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BEATA WOZIWODA[1] & DOROTA MICHALSKA-HEJDUK[2]

Department of Geobotany and Plant Ecology, University of Lodz, Banacha 12/16, 90-237 Lódź, Poland, [1]woziwoda@biol.uni.lodz.pl, [2]dhejduk@biol.uni.lodz.pl

IMPACT OF LAND USE CHANGES AND DYNAMIC VEGETATION CHANGES ON VASCULAR FLORA DIVERSITY IN MAŁKÓW-BARTOCHÓW (THE WARTA RIVER VALLEY)

Abstract: The paper presents the changes of vascular plant flora in the Małków-Bartochów peatland area (the Warta River valley) which took place over a 40-year period. Vanishing, permanent and new components of the flora are presented with a special focus on valuable (protected by the law, threatened and locally rare) species. Changes in the share of ecological groups are estimated and discussed. Anthropogenic and natural factors, directly or indirectly influencing (in the past and at present) flora composition, are noted and analyzed.

Key words: flora, peatland, land use, degradation, Małków & Bartochów, Central Poland

1. INTRODUCTION

Wetland ecosystems are one of the most endangered in Poland. They have been under multidirectional human influences through the centuries. Changes of land use and transformation of river valley landscapes are the main causes of the extinction of lowmoors (rich fens). Specialized flora associated with these habitats is strongly endangered.

The hydrological conditions of the Warta River valley (Central Poland) have been changed significantly as a result of long-term (over 200 years) hydro-technical activities, such as river regulation, floodbank building, drainage and water reservoir

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construction. These hydro-technical operations have also influenced wetlands situated near the "Jeziorsko" water reservoir. One of them is located upstream the reservoir, near the villages of Małków and Bartochów (Fig. 1).

The Małków-Bartochów peatland is located in the physical geographical mesoregion of the Sieradzka Basin (KONDRACKI 2002). Its geographical position is marked by the co-ordinates: 51°40′25″-51°40′57″ N and 18°38′11″-18°38′34″ E. It fills the bottom of an elongated part of the Warta River valley, 1200 metres in length and about 500 metres in width. It covers an area of 40 hectares.

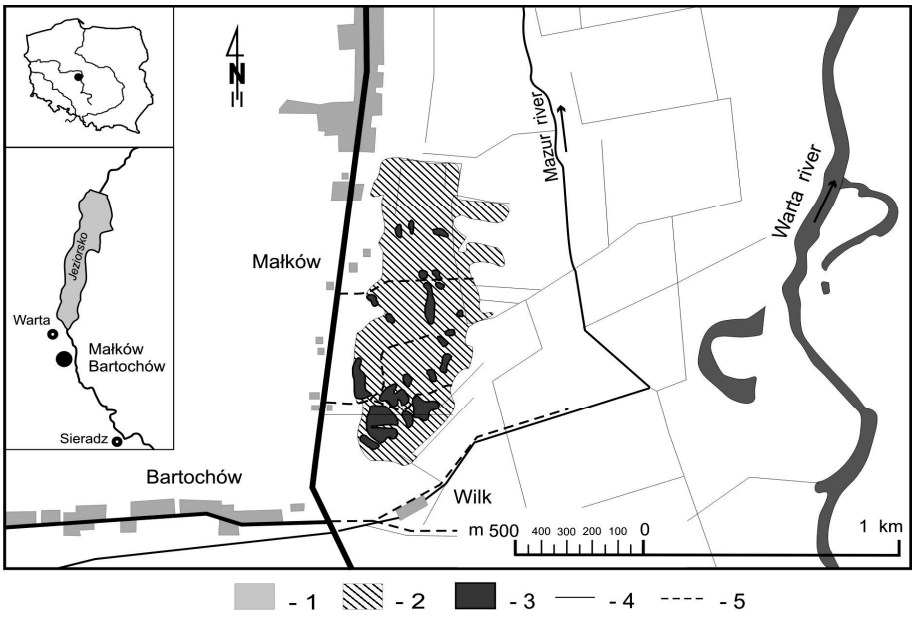

Fig. 1. Location of the study area. Explanation: 1 – buildings; 2 – forests and thick brushwoods on the peatland area; 3 – peat pits filled with water; 4 – permanent flow and drainage ditches; 5 – main tracks leading to the meadows and pastures.

This area has been strongly transformed due to long-lasting anthropogenic influences (Fig. 2). The peat deposits were extracted in the past for local demand. The largest peat pits were then changed into fishing ponds. They have slowly overgrown with rush communities as a result of the natural development of vegetation. This degraded peatland with partially saved peat seams was classified as

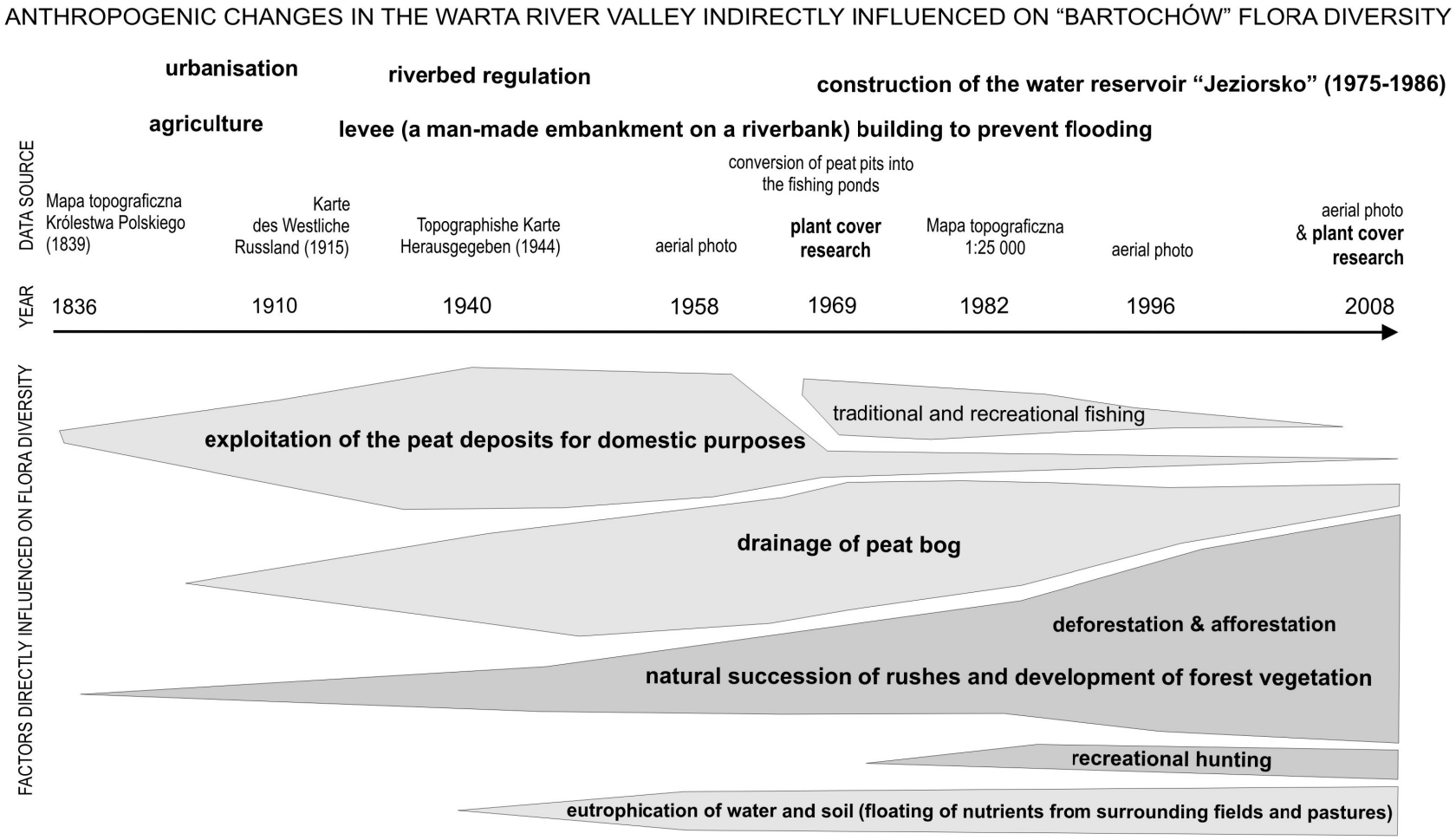

Fig. 2. Natural and anthropogenic factors influencing Małków-Bartochów flora diversity.

wasteland. Significant drainage of the whole area in the 1970's enabled its afforestation with alder trees. At present forest communities occupy almost all of the area. As a result of the changes in the water regime, the riparian forest was replaced by alder forest typical of swampy habitat.

The Małków-Bartochów peatland was researched by botanists in the 1960's. A description of this site, including the characteristics of its flora and vegetation can be found in the works of KRZYWAŃSKA (1970, 1974) and KRZYWAŃSKA & KRZYWAŃSKI (1972, 1974). For the purposes of this study, the plant cover research was repeated by the Authors in 2007 and 2008, and further supplemented in 2009.

The main subject of this article is the analysis of the changes of vascular flora diversity in the Małków-Bartochów peatland area after 40 years.

2. MATERIALS AND METHODS

The floristic data from the year 1969 (KRZYWAŃSKA 1970) and 2009 (own studies) have been compared. Vanishing, permanent and new components of vascular plant flora in this area were noted. Changes in the share of particular ecological groups were estimated using indicator values of vascular plants (ELLENBERG *et al.* 1991). Four indicators were taken into account: the light figure (L) whose value ranges from 1 (full shadow) up to 9 (full light); the moisture figure (F) which has a value from 1 (extremely dry soil) up to 12 (underwater plants); the reaction figure (R) from 1 (very acid soil) up to 9 (basic soil) and the nitrogen figure (N) from 1 (soil very poor in mineral nitrogen) up to 9 (soil very rich in mineral nitrogen). The frequency of species occurrence was considered. The following quantitative scale was applied for calculation: species very frequent (common in the majority of plant communities) – 20; common species (common but only in habitats typical of them) – 10; rare (occurrence between 6 and 20) – 3; very rare (occurrence between 1 and 5) – 1.

Changes in the share of ecological groups (the share of species characteristic of different plant communities and vegetation types) were also analyzed. The classification of species follows MATUSZKIEWICZ (2001). Special attention was paid to valuable plant species such as those protected by the law, endangered and rare.

In the alphabetic list of vascular plants given below all species noted in the investigated area are enumerated. The nomenclature of plants follows MIREK *et al*. (2002), synonymous names used by KRZYWAŃSKA (1969) are given in parentheses. Moreover, the following marks are used: (+) – species noted nowadays, not observed in the 1960's; (-) – species noted in the 1960's, not found in 2007-2009.

3. RESULTS

In the Bartochów-Małków peat-land complex, 207 species of vascular plants were found in the years 2007-2008. In the same area, 234 species were noted in the 1960's. 86 species which were noticed 40 years ago were not observed at present, but at the same time 59 new species were noticed. The majority of them were classified as sporadic or very rare.

List of vascular plant species noted in Małków-Bartochów peatland:

Achillea millefolium, *Acorus calamus*, *Actaea spicata*, *Aegopodium podagraria*, *Agrostis sp*. (+), *Alisma plantago-aquatica*, *Alliaria petiolata* (+), *Alnus glutinosa*, *Alnus incana* (-), *Alopecurus geniculatus*, *Alopecurus pratensis*, *Anagallis arvensis* (-), *Anchusa arvensis* (*Lycopsis arvensis*), *Anchusa officinalis*, *Angelica sylvestris*, *Anthemis arvensis*, *Anthoxanthum odoratum* (-), *Antriscus nitida* (+), *Antriscus sylvestris* (+), *Arctium lappa*, *Arrhenatherum elatius* (+), *Artemisia absinthium*, *Artemisia vulgaris*, *Asperugo procumbens* (-), *Athyrium filix-femina*, *Atriplex patula*, *Ballota nigra* (+), *Batrachium aquatile* (-), *Batrachium circinatum* (-), *Batrachium trichophyllum* (-), *Bellis perennis*, *Betula pendula*, *Betula pubescens*, *Bidens cernua* (+), *Bidens tripartita* (+), *Briza media* (-), *Butomus umbellatus* (-), *Caltha palustris*, *Calystegia sepium*, *Cannabis sativa* (-), *Capsella bursa-pastoris* (+), *Cardamine amara*, *Cardamine pratensis* (+), *Carduus acanthoides* (-), *Carduus crispus* (+), *Carex acutiformis*, *Carex appropinquata* (*C. paradoxa*), *Carex flava* (-), *Carex gracilis*, *Carex hirta*, *Carex nigra* (*C. fusca*) (-), *Carex ovalis* (*C. leporina*) (-), *Carex panicea* (-), *Carex paniculata*, *Carex pseudocyperus*, *Carex riparia* (+), *Carex rostrata* (-), *Carex vesicaria* (-), *Carex vulpina* (-), *Centaurea jacea*, *Cerastium arvense*, *Cerastium holosteoides* (*C. vulgatum*), *Ceratophyllum demersum*, *Chamomila suaveolens* (+), *Chara sp*. (+), *Chelidonium majus* (+),

Chenopodium album, *Chrysosplenium alternifolium* (+), *Cicuta vilosa* (-), *Circaea intermedia* (+), *Cirsium arvense*, *Cirsium oleraceum*, *Cirsium palustre*, *Conium maculatum* (+), *Cornus sanguinea*, *Corylus avellana*, *Crepis paludosa*, *Cuscuta europaea*, *Cyperus fuscus* (-), *Dactylis glomerata*, *Dactylorhiza maculata* (*Orchis maculata*) (-), *Dactylorhiza majalis* (*Orchis latifolia*) (-), *Daucus carota* (+), *Deschampsia caespitosa*, *Dryopteris austriaca* (+), *Dryopteris carthusiana* (*D. spinulosa*), *Dryopteris cristata*, *Dryopteris filix-mas*, *Echinochloa crus-galli* (-), *Eleocharis palustris* (*Heleocharis palustris*) (-), *Elodea canadensis* (-), *Elymus caninus* (*Agropyron caninum*), *Elymus repens* (*Agropyron repens*) (+), *Epilobium hirsutum*, *Epilobium palustre*, *Epipactis palustris* (-), *Equisetum arvense* (-), *Equisetum fluviatile* (*E. limosum*), *Equisetum palustre*, *Equisetum pretense* (+), *Eriophorum angustifolium* (-), *Euonymus europaea*, *Eupatorium cannabinum*, *Euphrasia rostkoviana* (-), *Fallopia dumetorum* (*Polygonum dumetorum*) (+), *Festuca gigantea*, *Festuca pratensis*, *Festuca rubra* (-), *Ficaria verna* (-), *Filipendula ulmaria*, *Filipendula vulgaris* (*F. hexapetala*) (-), *Frangula alnus* (+), *Fraxinus excelsior* (-), *Galeopsis speciosa*, *Galeopsis tetrahit*, *Galium aparine*, *Galium mollugo* (+), *Galium palustre*, *Galium uliginosum*, *Galium verum* (-), *Geranium palustre*, *Geranium pratense*, *Geranium robertianum*, *Geranium sanguineum* (-), *Geum rivale* (+), *Geum urbanum* (+), *Glechoma hederacea*, *Glyceria fluitans*, *Glyceria maxima* (*G. aquatica*), *Gnaphalium uliginosum*, *Heracleum sphondylium* (+), *Holcus lanatus*, *Hottonia palustris*, *Humulus lupulus*, *Hydrocharis morsus-ranae*, *Hypericum maculatum* (-), *Hypericum perforatum* (-), *Hypericum tetrapterum* (*H. acutum*) (+), *Impatiens glandulifera* (*I. roylei*) (-), *Impatiens noli-tangere*, *Iris pseudacorus*, *Juncus articulatus*, *Juncus bufonius*, *Juncus effusus* (+), *Lactuca serriola* (+), *Lamium maculatum*, *Lathyrus pratensis* (+), *Lemna gibba* (-), *Lemna minor*, *Lemna trisulca*, *Ligustrum vulgare* (-), *Lotus corniculatus*, *Lotus uliginosus*, *Lychnis flos-cuculi*, *Lycopus europaeus*, *Lysimachia nummularia* (-), *Lysimachia thyrsiflora* (+), *Lysimachia vulgaris*, *Lythrum salicaria*, *Malva neglecta* (-), *Medicago falcata* (+), *Medicago lupulina* (+), *Melandrium album*, *Mentha aquatica* (-), *Mentha arvensis*, *Mentha longifolia* (-), *Mentha* x *verticillata* (-), *Menyanthes trifoliata* (-), *Moehringia trinervia*, *Molinia caerulea*

(-), *Myosotis palustris* (+), *Myosotis sparsiflora*, *Myosoton aquaticum* (*Malachium aquaticum*), *Myriophyllum spicatum* (-), *Myriophyllum verticillatum* (-), *Nuphar lutea* (-), *Odontites serotina* (*O. rubra*) (-), *Oenanthe aquatica*, *Ophioglossum vulgatum* (-), *Padus avium* (+), *Papaver rhoeas*, *Paris quadrifolia*, *Parnassia palustris* (-), *Parthenocissus quinquefolia* (+), *Peplis portula* (-), *Peucedanum palustre* (-), *Phalaris arundinacea*, *Phleum pratense*, *Phragmites australis* (*P. communis*), *Pimpinella major* (-), *Plantago intermedia* (*P. pauciflora*) (-), *Plantago lanceolata*, *Plantago maior*, *Plantago media* (+), *Poa annua*, *Poa palustris*, *Poa pratensis*, *Poa trivialis*, *Polygonum amphibium* (-), *Polygonum aviculare*, *Polygonum bistorta*, *Polygonum hydropiper* (-), *Polygonum lapathifolium subsp. lapathifolium* (*P. nodosum*) (-), *Polygonum lapathifolium subsp. pallidum* (*P. tomentosum*) (-), *Polygonum persicaria*, *Populus alba* (-), *Populus nigra* (+), *Populus tremula*, *Potamogeton perfoliatus* (-), *Potentilla reptans* (+), *Prunella vulgaris*, *Prunus spinosa* (+), *Quercus robur* (+), *Ranunculus acris* (*R. acer*), *Ranunculus flammula*, *Ranunculus lanunginosus* (-), *Ranunculus lingua*, *Ranunculus repens*, *Ranunculus sceleratus*, *Rhinanthus minor* (*Alectorolophus minor*) (-), *Rhinanthus serotinus* (*Alectorolophus glaber*) (-), *Ribes nigrum*, *Ribes spicatum* (*R. schlechtendalii*), *Rorippa amphibia* (-), *Rorippa palustris*, *Rorippa sylvestris* (-), *Rosa canina*, *Rubus caesius*, *Rubus idaeus* (+), *Rumex acetosa* (+), *Rumex crispus*, *Rumex hydrolapathum*, *Rumex maritimus*, *Rumex obtusifolius*, *Rumex palustris* (-), *Sagina nodosa* (-), *Sagina procumbens* (-), *Salix alba* (+), *Salix aurita* (+), *Salix cinerea*, *Salix fragilis* (+), *Salix purpurea* (+), *Salix triandra* (-), *Sambucus nigra*, *Schoenoplectus lacustris*, *Scirpus sylvaticus*, *Scrophularia nodosa*, *Scrophularia umbrosa* (*S. alata*), *Scutellaria galericulata*, *Secale cereale* (+), *Sedum maximum* (-), *Senecio congestus* (*S. paluster*), *Senecio jacobaea* (-), *Sium latifolium* (-), *Solanum dulcamara*, *Sorbus aucuparia*, *Sparganium erectum* (*S. ramosum*), *Spirodela polyrhiza*, *Stachys palustris*, *Stachys sylvatica* (+), *Stellaria graminea* (+), *Stellaria media*, *Stellaria nemorum*, *Stellaria palustris*, *Stellaria uliginosa* (-), *Stratiotes aloides* (-), *Symphytum officinale*, *Taraxacum officinale*, *Teucrium scordium* (-), *Thalictrum aquilegiifolium* (+), *Thalictrum flavum* (+), *Thelypteris palustris* (*Dryopteris thelypteris*), *Torilis japonica*, *Trifolium campestre*

(+), *Trifolium repens* (+), *Triglochin palustre* (-), *Tussilago farfara*, *Typha angustifolia*, *Typha latifolia*, *Ulmus laevis* (+), *Urtica dioica*, *Urtica urens* (-), *Utricularia vulgaris*, *Valeriana dioica* (-), *Valeriana officinalis* (-), *Verbena officinalis* (-), *Veronica anagallis-aquatica* (*V. anagallis*) (-), *Veronica beccabunga* (-) *Veronica chamaedrys*, *Veronica scutellata* (-), *Viburnum opulus*, *Vicia cracca* (+), *Viola reichenbachiana* (*V. silvestris*) (+), *Wolffia arrhiza* (-).

Table 1 shows the most valuable vanishing species. Some hydro- and hygrophilous plants were not found, for example *Stratiotes aloides*, *Triglochin palustre*. It is interesting to notice that many species which are still present in the described peat-land are significantly lower in numbers (e.g. *Dryopteris cristata*, *Hottonia palustris*). The proportion of hygrophilous species associated with water plant and rush communities has also decreased.

In the investigated flora, nine alien species have disappeared. Seven new species of archeophytes and kenophytes have appeared but no invasive alien plants have been found.

Syntaxonomic analysis of the noted species indicates a decrease in the number of species characteristic of non-forest water plant and rush communities of the *Lemnetea*, *Potametea* and *Phragmitetea* classes (Fig. 3). The analysis of ecological indicator values, especially the humidity value (which changed from 7.7 to 7.2) confirms this tendency (Fig. 4). At the same time the number of forest community species (of the *Alnetea glutinosae* and *Querco-Fagetea* classes) remains stable. A slight decrease of the light indicator value (Fig. 4) shows that the penetration of light into the lowest layers of vegetation is smaller. It is connected with the overgrowing of peat pits and the development of thicket and forest communities.

4. DISCUSSION AND CONCLUSIONS

Significant changes of peatland plant cover have been observed in Poland for many years. Decreasing water level, eutrophication and bog exploitation are the

main causes of these changes. All these anthropogenic influences conducing to the degradation of habitats cause deep irreversible changes in vegetation, i.e.

Table 1. Special care species in the Małków-Bartochów forest-pit-bog complex. Explanation: ch – species under strict protection; czch – partially protected species (ROZPORZĄDZENIE 2004); 1 – threatened in Poland (ZARZYCKI, SZELĄG 2006), 2 – threatened in Central Poland (JAKUBOWSKA-GABARA, KUCHARSKI 1999), 3 – threatened pit bog species (JASNOWSKA, JASNOWSKI 1977): III – threatened species; rare species (+), common species (++).

Special care species	Species protection	Categories of threat			Occurrence	
		1	2	3	1969	2009
stable species						
Myosotis sparsiflora Pohl			CR		++	++
Ribes nigrum L.	czch				++	++
Senecio congestus (R. Br.) DC.			VU	III	+	+
Utricularia vulgaris L.	ch				+	+
vanishing species						
Dryopteris cristata (L.) A. Gray		V	VU	III	++	+
Hottonia palustris L.				III	++	+
Butomus umbellatus L.				III	+	
Carex flava L.				III	+	
Dactylorhiza maculata (L.) SOÓ	ch	V	EN		+	
Dactylorhiza majalis (Rchb.) P.F. Hunt & Summerh.	ch		LRnt		+	
Lemna gibba L.			LRnt		+	
Parnassia palustris L.				III	+	
Teucrium scordium L.		V	VU	III	+	
Nuphar lutea (L.) Sibth.& Sm.	czch				++	
Ophioglossum vulgatum L.	ch	V	VU	III	++	
Stellaria uliginosa Murray			LRnt	III	++	
Wolffia arrhiza (L.) Wimm			LRnt		++	
new species						
Frangula alnus Mill.	czch					+
Lysimachia thyrsiflora L.				III		+

the degeneration of peat-bog communities and succession of non-forest communities into forest ones (JASNOWSKI 1972, 1977; OLACZEK *et al*. 1990; HERBICH 2001; KUCHARSKI, MICHALSKA-HEJDUK 2000; KUCHARSKI *et al*. 2004 a, b).

The changes of flora and vegetation in Małków-Bartochów do not differ from those observed in other peat-bogs in Poland (JASNOWSKI 1972; HERBICH 2001; PISAREK, POLAKOWSKI 2001).

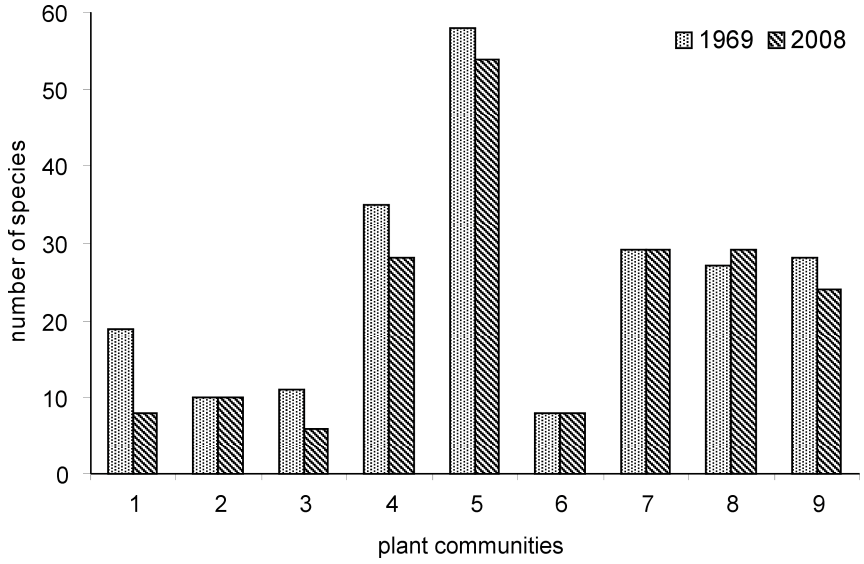

Fig. 3. Changes in the share of species characteristic of different types of vegetation. Explanation: 1 – water plant communities (*Potametea, Lemnetea, Charetea*); 2 – communities of summer terrophytes (*Isoëto-Nanojuncetea, Bidentetea*); 3 – lowmoors and transitional moors, boggy meadows (*Scheuchzerio-Caricetea*); 4 – rushes (*Phragmitetea*); 5 – meadows and pastures (*Molinio-Arrhenatheretea*); 6 – alder forests (*Alnetea glutinosae*); 7 – mezo- and eutrophic thickets and forests (*Rhamno-Prunetea, Salicetea purpureae, Querco-Fagetea*); 8 – nitrophilous ruderal communities (*Artemisietea*); 9 – others (*Agropyretea, Betulo-Adenostyletea, Epilobietea, Festuco-Brometea, Koelerio-Corynephoretea, Stellarietea, Trifolio-Geranietea, Vaccinio-Piceetea*).

The land-use changes are the main reason for the changes in the flora of this area. The end of peat deposit exploitation, the abandonment of fishing ponds and the

limitation of land reclamation have all created favourable conditions for dynamic development of stable communities. Small-scale disturbances caused by human management, such as the deepening of artificial water reservoirs or mowing of the sedges and reed rushes, are important mechanisms for maintaining species richness in space-limited communities by producing a mosaic of patches that vary species composition.

The handing over of this area to forestry use in the second half of the 20th century and its afforestation with *Alnus glutinosa* sped up the development of alder swamp forest. The water plant, sedge and rush communities have been successively replaced by shrub and forest communities. The loss of a water reservoir with open water surface and the vanishing of open, wet habitats are the main causes of the decrease in hygrophilous species abundance.

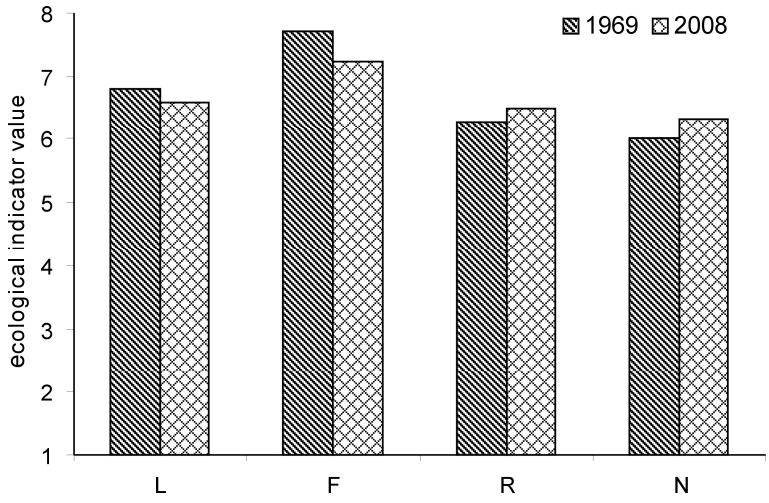

Fig. 4. Changes in ecological indicator values: L - light figure; F - moisture figure; R - reaction figure (soil acidity); N - nitrogen figure.

It is noteworthy that the degree of anthropogenic flora transformation in Małków-Bartochów is lower than in other sites with similar habitats. The share of alien species (including archeophytes, kenophytes and efemerophytes) is lower than 6%, whereas it reaches almost 8% in the other parts of the Warta River valley (RAKOWSKI, STACHNOWICZ 1999 a, b). Alien invasive plants such as *Epilobium*

ciliatum or alien species of the *Solidago* and *Bidens* genera (TOKARSKA-GUZIK 2005), which commonly invade wetland communities (RAKOWSKI, STACHNOWICZ 1999a; DAJDOK, TOKARSKA-GUZIK 2009; URBISZ *et al*. 2009; MICHALSKA-HEJDUK, KOPEĆ 2010), do not occur in Małków-Bartochów. Furthermore, two invasive species noted in the 1960's: *Elodea canadensis* and *Impatiens glandulifera*, were not found during recent field investigations. This situation can be linked to a high stability of plant communities in the described area.

Acknowledgements

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