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Effectiveness of Natura 2000 system for habitat types protection: A case study from the Czech Republic

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Abstract

In conservation biology, there is a general consensus that protected areas (PAs) are one of the most effective tools for biodiversity protection. Worldwide, the area of PAs is continually increasing. But is the effectiveness of biodiversity protection improving with it? Since many PAs only exist as "paper parks" (i.e. they exist on maps and in legislation but offer little actual protection), the answer is uncertain. Moreover, it has long been known that, not only an increase in the extent of PAs, but also the efficiency of their management is fundamentally important for effective nature conservation. Therefore, there is a wide-ranging discussion about the actual effectiveness of PAs and factors that influence it.

In the course of the EU pre-accession phase, a comprehensive field mapping of natural habitats took place in the Czech Republic in years 2001–2004. The mapping results were used to designate Special Areas of Conservation (SACs) as part of the Natura 2000 network.

In this study, the aim was to evaluate the effectiveness of this newly created system of SACs for protection of biodiversity represented by the mapped natural habitats. The NCEI index (Nature Conservation Effectiveness Index) was applied, calculated as the total area of a particular habitat type in all SACs in the Czech Republic divided by the total area of that same natural habitat in the entire Czech Republic. Habitat protection in the Czech Republic is focused primarily on the smallest types of rare habitats, many of which are classified as critically endangered. The Czech national system of SACs provides protection to a total of 4,491.68 km^2 of natural habitats. Based on these results, it can be concluded that the overall effectiveness of the SAC system in the Czech Republic, which is specifically aimed at protecting natural habitats, is low (NCEI = 0.36). Nevertheless, the critically endangered habitats receive maximum protection (NCEI = 1).

Keywords

Conservation effectiveness, natural habitats, mapping, Nature Conservation Effectiveness Index, Special Areas of Conservation

Introduction

The World Database on Protected Areas (WDPA), managed since 1981 by the UN Environment World Conservation Monitoring Centre based in Cambridge, UK, also included World Heritage sites such as the historic centre of Prague (Plesnik 2012). A significant shift in the international concept of PAs was brought in by a new definition proposed by IUCN in 2008 (Dudley et al. 2010). As claimed by the new definition, a protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values. According to Ervin et al. (2010), establishment of PAs and their community perception went through three distinct stages over the years: (1) A classic approach from the 19th century until the 1970s was based on the notion that PAs can exist independently from the surrounding landscape and the benefits of the PAs for the local population were considered irrelevant. (2) A modern approach, promoted with different intensity in different parts of the world, is based on a greater recognition of the needs of local residents in PAs. The cornerstone of the modern approach is the recognition of the fact that it is not enough for nature conservation to keep establishing new PAs as isolated islands of nature in the midst of a man-altered landscape, but that the actual effectiveness of the PAs is essential for maintaining biodiversity. (3) The current approach considers PAs as a strategy for sustaining life-giving processes in nature that provide benefits to society, anthropocentrically referred to as ecosystem services. Management of PAs is perceived as an interdisciplinary affair, beneficial to both nature and humans (Machar et al. 2016).

The extent of PAs worldwide is slowly but steadily increasing. More than 80% of today's PAs have been established after 1962, when the 1st World Congress on National Parks was held in Seattle (Chape et al. 2005). Between 1993 and 2008, the number of PAs in the world has doubled and their total area increased by 60% (UNEP 2008).

In 2010, the 10th COP to the CBD in Nagoya resulted in ambitious targets: to increase the area of the world PAs to 17% on land and 10% in the sea (including coastlines) by 2020, while ensuring that the applied conservation management is effective and the system of PAs is representative, interconnected and integrated into the surrounding unprotected landscape. In the context of ongoing climate changes, the importance of PAs for preserving biodiversity is further increasing and brings even more ambitious proposals. One of them suggests protecting a minimum of 25% of land and 15% of sea in order to maintain global priority areas for the conservation of global biodiversity and ecosystem services, particularly carbon sequestration (Conservation International 2010, Jenkins and Joppa 2009).

In the strongly anthropogenically altered Europe, nearly all PAs (90%) are smaller than 10 km^2 (Gaston et al. 2008), which makes it really difficult, for example, to effectively protect populations of large vertebrates (Kovarik et al. 2014).

Although the percentage limits for the total minimum extent of PAs on land and sea may be relatively good indicators of conservation effectiveness, it is obvious that these figures say nothing about whether the individual PAs are large enough, whether they are appropriately spatially arranged and whether they host key species and resources (Power et al. 1996). In other words, they say nothing about whether or not the PAs effectively fulfil their purpose (Hockings et al. 2006).

Worldwide, the area of PAs is continually increasing. But is the effectiveness of biodiversity protection improving with it? Since many PAs only exist as "paper parks" (i.e. they exist on maps and in legislation but offer little actual protection), the answer is uncertain. Moreover, it has long been known that not only an increase in the extent of PAs, but also the efficiency of their management is fundamentally important for effective nature conservation. Therefore, there is a wide-ranging discussion about the actual effectiveness of PAs and factors that influence them (Joppa and Pfaff 2009; Leverington et al. 2010; Simon et al. 2014).

In the post-World War II Czech Republic, the effectiveness of PAs has been addressed within the national framework of PAs with the aim of including all rare habitat types. This effort, however, had not been successful until the end of the 20th century (Bucek and Machar 2012). PAs, during the Communist era, were of a large extent but their conservation regime corresponded to that of "paper parks" (Lipsky 1995). These PAs received a real protection only after the change in the political regime in 1992 under the new Nature Conservation Act. In the course of the EU pre-accession phase, a comprehensive field mapping of natural habitats took place in the Czech Republic in the years 2001–2004. The mapping results were used to designate the Special Areas of Conservation (SACs) as a part of the Natura 2000 network.

The aim of this paper is to evaluate the effectiveness of the Natura 2000 network (Miko 2012), using the Czech Republic as a case study. To date, the effectiveness of PAs in the Natura 2000 network in protecting biodiversity has been addressed by a number of studies that generally confirm the positive protective effect of this European conservation concept. For example, Donald et al. (2007) showed that through establishing Special Protection Areas (SPAs), the Birds Directive successfully provides protection to the most endangered European bird species and it has prevented further decline of many bird populations. According to Sanderson et al. (2015), the bird species listed in Annex I of the Birds Directive show more positive trends both in short and long terms in comparison with species not listed in the Annex. The longer the enforcement of the Birds Directive in each particular country, the more obvious is the trend. Although protection of migratory birds on their nesting sites only, for example, is insufficient, it still has a demonstrable positive effect on these populations even in times of climate change. The SPAs also influence non-target species (Brodier et al. 2013). On the other hand, some SPAs in agricultural landscapes sustain target species and species adapted to fallow land but do not support other species (Santana et al. 2013). It is therefore necessary to also focus on non-target species and better link nature conservation and agricultural policy.

In this study, the effectiveness of the Natura 2000 network was analysed with a special focus on the SACs that are primarily designated to protect natural habitats. The aim of this paper was to evaluate the effectiveness of habitat conservation for all mapped natural habitats in the territory of the Czech Republic in the context of the Natura 2000 conservation objectives, i.e. preserving the existing character of the natural habitat types.

Materials and methods

To evaluate the effectiveness of SACs in the Czech Republic, data collected during a national habitat field survey conducted in the period 2001–2004 were used. The survey under the Habitats Directive, formally known as the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, was carried out over the entire territory of the Czech Republic on a scale of 1:10,000. The survey results were summarised in the Habitat Catalogue of the Czech Republic (hereinafter referred to as the "Catalogue") (Chytry et al. 2010) listing a total of 156 natural habitats (Table 1). The field survey provided detailed data on the diversity of canopy, shrub and herb layers of specific mapped habitat segments and basic data on ecological quality of individual habitats. All results have been completely digitised and used to designate Special Areas of Conservation as defined by Annex III of the Habitats Directive (Loncakova 2009).

Species rarity is usually evaluated based on three criteria: geographic distribution, habitat requirements and abundance. Species conservation efforts predominantly focus on habitat specialists with restricted distribution (e.g. endemic species or isolated relict populations of rare species) or species with a broad geographic range but strong ties to rare habitats. A similar approach is being applied to habitat protection. Particular attention is paid to unique habitats tied to geographically or ecologically rare phenomena (e.g. serpentinites or glacial corries). With more widespread habitats, conservation efforts focus on those that can only be found on very small areas with specific natural conditions (springs, salt marshes etc.). Therefore, data on abundance and distribution may provide sufficient guidance needed to assess the degree of vulnerability of individual habitat types. Following the publication of the Catalogue, the Red Book of Habitats of the Czech Republic (RBH) was produced in 2005 (Kučera 2012). Based on a detailed field survey, the Red Book of Habitats provides a critical evaluation of data on occurrence and spread of individual habitats

Table 1. Conservation effectiveness of natural habitats in the Czech Republic.

Habitat type	Natura 2000 habitat code	Habitat code (Chytrý et al. 2010)	Total area of habitat in Czech Republic [km²]	Code of vulnerability (Kučera 2012)	Number of habitat segments in SAC	Total area of habitat in the SAC [km²]	NCEI
Wind-swept alpine grasslands	6150	A1.1	1.65	VU	107	1.65	1
Closed alpine grasslands	6150	A1.2	7.59	VU	355	7.59	1
Alpine heathlands	4060	A2.1	1.26	VU	121	1.26	1
Subalpine *Vaccinium* vegetation	4060	A2.2	4.8	VU	455	4.8	1
Snow beds	6150	A3	0.02	CR	12	0.02	1
Subalpine tall grasslands	6430	A4.1	7.28	NT	821	7.28	1
Cliff vegetation in the Sudeten cirques	8220	A5	0.03	CR	11	0.03	1
Acidophilous vegetation of alpine cliffs	8220	A6B	0.41	NT	116	0.41	1
Pinus mugo scrub	4070	A7	12.17	VU	376	12.17	1
Salix lapponum subalpine scrub	4080	A8.1	0.04	CR	5	0.04	1
Subalpine deciduous tall scrub	4080	A8.2	0.29	NT	39	0.29	1
Low xeric scrub, secondary vegetation with *Prunus tenella*	40A0	K4B	0.01	CR	6	0.01	1
Calcareous fens with *Cladium mariscus*	7210	M1.8	0.04	CR	7	0.04	1
Vegetation of annual halophilous grasses	–	M2.4	0.04	CR	1	0.04	1
River gravel banks with *Myricaria germanica*	3230	M4.2	0.13	CR	1	0.13	1
River gravel banks with *Calamagrostis pseudophragmites*	3220	M4.3	0.07	EN	47	0.07	1
Subalpine springs	–	R1.5	0.07	VU	113	0.07	1
Peat soils with *Rhynchospora alba*	7150	R2.4	0.14	EN	48	0.14	1
Tall-forb vegetation of fine-soil-rich boulder screes	–	S1.4	0.06	VU	35	0.06	1
Subalpine *Nardus* grasslands	6230	T2.1	1.5	VU	296	1.5	1
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Salvinia natans*	3150	V1D	0.05	EN	6	0.05	1
Isoëtes vegetation	3130	V6	0.25	CR	2	0.25	1
Acidophilous vegetation of alpine boulder screes	8110	A6A	1.84	NT	417	1.83	0.99
Montane *Nardus* grasslands with alpine species	6230	T2.2	7.86	VU	1293	7.8	0.99
Subalpine tall-fern vegetation	6430	A4.3	0.54	NT	123	0.53	0.98
Bog hollows	7110	R3.3	0.84	EN	253	0.81	0.96
Basiphilous vegetation of vernal therophytes and succulents with dominance of *Jovibarba globifera*	6110	T6.2A	1.11	EN	36	1.07	0.96
Pinus rotundata bog forests	91D0	L10.4	10.01	EN	119	9.54	0.95
Open raised bogs	7110	R3.1	6.31	EN	732	5.98	0.95
Raised bogs with *Pinus mugo*	91D0	R3.2	17.04	EN	616	16.11	0.95

Vegetation of exposed bottoms in warm areas	3130	M2.3	0.32	EN	8	0.29	0.91
Pannonian sand steppe grasslands	6260	T5.4	0.98	VU	62	0.89	0.91
Acidophilous thermophilous oak forests with *Genista pilosa*	91I0	L6.5A	2.17	VU	187	1.93	0.89
Narrow-leaved dry grasslands with significant occurrence of orchids	6210	T3.3C	0.35	VU	12	0.31	0.89
Broad-leaved dry grasslands with significant occurrence of orchids and without *Juniperus communis*	6210	T3.4C	9.74	VU	259	8.6	0.88
Peri-Alpidic serpentine pine forests	–	L8.3	0.45	EN	33	0.39	0.87
Pannonian thermophilous oak forests on loess	91I0	L6.2	16.54	VU	371	13.98	0.85
Degraded raised bogs	7120	R3.4	7.85	NT	377	6.65	0.85
Montane sycamore-beech forests	9140	L5.2	9.21	VU	686	7.73	0.84
Montane *Calamagrostis* spruce forests	9410	L9.1	438.81	VU	6485	366.79	0.84
Montane grey alder galleries	91E0.	L2.1	5.56	VU	671	4.64	0.83
Calcareous fens	7230	R2.1	0.4	VU	77	0.33	0.83
Boreo-continental pine forests with lichens on sand	91T0	L8.1A	11.73	VU	718	9.53	0.81
Willow scrub of river gravel banks	3240	K2.2	0.76	VU	153	0.61	0.8
Sesleria grasslands	6190	T3.2	0.38	VU	144	0.3	0.79
Dry lowland and colline heaths with occurrence of *Juniperus communis*	5130	T8.1A	0.14	VU	26	0.11	0.79
Montane *Athyrium* spruce forests	9410	L9.3	9.44	EN	355	7.25	0.77
Peri-Alpidic basiphilous thermophilous oak forests	91H0	L6.1	9.11	VU	468	6.91	0.76
Sub-Pannonian steppic grasslands	6240	T3.3A	3.46	VU	293	2.62	0.76
Unvegetated river gravel banks	–	M4.1	1.82	VU	438	1.37	0.75
Pannonian loess steppic grasslands	6250	T3.3B	0.76	EN	46	0.57	0.75
Continental inundated meadows	6440	T1.7	11.56	EN	319	8.49	0.73
Bog spruce forests	91D0	L9.2A	60.02	EN	1935	43.05	0.72
Continental tall-forb vegetation	6430	T1.8	0.07	CR	6	0.05	0.71
Hardwood forests of lowland rivers	91F0	L2.3	241.38	EN/VU	6140	170.07	0.7
Transitional mires	7140	R2.3	29.81	EN	2971	20.97	0.7
Macrophyte vegetation of water streams with currently present aquatic macrophytes	3260	V4A	29.71	NT	738	20.73	0.7
Pannonian thermophilous oak forests on sand	91I0	L6.3	13.73	VU	384	9.54	0.69
Submontane and montane *Nardus* grasslands with scattered *Juniperus communis* vegetation	5130	T2.3A	3.32	VU	461	2.27	0.68
Ribes alpinum scrub on cliffs and boulder screes	–	S1.5	0.36	VU	193	0.24	0.67
Mobile screes of basic rocks	8160	S2A	0.24	VU	67	0.16	0.67
Subalpine tall-forb vegetation	6430	A4.2	0.41	NT	169	0.27	0.66
Broad-leaved dry grasslands with significant occurrence of orchids and with *Juniperus communis*	6210	T3.4A	0.6	EN	21	0.39	0.65

Pannonian-Carpathian oak-hornbeam forests	91G0	L3.3A	42.59	---	794	27.12	0.64
Limestone beech forests	9150	L5.3	9.6	VU	362	6.19	0.64
Annual vegetation on wet sand	3130	M2.2	0.11	VU	14	0.07	0.64
Acidic moss-rich fens	7140	R2.2	20.83	VU	1887	13.08	0.63
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Hydrocharis morsusranae*	3150	V1A	0.13	VU	59	0.08	0.62
Basiphilous vegetation of vernal therophytes and succulents without dominance of *Jovibarba globifera*	6110	T6.2B	0.41	VU	129	0.25	0.61
Waterlogged spruce forests	9410	L9.2B	298.13	VU	6799	178.49	0.6
Pannonian oak-hornbeam forests	91G0	L3.4	57.05	VU	1284	33.6	0.59
Secondary submontane and montane heaths with occurrence of *Juniperus communis*	5130	T8.2A	0.63	VU	60	0.37	0.59
Macrophyte vegetation of shallow still waters with dominant *Hottonia palustris*	–	V2B	0.29	EN	128	0.17	0.59
Birch mire forests	91D0	L10.1	14.48	EN	469	8.23	0.57
Rock-outcrop vegetation with *Festuca pallens*	6190	T3.1	3.15	NT	603	1.77	0.56
Broad-leaved dry grasslands without significant occurrence of orchids and with *Juniperus communis*	5310	T3.4B	1.25	VU	56	0.69	0.55
Vaccinium vegetation of cliffs and boulder screes	4030	T8.3	3.12	VU	689	1.68	0.54
Forest springs with tufa formation	7220	R1.3	0.19	VU	264	0.1	0.53
Broad-leaved dry grasslands without significant occurrence of orchids and without *Juniperus communis*	6210	T3.4D	110.76	NT	3476	57.76	0.52
Low xeric scrub, primary vegetation on rock outcrops with *Cotoneaster* spp.	40A0	K4A	0.7	VU	220	0.36	0.51
Pine forests of continental mires with *Eriophorum*	91D0	L10.3	0.73	EN	20	0.37	0.51
Chasmophytic vegetation of calcareous cliffs and boulder screes	8210	S1.1	1.85	VU	533	0.95	0.51
Dry herbaceous fringes	–	T4.1	2.04	NT	381	1.03	0.5
Herb-rich beech forests	9130	L5.1	1229.3	LC	20798	607.61	0.49
Acidophilous beech forests	9110	L5.4	1473.99	LC	24203	726.52	0.49
Riverine reed vegetation	–	M1.4	12.88	VU	1665	6.17	0.48
Submontane and montane *Nardus* grasslands without *Juniperus communis*	6230	T2.3B	88.12	NT	5285	42.64	0.48
Narrow-leaved dry grasslands without significant occurrence of orchids	6210	T3.3D	16.13	VU	766	7.65	0.47
Macrophyte vegetation of oligotrophic lakes and pools	3160	V3	0.3	EN	88	0.14	0.47
Forest-steppe pine forests	91U0	L8.2	3.84	VU	110	1.76	0.46
Acidophilous dry grasslands with significant occurrence of orchids	6210	T3.5A	0.26	VU	12	0.12	0.46

Secondary submontane and montane heaths without occurrence of *Juniperus communis*	4030	T8.2B	12.47	NT	749	5.69	0.46
Muddy river banks	3270	M6	0.66	NT	103	0.29	0.44
Montane *Trisetum* meadows	6520	T1.2	160.31	NT	4979	70.52	0.44
Acidophilous vegetation of vernal therophytes and succulents without dominance of *Jovibarba globifera*	8230	T6.1B	1.3	VU	266	0.57	0.44
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Stratiotes aloides*	3150	V1B	0.09	EN	10	0.04	0.44
Chasmophytic vegetation of siliceous cliffs and boulder screes	8220	S1.2	54.92	NT	7946	23.49	0.43
Mobile screes of acidic rocks	8150	S2B	0.83	VU	107	0.35	0.42
Macrophyte vegetation of water streams with potential occurrence of aquatic macrophytes or with natural or semi-natural bed	3260	V4B	66.56	LC	1719	27.94	0.42
Petasites fringes of montane brooks	6430	M5	3.67	VU	787	1.46	0.4
Willow-poplar forests of lowland rivers	91E0.	L2.4	26.5	VU	1134	10.41	0.39
Central European basiphilous thermophilous oak forests	91I0	L6.4	39.18	NT	677	15.38	0.39
Low xeric scrub, other stands	–	K4C	0.21	VU	97	0.08	0.38
Vegetation of perennial amphibious herbs	3130	M3	0.32	NT	44	0.12	0.38
Acidophilous thermophilous oak forests without *Genista pilosa*	91I0	L6.5B	66.13	NT	1441	24.66	0.37
Alder carrs	–	L1	37.47	VU	1171	13.44	0.36
Intermittently wet *Molinia* meadows	6410	T1.9	84.15	VU	2500	30.15	0.36
Dry lowland and colline heaths without occurrence of *Juniperus communis*	4030	T8.1B	1.79	VU	246	0.64	0.36
Forest springs without tufa formation	–	R1.4	8.6	NT	4078	3.02	0.35
Pine mire forests with *Vaccinium*	91D0	L10.2	43.73	VU	419	15.04	0.34
West Carpathian oak-hornbeam forests	9170	L3.3B	394.98	---	4913	134.5	0.34
Ravine forests	9180	L4	209.34	VU	5237	71.5	0.34
Herbaceous fringes of lowland rivers	6430	M7	1.46	NT	99	0.49	0.34
Meadow springs with tufa formation	7220	R1.1	0.12	VU	76	0.04	0.33
Caves not open to the public	8310	S3B	0.03	NT	106	0.01	0.33
Charophyceae vegetation	3140	V5	0.3	NT	60	0.1	0.33
Willow carrs	–	K1	59.64	VU	3849	18.8	0.32
Halophilous reed and sedge beds	–	M1.2	0.89	EN	31	0.27	0.3
Subcontinental pine-oak forests	–	L7.3	259.27	NT	3201	76.46	0.29
Tall-sedge beds	–	M1.7	76.81	VU	3788	22.55	0.29
Meadow springs without tufa formation	–	R1.2	0.89	VU	360	0.26	0.29

Acidophilous vegetation of vernal therophytes and succulents with dominance of *Jovibarba globifera*	8230	T6.1A	0.07	VU	16	0.02	0.29
Mesotrophic vegetation of muddy substrata	7140	M1.6	0.64	EN	74	0.18	0.28
Alluvial *Alopecurus* meadows	–	T1.4	159.57	VU	1628	44.04	0.28
Open sand grasslands with *Corynephorus canescens*	2330	T5.2	1.56	EN	81	0.44	0.28
Tall mesic and xeric scrub	–	K3	351.9	LC	12146	92.46	0.26
Hercynian oak-hornbeam forests	9170	L3.1	1010.61	NT	11806	263.77	0.26
Tall grasslands on rock ledges	–	S1.3	1.1	VU	165	0.29	0.26
Acidophilous dry grasslands without significant occurrence of orchids	6210	T3.5B	17.43	NT	595	4.59	0.26
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters without species specific to V1A–V1E	3150	V1F	70.05	VU	1316	18.54	0.26
Macrophyte vegetation of shallow still waters, other stands	–	V2C	1.6	NT	189	0.41	0.26
Reed beds of eutrophic still waters	–	M1.1	102.05	NT	3108	25.73	0.25
Wet *Filipendula* grasslands	6430	T1.6	129.65	LC	4736	32.4	0.25
Willow scrub of loamy and sandy river banks	–	K2.1	35.93	NT	1691	8.64	0.24
Mesic herbaceous fringes	–	T4.2	9.79	VU	916	2.37	0.24
Inland salt marshes	1340	T7	1.18	EN	34	0.28	0.24
Wet *Cirsium* meadows	–	T1.5	416.78	NT	11645	90.46	0.22
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters without macrophyte species valuable for nature conservation	–	V1G	203.02	VU	1577	44.44	0.22
Macrophyte vegetation of shallow still waters with dominant *Batrachium* spp.	–	V2A	1.74	NT	49	0.39	0.22
Boreo-continental pine forests, other stands	–	L8.1B	135.64	NT	2173	28.45	0.21
Vegetation of exposed fishpond bottoms	3130	M2.1	7.79	VU	233	1.66	0.21
Mesic *Arrhenatherum* meadows	6510	T1.1	1907.16	LC	22692	407.23	0.21
Vegetation of wet disturbed soils	–	T1.10	6.68	NT	1044	1.38	0.21
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Utricularia australis* or *U. vulgaris*	3150	V1C	3.1	VU	133	0.65	0.21
Eutrophic vegetation of muddy substrata	–	M1.3	3.75	VU	473	0.74	0.2
Cynosurus pastures	–	T1.3	408.56	NT	3920	81.16	0.2
Ash-alder alluvial forests	91E0.	L2.2	796.06	VU/LC	13814	149.47	0.19
Reed vegetation of brooks	–	M1.5	3.97	VU	505	0.7	0.18
Wet acidophilous oak forests	9190	L7.2	104.14	VU	842	18.15	0.17
Polonian oak-hornbeam forests	9170	L3.2	112.58	VU	864	17.69	0.16
Annual vegetation on sandy soils	2330	T5.1	0.55	EN	31	0.09	0.16
Dry acidophilous oak forests	–	L7.1	397.53	NT	2967	59.03	0.15

Acidophilous grasslands on shallow soils	–	T5.5	15.57	NT	397	1.8	0.12
Festucas and grasslands	2330	T5.3	6.75	VU	151	0.67	0.1
Acidophilous oak forests on sand	–	L7.4	10.86	NT	21	0.52	0.05
Caves open to the public	–	S3A	0.01	NT	23	0	0
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Aldrovanda vesiculosa*	3150	V1E	0.03	CR	0	0	0
Total of natural habitats	**–**	**---**	**12445.49**		**255244**	**4491.68**	**0.36**
Forest clearings	–	X10	318.01	---	9976	150.9	0.47
Stands of early successional woody species valuable for nature conservation	–	X12A	167.19	---	6778	79.29	0.47
Forest plantations of allochtonous coniferous trees	–	X9A	4867.39	---	47318	2022.37	0.42
Anthropogenic areas with sparse vegetation outside human settlements	–	X6	52.85	---	3198	20.52	0.39
Other stands of early successional woody species	–	X12B	103.83	---	5996	39.54	0.38
Herbaceous ruderal vegetation outside human settlements, stands valuable for nature conservation	–	X7A	81.02	---	2338	30.29	0.37
Forest clearings	–	X11	244.3	---	7476	86.79	0.36
Streams and water-bodies without vegetation valuable for nature conservation	–	X14	125.3	---	1452	43.25	0.35
Herbaceous ruderal vegetation outside human settlements, other stands	–	X7B	115.38	---	4718	39.36	0.34
Forest plantations of allochtonous deciduous trees	–	X9B	184.04	---	4197	61.05	0.33
Urbanised areas	–	X1	537.07	---	12675	173.41	0.32
Intensively managed meadows	–	X5	1212.39	---	8924	361.09	0.3
Stands of early successional woody species	–	X12	203.76	---	9585	59.69	0.29
Extensively managed fields	–	X3	104.72	---	1947	30.09	0.29
Scrub with ruderal or alien species	–	X8	14.3	---	774	4.2	0.29
Intensively managed fields	–	X2	738.66	---	1336	208.85	0.28
Woody vegetation outside forest and human settlements	–	X13	124.66	---	5405	32.84	0.26
Herbaceous ruderal vegetation outside human settlements	–	X7	159.3	---	5592	39.78	0.25
Permanent agricultural crops	–	X4	19.19	---	103	3.67	0.19
Total of non-natural habitats	**–**	**–**	**9373.36**		**139788**	**3486.98**	**0.37**

in the Czech Republic and defines the current status of habitats in terms of their threats, rarity and level of protection at the national scale. The categories of habitat vulnerability for specific habitats according to the RBH are listed in Table 1. The RBH is therefore being used as a professional basis for conservation of rare habitat types by means of PAs.

The NCEI index (Nature Conservation Effectiveness Index) was applied to measure the effectiveness of habitat conservation. The NCEI is calculated for specific habitat types as the total area of a particular habitat type in all SACs in the Czech Republic ($TANH_{SAC}$) divided by the total area of that same natural habitat in the entire Czech Republic ($TANH_{cz}$):

$$NCEI = TANH_{SAC} / TANH_{cz}$$

The NCEI index ranges from 0 (absence of protection) to 1 (totally effective protection). The calculated value of NCEI > 0.75 indicates a highly effective habitat protection (more than 75% of the total area of all identified natural habitats are protected by means of SACs), values between 0.74–0.50 indicate intermediate habitat protection (more than 50% of the total area of natural habitats are integrated in SACs) and values NCEI ≤ 0.49 indicate low habitat protection (SACs cover less than 50% of the total area of a particular natural habitat). To determine the NCEI index, two GIS datasets, administered by the Nature Conservation Agency of the Czech Republic, were used: 1) the habitat mapping layer and 2) the SAC border layer. All data (in vector format – *Esri geodatabase* and national coordinate system – epsg: 5514) were processed in ArcGIS 10.4. GIS technologies represent a very effective tool for deriving both primary and entirely new values that are applicable in the decision support process (Pechanec et al. 2015).

First, the total area of individual habitats in the entire Czech Republic was determined.

As the GIS layer of mapped habitats included habitat mosaics (i.e. areas for which one GIS feature is associated with several habitat types recorded in one data row), these mosaics had to be broken down into individual parts using a string of functions in Python language: a mosaic broken down into 2–6 items (i.e. separate attribute columns) was iteratively scanned using the *Select by Attributes* function in order to identify individual habitat codes. After identifying all habitat codes, the proportion of each habitat using the *Field Calculator* tool was determined. The unique values used for the identification were the habitat codes as listed in the Catalogue. To summarise the selected segments and calculate their areas, the *Summarise* and *Calculate Geometry* functions, respectively, were used. In the second phase, the habitat types in individual SACs were determined. The SAC border layer was then used to clip the national layer of habitats using the *Clip* function. The process of identifying, summarising and updating the selection was then repeated for the segments located within the SACs. Using the *Field Calculator*, the NCEI index was calculated and these figures were exported to the resulting table (Table 1).

Results

Natural habitats (156 types) cover 15.8% of the area of the Czech Republic (Table 1). The total of 255,244 mapped natural habitat segments occupies 12,445.49 km^2.

There are 55 (mostly non-forest) habitat types in the Czech Republic with a total area smaller than 1 km^2 (Table 1). Of these small-scale habitat types, 17 cover less than 0.10 km^2. The rarest habitats in the Czech Republic (based on their total area and a total number of mapped segments) are Snow beds (A3), Cliff vegetation in the Sudeten cirques (A5) and

Salix lapponum subalpine scrub (A8.1), all critically endangered due to climate-induced changes in vegetation zones in the Czech Republic (Machar et al. 2017a). Critically endangered are also Low xeric scrubs with *Prunus tenella* (K4B) with six mapped segments, Calcareous fens with *Cladium mariscus* (M1.8) with seven segments and two habitat types found at a single locality in the Czech Republic – Vegetation of annual halophilous grasses (M2.4) and River gravel banks with *Myricaria germanica* (M4.2) of the Bečva River. Only two sites are known for the unique aquatic habitat of Oligotrophic standing waters with *Isoëtes* vegetation (V6) in the Sumava National Park. Both Continental tall-forb vegetation (T1.8) and Still waters with *Salvinia natans* (V1D) have been found in six mapped segments. Very rare habitats with only a few known localities in the Czech Republic are T6.1A, V1B and V1E (Tab. 1). A very small area of the Czech Republic is occupied by Subalpine springs (R1.5, 0.07 km^2) and Tall-forb vegetation of fine-soil-rich boulder screes (S1.4, 0.06 km^2). The group of small-scale natural habitats also includes two unique habitat types with a very small total area: Caves open to the public (S3A), which receive sufficient protection through a strict visitor regime limiting both the number and frequency of visits (Hromas 2009) and Caves not open to the public (S3B; 106 localities), for which only entrance cave portals, typically not larger than few square metres, were mapped as natural habitats.

Habitat protection in the Czech Republic is concentrated primarily on these smallest types of rare habitats. The maximum protection (NCEI = 1) in the form of PAs applies to 22 types of natural habitats (Fig. 1). The maximum protection is given, for example, to 1) almost all natural habitats of the alpine zone above the tree line, which represent a unique environment threatened by the climate-induced upward tree-line shift (Machar et al. 2017b; Šenfeldr and Maděra 2011) and 2) River gravel banks with *Calamagrostis pseudophragmites* (M4.3), a rare habitat threatened by river regulations (Kilianova et al. 2017).

The highly effective habitat protection (NCEI = 0.99-0.75) is provided to 19 non-forest habitat types (Fig. 1), including rare alpine habitats, various types of peat bogs and small-scale segments of thermophilous lawns from the Pannonian biogeographical region, which extends to the southern part of the Czech Republic and by 10 rare forest habitat types from all forest vegetation zones present in the Czech Republic, representing unique examples of potential natural vegetation of the temperate forest of the European temperate zone.

Thirty-two natural habitats are associated with the intermediate effectiveness of habitat protection (NCEI = 0.74-0.50) (Fig. 1). This group of natural habitats includes those from the EN and VU categories of the threat classification list (Tab. 1), with the exception of two azonal forest types with a larger total area – L2.3. Hardwood floodplain forests of lowland rivers (TANHcz = 241 km^2, NCEI = 0.70) and L9.2B Waterlogged spruce forests (TANHcz = 298 km^2, NCEI = 0.60) are all of a small extent.

The majority (n = 73, Fig. 1) of natural habitat types in the Czech Republic is associated with low effectiveness of habitat protection (NCEI ≤ 0.49). Five habitat types from this group (four forest habitats L2.2, L3.1, L5.1, L5.4 and one non-forest habitat T1.1) have a total area of more than 500 km^2. The low protection effectiveness of these natural habitats reflects their large total area within the Czech Republic and the fact that the maintenance of their character (as defined in the Catalogue) is directly affected by

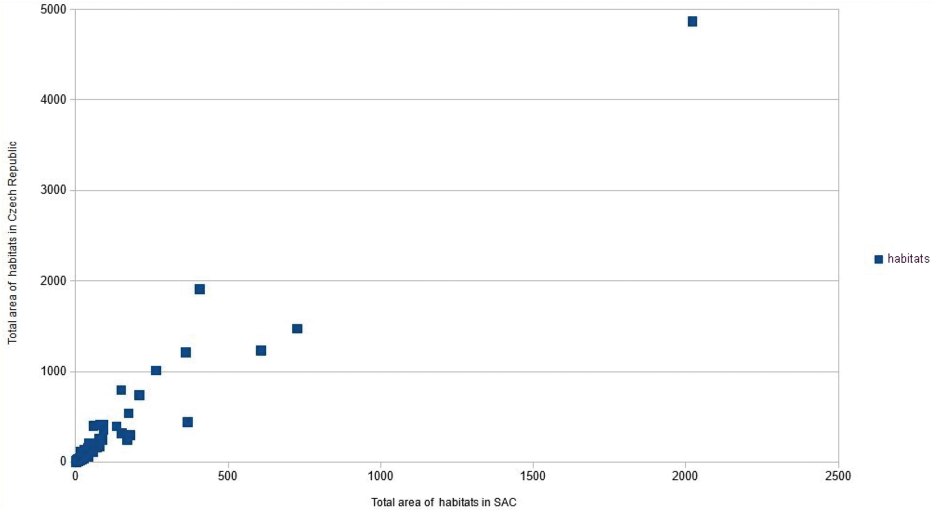

Figure 1. Area of natural habitats in the Czech Republic.

specific anthropogenic activities for which the SAC protection regime is not required. For instance, in order to maintain the defined character of L2.2 Ash-alder alluvial forests (TANHcz = 796 km^2, NCEI = 0.19), it is necessary to prevent eutrophication of the herb layer by nutrients supply from the surrounding (usually agricultural) land. For this particular habitat, changing the agricultural nitrogen management on the surrounding land is therefore of higher importance than declaring the SAC. Maintaining the defined character of L3.1 Hercynian oak-hornbeam forests ($TANH_{cz}$ = 1,010 km^2, NCEI = 0.26) requires re-implementation of the now defunct forest management type – coppice and coppice-with-standards (Machar 2009; Maděra et al. 2017). Functioning of the natural dynamics of beech forest habitats (L5.1 Herb-rich beech forests, $TANH_{cz}$ = 1,229 km^2, NCEI = 0.49 and L5.4 Acidophilous beech forests $TANH_{cz}$ = 1,473 km^2, NCEI = 0.49) depends on the natural beech restoration which is, however, being prevented by the overpopulation of deer (Machar et al. 2017c) due to the absence of their natural predators (Kovarik et al. 2014). The T1.1 Mesic Arrhenatherum meadows ($TANH_{cz}$ = 1,907 km^2, NCEI = 0.21) habitat is existentially dependent on regular mowing.

The Czech national system of SACs protects a total of 4,491.68 km^2 of natural habitats. Based on the NCEI value of 0.36, it can be concluded that the overall effectiveness of the SAC system in the Czech Republic (specifically aimed at protecting natural habitats) is low (Table 1). Nevertheless, the critically endangered habitats receive the maximum protection (NCEI = 1)

Discussion and conclusion

A large part of the territory of the Czech Republic, similarly to other Central European countries, is covered by human-altered land (Romportl et al. 2013), which does not meet the definition of natural habitats as described in the Catalogue. The controversial topic on "what are the conservation priorities – conservation of species or natural processes?" is being widely discussed in the Central European cultural landscape (Oprsal et al. 2016). Protection of natural habitats by creating PAs with non-intervention management or appropriate adaptive management may be one of the possible compromise solutions to this dilemma for nature conservation of Central European (Skokanova and Eremiasova 2013).

To maintain a stable habitat character as defined by the Catalogue, the majority of the habitat types in the Czech Republic require various levels of anthropogenic interventions or extensive farming, respecting the principles of ecosystem management (Grumbine 1994). Generally, it is impossible to define what type of habitat most influenced this result and if it is really low or not. Thus the authors' own expert range of NCEI (see above in section Methods) has been applied. In order to maintain the diversity of these natural habitats, conservation priorities will therefore need to be sought in methods of ecologically sound management rather than in further expansion of PAs. A study by Hoekstra et al. (2005) brought significant findings for defining global conservation priorities for the establishment of PAs. The study was based on an analysis of individual world biomes and their Conservation Risk Index (CRI; similar to the NCEI index used in this study). Contrary to the traditional belief about a need for priority conservation of the tropical rainforest, the study has shown that the grasslands and Mediterranean communities (biomes) are significantly more endangered. And the fact that the world's most endangered biomes are protected even less than the tundra and taiga biomes, which are least affected by humans, can be described as a global failure of nature conservation. A more recent study by Coad et al. (2009) newly reports that for 11 out of 14 biomes, the goal of protecting 10% of their area has been reached. Nevertheless, the terrestrial PAs rarely adequately encompass inland water ecosystems which are often not even listed amongst biomes (Herbert et al. 2010).

The habitat threat classification list used in this paper (Table 1) is based on the Czech national Red Book of Habitats (Divisek et al. 2014). The red list categories usually stem from the IUCN databases. The used criteria, however, are formulated for species and their population characteristics with respect to the degree of their isolation from other populations and are therefore difficult to apply to habitats. While for species which can be mapped e.g. local or endemic populations, a combined influence of a particular site and a vegetation type have to be taken into account for habitats. For this reason, the general criteria are applied in a process proposed by Gardenfors et al. (2001). According to this study, the global risk criteria can be only applied to habitats on a regional scale provided those are geographically isolated and without a continuous distribution across Europe.

The WDPA is currently a comprehensive global inventory of the world's PAs that 1) comply with the above mentioned IUCN definition from 2008, 2) for which exact spatial data (and designated boundaries) are known, 3) that have an assigned protected area category based on relevant national legislation, 4) for which year of designation or establishment is known and 5) all the data sources are appropriately quoted. As not all PAs meet these requirements, it is clear that even this most reputable database on PAs does not encompass all PAs worldwide (Rodrigues et al. 2004a). According to Visconti et al. (2013), only those areas which are listed in the WDPA, have a clearly defined management and therefore a clearly assigned IUCN category should be considered PAs. In this paper, the concept of SACs, corresponding with the IUCN categories 1–4, is followed.

It was not possible to focus on all of PAs categories in the Czech Republic (there are: national parks, protected landscape areas (PLAs), nature reserves, nature monuments, see in detail Machar 2012). Many of these categories of PLAs in the Czech Republic are overlapping each other (e.g. many of small nature reserves and nature monuments are situated in the area of large protected landscape areas or national parks). This fact comes from the long-term history of the system of PAs in the territory of the Czech Republic, which has resulted in current complicated overlapping layers of different types/categories of PLAs. Thus it is not possible to assess NCEI precisely for current situation of PLAs.

It is generally evident that the data on the total number and extent of PAs do not adequately reflect the effectiveness of the global system of PAs in protecting biodiversity (Rodrigues et al. 2004b). Nevertheless, a number of studies investigating the effectiveness of PAs based on analyses of their extent have provided crucial information for defining conservation priorities. A pioneering study by Prendergast et al. (1993) has surprisingly shown that the territorial overlap of occurrence of various species is very small and therefore not directly applicable for designing protected area networks. A comprehensive analysis of bird distribution by Orme et al. (2005) has shown that territorial overlaps of biodiversity hotspots and sites with endemic and endangered species are almost non-existent. According to Turner et al. (2007), the overlap of priority areas for biodiversity conservation and areas providing important ecosystem services varies greatly in different parts of the world (and is the largest in tropical rainforests due to high primary productivity). This is quite understandable, as PAs have been established for purposes other than the maintenance of ecosystem services. Not even exceptionally large PAs represent an optimum solution (Mittermeier et al. 2003; Olson and Dinerstein 2002), even though they usually encompass wilderness little affected by humans and more resistant to disruptive anthropogenic influences than PAs of a small extent (Cantú-Salazar and Gaston 2010). Similarly, regional studies of the Natura 2000 network show that territorial overlaps of sites with significant biodiversity (e.g. regional hotspots) and PAs are minor and the entire network may not be very effective (Dimitrakopoulos et al. 2004; Jantke et al. 2011; Wesolowski 2005).

Alongside the process of searching answers to the questions “how much and what kind of biodiversity is actually comprised in PAs?” or “are PAs managed to fulfil their role in protecting biodiversity and maintaining ecosystem services?” a new field has emerged, called conservation planning (Margules and Sarkar 2007). Despite a considerable development of this field, however, there is yet no generally accepted approach to evaluation of the effectiveness of PAs management. Meanwhile, the conceptual procedure proposed by the IUCN (Alexander 2008) is being used most often. According to the IUCN approach, good conservation management is based on an understanding of the existing values and threats of the protected area, followed by rational planning and fundraising. Moreover, it should foster ecosystem services that provide specific benefits to local people. This conceptual approach has been developed into several methodological tools, such as RAPPAM (Ervin 2003) or METT (Stoll-Kleemann 2010). Using this approach, IUCN has carried out the most extensive global assessment of the effectiveness of PAs. The assessment has revealed that only about 20% of evaluated sites provide an adequate level of nature protection and 14% of sites have serious deficiencies, with a lack of finances identified as a major problem (McDonald and Boucher 2011). Further, the analysis confirmed that local residents receive a significant income based on the existence of those PAs in which administrators inform in a timely and objective manner about prepared management plans and involve the residents in the implementation process.

When trying to assess the effectiveness of PAs, some studies have focused on determining the species richness of wild plants and animals living in the PAs. For this purpose, gap analyses have been used at different scales – for example Tantipisanuh et al. (2016). According to gap analyses by Ricketts et al. (2005), 764 endangered species of mammals, birds, amphibians and conifers occur only in a single protected site.

The study presented from the Czech Republic should be considered as a special type of gap analyses based on detailed habitat mapping. As was indicated, natural habitat protection in the Czech Republic is focused primarily on the smallest types of rare habitats, many of which are classified as critically endangered. The Czech national system of SACs provides protection to a total of 4,491.68 km^2 of natural habitats. Based on the presented results, it can be concluded that the overall effectiveness of the SAC system (a part of Natura 2000 network) in the Czech Republic, which is specifically aimed at protecting natural habitats, is low (NCEI = 0.36). Nevertheless, the critically endangered habitats receive a maximum protection (NCEI = 1). Methods used in this study can be applied in other European countries which have similar datasets from habitat mapping under Natura 2000 network establishment. Comparison of Natura 2000 network effectiveness both at national and European scale seems to be an important future conservation research challenge.

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