DISTRIBUTION OF AQUATIC MACROPHYTES IN PIT LAKES IN RELATION TO THE ENVIRONMENT (BORSKÁ NÍŽINA LOWLAND, SLOVAKIA)

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Abstract

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The numerous pit lakes in the Borská nížina lowland, are the results of gravel and sand extraction that took place in the later half of the 20^{th} century. After the retreat of natural wetlands from the farming lowland landscape, pit lakes contributed to its diversification. Hydrophytes and environmental parameters (morphometry, age of water bodies, land use and human impact) of eleven pit lakes were surveyed and mapped in 2001–2003. Among the 17 species identified in the set of lakes submerged plants prevailed. The find of critically endangered species *Hydrocotyle* vulgaris in sand pits is especially important. The dominant *Myriophyllum spicatum* and subdominant *Ceratophyllum demersum* showed continual distribution. Patches of floating leaf plant *Potamogenton nodusus* were found in almost all lakes. The mass of *Myriophyllum spicatum* positively correlated with segmentation of lakes (r = 0.52) and the age of a reservoir (r = 0.76), while *Ceratophyllum demersum* correlated with the muddy sediment (r = 0.95). The study emphasises the significance of location, morphometry and use of pit lakes in environmental planning.

Key words: aquatic macrophytes distribution, pit lakes, land cover/land use, environmental impact, the Borská nížina lowland, Slovakia

Introduction

Natural habitats of aquatic vegetation have rapidly diminished recently. This general trend relates to the socio-economic development and intensive land use. On the other side, many man-made water bodies have emerged in the territory of Slovakia (Oťaheľová et al., 1999b). Succession of macrophytes in these biotopes depends greatly on environmental properties. It can be either similar to that in natural conditions or the species diversity and their composition changed in the consequence of anthropic disturbance (morphology of water body, recreation, urbanization, agriculture, etc.).

The Borská nížina lowland was originally rich in open waters and wetlands (Krippel, 1959; Balátová-Tuláčková, 1976) which have diminished in the consequence of stream control and construction of dikes. Rich water vegetation survives now in the inundation area of the Morava river (Oťaheľová et al., 1994, 1999a; Schratt-Ehrendorfer, 1999). The onset of urbanization and construction in the 1960´s brought about an increased extraction of gravel and sand in the Borská nížina lowland. Numerous pit lakes characterized by a rapid succession of aquatic macrophytes sprang here after extraction ended and some of them also appeared in the last decade (Oťaheľ et al., 2004).

The aim of the contribution is to characterize floristic composition and distribution of water vegetation in anthropogenic biotopes – sand and gravel pit lakes in relation to the environmental (landscape-ecological) conditions. Cognition of these relationships may be applied to the management of anthropic aquatic habitats that contribute to diversity and natural balance of the landscape.

Material and methods

Study area

The study area covers the part of the Borská nížina lowland between the towns of Malacky and Holíč as far as the Morava river, the state frontier with Austria and Czech Republic. The surface of this territory is the fluvial plain (the Dolnomoravská and Dyjskomoravská floodplains) and the contiguous undulated fluvial-aeolian plain (Záhorské pláňavy and Gbelský bor plains) at the sea level altitude 145–189 m. As Mazúr and Lukniš (1980) assert, the territory forms part of higher geomorphological units – Záhorská nížina lowland and the Dolnomoravský úval valley.

The dominant morphological agent in the territory was the Morava river in the Quaternary. Its sedimentation of gravel, sand and clay determined the formation of surface system of river alluvia, terraces (preserved and isolated remnants) and of aeolian sand complexes. Blown sands form dispersed islands or a continuous compound in the Gbelský bor and Bor. Rests of old arms in various stages of silting and with different thickness of organic sediment, above all in the inundation area, interrupt the surface of the Holocene fluvial, prevailingly gravel floodplain.

Apart from tributaries of the Morava, such as Myjava, Rudava rivers – the territory is also drained by a system of canals. Numerous natural river lakes and artificial water bodies, results of gravel and sand extraction represent the surface water. The climate of the territory is of warm, dry or moderately dry lowland type with moderate temperature inversions. The mean January and July temperatures are from –1 to –4 °C and from 19.5 to 20.5 °C respectively and the mean annual precipitation moves between 530–650 mm (Tarábek, 1980).

Soil types in the territory under study vary from the gleic Fluvisols, Chernitsas, Cambisols to Regosols on blown sand. The potential vegetation (Michalko et al., 1986) has survived in form of discontinuous forest belts above all along the Morava (elm and willow-poplar floodplain forests), dispersed islands on terraces (*Potentillo-albae-Quercion* and *Pino-Quercion*) or larger compounds on blown sand (*Dicrano-Pinion*).

The character of the present landscape is rural where farming and forest-management prevail (Oťaheľ, Feranec, 1997). The network of settlements is linked to the remains of terraces and the transport is ensured by road and railway between Malacky and Holíč towns, including a section of motorway. The landscape along the Morava is typical of its high biodiversity of water and swamp associations and it is protected under the Protected Landscape Area (PLA) Záhorie. Rural settlements with typical regional architecture, numerous forests and water bodies have greatly contributed to the recreation function of the study territory.

Eleven man-made lakes situated between Kopčany and Malé Leváre villages were studied. The lakes bear names following the topology of Základné mapy Slovenskej republiky (Basic Maps of the Slovak Republic) at scale 1:10 000 published by the Úrad geodézie, kartografie a katastra SR (Geodesy, Cartography and Cadastre Authority of the Slovak Republic). Location of lakes is determined by the geographical coordinates of their centres (see Table 3).

Data on aquatic vegetation

The aquatic macrophyte vegetation of eleven lakes was surveyed and mapped from boat once during the main vegetation period 2001–2003 applying the standard method (Kohler, 1978; Janauer et al., 1993; Janauer, 2003). Each lake was divided into homogeneous survey units from the point of view of vegetation and ecology. The abundance of hydrophytes has been evaluated over a 5-level scale, which describes the Mass Index. The aspect of dominance is discussed using the numerical derivates – the Relative Plant Mass (RPM) and the Mean Mass indices (MMO stands for the Mean Mass index of an individual species with respect to the survey units where it occurs; MMT stands for Mean Mass index of a species with regard to all survey units of the water body), enabling to compare the quantitative relationships of macrophytes in aquatic habitats. The Distribution Ratio (d) is the ratio of the former two parameters ranging from 0 to 1. Numerical derivates were computed separately for each land and also for the whole set of pit lakes. The Total Mean Mass Index was used for the calculation of the Shannon Diversity Index Hs (Shannon, Weaver, 1949).

Each survey unit has been plotted out by GPS Garmin and an analysis of environmental parameters has been also drawn for each of them (see lower). In total 53 survey units were assessed. Simple correlation coefficient was applied to analysis of correlations. The plant nomenclature and grade of endangerment of plants are after Marhold, Hindák (1998).

Data on environmental parameters

The know data on man-made lakes (water habitats) related to extraction of materials, its finishing, shape of lakes and land use in the contact zone were included among the environmental parameters. They were analysed separately taking the relationships in the landscape system, and consequently their possible synergic effect, into account.

Morphometry of lakes was analysed applying the cartographic data of the Basic Map of the Slovak Republic and the GPS (Garmin) data, georeferenced in coordinate system of the Single Trigonometry Cadastre Network (S-JTSK). Digitised data were processed by the GIS ArcView in order to compute: the l – length of the shore lines of lakes including the shores of islands, A – area of water surface, S – segmentation of lakes (standardised quotient of the proportion of the shore length and area of water surface), L – the longest axis of lakes, CP – compactness of lake shapes to the Haggett´s formula (1965): $CP = 4.A / \pi..L^2$ in the context of studies by Bezák (1982), Frolov (1974), Husár (1996), and Ihse (1987).

The data on geological base rock of the area were processed according to Baňacký, Sabol (1973), Baňacký et al. (1996), Henkelová (1994). Further background information on the substrate composition, extraction of materials, and age of lakes were obtained from Geofond (Archives of research reports and reviews) of the State Geological Survey of the Slovak Republic in Bratislava. Bank structure and sediment types were processed by field research adhering the to methodology of Janauer (2003).

Land use in the environs of lakes was surveyed applying the CORINE land cover methodology (Heymann et al., 1994; Feranec, Oťaheľ 2001; Janauer, 2003). The dominant land cover/land use classes were identified and mapped within the 100 m long belt along the lake shores where the decisive impact on aquatic macrophytes exists. Human impact was measured observing the methods of the multicriterion statistics by determining the coefficient of effect hierarchy of the mapped classes – *hi* , their standardisation and calculation of the human impact coefficient – *HI* following the share of the individual classes in the contact zone of lakes.

Hydrochemical parameters pH value, electrical conductivity (µS/cm), dissolved oxygen saturation (%), dissolved oxygen (mg/l), were established by portable analyser (Hydrolab Corporations USA) only once at each locality. Water transparency was established by the Secchi disc, 30 cm in diameter.

T a b l e 1. The complete list of aquatic macrophytes, abbreviations of names, the growth forms and categories of threat.

Species	Abbrev.	G.f.	Threat
Batrachium circinatum	Bat cir	sa	
Ceratophyllum demersum	Cer dem	sa	
Hydrocotyle vulgaris	Hyd vul	fl	CR, §
Lemna minor	Lem min	ap	
Myriophyllum spicatum	Myr spi	sa	
Najas marina	Naj mar	sa	LR
Najas minor	Naj min	sa	
Nymphaea alba	Nym alb	fl	VU §
Nymphaea sp.	Nym sp.	fl	
Persicaria amphibia	Per amp	fl	
Potamogeton crispus	Pot cri	sa	
Potamogeton lucens	Pot luc	sa	
Potamogeton nodosus	Pot nod	fl,sa	LR
Potamogeton pectinatus	Pot pec	sa	
Utricularia australis	Utr aus	sa	§
Zannichellia palustris	Zan pal	sa	
Chara sp.	Cha sp.	sa	

Abbreviation: Growth forms: ap – acro-pleustophyte, sa – submersed anchored macrophyte, fl – floating leaf rhizophyte. Categories of threat and rareness: CR – critically endangered, LR – lower risk, VU – vulnerable, § – protected by law.

Results

Composition and distribution of macrophytes

In total 17 aquatic macrophytes were observed in pit lakes. Their number in the individual localities moved between 3–10 (Table 1). The prevailing growth form was the submersed anchored macrophyte. Shannon indices of species diversity oscillated between 1.5–3 (Table 2). The Adamov and M. Leváre lakes were floristically richest, while the lake of Kubovská was poorest in hydrophytes. A truly ubiquitous species with continuous distribution was *Myriophyllum spicatum* (Fig. 1). It was the dominant species (RPM > 50 %) in the majority of lakes (Fig. 2). It formed abundant submersed meadows especially along the shoreline. Both *MMT* and *MMO* were close (Fig. 3). *Ceratophyllum demersum* was subdominant in the whole set of lakes *(RPM* > 19%). However, fairly big differences were found between the individual lakes (see Table 2). Patches of floating leaf plant *Potamogeton nodosus* were

T a b l e 2. Characteristics of aquatic macrophytes in pit lakes.

Locality	*Hs*	*E*	*Nu*	*MMT*			*RPM* [%]		
				Myr spi	Cer dem	Pot nod	Myr spi	Cer dem	Pot nod
Kopčany	2.24	0.96	5	1.60	0.82	1.60	42	5.7	42
Boričky	2.63	0.94	7	1.48	0.94	2.40	13.7	3.5	59
Adamov	3.03	0.91	10	2.07	0.82	1.36	21.8	1.3	6
Kúty	2.69	0.96	7	2.56	0.81	1.61	34	1.1	8,6
U Janíčkov	2.03	0.87	5	1	1	3.7	1.6	1.6	79.4
Oširíd	2.75	0.98	7	0.91	1.23	0.79	13.1	31.4	8.5
Mláky W	2.59	0.86	8	4.89	2.99	1.95	42	5.7	42
Mláky E	2.04	0.88	5	2.68	3.66	0.84	27.4	69.5	0,8
Piesky	1.65	0.83	4	3.66	2.66	-	71.5	27.5	-
Kubovská	1.50	0.94	3	3.85	2.81	1.58	68.52	26.7	4.8
M. Leváre	2.95	0.89	10	3.07	1.98	0.44	69.8	18.8	0.21

Abbreviation: The values of diversity (H_s), evenness (*E*), number of macrophytes (*Nu*), mean mass total (*MMT*) and relative plant mass (RPM %) main species: *Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton nodosus*.

observed in almost all lakes, but with a small mean mass total (*RPM* = 12.4%, *MMT ´*= 1.9). A wide distribution in the pit lakes (*d* > 0.5) is typical only for mentioned species. Occurrence of other species was disjunctive. Among them the annual species *Najas marina* was the relatively most frequent (*d* = 0.3). Tall reeds such as *Phragmites australis*, *Typha angustifolia, T. latifolia,* occasionally *T. laxmannii* were the most frequent helophytes on shores.

Occurrence of *Hydrocotyle vulgaris,* the critically endangered species in Slovakia is the most remarkable. The floating leaf plants were found only in two lakes. *Najas marina* and *Utricularia australis* were identified only in one lake. Besides, clumped distribution of *Nymphaea alba* was identified. It may have been introduced here from natural biotopes or planted by people as a decorative plant. Garden cultivars of water lilies (*Nymphaea* sp.) were also planted in local gardens and they are thriving.

Environmental parameters assessment

The mineral composition of the geological substrate of fluvial floodplains, terraces and dunes is varied and it influences other elements and properties of the landscape system (the flow and regime of groundwater, self-cleaning capacity of the lake water, and the like).

Fig. 1. Distribution diagram of aquatic macrophytes in pit lakes. The five levels of Mass Index are reduced here to three levels (small bar: MI levels 1 and 2; medium bar: MI level 3; wide bar: MI levels 4 and 5). Localities: 1 – Kopčany; 2 – Boričky; 3 – Adamov; 4 – Kúty; 5 – U Janíčkov; 6 – Oširíd; 7 – Mláky W; 8 – Mláky E; 9 – Piesky; 10 – Kubovská; 11 – M. Leváre. The width of the columns is equivalent to the actual length of survey units.

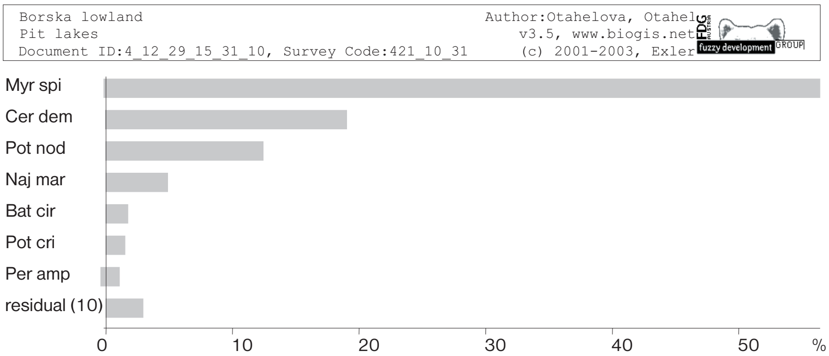

Fig. 2. Relative Plant Mass (RPM in %) of aquatic macrophytes in the set of pit lakes, as the ratio of all species (residual < 1%).

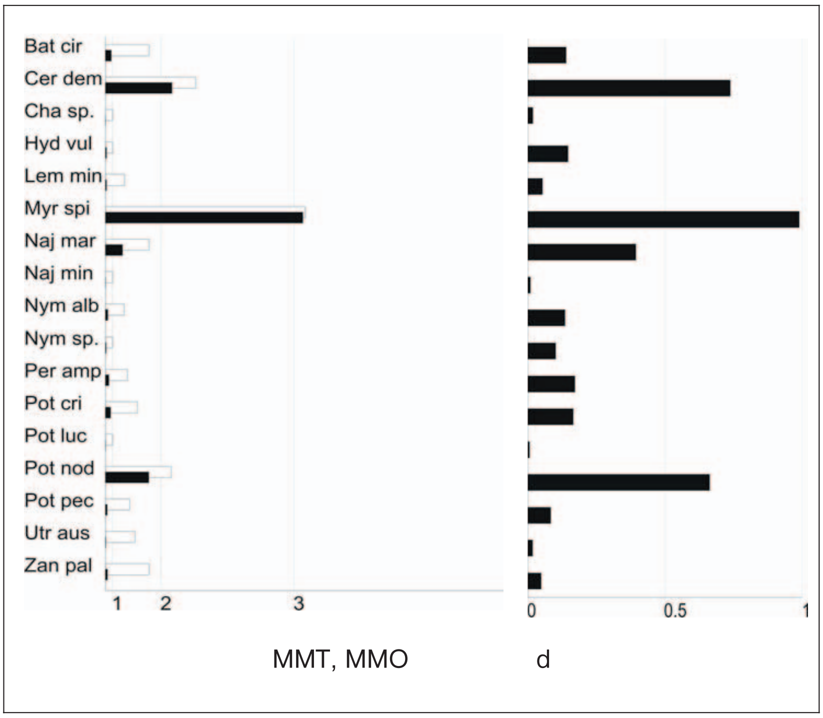

Fig. 3. Mean Mass Indices and Distribution Ratio of aquatic macrophytes in the set of pit lakes (MMT – dark column, MMO – blank column).

Three types of lake bank were identified and mapped in the studied area. Gravels (61.5%) were most abundantly represented. Sands (32.8%) and fine inorganic material (mud – 5.7%) followed. The lake bottoms in the sub littoral zone also contained three types of sediments composed of gravel (55.8%), sand sediments (29.2%) and mud sediments (15%).

The age of lakes was dated in relation to the time when gravel or sand extraction ended. Kúty, Mláky W, Mláky E, Kubovská, and Malé Leváre are among the oldest lakes (more than 40 years). It should be noted that the beginning of extraction was even earlier in, for instance Malé Leváre, where extraction started in the 1930´s (Henkelová, 1994). The youngest is the Ošiníd lake where extraction ended 10 years ago.

Morphometry, shape and segmentation of lakes were connected with the technique and ways of extraction. Larger segmentation and depth of lakes is the consequence of the use of loading machines in the oldest lakes. Bucket ladder dredges, which extracted gravel from the depth reaching the clay layer, were used in extraction of younger lakes. The clay basis of gravel sediments is in the depth of 6–7 m below surface in the study territory (Baňacký, Sabol, 1973; Henkelová, 1994).

The Malé Leváre and Kúty lakes have the longest and shortest shorelines and the largest and smallest water surface areas respectively. The highest and the lowest segmentation coefficients (*S*) were determined for the Mláky W and Piesky lakes respectively (Table 3). Correlation analysis confirmed dependence of dominant species mass on segmentation of lakes (Fig. 5).

The compactness rate of lakes (*CP*) points to their configuration. The highest and lowest compactness coefficients were found for the Ošiníd and Mláky W lakes respectively (Table 3). However, correlation analysis did not confirm any significant relationship between the compactness and distribution of macrophytes in lakes.

T a b l e 3. The geographical coordinates and values of environmental parameters of pit lake.

Locality	Longitude E	Latitude N	*l* m	A ha	S	L m	CP	Y	*HI*
Kopčany	17°05´20´´	48°46´40´´	4115	25.45	0.06	973	0.34	25	11.91
Boričky	17°04´47´´	48°45´55´´	5309	17.85	0.12	873	0.29	25	7
Adamov	17°01´34´´	48°43´36´´	3630	23.6	0.06	756	0.53	30	23.6
Kúty	17°01´25´´	48°40´02´´	591	2.23	0.11	215	0.61	40	26.45
U Janíčkov	17°00´02´´	48°38´11´´	885	4.76	0.07	350	0.49	30	26.8
Ošiníd	16°59´06´´	48°37´32´´	1278	8.37	0.06	411	0.63	10	18.1
Mláky W	16°59´56´´	48°37´15´´	2048	3.74	0.21	433	0.25	40	8.47
Mláky E	17°00´16´´	48°37´20´´	1354	4.29	0.13	453	0.27	40	10.15
Piesky	16°59´56´´	48°36´53´´	1925	13.9	0.06	590	0.51	35	8.9
Kubovská	16°59´04´´	48°35´50´´	2298	10.6	0.09	625	0.35	40	20.11
M. Leváre	16°57´16´´	48°29´44´´	6474	47.9	0.06	1432	0.30	40	17.74

Abbreviation: Length of shorelines (*l*); area of water surface (*A*); segmentation (*S*); axis (*L*); compactness (*CP*); age of pit lakes in years (*Y*); human impact (*HI*).

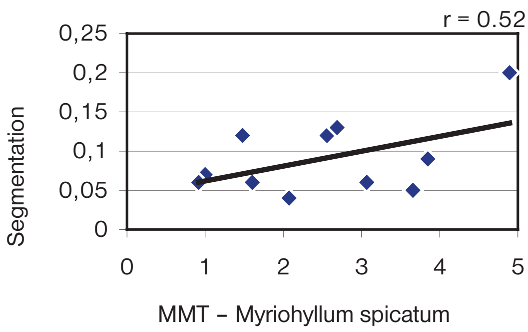

Fig. 4. Correlation between the mean mass total of *Myriophyllum spicatum* and the age of the pit lakes.

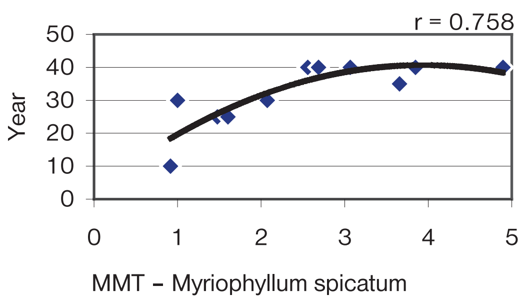

Fig. 5. Correlation between mean mass total of *Myriophyllum spicatum* and segmentation of the pit lakes.

Eight land use/land cover classes were identified in the contact zone of lakes: transport and industrial units, sport and leisure facilities, arable land, pasture, broad-leaved forest, coniferous forest, mixed forest, and shrubs. This order also indicates the intensity of their influence on the lake macrophytes. The effect of transport and industrial units represented by the motorway, roads and industrial structures is the highest (*hi* = 0.33), while that of forests and shrubs is the lowest (0.04). The coefficient of human impact *(HI)* is the highest in case of the U Janíčkov and Kúty and the lowest in case of the Boričky lakes (Table 3).

Table 4 quotes the hydrochemical characteristics. The pH values were slightly alkaline in the majority of cases. High values of oxygen saturation of water, as well as high pH values (Kúty, U Janíčkov) were caused by the large amount of green algae. Electrical conductivity oscillated be-

T a b l e 4. Quality of surface waters of surveyed pit lakes.

Locality	pH	SpCond µS/cm	DO mg/l	DO% Sat	Transp. m
Kopčany	9.09	784.9	8.76	99.5	0.45
Boričky	8.38	787.3	5.79	64.5	0.60
Adamov	8.73	880.0	5.99	69.0	0.80
Kúty	9.07	1695.0	10.10	116.4	0.75
U Janíčkov	9.35	762.5	9.23	107.2	0.50
Oširíd	8.37	767.4	7.36	82.1	1.80
Mláky W	8.35	431.4	6.43	66.8	1.50
Mláky E	7.49	499.8	2.39	25.0	0.60
Piesky	8.70	457.1	8.52	95.1	1.30
Kubovská	8.45	979.3	5.62	62.0	0.80
M. Leváre	8.95	483.5	9.01	98.8	1.70

tween 500–8000 µS/cm. This parameter reached double values in the lake situated within the town of Kúty and it correlates with the human impact coefficient (r = 0.639). Although the water transparency alters in the course of the year, the single measuring proved the best water transparency in the youngest lake and the worst water transparency was confirmed in lakes contacting holiday cottages (sport facilities), above all with intensive fishing.

Discussion

The survey of aquatic macrophytes proved that the newly made water reservoirs in lowland terrain rapidly overgrow. Numerous studies are involved with the issue and apart from life strategies of plant species, dependence on abiotic factors and human disturbance are generally emphasised. The vicinity of natural resources in diasporas of the Borská nížina lowland, and above all in inundation territory of the Morava river also contributes to the species diversity.

Myriophyllum spicatum is the species that overgrows all studied water reservoirs. Although it is autochthonous (Eurasian) species, its behaviour in these anthropogenic biotopes is invasive. It became a weed of concern in the lakes of the Northern America where it appeared as late as the 19th century (Painter, 1988). It is a perennial plant that propagates vegetatively and generatively. The highest mass values were found in the set of > 40–35 year old sand lakes which are very dissected with many islands covered by willow stands (*Salix cinerea*). The mass of *Myriophyllum spicatum* positively correlated with segmentation of lakes (Fig. 4) and with the age of reservoir (Fig. 5). On the other side it is also a pioneer species in the youngest of the lakes (Ošiříd), however, its mass is small. A wide ecological range of the species is known from literature; it is relatively tolerant to pollution, it resists salinity well and its occurrence was also reported in brackish waters with salinity 5–10%. The range of pH is also wide, it moves from 5.4 to 11 (Aiken et al., 1979; Casper, Krausch, 1981; Hejný et al., 1993; Smith, Adams, 1986).

Ceratophyllum demersum is frequently found in stagnant and slow flowing water of lowlands. It also successfully inhabits man-made water bodies because of its vegetative propagation (Casper, Krausch, 1981). A positive correlation between the mass of *C. demersum* and the muddy sediment (r = 0.95) was observed in study lakes.

Potamogeton nodosus is comparatively abundantly spread in slowly flowing and standing waters in the Borská nížina lowland (Oťaheľová, 1995). It is also a pioneer species in new reservoirs. It can form both submersed and floating leaves (heterophylia). It competes successfully with submersed plants in sites with low water transparency (U Janíčkov, Boričky).

Najas marina, which was considered as a rare species in Slovakia (Maglocký, Feráková, 1994), is now spreading above all in anthropogenic reservoirs (Oťaheľová, 1995), as confirmed by carried out analysis. As it is annual plant, its distribution varies in the individual years.

The relationship between the effect of land use classes (Fig. 6), or the human impact coefficient (*HI*) computed according to these classes is rather poor. The effect of param-

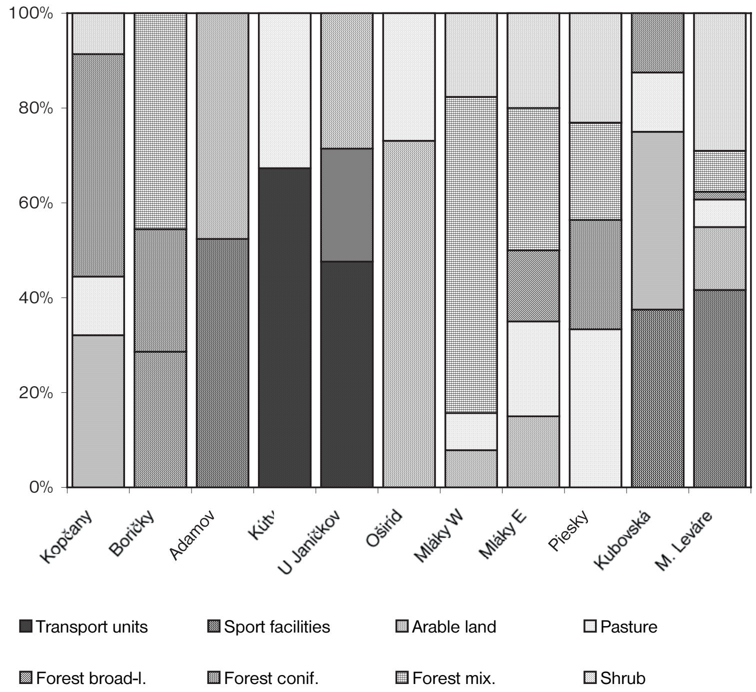

Fig. 6. Share of land use classes in the contact zone of lakes.

eters expressed by quantitative attributes of the human activities on aquatic vegetation is probably more significant as manifested by the amount of nutrients both in the sediment and water (e.g. Barko et al., 1991; Denny, 1972; Jones at al., 1983). The importance of the research focused on factors related to fishing (fry, feeding), recreation (number of cottages, bathing trippers and holidaymakers) and agriculture (fertilization and cultivation) should be also taken into account.

Mäkelä et al. (2004) confirmed better correlations of macrophyte vegetation structure with morphometrical characteristics of boreal lakes than with the chemical parameters. The most species richness was found in large lakes with a wider range of littoral habitats. The way of extraction of raw materials has affected the segmentation of shoreline of the pit lakes in the Borská nížina lowland. Succession of macrophytes starts precisely in the sub-littoral rim and the more diversified morphology of the reservoir, the more rapid succession (Fig. 4). This effect is stronger on the sand sediment (Mláky) as along the eroded shores, above all those of islands, are flat or gentle sloping and the sub-littoral rim is broad. Landwards, the shrubby stands of willows (*Salix cinerea*) grow. Transitions of lakes on gravel are steeper. The Boričky lakes with many islands but with steep shores are good examples. Islands are often covered by poplar trees (*Populus alba, P. tremula),* and in lesser extent by trees of elm floodplain forest *(Fraxinus angustifolia, Quercus robur)* and the water reservoir is poor in macrophytes. As a whole, the age of the reservoir correlates with the mass of hydrophytes, above all with *Myriophyllum spicatum* in studied lakes (Fig. 5).

Light condition is the limiting factor of all green plants. The significance of the data on depth of water column is taken into account. Differences in depth were so great in the individual survey units that the data gathered in this study can hardly be applied to the evaluation of water vegetation structure. However, even single measuring reveals a moderate correlation between the occurrence of submersed species and the water depth, while the floating leaf *P. nodosus* was more frequent in soiled waters.

Conclusion

Analysis of the distribution of aquatic macrophytes in pit lakes confirmed its varied relationships to the environmental (landscape-ecological) parameters. These parameters often represent relevant elements (properties) of the landscape system, functioning of which determines the way of use and management. Importance of the landscape planning should be also emphasised here. The selection and location of human activities, their spatial arrangement and organisation should respect the principles of eco-stabilising (self-regulating) capacity of the landscape above all in the context of long-term development or sustainability. It concerns especially extraction of natural resources including minerals and the subsequent recovery or use of the territory. Extraction of minerals in the study area is connected with the origin of man-made lakes, areas, shapes or segmentation of which can determine their further use.

It is necessary to plan the future way of use of pit lakes before the extraction starts. In order to have the succession draw the closest possible to the natural conditions, in other words, if biodiversity is born in mind, it is necessary to segment the surface of water reservoirs (to preserve islands and to segment the shoreline) and to create the habitats with different depth zones in order to preserve the threatened species. The Mláky and Boričky lakes (occurrence of *Hydrocotyle vulgaris*) are good examples. Land use in the contact zone of the Boričky lake, and above all its biodiversity, have aroused the interest of conservationists in this locality.

Overgrowing by *M. spicatum* species with required mowing should be counted on in case of lakes that are intended for further use for leisure, recreation or fishing. Overgrowing can be slowed down by making the lake larger and deeper (steep shores) with a mild part of shore left in its relatively natural state. Special attention should be given to the bearing capacity of lakes in terms of hygiene as they are fed only by seeping water.

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Oťaheľová H., Oťaheľ J.: **Distribúcia vodných makrofytov v zaplavených ťažobných jamách vo vzťahu k environmentálnym podmienkam (Borská nížina, Slovensko).**

V Borskej nížine vznikli v druhej polovici 20. storočia, po ťažbe štrkov a pieskov početné vodné nádrže, ktoré zarastajú vodnými makrofytami. Keďže v tomto území zaniklo veľa prírodných mokradí, nové antropogénne jazerá prispievajú k zvýšeniu biodiverzity nížinnej krajiny. V rokoch 2001–2004 sme mapovali a analyzovali štandardnou metódou (Kohler, 1978; Janauer, 2003) distribúciu hydrofytov a environmentálnych parametrov (morfometria, vek nádrží, využitie krajiny a antropický vplyv) v jedenástich jazerách. Celkove v jazerách rástlo 17 druhov, prevládala submerzná rastová forma. Dominantný druh *Myriophyllum spicatum* a subdominantný *Ceratophyllum demersum* mali kontinuálnu distribúciu. Mozaika porastov *Potamogeton nodosus* bola takmer na hladine väčšiny jazier. Abundancia *M. spicatum* v študovaných jazerách mala pozitívnu koreláciu s členitosťou (segmentáciou) vodnej plochy ($r = 0.52$) a vekom nádrže ($r = 0.76$) a abundancia *C. demersum* s bahnitým sedimentom ($r = 0.95$). Významný je nález kriticky ohrozeného druhu *Hydrocotyle vulgaris* v pieskových jazerách. Príspevok zdôrazňuje význam lokalizácie a morfometrických vlastností jazier, ako aj využívania priľahlej krajiny v environmentálnom plánovaní.