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Are Valuable and Representative Natural Habitats Sufficiently Protected? Application of Marxan model in the Czech Republic

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Abstract: The joint impact of human activities and climate change on natural resources lead to biodiversity loss. Therefore, it is important to select protected areas through systematic conservation planning. The present study assessed how representative natural habitats are protected under the nature conservation network, and to identify new—but so far insufficiently—protected areas containing these habitats for sustainable management. We used the Marxan model to select the most valuable insufficiently protected natural habitats in the Czech Republic as a representative example for a conservation strategy for Central–Eastern European environments. We set three conservation targets (25%, 50%, and 75%), defining how much percent area of valuable representative natural habitats should be added to the area of the habitats already included in the Nature Protection Network. To implement these conservation targets it is necessary to preserve 22,932 ha, 72,429, ha and 124,363 ha respectively of the conservation targets occurring in the insufficiently protected areas, and 17,255 ha, 51,620 ha, and 84,993 ha respectively of the conservation features in the areas without protection status. Marxan was revealed to be an appropriate tool to select the most valuable and insufficiently protected natural habitats for sustainable management.

Keywords: biodiversity; nature habitats; protection level; conservation planning; Marxan model

1. Introduction

The increasing human population and the rising demand of natural resources as world domestic product, global tree cover loss, fossil fuel consumption, and increasing of carbon dioxide (CO2) emissions and increasing the temperature together with the impact of global climate change clearly and unequivocally show that the planet Earth is facing a climate emergency. It is essential to prevent the collapse of ecosystem functioning by protection and restoration of ecosystems and biodiversity [1,2]. Therefore, it is important to design protected areas to maintain minimally a present status of biodiversity. One way of promoting biodiversity conservation is to implement systematic conservation planning by effectively defining protected areas in both natural and agricultural landscapes. In addition, the newly designated protected areas can provide ecosystem services and biodiversity protection [3]. Climate change has brought uncertainties to conservation planning; therefore, species protection needs to model population changes based on climate models [4]. To help politicians, landscape planners, and managers in designating protected areas, it is important to make an inventory and a subsequent valuation of the required elements of biodiversity in the selected areas [5]. Currently, there are increasingly more reserves focusing on the protection of specific habitats for plant and animal species [6,7]. Goal setting depends on the degree of the biodiversity representativeness of a reserve in the area [8], and on its persistence—long-term survival of species and biodiversity elements in the protected area [9]. Some protected areas were selected based on the occurrence of very high biodiversity hotspots [10]. Systematic protective planning has fixed characteristics since it requires clearly defined biodiversity elements and detailed information about the existing protected areas [11,12]. Equally important is information about the design of reserves, e.g., perimeter boundaries or connectivity [12,13].

The Marxan model can be used to design new locations for systematic nature protection planning, and to select the elements that represent the biodiversity value in conservation planning [14]. Primarily, Marxan was created to update the boundaries of an official reserve at the Great Barrier Reef off the Queensland coast of Australia. Each reef corresponded to one planning unit, and the main conservation features were bioregions with a representation limit of 20% of their original area. Based on the results generated by Marxan, an enlargement of the original reserve with a fishing prohibition of more than 400 km^2 was proposed [14]. Marxan was also used to design conservation areas in mangrove forests, around coral reefs, on beaches, and wetlands off the coast of Florida [15]. Reining et al. [16] used various ecological land units, e.g., wetlands, dry basins, river systems, steep slopes or mountain peaks, and top predator species such as lynx (*Lynx lynx*), wolf (*Canis lupus*), and marten (*Marten sp.*) as conservation features in the Apalachee Mountains. Meerman [6] proposed 16 habitat groups as primary conservation features in Belize, including habitats with protected and endangered species of birds, reptiles, fish, and flora. Munro [7] also suggested various types of habitats as conservation features: grass habitats, alpine tundra, and water habitats such as lakes, rivers, wetlands, and ponds. He also suggested habitats with endangered reptiles, birds, and mammal species in the Okanagan Valley, north of the Canadian–American border. Marxan was also used for conservation purposes on the islands of Indonesian Borneo [17] and in Papua New Guinea [18].

In the Czech Republic, protected areas form the Nature Protection Network (NPN) according to the national law dealing with nature and landscape conservation [19,20]. Nature protection is divided into species and territorial protection. Because the Marxan model works only with territorial protection, for its application in the Czech Republic we worked only with this issue. Our national categories of protected areas can be assigned to the categories of International Union for Conservation of Nature (IUCN). The large-scale protected areas include four National Parks (NPs)—three NPs belong to the category II and one NP to the category V—and 26 Landscape Protected Areas (LPAs) belonging to the category V. The small-scale protected areas included National Natural Reserves, National Natural Monuments, Nature Reserves and Nature Monuments correspond with the categories I, III, IV, V, but the categories III and IV dominate [19,21].

Land protection is guaranteed under Act No. 114/1992 Coll. on the Conservation of Nature and Landscape of the Czech Republic [19], and its implementing regulations are Decree 395/1992 Coll. [22] and Decree 45/2018 Coll. [23]. The accession to the European Union in 2004 determined the obligation to define the Natura 2000 network of protected areas. Both the Birds Directive [24] on the conservation of wild birds and the Habitats Directive [25] on the conservation of natural habitats and of wild fauna and flora were included in the national law. Especially the Habitats Directive and its processes work with the term sufficiency of coverage of habitats and species included in the Natura 2000 network. The sufficiency is based on arbitrary formal decisions while the Marxan model provides control over the results of such a formal process. In the Czech Republic, there are 41 Special Protection Areas (SPAs) and 1112 Special Areas of Conservation (SACs) defined in the Natura 2000 network, covering 14.1% of the total area of the Czech Republic [26]. Both areas (SPAs, SACs) are in the "not reported category" according to IUCN [21]. All the protected areas forming NPN extend 1,845,496 ha, i.e., 23% of country land. The Natura 2000 sites cover about 21% of the land and marine waters territory of the European Environment Agency's member countries and collaborating countries [27]. The European Environmental Agency (EEA) is responsible for developing The European Environment Information and Observation Network (Eionet) and coordinates its activities together with National Focal Points (NFPs) in the countries. The Eionet constellation is supplemented by seven European Topic Centres [28].

In our study, we divided the various categories of protected areas into sufficiently and insufficiently protected according to the level of habitat biodiversity protection (see Table 1). The distribution of protected areas in the Czech Republic is shown in Figure 1. The aim of our study was to assess how the valuable representative natural and near-natural habitats, identified by the national Habitat Mapping of the Czech Republic project, are protected under the nature conservation network, and to identify the new areas containing valuable natural habitats for sustainable management, not yet sufficiently protected.

Table 1. The status of Planning Units (PUs) based on the degree of protection under the Nature Protection Acts of the Czech Republic (Conserved—sufficiently protected areas, Available—insufficiently protected areas, Excluded—excluded from protection).

Categories of Territories for Placement of Planning Units (PUs)	Conserved	Available	Excluded
Characteristics	Existing functional protection—Marxan model does not work with these PUs	Insufficient or nonexistent protection—Marxan model selects PUs to complete the protected network	Excluded from the protection—Marxan model does not work with these PUs
Conservation status	1st and 2nd zones of National Parks (NPs), 1st zone of Landscape Protected Areas (LPAs), National Natural Reserve; areas of National Natural Monument, Natural Reserve, Nature Monument situated in the LPAs or NPs	3rd zone of NP and protection zone of NP, 2nd–4th zones of LPAs, National Natural Monument, Nature Reserve and Nature Monument outside of NPs and LPAs; Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and the rest of the Czech Republic	Non-protected territory (e.g., urban and industrial areas, roads, railways, arable land)

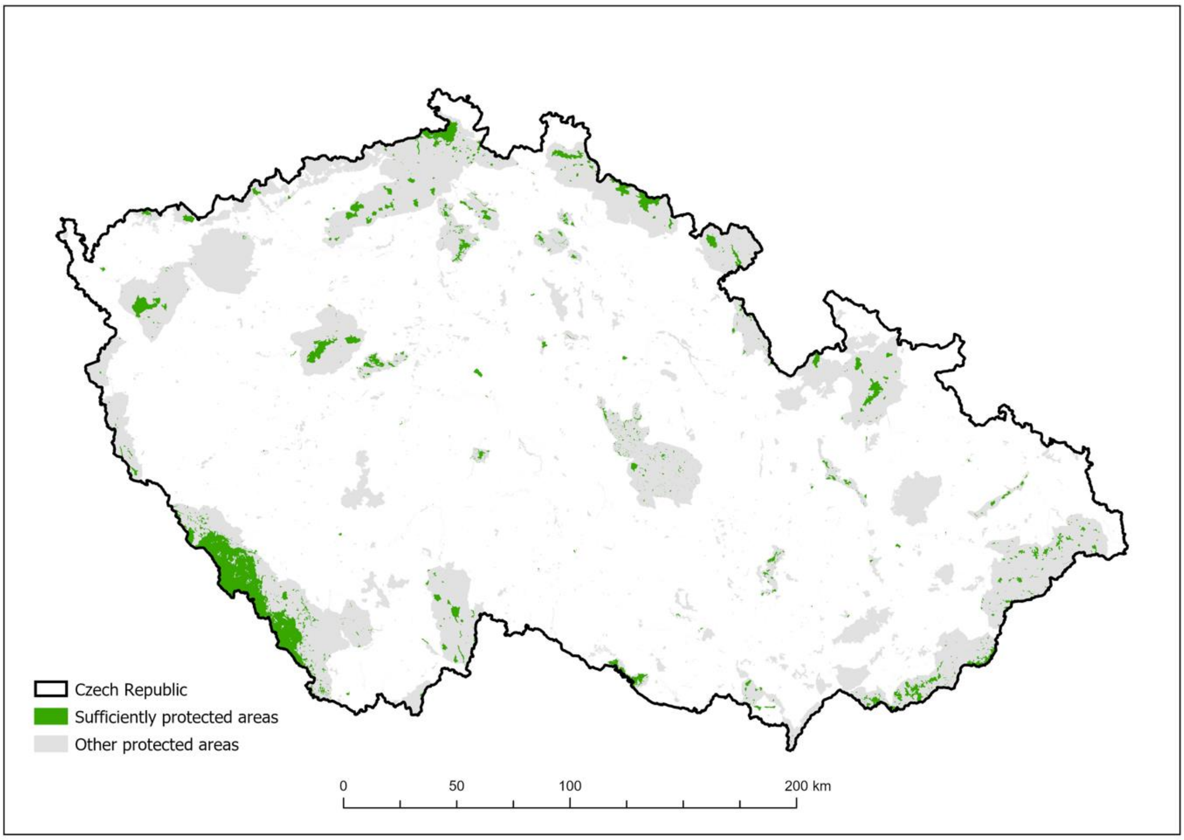

Figure 1. Protected areas creating the Nature Protection Network (NPN) according to the national law dealing with nature and landscape conservation in the Czech Republic.

2. Materials and Methods

2.1. A Description of the Marxan Model

The Marxan model was designed by Ball et al. [14] to plan new representative and spatially compact protection sites for landscape planning. The model uses a combination of Planning Units (PUs) that include all defined conservation features (CFs), minimising the total cost of the selected PUs. The Marxan model divides the area of interest into PUs that have either hexagonal or square meshes [29]. The PUs are divided into (i) conserved units—situated in sufficiently protected areas; (ii) available units—which can be selected if they include suitable conservation features; (iii) excluded units—excluded from the selection (e.g., built-up areas). Areas with strict protection of habitats located in larger protected areas or having a larger protection zone around them are considered as sufficiently protected areas. This category includes: 1st and 2nd zones of NPs, 1st zone of LPAs, National Natural Reserve and small-scale plots of National Natural Monuments, Natural Reserves, and Nature Monuments, situated in the LPAs or NPs. The Marxan model uses the "object function" to calculate the optimal selection of PUs by comparing the selected combinations of PUs. For each combination of PUs, the software adds up the total costs needed to create them. It performs ongoing combination tests to achieve the lowest possible object function with the lowest costs.

The optimisation algorithm within Marxan attempts to find good systems of sites through simulated annealing, whereby different sets of potential conservation areas are compared with user-defined targets and costs, and the set of areas that achieves its objective most efficiently is determined. With the use of stochastic optimisation routines (simulated annealing) it generates spatial reserve systems that achieve particular biodiversity representation goals with reasonable optimality. Computationally, Marxan provides solutions to a conservation version of the 0–1 knapsack problem, where the objects of interest are potential reserve sites with given biological attributes. The simulated annealing algorithm attempts to minimise the total cost of the reserve system, while achieving a set of conservation goals (typically that a certain percentage of each geographical/biological feature is represented by the reserve system). The object function of the total cost of the solution is calculated according to the following formula:

$$C = \sum C_{PU} + \sum SPF + (\sum C_{BL}) \times BLM \quad (1)$$

C – total cost of the final design solution,
$\sum C_{PU}$ – the costs of all planning units involved in the solution,
$\sum SPF$ – total penalty for non-compliant conservation features,
$\sum C_{BL}$ – the length of the border surrounding the final protected area,
BLM – a coefficient accounting for the complexity of the final protected area.

2.2. Planning Units (PUs)

Our analysis was carried out considering the whole of the Czech Republic as the study area. Country land was divided into PUs with a hexagonal net (edge of 310 m, area of one hexagon was 25 ha) that were divided into three categories: conserved, available, and excluded. At the beginning of the analysis, the nature protection effectiveness of different types of protected areas in the Czech Republic was critically assessed [30] (Table 1). To describe PUs in the conserved category, we used data from the Nature Conservation Agency in the Czech Republic (NCA CR). To delineate PUs in the available category, ZABAGED and OpenStreetMap and NCA CR data were used, while for identifying PUs in the excluded category, ZABAGED and OpenStreetMap only were used. All data were in the scale 1:10,000 with a projection of EPSG 5514.

The PUs in the Nature Protection Network (NPN) of the Czech Republic with sufficient protection have been categorized as conserved units, see Table 1. The excluded units included built-up areas, industrial areas, roads and their immediate surroundings. The Marxan model did not select any PUs from these categories. The rest of the Czech Republic was included in the available units (Table 1).

The cost of individual PUs was calculated as the weighted average of the point value of biodiversity determined by the Habitat Valuation Method (HVM) (see Table 1) for all natural and non-natural habitats [31–33]. The Boundary Length Modifier (BLM) parameter determines the length of PU borders. For the interfaces Conserved vs. Excluded and Available vs. Excluded, the length of the PUs was increased three times.

2.3. Conservation Features

The Conservation Feature (CF) is a measurable, spatially defined element of biodiversity that is present in the final solution of the protected network; the CF is also included in the PU. CFs can be individual species and habitats, but also larger units such as biomes [34]. Each CF has a target which represents the minimum limit of CFs to be included in the final solution of the Marxan model. If the target is not met, the object function of the final solution is penalized.

We identified CFs as the natural and near-natural habitats of the Habitat Mapping from NCA CR [35]. The near-natural habitats represented habitats established by humans, but having species and structural diversity similar to nature habitats (e.g., cultural orchids meadows). Unit classification was defined by the Habitat Catalogue of the Czech Republic [36]. We used only those CFs which complied with the strict criteria of two quantitative parameters. The first parameter included (i) higher levels of representativeness and the well-protected status, and it was divided into the classes AA, AB, BA, BB, for the habitats valuated according to the original Methods of Habitat Mapping of Natura 2000 and the Emerald Network in 2000–2009 [37], and (ii) representativeness and degradation, according to the methodology for updated valuation of habitats [38]. The second parameter for each habitat segment was the achievement of the minimum area necessary for ecosystem self-regulation, derived from the HVM method for each natural and near-natural habitat [31]. A total of 139 habitat types were identified as CFs, expressed in 149,906 segments and with a total area of 470,939 ha.

We created three scenarios representing the percent area of CFs included in the final proposal of the Marxan model to meet different protection targets (25%, 50%, and 75%), considering valuable habitats from all selected CFs in the Czech Republic. If part of the CF was already protected in the conserved PU, the protected area was deducted from the target area. The Marxan model selected the conservation features in hexagons with the highest biodiversity point values determined by the HVM method. If two hexagons had the same point value, the Marxan model chose a hexagon with a shorter boundary length than the edge of the PU.

2.4. Technical Description of Marxan Calculations

Our analysis was done in QGIS 3.6 and in the Marxan version 2.43 (64b). QGIS 3.6 was needed to pre-process spatial data and visualize the results. Each analysis was run in 20 steps with 1,000,000 iterations. To create input files with control parameters for Marxan, the Conservation Land-Use Zoning software (CLUZ) in QGIS was used. The CLUZ is a QGIS plugin that assists in designing protected area networks and other conservation landscapes [39]. After the simulation, we analysed how the PUs conform to the scenarios, and compared them with the rest of the existing network of protected areas in the Czech Republic. The compliance analysis was performed using GIS overlay operations.

3. Results

3.1. PUs and Protection Scenarios

The area of the Czech Republic for PUs was divided into 318,006 PUs with a total area of 7,950,150 ha (Table 2). This area is larger than the original area of the Czech Republic (7,886,879 ha) because the model includes the hexagons that cross the national borders. Marxan unifies PUs (hexagons) into patches. The total number of patches was 897, and the median patch area was 100 ha (Table 3). The smallest patch is an area of one PU containing at least one segment of a CF. The PUs in the available category covered the largest area; however, the PUs in the conserved category had the highest cost per ha according to HVM [31]. The most valuable habitats, defined in terms of their CFs, occupied an area of 470,939 ha, and made up 6% of the area of the Czech Republic. The spatial distribution of CFs and PUs is shown in Figure 2.

Table 2. Representation of the PU status in the Czech Republic and the value of biodiversity valuated with the Habitat Valuation Method (HVM) method [31].

Status	Total Area (ha)	Total Cost (million EUR)	Cost Per 1 ha (EUR)	Number of PUs
Available	4,460,875	33,029	7404	178,435
Conserved	302,700	3561	11,764	12,108
Excluded	3,186,575	19,910	6248	127,463
Total	7,950,150	56,500	25,417	318,006

Table 3. Number and area of the studied patches, Czech Republic.

Metric	Value
Number of patches	897
Area of the smallest patch	25 ha
Median area of patches	100 ha
Area of the largest patch	29,650 ha

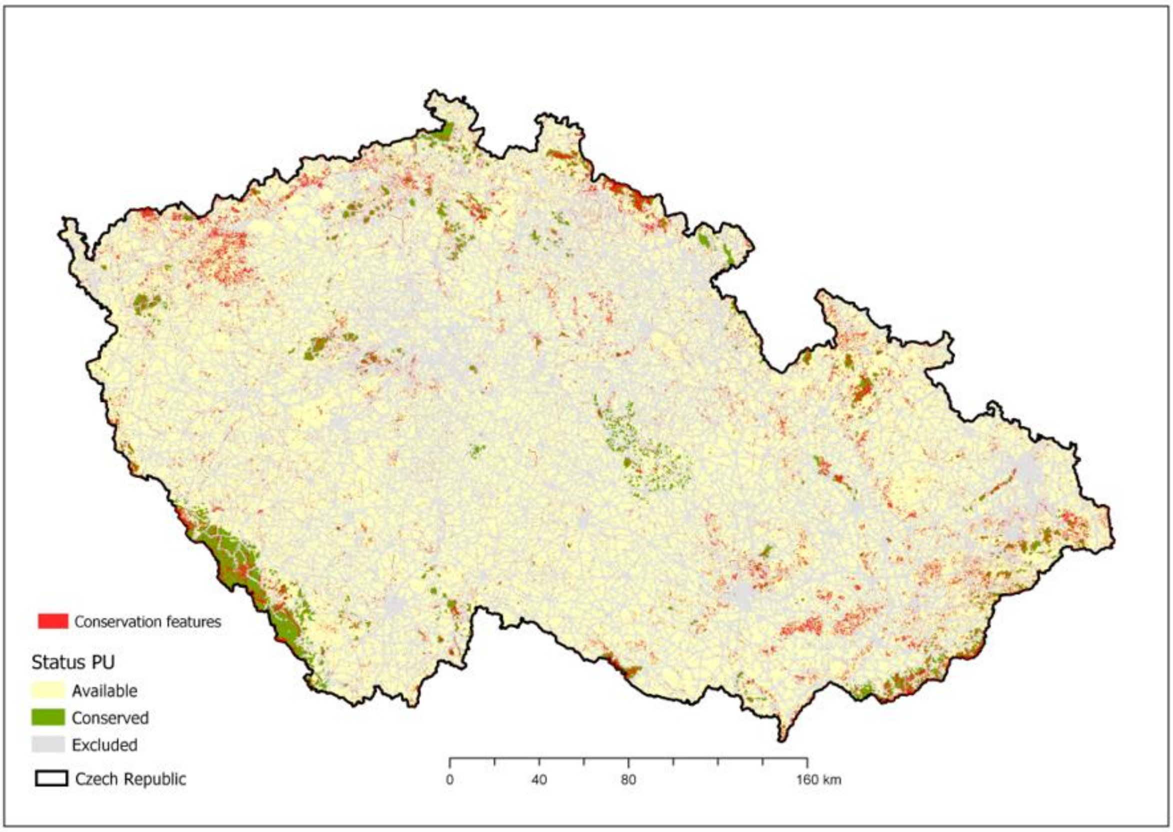

Figure 2. Distribution of Planning Units (PUs) containing Conservation Features (CFs) in the Czech Republic. The PUs are polygons which contain at least one segment of a CF. The CFs are the natural and near-natural habitats of the Habitat Mapping from Nature Conservation Agency in the Czech Republic (NCA CR). The PUs are divided into (i) conserved units—situated in sufficiently protected areas; (ii) available units—which can be selected if they include suitable conservation features; (iii) excluded units—excluded from the selection (e.g., built-up areas).

PUs containing valuable natural and near-natural habitats (CFs) not yet conserved in protected areas were selected using the Marxan model (Table A1, Appendix A). To obtain a better overview of proposed new CFs, we aggregated the selected valuable habitats into habitat formation groups with similar environmental conditions, e.g., all types of meadows to the grasslands group and all wetlands and peatbogs to the wetlands group [36] (Table 4). The largest area of natural and near-natural habitats was covered by beech and oak, and oak–hornbeam forests, and mesophilic meadows with an area in the range of 90,260 ha to 108,969 ha, respectively. The smallest area with rocks and rubble, natural *Pinus mugo* scrubs and alpine grasslands was found in the interval of 1242 ha to 1465 ha. The results show that the groups of habitats with the largest areas are not sufficiently protected over 50% of their area. A different situation was found for the following habitats: natural alpine grasslands, *Pinus mugo* scrubs, bog forests, spruce forests, peatbogs, and springs. These habitats are mostly protected over 50% of their area and for sufficient protection it is enough to add 392 ha. Groups of habitats with less than 10% of the total area sufficiently protected featured oak and oak–hornbeam forests, macrophytic vegetation of standing waters, alluvial forests, alluvial meadows and mesophilic meadows. Table 5 shows the required target areas for individual natural habitats classified as CFs, to be added to the proposal of new protected areas according to the three scenarios.

Table 4. The representation of the most valuable habitats selected as CFs in the total area of PUs and Conserved PUs. The all-natural and near-natural habitat codes are shown in Table 5, and abbreviations of these habitats according to the Habitat Catalogue of the Czech Republic [36] are reported in Table 3A in Appendix A.

Habitat Category	Formation	Natural and near-Natural Habitats	Total Area CFs (ha)	Area of Conserved PUs (ha)	Area of Conserved PUs (%)	Number of Habitat Patches in CR
Grasslands	Alluvial meadows	R1.1, R1.2, T1.4–T1.9	25,230.14	1915.07	7.6	464
	Dry grasslands	T3.1–T3.5, T5.1–T5.5, T6.1, T6.2	7073.6	905.18	12.8	188
	Mesic meadows	T1.10, T1.1–T1.3, T2.3, T4.1, T4.2	90,260.33	4643.52	5.1	653
	Alpine grasslands	A1.1, A1.2, A3, A4.1, T2.1, T2.2	1464.53	1141.79	78.0	22
	Heaths	A2.1, T8.1–T8.3	823.91	160.11	19.4	43
Forests	Alluvial forests	L1, L2.1–L2.4	43,258.76	3306.83	7.6	474
	Oak, Oak–hornbeam forests	L3.1–L3.4, L6.1–L6.5, L7.1–L7.4	91,683.96	9196.01	10.0	366
	Ravine forests	L4	8331.27	1390.18	16.7	128
	Beech forests	L5.1–L5.4	108,968.95	22,667.6	20.8	444
	Dry pine forests	L8.1–L8.3	5274.12	1118.34	21.2	61
	Spruce forests	L9.1–L9.3	30,827.82	17,100.71	55.5	124
	Bog forests	L10.1–L10.4	2521.68	1666.58	66	63
	Natural *Pinus mugo* scrub	A7	1249.42	1186.19	94.9	2
	Natural shrub vegetation	A2.2, A8.1, A8.2, K1, K2.1, K2.2, K3, K4	16,952.32	1449.41	8.5	319
Wetlands	Wetlands and litoral vegetation	A4.2, A4.3, M1.1–M1.8, M2.1–M2.4, M3, M4.1, M4.3, M5–M7	9635.55	1286.66	13.4	371
	Peatbogs and springs	R1.3–R1.5, R2.1–R2.4, R3.1–R3.4, T7	5014.68	2519.81	50.2	384
Macrophytic vegetation of standing and flowing waters		V1–V6	26,522.86	2224.45	27.50	427
Rocks, Rubble		A5, A6, S1.1–S1.5, S2	1241.84	421.92	34.0	199

Table 5. Required target area (ha) for habitats (CFs) to be added to the proposal of new conservation areas according to three target scenarios. The abbreviations of natural and near-natural habitats are formulated according to the Habitat Catalogue of the Czech Republic [36] and Table 3A in the Appendix A.

Habitat Category	Formation	Natural and near Natural Habitats	Scenario 25%	Scenario 50%	Scenario 75%
Grasslands	Alluvial meadows	R1.1, R1.2, T1.4, T1.5, T1.6, T1.7, T1.8, T1.9	4392.47	10,700.01	17,007.53
	Dry grasslands	T3.1, T3.2, T3.3, T3.4, T3.5, T5.1, T5.2, T5.3, T5.4, T5.5, T6.1, T6.2	997.1	2646.04	4400.03
	Mesic meadows	T1.10, T1.1, T1.2, T1.3, T2.3, T4.1, T4.2	17,921.57	40,486.64	63,051.72
	Alpine grasslands	A1.1, A1.2, A3, A4.1, T2.1, T2.2	32.92	110.33	188.65
	Heaths	A2.1, T8.1, T8.2, T8.3	87.83	277.66	470.73
Forests	Alluvial forests	L1, L2.1, L2.2, L2.3, L2.4	7519.89	18,322.53	29,137.23
	Oak and oak-hornbeam forests	L3.1, L32, L3.3, L3.4, L6.1, L6.2, L6.3, L6.4, L6.5, L7.1, L7.2, L7.3, L7.4	13,859.12	36,670.07	59,566.97
	Ravine forests	L4	692.64	2775.46	4858.28
	Beech forests	L5.1, L5.2, L5.3, L5.4	4625.98	31,816.87	59,059.1
	Dry pine forests	L8.1, L8.2, L8.3	371.46	1570.91	2837.25
	Spruce forests	L9.1, L9.2, L9.3	0	382.52	6020.15
	Bog forests	L10.1, L10.2, L10.3, L10.4	0	39.74	369.47
	Natural *Pinus mugo* scrub	A7	0	0	0
	Natural shrub vegetation	A2.2, A8.1, A8.2, K1, K2.1, K2.2, K3, K4	2965.76	7138.46	11,314.53

Table 5. *Cont.*

Habitat Category	Formation	Natural and near Natural Habitats	Scenario 25%	Scenario 50%	Scenario 75%
Wetlands	Wetlands and litoral vegetation	A4.2, A4.3, M1.1, M1.2, M1.3, M1.4, M1.5, M1.6, M1.7, M1.8, M2.1, M2.2, M2.3, M2.4, M3, M4.1, M4.3, M5, M6, M7	1170.26	3550.19	5946.22
	Peatbogs and springs	R1.3, R1.4, R1.5, R2.1, R2.2, R2.3, R2.4, R3.1, R3.2, R3.3, R3.4, T7	44.68	392.04	1245.44
Macrophytic vegetation of standing and flowing waters		V1, V2, V3, V4, V5, V6	7129.96	174,838.48	294,252.02
Rocks, Rubble		A5, A6, S1.1, S1.2, S1.3, S1.4, S1.5, S2	8.3	269.39	543.53

3.2. Assessment and Proposed Extension of the Protected Network

The existing NPN in the Czech Republic is considered sufficient in the representation and distribution of individual types of protected areas. Nevertheless, even if a CF area of 73,805 ha, corresponding to 15.6% of all CFs, is included in the sufficiently protected part of the NPN, it is necessary to provide increased biodiversity protection for the remaining valuable natural habitats classified as CFs. According to our proposal including three scenarios to protect 25%, 50%, or even 75% of CFs, it is necessary to conserve them in 22,932 ha, 72,429 ha, and 124,363 ha respectively in the insufficiently protected areas, and in 17,255 ha, 51,620 ha, and 84,993 ha respectively in the non-protected areas (Table 6).

Table 6. Final area (ha) and percent share in total area of all CFs of the most valuable habitats selected as CFs for the three scenarios.

Area (ha, %)/Scenarios	Scenario 25%	Scenario 50%	Scenario 75%
Final area (ha) and (%) of CFs with insufficiently protected areas	22,932.42 4.99	72,428.55 15.49	124,362.99 26.41
Final area (ha) and (%) of CFs without any protection	17,255.01 3.66	51,620.15 10.96	84,993.43 18.05
Final area (ha) and (%) of CFs with insufficiently protected areas and without any protected areas	40,187.43 8.53	124,048.62 26.34	209,356.29 44.46

For the Czech Republic, the Marxan model selected 3.66%, 10.96%, and 18.05% of the most valuable habitats without any protection according to our three scenarios. The largest non-protected land patches are situated mostly in the mountain forest areas along the borders of the Czech Republic and in military areas, e.g., in the Doupovské Mountains in Northwest Bohemia. To achieve the abovementioned scenarios, especially the scenario of adding valuable habitats to 75% of the area, Marxan selected and added isolated segments throughout the country (Figure 3).

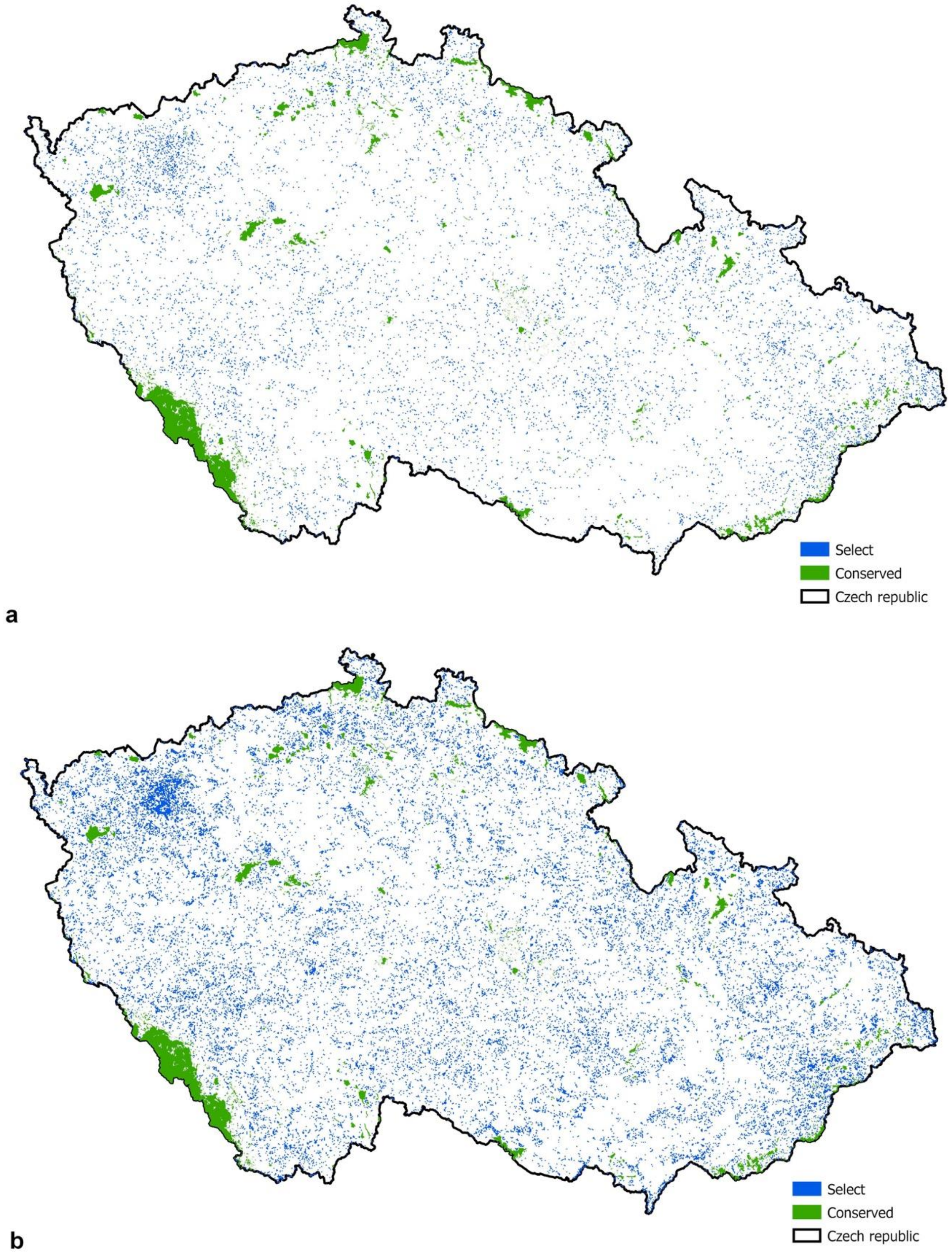

Figure 3. *Cont*.

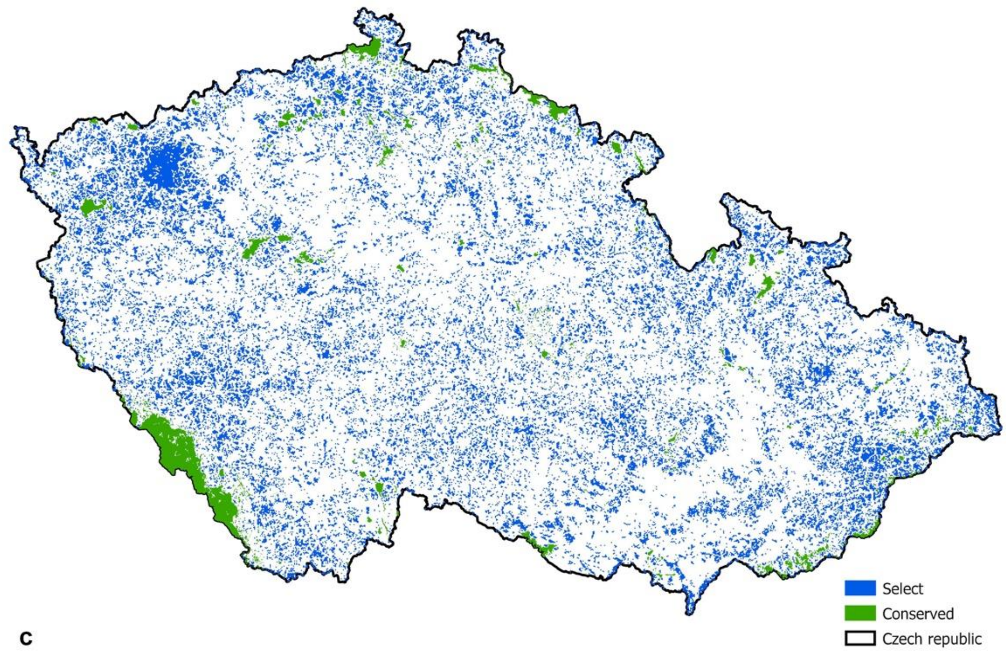

Figure 3. The planning units, including conservation features (CFs), in scenarios with the required areas of (**a**) 25%, (**b**) 50%, (**c**) 75% of the target planning units.

4. Discussion

Our results show that the most valuable habitats selected as CFs are included in the current NPN of the Czech Republic (Table 4). However, only some of the most valuable habitats are sufficiently protected in these areas, such as alpine grasslands (only A1.1–A8.2), bog forests (only L10.3, L10.4), wetlands (only M2.2), peat bogs and springs (only R1.5, R3.1), and *Isoëtes* vegetation (V6) (Table 5, and Table A2 in the Appendix A). According to the Habitat Catalogue of the Czech Republic [36], these selected habitats cover only a small area and have specific natural conditions. All these habitats (except for the habitats R1.4, R1.5 included in peat bogs and springs) belong to the network Natura 2000 sites, and they are included as SACs in the national law of the Czech Republic [19]. This network consists of important habitats that are protected by the member states of the European Union. These habitats are important for biodiversity conservation but, because of their small size, they have little impact on the Territorial System of Ecological Stability of the Landscape (TSES). The objective of planning and developing the TSES is to halt the unfavourable trend in the development of ecological stability and to hamper biodiversity loss in the culture according to Czech law No. 114/1992 [19]. However, our three scenarios show that the most of the remaining habitats are not sufficiently protected. Each scenario represents the percentage of CFs that should be included in the final proposal of Marxan to achieve the targets of 25%, 50%, and 75% of all selected CFs. The most frequent habitats, covering large areas but with only 10% of the area sufficiently protected in NPN, belong mostly to the following habitats: Hercynian oak–hornbeam forests (L3.1), ash–alder alluvial forests (L2.2), willow–poplar forests of lowland rivers (L2.4), wet Filipendula grasslands (T1.6), intermittently wet Molinia meadows (T1.9), and mesophilic Arrhenatherum meadows (T1.1). According to Bastian [40], natural habitats occurring in insufficiently or non-protected areas, such as intermittently wet Molinia meadows (T1.9) and ash–alder alluvial forests (L2.2), are important for supplying ecosystem services, e.g., provisioning, regulating, and cultural services. The national Nature Conservation Agency evaluated the state and importance of the habitats included in the Natura 2000 sites in the years 2007 and 2013 in the Czech Republic. The Agency reported a higher number of important European habitats in 2013 compared to 2007, while admitting a possible estimation bias due to changes in assessment methods during this period. In addition, the number of habitats in an unfavourable state, translated into classification according to the Habitat Catalogue of the Czech Republic [36], e.g., macrophyte vegetation of water streams (V4), intermittently wet Molinia meadows (T1.9), and wet acidophilous oak forests (L7.2), has increased in the year 2017. All alpine grasslands were the only habitats with a better status (A1.1–A8.2) in the year 2017 [41].

The division of protected areas into sufficiently and insufficiently protected areas was carried out by our expert assessment, based on management of habitat biodiversity in protected areas and on the definition of protected areas in nature and landscape conservation law [19]. Sufficiently protected areas are large-scale sites where the main objective is to protect biodiversity and ecosystem processes and human intervention is excluded or strongly limited. Furthermore, some small-scale protected areas that are situated in the territory of large-scale protected areas and have a sufficiently large protection zone containing human disturbance, are also considered as sufficiently protected areas. Most sites in the Natura 2000 network tend to overlap with large-scale protected areas, such as NPs and LPAs. However, most of these overlapped areas include zones with low protection such as the 3rd zone of NPs and protection zone of NP, and 2nd to 4th zones of LPAs. In the case of significant habitats or species occurrence, a management contract can be signed with the landowner or tenant [19].

There are issues with the inefficient use of subsidies from the EU and insufficient control of nature protection by the central EU authorities [42], including problems with the non-functional compensation mechanism for private forests included in the Natura 2000 network [43]. According to Křenová and Kindlmann [42], the negative effects on Natura 2000 habitats and species are stronger in the states with the weak position of the state representatives, such as the Czech Republic or, more generally, Eastern European countries. Most of all, post-communist countries, e.g., Slovakia, Hungary and Romania, have been relatively unsuccessful in implementing Natura 2000 in agricultural landscapes. The main causes can be found in the discrepancy between local communities and authorities and the formal protection of sites, and the lack of financial support for management [44]. In addition, some habitats of European importance are fully or partly dependent on the continuation of traditional agricultural management [45].

The only important areas for biodiversity protection not included in the NPN are military training areas, including habitats with manmade irregular mechanical disturbances. These interventions result in fine-scaled mosaics of ecological conditions important for many species of plants and insects, above all butterflies [46]. Warren and Buttner [47] confirmed the importance of active military training areas as refuges for disturbance-dependent endangered insects in Germany. After the army abandoned these areas, their conservation value is threatened. To conserve the threatened species, Cizek et al. [46] recommended implementing alternative projects mimicking army activities, or sustainable management systems.

There are several ways to establish new protected areas in the Czech Republic: (1) by creating new protected areas in the currently most valuable unprotected habitats identified as CFs by Habitat Mapping of the Czech Republic (e.g., in previous military areas); (2) by connecting selected CFs with existing protected areas or their buffer zones, mostly in the forest mountainous regions along the state borders; (3) by improving the protection of insufficiently protected areas through effective financial investments [38] (e.g., supporting traditional mowing management for keeping valuable meadows [45,48] or using the regional seed mixtures [49]); (4) by supporting the natural species composition in near-natural forests by close-to-nature forest management (e.g., oak forests). This type of management leads to an emphasis on stability, productivity, diversity, and continuity of forest conditions [50].

The Marxan model has been used in a number of regional studies to design protected sites, including a wide range of habitats as anthropogenic land, terrestrial lowland forests, mangrove forests, mountain areas, lakes, the coral reef and open sea with a size of one PU of 10 km^2 [6,7,16]. In our study, we have reduced the scale of habitats such as grasslands, forests, wetlands, and water bodies to only 0.25 km^2 for each PU. Our results show that it is possible to use Marxan for large areas with relatively detailed PUs. Further research should determine which scenario provides an optimal representation of valuable natural habitats, that is sufficient to maintain sustainable state of biodiversity in the cultural forest–agricultural landscape.

For better protection of biodiversity, it is also necessary to improve the connectivity among protected areas with different degrees of protection. The green infrastructures as a terrestrial ecosystem may play a key role in improving the coherence and resilience of protected areas [27]. For example, contractual agreements can be used to support the protection and connectivity of valuable habitats in insufficiently protected areas or in the areas without protection status at all. Three military territories with valuable habitats have been included in the Natura 2000 network as Special Protection Areas (SPAs) and Special Areas of Conservation (SACs), and at the same time they had the status of Contract Protected Area under Czech legislation. Another example is from the Landscape Protected Areas (LPA) Beskydy, where the forests of the Czech Republic manage the zone II of the LPA, overlapping with the SACs as a zone I of the LPA. In this case, forest owners may be supported by a financial contribution from landscape programs of the Ministry of the Environment.

Preliminary investigations on Natura 2000-protected areas suggest that there is now a relatively good spatial and functional connectivity among sites across national borders. The Alpine Network of Protected Areas (ALPARC) and the Carpathian Convention framework for protected areas are good examples of over-boundary cooperation. Both areas contain the large protected areas with another type of protection and both areas almost touch. Part of the Carpathian protected areas passes through the Czech Republic [27].

Results from the Marxan model can also serve to verify some categories of the Nature Protection Network (NPN). Not all types of protected areas have been proposed by the Ministry of the Environment of the Czech Republic on the basis of sufficient background data. At the same time, stakeholders such as foresters and farm holders, as well as fishing and hunting associations, should be involved in a sustainable management of near-natural agricultural and forestry management in natural valuable habitats [51–53]. Sustainable management is a conservation type of management containing appropriate procedures for conserving nature, e.g., extensive mowing and grazing, selective forest management, supported by subsidy funds from the Ministry of the Environment. Non-governmental organizations should also be involved in this issue, in particular by disseminating information on the importance of promoting valuable habitats in the cultural landscape to government officials and the general public.

5. Conclusions

The existing Nature Protection Network in the Czech Republic was found to be only partly adequate in terms of effective protection of representative valuable natural habitats mapped by the Nature Conservation Agency of the Czech Republic. A total area of 73,805 ha (15.6%), of the most valuable natural habitats classified as CFs, is sufficiently protected at present from the remaining CF area. Therefore, according to three conservation targets aimed at preserving 25%, 50%, and 75% of the CFs, it is still necessary to preserve 22,932 ha, 72,429 ha, and 124,363 ha of the CFs included in the insufficiently protected area, and 17,255 ha, 51,620 ha, and 84,993 ha of the CFs in non-protected areas. The group of most valuable habitats that sufficiently protect more than 50% of their total area included small habitats with specific environmental conditions, e.g., alpine grasslands and bog forests. The sufficiently protected area of large-area habitats, such as oak and alluvial forests, alluvial and Mesic meadows, covered less than 10% of their total area. Nevertheless, these significantly represented habitats in the CR affected by human activity are still important for the provision of ecosystem services and require protection in the form of appropriate land management.

We proved that Marxan model is applicable over relatively large regions with relatively small size of planning units. The Marxan model is a candidate tool for verification of currently protected areas by the Nature Conservation Agency of the Czech Republic. According to our results, only large segments of valuable habitats without any protection have been found in military areas that are considered particularly important sites for biodiversity in Eastern Europe. Stakeholders managing the landscape and the non-governmental organizations should be involved in the protection of selected valuable habitats selected by the Marxan model in the insufficiently or even completely unprotected areas. A sustainable land management strategy promoting less intensive agriculture and close-to-nature forestry should be specifically designed for (and applied to) these areas. The Marxan model revealed itself to be a suitable tool for supporting large-scale strategic planning in larger administrative units up to the national scale in the Czech Republic.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. The most valuable habitats from Habitat Mapping Layers [35].

Habitats of the CR, according Chytrý et al. (2010) [33]	Total Area (ha)	Area in Conserved PU (ha)	Area in Conserved PU (Percentage)	Number of All Patches of Habitat in the CZ
A1.1	113.24	113.24	100	4
A1.2	593.08	583	98.3	4
A2.1	51.64	51.64	100	2
A2.2	223.5	211.2	94.5	4
A3	0.82	0.82	100	1
A4.1	404.29	368.55	91.2	4
A4.2	17.41	14.5	83.3	7
A4.3	28.87	26.39	91.4	6
A5	1.29	1.29	100	2
A6	143.98	141.73	98.4	4
A7	1249.42	1186.19	94.9	2
A8.1	0.94	0.94	100	1
A8.2	23.58	23.58	100	2
K1	1811.64	288.6	15.9	100
K2.1	1111.67	148.58	13.4	28
K2.2	25.04	0.72	2.9	2
K3	13,734.43	767.04	5.6	175
K4	19.8	8.09	40.9	4
K4C	1.72	0.66	38.4	1
L1	1850.71	262.22	14.2	49
L10.1	567.28	243.91	43	19
L10.2	1086.6	627.04	57.7	20
L10.3	39.96	36.67	91.8	6
L10.4	827.84	758.96	91.7	18
L2.1	180.33	57.13	31.7	26
L2.2	20,115.37	1070.15	5.3	249
L2.2B	9459.99	241.14	2.5	106
L2.3	7397.93	1045	14.1	23
L2.3B	3432.37	534.1	15.6	9
L2.4	822.06	97.09	11.8	12
L3.1	35,284.14	3475.36	9.8	95
L3.2	3977.74	157.44	4	10

Table A1. *Cont.*

Habitats of the CR, according Chytrý et al. (2010) [33]	Total Area (ha)	Area in Conserved PU (ha)	Area in Conserved PU (Percentage)	Number of All Patches of Habitat in the CZ
L3.3	21,602.2	2501.52	11.6	49
L3.4	2148.9	198	9.2	10
L4	8331.27	1390.18	16.7	128
L5.1	56,508.87	9534.06	16.9	197
L5.2	288.08	123.37	42.8	11
L5.3	497.78	117.79	23.7	18
L5.4	51,674.22	12,892.38	24.9	218
L6.1	440.87	188.69	42.8	21
L6.2	700.14	94.18	13.5	3
L6.3	500.32	0	0	0
L6.4	1591.64	137.95	8.7	21
L6.5A	126.35	87.24	69	1
L6.5B	3114.33	273.74	8.8	25
L7.1	13,717.97	1075.72	7.8	60
L7.2	2740.75	105.3	3.8	14
L7.3	5617.85	900.87	16	57
L7.4	120.76	0	0	0
L8.1A	476.29	290.34	61	9
L8.1B	4615.27	813.1	17.6	46
L8.2	145.66	10.16	7	3
L8.3	36.9	4.74	12.8	3
L9.1	17,936.36	10,960.8	61.1	35
L9.2	12,386.42	5810.69	46.9	77
L9.3	505.04	329.22	65.2	12
M1.1	5310.88	541.85	10.2	88
M1.2	35.1	3.02	8.6	1
M1.3	113.68	5.18	4.6	19
M1.4	406.67	114.96	28.3	31
M1.5	102.27	12.12	11.9	25
M1.6	19.53	3.37	17.3	12
M1.7	3012.91	459.76	15.3	126
M1.8	2.5	0	0	0
M2.1	364.19	70.58	19.4	6
M2.2	4.95	3.78	76.4	1
M2.3	3.09	0.71	23	2
M2.4	3.55	0	0	0
M3	12.06	5.89	48.8	3
M4.1	50.01	12.4	24.8	17
M4.3	0.63	0	0	0
M5	109.02	9.38	8.6	23
M6	12.04	1.48	12.3	2
M7	26.19	1.29	4.9	2
R1.1	4.67	0.76	16.3	12
R1.2	21.62	2.32	10.7	17
R1.3	6.79	1.44	21.2	16
R1.4	273.45	51.75	18.9	128
R1.5	3.5	3.44	98.3	5
R2.1	17.32	0.81	4.7	6
R2.2	923.92	313.69	34	80
R2.3	1564.66	733.94	46.9	84
R2.4	9.24	6.19	67	4
R3.1	360.07	273.47	75.9	23
R3.2	1511.92	1060.59	70.1	14
R3.3	38.52	22.45	58.3	13
R3.4	279.63	47.01	16.8	9
S1.1	35.96	3.48	9.7	19

Table A1. *Cont.*

Habitats of the CR, according Chytrý et al. (2010) [33]	Total Area (ha)	Area in Conserved PU (ha)	Area in Conserved PU (Percentage)	Number of All Patches of Habitat in the CZ
S1.2	1004.58	262.93	26.2	149
S1.3	13.83	1.34	9.7	3
S1.4	1.62	0.06	3.7	1
S1.5	7.08	1.82	25.7	8
S2A	10.22	3.78	37	6
S2B	23.28	5.49	23.6	7
S3	0.84	0.34	40.5	2
T1.1	65,935.86	2862.18	4.3	325
T1.10	169.88	16.4	9.7	32
T1.2	5771.62	588.67	10.2	42
T1.3	15421.3	637.22	4.1	89
T1.4	5976.69	277.74	4.6	36
T1.5	11,593.79	1000.32	8.6	219
T1.6	4448.57	357.46	8	112
T1.7	367.28	0.98	0.3	2
T1.8	3.2	0	0	0
T1.9	2814.32	275.49	9.8	66
T2.1	43.48	31.7	72.9	5
T2.2	309.62	44.48	14.4	4
T2.3	2669.61	511.02	19.1	101
T3.1	103.98	33.19	31.9	22
T3.2	27.76	7.83	28.2	10
T3.3	251.66	54.18	21.5	13
T3.3D	453.73	43.84	9.7	19
T3.4	445.49	237.16	53.2	13
T3.4B	92.87	3.91	4.2	3
T3.4D	3798	458.24	12.1	61
T3.5A	13.08	2.46	18.8	1
T3.5B	667.26	9.83	1.5	8
T4.1	53.71	10.51	19.6	19
T4.2	238.35	17.52	7.4	45
T5.1	21.37	0.4	1.9	1
T5.2	71.38	1.41	2	2
T5.3	379.65	32.82	8.6	8
T5.4	65.22	0	0	0
T5.5	553.13	9.67	1.7	22
T6.1	14.65	2.54	17.3	1
T6.2	114.37	7.7	6.7	4
T7	25.66	5.03	19.6	2
T8.1	83.55	24.13	28.9	5
T8.2	648.54	77.87	12	30
T8.3	40.18	6.47	16.1	6
V1	46.07	0.89	1.9	4
V1F	3455.98	395.75	11.5	59
V1G	12,039.25	807.11	6.7	103
V2	134.46	3.03	2.3	4
V3	14.84	9.83	66.2	7
V4A	1942.2	226.04	11.6	33
V4B	3454.88	265.18	7.7	90
V5	12.72	0.02	0.2	2
V6	25.38	25.38	100	2

Table A2. Required target area (ha) to be added to each scenario. The habitats were selected from Habitat Mapping Layers [35].

Habitat	Required Area to Complete for Scenario 25%	Required Area to Complete for Scenario 50%	Required Area to Complete for Scenario 75%
A1.1	0	0	0
A1.2	0	0	0
A2.1	0	0	0
A2.2	0	0	0
A3	0	0	0
A4.1	0	0	0
A4.2	0	0	0
A4.3	0	0	0
A5	0	0	0
A6	0	0	0
A7	0	0	0
A8.1	0	0	0
A8.2	0	0	0
K1	164.31	617.22	1070.12
K2.1	129.34	407.26	685.18
K2.2	5.54	11.8	18.06
K3	2666.57	6100.17	9533.78
K4	0	1.81	6.76
K4C	0	0.2	0.63
L1	200.45	663.13	1125.81
L10.1	0	39.74	181.56
L10.2	0	0	187.91
L10.3	0	0	0
L10.4	0	0	0
L2.1	0	33.03	78.11
L2.2	3958.69	8987.53	14,016.38
L2.2B	2123.86	4488.86	6853.85
L2.3	804.48	2653.96	4503.45
L2.3B	323.99	1182.08	2040.18
L2.4	108.42	313.94	519.45
L3.1	5345.67	14,166.71	22,987.74
L3.2	837	1831.43	2825.87
L3.3	2899.03	8299.58	13,700.14
L3.4	339.23	876.46	1413.68
L4	692.64	2775.46	4858.28
L5.1	4593.16	18,720.38	32,847.59
L5.2	0	20.67	92.69
L5.3	6.65	131.09	255.54
L5.4	26.17	12,944.73	25,863.28
L6.1	0	31.75	141.96
L6.2	80.85	255.89	430.92
L6.3	125.08	250.16	375.24
L6.4	259.96	657.87	1055.78
L6.5A	0	0	7.52
L6.5B	504.85	1283.43	2062.01
L7.1	2353.78	5783.27	9212.76
L7.2	579.89	1265.08	1950.26
L7.3	503.59	1908.06	3312.52
L7.4	30.19	60.38	90.57
L8.1A	0	0	66.88
L8.1B	340.72	1494.53	2648.35
L8.2	26.25	62.67	99.08
L8.3	4.49	13.71	22.94
L9.1	0	0	2491.47
L9.2	0	382.52	3479.12
L9.3	0	0	49.56

Table A2. *Cont.*

Habitat	Required Area to Complete for Scenario 25%	Required Area to Complete for Scenario 50%	Required Area to Complete for Scenario 75%
M1.1	785.87	2113.59	3441.31
M1.2	5.75	14.53	23.3
M1.3	23.24	51.66	80.08
M1.4	0	88.38	190.05
M1.5	13.45	39.02	64.58
M1.6	1.52	6.4	11.28
M1.7	293.47	1046.7	1799.92
M1.8	0.62	1.25	1.87
M2.1	20.47	111.51	202.56
M2.2	0	0	0
M2.3	0.06	0.83	1.6
M2.4	0.89	1.78	2.66
M3	0	0.14	3.16
M4.1	0.1	12.6	25.1
M4.3	0.16	0.32	0.47
M5	17.87	45.13	72.38
M6	1.53	4.54	7.55
M7	5.26	11.81	18.35
R1.1	0.41	1.58	2.74
R1.2	3.09	8.5	13.9
R1.3	0.26	1.95	3.65
R1.4	16.61	84.97	153.34
R1.5	0	0	0
R2.1	3.53	7.86	12.19
R2.2	0	148.27	379.25
R2.3	0	48.39	439.55
R2.4	0	0	0.74
R3.1	0	0	0
R3.2	0	0	73.35
R3.3	0	0	6.45
R3.4	22.89	92.8	162.71
S1.1	5.51	14.5	23.49
S1.2	0	239.36	490.5
S1.3	2.12	5.58	9.04
S1.4	0.34	0.75	1.15
S1.5	0	1.72	3.49
S2A	0	1.33	3.89
S2B	0.33	6.15	11.97
S3	0	0.08	0.29
T1.1	13,621.79	30,105.75	46,589.72
T1.10	26.07	68.54	111.01
T1.2	854.24	2297.14	3740.04
T1.3	3218.1	7073.43	10,928.75
T1.4	1216.43	2710.6	4204.77
T1.5	1898.13	4796.58	7695.03
T1.6	754.68	1866.82	2978.96
T1.7	90.84	182.66	274.48
T1.8	0.8	1.6	2.4
T1.9	428.09	1131.67	1835.25
T2.1	0	0	0.91
T2.2	32.92	110.33	187.74
T2.3	156.39	823.79	1491.19
T3.1	0	18.8	44.79
T3.2	0	6.05	12.99
T3.3	8.74	71.65	134.57
T3.3D	69.59	183.03	296.46

Table A2. *Cont.*

Habitat	Required Area to Complete for Scenario 25%	Required Area to Complete for Scenario 50%	Required Area to Complete for Scenario 75%
T3.4	0	0	96.96
T3.4B	19.31	42.53	65.75
T3.4D	491.25	1440.75	2390.25
T3.5A	0.81	4.08	7.35
T3.5B	156.99	323.8	490.61
T4.1	2.91	16.34	29.77
T4.2	42.07	101.65	161.24
T5.1	4.95	10.29	15.63
T5.2	16.44	34.28	52.13
T5.3	62.09	157	251.92
T5.4	16.31	32.61	48.92
T5.5	128.61	266.9	405.18
T6.1	1.12	4.78	8.44
T6.2	20.89	49.49	78.08
T7	1.39	7.8	14.21
T8.1	0	17.64	38.53
T8.2	84.26	246.4	408.53
T8.3	3.57	13.62	23.67
V1	10.63	22.15	33.67
V1F	468.25	1332.24	2196.23
V1G	2202.71	5212.52	8222.33
V2	30.58	64.2	97.81
V3	0	0	1.3
V4A	259.51	745.05	1230.6
V4B	598.54	1462.26	2325.98
V5	3.16	6.35	9.53
V6	0	0	0
Total	58,263.36	165,993.71	280,134.57

Table A3. Full name and code of nature and near-nature habitats according to the Habitat Catalogue of the Czech Republic [36] and inclusion of these habitats into the system Natura 2000 as Special Areas of Conservation.

Name of Habitats of the CR	Habitats of the CZ	Natura 2000 Habitats
Wind-swept alpine grasslands	A1.1	6150
Closed alpine grasslands	A1.2	6150
Alpine heathlands	A2.1	4060
Subalpine *Vaccinium* vegetation	A2.2	4060
Snow beds	A3	6150
Subalpine tall grasslands	A4.1	6430
Subalpine tall-forb vegetation	A4.2	6430
Subalpine tall-fern vegetation	A4.3	6430
Cliff vegetation in the Sudeten cirques	A5	8220
Acidophilous vegetation of alpine boulder screes	A6A	8110
Acidophilous vegetation of alpine cliffs	A6B	8220
Pinus mugo scrub	A7	4070
Salix lapponum subalpine scrub	A8.1	4080
Subalpine deciduous tall scrub	A8.2	4080
Willow cars	K1	—
Willow scrub of loamy and sandy river banks	K2.1	—
Willow scrub of river gravel banks	K2.2	3240
Tall mesic and xeric scrub	K3	—
Low xeric scrub, primary vegetation on rock outcrops with *Cotoneaster spp.*	K4A	40A0
Low xeric scrub, secondary vegetation with *Prunus tenella*	K4B	40A0
Low xeric scrub, other stands	K4C	—

Table A3. *Cont.*

Name of Habitats of the CR	Habitats of the CZ	Natura 2000 Habitats
Alder cars	L1	—
Birch mire forests	L10.1	91D0
Pine mire forests with *Vaccinium*	L10.2	91D0
Pine forests of continental mires with *Eriophorum*	L10.3	91D0
Pinus rotundata bog forests	L10.4	91D0
Montane grey alder galleries	L2.1	91E0.
Ash–alder alluvial forests	L2.2	91E0.
Hardwood forests of lowland rivers	L2.3	91F0
Willow–poplar forests of lowland rivers	L2.4	91E0.
Hercynian oak–hornbeam forests	L3.1	9170
Polonian oak–hornbeam forests	L3.2	9170
Pannonian–Carpathian oak–hornbeam forests	L3.3A	91G0
West Carpathian oak–hornbeam forests	L3.3B	9170
Pannonian oak–hornbeam forests	L3.4	91G0
Ravine forests	L4	9180
Herb-rich beech forests	L5.1	9130
Montane sycamore–beech forests	L5.2	9140
Limestone beech forests	L5.3	9150
Acidophilous beech forests	L5.4	9110
Peri-Alpidic basiphilous thermophilous oak forests	L6.1	91H0
Pannonian thermophilous oak forests on loess	L6.2	91I0
Pannonian thermophilous oak forests on sand	L6.3	91I0
Central European basiphilous thermophilous oak forests	L6.4	91I0
Acidophilous thermophilous oak forests with *Genista pilosa*	L6.5A	91I0
Acidophilous thermophilous oak forests without *Genista pilosa*	L6.5B	—
Dry acidophilous oak forests	L7.1	—
Wet acidophilous oak forests	L7.2	9190
Subcontinental pine–oak forests	L7.3	—
Acidophilous oak forests on sand	L7.4	—
Boreo-continental pine forests with lichens on sand	L8.1A	91T0
Boreo-continental pine forests, other stands	L8.1B	—
Forest-steppe pine forests	L8.2	91U0
Peri-Alpidic serpentine pine forests	L8.3	—
Montane *Calamagrostis* spruce forests	L9.1	9410
Bog spruce forests	L9.2A	9410
Waterlogged spruce forests	L9.2B	9410
Montane *Athyrium* spruce forests	L9.3	9410
Reed beds of eutrophic still waters	M1.1	—
Halophilous reed and sedge beds	M1.2	—
Eutrophic vegetation of muddy substrata	M1.3	—
Riverine reed vegetation	M1.4	—
Reed vegetation of brooks	M1.5	—
Mesotrophic vegetation of muddy substrata	M1.6	7140
Tall-sedge beds	M1.7	—
Calcareous fens with *Cladium mariscus*	M1.8	7210
Vegetation of exposed fishpond bottoms	M2.1	3130
Annual vegetation on wet sand	M2.2	3130
Vegetation of exposed bottoms in warm areas	M2.3	3130
Vegetation of annual halophilous grasses	M2.4	—
Vegetation of perennial amphibious herbs	M3	3130
Unvegetated river gravel banks	M4.1	—
River gravel banks with *Myricaria germanica*	M4.2	3230
River gravel banks with *Calamagrostis pseudophragmites*	M4.3	3220
Petasites fringes of montane brooks	M5	6430
Muddy river banks	M6	3270
Herbaceous fringes of lowland rivers	M7	6430
Meadow springs with tufa formation	R1.1	7220
Meadow springs without tufa formation	R1.2	—
Forest springs with tufa formation	R1.3	7220
Forest springs without tufa formation	R1.4	—
Subalpine springs	R1.5	—

Table A3. *Cont.*

Name of Habitats of the CR	Habitats of the CZ	Natura 2000 Habitats
Calcareous fens	R2.1	7230
Acidic moss-rich fens	R2.2	7140
Transitional mires	R2.3	7140
Peatsoils with *Rhynchospora alba*	R2.4	7150
Open raised bogs	R3.1	7110
Raised bogs with *Pinus mugo*	R3.2	91D0
Bog hollows	R3.3	7110
Degraded raised bogs	R3.4	7120
Chasmophytic vegetation of calcareous cliffs and boulder screes	S1.1	8210
Chasmophytic vegetation of siliceous cliffs and boulder screes	S1.2	8220
Tall grasslands on rock ledges	S1.3	—
Tall-forb vegetation of fine-soil-rich boulder screes	S1.4	—
Ribes alpinum scrub on cliffs and boulder screes	S1.5	—
Mobile screes of basic rocks	S2A	8160
Mobile screes of acidis rocks	S2B	8150
Caves open to the public	S3A	—
Caves not open to the public	S3B	8310
Mesic Arrhenatherum meadows	T1.1	6510
Vegetation of wet disturbed soils	T1.10	—
Montane Trisetum meadows	T1.2	6520
Cynosurus pastures	T1.3	—
Alluvial Alopecurus meadows	T1.4	—
Wet Cirsium meadows	T1.5	—
Wet Filipendula grasslands	T1.6	6430
Continental inundated meadows	T1.7	6440
Continental tall-forb vegetation	T1.8	6430
Intermittently wet *Mollinia* meadows	T1.9	6410
Subalpine *Nardus* grasslands	T2.1	6230
Montane *Nardus* grasslands with alpine species	T2.2	6230
Submontane and montane *Nardus* grasslands with scattered *Juniperus communis* vegetation	T2.3A	5130
Submontane and montane *Nardus* grasslands without *Juniperus communis*	T2.3B	6230
Rock-outcrop vegetation with *Festuca pallens*	T3.1	6190
Sesleria grasslands	T3.2	6190
Sub-Pannonian steppic grasslands	T3.3A	6240
Pannonian loess steppic grasslands	T3.3B	6250
Narrow-leaved dry grasslands with significant occurrence of orchids	T3.3C	6210
Narrow-leaved dry grasslands without significant occurrence of orchids	T3.3D	6210
Broad-leaved dry grasslands with significant occurrence of orchids and with *Juniperus communis*	T3.4A	6210
Broad-leaved dry grasslands without significant occurrence of orchids and with *Juniperus communis*	T3.4B	5310
Broad-leaved dry grasslands with significant occurrence of orchids and without *Juniperus communis*	T3.4C	6210
Broad-leaved dry grasslands without significant occurrence of orchids and without *Juniperus communis*	T3.4D	6210
Acidophilous dry grasslands with significant occurrence of orchids	T3.5A	6210
Acidophilous dry grasslands without significant occurrence of orchids	T3.5B	6210
Dry herbaceous fringes	T4.1	—
Mesic herbaceous fringes	T4.2	—
Annual vegetation on sandy soils	T5.1	2330
Open sand grasslands with *Corynephorus canescens*	T5.2	2330
Festucasand grasslands	T5.3	2330
Pannonian sand steppe grasslands	T5.4	6260
Acidophilous grasslands on shallow soils	T5.5	—

Table A3. *Cont.*

Name of Habitats of the CR	Habitats of the CZ	Natura 2000 Habitats
Acidophilous vegetation of vernal therophytes and succulents with dominance of *Jovibarba globifera*	T6.1A	8230
Acidophilous vegetation of vernal therophytes and succulents without dominance of *Jovibarba globifera*	T6.1B	8230
Basiphilous vegetation of vernal therophytes and succulents with dominance of *Jovibarba globifera*	T6.2A	6110
Basiphilous vegetation of vernal therophytes and succulents without dominance of *Jovibarba globifera*	T6.2B	6110
Inland salt marshes	T7	1340
Dry lowland and colline heaths with occurrence of *Juniperus communis*	T8.1A	5130
Dry lowland and colline heaths without occurrence of *Juniperus communis*	T8.1B	4030
Secondary submontane and montane heaths with occurrence of *Juniperus communis*	T8.2A	5130
Secondary submontane and montane heaths without occurrence of *Juniperus communis*	T8.2B	4030
Vaccinium vegetation of cliffs and boulder screes	T8.3	4030
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Hydrocharis morsusranae*	V1A	3150
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Stratiotes aloides*	V1B	3150
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Utricularia australis* or *U. vulgaris*	V1C	3150
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Salvinia* natans	V1D	3150
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with *Aldrovanda vesiculosa*	V1E	3150
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters without species specific to V1A–V1E	V1F	3150
Macrophyte vegetation of naturally eutrophic and mesotrophic still waters without macrophyte species valuable for nature conservation	V1G	—
Macrophyte vegetation of shallow still waters with dominant *Batrachium spp.*	V2A	—
Macrophyte vegetation of shallow still waters with dominant *Hottonia palustris*	V2B	—
Macrophyte vegetation of shallow still waters, other stands	V2C	—
Macrophyte vegetation of oligotrophic lakes and pools	V3	3160
Macrophyte vegetation of water streams with currently present aquatic macrophytes	V4A	3260
Macrophyte vegetation of water streams with potential occurrence of aquatic macrophytes or with natural or semi-natural bed	V4B	3260
Charophyceae vegetation	V5	3140
Isoëtes vegetation	V6	3130

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