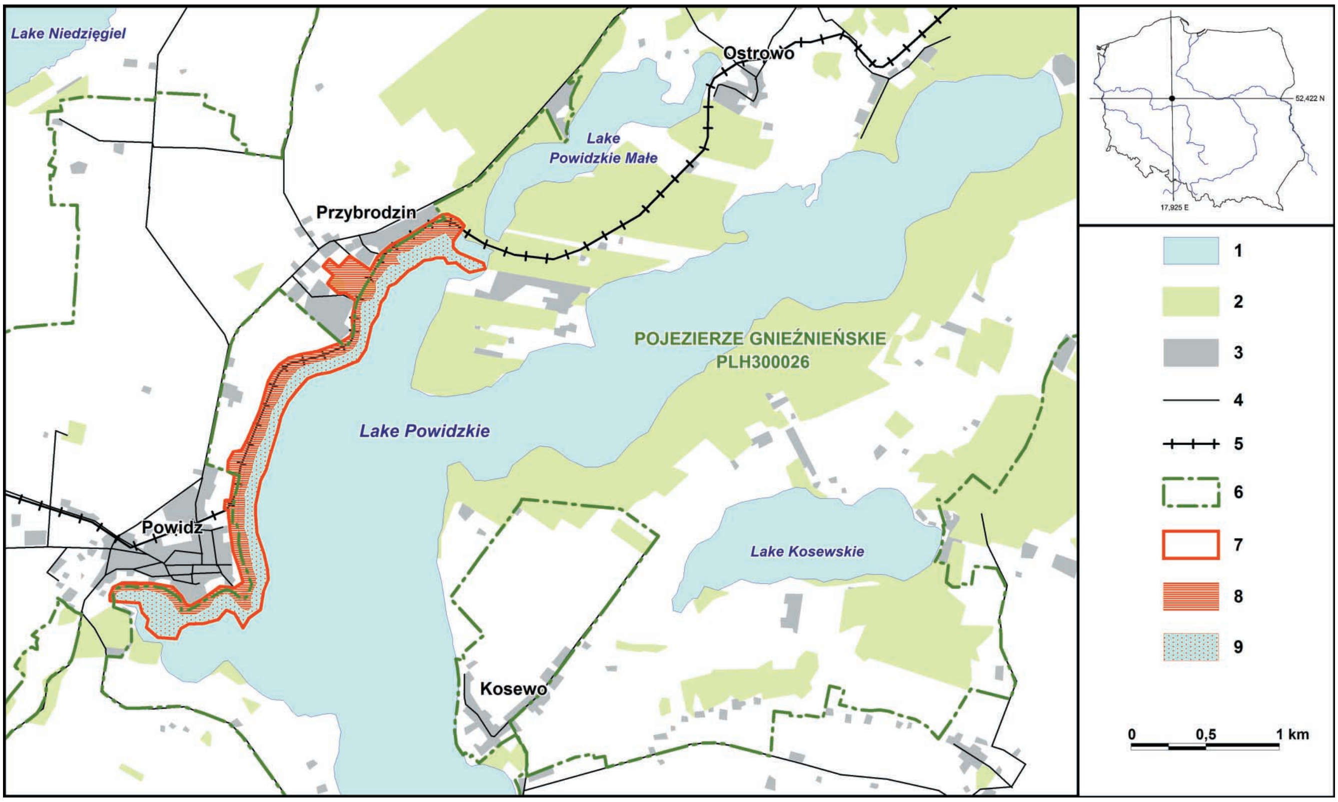

Fig. 1. Situation of the investigated area
Explanations: 1 – lakes, 2 – forests, 3 – built-up areas, 4 – main roads, 5 – narrow-gauge railway, 6 – borders of the Natura 2000 site, 7 – boundary of the investigated area, 8 – terrestrial part of the investigated area, 9 – investigated part of Lake Powidzkie

Table 1. Morphometric indices and physic-chemical water parameters of selected charophyte lakes in Western Poland (acc. to Jańczak 1996)

Lake	Powidzkie	Bytyń Wielki (Betyń)	Niesłysz
Latitude	52°24.4'	53°17.4'	52°13.9'
Longitude	17°57.4'	16°16.4'	15°23.8'
Elevation [m a.s.l.]	97.8	113.4	78.4
Surface area [ha]	1035.9	877.1	486.2
Water volume [m^3x1000]	131279.2	91534.9	34457.6
Maximal depth [m]	45.4	41.0	34.7
Mean depth [m]	12.7	10.4	7.8
Maximal length [m]	11050	10800	4700
Maximal width [m]	2060	2610	1700
Length of the shore line [m]	33910	38750	18925
Shore line development ratio	2.97	3.69	2.03
Date of morphometric measurements	Oct. 1993	Feb. 1954	Feb. 1960
Conductivity [μS]	190	160	240
pH	8.3	7.9	7.7
Oxidation [mgO_2/dm^3]	8.7	6.7	7.6
Calcium [mg Ca/dm^3]	48.1	31.6	34.3
Sulphates [$mgSO_4/dm^3$]	40.0	25.0	25.0
Chlorides [$mgCl/dm^3$]	11.9	23.0	4.0
Date of physic-chemical analysis	19-05-1981	1989	07-08-1984

Przybrodzin (Fig. 1) its relatively long sections are man-modified (beaches, marinas and fishing piers, ground roads and footpaths etc.). A recent development of mainly seasonal, though intensive recreational colonization resulted in permanent changes in lakeside landscape which is built-up by many private cottages and tourist infrastructure. Between the mentioned villages the lake vicinity has still retained an agricultural character which results in the relatively less intensive pressures. There is also a seasonally operating narrow-gauge tourist railway stretching from the northern edge of Powidz to Przybrodzin and further along the lakeshore.

The floristical investigations were concentrated in ca. 85 ha, most of which is situated within the Natura 2000 SAC "Pojezierze Gnieźnieńskie" ("The Gnieźnieńskie Lakeland" – PLH300026). The whole SAC is much more extensive. It comprises ca. 14462.8 ha, and as such it belongs to the largest Natura 2000 sites in Wielkopolska. According to the Standard Data Form (PLH300026) it houses, among others, as many as 19 types of habitats of European importance, four of which have been assessed as having both the highest representativeness (grade "A"), as well as the excellent ("A") protection state. I am listing them below with international Natura 2000 codes (acc. to Annex 1. of the 92/43/EEC directive) along with names of plant communities which represented these types locally, i.e. within or in the vicinity of the investigated area (Stachnowicz & Nagengast 2010): (*i*) code 3140 – i.e. underwater communities of charophytes (*Charetea fragilis*) – locally developed in a form of five plant associations: *Charetum contrariae*, *Charetum fragilis*, *Charetum tomentosae, Nitelletum opacae* and *Nitellopsidetum obtusae*; (*ii*) 3150 – natural eutrophic water reservoirs – although Lake Powidzkie should generally be treated as a mesotrophic reservoir, some of its parts are overgrown by phytocoenoses which are more typical to eutrophic waters. In the investigated area 8 such plant communities have been reported: *Ceratophylletum demersi, Elodeetum canadensis, Lemnetum trisulcae, Nymphaeo albae-Nupharetum lutei, Potametum lucentis, Potametum pectinati, Potametum perfoliati* and *Stratiotetum aloidis* (Stachnowicz & Nagengast 2010); (*iii*) 7140 – transitional bogs and fens and 7210 – the chalk-bog communities – both were not present within the investigated area, but reported from the Powidzki Landscape Park (Brzeg *et al*. 1999).

The vegetation was composed of 69 plant communities, 59 of which were stabilised enough to be classified within the rank of plant association (Stachnowicz & Nagengast 2010). 23 syntaxa were classified as more or less threatened in the Wielkopolska region (according to Brzeg & Wojterska 2001), whereas seven habitat types (represented by more plant communities) are under protection in the Natura 2000 system (Annex 1 to the 92/43/EEC directive). Aside from the mentioned habitat No. 3140, i.e. the charophyte communities (*Charetea fragilis*) which are locally extensive and very well-developed, and 3150, i.e. natural eutrophic lakes (locally small-area communities of *Nymphaeion*, *Potamion*, *Lemnion minoris* and *Hydrocharition morsus-ranae*), they comprise the following habitats: 6430 – i.e. riparian herbal communities, locally well-developed, though usually not large phytocoenoses of the *Calystegion sepium* alliance (*Carduo crispi-Rubetum caesii*, *Eupatorietum cannabini*, *Fallopio-Humuletum lupuli* and *Urtico-Convolvuletum sepium*); 6410 – the semi-moist purple moor-grass meadows, locally represented by small patches of the *Selino carvifoliae-Molinietum* association; 6510 – well developed in the area, extensively managed, mesophilous meadows (*Arrhenatheretum elatioris, Potentillo-Festucetum arundinaceae* and *Ranunculo repentis-Alopecuretum pratensis*); 9170 – the Central-European oak-hornbeam forest (*Galio silvatici-Carpinetum*), fragmentarily developed in the investigated area; 91E0 – i.e. riparian forests and thickets, including alder forests (*Fraxino-Alnetum*) and locally not frequent, small patches of initial alluvial willow-poplar forests (*Salicetum albae*, *Populetum albae*).

3. Material and methods

In this article I am presenting chosen results of geobotanical investigations carried out in July and August 2009 in all vegetation types within the mentioned ca. 85 ha of the lakeshore (Fig. 1). Most of floristical documentation was collected on the land or on its border with the littoral zone (i.e. within the reeds or using piers etc.). It comprised: 383 records made in 200 separate sites which constituted 2440 data on occurrence of vascular plants. A 'site' means here a single locality distinguishable using a 1:10 000 topographic map and the GPS-measured coordinates with ca. ± 10 m average accuracy. In practice, these sites were separated from each other by a distance of at least (and usually much more than) 20 m. Different plant communities were always considered separately at each site, depending on the local vegetation diversity. Consequently, many species which occurred in more than one of these communities, had adequate numbers of records (usually larger than total numbers of sites). It may be summarized that in this article I am using the term 'site' as a synonym of a 'locality' in a purely geographical context (i.e. represented by point-like signatures on a topogram map), whereas the term 'record' refers to a singular observation of a certain species in one phytocoenosis.

Terrestrial investigations were supplemented by the results of a parallel hydro-botanical inventory made from boat on lake up to ca. 150 m of the land (Stachnowicz & Nagengast 2010) which comprised 253 data on occurrence of vascular plants and macro-algae (Charophyceae) in 189 spot-like sites. Both terrestrial, as well as aquatic records were localised using the satellite navigation (GPS units) with an average accuracy of positioning in between ca. 4 m and ca. 15 m (usually below 10 m). While in case of land investigations this accuracy (read from the units) seems rather reliable, in case of hydrobiological research it may be less credible due to movements of boats and the way of sampling of underwater vegetation using the so-called Bernatowicz's anchor. Nevertheless, the results presented on floristical maps (Fig. 3, 5), elaborated on the basis of the mentioned GPS measurements, in case of water plants, may be treated as accurate enough sampling of usually more extensive populations.

All floristical data presented in this article were recorded within a singular 10 x 10 km basic square No. CD05 of the national ATPOL cartogram grid used for vascular plants distribution in Poland (Zając & Zając 2001). Floristical maps were elaborated according to the topogram method (Faliński 1990) which means that signatures presented in figures 3 and 5 should be treated as representing a geographical centre of each locality, regardless of the size and shape of each sign. This also means that in case of synthetic floristical maps some of the localities of different species were actually situated precisely in the same place which was indicated by overlapping, different in colour and size signatures.

To assess local species frequency in the investigated part of the Lake Powidzkie shore I used percentages of the numbers of their records – in relation to the locally most common taxon which was *Phragmites australis* (141 records, i.e. ca. 37% of all). The scale of frequency is presented in the explanations to species list (Appendix).

Scientific names of vascular plants are used according to Mirek *et al.* (2002). Nomenclature of charophytes is cited after Krause (1997), their threat in Poland – according to Siemińska *et al.* (2006), phytocoenological classification – according to Pełechaty & Gąbka (2006). Names of syntaxa, their origin (natural, semi-natural or anthropogenic), as well as regional threat of plant communities in Wielkopolska are used after Brzeg & Wojterska (2001).

Legal protection status of plants in Poland was based on the Ministry of Environment Directive of 9th July 2004 (Regulation... 2004).

As far as species threat is considered, it should be mentioned that categories used in national and regional 'red lists' are not entirely congruent. In Wielkopolska, the modern IUCN (2001) classification was used for vascular plants (Jackowiak *et al.* 2007). None of the investigated vascular plant taxa were regarded as threatened in Poland (cf. Zarzycki & Szeląg 2006). Siemińska *et al.* (2006) classified Polish macro-algae according to older categories of threat. They are listed below together with their most adequate equivalents in the mentioned new IUCN (2001) system: Ex – (probably) extinct species; E – endangered (compatible with the modern CR and EN categories); R – rare taxa (which are more or less adequate to modern LC – least concern); I – indeterminate threat (compatible with DD – data deficient). Whenever I cite regional (for vascular plants) or national threat (for charophytes) I always refer to the original categories used in the mentioned sources.

I considered the origin and naturalization status of vascular plant species using the well established in Central-European literature concept of geographical-historical groups (Thellung 1915; Kornaś 1968; Kornaś & Medwecka-Kornaś 2002; Mirek 1981; Zając 1979; Zając *et al.* 1998, 2009). This classification was made in relation to the area of investigation (apophytism and naturalization of anthropophytes) and the region of Wielkopolska (archaeophytes). Geographical origin of recently established alien species of vascular plants (kenophytes) is cited according to Tokarska-Guzik (2005).

4. Results

4.1. Species richness in terrestrial and aquatic habitats

Altogether the recorded flora of the whole investigated area comprises 296 species of vascular plants (Appendix) and 7 species of charophytes (Charophyceae). Considering that the explored terrestrial and aquatic zone were well comparable (almost equal) in size, it may be generally concluded that the predominant part of the species richness was concentrated on land. Only 22 taxa were exclusively hydrophytes, including 15 species of vascular plants and the mentioned 7 species of macro-algae. Even if taking into account another 12 helophytes, the total species richness of the lake alone consisted of 36 species, which is merely 11.9% of the entire analysed flora.

While in total numbers of the mentioned 22 aquatic species Magnoliophytina (15 species) outnumbered Charophyceae (7), in fact the structural role of the first group in water vegetation was relatively much less important. Only 6 aquatic plant communities were formed by vascular plants: *Ceratophylletum demersi, Elodeetum canadensis, Lemnetum trisulcae, Nymphaeo albae-Nupharetum luteae, Potametum pectinati* and *Potametum perfoliati* (Stachnowicz & Nagengast 2010). None of them formed extensive patches.

The role of charophytes in local aquatic flora would be certainly underestimated if considering only their share (31.8%) in the mentioned total number of 22 water plant species. Within the investigated part of Lake Powidzkie seven taxa of this evolutionary old macro-algae were recorded: *Chara aspera*, *Chara contraria*, *Chara filiformis*, *Chara globularis*, *Chara tomentosa*, *Nitellopsis obtusa* and *Nitellla opaca*. Six of these species formed their own, different plant communities which constituted most of the investigated littoral zone's vegetation: *Nitellopsidetum obtusae* (a locally dominant community), *Charetum tomentosae*, *Ch. contrariae*, *Ch. fragilis*, *Ch. asperae* and *Nitelletum opacae*. Altogether ca. 26.7 ha of underwater 'meadows' defining the habitat of European importance (type 3140), represented by the above-mentioned syntaxa of *Charetea fragilis*, was diagnosed in the investigated area. In fact, they covered almost entire littoral zone of the NW shore of Lake Powidzkie, excluding only places which were frequently penetrated by humans, where the aquatic vegetation had been almost completely destroyed (Stachnowicz & Nagengast 2010).

In Lake Powidzkie three other species of charophytes have also been recorded, i.e. *Chara polyacantha*, *Ch. delicatula* and *Ch. rudis* (Gąbka & Burchardt 2006). *Chara intermedia* is another species reported once from this water body (Chojnacka 2003), though this information needs confirmation.

4.2. Taxonomical and biological structure of vascular plant flora

The investigated flora contains 165 genera. *Salix* was the richest-in-species genus (represented by 9 species), the second position was occupied by *Carex* (8 species), the third ones (5 species each) were: *Cirsium*, *Rumex* and *Trifolium*. Four species were recorded for each of the following genera: *Bromus*, *Galium*, *Poa* and *Festuca*, whereas 13 others were represented by three species, and all the rest – by two or one species. The mentioned nine richest-in-species genera altogether comprised 48 species which is ca. 16.2% of the whole analysed flora. The main position of *Salix* and *Carex* seems to be understandable in the light of a relatively wide transitional zone between land and typical water vegetation. This zone was occupied by reed and sedge communities which were, in many places, overgrown by willow thickets and initial riparian forests (Stachnowicz & Nagengast 2010).

The vascular flora comprises 61 families, the richest in species of which were the following ones: Asteraceae (36 species), Poaceae (31), Rosaceae (17), Fabaceae (16), Apiaceae (14), Salicaceae, Cyperaceae and Lamiaceae (12 species each of them), Polygonaceae (9), Caryophyllaceae (8). The mentioned 10 locally richest families (represented by 8 or more species) concentrate 167 species which is ca. 56.4% of the investigated flora.

The biological (life forms) spectrum of vascular flora (Fig. 2) is generally similar to the pattern known from the Wielkopolska region (Jackowiak 2001), as well as from the whole Poland and even the temporal vegetation zone (Kornaś & Medwecka-Kornaś 2002). A relatively high share of phanerophytes (represented by 48 species which is 16.2 % of the investigated flora) is noticeable locally. Herbaceous (non-lignified) plants altogether comprised 246 taxa which is 83.1% of the flora.

4.3. Distribution of threatened and legally protected species

Each of the mentioned seven species of charophytes found in the investigated area is considered (by Siemińska *et al.* 2006) to be more or less threatened in Poland (Fig. 3): (*i*) two nationally endangered species (category E): *Chara aspera* and *Chara filiformis*; (*ii*) two vulnerable species (V): *Chara contraria* and *Chara globularis*; (*iii*) two rare (R) species in Poland: *Chara*

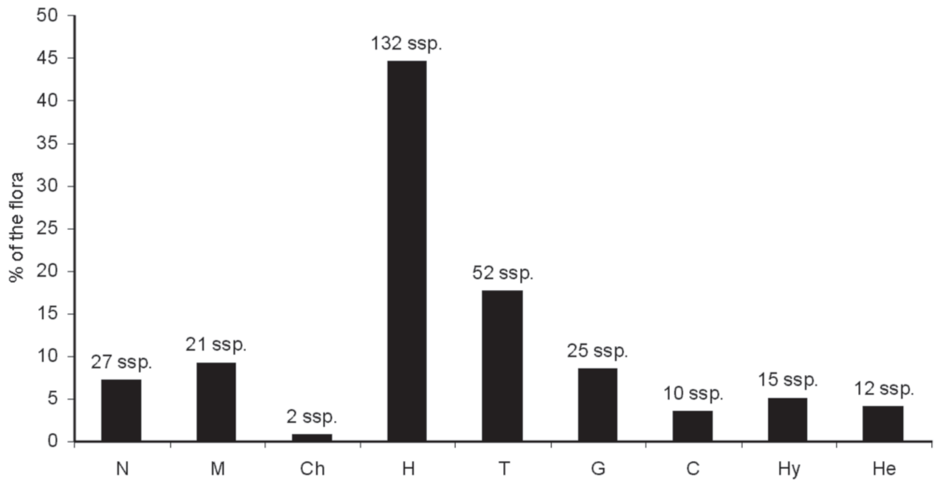

Fig. 2. Biological spectrum of the investigated flora of vascular plants
Explanations: M – megaphanerophytes (trees), N – nanophanerophytes (shrubs), Ch – lignified chamaephytes, C – herbaceous chamaephytes, H – hemicryptophytes, G – geophytes, He – helophytes, Hy – hydrophytes, T – therophytes (annuals)

tomentosa and *Nitellopsis obtusa*; (*iv*) one species of indeterminate threat (I) – *Nitella opaca*.

Three species recorded in the investigated area (Appendix) are listed in the regional 'red list' of threatened vascular plants in Wielkopolska (Jackowiak *et al*. 2007; Fig. 3): *Parnassia palustris* (category VU), *Populus nigra* (LC) and *Potamogeton friesii* (VU).

So far, within the investigated area no plants demanding special protection within Natura 2000 sites (Annex 2 to the 92/43/EEC directive) have been found, although such species have been reported from the neighbourhood (e.g. *Aldrovanda vesiculosa*, *Liparis loeselii* according to Chmiel 2006a). As far as the legal protection in Poland is concerned (Regulation… 2004), eleven taxa were recorded in numerous localities in the investigated area: (*i*) partially protected in Poland: *Convallaria majalis*, *Frangula alnus*, *Hedera helix*, *Helichrysum arenarium*, *Nuphar lutea* and *Ononis arvensis*; (*ii*) five species being under strict legal protection, i.e. three taxa of vascular plants: *Centaurium erythraea* ssp. *erythraea*, *Epipactis helleborine*, *Utricularia vulgaris* and two species of charophytes – *Chara filiformis* and *Nitella opaca*. Local distribution of these species concentrates in the investigated water (littoral) and reed zone of Lake Powidzkie (on the whole investigated length) and along the narrow-gauge railway between Powidz and Przybrodzin (Fig. 3).

While sites of protected taxa are scattered along the lakeshore, both in its terrestrial part, as well as in the littoral zone, most of threatened species are distributed in the shallow waters of Lake Powidzkie. The maps confirm that substantial resources of valuable native species (all of nationally threatened components) are constituted by macro-algae of Charophyceae. Taxa considered to be under threat in regional scale are locally rare both in terrestrial habitats (*Parnassia palustris*, *Populus nigra*) as in the lake (*Potamogeton friesii*). On the other hand, legally protected species are more numerous and frequent on land (*Centaurium erythraea* ssp. *erythraea*, *Convallaria majalis*, *Epipactis helleborine*, *Frangula alnus*, *Hedera helix*, *Helichrysum arenarium*, *Ononis arvensis*) than in water (*Nuphar lutea*, *Utricularia vulgaris* and two species of charophytes – *Chara filiformis* and *Nitella opaca*).

4.4. Synanthropization of the flora: alien species, their distribution and potential expansion

The geographical-historical classification indicates that 79.4% of all 296 species is represented by 235 native taxa, whereas 140 of them (i.e. 59.6 % of natives) are non-synanthropic species (Fig. 4). However, there is a considerable number of 61 alien species (20.6% of the flora), 56 of which (18.9% of the flora) are metaphytes, i.e. permanent alien components of the area. Kenophytes seem to be a particularly important group among aliens (44.3% of alien flora). Locally more frequent (and/or abundant) kenophytes are obviously more dangerous to native biodiversity but there may be some others which are also potentially expansive (Fig. 5). To find it out I decided to check out the distribution of alien taxa in the investigated area and their occurrence across different vegetation types of natural origin (Table 2). The last analysis shows that 21 of 29 kenophytes in the investigated area have appeared at least once in natural plant communities. Below, I am going to pay a little more attention to these plants.

Acer negundo – is a kenophyte of North American origin, associated with river valleys (Tokarska-Guzik 2005). Currently, in the investigated area the species occurs only in the vicinity of a park in Powidz (Fig. 5) but considering its affiliation to riparian habitats, it is probable that it will soon expand its local range.

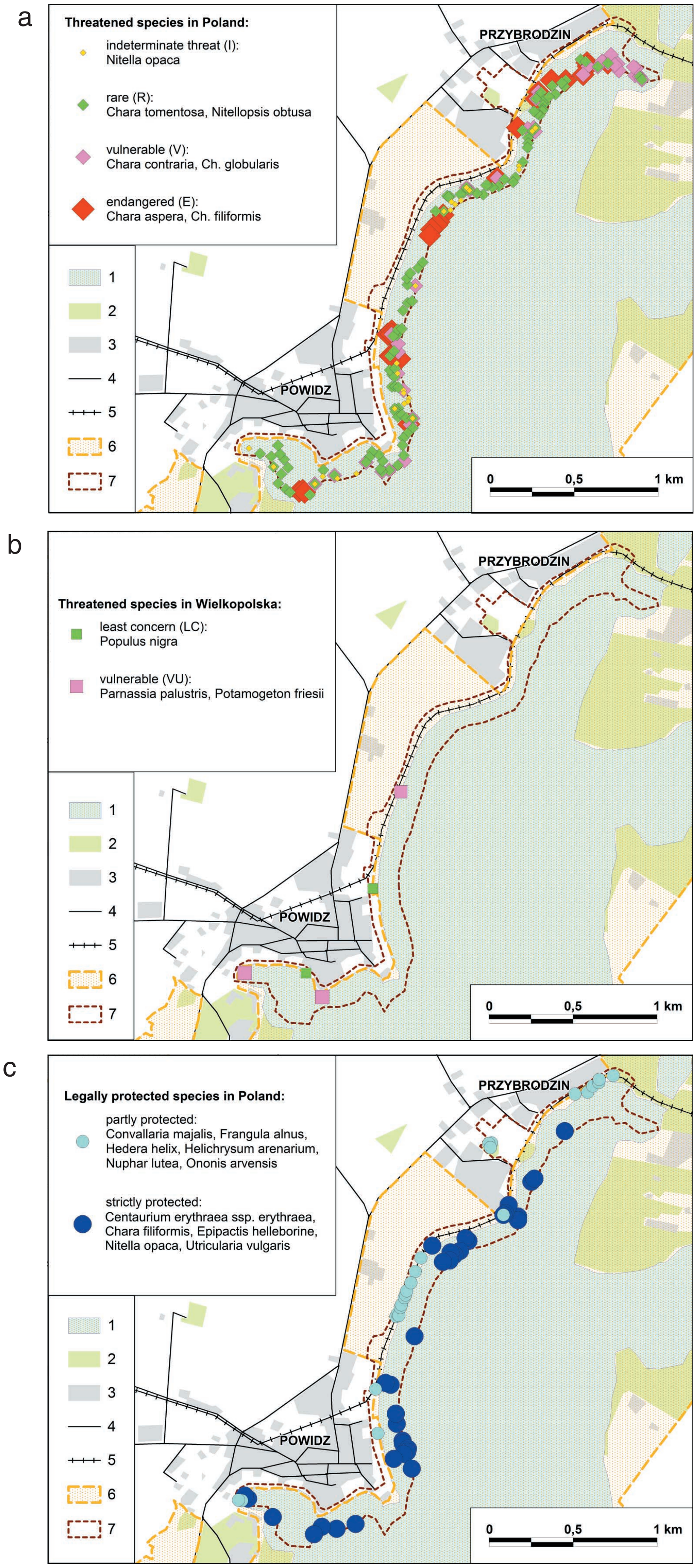

Fig. 3. Distribution of chosen special care species in the NW shore of Lake Powidzkie: a – threatened species in Poland, b – threatened species in Wielkopolska, c – legally protected species in Poland

Explanations: 1-7 see Fig. 1

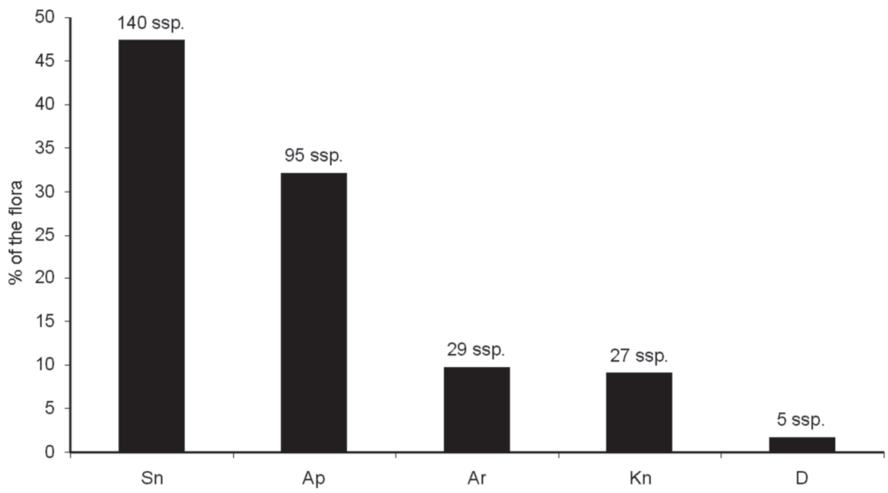

Fig. 4. Share of native and alien species in the investigated flora – geographical-historical spectrum
Explanations: Sn – non-synanthropic spontaneophytes, Ap – apophytes, Ar – archaeophytes (ancient alien species), Kn – kenophytes (alien species established since the end of the XVth century), D – diaphytes (non-established aliens)

Aster lanceolatum – another N. American species of riparian character (Tokarska-Guzik 2005). It was recorded only once on the shore of a small bay of Lake Powidzkie in Powidz (Fig. 5). However, what seems more important is that the species formed there its own plant community classified as *Calystegio-Asteretum lanceolati* (Stachnowicz & Nagengast 2010). This vegetation type originated from a natural tall-herb community (most probably *Urtico-Convolvuletum sepium*) which had been overgrown by *Aster lanceolatum*. It may be treated as a first evidence of the species local expansiveness. Such a type of plant communities, the species combination of which originated from the expansion of alien taxa within initially natural vegetation, is classified as xenospontaneous communities, whereas kenophytes which form their own self-dominated vegetation types are also called post-neophytes (according to Faliński 1969a). Thus, *Aster lanceolatus* may be treated as a locally potentially expansive species.

Bidens frondosa – is also a riparian species native to N. America (Tokarska-Guzik 2005). In the investigated area it was recorded exclusively in reed communities, most frequently in *Phragmitetum communis* (Table 2) where it was never particularly abundant. Due to its annual character (therophyte) it seems to be hardly possible to control its populations. Moreover, in consequence of a relatively high productivity of its small, epizoochoric, winter-hardy fruits, it is improbable that the species will ever disappear from the area. A similar status may be attributed to another N. American annual *Conyza canadensis* which is also a common species in transformed habitats (arable fields and urban areas).

Echinocystis lobata – this N. American kenophyte (Tokarska-Guzik 2005) seems to be particularly important as it appeared locally at least in four different localities along the lake shore: three sites in Powidz and one, large station in Przybrodzin (Fig. 5). The species is annual, though it is also an effective creeper and it grows so rapidly that within one season it may reach up to 7 metres of length (Tokarska-Guzik 2005). It prefers riparian habitats and in the investigated area it was reported most frequently in natural communities (Table 2) of tall herbs (*Convolvulion sepium*). This species may have been introduced locally in gardens because of its ornamental character. Potentially, it is a highly expansive alien.

Elodea canadensis – is the only water plant of alien origin (from N. America – Tokarska-Guzik 2005) so far reported form the investigated area. It was found rarely in shallow water along the lake shore in Powidz (Fig. 5), though it seems probable that the species may be more dispersed in the area. Nonetheless, it is currently not a locally expansive taxon.

Impatiens glandulifera – originating from Central Asia (Himalayan) and in Poland it prefers riparian, as well as man-made habitats (Tokarska-Guzik 2005). Locally, it is still a very rare taxon; found only in a singular site, within the tall-herb community *Urtico-Convolvuletum*. It is also a potentially expansive alien.

Impatiens parviflora – another Asian species (Tokarska-Guzik 2005) which prefers deciduous forests but also grows abundantly in herbal forest edge communities and in tall herb vegetation (*Convolvuletalia*). This annual plant is currently a common component of regional flora, though it was classified by Chmiel (2006b) as less frequent, though well established in NE part of Wielkopolska. It occurs in several sites along the shore of Lake Powidzkie (Fig. 5), especially in the vicinity of parks, forests and small aggregations of trees. Locally, this is a post-neophyte (cf. Faliński 1969a) forming its own community *Impatientetum parviflorae*.

Table 2. Naturalization of kenophytes, defined as their ability to grow (number of localities) and reproduce in natural plant communities (neophytism acc. to Faliński 1969a)

Syngenesis	Plant community	*Acer negundo*	*Aesculus hippocastanum*	*Aster lanceolatus*	*Bidens frondosa*	*Conyza canadensis*	*Cornus alba*	*Echinocystis lobata*	*Elodea canadensis*	*Galinsoga parviflora*	*Helianthus tuberosus*	*Impatiens glandulifera*	*Impatiens parviflora*	*Lycium barbarum*	*Malus domestica*	*Medicago x varia*	*Padus serotina*	*Parthenocissus inserta*	*Rhus typhina*	*Ribes uva-crispa*	*Robinia pseudacacia*	*Rudbeckia laciniata*
N	*Fraxino-Alnetum* W.Mat. 1952	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
N	community of *Fraxinus excelsior* a1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.
N	comm. of *Populus alba* a1	.	.	.	.	1	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.
N	comm. of *Populus alba* b/a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
N	comm. of *Salix alba* a1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
N	comm. of *Salix alba* a2/b	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
N	comm. of *Salix fragilis* a1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
N	comm. of *Tilia cordata* a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
N	comm. of *Frangula alnus* b	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
N	initial aquatic community (*Potamion*)	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
NA	*Aegopodio-Sambucetum nigrae* Doing 1962 em. M. Wojterska 1990	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.
NA	*Agropyro repentis-Aegopodietum podagrariae* R.Tx 1967 em. Neuhäuslová-Novotná et al. 1969	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2	.
NA	*Alliario-Chaerophylletum temuli* Lohmeyer 1949	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NA	*Carduo crispi-Rubetum caesii* Brzeg in Brzeg et M. Wojterska 2001	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	1	.	.	.	.	.
NA	*Eupatorietum cannabini* R.Tx. 1937	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	1	.	.	.	.	1
NA	*Fallopio-Humuletum lupuli* Brzeg 1989 ex Brzeg et M. Wojterska 2001	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	2	.	.	.	.
NA	*Phragmitetum communis* (W.Koch 1926) Schmale 1939	.	.	.	4	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NA	*Rubetum idaei* Malinowski et Dziubałtowski 1914 em. Oberd. 1973	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NA	*Salicetum cinereae* Kobendza 1930	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NA	*Salicetum triandro-viminalis* Lohmeyer 1952	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.
NA	*Urtico-Convolvuletum sepium* Görs et Th.Müller 1969	.	.	.	.	1	.	1	.	.	.	1	1	.	.	.	1	.	.	.	.	.
NA	comm. of *Rubus* sp.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.
NA	comm. of *Urtica dioica*	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.
NP	*Galio silvatici-Carpinetum* (R.Tx. 1937) Oberd. 1957	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.
NP	*Thelypterido-Phragmitetum* Kuiper 1958	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
X	*Calystegio-Asteretum lanceolati* Holzner, Hilbig et Forstner ex Pass. 1993	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
X	*Elodeetum canadensis* Eggler 1933	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
X	*Impatientetum parviflorae* Brzeg 1989 ex Borysiak 1994	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	.	.	.	.
X	comm. of *Rhus typhina* b/a2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
	Reproduction in natural or xenospontaneous communities:	g	?	g/v	g	g	?	g	v	g	?	g!	g!	?	g	g	g	?	?	?	g/v	g/v
	Neophytism:	e	pr	pn	e	e	pr	e	pn	e	pr	e	e/pn	pr	e	e	e	pr	pn?	pr	e	e

Explanations: syngenesis (Faliński 1969b, 1972) of plant communities in Wielkopolska (acc. to Brzeg & Wojterska 2001, supplemented), N – natural community, NA – natural auksochoric (increasing its range as a result of human activity) community, X – xenospontaneous community (a result of expansion of alien species within formerly natural communities); reproduction, g – generative, ! – very effective, v – vegetative growth; neophytism (acc. to Faliński 1969a), pr – pro-neophyte, e – eu-neophyte, pn – post-neophyte

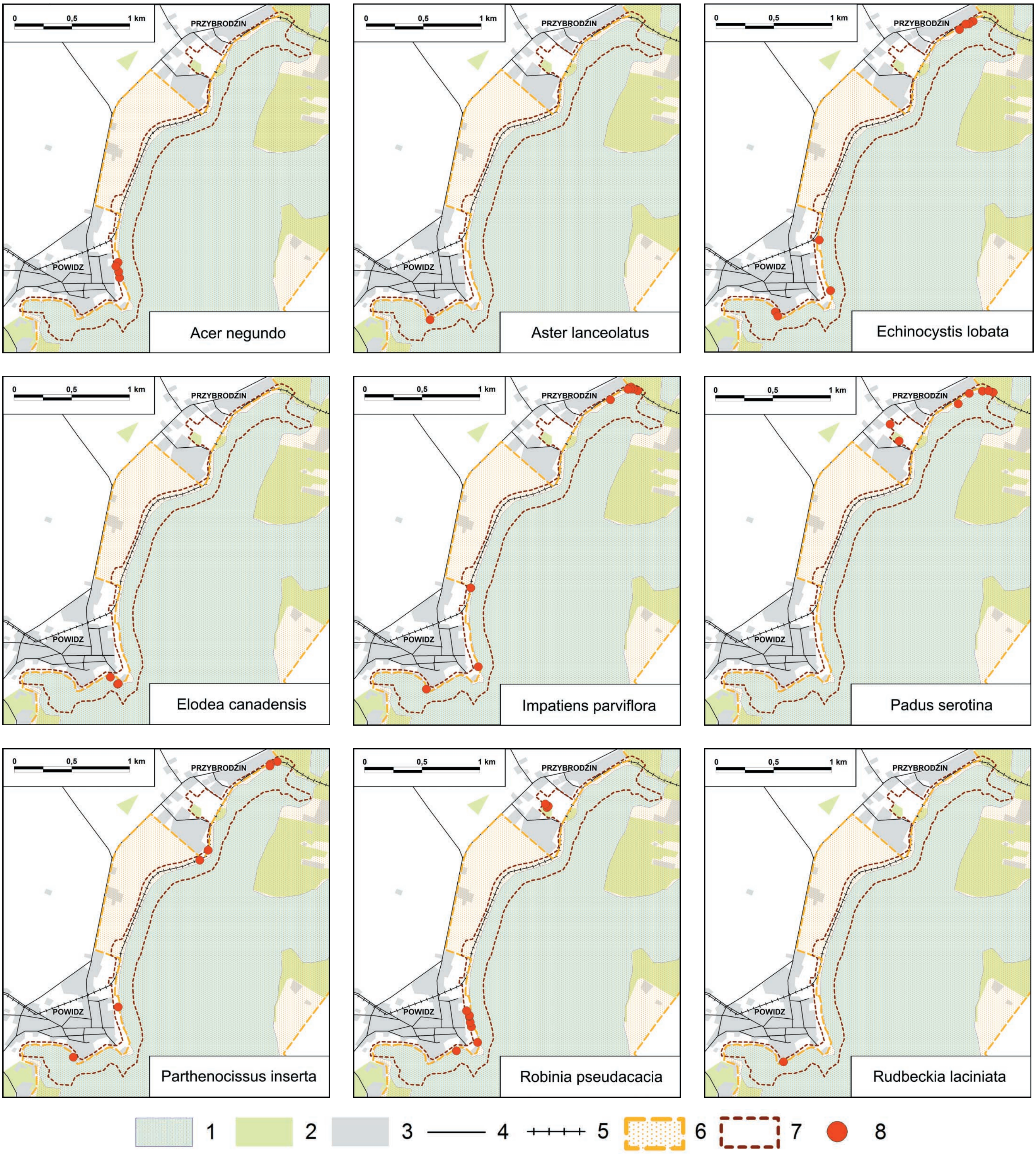

Fig. 5. Distribution of chosen alien species (kenophytes) in the investigated area
Explanations: 1-7 see Fig. 1, 8 – localities of alien species

Padus serotina – an invasive American (acc. to Tokarska-Guzik 2005) forest shrub species which in the investigated area is present in the vicinity of Przybrodzin (Fig. 5), also in riparian herbal communities (*Convolvulion sepium*) where it has probably been introduced by birds (ornithochoric fruits). Potentially, it is dangerous to the diversity of native species in natural forests.

Parthenocissus inserta – a N. American kenophyte (Tokarska-Guzik 2005) which is regionally still rather a rare species (unpublished observations from different parts of Wielkopolska), however, in the vicinity of Powidz and Przybrodzin it is already surprisingly spread along the lake shore (Fig. 5). The taxon is locally present in riparian forests and herbal communities. It may have escaped from gardens (where it is often cultivated as an ornamental liana), though in some places, especially in natural riparian herb communities of *Fallopio-Humuletum lupuli* (Table 2), it becomes expansive.

Rhus typhina – regarded as an established anthropophyte in Poland (Mirek *et al.* 2002), it was locally observed at least in 2 separate patches growing on the edge of a natural riparian forest and reed-herbal communities. It is a problematic species as far as its naturalization is considered (see Discussion).

Robinia pseudacacia – in Central Europe it is a well-known invader originating from N. America (Tokarska-Guzik 2005). Its local centres of expansion are situated in Powidz and Przybrodzin (Fig. 5) where it grows in forests and in neighbouring herbal communities. It is not only a remnant of a former environmentally inadequate forest management but also a potentially invasive species with an ability to transform soils through assimilation of atmospheric nitrogen, using its root nodules containing symbiotic bacteria (*Rhizobium*). The species is capable to regenerate effectively from coppicing and this is another reason for it to be treated as potentially dangerous.

The last alien species worth mentioning here is *Rudbeckia laciniata* – another N. American riparian species (Tokarska-Guzik 2005). It was found only in one site on the lakeshore in Powidz (Fig. 5) where it grew in riparian tall herb community of *Eupatorietum cannabini*, on the edge of the reed zone. It is very likely that the species had been introduced to local gardens and eventually has escaped to neighbouring natural vegetation. Currently it is a rare species but it grows luxuriantly and may soon become locally expansive.

5. Discussion

As far as the so-called 'charophyte lakes' are concerned, in the region of Wielkopolska Lake Powidzkie is one of the largest reservoirs of this type, and data presented in this article obviously refer only to a part of this extensive ecosystem. On the other hand, there seems to be no available, complete floristical data of such type of lake in the region. This is perhaps because of the mentioned large sizes and complication of morphometric, physic and even chemical parameters of such reservoirs (Table 1). Concise information on flora referring to three examples of large charophyte lakes is shown in Table 3. Two of the compared reservoirs are situated in Wielkopolska, i.e Lake Niesłysz (investigated by Pełechaty *et al.* 2007) and Lake Powidzkie (Stachnowicz & Nagengast 2010 and data presented here), and one in the neighbouring, S part of the Western Pomeranian Lakeland (Lake Bytyń Wielki investigated by Stachnowicz & Nagengast 2009). Generally, all these lakes are relatively deep (from ca. 35 up to ca. 45 m of maximal depth), although extensive parts of their littoral zones are shallow (with the *Charetea* communities), and their shore lines are also well-developed (Table 1). Physical and chemical parameters of water are diversified, and in this comparison, water in Lake Powidzkie seems to be distinctly basic (pH 8.3), well-oxidated (98.7 mg $0_2/dm^3$), and particularly rich in calcium and sulphates, with an intermediate amount of chlorides. Perhaps these features decided on a relatively high number of Charophyceae species (10) reported from the lake (Table 3). Furthermore, only one species, recorded in Lake Bytyń Wielki (*Chara aculeolata*), was not found in Lake Powidzkie.

Underwater vegetation of *Charetea fragilis* is considered to be of European interest (Annex 1 to the 92/43/EEC directive). Most of these plant communities are also regionally threatened (Brzeg & Wojterska 2001), as well as the species of Charophyceae in Poland (Siemińska *et al.* 2006; Fig. 3). Probably even more important reason for conservation of these stenobiotic macro-algae is their ecological significance for maintaining the low trophy status of water within the whole lake ecosystem. Charophyceae are important competitors for planktonic algae (including Cyanophyta) as they absorb excess of nutrients, and in consequence, prevent phytoplankton blooms (Scheffer 2001). This role may be particularly significant in early spring when other vegetation types are still not distinctly developed and some of charophytes, as e.g. *Chara tomentosa* (Dąmbska 1964) are winter-hardy. In favourable conditions this may also refer to *Nitellopsis obtusa* and *Chara contraria* (Pełechaty & Pukacz 2008).

Charophytes and their communities are generally rare and threatened in the whole country (Siemińska *et al.* 2006; Piotrowicz 2004). Most of them do not tolerate amounts of phosphates exceeding 0.002 mg/l and are particularly susceptible to a decrease in water clarity – mainly in consequence of its eutrophication. The other factors limiting distribution of charophytes comprise fluctuations in water level and mechanical destroying of plants by people (Piotrowicz 2004). The first of the mentioned phenomena was observed in Lake Powidzkie quite a long time ago (Jańczak 1996), whereas the second problem was documented recently (Stachnowicz & Nagengast 2010). According to Piotrowicz (2004) a proper protection of lakes containing charophytes should comprise their direct catchment areas, where for instance, forest clearings should be limited. On the other hand, as the same author suggested, in a direct vicinity of such lakes, planting of some broadleaved trees (especially *Populus* spp.) should be avoided – to prevent toxic phenol substances to get into water with decomposing leaves. Inside charophyte lakes, any introduction of herbivorous fish should be prohibited, whereas fishing requires a limitation of using certain tools. Perhaps the most important conservation postulate sug-

Table 3. Outline comparison of aquatic flora of selected charophyte lakes in Western Poland

Lake	Powidzkie[1, 4]	Bytyń Wielki[2, 5] (Betyń)	Niesłysz[3]
Flora of Charophyceae			
Chara aspera Detharding ex Willdenow 1809	+	-	+
Chara contraria A. Braun ex Kützing 1845	+	+	+
Chara delicatula Agardh 1824	+	-	+
Chara globularis Thuillier 1799 (= *Ch. fragilis* Desvaux in Loiseleur-Deslongchamps 1810)	+	+	+
Chara filiformis Hertzsch 1855 (= *Ch. jubata* A. Braun)	+	+	+
Chara intermedia A. Braun 1836 (= *Ch. aculeolata* Kützing in Reinchenbach 1832*)*	-	+	-
Chara polyacantha A. Braun in Braun, Rabenhorst et Stizenberger 1859	+	-	+
Chara rudis A. Braun in Leonhardi 1882	+	-	-
Chara tomentosa Linnè 1753	+	+	+
Nitella opaca (Bruzelius) Agardh 1824	+	-	-
Nitellopsis obtusa (Desvaux in Loiseleur-Deslongchamps) J. Groves 1919	+	-	+
Total number of charophytes	10	5	8
Aquatic vascular plants (hydrophytes)			
Number of (typical) hydrophytes	15	24	n.a.
Number of alien hydrophytes	1	1	n.a.

Explanations: source of information on charophytes, 1 – Gąbka & Burchardt (2006), Stachnowicz & Nagengast (2010), 2 – Stachnowicz & Nagengast (2009), 3 – Pełechaty *et al.* (2007); source of information on aquatic vascular plants (hydrophytes), 4 – Appendix (*hoc loco*), 5 – Stachnowicz (2004 unpubl.); n.a. – date not available

gested by Piotrowicz (2004), particularly in relation to Lake Powidzkie, should be the environmentally-focused water management and sewage-system. This task remains still not fully implemented in Powidz and other communities along the lake.

Vascular flora of a whole 'charophyte lake' with its shore was a subject of research in the vicinity of Wielkopolska only in case of Lake Bytyń Wielki (Stachnowicz & Nagengast 2009). In total it comprised 455 species, including 38 species of alien plants. Obviously it is not possible to fully compare these numbers with the results presented here, referring only to a part of Lake Powidzkie and its shore. However, a relatively high share of 96 anthropophytes recorded in the NW shore of Lake Powidzkie, suggests that its flora is already more anthropogenically transformed even though the whole lake was not investigated.

As it was shown above in this article, several alien species are present along the shore, many of which seem to be potentially invasive, e.g. *Acer negundo*, *Aster lanceolatum*, *Echinocystis lobata*, *Padus serotina*, *Parthenocissus inserta*, *Robinia pseudacacia* and *Rudbeckia laciniata*. Most of these species are also known as invasive kenophytes from other areas of Poland (Tokarska-Guzik 2005). 21 of 27 kenophytes have already demonstrated their local neophytism (Table 2) and at least three of them have the status of post-neophytes (acc. to Faliński 1969a) as they have already formed their own, xenospontaneous plant communities. On the other hand, several natural vegetation types are locally endangered by neophytization (Table 2) and perhaps the most threatened of them are natural riparian herbal communities of *Convolvulion sepium* which represent a habitat type of European importance (the Natura 2000 code: 6430). Altogether, 21 kenophytes were components of one or more natural or xenospontaneous (i.e. originating from natural – Faliński 1969a, 1969b, 1972) plant communities (Table 2). Another, locally important observation is that three of the four xenospontaneous vegetation types were developed in a close vicinity or within Lake Powidzkie: in man-modified parts of the littoral (*Elodeetum canadensis*) or in the semi-moist, ecotone zone of the lake shore (*Calystegio-Asteretum lanceolati*, and a community dominated by *Rhus typhina*). In the large NE part of the Gnieźnieńskie Lakeland *Rhus typhina* was recorded only 12 times and classified as a rare diaphyte (Chmiel 2006b). However, it seems that once established the species may easily become a permanent component of local flora due to its durability and vegetative growth. Admittedly, the species might have been planted along a lakeside footpath in Powidz, but at the same time there was no doubt that its population was well established and consisted of different size individuals (thus probably also differentiated according to their age). Therefore, I decided to classify this alien species as a local kenophyte which is in accordance with its 'established anthropophyte' status in the flora of Poland (Mirek *et al.* 2002).

Local distribution maps of kenophytes (Fig. 5) also seem to suggest that human settlements are most likely the main source of alien species. Many of them, now growing in wild, must have recently escaped from neighbouring gardens (*Aster lanceolatus*, *Echinocystis lobata*, *Parthenocissus inserta* and *Rudbeckia laciniata* in particular) or from parks (*Acer negundo*, *Robinia pseudacacia*) where they have been cultivated as ornamental plants.

Both floristical observations together with current condition of vegetation (Stachnowicz & Nagengast 2010), indicate that anthropization and neophytism are the on-going, though locally still not advanced processes. Considering also that the results refer to probably the most man-modified part of the Lake Powidzkie shore, it seems reasonable to start controlling and limiting further expansion of existing populations of chosen alien species. These are crucially important tasks for managing many of the Natura 2000 habitats.

6. Main conclusions

The analysed flora consists of many valuable native components which are concentrated in Lake Powidzkie and along its shore. On the other hand, most of local species richness is composed of generally terrestrial plants as the investigated vascular flora contains only 15 hydrophytes and 12 helophytes. However, the relatively small number of macro-algae species seems to play an important role in maintaining environmental balance between inflow and assimilation of nutrients in water, particularly in early spring when vascular hydrophytes are not effective. Considering the well developed, mostly wide zone of reed-sedge communities, sometimes overgrown by dense willows (mainly *Salix cinerea*), it also seems that aquatic communities of charophytes are partly isolated at least from some forms of anthropopressure by the mentioned amphibious formations.

However, the lake shore in Powidz and Przybrodzin has recently been built up by many recreational cottages, and the number of tourists, at least seasonally, seems to be particularly high. A devastation of reed and aquatic communities in the vicinity of beaches (also those unofficial), marinas, piers etc. is already visible. I am convinced that, probably sooner than later, anthropophytisation of the flora and particularly, neophtization of vegetation will become the most important problems in nature conservation of Lake Powidzkie and its vicinity. In this context, it seems indispensable to continue monitoring of both valuable components of native flora, as well as already and potentially expansive aliens. This task should be obligatory demanded when the management plan for the Natura 2000 site is elaborated. Additionally, it may not be omitted in any assessment of environmental impact of investments if they are considered in the vicinity of Lake Powidzkie – in accordance with the article 6th of the 92/43/EEC Directive (European Commission 2000).

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Appendix. Census of vascular plant species recorded in 2009 in the investigated area

Acer negundo L. – Kn, M, -, -, 4, 2.84, vr; *Acer platanoides* L. – Ap, M, -, -, 14, 9.93, r; *Acer pseudoplatanus* L. – Sn, M, -, -, 9, 6.38, r; *Achillea millefolium* L. – Ap, H, -, -, 46, 32.62, c; *Acinos arvensis* (Lam.) Dandy – Sn, T, -, -, 3, 2.13, vr; *Aegopodium podagraria* L. – Sn, G, -, -, 17, 12.06, a; *Aesculus hippocastanum* L. – Kn, M, -, -, 3, 2.13, vr; *Aethusa cynapium* L. – Ar, T, -, -, 4, 2.84, vr; *Agrimonia eupatoria* L. – Sn, H, -, -, 9, 6.38, r; *Agrostis capillaris* L. – Ap, H, -, -, 3, 2.13, vr; *Agrostis stolonifera* L. – Ap, H, -, -, 13, 9.22, r; *Alcea rosea* L. – Erg, H, -, -, 1, 0.71, vr; *Alliaria petiolata* (M. Bieb.) Cavara & Grande – Ap, H, -, -, 5, 3.55, vr; *Alnus glutinosa* (L.) Gaertn. – Sn, M, -, -, 27, 19.15, a; *Alopecurus pratensis* L. – Sn, H, -, -, 3, 2.13, vr; *Amaranthus retroflexus* L. – Kn, T, -, -, 1, 0.71, vr; *Anagallis arvensis* L. – Ar, T, -, -, 1, 0.71, vr; *Angelica sylvestris* L. – Sn, H, -, -, 3, 2.13, vr; *Anthemis arvensis* L. – Ar, T, -, -, 1, 0.71, vr; *Anthriscus sylvestris* (L.) Hoffm. – Sn, H, -, -, 2, 1.42, vr; *Apera spica-venti* (L.) P. Beauv. – Ar, T, -, -, 3, 2.13, vr; *Arctium minus* (Hill) Bernh. – Sn, H, -, -, 1, 0.71, vr; *Arenaria serpyllifolia* L. – Ap, T, -, -, 1, 0.71, vr; *Armoracia rusticana* P. Gaertn., B. Mey & Schreb. – Ar, G, -, -, 1, 0.71, vr; *Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl – Ap, H, -, -, 37, 26.24, c; *Artemisia absinthium* L. – Ap, C, -, -, 1, 0.71, vr; *Artemisia campestris* L. – Ap, C, -, -, 8, 5.67, r; *Artemisia vulgaris* L. – Ap, C, -, -, 48, 34.04, c; *Aster lanceolatus* Willd. – Kn, G, -, -, 1, 0.71, vr; *Avena sativa* L. – Erg, T, -, -, 1, 0.71, vr; *Ballota nigra* L. – Ar, H, -, -, 18, 12.77, a; *Batrachium circinatum* (Sibth.) Fr. – Sn, Hy, -, -, 2, 1.42, vr; *Bellis perennis* L. – Ap, H, -, -, 2, 1.42, vr; *Berteroa incana* (L.) DC. – Ap, H, -, -, 2, 1.42, vr; *Berula erecta* (Huds.) Coville – Sn, Hy, -, -, 1, 0.71, vr; *Betula pendula* Roth – Ap, M, -, -, 22, 15.60, a; *Bidens frondosa* L. – Kn, T, -, -, 6, 4.26, r; *Brassica napus* L. – Erg, T, -, -, 1, 0.71, vr; *Bromus carinatus* Hook. & Arn. – Kn, H, -, -, 2, 1.42, vr; *Bromus hordaceus* L. – Ap, T, -, -, 2, 1.42, vr; *Bromus inermis* Leyss. – Ap, H, -, -, 5, 3.55, vr; *Bromus sterilis* L. – Ar, T, -, -, 2, 1.42, vr; *Bromus tectorum* L. – Ar, T, -, -, 1, 0.71, vr; *Calamagrostis canescens* (Weber) Roth. – Sn, H, -, -, 4, 2.84, vr; *Calamagrostis epigejos* (L.) Roth. – Ap, G, -, -, 25, 17.73, a; *Calystegia sepium* (L.) R. Br. – Ap, G, -, -, 83, 58.87, ec; *Capsella bursa-pastoris* (L.) Medik. – Ar, H, -, -, 5, 3.55, vr; *Cardamine amara* L. subsp. *amara* – Sn, H, -, -, 1, 0.71, vr; *Carduus acanthoides* L. – Ap, H, -, -, 3, 2.13, vr; *Carduus crispus* L. – Sn, H, -, -, 1, 0.71, vr; *Carex acutiformis* Ehrh. – Sn, He, -, -, 28, 19.86, a; *Carex disticha* Huds. – Sn, G, -, -, 1, 0.71, vr; *Carex elata* All. – Sn, He, -, -, 2, 1.42, vr; *Carex hirta* L. – Ap, G, -, -, 18, 12.77, a; *Carex paniculata* L. – Sn, H, -, -, 6, 4.26, r; *Carex pseudocyperus* L. – Sn, He, -, -, 7, 4.96, r; *Carex riparia* Curtis – Sn, He, -, -, 3, 2.13, vr; *Carex viridula* Michx. – Sn, H, -, -, 1, 0.71, vr; *Centaurea cyanus* L. – Ar, T, -, -, 2, 1.42, vr; *Centaurea jacea* L. – Sn, H, -, -, 9, 6.38, r; *Centaurea scabiosa* L. – Sn, H, -, -, 3, 2.13, vr; *Centaurea stoebe* L. – Ap, H, -, -, 2, 1.42, vr; *Centaurium erythraea* Rafn. subsp. *erythraea* – Sn, T, -, S, 1, 0.71, vr; *Cerastium arvense* L. s. str. – Ap, C, -, -, 1, 0.71, vr; *Cerastium holosteoides* Fr. emend. Hyl. – Sn, C, -, -, 3, 2.13, vr; *Ceratophyllum demersum* L. s. str. – Sn, Hy, -, -, 4, 2.84, vr; *Chaerophyllum aromaticum* L. – Sn, H, -, -, 1, 0.71, vr; *Chaerophyllum temulum* L. – Ap, T, -, -, 7, 4.96, r; *Chamomilla suaveolens* (Pursch) Rydb. – Kn, T, -, -, 4, 2.84, vr; *Chelidonium majus* L. – Ap, H, -, -, 4, 2.84, vr; *Chenopodium album* L. – Ap, T, -, -, 11, 7.80, r; *Chondrilla juncea* L. – Ap, H, -, -, 1, 0.71, vr; *Cichorium intybus* L. – Ar, H, -, -, 10, 7.09, r; *Cicuta virosa* L. – Sn, H, -, -, 1, 0.71, vr; *Cirsium acaule* Scop. – Sn, H, -, -, 1, 0.71, vr; *Cirsium arvense* (L.) Scop. – Ap, G, -, -, 67, 47.52, ec; *Cirsium oleraceum* (L.) Scop. – Sn, H, -, -, 6, 4.26, r; *Cirsium palustre* (L.) Scop. – Sn, H, -, -, 3, 2.13, vr; *Cirsium vulgare* (Savi) Ten. – Ap, H, -, -, 2, 1.42, vr; *Consolida regalis* Gray – Ar, T, -, -, 1, 0.71, vr; *Convallaria majalis* L. – Ap, G, -, P, 2, 1.42, vr; *Convolvulus arvensis* L. – Ar, G, -, -, 3, 2.13, vr; *Conyza canadensis* (L.) Cronquist – Kn, T, -, -, 12, 8.51, r; *Cornus alba* L. – Kn, N, -, -, 1, 0.71, vr; *Cornus sanguinea* L. – Sn, N, -, -, 5, 3.55, vr; *Cornus sericea* L. emend. Murray – Kn, N, -, -, 1, 0.71, vr; *Coronilla varia* L. – Sn, H, -, -, 6, 4.26, r; *Corylus avellana* L. – Sn, N, -, -, 1, 0.71, vr; *Crataegus monogyna* Jacq. – Sn, N, -, -, 18, 12.77, a; *Dactylis glomerata* L. – Ap, H, -, -, 18, 12.77, a; *Daucus carota* L. – Ap, H, -, -, 13, 9.22, r; *Deschampsia caespitosa* (L.) P. Beauv. – Ap, H, -, -, 20, 14.18, a; *Dryopteris carthusiana* (Vill.) H.P. Fuchs – Sn, H, -, -, 1, 0.71, vr; *Echinochloa crus-galli* (L.) P. Beauv. – Ar, T, -, -, 1, 0.71, vr; *Echinocystis lobata* (F. Michx.) Torr. & A. Gray – Kn, T, -, -, 10, 7.09, r; *Eleocharis palustris* (L.) Roem. & Schult. – Sn, He, -, -, 6, 4.26, r; *Elodea canadensis* Michx. – Kn, Hy, -, -, 4, 2.84, vr; *Elsholtzia ciliata* (Thunb.) Hyl. – Ef, T, -, -, 1, 0.71, vr; *Elymus caninus* (L.) L. – Sn, H, -, -, 1, 0.71, vr; *Elymus repens* (L.) Gould – Ap, G, -, -, 18, 12.77, a; *Epilobium hirsutum* L. – Ap, H, -, -, 23, 16.31, a; *Epilobium palustre* L. – Sn, H, -, -, 9, 6.38, r; *Epilobium parviflorum* Schreb. – Sn, H, -, -, 2, 1.42, vr; *Epipactis helleborine* (L.) Crantz s. str. – Sn, G, -, S, 4, 2.84, vr; *Equisetum arvense* L. – Ap, G, -, -, 29, 20.57, c; *Equisetum palustre* L. – Ap, G, -, -, 5, 3.55, vr; *Euonymus europaeus* L. – Ap, N, -, -, 10, 7.09, r; *Eupatorium cannabinum* L. – Sn, H, -, -, 57, 40.43, ec; *Euphorbia cyparissias* L. – Ap, G, -, -, 1, 0.71, vr; *Euphorbia helioscopia* L. – Ar, T, -, -, 3, 2.13, vr; *Fallopia convolvulus* (L.) Á. Löve – Ar, T, -, -, 2, 1.42, vr; *Fallopia dumetorum* (L.) Holub – Ap, T, , -, 3, 2.13, vr; *Festuca arundinacea* Schreb. – Sn, H, -, -, 4, 2.84, vr; *Festuca pratensis* Huds. – Sn, H, -, -, 3, 2.13, vr; *Festuca rubra* L. s. str. – Ap, H, -, -, 15, 10.64, a; *Festuca trachyphylla* (Hack.) Krajina – Ap, H, -, -, 9, 6.38, r; *Fragaria vesca* L. – Ap, H, -, -, 1, 0.71, vr; *Frangula alnus* Mill. – Sn, N, -, P, 5, 3.55, vr; *Fraxinus excelsior* L. – Sn, M, -, -, 22, 15.60, a; *Galeopsis pubescens* Besser – Ap, T, -, -, 1, 0.71, vr; *Galinsoga parviflora* Cav. – Kn, T, -, -, 2, 1.42, vr; *Galium aparine* L. – Ap, T, -, -, 11, 7.80, r; *Galium mollugo* L. s. str. – Sn, H, -, -, 18, 12.77, a; *Galium palustre* L. – Sn, H, - , -, 13, 9.22, r; *Galium uliginosum* L. – Sn, H, -, -, 4, 2.84, vr; *Geranium pratense* L. – Sn, H, -, -, 13, 9.22, r; *Geranium pusillum* Burm. f. ex L. – Ar, T, -, -, 2, 1.42, vr; *Geranium robertianum* L. – Sn, T, -, -, 4, 2.84, vr; *Geum urbanum* L. – Ap, H, -, -, 14, 9.93, r; *Glechoma hederacea* L. – Sn, G, -, -, 2, 1.42, vr; *Glyceria fluitans* (L.) R. Br. – Sn, He, -, -, 1, 0.71, vr; *Hedera helix* L. – Ap, Ch, -, P, 4, 2.84, vr; *Helianthus tuberosus* L. – Kn, G, -, -, 1, 0.71, vr; *Helichrysum arenarium* (L.) Moench – Ap, H, -, P, 5, 3.55, vr; *Heracleum sibiricum* L. – Sn, H, -, -, 29, 20.57, c; *Hieracium pilosella* L. – Ap, H, -, -, 1, 0.71, vr; *Holcus lanatus* L. – Ap, H, -, -, 10, 7.09, r; *Humulus lupulus* L. – Sn, H, -, -, 46, 32.62, c; *Hypericum perforatum* L. – Ap, H, -, -, 3, 2.13, vr; *Hypericum tetrapterum* Fr. – Sn, H, -, -, 1, 0.71, vr; *Impatiens glandulifera* Royle – Kn, T, -, -, 1, 0.71, vr; *Impatiens parviflora* DC. – Kn, T, -, -, 10, 7.09, r; *Juncus articulatus* L. emend. K. Richt. – Ap, H, -, -, 14, 9.93, r; *Juncus bufonius* L. – Ap, T, -, -, 1, 0.71, vr; *Juncus inflexus* L. – Ap, H, -, -, 5, 3.55, vr; *Lactuca serriola* L. – Ar, H, -, -, 9, 6.38, r; *Lamium purpureum* L. – Ar, T, -, -, 1, 0.71, vr; *Lapsana communis* L. s. str. – Sn, H, -, -, 2, 1.42, vr; *Lathyrus pratensis* L. – Sn, H, -, -, 1, 0.71, vr; *Lemna minor* L. – Sn, Hy, -, -, 1, 0.71, vr; *Lemna trisulca* L. – Sn, Hy, -, -, 2, 1.42, vr; *Leontodon autumnalis* L. – Ap, H, -, -, 3, 2.13, vr; *Leontodon hispidus* L. subsp. *hispidus* – Sn, H, -, -, 3, 2.13, vr; *Leonurus cardiaca* L. – Ar, H, -, -, 5, 3.55, vr; *Lolium perenne* L. – Ap, H, -, -, 39, 27.66, c; *Lotus corniculatus* L. – Sn, H, -, -, 1, 0.71, vr; *Lychnis flos-cuculi* L. – Sn, H, -, -, 1, 0.71, vr; *Lycium barbarum* L. – Kn, N, -, -, 1, 0.71, vr; *Lycopus europaeus* L. – Sn, H, -, -, 34, 24.11, c; *Lysimachia nummularia* L. – Sn, C, -, -, 1, 0.71, vr; *Lysimachia vulgaris* L. – Sn, H, -, -, 38, 26.95, c; *Lythrum salicaria* L. – Sn, H, -, -, 18, 12.77, a; *Malus domestica* Borkh. – Kn, M, -, -, 4, 2.84, vr; *Matricaria maritima* L. subsp. *inodora* (L.) Dostal – Ar, T, -, -, 3, 2.13, vr; *Medicago falcata* L. – Ap, H, -, -, 5, 3.55, vr; *Medicago lupulina* L. – Ap, H, -, -, 7, 4.96, r; *Medicago sativa* L. s. str. – Kn, H, -, -, 1, 0.71, vr; *Medicago ×varia* Martyn – Kn, H, -, -, 2, 1.42, vr; *Melandrium album* (Mill.) Garcke – Ap, H, -, -, 10, 7.09, r; *Melilotus alba* Medik. – Ap, H, -, -, 9, 6.38, r; *Mentha aquatica* L. – Ap, H, -, -, 6, 4.26, r; *Mentha arvensis* L. – Sn, G, -, -, 3, 2.13, vr; *Mentha ×verticillata* L. – Sn, H, -, -, 20, 14.18, a; *Moehringia trinervia* (L.) Clairv. – Sn, T, -, -, 1, 0.71, vr; *Molinia caerulea* (L.) Moench s. str. – Sn, H, -, -, 11, 7.80, r; *Myosotis arvensis* (L.) Hill – Ar, T, -, -, 1, 0.71, vr; *Myosotis palustris* (L.) L. emend. Rchb. – Sn, H, -, -, 4, 2.84, vr; *Myosoton aquaticum* (L.) Moench – Sn, G, -, -, 1, 0.71, vr; *Myriophyllum spicatum* L. – Sn, Hy, -, -, 1, 0.71, vr; *Najas marina* L. – Sn, Hy, -, -, 1, 0.71, vr; *Nuphar lutea* (L.) Sibth. & Sm. – Sn, Hy, -, C, 2, 1.42, vr; *Odontites serotina* (Lam.) Rchb. s. str. – Sn, T, -, -, 3, 2.13, vr; *Oenothera biennis* L. s.l. – Ap, H, -, -, 1, 0.71, vr; *Ononis arvensis* L. – Sn, H, -, C, 12, 8.51, r; *Padus serotina* (Ehrh.) Borkh. – Kn, N, -, -, 7, 4.96, r; *Papaver argemone* L. – Ar, T, -, -, 1, 0.71, vr; *Papaver rhoeas* L. – Ar, T, -, -, 7, 4.96, r; *Parnassia palustris* L. – Sn, H, VU, -, 1, 0.71, vr; *Parthenocissus inserta* (A. Kern.) Fritsch – Kn, N, -, -, 7, 4.96, r; *Peucedanum palustre* (L.) Moench – Sn, H, -, -, 1, 0.71, vr; *Phleum pratense* L. – Sn, H, -, -, 5, 3.55, vr; *Phragmites australis* (Cav.) Trinn. ex Steud. – Ap, He, -, -, 141, 100.00, ec; *Pimpinella saxifraga* L. – Sn, H, -, -, 4, 2.84, vr; *Pinus sylvestris* L. – Sn, M, -, -, 1, 0.71, vr; *Plantago lanceolata* L. – Ap, H, -, -, 18, 12.77, a; *Plantago major* L. s. str. – Ap, H, -, -, 14, 9.93, r; *Plantago media* L. – Ap, H, -, -, 1, 0.71, vr; *Poa angustifolia* L. – Ap, H, -, -, 1, 0.71, vr; *Poa annua* L. – Ap, H, -, -, 5, 3.55, vr; *Poa nemoralis* L. – Sn, H, -, -, 4, 2.84, vr; *Poa palustris* L. – Sn, H, -, -, 3, 2.13, vr; *Poa pratensis* L. s. str. – Ap, H, -, -, 1, 0.71, vr; *Poa trivialis* L. – Sn, H, -, -, 4, 2.84, vr; *Polygonum amphibium* L. – Sn, He, -, -, 7, 4.96, r; *Polygonum aviculare* L. – Ap, T, -, -, 6, 4.26, r; *Polygonum lapathifolium* L. subsp. *lapathifolium* – Sn, T, -, -, 1, 0.71, vr; *Populus alba* L. – Sn, M, -, -, 18, 12.77, a; *Populus nigra* L. – Sn, M, LC, -, 2, 1.42, vr; *Populus tremula* L. – Sn, M, -, -, 3, 2.13, vr; *Potamogeton friesii* Rupr. – Sn, Hy, VU, -, 2, 1.42, vr; *Potamogeton lucens* L. – Sn, Hy, -, -, 6, 4.26, r; *Potamogeton pectinatus* L. – Sn, Hy, -, -, 12, 8.51, r; *Potentilla anserina* L. – Ap, H, -, -, 17, 12.06, a; *Potentilla argentea* L. s. str. – Sn, H, -, -, 4, 2.84, vr; *Potentilla reptans* L. – Ap, H, -, -, 16, 11.35, a; *Prunella vulgaris* L. – Sn, H, -, -, 1, 0.71, vr; *Prunus domestica* L. subsp. *insititia* (L.) Bonnier & Layens – Erg, N, -, -, 6, 4.26, r; *Prunus spinosa* L. – Sn, N, -, -, 8, 5.67, r; *Pyrus communis* L. – Sn, M, -, -, 4, 2.84, vr; *Quercus petraea* (Matt.) Liebl. – Sn, M, -, -, 2, 1.42, vr; *Quercus robur* L. – Sn, M, -, -, 3, 2.13, vr; *Ranunculus acris* L. s. str. – Ap, H, -, -, 12, 8.51, r; *Ranunculus auricomus* L. – Sn, H, -, -, 1, 0.71, vr; *Ranunculus bulbosus* L., Ap, G, -, -, 1, 0.71, vr; *Ranunculus repens* L. – Ap, H, -, -, 11, 7.80, r (probably more frequent); *Rhamnus cathartica* L. – Sn, N, , -, 4, 2.84, vr; *Rhus typhina* L. – Kn, N, -, -, 2, 1.42, vr; *Ribes spicatum* E. Robson – Sn, N, -, -, 3, 2.13, vr; *Ribes uva-crispa* L. – Kn, N, -, -, 1, 0.71, vr; *Robinia pseudacacia* L. – Kn, M, -, -, 13, 9.22, r; *Rosa canina* L. – Sn, N, -, -, 3, 2.13, vr; *Rubus caesius* L. – Sn, N, -, -, 23, 16.31, a; *Rubus idaeus* L. – Sn, N, -, -, 5, 3.55, vr; *Rubus* sp. – Ap, N, -, -, 4, 2.84, vr; *Rudbeckia laciniata* L. – Kn, H, -, -, 1, 0.71, vr; *Rumex acetosa* L. – Ap, H, -, -, 13, 9.22, r; *Rumex acetosella* L. – Ap, G, -, -, 1, 0.71, vr; *Rumex crispus* L. – Ap, H, -, -, 6, 4.26, r; *Rumex hydrolapathum* Huds. – Sn, He, -, -, 10, 7.09, r; *Rumex maritimus* L. – Sn, T, -, -, 1, 0.71, vr; *Rumex obtusifolius* L., Sn, H, -, -, 5, 3.55, vr; *Salix alba* L. – Sn, M, -, -, 8, 5.67, r; *Salix aurita* L. – Sn, N, -, -, 5, 3.55, vr; *Salix caprea* L. – Sn, N, -, -, 1, 0.71, vr; *Salix cinerea* L. – Sn, N, -, -, 44, 31.21, c; *Salix fragilis* L. – Sn, M, -, -, 26, 18.44, a; *Salix purpurea* L. – Sn, N, -, -, 7, 4.96, r; *Salix repens* L. subsp. *rosmarinifolia* (L.) Hartm. – Sn, Ch, -, -, 1, 0.71, vr; *Salix triandra* L. – Sn, N, -, -, 8, 5.67, r; *Salix viminalis* L. – Sn, N, -, -, 9, 6.38, r; *Sambucus nigra* L. – Ap, N, -, -, 35, 24.82, c; *Saponaria officinalis* L. – Ap, H, -, -, 1, 0.71, vr; *Schoenoplectus lacustris* (L.) Palla – Sn, Hy, -, -, 4, 2.84, vr; *Schoenoplectus tabernaemontani* (C. C. Gmel.) Palla – Sn, He, -, -, 10, 7.09, r; *Scirpus sylvaticus* L. – Sn, G, -, -, 1, 0.71, vr; *Scrophularia nodosa* L. – Sn, H, -, -, 2, 1.42, vr; *Scrophularia umbrosa* Dumort. – Sn, H, -, -, 3, 2.13, vr; *Scutellaria galericulata* L. – Sn, H, -, -, 7, 4.96, r; *Sedum acre* L. – Ap, C, -, -, 6, 4.26, r; *Sedum sexangulare* L. – Ap, C, -, -, 1, 0.71, vr; *Selinum carvifolia* (L.) L. – Sn, H, -, -, 2, 1.42, vr; *Senecio vernalis* Waldst. & Kit. – Kn, T, -, -, 1, 0.71, vr; *Setaria viridis* (L.) P. Beauv. – Ar, T, -, -, 1, 0.71, vr; *Silene vulgaris* (Moench) Garcke – Sn, H, -, -, 3, 2.13, vr; *Solanum dulcamara* L. – Sn, C, -, -, 7, 4.96, r; *Sonchus arvensis* L. – Sn, H, -, -, 12, 8.51, r; *Sonchus oleraceus* L. – Ar, T, -, -, 1, 0.71, vr; *Sorbus aucuparia* L. emend. Hedl. – Sn, M, -, -, 1, 0.71, vr; *Stachys palustris* L. – Sn, G, -, -, 7, 4.96, r; *Stellaria media* (L.) Vill. – Ap, T, -, -, 14, 9.93, r; *Stellaria palustris* Retz. – Sn, H, -, -, 2, 1.42, vr; *Stratiotes aloides* L. – Sn, Hy, -, -, 5, 3.55, vr; *Taraxacum officinale* F.H. Wigg. – Ap, H, -, -, 41, 29.08, c; *Thelypteris palustris* Schott – Sn, G, -, -, 2, 1.42, vr; *Tilia cordata* Mill. – Sn, M, -, -, 7, 4.96, r; *Torilis japonica* (Houtt.) DC. – Ap, H, -, -, 8, 5.67, r; *Tragopogon pratensis* L. s. str. – Ap, H, -, -, 6, 4.26, r; *Trifolium arvense* L. – Ap, T, -, -, 2, 1.42, vr; *Trifolium fragiferum* L. – Sn, H, -, -, 3, 2.13, vr; *Trifolium hybridum* L. – Ap, H, -, -, 1, 0.71, vr; *Trifolium pratense* L. – Ap, H, -, -, 11, 7.80, r; *Trifolium repens* L. – Ap, H, -, -, 9, 6.38, r; *Tussilago farfara* L. – Ap, G, -, -, 26, 18.44, a; *Typha angustifolia* L. – Sn, He, -, -, 7, 4.96, r; *Typha latifolia* L. – Sn, He, -, -, 3, 2.13, vr; *Ulmus glabra* Huds. – Sn, M, -, -, 3, 2.13, vr; *Urtica dioica* L. – Ap, H, -, -, 84, 59.57, ec; *Utricularia vulgaris* L. – Sn, Hy, -, S, 1, 0.71, vr; *Valeriana officinalis* L. – Sn, H, -, -, 1, 0.71, vr; *Verbascum lychnitis* L. – Ap, H, -, -, 1, 0.71, vr; *Veronica chamaedrys* L. s. str. – Ap, C, -, -, 3, 2.13, vr; *Vicia angustifolia* L. – Ap, T, -, -, 4, 2.84, vr; *Vicia cracca* L. – Ap, H, -, -, 8, 5.67, r; *Vicia hirsuta* (L.) S. F. Gray – Ar, T, -, -, 1, 0.71, vr; *Viola arvensis* Murray – Ar, T, -, -, 2, 1.42, vr; *Viola odorata* L. – Ar, H, -, -, 5, 3.55, vr.

Explanations (in order of appearance): 1 – names of taxa; 2 – origin and local naturalization status, Ap – apophytes, Sn – non-synanthropic spontaneophytes, Ar – archaeophytes (ancient alien species), Kn – kenophytes (alien species established since the end of the XVth century), D – diaphytes (non-established aliens); 3 – life form (Raunkiaer 1934) – dominant in the invetigated area, M – megaphanerophytes, N – nanophanerophytes, Ch – lignified chamaephytes, C – herbaceous chamaephytes, H – hemicryptophytes, G – geophytes, He – helophytes, Hy – hydrophytes, T – therophytes (annuals); 4 – regional category of threat in Wielkopolska; 5 – legal protection in Poland, S – strict protection, P – partial protection; 6 – total number of records in the investigated flora; 7 – % of the number of records related to the most frequent species (*Phragmites australis* – 141 rec.); 8 – local frequency levels (acc. to data in previous item), vr – very rare (<4%), r – rare (4-9.9%), a – averagely frequent (10-19.9%), c – common (20-39.9%), ec – extremely common (40-100%)