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VARIABILITY OF TAXONOMIC STRUCTURE OF MACROPHYTES ACCORDING TO MAJOR MORPHOLOGICAL MODIFICATIONS OF LOWLAND AND UPLAND RIVERS WITH DIFFERENT WATER TROPHY*

ZMIENNOŚĆ STRUKTURY TAKSONOMICZNEJ MAKROFITÓW NA TLE WAŻNIEJSZYCH PRZEKSZTAŁCEŃ MORFOLOGICZNYCH RZEK NIZINNYCH I WYŻYNNYCH O ZRÓŻNICOWANEJ TROFII WODY

Summary. The surveys made on 80 river sites in Ecoregion 14 (Poland) were undertaken in years 2006-2008 to determine influence of river modifications and water trophy on variability of taxonomic structure of macrophyte taxa. Field surveys were conducted using widely accepted methods such as the River Habitat Survey and Mean Trophic Rank, supplemented by physico-chemical analyses of water and hydrochemical index for evaluation of trophic level. Obtained results showed, that there are significant differences between lowland and upland river sites according to the rate of channel modifications, concentration of trophic parameters and thus between aquatic macrophyte structure. The variability of taxonomic structure of aquatic macrophytes was found according to site altitude, rate of modifications and water quality parameters. It was found, that in case of lowland rivers the simultaneous influence of modifications and water trophy can affect taxonomic structure stronger than in upland sites, where level of kinetic energy of water flow plays the most important role.

Key words: macrophytes, river modifications, phosphorus, trophic state, Kujawskie Lakeland, Sudety Mountains

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Introduction

Surveys were carried out in the years 2006-2008 on 54 sites (20 rivers) in lowland rivers and on 26 sites (13 rivers) in upland (Ecoregion 14, Poland) to asses impact of river modifications and water trophy on structure of aquatic vegetation. The aim of the studies was the evaluation of the variability of taxonomic structure of aquatic vegetation related to river morphological modifications. Additionally, assessment of combined influence of river modifications and trophic status of water on presence of certain aquatic taxa was undertaken. Recently, there have been many studies on particular influence of modified river channels, water quality or physical features on presence of plant species (DEMARS and HARPER 1998, BAATTRUP-PEDERSEN and RIIS 1999, HAURY et AL. 2002, STANISZEWSKI et AL. 2004, O'HARE et AL. 2006, STANISZEWSKI et AL. 2006 b, SZOSZKIEWICZ et AL. 2006, 2007 and others). At the same time there is very limited literature about simultaneous impact of modifications and trophic level on vegetation structure of vascular plants or algae and exists only as a comment to main topic of studies (AGUIAR et AL. 2011). The aim of the studies was to determine the simultaneous influence of river modifications and water trophy on variability of taxonomic structure of aquatic vegetation represented by macrophyte taxa. Macrophytes, like vascular plants and macroscopic algae, were taken into account, both in lowland and in upland river sites.

Materials and methods

River sites for surveys were selected (site selection after field trips and cameral studies) to obtain possibly wide range of modifications and trophic conditions. Lowland river sites were situated mostly in Kujawskie Lakeland, Wielkopolskie and Lubuskie provinces, while upland river sites were situated in Dolnośląskie (Sudety Mountains), Małopolskie, Świętokrzyskie and Śląskie provinces.

Important for these studies physico-chemical parameters of river waters were analysed, as: soluble reactive phosphates – Ascorbic Acid Method (samples filtered using 0.45 μm pore size), total phosphorus – Acid Persulfate Digestion Method, nitrates – Cadmium Reaction Method (0.45 μm pore size), conductivity and pH reaction – electrometrically.

Mean Trophic Rank (MTR) methodology was used in these studies as ecological index and as a list of macrophyte taxa occurring in rivers for statistical analyses. Detailed description of MTR was given in earlier publications (NEWMAN et AL. 1997, DAWSON and SZOSZKIEWICZ 1999, DAWSON et AL. 1999, HOLMES et AL. 1999). To avoid potential inter-surveyor uncertainty in plant identification (SZOSZKIEWICZ et AL. 2007) difficult taxa were discussed among surveyors and consulted with botanist. The river bank and channel modifications were surveyed using River Habitat Survey (RHS) methodology (RAVEN et AL. 1997). Surveys were carried out on 500 m of watercourse. Bank and channel features were recorded in 10 spot-checks, spaced every 50 m. Two standard metrix as like Habitat Modification Score (HMS) and Habitat Quality Assessment (HQA) were calculated. Chemical Index of Trophy (CIT) was used to evaluate water trophy in selected sites. CIT is an indice based on concentrations of total phosphorus

(TP), soluble reactive phosphates (SRP) and nitrates measured in river waters (STANISZEWSKI et AL. 2006 a). Although originally index was tested in lowland rivers in Kujawskie Lakeland, attempt to use it in uplands was made. Chemical analyses of river were made several days after rain to minimise its impact on results. Trophic level of river waters could be also evaluated using Mean Trophic Rank but in that case macrophyte taxa would be in the same time both under survey (structure of aquatic vegetation) and as a tool to evaluate river trophy. Combined categories of river modifications and water trophy (Modif_trophy) were established on the base of RHS and CIT methodologies. The Modif_trophy categories were adapted from STANISZEWSKI et AL. (2006 a) and divide rivers into six categories from low modification and low trophy (LL) to high modification and high water trophy (HH). Intermediate conditions are marked with M letter, eg. ML – intermediate modifications and low trophy (Table 1).

Table 1. Proposed Modif_trophy types of rivers as ranges of Habitat Modification Score (RAVEN et AL. 1997) and Chemical Index of Trophy (STANISZEWSKI 2001)
Tabela 1. Proponowane typy rzeczne dla wskaźnika Modif_trophy określane na podstawie zakresów modyfikacji HMS (RAVEN i IN. 1997) oraz Chemicznego Indeksu Trofii (STANISZEWSKI 2001)

Types of river modification and trophy Typy modyfikacji i trofii rzek	Modification – range of HMS Modyfikacja – zakres HMS	Trophy – range of CIT Trofia – zakres CIT
Low Modyfikacje nieznaczne/Niska trofia (L)	0-2	3-4
Intermediate Modyfikacje umiarkowane/Umiarkowana trofia (M)	3-20	5-8
High Modyfikacje znaczne/Wysoka trofia (H)	> 20	9-12

Statistical analyses were made using Kruskal-Wallis ANOVA, canonical correspondence analysis (CCA) and Spearman rank correlation (STATISTICA... 2004, LEPS and SMILAUER 2007). For statistical purposes river habitat data were extracted from RHS database for the 100 m river length (where macrophytes were identified) and controlled with information about habitat gathered during MTR survey.

Results

Surveys were carried on previously selected 80 river sites in Ecoregion 14 representing most frequent types of geology (Table 2). Results of physico-chemical parameters in surveyed rivers indicate that higher water quality was in upland rivers and the obtained results were more homogeneous than in lowland river sites (Table 3). Only in case of concentration of nitrates the average value was higher in mountain areas, although maximum values were found in lower altitudes.

Table 2. Number of surveyed river sites according to watershed area and sediments characteristics (WATER... 2000)
Tabela 2. Liczba przebadanych odcinków rzecznych dla poszczególnych wielkości zlewni i rodzaju materiału dennego (WATER... 2000)

Watershed area Wielkość zlewni	Sediment type Typ osadów	Number of surveyed sites Liczba przebadanych odcinków
Uplands (200-400 m a.s.l.) Tereny wyżynne (200-400 m n.p.m.)		
Small – Mała	Siliceous – Krzemianowy	14
Small – Mała	Calcareous – Wapienny	4
Medium – Średnia	Siliceous – Krzemianowy	2
Medium – Średnia	Calcareous – Wapienny	6
Lowlands (0-200 m a.s.l.) Tereny nizinne (0-200 m n.p.m.)		
Small – Mała	Siliceous – Krzemianowy	10
Small – Mała	Organic – Organiczny	8
Medium – Średnia	Siliceous – Krzemianowy	14
Medium – Średnia	Organic – Organiczny	14
Large – Duża	Siliceous – Krzemianowy	8

Table 3. Characteristics of physico-chemical parameters, MTR scores, HQA, HMS and CIT in surveyed upland and lowland river sites
Tabela 3. Charakterystyka wskaźników fizyczno-chemicznych, MTR, HQA, HMS oraz CIT w badanych odcinkach rzek wyżynnych i nizinnych

Parameter Wskaźnik	Conductivity Przewodność ($mS \cdot cm^{-1}$)	pH	Total phosphorus Fosfor ogólny ($mg \cdot dm^{-3}$)	Soluble reactive phosphates Fosforany rozpuszczone ($mg \cdot dm^{-3}$)	Nitrate Azot azotanowy ($mg \cdot dm^{-3}$)	MTR	HQA	HMS	CIT
1	2	3	4	5	6	7	8	9	10
Uplands – Tereny wyżynne									
Average Średnio	0.280	–	0.34	0.18	1.21	48.0	50.9	33.3	8.5
Median Mediana	0.304	7.9	0.23	0.11	1.00	48.0	50.9	33.3	8.5
Minimum Minimum	0.033	7.6	0.12	0.10	0.15	13	35	0	7
Maximum Maksimum	0.611	8.2	1.02	0.36	2.20	92	71	106	10

Table 3 – cont. / Tabela 3 – cd.

1	2	3	4	5	6	7	8	9	10
Standard deviation Odchylenie standardowe	0.201	0.2	0.26	0.10	0.73	20.1	11.5	37.5	0.9
Lowlands – Tereny nizinne									
Average Średnio	0.815	–	0.70	1.57	0.97	34.4	32.5	14.6	8.6
Median Mediana	0.854	7.9	0.41	0.60	0.40	32.6	28.0	14.0	9.0
Minimum Minimum	0.311	7.0	0.09	0.14	0.01	20	15	0	7
Maximum Maksimum	1.202	8.9	3.85	9.35	7.80	80	64	54	11
Standard deviation Odchylenie standardowe	0.263	0.4	0.81	2.14	1.64	10.0	13.5	14.3	1.3

The Kruskal-Wallis ANOVA showed that lowland and upland river sites were often statistically significantly different according to physico-chemical parameters, hydromorphology and structure of vegetation (Table 4, Fig. 1, Fig. 2). Unmodified upland sites with minor modifications had higher HQA scores than similar lowland sites and heavily modified upland river sites had higher HMS scores than modified lowland sites (Fig. 2).

Table 4. Analysis of differences between upland and lowland rivers in chemical parameters of water, MTR index and morphological indexes based on the Kruskal-Wallis test
Tabela 4. Wyniki testu Kruskala-Wallisa dla rzek wyżynnych i nizinnych odnośnie do wskaźników jakości wody, wielkości MTR oraz wskaźników morfologicznych

Parameter Wskaźnik	Wartość statystyki H H value	Significance level Poziom istotności
Conductivity – Przewodność	**34.710**	***
Total phosphorus – Fosfor ogólny	**5.276**	*
Soluble reactive phosphates – Fosforany rozpuszczone	**33.446**	***
MTR	**20.777**	***
HQA	**24.013**	***
HMS	**4.714**	*

Statistically significant values are thickened. ***p < 0.001, **p < 0.01, *p < 0.05.
Wytłuszczono wartości istotne statystycznie. ***p < 0,001, **p < 0,01, *p < 0,05.

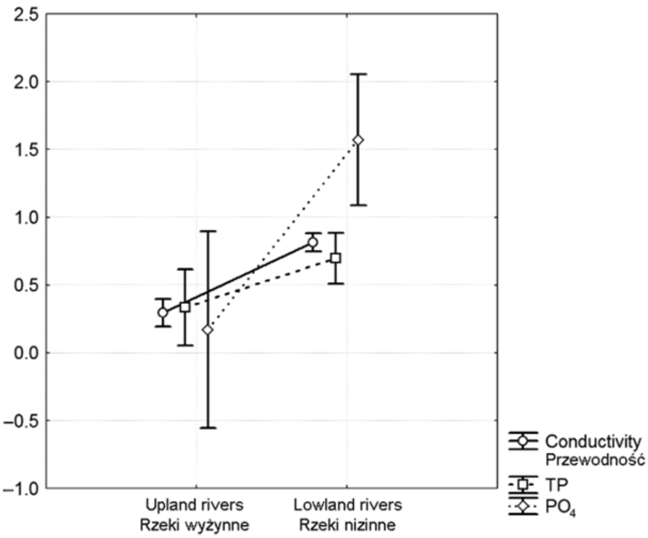

Fig. 1. Comparison of average values of conductivity, total phosphorus (TP) and soluble reactive phosphates (PO_4) concentrations in upland and lowland rivers, the whiskers mark 95% confidence
Rys. 1. Porównanie średnich wartości przewodności, stężeń fosforu ogólnego (TP) i fosforanów rozpuszczonych (PO_4) w rzekach wyżynnych i nizinnych przy pewności 95%

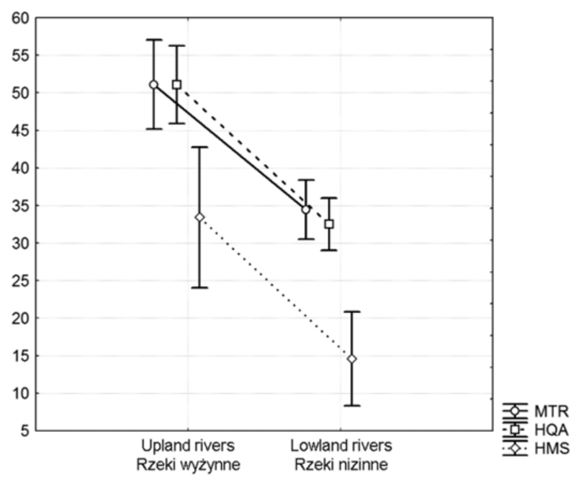

Fig. 2. Comparison of average MTR scores and hydromorphological indices in upland and lowland rivers, the whiskers mark 95% confidence
Rys. 2. Porównanie średnich wartości wskaźnika MTR oraz wskaźników hydromorfologicznych dla rzek wyżynnych i nizinnych przy pewności 95%

Relations between macrophyte structure and environmental factors were studied using CCA method. First CCA axis of presented diagram describes 26.4% of variability and is positively correlated with MTR score, turbulent water flow, upwelling and the presence of cobbles and boulders in river channel (Fig. 3). It showed negative relations

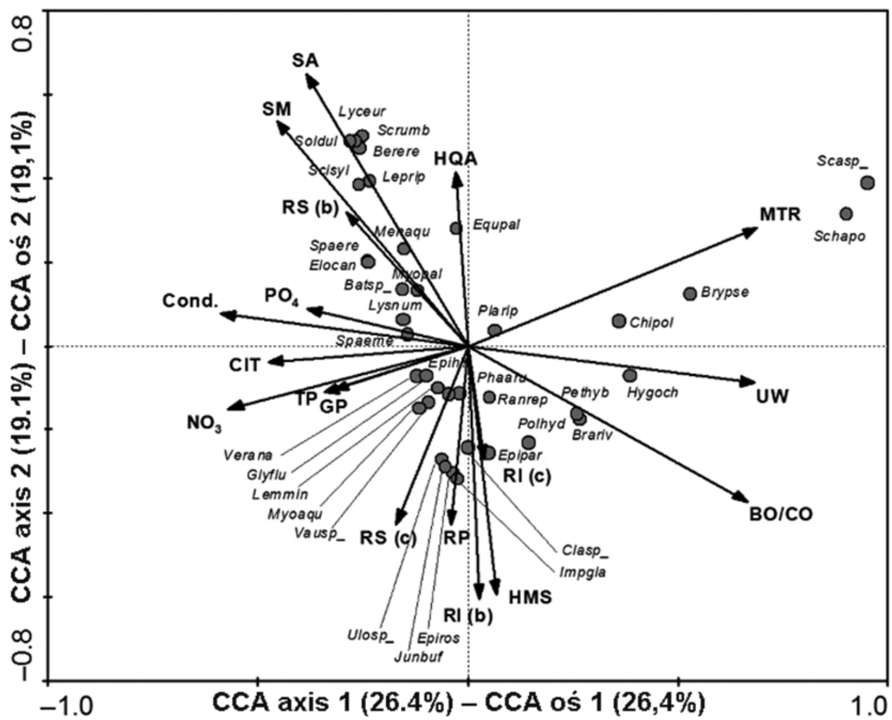

Fig. 3. Canonical correspondence analysis (CCA) ordination diagram for physico-chemical parameters and aquatic taxa of upland river sites; NO_3 – nitrates, PO_4 – soluble reactive phosphates, TP – total phosphorus, RI (b) – bank reinforcement, RI (c) – channel reinforcement, RS (b) – bank resection, RS (c) – channel resection, SM – smoth flow, RP – rippled flow, UW – upwelling, BO/CO – boulders and/or cobbles, GP – gravel and pebble, SA – sand

Rys. 3. Diagram kanonicznej analizy korespondencji (CCA) dla wskaźników fizyczno-chemicznych oraz taksonów roślin wodnych stanowisk wyżynnych; NO_3 – azotany, PO_4 – fosforany rozpuszczone, TP – fosfor ogólny, RI (b) – umocnienie brzegu, RI (c) – umocnienie koryta, RS (b) – profilowanie brzegu, RS (c) – profilowanie koryta, SM – przepływ gładki, RP – przepływ wartki, UW – przepływ wznoszący, BO/CO – głazy i kamienie, GP – żwir i kamienie, SA – piasek

Acocal – *Acorus calamus*, Agrsto – *Agrostis stolonifera*, Batsp_ – *Batrachospermum* sp., Berere – *Berula erecta*, Bidcer – *Bidens cernua*, Brariv – *Brachythecium rivulare*, Brypse – *Bryum pseudotriquetrum*, Butumb – *Butomus umbellatus*, Calcop – *Callitriche cophocarpa*, Calsep – *Calystegia sepium*, Caracu – *Carex acutiformis*, Cargra – *Carex gracilis*, Carrip – *Carex riparia*, Cerdem – *Ceratophyllum demersum*, Cersub – *Ceratophyllum submersum*, Chipol – *Chiloscyphus polyanthos*, Clasp_ – *Cladophora* sp., Elocan – *Elodea* *canadensis*, Epihir – *Epilobium hirsutum*, Epipar – *Epilobium parviflorum*, Epiros – *Epilobium roseum*, Equpal – *Equisetum palustre*, Eupcan – *Eupatorium cannabinum*, Glyflu – *Glyceria fluitans*, Glymax – *Glyceria maxima*, Hilriv – *Hildenbrandia rivularis*, Hydmor – *Hydrocharis morsus-ranae*, Hygoch – *Hygrohypnum ochraceum*, Impgla – *Impatiens glandulifera*, Iripse – *Iris pseudacorus*, Junbuf – *Juncus bufonius*, Juneff – *Juncus effusus*, Lemgib – *Lemna gibba*, Lemmin – *Lemna minor*, Lemtri – *Lemna trisulca*, Leprip – *Leptodictyum riparium*, Lyceur – *Lycopus europaeus*, Lysnum – *Lysimachia nummularia*, Lytsal – *Lythrum salicaria*, Melsp_ – *Melosira* sp., Menaqu – *Mentha aquatica*, Myoaqu – *Myosoton aquaticum*, Myopal – *Myosotis palustris*, Nuplut – *Nuphar lutea*, Oenaqu – *Oenanthe aquatica*, Pethyb – *Petasites hybridus*, Phaaru – *Phalaris arundinacea*, Plarip – *Platyhypnidium riparioides*, Polamp – *Polygonum amphibium*, Polhyd – *Polygonum hydropiper*, Potcri – *Potamogeton crispus*, Potnat – *Potamogeton natans*, Potpec – *Potamogeton pectinatus*, Ranrep – *Ranunculus repens*, Ransce – *Ranunculus sceleratus*, Roramp – *Rorippa amphibia*, Rumhyd – *Rumex hydrolapathum*, Sagsag – *Sagittaria sagittifolia*, Scasp_ – *Scapania* sp., Schapo – *Schistidium apocarpum*, Scisyl – *Scirpus sylvaticus*, Scrumb – *Scrophularia umbrosa*, Scugal – *Scutellaria galericulata*, Siulat – *Sium latifolium*, Soldul – *Solanum dulcamara*, Spaeme – *Sparganium emersum*, Spaere – *Sparganium erectum*, Spipol – *Spirodela polyrhiza*, Stapal – *Stachys palustris*, Symoff – *Symphytum officinale*, Typlat – *Typha latifolia*, Ulosp_ – *Ulothrix* sp., Vausp_ – *Vaucheria* sp., Verana – *Veronica anagallis-aquatica*

with physico-chemical parameters of river waters, CIT score (high values of CIT indicates high water trophy, high values of MTR indicates low trophic level) and domination of gravel in river bed. Second CCA axis describes 19.1% of total variability and is generally correlated with river morphology. Is positively relate to HQA score, sandy river bed, smooth water flow and negatively with different forms of anthropogenic pressure (bank and channel modifications).

River sites with low concentrations of biogens and low conductivity of water were typical for uplands and where colonised mostly by mosses (*Brachythecium rivulare*, *Bryum pseudotriquetrum*, *Hygrohypnum ochraceum*, *Schistidum apocarpum*) while vascular plants and macroscopic algae were represented very sparsely in that conditions. Occasionally, liverworths taxa were observed together with mosses, as like *Chiloscyphus polyanthus* and *Scapania* sp. In strongly modified sites the significant participation of terrestrial and ecotone species with wide ecological tolerance, as like *Epilobium parviflorum*, *E. roseum*, *Juncus bufonius*, *Polygonum hydropiper*, *Ranunculus repens* and *Cladophora* sp. In upland river sites characterised with low rate of modifications and numerous natural features of river bank and channel limnodophyte plants were observed with significant participation of *Berula erecta*, *Equisetum palustre*, *Lycopus europaeus*, *Mentha aquatica*, *Scrophularia umbrosa* and *Solanum dulcamara.*

Interpretation of CCA diagram (Fig. 4) for lowland rivers is not as clear as for upland river sites. It is due to the interlacing of trophic (CIT, soluble reactive phosphates) and morphological parameters (bank resection). In general, in strongly modified river sites and high water trophy *Ceratophyllum demersum*, *C. submersum*, *Lemna gibba*, *Potamogeton pectinatus* and algae *Cladophora* sp. and *Melosira* sp. were observed. These taxa are perceived as tolerant for eutrophication. In few sites with low rate of modification and low water trophy *Callitriche cophocarpa*, *Glyceria fluitans*, *Mentha aquatica*, *Lysimachia nummularia* and algae *Hildenbrandia rivularis* were found.

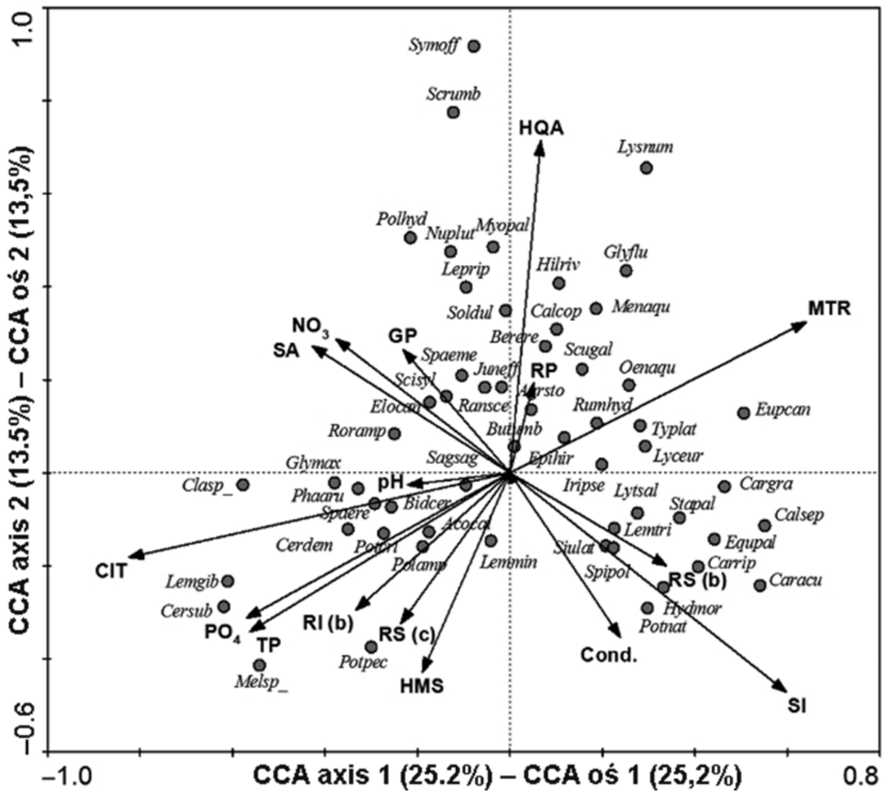

Fig. 4. Canonical correspondence analysis (CCA) ordination diagram for physico-chemical parameters and aquatic taxa of lowland river sites. Explanatory notes – as to Figure 3
Rys. 4. Diagram kanonicznej analizy korespondencji (CCA) dla wskaźników fizyczno--chemicznych oraz taksonów roślin wodnych stanowisk nizinnych. Objaśnienia – jak do rysunku 3

According to Spearman rank correlation for upland and lowland rivers, slightly different relations among surveyed parameters were found. For sites localised in higher altitudes higher correlations were observed, especially in case of MTR score and sometimes CIT (Tables 5 and 6). Mean Trophic Rank score was negatively and significantly correlated with all surveyed physico-chemical parameters in uplands and with trophic parameters in lowlands. In both groups of river sites the HQA and HMS showed correlation (negative and positive respectively) with the presence of major river modifications except channel reinforcement in lower altitudes, due to its lack in the studied sites and bank resection in uplands, which showed lack of any correlation. There were no statistically significant relations between Modif_trophy types and aquatic taxa. The reason of such a situation was the presence of particular species in different conditions, eg. *Lemna minor* was dominant taxus in rivers with different rates of channel modifications and at the same time was present in all observed levels of water trophy. Despite low statistical

Table 5. Results of the Spearman rank correlation among MTR score, HQA, HMS, CIT, major river modifications and water quality parameters in upland river sites
Tabela 5. Wyniki testu korelacji Spearmana między wskaźnikami MTR, HQA, HMS, CIT, ważniejszymi przekształceniami rzek oraz wskaźnikami jakości wody cieków wyżynnych

	MTR	HQA	HMS	CIT
RI (c)	–0.06	–0.31	0.38	0.10
RS (c)	–0.31	**–0.58**	**0.49**	0.39
RI (b)	–0.07	**–0.78**	**0.76**	0.07
RS (b)	–0.30	0.05	–0.03	**0.44**
Conductivity Przewodność	**–0.87**	–0.09	0.06	**0.71**
pH	**–0.51**	–0.24	0.24	**0.63**
Total phosphorus Fosfor ogólny	**–0.67**	**–0.51**	0.33	**0.76**
Soluble reactive phosphates Fosforany rozpuszczone	**–0.54**	–0.30	0.15	**0.93**
Nitrate Azot azotanowy	**–0.72**	–0.35	0.31	**0.63**
MTR	1.00	0.10	–0.07	**–0.66**
HQA	0.10	1.00	**–0.92**	–0.22
HMS	–0.07	**–0.92**	1.00	0.09
CIT	**–0.66**	–0.22	0.09	1.00

RI (c) – channel reinforcement, RS (c) – channel resection, RI (b) – bank reinforcement, RS (b) – bank resection.

Statistically significant values are thickened.

RI (c) – umocnienie koryta, RS (c) – profilowanie koryta, RI (b) – umocnienie brzegu, RS (b) – profilowanie brzegu.

Wytłuszczono wartości istotne statystycznie.

Table 6. Results of the Spearman rank correlation among MTR score, HQA, HMS, CIT, major river modifications and water quality parameters in lowland river sites
Tabela 6. Wyniki testu korelacji Spearmana między wskaźnikami MTR, HQA, HMS, CIT, ważniejszymi przekształceniami rzek oraz wskaźnikami jakości wody cieków nizinnych

	MTR	HQA	HMS	CIT
1	2	3	4	5
RS (c)	–0.17	**–0.38**	**0.57**	0.27
RI (b)	**–0.34**	**–0.37**	**0.47**	**0.36**
RS (b)	0.11	**–0.40**	**0.53**	–0.23
Conductivity Przewodność	–0.13	**–0.34**	0.13	0.25

Table 6 – cont. / Tabela 6 – cd.

1	2	3	4	5
pH	–0.09	–0.01	**–0.31**	0.24
Total phosphorus Fosfor ogólny	**–0.58**	**–0.37**	0.17	**0.80**
Soluble reactive phosphates Fosforany rozpuszczone	**–0.42**	–0.23	0.03	**0.64**
Nitrate Azot azotanowy	**–0.44**	0.14	–0.17	**0.73**
MTR	1.00	**0.29**	–0.24	**–0.67**
HQA	**0.29**	1.00	**–0.61**	–0.16
HMS	–0.24	**–0.61**	1.00	0.07
CIT	**–0.67**	–0.16	0.07	1.00

RS (c) – channel resection, RI (b) – bank reinforcement, RS (b) – bank resection.
Statistically significant values are thickened.
RS (c) – profilowanie koryta, RI (b) – umocnienie brzegu, RS (b) – profilowanie brzegu.
Wytłuszczono wartości istotne statystycznie.

Table 7. Most frequent upland and lowland river types representing combined influence of modifications and water trophy (Modif_trophy) and structure of aquatic taxa
Tabela 7. Najliczniej reprezentowane typy Modif_trophy w rzekach wyżynnych i nizinnych oraz struktura taksonomiczna roślinności wodnej

Taxa – Taksony	Uplands – Tereny wyżynne	Lowlands – Tereny nizinne
1	2	3
	Modif_trophy	
	MH	LH
Dominant Dominujące	*Berula erecta*, *Myosotis palustris*, *Phalaris arundinacea*	*Lemna minor*, *Phalaris arundinacea*
Others Inne	*Mentha aquatica*, *Scrophularia umbrosa*, *Solanum dulcamara*	*Agrostis stolonifera*, *Polygonum hydropiper*, *Cladophora* sp.
	Modif_trophy	
	HM	MM
Dominant Dominujące	*Agrostis stolonifera*, *Brachythecium rivulare*	*Lemna minor*, *Rumex hydrolapathum*
Others Inne	*Chiloscyphus polyanthus*, *Hygrohypnum ochraceum*, *Scapania* sp., *Nasturtium officinale*, *Phalaris arundinacea*, *Ranunculus repens*, *Veronica beccabunga*	*Agrostis stolonifera*, *Bidens tripartita*, *Lycopus europaeus*, *Phalaris arundinacea*, *Urtica dioica*

Table 7 – cont. / Tabela 7 – cd.

1	2	3
	Modif_trophy	
	HH	HH
Dominant Dominujące	*Agrostis stolonifera*, *Glyceria fluitans*, *Ranunculus repens*, *Veronica beccabunga*	*Phalaris arundinacea*, *Lemna minor*, *Sparganium erectum*
Others Inne	*Epilobium hirsutum*, *Veronica anagallis-aquatica*, *Myosoton aquaticum*	*Cladophora* sp.

significance simultaneous pressure of modifications and water trophy on aquatic macrophytes structure can be described on the base of obtained results (Table 7). Variability of taxonomic structures of macrophytes according to Modif_trophy types were observed in both latitudes, i.e. presence of *Veronica beccabunga* (HM, HH) and mosses (HM, HH) in upland river sites and domination of *Lemna minor* (LH, MM, HH), *Phalaris arundinacea* (LH, MM, HH) and *Cladophora* sp. (LH, HH) in lowland sites (Table 6).

Discussion

Surveyed lowland and upland river sites had different levels of phosphorus concentration and conductivity, while pH reaction was similar (Table 3). In both altitudes the siliceous sediment geology was strongly represented. The range of modifications was higher in upland parts where heavily modified and almost pristine rivers were observed (Fig. 2, Table 3). In those conditions, as many as 202 taxa living in rivers or river banks were recorded and utilised in further analyses.

Macrophytes are widely used indicators of ecological quality in running waters and their usefulness was proved in many studies (DEMARS and HARPER 1998, DAWSON et AL. 1999, HOLMES et AL. 1999, STANISZEWSKI 2001, HAURY et AL. 2002, SCHAUMBURG et AL. 2004, SZOSZKIEWICZ et AL. 2007, KOPEĆ et AL. 2010 and others). Different aquatic taxa are characteristic for particular conditions of rivers, such as chemical patterns, bank and channel modifications, flow types, current velocity and other. Thus the presence or absence of macrophytes is an important information, which can be used for evaluation of water trophy or ecological state of river water. Variability of macrophyte taxa in both groups of river sites (upland and lowland) was observed according to flow type (kinetic energy of water current), modifications and water trophy (Fig. 3, Fig. 4). It was found in other studies that in upland rivers very important factors limiting extent of macrophytes were water velocity and rate of sediment transport (JANAUER and DOKULIL 2006). It caused difficult living conditions for vascular plants while mosses, which are less susceptible to these factors were represented in higher amounts than in lower altitudes. Mosses are often typical for oligotrophic and mesotrophic waters (DAWSON et AL. 1999) and their presence is strongly affecting MTR score (Fig. 2).

In lowland rivers strongly modified sites with high water trophy (eg. Masłówka, Dąbrocznia, Radęca) were sometimes strongly covered by *Ceratophyllum demersum*, *C. submersum*, *Lemna gibba*, *Potamogeton pectinatus* and macroscopic algae. These taxa are perceived as tolerant for eutrophication (DAWSON et AL. 1999). In several sites with low HMS and moderate water trophy *Callitriche cophocarpa*, *Glyceria fluitans*, *Mentha aquatica*, *Lysimachia nummularia* and algae *Hildenbrandia rivularis* were recorded, i.e. in the Noteć and Oleśnica Rivers. Upland river sites with moderate concentrations of biogens and low conductivity of water (i.e. Kacza River) were colonised mostly by mosses while vascular plants and macroscopic algae were represented very sparsely. In strongly modified sites (eg. Ścinawka, Włodzica Rivers) significant participation of terrestrial and ecotone species with wide ecological tolerance, such as *Epilobium parviflorum*, *E. roseum*, *Juncus bufonius*, *Polygonum hydropiper*, *Ranunculus repens* and *Cladophora* sp., was observed. Sites characterised with low rate of modifications and presence of natural features of river bank and channel the limnodophyte plants were observed with significant participation of *Berula erecta*, *Equisetum palustre*, *Lycopus europaeus*, *Mentha aquatica*, *Scrophularia umbrosa* and *Solanum dulcamara.*

Reinforcement and resection were very common modifications in the surveyed river sites. Gabions and laid stones were dominant in upland rivers and sheet and wood piling in lowland river sites. The type of river bed reinforcement depends among others on the rate of erosion caused by water current velocity, so in upland river sites durable technical reinforcement such as concrete, laid stones, sheet pillings and gabions were found. In lowland river sites with smooth flow the wood pilling was observed as a main modification. It was observed also in other studies made by BEGEMANN and SCHIECHTL (1999), ŻELAZO and POPEK (2002).

The Spearman correlation showed, that in sites localised in higher altitudes the higher correlations among variables were observed (Tables 5 and 6). Mean Trophic Rank was negatively and significantly correlated with all surveyed physico-chemical parameters in uplands and with trophic parameters in lowlands. Similar observations were made in other studies (SZOSZKIEWICZ et AL. 2006) where MTR in uplands was significantly correlated with soluble reactive phosphates and with trophic parameters in lower altitudes. In both groups of rivers the HQA and HMS showed correlation (negative and positive respectively) with river modifications. The exception was channel reinforcement in lower altitudes due to its lack in the studied sites and bank resection in uplands.

Due to very limited literature treating on simultaneous influence of water trophy and river modifications on aquatic vegetation the test of such an influence was undertaken. During surveys there was no significant relation found between Modif_trophy types of rivers and macrophyte variability but some interesting observations were made (Table 7). In studied lowland river sites, basing on actual rate of modifications and water trophy the three main types were found, as like MM, LH and HH (Tables 1 and 7). In higher altitudes MH, HM and HH river types were present. There was variability in vegetation structure among the above types and future studies made on greater database should help to obtain precise answer to the problem how strong is that simultaneous influence on structure of aquatic plants. The only Modif_trophy type common in both altitudes – high modification rate and high water trophy (HH) showed important differences in lists of dominant taxa, which were completely opposite (Table 7). In lowland watercourses (Noteć, Oleśnica, Orla Rivers, etc.) typical taxa tolerant for anthropogenic modifications and eutrophic conditions as like *Lemna minor*, *Sparganium erectum* and *Cladophora* sp. were recorded, while *Glyceria fluitans*, *Veronica beccabunga* and *V. anagalis-aquatica* were frequently found in uplands. It is possible, that future comparisons between Modif_trophy types not found or sparsely represented in the studied sites would give very differential and statistically significant results.

Conclusions

The variability of taxonomic structure of aquatic macrophytes was found according to site altitude, rate of modifications, water conductivity and water trophy. Complexity of factors affecting aquatic plants indicates, that in case of lowland rivers the simultaneous influence of modifications and water trophy can affect taxonomic structure stronger than in upland sites, where level of kinetic energy of water flow plays most important role. In upland sites the variability was related to flow type of water, sediment type and water trophy. Macrophyte variability in river sites in lower altitudes was related to several interlacing factors but mostly to water trophy and presence of bank resection.

Because of limited literature on complex influence of water trophy and river modification on aquatic vegetation the obtained results cannot be compared with earlier studies. The influence of Modif_trophy types of rivers on aquatic taxa was not statistically significant but in case of river type common for both altitudes meaningful differences in lists of dominant taxa were observed (Table 7).

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ZMIENNOŚĆ STRUKTURY TAKSONOMICZNEJ MAKROFITÓW NA TLE WAŻNIEJSZYCH PRZEKSZTAŁCEŃ MORFOLOGICZNYCH RZEK NIZINNYCH I WYŻYNNYCH O ZRÓŻNICOWANEJ TROFII WODY

Streszczenie. Badania prowadzono w latach 2006-2008 na 80 odcinkach rzecznych Ekoregionu 14 celem określenia wpływu modyfikacji rzek oraz trofii wody na zmienność struktury taksonomicznej makrofitów. Oceny w terenie prowadzono z wykorzystaniem szeroko stosowanych metod River Habitat Survey oraz Mean Trophic Rank, które uzupełniono o analizy fizyczno-chemiczne i wskaźnik hydrochemiczny do oceny trofii wody. Uzyskane wyniki wskazały na znaczące różnice w stopniu przekształcenia koryt rzecznych i w stężeniach wskaźników troficznych pomiędzy rzekami nizinnymi i wyżynnymi. Stwierdzono zmienność struktury taksonomicznej makrofitów badanych odcinków rzecznych w odniesieniu do ich wysokości nad poziomem morza, zakresu modyfikacji oraz wskaźników jakości wody. Na podstawie przeprowadzonych analiz można wnioskować, iż oddziaływanie stopnia modyfikacji oraz trofii wody wpływa silniej na strukturę makrofitów rzek nizinnych. W przypadku rzek wyżynnych oddziaływanie to nie jest tak silne, ponieważ głównym czynnikiem kształtującym warunki życiowe jest tam wielkość energii kinetycznej przepływającej wody.

Słowa kluczowe: makrofity, modyfikacje rzek, fosfor, trofia, Pojezierze Kujawskie, Sudety

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