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THREATENING FACTORS ENCOUNTERED: ACTUAL ENDANGERMENT OF THE HUNGARIAN (SEMI-)NATURAL HABITATS

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Due to the global land use and climate change, endangerment of natural vegetation is increasing. That is why the threatening factors were documented in details during the MÉTA mapping. We have documented the impacts of water management, land use (management of woodlands and grasslands), the invasive species, urbanisation, habitat fragmentation and the neighbourhood, as well. In the present article (1) we evaluate the actual state of the habitats by the 28 threat types documented during the MÉTA mapping; (2) we introduce 12 newly developed indicators, which were applied for the semi-quantitative comparison of the overall degree of endangerment of the Hungarian habitats.

Based on the summarisation of our results the most seriously endangered habitats in Hungary are as follows: sand and loess steppe oak woodlands (M2, M4, L2x), tussock sedge communities (B4), extensive orchards (P7), closed lowland oak woodlands (L5, L6), water-fringing and fen tall herb communities (D5), wooded pastures (P45), vegetation of loess cliffs (I2), rich fens and *Molinia* meadows (D1, D2), Cynosurion grasslands and *Nardus* swards (E34), swamp woodlands (J2), xero-mesophilous grasslands (H4) and salt steppe oak woodlands (M3).

The least endangered types are the rocky habitats (I4, LY3, H1, G2, M7), certain halophytic (F1a, F5, F1b, F2, B6) and aquatic habitats (A23, A3a, A1), open acidophilous woodlands (L4b), dry shrub vegetation with *Crataegus* and *Prunus spinosa* (P2b) and the beech woodlands (K5).

Key words: evaluation for nature conservation, indicators, landscape ecology

INTRODUCTION

Human devastation of the nature has considerably been accelerated. So that to have a relevant picture about the actual situation and to define the actions that should be taken, we have to know which habitats are endangered, what kind of threats endanger them, and what is the extent of their endangerment. Though the degree of endangerment of the plant species was assessed in almost each European country (e.g. already twice in Hungary: Németh (1989), Király (2007)), the endangerment status of the habitats and vegetation types is estimated quite more rarely, because this process requires accurate data on the actual habitats and habitat maps of vast areas.

Lists of endangered vegetation types have been compiled since the 1980s. First of them was elaborated in the Czech Republic (Moravec *et al.* 1983), subsequently in Germany (Schulte and Wolf-Straub 1986, Riecken *et al.* 1994, 2006, Rennwald 2000), in Switzerland (Hegg *et al.* 1992, Delarze *et al.* 1999), for the habitats of the Baltic Sea (HELCOM 1998), then of Hungary (Borhidi and Sánta 1999) and Austria (Essl *et al.* 2002). Prior to – and sometimes parallel with – the compilation of these lists, methodological developments were also evolved (Bonn 1986, Riecken *et al.* 1994, Blab *et al.* 1995, 2005). The most important conclusions of these are as follows: (1) habitats are more difficult to evaluate, than species, because they are hard to define and typify (e.g. there might be numerous subtypes; a certain habitat may change to another as a result of degradation, several, different vegetation classification systems can be applied for the assessment); (2) the quantity indicator should rest on the changes of the habitat areas observed during the past 100–150 years; (3) application of quality indicators is also necessary (degradation, lack of characteristic traits, similarly to the Hungarian system of habitat naturalness set up by Németh and Seregélyes 1989); (4) zoological aspects should also be included (since animals react quite differently to the landscape pattern as habitats do, and the animals' habitat preference also differs); (5) regeneration ability of the habitats should also be taken into consideration (Regeneration durch Sukzession and Neuentwicklung, Riecken *et al.* 1994, Blab *et al.* 1995); (6) IUCN categories (2001) should be applied for the final assessment; (7) the process of assessment should be as clear, reproducible and quantifiable as possible.

Simultaneously with the elaboration of endangerment lists, monographs describing habitats and vegetation types have a tendency to discuss the status of endangerment and the pressures affecting them, yet only textually, in few sentences, and not based on accurate data (e.g. Pott 1996, Borhidi and Sánta 1999, Delarze *et al.* 1999).

Several different threats endanger the habitats; they can be sorted into the following main categories: (1) direct human devastation (tillage, building, overexploitation); (2) change in sustainable traditional land use; (3) spread of invasive species, overpopulated game; (4) diffuse ecological background pressure (e.g. terrestrial eutrophisation, decrease of groundwater level, climate change); and (5) the disadvantageous effects of the adverse natural state (e.g. loss of species due to the small patch size and isolation) (HELCOM 1998, Delarze *et al.* 1999, Borhidi and Sánta 1999, Essl *et al.* 2002, Riecken *et al.* 2006).

As a consequence of lack of expert data scientifically sound evaluation of the degree of endangerment is not easy, almost impossible. Expert assessment thus should rest partly on scientifically sound data (e.g. data on the change in distribution or extension), partly on indirect information (e.g. qualitative data of the pressures) and partly on personal expert knowledge (e.g. long-term field experience). The innate anthropocentricity of the decisions is also an unsolvable problem (e.g. most people usually regard grasslands as less complex and less valuable communities, than woodlands). Moreover, evaluations are often value-based: habitats being important for the scientists or the society are expected to receive stricter protection (e.g. endemic ones, important bird areas, rare habitats). Though the editors (Riecken *et al.* 1994, HELCOM 1998, Essl *et al.* 2002) regard the classification system of the endangerment status of the habitats accurate and objective, the expressions they use (e.g. "sehr eng begrenzt", "meist wenige", "sehr grossflächig") indicate that the classification process is only partially objective, partly documented and not controlled accurately from every aspects (Essl *et al.* 2002). Thus, expert assessment should complete the overall process. However, the increasing amount and improving quality of available base data enable more accurate expert assessment (see HELCOM 1998).

In the present article (1) we assess the effects of the 28 threats documented in the MÉTA database, and (2) on the grounds of newly developed indicators we also evaluate semi-quantitatively and semi-objectively the overall degree of endangerment of the Hungarian habitats.

METHODS

The base data for the analysis derived from the MÉTA database (Molnár *et al.* 2007, Horváth *et al.* 2008). All the 86 Hungarian habitats (Bölöni *et al.* 2008, see also Appendix) were surveyed during the MÉTA field survey. Hungary was covered by a 35 hectare sized grid system (Horváth *et al.* 2008). In each cell for each occurring habitat the "most important" threats were selected from the 28 predetermined threatening factors by the mappers based on his local experience, the features of the local landscape. No pre-set criteria were provided, data collection was based on expert judgement.

For the evaluation of endangerment the cumulative area of the endangered habitats regarding both the habitat types and the different threats was estimated. In case of the three subgroups (wetlands, woodlands, grasslands) we ignored the following vegetation types during the analysis: degraded, uncharacteristic woodlands and treeless habitats (OA, OB, OC, BA, RA, RB, RC, RD), and Nanocyperion communities (I1), because this latter category was used also for both flooded arable fields and riverbeds (for the codes of the habitat types see Appendix of the volume).

Based on the thematic grouping of the endangering threats we developed 12 synthetic indicators, which were applied for the evaluation. We have ordered the indicator values of the habitats according to their ranks, then these ranks were averaged (higher rank meant lower degree of endangerment). Biologically irrelevant values were ignored. Such ignored values were, for example, in the case of the rocky vegetation (or other edaphic habitats) the local and landscape scale connectedness, the proportion of fragments, and the regeneration potential on the place of the neighbouring vegetation patches or old-fields (indicated as underlined in the table). In case of Indicators 4 and 7, ranks weighted by the extension and ranks weighted by the occurrences were averaged. In Table 1 contractions were used for the sake of clarity and comprehensibility (wetlands: all hydrophyte and marsh and fen vegetation, grasslands: all grassland types, woodlands: all woodland and shrub vegetation type).

Threats estimated during the MÉTA mapping

During the field survey from the 28 threat types (Th1–Th28) the most characteristic ones had to be selected that actually threaten the survival and maintenance of the habitat type in the MÉTA hexagon in the next 10–15 years (Molnár *et al.* 2007, cf. HELCOM 1998). The strength of the threats was not recorded.

Th1 = water shortage, Th2 = access water, Th3 = improper water dynamics, Th4 = overgrazing, Th5 = undergrazing, Th6 = improper grazing regime, Th7 = abandonment from grazing, Th8 = improper mowing, Th9 = abandonment from mowing, Th10 = melioration, Th11 = encroachment of shrubs and trees, Th12 = non-natural burning, Th13 = afforestation with improper species, Th14 = woodland patches managed homogeneously, Th15 = improper selection of trees for timber extraction, Th16 = logging trees at low age, Th17 = new plantations on grasslands, Th18 = overpopulated game, Th19 = colonisation by invasive plant species, Th20 = tillage, Th21 = building and construction, Th22 = spread of gardens threatens vegetation, Th23 = mines destroying vegetation, Th24 = establishment of a pond destroying vegetation, Th25 = trampling, Th26 = pollution, Th27 = rubbish, Th28 = commercial collection of plants.

The 12 indicators

The following indicators were developed for the assessment.

Indicator 1. Proportion of habitat area under documented pressure. We have documented the presence of the discernible threats in each case, so we had the possibility to use the proportion of endangered habitats as an indicator. (Mappers could also indicate "no pressure found locally".)

Indicator 2. Proportion of habitat area affected by invasive species. Considered as the most serious endangering threat, we have evaluated this as a separate indicator.

Indicator 3. Proportion of habitat area affected by game, bush encroachment, drainage or "industrial" forestry. So that to avoid the over-emphasis of the 28 threats, only the most important ones are represented among the indicators; from the 2nd to the 5th most important ones (for the whole country) joined in a common indicator.

Indicator 4a. Proportion of habitat area not connected locally. Local connectedness means the potential of dispersal of the species of one vegetation stand from the surrounding areas at the scale of several hundreds of metres (Molnár *et al.* 2007).

Indicator 4b. Proportion of habitat occurrences not connected locally. The value of Indicator 4 was calculated as the average of two values (4a and 4b), the value weighted by the extension (what is the percentage proportion of the affected extension to the total in Hungary), and the number of occurrences (the percentage proportion of the occurrences (hexagons) of the threat to the total number of the hexagons occupied by the habitat type).

Indicator 5. Proportion of habitat localities not connected at the landscape scale. Landscape level connectedness means the potential of dispersal of the species of one vegetation stand from the surrounding areas at the scale of several kilometres (Molnár *et al.* 2007).

Indicator 6. Proportion of habitat localities with less than 1% cover in the hexagon was calculated (as an estimation of fragmentation).

Indicator 7a. Proportion of habitat area with negative neighbourhood. Effect of the neighbourhood shows whether the neighbouring patches aid or hinder the survival of the particular patch in the next few (10–15) years (Molnár *et al.* 2007).

Indicator 7b. Proportion of habitat occurrences (hexagon) with negative neighbourhood. The value of Indicator 7 was calculated as the average of two values, the value weighted by the extension and the numbers of occurrences.

Indicator 8. Proportion of habitat area of degraded stands. We assumed that the higher is the proportion of degraded patches, the higher is the degree of endangerment the remaining actual stands have to face with.

Indicator 9. Habitat loss in the last 150 years. We estimated (expert assessment on the grounds of landscape history) the proportion of the area lost since the intensification of agriculture in the 19th century: (1) only a smaller part (<20%) was lost, or even expanded in extension; (2) considerable proportion was lost; (3) the majority of the area (above 90%) was lost (see Riecken *et al.* 1994, Essl *et al.* 2002). We assumed that the higher is the proportion of the area lost, the higher is the degree of endangerment the remaining actual stands have to face with (see Riecken *et al.* 2006).

Table 1

Cumulative data of the total extension of the habitats endangered by the threats, calculated for the whole country (taking all vegetation types into consideration, including featerless ones and also calculated separately for woodlands and shrubs, grasslands and wetlands). We also indicated the importance (rank) of the threat indicated by the results of the Corine Biotopes program and the red book. Abbreviations: AA = area (ha) affected; PA = % affected, CR = CORINE rank; RR = Red book rank.

Total					**Woodlands and shrubs**			
Pressure type	AA	PA	CR	RR	Pressure type	AA	PA	RR
Invasive species	553302	21	8	8	Invasive species	194616	33	4
Overpopulated game	245552	9	6	2	Overpopulated game	186067	31	3
Homogeneous forestry	229288	9	3	3	Homogeneous forestry	178956	30	1
Drainage	186942	7	1	1	Improper tree thinning	112672	19	6
Shrub encroachment	147991	6	14	6	Cut at early age	83573	14	8
Improper tree thinning	134022	5	18	13	Improper tree planted	76444	13	2
Improper tree planted	124606	5	2	9	Drainage	25035	4	5
Destroying by ploughing	114843	4	16	13	Rubbish	17987	3	7
Cut at early age	110623	4	15	14	Improper plantation	16179	3	10
Trampling	104113	4	4	9	Trampling	12048	2	9
Lack of mowing	97394	4	15	8	Construction	10635	2	11
Lack of grazing	63670	2	17	16	Shrub encroachment	6886	1	10
Construction	61594	2	12	13	Improper water regime	6762	1	11
Improper plantation	60265	2	16	12	Pollution	5027	1	10
Rubbish	59157	2	10	9	Collection of plants	4802	1	11
Improper mowing	55026	2	17	12	Destroying by ploughing	4626	1	11
Overgrazing	53309	2	11	5	Burning	4116	1	10
Improper water regime	34932	1	17	11	Establish. of new gardens	3293	1	11
Pollution	32168	1	5	4	Lack of grazing	2722	0	11
Undergrazing	24690	1	17	16	Mining	2607	0	7
Grassland melioration	22553	1	18	7	Access water	2221	0	11
Improper grazing	17134	1	14	15	Lack of mowing	1271	0	10
Mining	16718	1	7	10	Overgrazing	523	0	10
Burning	15992	1	9	13	Establish. of new ponds	474	0	11
Establish. of new ponds	15546	1	18	14	Undergrazing	290	0	10
Access water	15515	1	18	16	Improper grazing	82	0	11
Establish. of new gardens	15162	1	12	15	Improper mowing	42	0	11
Collection of plants	6761	0	13	14	Grassland melioration	13	0	11

Table 1 (continued)

Grasslands				**Wetlands**			
Pressure type	AA	PA	RR	Pressure type	AA	PA	RR
Drainage	98038	26	4	Invasive species	28473	27	7
Invasive species	92518	25	6	Drainage	24281	23	1
Shrub encroachment	66856	18	1	Improper water regime	10107	9	4
Destroying by ploughing	65727	18	5	Shrub encroachment	8534	8	6
Trampling	56811	15	5	Pollution	7432	7	2
Lack of mowing	43745	12	3	Construction	5903	6	3
Improper mowing	40951	11	4	Trampling	5781	5	5
Overgrazing	34832	9	1	Destroying by ploughing	5568	5	7
Lack of grazing	28200	8	6	Improper mowing	4689	4	7
Construction	21673	6	10	Rubbish	4527	4	4
Undergrazing	15391	4	8	Lack of mowing	4360	4	5
Improper grazing	13407	4	8	Establish. of new ponds	3060	3	4
Improper water regime	13282	4	6	Access water	2677	3	6
Grassland melioration	12679	3	2	Overpopulated game	2605	2	4
Rubbish	12091	3	7	Lack of grazing	2554	2	7
Improper plantation	11926	3	5	Burning	1926	2	5
Establish. of new ponds	10156	3	10	Mining	1324	1	5
Pollution	8178	2	4	Overgrazing	736	1	5
Access water	8013	2	10	Improper plantation	726	1	7
Mining	8005	2	6	Improper grazing	656	1	6
Overpopulated game	7708	2	3	Collection of plants	494	0	6
Burning	5303	1	7	Establish. of new gardens	441	0	6
Establish. of new gardens	3374	1	8	Undergrazing	238	0	7
Collection of plants	298	0	7	Grassland melioration	50	0	5
Improper tree thinning	0	0	9	Improper tree thinning	0	0	7
Homogeneous forestry	0	0	9	Homogeneous forestry	0	0	7
Improper tree planted	0	0	9	Improper tree planted	0	0	7
Cut at early age	0	0	9	Cut at early age	0	0	7

Indicator 10. Proportion of habitat localities with at least a medium regeneration potential on spot (Molnár *et al.* 2007). We assumed that habitats of higher regeneration potential has lower degree of endangerment (Seregélyes *et al.* 2008).

Indicator 11. Proportion of habitat localities with at least a medium regeneration potential on neighbouring vegetation stands (Molnár *et al.* 2007). We assumed that habitats having the possibility to extend onto the neighbouring vegetation stands have lower degree of endangerment.

Indicator 12. Proportion of habitat localities with at least a medium regeneration potential on arable fields, open water or on rock surfaces (Molnár *et al.* 2007). We assumed that habitats having the possibility to extend onto the neighbouring old-fields, open water or rock surfaces, have lower degree of endangerment.

RESULTS

The 28 endangering threats estimated directly

Taking all the habitats into consideration, most important endangering threats in Hungary are the spread of invasive species (21%, i.e. 21% of the total area covered by (semi-)natural vegetation is endangered), overpopulated game (9%), "industrial" forestry, managing vast areas in the same, homogeneous manner (9%), drainage (7%), bush encroachment (6%) (Table 1). In case of wetlands, the most important threats are invasive species (27%), drainage (23%), improper water dynamics (9%), bush encroachment (8%) and pollution (7%). For grasslands: drainage (26%), invasive species (25%), bush encroachment (18%), tillage (18%), trampling of the vegetation (15%), abandonment of mowing (12%), improper mowing (12%), overgrazing (9%), abandonment of grazing (8%). In case of woodlands: invasive species (33%), overpopulated game (31%), homogeneous woodland management (30%), improper selection of trees for timber extraction (19%), logging trees at low age (14%) and afforestation with improper species (e.g. the preference of the Turkey oak) (13%).

Below, we give an outline of the most important results (Tables 2, 3) (for each threat we evaluate the relative proportion of the affected stands of each habitat types, then we give a list of those vegetation types that are most seriously affected by the threat concerning the absolute value of the extension).

Concerning the proportion of the affected area, drainage has the most serious effects on the fen (D1, D2, C23, B4, J1a, J2) and halophytic vegetation (e.g. F2). The majority of the drained areas, however, are covered by halophytic meadows (F2), mesotrophic meadows (D34) or reed beds (B1a).

Table 2

Endangering forms of land use threatening the different vegetation types (given as the percentage proportion of the affected area), and the degree of endangerment caused by the spread of invasive species and the encroachment of bushes (type of threats is given in brackets)

	Wetlands	Grass-lands	Wood-lands
1. Non-sustainable forestry (Th13, Th14, Th15, Th16)	0	0	59
2. Unfavourable grazing and mowing (Th4, Th5, Th6, Th7, Th8, Th9)	5	19	0
3. Bush encroachment and invasive species (Th11, Th19)	28	33	32
4. Effects of creation of mines, ponds, gardens, buildings, other construction (Th21, Th22, Th23, Th24)	8	9	2
5. Destroyment by tillage, and afforestation (Th20, Th17)	6	19	4
6. Sum of 4 and 5 (Th17, Th20, Th21, Th22, Th23, Th24)	13	23	6

Table 3

Data of the 28 endangering threats (given as the percentage proportion of affected areas for each vegetation type and also for each threat). Abbreviations: VT = vegetation type, 1 = sum area (in hectares), 2 = drainage, 3 = access water, 4 = improper water regime, 5 = undergrazing, 6 = overgrazing, 7 = improper grazing, 8 = lack of grazing, 9 = improper mowing, 10 = lack of mowing, 11 = grassland melioration, 12 = shrub encroachment, 13 = burning, 14 = improper tree planted, 15 = homogeneous forestry, 16 = improper tree thinning, 17 = cut at early age, 18 = improper plantation, 19 = overpopulated game, 20 = invasive species, 21 = destroying by ploughing, 22 = construction, 23 = establishment of new gardens, 24 = mining, 25 = establishing of new ponds, 26 = trampling, 27 = pollution, 28 = rubbish, 29 = collection of plants, 30 = pressure not observed

VT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
A1	5,912	3	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	4	0	0	1	2	15	4	4	66
A23	864	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	7	2	2	81
A3a	938	3	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	0	1	24	9	15	49
A4	4	24	0	1	0	1	0	0	0	0	0	9	0	0	0	0	0	0	1	0	0	1	0	0	0	1	2	0	0	66
A5	655	3	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	2	0	1	57
B1a	58,368	25	4	6	0	0	1	3	0	0	0	8	2	0	0	0	0	1	3	30	7	6	1	1	3	7	7	5	0	34
B1b	4,411	24	0	1	0	1	0	0	1	1	0	4	3	0	0	0	0	2	2	23	0	1	0	1	1	0	0	1	0	59
B2	3,754	15	1	7	0	1	0	1	1	2	0	22	5	0	0	0	0	1	3	32	4	2	0	1	1	6	2	4	0	40
B3	1,377	16	0	17	0	1	0	0	0	0	0	2	0	0	0	0	0	1	1	9	7	4	0	1	1	8	1	4	0	52
B4	711	53	0	1	0	12	0	0	2	2	0	7	7	0	0	0	0	1	9	37	4	2	1	2	3	1	1	1	0	32
B5	11,365	32	0	5	0	2	0	1	3	4	0	12	2	0	0	0	0	2	4	38	5	2	0	0	1	4	2	2	0	31
B6	7,059	18	2	18	1	3	1	1	4	4	0	0	0	0	0	0	0	0	0	6	5	4	0	6	10	11	7	2	0	44
C1	4	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	19	11	0	1	0	0	0	2	0	1	0	65
C23	8	74	0	0	0	0	0	0	0	0	0	71	0	0	0	0	0	0	10	19	0	0	0	0	0	39	0	0	0	5
D1	444	38	0	0	1	21	0	0	6	2	0	2	2	0	0	0	0	1	3	45	7	4	1	1	1	20	7	4	0	16
D2	7,853	67	0	4	1	7	1	1	14	15	1	15	1	0	0	0	0	1	1	25	23	5	0	9	19	6	4	1	0	10
D34	70,998	35	2	7	2	8	3	5	16	14	7	15	2	0	0	0	0	5	2	34	21	4	1	1	1	9	2	3	0	18
D5	662	25	0	1	0	2	1	1	5	10	0	13	1	0	0	0	0	2	11	58	4	3	1	1	1	4	2	6	0	14
D6	2,162	22	0	3	0	2	0	2	3	12	0	14	4	0	0	0	0	1	1	64	6	1	0	0	0	8	3	4	0	13
E1	20,969	13	0	4	3	4	3	12	9	20	12	29	1	0	0	0	0	1	7	34	3	3	1	0	0	7	2	3	1	22
E2	2,744	2	0	0	5	5	2	8	5	31	2	54	4	0	0	0	0	7	16	28	7	3	0	0	0	5	0	2	1	19
E34	876	0	0	0	2	9	0	11	6	17	3	48	6	0	0	0	0	2	10	37	7	3	0	0	0	14	0	7	6	11
E5	20	0	0	0	0	18	0	0	18	0	0	51	0	0	0	0	0	25	21	25	0	18	0	2	0	2	0	0	0	23

Table 3 (continued)

VT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
F1a	30,053	25	1	0	5	14	4	8	8	6	1	1	0	0	0	0	0	0	0	4	13	4	0	1	1	16	2	2	0	38
F1b	42,529	35	0	0	11	10	4	10	10	10	3	1	0	0	0	0	0	0	0	12	15	6	0	0	1	22	2	3	0	22
F2	89,764	41	7	6	5	9	5	10	16	12	2	5	0	0	0	0	0	1	0	16	24	6	0	3	5	16	3	2	0	22
F3	826	24	0	1	0	1	7	3	9	11	3	11	0	0	0	0	0	4	0	20	27	14	1	0	0	20	5	6	0	26
F4	5,936	35	1	16	1	8	6	1	4	6	1	0	0	0	0	0	0	0	0	0	9	6	0	7	14	34	2	3	0	23
F5	2,511	21	0	2	4	9	4	7	1	0	0	0	0	0	0	0	0	0	0	0	4	4	0	1	1	27	2	2	0	46
G1	9,564	0	0	0	1	13	0	2	0	0	0	48	1	0	0	0	0	7	0	69	3	7	0	1	0	14	0	6	0	7
G2	754	0	0	0	1	13	0	0	0	1	0	5	2	0	0	0	0	2	11	13	0	12	0	10	0	44	0	6	0	25
G3	231	0	0		12	1	0	1	0	0	0	16	1	0	0	0	0	1	51	5	0	2	0	2	0	24	0	7	0	27
H1	99	0	0	0	0	1	0	0	1	0	0	12	9	0	0	0	0	0	26	1	0	1	0	1	0	30	0	2	0	53
H2	5,617	0	0	0	0	7	0	0	0	4	0	46	8	0	0	0	0	15	9	18	1	10	4	6	0	33	1	12	0	16
H3a	9,298	1	0	1	4	9	1	4	1	7	0	48	7	0	0	0	0	2	12	15	2	4	2	2	0	26	2	5	0	18
H4	15,221	0	0	0	4	3	1	9	3	21	0	68	6	0	0	0	0	3	8	30	3	5	2	2	0	14	3	4	0	10
H5a	24,368	0	0	1	2	11	4	10	8	12	2	39	2	0	0	0	0	6	3	31	22	11	2	2	1	19	4	5	0	19
H5b	28,324	0	1	0	2	15	4	5	7	7	3	32	1	0	0	0	0	11	1	47	34	12	2	5	6	12	1	5	0	11
I2	61	0	0	0	0	6	0	6	0	1	0	14	1	0	0	0	0	0	3	59	10	12	1	1	0	4	0	21	0	9
I4	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	4	0	0	0	0	0	3	0	0	0	57
J1a	1,521	41	0	2	0	1	0	0	0	0	0	1	1	0	0	0	1	0	4	29	3	2	0	0	1	1	2	3	1	35
J1b	20	28	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	18	0	0	0	0	0	0	0	0	0	56
J2	3,531	44	0	1	0	0	0	0	0	0	0	1	1	1	12	1	11	0	20	55	1	0	0	0	0	0	2	2	0	24
J3	1,264	6	0	2	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	41	0	3	0	1	0	7	1	9	0	49
J4	20,927	7	1	24	0	0	0	1	0	0	0	1	0	7	11	3	30	2	3	83	1	6	1	1	0	3	1	6	1	7
J5	14,972	30	1	1	0	0	0	2	0	0	0	1	0	7	12	4	6	1	18	64	2	2	0	0	0	1	2	4	0	16
J6	16,374	23	1	5	0	0	0	2	0	0	0	2	0	20	44	13	12	2	22	48	2	1	0	0	0	1	1	2	0	12
K1a	34,399	4	0	0	0	0	0	0	0	0	0	0	0	22	32	26	13	5	40	43	1	1	0	0	0	1	0	1	1	14
K2	152,321	1	0	0	0	0	0	0	0	0	0	0	0	17	33	23	17	2	35	26	0	1	0	0	0	2	1	3	1	21
K5	90,314	0	0	0	0	0	0	0	0	0	0	0	0	10	49	23	16	1	38	15	0	1	0	0	0	2	0	1	0	16
K7a	1,847	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	1	0	2	1	0	0	0	0	0	0	0	0	0	1
K7b	1,817	0	0	0	0	0	0	0	0	0	0	1	0	10	20	24	44	2	51	9	0	7	0	2	0	0	0	1	1	12
L1	19,824	0	0	0	0	0	0	0	0	0	0	2	0	16	14	16	6	7	42	18	0	5	3	1	0	7	1	5	0	20

Table 3 (continued)

VT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
L2a	126,273	0	0	0	0	0	0	0	0	0	0	1	1	12	35	25	14	3	37	31	1	2	0	0	0	2	1	3	1	15
L2b	14,497	3	0	1	0	0	0	0	0	0	0	0	0	34	49	36	19	3	35	48	0	0	0	0	0	1	0	3	0	6
L2x	6,060	0	0	0	0	0	0	0	0	0	0	0	1	8	15	20	31	12	30	49	2	3	1	1	0	1	0	4	3	19
L4a	398	0	0	0	0	0	0	0	0	0	0	7	0	1	20	7	13	0	55	7	0	6	3	3	0	4	0	6	0	16
L4b	2,437	0	0	0	0	0	0	0	0	0	0	2	0	8	33	12	18	3	29	20	0	5	1	1	0	5	0	10	1	25
L5	8,954	14	7	0	0	0	0	8	0	0	0	6	0	21	37	19	23	8	21	67	3	3	0	0	1	3	1	8	0	8
LY1	731	0	0	0	0	0	0	0	0	0	0	0	0	2	6	7	7	2	29	10	0	3	0	0	0	11	2	8	0	50
LY2	2,444	1	0	0	0	0	0	0	0	0	0	0	0	4	9	7	11	1	45	5	0	2	0	1	0	5	0	4	1	41
LY3	1,168	0	0	0	0	0	0	0	0	0	0	0	0	4	4	3	6	0	15	0	0	0	0	0	0	2	0	0	0	74
LY4	1,910	0	0	0	0	0	0	0	0	0	0	0	0	3	19	10	7	1	56	5	0	1	0	0	0	6	0	2	0	31
M1	2,732	0	0	0	0	0	0	0	0	0	0	2	1	7	4	0	2	3	49	20	0	2	2	2	0	9	0	4	0	25
M2	180	0	0	0	0	1	0	4	1	11	0	26	0	6	10	15	35	12	27	42	0	1	3	0	0	7	1	9	2	20
M3	213	8	13	2	0	0	5	14	0	18	0	19	5	3	12	1	16	8	12	45	9	1	0	0	0	1	1	2	0	20
M4	389	7	0	2	4	0	0	2	0	2	0	9	0	13	20	8	20	26	18	74	0	1	0	0	0	9	0	7	1	12
M5	1,889	2	0	0	0	0	0	0	0	0	0	2	0	1	19	0	5	24	1	49	0	0	0	1	0	5	0	1	0	16
M6	112	0	0	0	1	0	0	0	0	0	0	23	4	0	0	0	0	1	16	13	7	5	3	4	0	5	0	10	0	38
M7	129	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	30	0	0	0	0	0	1	8	0	0	0	53
M8	366	0	0	0	0	0	0	1	0	1	0	10	2	1	26	2	2	4	15	28	0	2	0	0	0	5	0	4	2	31
N23	1,108	1	0	0	0	0	0	0	0	0	0	0	0	1	0	2	78	2	50	3	0	0	0	1	0	1	0	0	0	10
N2	61	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	21	0	32	77	0	17	0	1	0	0	0	0	1	2
P2a	16,109	17	2	3	0	0	0	1	0	1	0	0	1	0	0	0	1	1	10	58	5	3	1	0	1	1	2	4	0	23
P2b	39,823	1	0	0	1	1	0	1	0	3	0	0	4	1	0	0	1	3	10	45	2	2	2	1	0	2	2	4	1	34
P45	5,238	9	0	0	9	2	4	18	1	23	0	49	3	2	0	0	4	1	22	44	3	1	1	0	0	4	2	2	0	12
P7	3,064	1	0	3	3	0	0	4	10	28	1	40	7	0	0	0	6	3	4	55	3	7	8	1	0	1	0	4	1	12

Under-management (undergrazing, abandonment of grazing and mowing) affects at least 20% of the grasslands, principally meadows, and grasslands with woodland origin (e.g. E1, E2, E34, P45, P7, H4, F1b, F2, D2, D34, H5a). Encroachment of shrubs endangers principally the grasslands with woodland origin (E2, E34, E5, H2, H3a, H4, P45, P7, G1), yet the absolute extension of the area invaded by shrubs is the largest in case of the meadows (D34, E1) and steppes (H4, H5a, H5b). Invasive species infect most seriously the riverine willow-poplar woodlands (J4) and sand oak woodlands (M4), but the largest areas are invaded in the oak-hornbeam woodlands (K2) and Turkey oak woodlands (L2a) (see also Botta-Dukát 2008). Encroachment of bushes and invasive species endangers 33% of the grasslands (G1, H4, P45, P7, M4, J4, N2, E5, E34). Melioration (though repressed) even nowadays endangers our meadows and steppe meadows (D34, E1, F1b, F2, H5a, H5b).

"Industrial" forestry threats at least 59% of the woodlands. Homogeneous management of woodland patches and afforestation with improper species endanger chiefly the woodlands of better site conditions, with deep soil (K2, K5, K1a, L2a, L2b, L5, J6). Afforestation threats the clearings of steppe woodlands (M2, M4, M5), the *Calluna* heaths (E5) and slope steppes (H3a) to the highest proportion, while the most extended areas are threatened on meadows (D34, F2) and steppes (H5a, H5b). Overpopulated game degrades the highest proportion in case of rock vegetation (LY2, LY4, L4b, K7b, M1, G3), and widest areas, however, were observed being degraded by game in the zonal woodlands (L2a, K2, K5).

Direct devastation of habitats affects 23% of grasslands, only 13% of wetlands and merely 6% of woodlands. (The following treats were treated as a common category: tillage, building and construction, afforestation, establishment of ponds, spread of gardens or mines destroying vegetation.) Tillage endangers the grasslands formed on rather thick, but not rocky soil, and those of lower salt concentration (D2, D34, H5a, H5b, F1a, F1b, F2, F3); spread of gardens destroys our extensive orchards (P7) and calcareous rock steppes (H2) to the highest proportion, and the widest area in case of the dry shrub vegetation (P2a), mesotrophic meadows (D34) and thermophilous oak woodlands (L1). Maybe surprisingly, mining considerably destroys our non-rock vegetation, too (cf. loess, sand and gravel-pits, temporary ponds). Burning by humans destroys the widest areas in case of the meadows (D34), dry shrubs (P2a) and reed beds (B1a).

The values of the 12 indicators

On the basis of Indicator 1 (proportion under pressure), least endangered habitats are the edaphic ones (A1, A23, A4, A5, C1, B1b, J1b, B3, LY1, LY3, M7, H1, I4), i.e. certain rock, fen and aquatic habitats (Table 4). The highest proportion was documented as endangered in case of calcareous Scots pine woodlands (N2), Turkey oak-pedunculate oak woodlands (L2b), transition mires and raised bogs (C23), closed lowland steppe oak woodlands (L5), riverine willow-poplar woodlands (J4), open sand steppes (G1), sand steppe oak woodlands (M4), forest steppe meadows (H4), etc. Values of Indicator 2 and 3 were evaluated in the section above.

Assessment of Indicator 4a and 4b (isolatedness) is more difficult, because some habitats turn up in small, isolated patches even among natural circumstances, so not obviously the fragmentation of the landscape sorted them among the first lines of the list (e.g. C23, M6, J1b, I2, H1, C1, M7, A4). These biologically irrelevant values were ignored. The fragmentation – and so the isolation – of other vegetation types may have considerably increased as a result of the devastation of the landscape (e.g. M4, B4, D5, H4, D2, M2, F3). Local isolation endangers least seriously the coniferous woodlands mixed with deciduous species (N13), oak-hornbeam woodlands (K2), riverine willow-poplar woodlands (J4), Turkey oak woodlands (L2a), beech woodlands (K5), etc.

The same conclusions can be stated for Indicator 5 (isolatedness on the landscape level). Least isolated habitats are the coniferous woodlands mixed with deciduous species (N13), zonal woodlands (e.g. L2a, K2, K5) and usually the riverine and the halophytic habitats (e.g. J4, F1a, F1b). A generally observed tendency is that the values of local isolatedness are considerably lower than those of the landscape level, what might be decisively explained by the fragmented structure of the landscape, developed as a result of tillage, plantations and settlements.

The values of Indicator 6 (the proportion of habitats with less than 1% cover in a hexagon, i.e. 0.35 ha) can be explained partially by natural, partially by human causes. We attributed the high proportion of the small fragments to human influence in case of the following habitats: E5, A3a, A23, B4, D6, B6, F3, B5, M2, H4, H5a, etc. Obviously, lowest is the proportion of small fragments in the zonal woodlands.

On the grounds of Indicator 7 (neighbourhood), the least endangered vegetation types are the rock and the acidophilous woodlands (K7a, K7b, LY4, L4b), aquatic habitats (A1, A23, A3a, A5), the highly halophytic (F5) and riverine habitats (J3), rock grasslands (I4, G2) and the zonal woodlands (K2, K5), while most destructive is the neighbourhood of the *Calluna* heaths (E5), sand steppe oak woodlands (M4), sand steppes (G1, H5b), acidophilous pine woodlands (N13), and *Molinia* meadows (D2).

Worst are the values of degradation as a threat (Indicator 8) in case of mesic and dry shrub vegetation (P2a, P2b), closed steppes on loess (H5a), hay meadows (E1), salt steppe oak woodlands (M3), slope steppes (H3a), vegetation of the loess cliffs (I2), closed sand steppes (H5b), xero-mesophilous grasslands (H4). The highest is the value of this indicator for limestone beech woodlands (LY3), aquatic communities with *Nymphaea* (A23), certain halophytic habitats (F4, B6, F5), steppe thickets (M6), ravine and slope woodlands (LY1, LY2). For a more detailed evaluation of the values of this indicator see Bölöni *et al.* (2008).

Historical loss (Indicator 9) affected most seriously the wetlands (e.g. B1a, B2), zonal woodlands (e.g. L2a, K2), and least the rock vegetation (e.g. G2, G3, I4).

Indicators of regeneration potential indicated that best is the regeneration ability on the spot (Indicator 10) in case the aquatic habitats (A1, A3a, A5), shrub vegetation (P2b), halophytic vegetation (F1a, F1b, F2, F4); this value is the lowest for the forest steppe woodlands (M4, L5, M3, M2, L2x). Quite easily invade the neighbouring vegetation patches (Indicator 11) the halophytic vegetation types (F1a, F1b, F2, F4), the poplar-juniper steppe woodlands (M5), moist and dry shrub vegetation (P2a, P2b), certain aquatic habitats (e.g. A3a); poor or no invasion was observed in case of the xeric woodlands (L1, L2b, L4a, L4b, K7a), rock vegetation (H1, M7, LY1, LY2, LY3, LY4) and the rich fens (D1). Relatively well regenerate on new open surfaces (Indicator 12) the dry shrub vegetation (P2b), the poplar-juniper steppe woodlands (M5), acid coniferous woodlands (N13), halophytic habitats (F1a, F1b, F2, F3), certain aquatic habitats (A3a) and marshes (B1a, B6); no or poor regeneration was observed in case of certain swamp, bog and fen vegetation types (D1, C23, J1b, C1, J2), forest steppe oak woodlands (M3, M4), some of the rocky vegetation types (H1, M7, LY1, LY3, LY4), acidophilous woodlands (K7a, L4a, L4b) and calcareous Scots pine woodlands (N2). For more detailed evaluation of the regeneration potential see Seregélyes *et al.* (2008).

The overall degree of endangerment of the Hungarian vegetation

Based on the synthesis of endangering threats, habitats with the highest degree of endangerment in Hungary are as follows: open sand and loess steppe oak woodlands (M2, M4), tussock sedge communities (B4), traditionally managed extensive orchards (P7), closed lowland steppe oak woodlands (L5, L6), water-fringing and fen tall herb communities (D5), wooded pastures (P45), vegetation of loess cliffs (I2), rich fens and *Molinia* meadows (D1, D2), Cynosurion grasslands and *Nardus* swards (E34), swamp woodlands (J2), xero-mesophilous grasslands (H4) and salt steppe oak woodlands (M3).

The least endangered habitats are the rock habitats (I4, LY3, H1, G2, M7), some of the halophytic habitats (F1a, F5, F1b, F2, B6) and aquatic habitats and marshes (A23, A3a, A1), open acidophilous oak woodlands (L4b), dry shrub vegetation with *Crataegus* and *Prunus spinosa* (P2b) and beech woodlands (K5).

DISCUSSION

Concerning a sufficient amount of sites, endangering threats were estimated for the first time in Hungary in course of the Corine Biotopes Program (Kovács-Láng *et al.* 1997, field observations originate from the second half of the 1980s and the first half of the 1990s) (Table 1). Although the survey covered the whole country, the results were biased because dominantly the most outstanding natural values were assessed, which themselves are often recreational areas, as well (e.g. effect of tourism was overestimated). Nevertheless, data of the Corine Biotopes Program provided valuable information to analyse changes of endangerment in Hungary. In comparison with our analysis, they regarded pollution (basically eutrophisation) a more serious threat (being most frequently mentioned in comparison with other threats), and experts evaluated also melioration as an important risk for the vegetation. Overgrazing was considered to be a more serious problem than undergrazing (today it is just in the other way round), and rather mowing was missed than grazing. Due to the high proportion of the rock habitats, the role of overpopulated game was overemphasised. The spread of invasive species did not affect as wide areas as nowadays, but the encroachment of the shrubs was, however, advanced already those days.

So far, the most detailed evaluation of the degree of endangerment in Hungary, which was based on expert assessment, was published in the Red Book (371 plant communities, Borhidi and Sánta 1999). Summarising the endangering threats mentioned for the plant communities (Table 1, for the algorithm see the Methods section), we drew the conclusion that the authors considered the coniferous woodlands, fen and steppe habitats and natural shrub vegetation as the most threatened vegetation types. Most important (most often mentioned) threats were the followings (in the order of their importance, semi-quantitative estimation): drainage, overpopulated game, homogeneous woodland management, pollution, overgrazing, encroachment of shrubs, the abandonment of mowing and grazing. In case of wetlands these were the drainage and pollution, on grasslands the overgrazing, encroachment of shrubs, melioration, the abandonment of mowing and grazing, overpopulated game, in case of woodlands the homogeneous management, afforestation with improper species, overpopulated game, plantation and spread of invasive species. Spread of invasive species was not so emphasised as it is today, however, the effect of mines, rubbish and melioration may have been overestimated (some of the authors might have had 5- or even 15-year-old field experience, and often focused on the sites of outstanding conservational value). Partly on the grounds of the degree of endangerment, they proposed several communities for protection: coniferous woodlands, Pannonian steppes, Pannonian rock grasslands, natural shrub communities, bogs, rich fens, rare aquatic habitats (some communities were recommended for protection, despite being less threatened, principally owing to their national significance; for example, the sand poplar-juniper steppe woodlands).

Borhidi and Sánta (1999) documented some threats that were not evaluated expediently in the MÉTA program. These are the leaching of salts in halophyte habitats, water quality (e.g. salt content, temperature) in case of wetlands, erosion, the obstruction of the free water movements of the rivers, acidification of the soil, the spread of aggressive species (other than shrubs or invasive species, e.g. the quick spread of reed, ash or *Elymus repens*). However, these seemed to be insignificant at the country level.

When evaluating the results, we have to take into consideration that in the MÉTA survey we assessed the degree of endangerment of the total vegetation heritage of Hungary (e.g. zonal woodlands, hay fields, pastures, all the rock grasslands, all the bogs), and not only the areas of the highest value of naturalness, with substantial ecological value.

We would also like to stress, that the degree of endangerment of the habitats, calculated for the whole country as an average of the ranks of the 12 indicators is measured on a relative scale. It indicates the habitats that are more or less threatened than the average calculated for the whole country. It is important to note, that the numbers are averages, thus considerable regional differences may occur among the values of the certain vegetation types (for instance, open sand grasslands has higher degree of endangerment in the Somogy or the Nyírség, than the average calculated for the whole country; the loess steppes are more seriously threatened on the Great Hungarian Plain, the mesotrophic meadows in southwestern Transdanubia, the riverine willow-poplar woodlands in the valley of the Tisza). It is hard to compare our results with those of the German assessment (Riecken *et al.* 2006), because that survey estimated the endangerment status of the habitat types on the basis of the mere proportion of the endangered habitats covered by a certain habitat to the total number of the habitats, and not on the grounds of the total extension of threatened habitats.

During the quality control of the database we found heterogeneity among the field results, thus we propose to change certain values, what is indicated with a number (e.g. +5) in the last column of Table 4. Our decision can be reasoned, for example, by the fact that some mappers classified the almost featureless, marginal stands of some habitats into the main category of the habitat type, what increased the rank of the indicators (such habitats are e.g. D5, E34, H4, G1, J5, H3a). In case of other vegetation types, the degraded stands were sorted into another habitat category, what lowered the estimated degree of endangerment (e.g. in case of L2x, L6).

FUTURE PROSPECTS

Since the effects of different threats on the habitat types are qualitatively quite different, also the consequences for nature conservation are not the same. The degree of endangerment of the remained (semi-)natural vegetation of Hungary can be decreased in several different ways. In one respect with local protection, local management (e.g. grazing, eradication of shrubs or water management) and with the elaboration of European or county scale strategies for nature conservation (e.g. agro-environmental management), or indirectly, by reducing the driving forces through the influence of environmental consciousness. With our results presented above, we would like to support all these crucial decisions e.g. by providing data that can be applied directly in the assessment of the DPSIR model.

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