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Mine reclamation planning and management: Integrating natural habitats into post-mining land use

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ABSTRACT

The reclamation of mined land in the Czech Republic has been focused on preparing the land for final use for productive purposes. The current national regulatory framework does not consider non-productive habitats as a legal type of post-mining land use. In the study presented here, we mapped, categorized, and analyzed non-productive post-mining habitats and defined appropriate management measures applicable under the present legal framework. Thirty different types of non-productive and productive post-mining habitats were distinguished in the study area of the North Bohemian Brown Coal Basin. Spatial and on-site analyses were conducted to identify their landscape and ecological functions, using measures such as the average area, the perimeter, and the relative length of the ecotones. The results showed that non-productive habitats accounted for 9.9% of the study area and that the non-productive habitats were significantly smaller than the productive habitats. There was an average area of 1 ha for non-productive habitats and an average area of 4 ha for productive habitats. In hydric reclamation, we identified more than 96% of the habitats as non-productive. However, only 6.7% of forest reclamation land, 4.4% of 'other' reclamation land, and 2.6% of agricultural reclamation land have been officially classified as non-productive habitat. Supported by a case study and our literature review, we have developed a typology of non-productive post-mining habitats. The typology systematizes non-productive habitats and makes clear recommendations for their establishment and management measures. The typology can be communicated to a multi-stakeholder audience to increase the knowledge baseline for incorporating non-productive habitats into post-mining land use.

1. Introduction

Land use change is one of the major drivers of loss of terrestrial biodiversity and alterations to ecosystem functions and services (Ridding et al., 2020; Tittensor et al., 2014). As highlighted by Ridding et al. (2019), there has been a significant decline in many semi-natural and natural habitats across Europe in the last century. These declining trends are presumed to be common across all habitat types (Hooftman and Bullock, 2012). However, most studies have been focused on traditional rural or urban landscapes (e.g. Ridding et al., 2020; Zhang, 2016; Watson and Albon, 2011; Macdonald and Johnson, 2000). Natural habitats in industrialized post-mining landscapes have been subjected to less examination and are less understood.

Semi-natural and natural habitats have high conservation importance in many parts of the world. Such sites often support a high diversity of species (Gammal et al., 2019; Hendrychová and Kabrna, 2016), and can provide a variety of ecosystem services including pollination, carbon storage, or cultural and aesthetic values (Bengtsson et al., 2019; Cordingley et al., 2015; Svobodova et al., 2012).

The mining industry is an industry that changes entire landscapes, making it the source of a variety of impacts (Owen et al., 2020; Fleming-Muñoz et al., 2020; Werner et al., 2019; Svobodova et al., 2019a). Mining as an activity produces temporary land use (Bowie and Fulcher, 2017), which transforms the land into a final post-mining landscape through complex processes of mine closure and mine rehabilitation. As highlighted by ICMM (2019), a successful definition of the final post-mining land use is a crucial part of every mine closure plan in mining regions across the world.

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The return of post-mining land to safe, stable, non-polluting landforms with economically productive land uses is in the interests of landowners and local communities. In practice, however, the planning of post-mining land use has been driven mainly by economics. From the perspective of the mining industry, the key commercial drivers are an attempt to reduce (or ultimately remove) liability and ongoing costs, generally the sooner the better (Bowie and Fulcher, 2017). It has been demonstrated (e.g. by Everingham et al., 2020; Svobodova et al., 2020a; Svobodova et al., 2019b) that developing a sustainable post-mining land requires partnering between planners, developers, local governments, ecologists, and local communities. Studies, such as Liu et al. (2019), Avera et al. (2015), Tropek and Prach (2012), and Řehounková et al. (2011), have reported ecological restoration as a valuable method for mine land recovery resulting in natural or semi-natural habitats with high ecological values and diverse ecological functions.

In this study, we demonstrate that integrating non-productive 'natural' habitats into mine reclamation planning and management is, in terms of sustainability, an effective method for restoring large-scale post-mining sites. Post-closure environments that offer a diversity of habitats have a versatile, positive impact on their surroundings, and contribute greatly to ecological stability, biodiversity, and the associated ecological functions.

Our study focuses on mine rehabilitation planning and management in the Czech Republic. The current national legal frameworks do not consider non-productive natural habitats as a legal type of post-mining land use. Therefore, our study aims to map, categorize, and analyze non-productive post-mining habitats and to define appropriate management measures. The objectives of the study are: (1) to compile a list of habitats that are or may be located in brown coal mine rehabilitated areas; (2) to map these habitats in the study area, i.e. all brown coal spoil heaps in the North Bohemia Brown Coal Basin; (3) to analyze the habitats in terms of landscape ecological functions, and (4) to define management measures for these non-productive habitats in the form of an innovative reclamation planning tool.

2. Context of the study

The Czech Republic is the fourth-largest producer of brown coal in the European Union (European Association for Coal and Lignite, 2018). Brown coal has been an important part of the national electricity mix (brown coal 44.63%, hard coal 4.18%, gas 5.80%, nuclear 36.88%, renewables 6.17%; OTE, 2018), and this situation seems likely to continue in the future, as indicated by Svobodova et al. (2020b) and Ocelík et al. (2019). According to the current State Energy Policy, the Czech government expects coal to account for at least 30.5% of energy production until 2030 (SEC, 2014).

Czech legislation, in particular Act No. 44/1988 Coll. On the protection and utilization of mineral resources (Mining Act), requires mining companies to restore post-mining land to its state before mining started. In a practical sense, this means prioritizing agricultural or forest land use over natural areas, as the national regulatory framework (Act No. 334/1992 Coll. On the conservation of agricultural land; Act No. 289/1995 Coll. On forests) provides strong protection against the loss of agricultural and forested land. As discussed by Schulz and Schwartzkopf (2018), mine reclamation practice in the Czech Republic has been working on the assumption that the initial environmental conditions in post-mining sites are highly unfavorable, which hinders the early development of plants and other organisms. Furthermore, as coal fields are typically surrounded by a dense network of settlements, operating mining companies face pressure from the public to make reclamation areas available as soon as possible. A variety of habitats are therefore merged into a single large unit that is easier to manage and maintain with the use of technologies that shorten the initial natural phase of the planned reclamation.

Traditionally, Czech reclamation planning works with four types of mine reclamation, according to the prevailing final land use: hydric, forest, agricultural, and others (mainly recreational). These involve many technical interventions and intensive initial management activities, known as planned (or technical) reclamation (Prach et al., 2019a; Chuman, 2015; Kabrna, 2011). Methods widely used in technical reclamation, such as ground leveling and dense even-aged forests (Feng et al., 2019), do not reflect the current state of scientific knowledge for best practice in land restoration. The currently applied management of technical reclamation can have long-lasting negative environmental consequences, such as the elimination of indigenous wildlife species, the destruction of natural ecosystems, and habitat depletion, as recognized by Šebelíková et al. (2019), and by Hendrychová and Kabrna (2008). Prach et al. (2019a) and Řehounková et al. (2018) highlighted that the benefits of near-natural 'passive' restoration have not yet been fully utilized in the Czech legal and practical frameworks for reclamation. These reflect contradictory and outdated needs and interests of different stakeholders. Prach et al. (2019b) consider the implementation of up-to-date approaches of near-natural restoration and methods for evaluating restoration success that would align with the best global knowledge and practice as the most urgent issue that needs to be targeted by national legislation very soon. Integrating non-productive natural habitats into current reclamation practice is part of these requirements, as supported by Moradi et al. (2018), Prach and Hobbs (2008), Prach (2003), and Schulz and Wiegleb (2000).

Although mine closure planning in the Czech Republic fails to consider non-productive habitats, other planning mechanisms such as land consolidation and urban planning incorporate non-productive habitats into a plan through the concept embodied in the Territorial System of Ecological Stability (TSES) (Sklenička, 2007; Löw, 1995). As defined by Act No. 114/1992 Coll. On nature and landscape preservation, the TSES is a set of mutually interlinked natural and semi-natural ecosystems that strengthen the ecological stability of the landscape. This inconsistent approach to considerations of non-productive habitats in planning mechanisms creates an internal contradiction in national planning practice.

Marginal or dysfunctional parts of productive habitats, e.g. field borders, waterlogged sites, poorly accessible locations, and steep slopes, and also areas with spontaneous succession, have the greatest potential to form non-productive habitats. Research studies conducted in rehabilitated mine areas in the Czech Republic have demonstrated multiple benefits associated with these habitats. For example, as shown by Hodecek et al. (2016) and by Hendrychová (2008), non-productive habitats are usually self-sustaining in the long term perspective in mine reclamations, unlike productive habitats. Non-productive habitats are naturally located close to each other, which is an important beneficial factor for gradual colonization, for the meta-population dynamics of various species (Hanski, 1999), and it is a determining factor for less mobile species (Ricketts et al., 2008). Soil biota communities thrive better in non-productive natural habitats than in productive habitats (Frouz et al., 2008). Non-productive habitats provide a great variety of places with a range of hydric properties and nutrition within a relatively small area, ranging from wetlands to extremely dry habitats, or from areas completely free of vegetation to areas with abundant flowers and forests (Prach et al., 2013; Řehounková et al., 2011). This type of habitat-rich landscape hosts numerous invertebrate and vertebrate species whose adults live in completely different nestling, grazing, wintering, and sheltering habitats (Hendrychová and Bogusch, 2016; Tropek and Řehounek, 2012; Šálek et al., 2010), or their females need somewhat warmer micro-habitats than the males of the same species (Volf et al., 2018). These habitats include non-crop habitats that provide floral resources and suitable overwintering sites for the beneficial insects that are of great importance in agroecosystems (near crop fields) for biological pest control conservation (Ramsden et al., 2015).

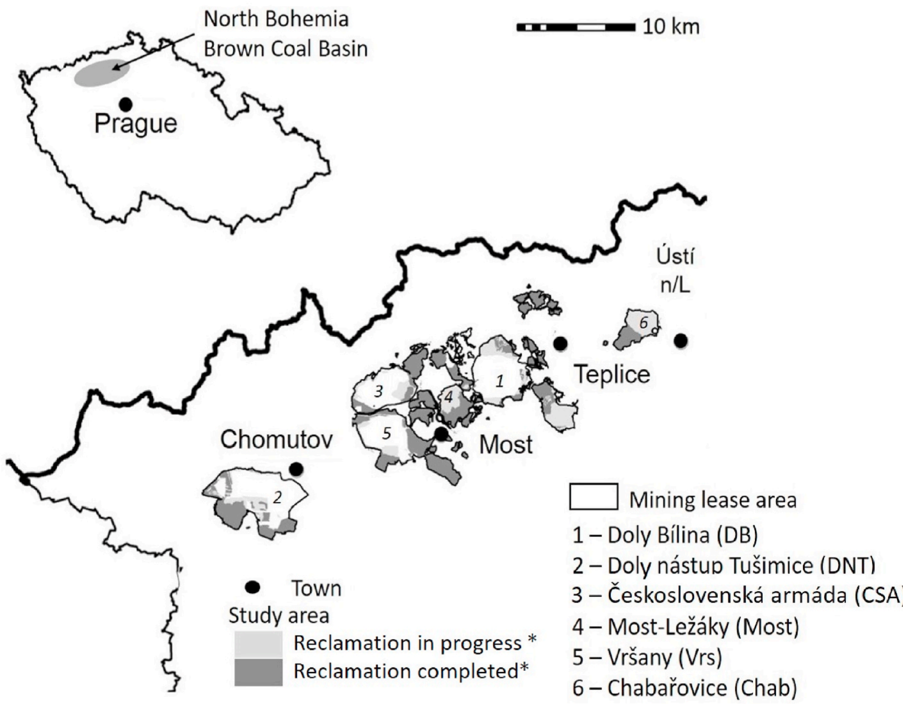

Fig. 1. The study area includes six study localities. This figure shows the location of these localities, mining lease areas, the progress of reclamation work in 2017, and the regional centers: the towns of Chomutov, Most, Teplice, and Ústí n/L.

3. Methods

3.1. Study area

The study was carried out in the North Bohemian Brown Coal Basin, the largest coal mining region in the Czech Republic (Fig. 1). There are four operating surface mines in the study area. More than 100 km^2 of land will be rehabilitated after the mines are ceased.

In terms of physical and geographical conditions, the study area is the driest part of the Czech Republic, with average total annual precipitation of 450–550 mm and an average temperature of 8–9 °C (Quitt, 1971). These climatic conditions support the development of oak-hornbeam forests and alders in localities adjacent to water. The most frequent soils are Miocene clays, which can swell considerably and are highly plastic. These clay soils favor the spontaneous formation of shallow water bodies. The character of the study area has been heavily impacted by the brown coal open-cast and deep mining activities that started more than 150 years ago. Underground mines and small open pits were in operation until the 1950s, at which time the growing demand for brown coal prompted the application of large-capacity excavators on the overburden layers and the coal layers (Valášek and Chytka, 2009). As a result, the originally flat topography of the study area has continuously been changed into deep open pits and large spoil heaps, as shown by Hendrychová and Kabrna (2016). If they are not reclaimed in a planned way, the post-mining sites, usually convert into forest-steppe communities with a dominant occurrence of birch and willow, thermophilic shrubs, and bush grass.

Our study focuses on six study localities, as shown in Fig. 1 and Table 1, covering an area of approximately 259 km^2. Of the total area, 64% has already been reclaimed or are in progress. The study

Table 1
A description of the six study localities, as sourced in their mine reclamation plans.

Study locality	Main components/spoil heaps	Mining company	Mine closure[a] (year)	Total area (ha)	Reclaimed (%)	Reclamation completed (ha)	Reclamation in progress (ha)
1. Doly Bílina	Radovesice, Pokrok, Bílina, Teplicko	Severočeské doly[b]	2055	6897	63	2544	1769
2. Doly Nástup Tušimice	Merkur, Březno, Prunéřov	Severočeské doly [b]	2038	6227	44	1998	739
3. Československá Armáda	ČSA, OM, Kopisty, Horní Jiřetín, Albrechtice, Růžodol, Lomsko	Severní energetická [b]	2024	5094	63	2696	535
4. Most-Ležáky	Ležáky, Most, Střimice, Hrabák, Benedikt, Elisabeth, Šibeník	Palivový kombinát [c]	1995	1795	100	1173	622
5. Vršany	Vršany, M. Březno, DJŠ	Vršanská uhelná [b]	2052	4465	68	2741	310
6. Chabařovice	Milada, Lochočice, Žichlice	Palivový kombinát [c]	1993	1454	100	558	896
Total				*25,932*	*64*	*11,710*	*4871*

[a] Expected dates of mine closure refer to closure dates in reclamation plans of the mines (BPT, 2016, 2017; R-Princip, 2017, 2018).
[b] Joint-stock company.
[c] State enterprises.

investigates reclamation sites on both the inner spoil heaps and the outer spoil heaps, where reclamation has been completed or is currently in progress. While two of the study localities (Most-Ležáky, Chabařovice) have already been closed, the remaining four (Doly Bílina, Doly Nástup Tušimice, Československá Armáda, and Vršany) have their closure planned within about 30 years (data from general reclamation and sanitation plans). The study exclusively investigates reclamation sites on both the inner spoil heaps and the outer spoil heaps, where reclamation has been completed or is currently in progress. These sites were selected to map the final post-mining land use, as set out in the mine reclamation plans.

3.2. Systematization of post-mining habitats

The first step in our study was to define post-mining habitats that can potentially be created, or that have been created, on spoil heaps during reclamation works as part of the final land use. We considered all potential and existing habitats, classified based on their productive functions into non-productive habitats (which were usually formed by natural processes without human intervention; prevailing non-productive functions) and productive habitats (created by human intervention; prevailing productive functions). The potential post-mining habitats were defined based on the experience of the authors, their observations, and surveys conducted in the study area. Potential habitats and existing habitats were further divided into four groups, according to their potential and actual occurrence in four types of mine reclamation (forestry, agricultural, hydric, and other). In addition to the four groups, some habitats were categorized as universal, because they could be established in any of the reclamation types. The post-mining habitats have been systematized into a list of 30 types, which are characterized in Table 2. This process of dividing habitats into four types was based on the types of reclamation corresponding to the relevant Czech national legislation, in particular Act No. 334/1992 Coll., On the conservation of agricultural land resources and Act No. 289/1995 Coll., On forests. Both of these acts require degraded land to be reclaimed for its original land use, emphasizing forests or agricultural land with productive functions. In our study, we have defined only habitats that would be recognized under these acts in mine reclamation practice.

3.3. Spatial analyses, ecological functions

Spatial and on-site analyses were conducted to analyze the actual occurrence of productive and non-productive habitats in six study localities. The geographical identification of the habitats was two-fold. First, detailed analyses of orthophoto maps (LSO (Land Survey Office), 2014) and mine reclamation plans were conducted to identify the actual locations and the extent of the habitats. Second, the habitats were verified on site. The perimeter of each habitat was tracked by GPS and was transferred to ArcGIS, as shown in Fig. 2. We analyzed elementary measurements indicating the landscape and ecological function of each habitat, e.g. the average area (ha), the perimeter (m), and the relative length of their ecotones (m/m^2). The total number of all habitats per type of reclamation was also calculated.

The relative length of the ecotones was calculated as the ratio of the perimeter to the area of the polygon (m/m^2). The relative length of the edges of the habitat, the so-called relative ecotones, characterizes the heterogeneity of the reclaimed landscape and determines its ecological value (Forman and Godron, 1986). According to Begon et al. (1986), longer ecotones contribute to higher biodiversity inside the habitat and in neighboring habitats.

We evaluated the correlation between the relative habitat properties for the possible reduction of mutual interchange of variables. The size of the habitats was not presented in relation to the relative ecotone length ($r = -0.0138$; $p = 0.5578$). These two habitat characteristics were therefore assessed separately. The significance of the differences in area and the relative length of the ecotones of individual habitats was tested

Table 2
List of habitats based on the four mine reclamation types based on their prevailing function – productive (P) or non-productive (N), and a description.

Reclamation type	Code	Habitat name	Habitat description	P/N
Forestry	F_I	Compact forest stands for timber production	Forest stands created by planting forest seedlings in a regular clip. Usually 8333 seedlings per hectare and 9 years of cultivation care (planting, mowing the weeds around the seedlings, hoeing, fertilizing, protection against damage caused by the game, shape cut of woody plants).	P
	F_1	A small treeless area in a compact forest stand	Sections without any planted species such as forest glades, grass plots, grassy lanes.	N
	F_2	Woodland meadow with solitary trees	Half-open forest-steppe areas that are rich in terms of biodiversity.	N
	F_3	An open area in compact forest stands left to spontaneous development	Areas that allow for the spontaneous spreading of tree/shrub species from surrounding stands, creation of wetlands, etc.	N
	F_4	Area planted with tree seeds	Denser and more natural forest (irregular or cluster-like row-spacing) originating from the spread of tree seeds, not seedlings.	N
	F_5	Spontaneously developed forest stand	Forest formations occurring on the spoil heap spontaneously - without human intervention. Usually with higher aesthetical and ecological values.	N
	F_6	Forest edge	Ecotonal zone between forest and open landscape. Usually forest-agricultural land transition, including lower tree species and a grassy belt.	N
	F_7	Sparse forest	Sunny forest stands with a wide clip of planted or spontaneously flowing woody plants enabling the development of rich vegetation in the shrub and herbaceous layer.	N
	F_8	Managed succession	A combination of natural succession with additional human intervention (control of invasive species, planting of trees typical for later succession stages).	N
Agricultural	A_I	An arable field for crop production	Flatland with a thicker topsoil layer (usually 0.5 m) dispersed on a levelled surface during technical reclamation. The grassland is usually a temporary land use for 5-8-years of special care, including green manuring. The final land use is as arable land.	P
	A_II	Permanent grassland for grazing or mowing	Agriculture land with the application of a tiny topsoil layer (usually 0.2 m). Grassland (meadow)	P

(continued on next page)

Table 2 (*continued*)

Reclamation type	Code	Habitat name	Habitat description	P/N
			is the final land use, it is not appropriate for deep tillage.	
	A_1	Shrub belt	Linear habitats at forest edges or inside a farmland area. Shrubs dominate.	N
	A_2	Herb-rich belt and fallow area	Flowering patches and temporary areas without maintenance.	N
	A_3	Hedgerow	Narrow grassy linear habitats inside arable land.	N
	A_4	Grove	Compact habitats with trees, shrubs, small grasslands, or a bare substratum, usually in the form of small forests inside a field or meadow,	N
	A_5	Solitary trees	Tree individuals or a small group of trees in an open landscape.	N
	A_6	Tree alley	Linear greenery, usually along routes with regular tree spacing.	N
	A_7	Orchard	Vineyards or fruit trees planted in regular spacing.	N
	A_8	Wet meadow and polder	A small grassy depression filled up with water, long-term or temporary character after more intense rainfalls.	N
Hydric	H_I	Sumps and other hydric reclamation	Technical water reservoirs with steep, often concrete banks.	P
	H_1	A shallow water body on top of a spoil bank	Small water bodies developed due to natural spoil heap consolidation in small depressions.	N
	H_2	Water body at the foot of a spoil bank	Water bodies along a spoil heap border caused by the natural expulsion of water by the weight of the spoil heap.	N
	H_3	Small water body	Very small water bodies in terrain pits or depressions.	N
	H_4	Flood plain along drainage ditches and watercourses	Water bodies developed in connection with flowing water, for example, in places where a technical ditch is broken.	N
	H_5	Drainage ditch	Flowing water in linear water features.	N
	H_6	Water reservoir and reservoir shores	Larger water bodies and their littoral zones.	N
	H_7	Residual pit lake	Flooded residual mine pit.	N
	H_8	Island, peninsula, or beach for birds	Island inside water bodies or stony/sandy shores beneficial mainly for birds.	N
	H_9	Other wetlands	Very shallow, small, and temporary wetlands. Most often ruts or puddles on previously unpaved roads.	N
Other	O_I	Technical grassland, roads, and other	Very intensively used or degraded grasslands in industrial/recreation areas, roads, landfills of building material, operating areas, mining equipment stock.	P
	O_1	A grassland with groups of trees	Groups of trees inside grassland. Up to 0.5 ha in area, but larger than solitary trees.	N
	O_2	Xerothermic grassland	Steppe formation on very dry and hot sites, usually with sparse grass and herbaceous vegetation.	N
	O_3	Area left to spontaneous development	Sites developing completely spontaneously, even diverse terrain produced by heaping/mining technology is left without technical and biological reclamation.	N
	O_4	Area left to assisted development	Semi-natural habitats that are affected/improved by some human interventions.	N
	O_5	Bare-surface site without vegetation	Semi-desert habitats in a very early succession stage, or a site where ecosystem development is blocked, in most cases by soil characteristics.	N
	O_6	Sandy site	Small or larger areas with sand on top of a spoil heap.	N
	O_7	Rubble site	Stony spoil heap slopes or mine edges, often as a product of dewatering systems.	N
	O_8	Open pit walls and edges	Very steep slopes or exposed walls.	N
	O_9	Area of special importance	A specific, usually small, site demonstrating an interesting geomorphological phenomenon, an archeological or geological site, a research area	N
	O_10	A site with halophytic vegetation	Usually a dry site with salty soil. Can be temporarily wet.	N
	O_11	Meadow with scattered trees	Non-managed meadows spontaneously overgrown by trees.	N
Universal	U_1	Shelter installations or hiding places	Nesting features supporting mainly birds (birdhouses), reptiles (stone walls), invertebrates (hives, loggers)	N

using the non-parametric Kruskal-Wallis H test, where KW-H is the statistics for one-way analysis of variance. Differences in the medians of the test groups are significant when $p < 0.05$.

4. Results

A total of 4499 productive habitats and 1827 non-productive habitats were identified in six study localities (Table 3). The non-productive habitats occupied 9.85%, (1677 ha) of the study area. The productive habitats covered 90.15% (14,903 ha) of the study area. Scree-surface sites, saline soil, orchards, and xerothermic grasslands were found very sporadically in the study localities, and they were therefore included in the habitat category which spatially surrounded the habitat. For example, xerothermic grasslands were included in sandbanks or succession area habitats, and talus areas were included in the spontaneously developed forest. Old abandoned orchards were included in the category of spontaneous forest growth. Universal U category habitats were found very sporadically.

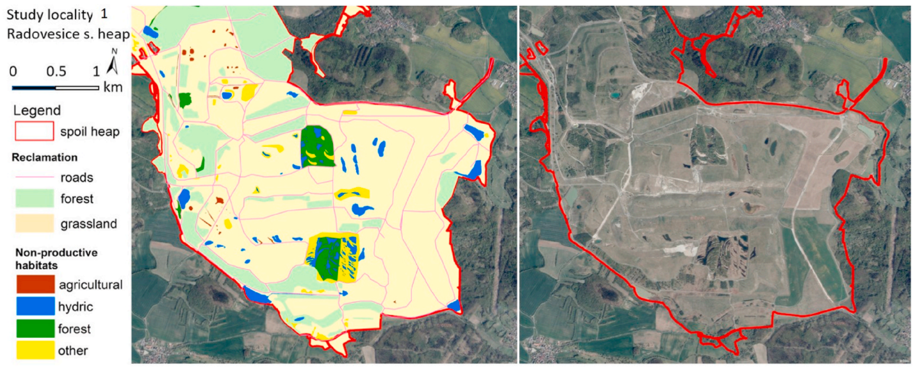

Fig. 2. An example of mapping non-productive habitats in the reclamation project at the Radovesice spoil heap (study locality 1. Doly Bílina). The figure shows larger compact areas of productive habitats and smaller non-productive habitats identified for each type of reclamation.

Table 3
Productive and non-productive habitats identified in six study localities (productive (P) and non-productive (N) habitats, the number of habitats in the study area (No), and the average area and the total area of the habitats in the study area).

Reclamation type	Code	Description	P/N	No	Average area (ha) [a]	Total area (ha)
Forestry	F_I	Compact forest stands for timber production	P	840	8.66	7274.85
	F_1	A small treeless area in a compact forest stand	N	31	0.52	16.18
	F_2	Woodland meadow with solitary trees	N	10	0.35	3.50
	F_3	An open area in compact forest stands left to spontaneous development	N	37	1.52	56.23
	F_4	Area planted with trees	N	0		
	F_5	Spontaneously developed forest stand	N	59	3.95	232.78
	F_6	Forest edge	N	25	0.94	23.52
Agricultural	A_I	An arable field for crop production[b]	P	558	7.92	4420.61
	A_II	Permanent grassland for grazing or mowing[b]	P			
	A_1	Shrub belt	N	14	0.57	7.91
	A_2	Herb-rich belt and fallow area	N	91	0.38	40.00
	A_3	Hedgerow	N	27	0.25	6.64
	A_4	Grove	N	132	0.16	20.53
	A_5	Solitary trees	N	278	0.03	8.68
	A_6	Tree alley	N	98	0.27	26.92
	A_7	Orchard	N	0	0.00	0.00
	A_8	Wet meadow and polder	N	87	0.19	16.85
	H I	Sumps and other hydric reclamation	P	39	0.944	36.45
Hydric	H_1	The shallow water body in a surface depression spontaneously developed on top of a spoil bank	N	349	0.19	67.45
	H_2	The water body spontaneously developed at the foot of a spoil bank	N	26	1.97	51.23
	H_3	A tiny water body in a terrain pit or a depression	N	1	0.01	0.01
	H_4	Flood plain along drainage ditches and watercourses	N	1	0.18	0.18
	H_5	Drainage ditch	N	31	0.09	2.70
	H_6	Water reservoir and reservoir shores	N	134	1.61	215.16
	H_7	Residual pit lake	N	6	102.69	616.11
	H_8	Island or beach for birds	N	18	0.04	0.71
	H_9	Wetland	N	173	0.21	33.53
	O_I	Technical grassland, roads, and other sites	P	2148	2.07	3171.36
Other	O_1	A grassland with groups of trees	N	74	0.32	23.82
	O_3	Area left to spontaneous development	N	17	8.04	136.71
	O_4	Area left to assisted development	N	15	2.56	38.33
	O_5	Bare-surface site without vegetation	N	53	0.22	11.45
	O_6	Sandy site	N	18	0.67	12.07
	O_8	Open pit walls and edges	N	6	0.45	2.70
	O_9	Area of special importance	N	1	0.78	0.78
	O_10	A site with halophytic vegetation	N	9	0.09	0.78
	O_11	Meadow with scattered trees	N	5	0.85	4.27
Universal	U_1	Shelter installations or hiding places	N	10		
Summary		All productive habitats	P	4499	4.90	14,903.27
		All non-productive habitats	N	1827	4.20	1677.73

[a] Average area means the arithmetic average of the area of all patches of a given habitat type with respect to the Total area (i.e. patches that were found at all 6 study sites).
[b] Arable field and permanent grassland were merged because areas intended for future use as arable land are terminated by grassland in the reclamation sowing process. They are usually not used for crop production and are maintained as permanent grasslands.

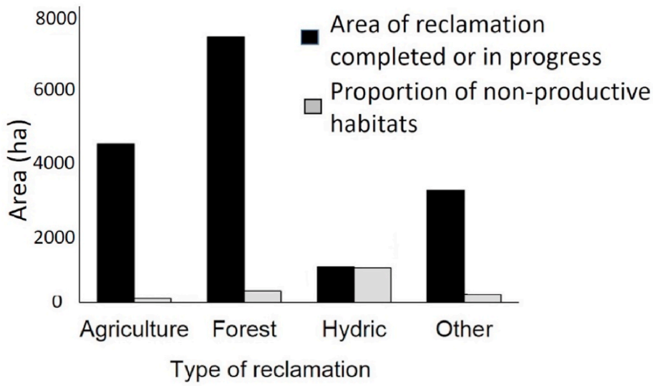

Fig. 3. The total area of reclamation divided into four types: Agriculture, Forest, Hydric, Other, and the proportions of non-productive habitats in these types of reclamation.

Table 4
The proportion of non-productive habitats, their numbers, and their average areas in the study localities.

Study locality	Proportion of non-productive habitats (%)	Number of non-productive habitats	Average area (ha)
1. Doly Bílina	8.5	342	1.07
2. Doly Nástup Tušimice	4.5	286	0.43
3. Československá Armáda	12.1	455	0.86
4. Most-Ležáky	21.6	298	1.30
5. Vršany	3.8	302	0.38
6. Chabařovice	19.7	144	1.99
Study area[a]	11.7	304.5	1.01

[a] Average value from study localities.

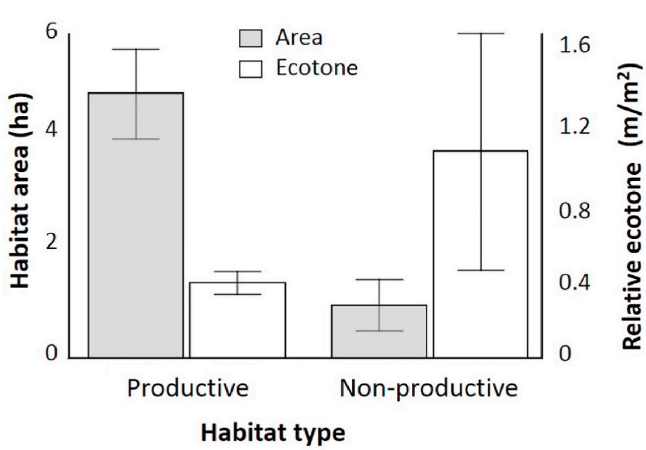

Fig. 4. Habitat area (ha) and relative ecotone (m/m2) of productive and non-productive habitats in the study area.

4.1. The representation and the ecological functions of non-productive habitats

Spatial analyses showed the following representation of four reclamation types in the study area: forest reclamation 46%, agricultural reclamation 27%, other reclamation 21%, hydric reclamation 6%. The representation of non-productive habitats across these types of reclamation is shown in Fig. 3. While more than 96% of the habitats in hydric reclamation were identified as non-productive, agricultural reclamation included non-productive habitats only very sporadically (2.6%). The occurrence of non-productive habitats identified in forest reclamation was 6.7%, and the occurrence of non-productive habitats identified in 'other reclamation' was 4.4%.

The presence of non-productive habitats varied across the study localities. However, these differences were not statistically significant. The proportion of non-productive habitats, their numbers, and average areas in the study localities are shown in Table 4.

The biggest proportion of non-productive habitats was found in study locality 6 Chabařovice (19.7%) and in study locality 5 Most-Ležáky (21.6%). The reclamation works in both of these localities started before 2000. Flooded pit voids covered most of these localities. The pit lakes had a total area of 297 ha (locality 6) and 253 ha (locality 5).

Although our findings demonstrated that the median area of the non-productive habitats was significantly smaller than the median area of the productive habitats (KW–$H_{(1;5412)} = 575.75$; $p = 0.0000$), the relative ecotone of the non-productive habitats (calculated as the ratio of the perimeter of the total area) was significantly higher than the relative ecotone of the productive habitats (KW–$H_{(1;5412)} = 225.78$; $p = 0.0000$; Fig. 4). While the median area of the productive habitats was approximately 5 ha, the median area of the non-productive habitats was approximately 1 ha. However, the area of the individual non-productive habitats ranged from several square meters (in the case of habitats such as natural pools and groups of trees) to hundreds of hectares (mainly lakes). Habitats larger than 2 ha included 16 hydric habitats (most often H_6), 24 forest habitats (most often F_5), and 4 other habitats (O_3, O_5, O_6).

For the non-productive habitats, we measured the variability of the median area per habitat type identified in the study area. The results are shown in Fig. 5 and Table 5. While the greatest variability was measured in habitat types O_3, O_4, O_11, F_5, H7, and A_2, habitat types A_5, F_2, O_10 and most of the hydric habitats showed low variability in their sizes.

After analyzing the variability of the median area per habitat type, we analyzed the variability of the relative ecotone length of the non-productive habitats in the study area. Our findings show that the habitats located in agriculture reclamation were small and compact in comparison with other types of reclamation (see Table 5), with ecotones of 2–35 m/m^2, as shown in the graphs in Fig. 6.

Residual pit lakes (H_7) and spontaneously developing sites (O_3 and F_5) showed the greatest variability in the relative length of their ecotones. Hydric reclamation habitats had the greatest relative length of the ecotones among all measured elements. The relative ecotones of residual pit lakes (H_7) varied from 23 m/m^2 up to 310 m/m^2 (Fig. 6). By contrast, some habitats were not identified. For example, there were only a few observations of small water bodies (H_3), flood plains along drainage ditches and watercourses (H_4), and specific sites (O_9 – paleontological site); and some habitats were very small in size (halophytic sites 0_10, solitary trees A_5). For this reason, the relative length of their ecotones had a low level of variability (2–4 m/m^2; Fig. 6).

4.2. Management measures and a habitat typology

Based on the results of the case study, the literature review, and the practical experience of the authors, we defined recommendations for management measures for non-productive post-mining habitats. These recommendations focus on the design and the size of the habitats (the shape, the minimum, and maximum area, ecotone length), the establishment method (seed dose per hectare, distance between plated species and terrain parameters), and the follow-up long-term management and maintenance. Our detailed recommendations for each non-productive habitat mapped in this study are outlined in the Supplementary Material. The Supplementary Material under the title 'Post-Mining Habitats: Typology & Management' represents a simplified version of a reclamation planning tool that has been developed for the Czech Mining Authorities and the mining industry. This innovative and easy-to-

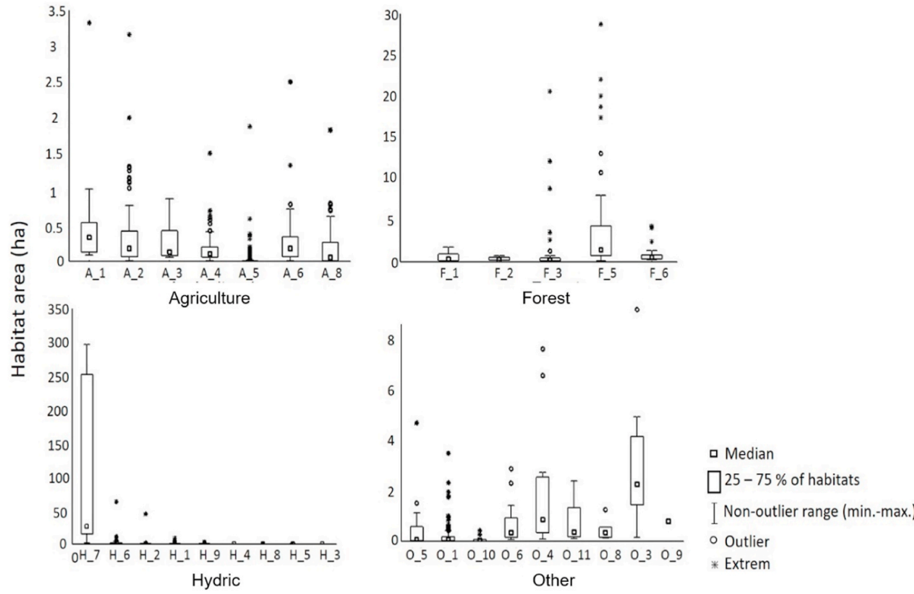

Fig. 5. Variability of the habitat area for each assessed habitat across four reclamation types (1827 habitats in total). Box plots indicate variability outside the upper and lower quartiles of the sample. The spacings between the different parts of the box indicate the degree of dispersion (spread) and skewness in the data, including outliers.

Table 5
Characteristics of non-productive habitats measured across the four reclamation types in the study area. The table shows the number of habitats and habitat types, the minimum and maximum areas, the average areas, and the average relative ecotone length of these habitats.

Type of reclamation	Number of habitats	Number of habitat types	Area min (ha)	Area max (ha)	Average area (ha)	Median area (ha)	Average relative ecotone (m/m^2)
Agriculture	727	7	0.00036	3.32	0.17	0.02	5.0
Forest	162	5	0.02545	28.74	2.06	0.69	18.7
Hydric	740	9	0.00004	296.40	1.33	0.07	9.3
Other	198	9	0.00097	33.31	1.17	0.06	12.4

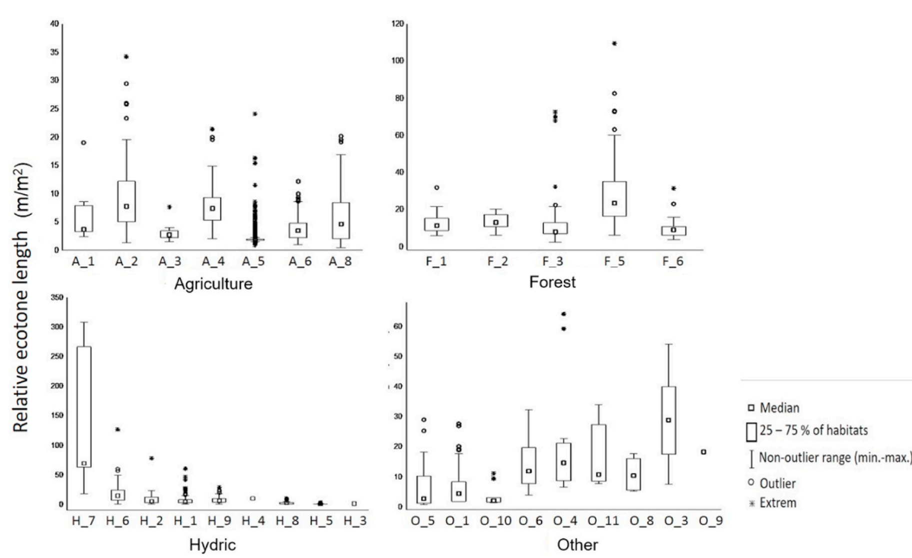

Fig. 6. The variability of the relative length of the ecotones measured for non-productive habitats in the study area.

understand toolset out management measures for non-productive habitats, and is recommended for use in all phases of the life cycle of the mine, when selecting, designing, implementing, and monitoring the final land use.

5. Discussion

In this study, we have investigated non-productive habitats, their size, management, and ecological functions on mine reclamation sites in the Czech Republic. Based on the mapping of these habitats in the study localities in the North Bohemian brown coal basin, and based on our experience and our knowledge, we have designed a typology of non-productive habitats and management measures aimed at guiding mine reclamation practice towards achieving higher natural values in post-mining sites. The following sections outline our findings and our recommendations for implementing the typology within current legislative, regulative, and practical frameworks for mine reclamation in the Czech Republic.

5.1. Implications of the habitat typology in the study area

Our study has shown that non-productive habitats occupied approximately 10% of the study area. In a traditional agricultural landscape that has never been mined, ecologists consider 1.5% coverage of non-productive habitats as a minimum to achieve ecological stability of the area. In more diverse terrain with steep elements, the recommended coverage of non-productive habitats goes up to 6% (Housarová et al., 2009). In mine rehabilitation in countries such as Germany and the United Kingdom, approximately 15–20% of the mining site is usually left to natural recovery (Řehounková et al., 2011; Schulz and Wiegleb, 2000). Prach et al. (2011) found natural restoration to be a suitable alternative to reclamation for up to 95–100% of abandoned post-mining sites.

Our results indicated that spontaneously developed forests (F_5) were the dominant non-productive habitat type (70% of the total area) in **forest reclamation.** These forests have an outstanding level of biodiversity, as documented by Frouz et al. (2015). In 25 years of their development, they produced greater amounts of woody biomass than productive forests. Open areas in compact forest stands left to spontaneous development (F_3) were another significant type of non-productive habitat in the study area (16.5%). Other non-productive habitats, such as forest edges and small meadows, covered less than 1% of forest reclamation in the study area. Their more extensive presence in mine reclamation is usually blocked by active forest management and by immediate replanting of dead seedlings, as the standard procedures require dense and well-developed forest growths. The methodology for forest reclamation (Čermák et al., 2002), which has been implemented in Czech reclamation practice, focuses on selecting and managing tree species in afforested areas based on the rate of growth and the amelioration effects of the trees, the distance between the plants and the requirements for cultivation care, rather than based on their contribution to biodiversity and the ecological values of the area. We further identified a low level of presence of shrubs in forest reclamation. In the study localities, shrubs were found mostly in 1 or 2 rows along the edge of a forest block or group plantings on grassy areas. It has been observed that birds nest predation is usually higher at the edges of habitats (at the ecotones). Bird species are more successful in their reproduction if they nest in stand-alone shrubs or groups of shrubs inside growths. In the case of invertebrates, the diversity of the reclaimed forests can be positively affected in their management by importing soils with different soil characteristics to small sites at spoil heaps (Hendrychová et al., 2012). Besides, different tree species have a different influence on the development of the soil through the production of leaf litter (Frouz et al., 2011). This also affects the composition of the vegetation in the lower layer, due to the shadow that the crown of the tree casts (Rawlik et al., 2018), or due to differences in moisture levels and other micro-climatic differences (Hendrychová and Kabrna, 2008).

Our case study showed that almost 75% of the **agricultural** non-productive habitats consisted of groves, tree alleys, herb-rich belts, and fallow areas (habitat types A_1, A_2, A_3, A_4, A_6). These habitats are also common in European agricultural landscapes with a higher level of biodiversity (Morelli, 2013). The habitat with the highest mapped representation in the study area was A_5 solitary trees (a total of 278 trees). It was observed in the study area that if trees started growing on the spoil heaps before the beginning of controlled (technical) reclamation works, and if no major surface works were carried out, these solitary trees, or large or small groups of trees, would get successfully integrated into the agricultural reclamation. Golawski and Dombrowski (2002) and Vanhinsbergh et al. (2002) demonstrated that dispersed tree vegetation serves for bird nesting, provides a source of food and shelter, provides protection against predators, and adverse weather conditions, and facilitates the migration of various species through the landscape. Other important landscape features in agricultural post-mining areas are grassy edges of dispersed vegetation areas, as shown by Parish et al. (1995). Kirmer et al. (2012) pointed out the high diversity of seed mixtures of local provenance, the use of which in the formation of grassy areas along the edges supports the local biodiversity. Up to 4 times more nesting bird species with up to 7 times greater abundance were found in landscapes with dispersed vegetation, in comparison with landscapes without dispersed vegetation (Wuczyński, 2016). Hedgerows have also been shown to be important in promoting the population viability of woodland fauna (Davies and Pullin, 2007). In our study, the proportion of linear landscape features, such as hedgerows, shrub belts, and alleys, was extremely low (only 0.9%). However, it has been shown, e.g. by Baum et al. (2004), that linear non-productive habitats function as corridors and as stepping stones in agricultural landscapes, and thus provide significantly improved connectivity, especially in a low-resistance matrix. These habitats, except alleys, have not been used as targeted post-mining land use in Czech mine reclamation. Our finding showed that almost all non-productive habitats were formed spontaneously, usually in narrow belts along agricultural land edges that are not affected by farm machinery. Non-productive habitats were further formed in areas with an absence of management, where post-mining agricultural land was not actively used for production purposes and the area became naturally covered through plant spreading. Unplanned wet or wetland areas were formed after minor subsidence of the terrain due to the consolidation of spoil heaps.

We found out that 84% of the area of **hydric reclamation** consisted of 18 residual pit lakes (H_7) larger than 10 ha and other water bodies of a non-productive character (H_6). As was pointed out by Pecharová et al. (2011), lakes and related water elements are key elements for fully restoring post-mining landscapes. These large water bodies featuring a major water reservoir and anti-flooding measures contribute significantly to the restoration of the water cycle in post-mining sites. The lakes may further be used for generating hydropower. Sixteen percent of the non-productive habitats were small water bodies in ground depressions or shallow wetlands (533 habitats in categories H_1, H_2, H_3, H_9). These water bodies were very diverse not only in their horizontal shape but also in their vertical profile. The presence of shallow pools is of principal significance for some animal species. These shallow bodies of water are partly dry in summer, which facilitates the development of very rare vegetation of periodically flooded habitats and semi-terrestrial animal species (Calhoun et al., 2017). Precious wet meadows that are used by wetland species were also bound to these spontaneously developing water bodies in the study localities. Vojar et al. (2016) and Doležalová et al. (2012) found that natural habitats established via natural spontaneous restoration were more preferable features than technically planned reclamation for amphibians. For example, 18 water bodies with amphibians were identified within 300 m from one small water body at the Hornojiřetínská spoil heap. These communities are incomparably more numerous in non-productive habitats than in non-mined areas of the Czech Republic (Vojar, oral communication, 2019). The reason why these habitats are populated by diverse communities of amphibians can lie in the large-scale landscape changes in the past century. One-third of the area of wetlands, pools, and small lakes in the Czech Republic has disappeared due to large-scale drainage as an aspect of the collectivization of farming land in the Eastern Block. Watercourses have been shortened by one third due to technical control. Pipeline drainage systems are still in use on at least one-quarter of all agricultural land in the Czech Republic (Just, 2005). As documented by Tropek and Prach (2012), when the surface of a spoil heap is left without any added fertile soil layer, or when the ground is not even leveled, shallow pools form quickly and spontaneously on clay substrates, saturated mostly with precipitation water. This water is of lower chemical quality than the water in rural landscapes. This lower quality is a key factor that supports the survival of less competitive but scarce plant and animal species. Integration of hyperspectral and LiDAR data can greatly improve the identification of small water bodies emerging on spoil heaps and can facilitate future restoration management (Prošek et al., 2020).

Most of the non-productive habitats (86%) in the **other reclamation** areas in the study area had been subjected to passive or semi-passive management. The habitats showed a high diversity of shrub communities of habitats O_3 and O_4. These non-productive communities host more invertebrate and bird species than are hosted by productive habitats (Hendrychová et al., 2012). As has been shown by Šálek (2012), bird species diversity increases with the age of the habitat. A frequently present phenomenon in these habitats is a very diverse terrain profile, including elevated waves and depressions formed by belt loaders as an aspect of the "layering" of spoil heaps. This diverse terrain profile is considered to be the most important factor supporting the heterogeneity of the soil conditions, the plant cover, and the soil fauna in non-productive habitats (Frouz et al., 2011; Vicentini et al., 2020). In our study, one-tenth (10.2%) of the non-productive habitats in the **other reclamation** areas are represented by sandy sites and bare-surfaced sites without vegetation (O_5, O_6). These are among the most endangered habitats in Europe. Their occurrence in the study area is of critical importance for nature preservation in the EU countries, as has been highlighted by Tropek et al. (2013) and by Řehounková and Prach (2008).

5.2. The importance of small-scale and diverse non-productive habitats

The main typical feature of non-productive habitats was their smaller size in comparison with productive habitats (non-productive habitats have an average area of 1 ha versus an average area of 4 ha for productive habitats). Small-sized habitats are beneficial in maintaining metapopulation dynamics, species diversity, and ecological stability (Doležalová et al., 2012). However, large-sized habitats can significantly impair diversity, as shown by Kabrna et al. (2014). Large productive habitats can act as a migration or colonization barrier for species requiring different environmental features. For example, large areas of agricultural reclamation without pools, watercourses lined with greenery, alleys, lanes of shrubs, or groves can be an insurmountable green desert for wetland or forest species. At the same time, dense extensive forests can be impassable for open landscape species, especially for invertebrates (Šarapatka and Urban, 2006). Intensively managed large compact parts of spoil heaps can then become inaccessible or can even become ecological traps for seasonally migrating species (Baguette and Van Dyck, 2007). Hendrychová and Bogusch (2016) showed that small-scale non-productive habitats can sustain significant species. Their study of stinging insects living on spoil heaps of coal mines showed that the richest areas with the occurrence of very rare species were less than 1 ha in size, including sandy sites and bare-surface sites with no vegetation (habitats O_5 and O_6 in our study). Šálek et al. (2010) documented that small habitats F_5 or, in less dense reclaimed forest areas, habitats F_2 and F_3 host higher numbers of the endangered northern sparrowhawk (*Accipiter nisus)* than larger productive habitats. Vojar et al. (2016) identified greater diversity of amphibians in small, shallow, natural water bodies with moderately sloped shores, and partial littoral stands than in larger water bodies. Furthermore, rich communities of dragonflies were found in small non-productive line habitats such as drainage ditches, as documented by Tichanek and Tropek (2016) and by Harabiš et al. (2013).

The type of reclamation that showed the most significant difference between the relative sizes of productive habitats and non-productive habitats was found to be agricultural reclamation (on an average of 7.92 ha in productive habitats, and 0.16 ha in non-productive habitats). Háková et al. (2004) consider that this difference is due to how agriculture reclamation is managed. Productive habitats are usually maintained by active management in the prevailing productive conditions, and the creation of non-productive habitats is not targeted. A major difference between the size of productive habitats and the size of non-productive habitats was also observed in forest reclamation (8.66 ha versus 2.10 ha). Based on our observations in the study area, various incidental changes usually occurred after completion of the basic care in planned technical reclamation, and non-productive habitats were formed, for example, due to locally dying tree species. However, the forest stands that were initially produced were quite extensive without any non-productive habitats being deliberately established. By contrast, if we compare the average area of productive habitats and non-productive habitats in the other reclamation types, we find that they are quite similar in size. Small non-productive habitats were more likely to be maintained even in the initial reclamation works. In hydric reclamation, the non-productive functions of the habitats were predominant. Exceptions included pits with excessively steep shores and ponds used for intensive fish breeding. The average area of productive habitats and non-productive habitats provided by hydric reclamation did not differ significantly (0.99 ha for productive habitats, 1.33 ha for non-productive habitats).

Non-productive habitats differed from productive habitats in the relative length of their ecotone, or the shape and the segmentation of the ecotones. This finding is in accordance with studies by Hendrychová et al. (2012) and by Šálek et al. (2010). In our study, we demonstrated that the relative ecotones of non-productive habitats were approximately 2.5 times longer than the ecotones of productive habitats. The relative ecotones of the non-productive habitats showed greater morphological diversity than the ecotones of the productive habitats (1.4 m/m^2 for the productive habitats, 3.7 m/m^2 for the non-productive habitats). The ecotones of the productive habitats were also straighter and shorter than the ecotones of the non-productive habitats. As shown by Šálek et al. (2010), more small perching birds were observed in forest growths that include a large number of small, irregular open areas. Birds of prey were found in growths of varying heights.

5.3. Recommendations for mine reclamation practice

To create post-mining land use with higher natural values, the first step is to reconsider the goals of mine reclamation, as defined by the legislation frameworks. In the case of the Czech Republic, the current objectives of mine reclamation favor production values over non-production values. This severely limits the implementation of natural recovery in mine reclamation practice. However, some moves towards more natural mine reclamation have been recognized. For example, the District Mining Authorities, which are the responsible regional authorities for mining approvals in the Czech Republic, have recently established several mandatory conditions in the domain of nature conservation and natural restoration that are to be included in Environmental Impact Assessments (EIA) for decisions on mining permits. However, successful implementation of these conditions in reclamation practice presupposes that all participants involved in the process have a solid knowledge of the principles of natural restoration. The participants in reclamation projects include environmental engineers and others who are responsible for reclamation plans, the mining company, its shareholders and contractors who carry out the reclamation works, and the representatives of state authorities, who decide whether or not mine reclamation is being carried out in compliance with the law. Knowledge of the principles of natural restoration varies substantially among stakeholders. Consequently, the requirements may easily be misinterpreted, and the mining company may be challenged to meet all requirements specified by the state authorities.

Another important step towards implementing natural restoration in mine reclamation in the Czech Republic is a study by Frouz and Máca (2016). Based on a detailed analysis of Czech national legislation, the authors summarized the time sequence of the different phases of the mine life cycle, from pre-mining exploration to mine closure and relinquishment, and defined the management measures that can be undertaken in each phase to support the involvement of natural restoration across the lifetime of a mine. These recommendations were addressed to the State Nature Conservation Agencies of the Czech Republic. They included requirements that: the littoral zone should be considered as a water body in mine reclamation plans; and naturally recovered areas should be registered as important landscape elements, or as a temporarily protected area, according to Act No. 114/1992 Coll., On nature and landscape protection. Integrating these requirements would take away the significant fees for a permanent exemption from the agricultural and forest land required by Act No. 334/1992 Coll., On the conservation of agricultural land, and by Act No. 289/1995 Coll., On forests.

Our typology of non-productive habitats in the form of the Supplementary Material attached to this paper provides recommendations for reclamation planning in the Czech Republic. These recommendations are applicable in other countries with similar physical and geographical conditions. The typology supports systematic and consistent planning of non-productive habitats in mine reclamation and the implementation of suitable management practices. For legal implementation, recommendations, or direct enforcement by authorities such as the National Mining Authority, the District Mining Authorities, and the State Nature Conservation Authorities are crucial. Implementation should form a part of the EIA process before a mining permit is applied for.

In addition to setting up a habitat typology, we have summarized our findings and our knowledge into the following recommendations. These recommendations, if respected and implemented in practice, can raise the natural values of post-mining land use.

(i) Extensive forest growths are a dominant type of final post-mining land use in the Czech Republic. Understanding the ecological functions that support natural defensive mechanisms, we recommend that compact forest growths should be diversified by including forest meadows and small areas without any trees that will be allowed to develop spontaneously.

(ii) Where there is insufficient growth of seedlings, or where there is high mortality of seedlings in the forest reclamation due to adverse site conditions (e.g. the chemistry of the substrate, or the water regime), we recommend that not every dead seedling be replaced to restore a compact forest plantation. Instead, these areas should be left without direct management, as these sites can naturally benefit the spatial and ecological heterogeneity of the forest stands and can reduce the vulnerability of post-mining ecosystems.

(iii) Agricultural productive plots as a dominant type of post-mining land use should be complemented by small-sized or linear non-productive habitats that enhance the heterogeneity of the landscape. These small habitats can provide shelter for various species, can reduce crop pests, and can support migration between larger landscape elements. We further recommend the creation of small temporary ponds and wet meadows within large-scale agriculture plots. This will increase the overall biodiversity and the ecosystem stability of the plots.

(iv) The edges of compact productive habitats of agricultural and forest types of final land use should form gradual transition zones to increase the length and the diversity of their ecotones.

(v) In cases where the total area of non-productive habitats is limited, we recommend setting up larger numbers of small habitats that are located close to each other. These ‘stepping stones’ will facilitate the settling of spoil heap areas, and also environmental functions such as pollination, pest control, and flood prevention. The organisms that inhabit these habitats and the organisms that use the habitats as food sources or for shelter have limited mobility. It is therefore more efficient to space the habitats out evenly, rather than cumulate them in limited areas. Equal distribution of small-scale non-productive habitats is also more effective for preventing erosion.

6. Conclusion

In this study, we have investigated the quality of current reclamation practices in the Czech Republic from the perspective of non-productive habitats. We have found that the national regulatory framework for mine reclamation does not provide conceptual support for natural values in post-mining land use. The results of the study have also indicated an insufficient representation of non-productive habitats. This significantly impairs the ecological value of the reclaimed sites and reduces their long-term resilience.

We have presented a typology of non-productive habitats as a practical outcome of our study. The typology systematizes a variety of non-productive habitats, and measures for establishing and managing them in a clear, illustrative form that is easy for a wider audience to understand. The typology can easily be communicated to all stakeholders to raise their understanding of the benefits provided by incorporating non-productive habitats into post-mining land use. Done well, this will provide an opportunity to create a diverse and stable post-mining landscape by incorporating habitats with high natural values. The typology has already been presented to the Regional Authority of the Usti and Labem region, in which the study area is located. The Authority has confirmed that the typology will be considered as a supplement to the relevant mandatory conditions established in the Environmental Impact Assessment procedures.

CRediT authorship contribution statement

Markéta Hendrychová: Coordination of the research, GIS mapping, field work, Data curation, statistical analyses, Visualization, Writing - original draft, supplement material, revision process. **Kamila Svobodova:** Conceptualization, manuscript conceptualization, setting the study to research and legislation context, English translation, revision process. **Martin Kabrna:** preparation of background documents and map materials, Methodology, Writing - original draft, supplement material.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resourpol.2020.101882.

References

Avera, B.N., Strahm, B.D., Burger, J.A., Zipper, C.E., 2015. Development of ecosystem structure and function on reforested surface-mined lands in the Central Appalachian Coal Basin of the United States. N. For. 46 (5–6), 683–702.

Baguette, M., Van Dyck, H., 2007. Landscape connectivity and animal behavior: functional grain as a key determinant for dispersal. Landsc. Ecol. 22, 1117–1129.

Baum, KA, et al., 2004. The matrix enhances the effectiveness of corridors and stepping stones. Ecology 85 (10), 2671–2676.

Begon, M., Harper, J.L., Townsend, C.R., 1986. Ecology. Individuals, Populations, and Communities. Blackwell scientific publications.

Bengtsson, J., Bullock, J.M., Egoh, B., Everson, C., Everson, T., O'Connor, T., et al., 2019. Grasslands—more important for ecosystem services than you might think. Ecosphere 10 (2), e02582.

Bowie, L., Fulcher, J., 2017. Planning for post-mining land uses. In: Planning Institute of Australia (Qld) Annual Conference, vol. 14. Bundaberg.

Bpt, 2016. Souhrnný Plán Sanace a Rekultivace Lomu ČSA, Aktualizace 2016. (General Sanitation and Reclamation Plan of the Czechoslovak Army Mine, Update 2016). Stored in the Archive of the Mining Project Teplice, j.s.C. Teplice. Czech Republic.

Bpt, 2017. Souhrnný Plán Sanace a Rekultivace Lomu Vršany – Těžba V Hořanském Koridoru. (General Sanitation and Reclamation Plan of Vršany Mine – Mining in Hořany Corridor). Stored in the Archive of the Mining Project Teplice, j.s.C. Teplice. Czech Republic.

Calhoun, A.J., Mushet, D.M., Bell, K.P., Boix, D., Fitzsimons, J.A., Isselin-Nondedeu, F., 2017. Temporary wetlands: challenges and solutions to conserving a 'disappearing' ecosystem. Biol. Conserv. 211, 3–11.

Čermák, P., Kohel, J., Dedera, F., 2002. Rekultivace území devastovaných báňskou činností v oblasti Severočeského hnědouhelného revíru:(metodika pro praxi). (Reclamation of Areas Devastated by Mining in North Bohemia: Methodology for Practical Application). Agentura Bonus. Hrdějovice.

Chuman, T., 2015. Restoration practices used on post mining sites and industrial deposits in the Czech Republic with an example of natural restoration of granodiorite quarries and spoil heaps. J. Lands. Ecol. 8 (2), 29–46.

Cordingley, J.E., Newton, A.C., Rose, R.J., Clarke, R.T., Bullock, J.M., 2015. Habitat fragmentation intensifies trade-offs between biodiversity and ecosystem services in a heathland ecosystem in southern England. PloS One 10 (6), e0130004.

Davies, Z.G., Pullin, A.S., 2007. Are hedgerows effective corridors between fragments of woodland habitat? An evidence-based approach. Landsc. Ecol. 22, 333–351.

Doležalová, J., Vojar, J., Smolová, D., Solský, M., Kopecký, O., 2012. Technical reclamation and spontaneous succession produce different water habitats: a case study from Czech post-mining sites. Ecol. Eng. 43, 5–12.

European Association for Coal and Lignite, 2018. Coal in Europe. Available online from: https://euracoal.eu/info/euracoal-eu-statistics/. (Accessed 10 September 2019).

Everingham, J., Svobodova, K., Mackenzie, S., Witt, K., 2020. Participatory Processes for Mine Closure and Social Transitions. Centre for Social Responsibility in Mining. In: https://www.mineclosure.net/elibrary/participatory-processes-mine-closure-and-social-transitions.

Feng, Y., Wang, J., Bai, Z., Reading, L., 2019. Effects of surface coal mining and land reclamation on soil properties: a review. Earth Sci. Rev. 191, 12–25.

Fleming-Muñoz, D.A., Poruschi, L., Measham, T., Meyers, J., Moglia, M., 2020. Economic vulnerability and regional implications of a low carbon emissions future. Aust. J. Agric. Resour. Econ. 64 (3), 575–604.

Forman, R.T., Godron, M., 1986. Landscape Ecology. John Wiley & Sons, New York.

Frouz, J., Máca, V., 2016. *Metodika pro Postupy OOP V Souvislosti S Využitím Přírodě Blízké Obnovy Území Zdevastovaných Těžbou Nebo Deponiemi Materiálů. (Guidelines for Administrative Procedures of Nature Protection Authorities to Promote Natural Restoration in Areas Affected by Mining)*. TA CR, Beta Programme. Charles University, Prague.

Frouz, J., Prach, K., Pižl, V., Háněl, L., Starý, J., Tajovský, K., Materna, J., Balík, V., Kalčík, J., Řehounková, K., 2008. Interactions between soil development, vegetation and soil fauna during spontaneous succession in post mining sites. Eur. J. Soil Biol. 44 (1), 109–121.

Frouz, J., Kalčík, J., Velichová, V., 2011. Factors causing spatial heterogeneity in soil properties, plant cover, and soil fauna in a non-reclaimed post-mining site. Ecol. Eng. 37, 1910–1913.

Frouz, J., Dvorščík, P., Vávrová, A., Doušová, O., Kadochová, Š., Matějíček, L., 2015. Development of canopy cover and woody vegetation biomass on reclaimed and unreclaimed post-mining sites. Ecol. Eng. 84, 233–239.

Gammal, J., Järnström, M., Bernard, G., Norkko, J., Norkko, A., 2019. Environmental context mediates biodiversity–ecosystem functioning relationships in coastal soft-sediment habitats. Ecosystems 22 (1), 137–151.

Golawski, A., Dombrowski, A., 2002. Habitat use of yellowhammers Emberiza citrinella, ortolan buntings E. hortulana, and corn buntings Miliaria calandra in farmland of east-central Poland. Ornis Fenn. 79 (4), 164–172.

Háková, A., Klaudisová, A., Sádlo, J., 2004. Zásady Péče O Nelesní Biotopy V Rámci Soustavy Natura 2000 (Management of Non-forest Habitats in Terms of NATURA 2000). Ministry of Environment, Prague. PLANETA XII.

Hanski, I., 1999. Metapopulation Ecology. Oxford University Press, Oxford.

Harabiš, F., Tichánek, F., Tropek, R., 2013. Dragonflies of freshwater pools in lignite spoil heaps: restoration management, habitat structure and conservation value. Ecol. Eng. 55, 51–61.

Hendrychová, M., 2008. Reclamation success in post-mining landscapes in the Czech Republic: a review of pedological and biological studies. J. Lands. Stud. 1, 63–78.

Hendrychová, M., Bogusch, P., 2016. Combination of reclaimed and unreclaimed sites is the best practice for protection of aculeate Hymenoptera species on brown coal spoil heaps. J. Insect Conserv. 20 (5), 807–820.

Hendrychová, M., Kabrna, M., 2008. Aplikace rekultivačního výzkumu do praxe - možnost uplatnění spontánní sukcese (Application of reclamation research in practice – a chance for spontaneous succession). Zpravodaj Hnědé uhlí 4, 2–9.

Hendrychová, M., Kabrna, M., 2016. An analysis of 200-year-long changes in a landscape affected by large-scale surface coal mining: history, present and future. Appl. Geogr. 74, 151–159.

Hendrychová, M., Šálek, M., Tajovský, K., Řehoř, M., 2012. Soil properties and species richness of invertebrates on afforested sites after brown coal mining. Restor. Ecol. 20 (5), 561–567.

Hodecek, J., Kuras, T., Sipos, J., Dolny, A., 2016. Role of reclamation in the formation of functional structure of beetle communities: a different approach to restoration. Ecol. Eng. 94, 537–544.

Hooftman, D.A.P., Bullock, J.M., 2012. Mapping to inform conservation: a case study of changes in semi-natural habitats and their connectivity over 70 years. Biol. Conserv. 145 (1), 30–38.

Housarová, M., Myslík, Z., Štajerová, R., 2009. Křoviny – Významný Biotop V Kulturní Krajině. (Schrubs – an Important Habitat in Cultural Landscape). AOPK, Plzeň.

ICMM, 2019. Integrated Mine Closure. Good Practice Guide, second ed. International Council on Mining and Metals, UK https://www.icmm.com/en-gb/environment/mine-closure/integrated-mining-closure.

Just, T., 2005. Vodohospodářské Revitalizace a Jejich Uplatnění V Ochraně Před Povodněmi (Water Management Revitalization and their Application in Flood Protection). Český Svaz Ochránců Přírody. ČSOP, MŽP, Praha.

Kabrna, M., 2011. Studies of land restoration on spoil heaps from brown coal mining in the Czech Republic–a literature review. J. Lands. Stud. 4, 59–69.

Kabrna, M., Hendrychová, M., Prach, K., 2014. Establishment of target and invasive plant species on a reclaimed coal mining dump in relation to their occurrence in the surroundings. Int. J. Min. Reclamat. Environ. 28 (4), 242–249.

Kirmer, A., Baasch, A., Tischew, S., 2012. Sowing of low and high diversity seed mixtures in ecological restoration of surface mined-land. Appl. Veg. Sci. 15 (2), 198–207.

Liu, Y., Lei, S., Gong, C., 2019. Comparison of plant and microbial communities between an artificial restoration and a natural restoration topsoil in coal mining subsidence area. Environ. Earth Sci. 78 (6), 204.

Löw, J., 1995. Rukověť projektanta místního územního systému ekologické stability: metodika pro zpracování dokumentace. (A guide for a designer of a local territorial system for ecological stability: methodolgy for projects). Doplněk. Brno.

LSO (Land Survey Office), 2014. Orthophotomaps of the Czech Republic. Czech. Available online from: https://geoportal.cuzk.cz.

Macdonald, D.W., Johnson, P.J., 2000. Farmers and the custody of the countryside: trends in loss and conservation of non-productive habitats 1981–1998. Biol. Conserv. 94 (2), 221–234.

Moradi, J., Potocký, P., Kočárek, P., Bartuška, M., Tajovský, K., Tichánek, F., Frouz, J., Tropek, R., 2018. Influence of surface flattening on biodiversity of terrestrial arthropods during early stages of brown coal spoil heap restoration. J. Environ. Manag. 220, 1–7.

Morelli, F., 2013. Relative importance of marginal vegetation (shrubs, hedgerows, isolated trees) surrogate of HNV farmland for bird species distribution in Central Italy. Ecol. Eng. 57, 261–266.

Ocelík, P., Svobodová, K., Hendrychová, M., Lehotský, L., Everingham, J.A., Ali, S., Badera, J., Lechner, A., 2019. A contested transition toward a coal-free future: advocacy coalitions and coal policy in the Czech Republic. Energy Res. Soc. Sci. 58, 101283.

OTE, 2018. National energy mix. Available online from: https://www.ote-cr.cz/cs/statistika/narodni-energeticky-mix/narodni-energeticky-mix. (Accessed 10 September 2019).

Owen, J.R., Kemp, D., Lèbre, É., Svobodova, K., Murillo, G.P., 2020. Catastrophic tailings dam failures and disaster risk disclosure. Int. J. Disa. Risk Red. 42, 101361.

Parish, T., Lakhani, K.H., Sparks, T.H., 1995. Modelling the relationship between bird population variables and hedgerow, and other field margin attributes. II. Abundance of individual species and of groups of similar species. J. Appl. Ecol. 32, 362–371.

Pecharová, E., Svoboda, I., Vrbová, M., Drábek, K., 2011. *Obnova jezerní krajiny pod Krušnými horami. (Restoration of a lake landscape under the Krušné hory Mts.)* Lesnická práce (Kostelec nad Černými Lesy).

Prach, K., 2003. Spontaneous succession in Central-European man-made habitats: what information can be used in restoration practice? Appl. Veg. Sci. 6, 125–129.

Prach, K., Hobbs, R.J., 2008. Spontaneous succession versus technical reclamation in the restoration of disturbed sites. Restor. Ecol. 16, 363–366.

Prach, K., Řehounková, K., Řehounek, J., Konvalinková, P., 2011. Ecological restoration of central European mining sites: a summary of a multi-site analysis. Landsc. Res. 36 (2), 263–268.

Prach, K., Lencová, K., Řehounková, K., Dvořáková, H., Jírová, A., Konvalinková, P., Mudrák, O., Novák, J., Trnková, R., 2013. Spontaneous vegetation succession at different central European mining sites: a comparison across series. Environ. Sci. Pollut. Control Ser. 20 (11), 7680–7685.

Prach, K., Šebelíková, L., Řehounková, K., del Moral, R., 2019a. Possibilities and limitations of passive restoration of heavily disturbed sites. Landsc. Res. 45, 247–253.

Prach, K., Durigan, G., Fennessy, S., Overbeck, G.E., Torezan, J.M., Murphy, S.D., 2019b. A primer on choosing goals and indicators to evaluate ecological restoration success. Restor. Ecol. 27, 917–923.

Prošek, J., Gdulová, K., Barták, V., Vojar, J., Solský, M., Rocchini, D., Moudrý, V., 2020. Integration of hyperspectral and LiDAR data for mapping small water bodies. Int. J. Appl. Earth Obs. Geoinf. 92, 102181.

Quitt, E., 1971. Klimatické Oblasti Československa. Academia, Prague, p. 73.

R-Princip, 2017. Souhrnný Plán Sanace a Rekultivace Dolů Bílina DB Při Postupu Do Hranic Územně Ekologických Limitů Dle Usnesení Vlády Č. 827/2015. (General Sanitation and Reclamation Plan of the Bílina DB Mines in Progress to the Limits of Territorial Ecological Limits Pursuant to Government Resolution No. 827/2015. Stored in the Archive of the R-Principle Most. Most, Czech Republic.

R-Princip, 2018. Souhrnný Plán Sanace a Rekultivace Území Dotčeného Těžbou DNT. (General Sanitation and Reclamation Plan of Areas Affected by Mining Activities in DNT Mine). Stored in the Archive of the R-Princip Most. Most. Czech Republic.

Ramsden, M.W., Menéndez, R., Leather, S.R., Wäckers, F., 2015. Optimizing field margins for biocontrol services: the relative role of aphid abundance, annual floral resources, and overwinter habitat in enhancing aphid natural enemies. Agric. Ecosyst. Environ. 199, 94–104.

Rawlik, M., Kasprowicz, M., Jagodziński, A.M., 2018. Differentiation of herb layer vascular flora in reclaimed areas depends on the species composition of forest stands. For. Ecol. Manag. 409, 541–551.

Ricketts, T.H., Regetz, J., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S.S., Klein, M.A., Mayfield, M.M., Morandin, L.A., Ochieng, A., Viana, B.F., 2008. Landscape effects on crop pollination services: are there general patterns? Ecol. Lett. 11 (5), 499–515.

Ridding, L.E., Watson, S.C., Newton, A.C., Rowland, C.S., Bullock, J.M., 2020. Ongoing, but slowing, habitat loss in a rural landscape over 85 years. Landsc. Ecol. 35 (2), 257–273.

Šálek, M., 2012. Spontaneous succession on opencast mining sites: implications for bird biodiversity. J. Appl. Ecol. 49 (6), 1417–1425.

Šálek, M., Hendrychová, M., Řehoř, M., 2010. Breeding habitat of sparrowhawks, Accipiter nisus, on spoil heaps after coal mining. Acta Oecol. 36 (2), 197–201.

Šarapatka, B., Urban, J., 2006. Ekologické zemědělství v praxi (Ecological Agriculture in Practice). PRO-BIO, Šumperk.

Schulz, S., Schwartzkopf, J., 2018. European Lignite-Mining Regions in Transition. Challenges in the Czech Republic and Germany, ISBN 978-80-88289-04-3 (digital only). https://cz.boell.org/sites/default/files/final_report_eng_online_kb.pdf.

Schulz, F., Wiegleb, G., 2000. Development options of natural habitats in a post-mining landscape. Land *Degrad. Dev.* 11 (2), 99–110.

Šebelíková, L., Csicsek, G., Kirmer, A., Vítovcová, K., Ortmann-Ajkai, A., Prach, K., Řehounková, K., 2019. Spontaneous revegetation versus forestry reclamation—vegetation development in coal mining spoil heaps across Central Europe. Land Degrad. Dev. 30 (3), 348–356.

SEC, 2014. State energy concept. Online available from: https://mpo.cz/assets/dokumenty/52841/60959/636207/priloha006.pdf. (Accessed 10 September 2019).

Sklenička, P., 2007. Landscape ecology in the landscape planning system of the Czech republic. Životné Prostr. 41, 126–130.

Svobodova, K., Sklenicka, P., Molnarova, K., Salek, M., 2012. Visual preferences for physical attributes of mining and post-mining landscapes with respect to the sociodemographic characteristics of respondents. Ecol. Eng. 43, 34–44.

Svobodova, K., Owen, J.R., Lebre, E., Edraki, M., Littleboy, A., 2019a. The multi-risk vulnerability of global coal regions in the context of mine closure. In: Proceedings of the 13th International Conference on Mine Closure. Australian Centre for Geomechanics, pp. 553–562.

Svobodova, K., Yellishetty, M., Vojar, J., 2019b. Coal mining in Australia: understanding stakeholder knowledge of mining and mine rehabilitation. Energy Pol. 126, 421–430.

Svobodova, K., Vojar, J., Yellishetty, M., Molnarova, K.J., 2020a. A multi-component approach to conceptualizing the reputation of the mining industry from a stakeholder perspective. Resour. Pol. 68, 101724.

Svobodova, K., Owen, J.R., Harris, J., Worden, S., 2020b. Complexities and contradictions in the global energy transition: a re-evaluation of country-level factors and dependencies. Appl. Energy 265, 114778.

Tichanek, F., Tropek, R., 2016. The endangered damselfly Coenagrion ornatum in post-mining streams: population size, habitat requirements and restoration. J. Insect Conserv. 20 (4), 701–710.

Tittensor, D.P., Walpole, M., Hill, S.L., Boyce, D.G., Britten, G.L., Burgess, N.D., Butchart, S.H., Leadley, P.W., Regan, E.C., Alkemade, R., Baumung, R., 2014. A mid-term analysis of progress toward international biodiversity targets. Science 346 (6206), 241–244.

Tropek, R., Prach, K., 2012. Mining and post-industrial sites. Ecol. Restor. Czech Repub. 87–93.

Tropek, R., Řehounek, J., 2012. Bezobratlí Postindustriálních Stanovišť: Význam, Ochrana a Management. (Invertebrates of Postindustrial Sites: Importance, Protection and Management), vol. 152. ENTÚ BC AV ČR & Calla, České Budějovice.

Tropek, R., Cerna, I., Straka, J., Cizek, O., Konvicka, M., 2013. Is coal combustion the last chance for vanishing insects of inland drift sand dunes in Europe? Biol. Conserv. 162, 60–64.

Valášek, V., Chytka, L., 2009. Velká Kronika O Hnědém Uhlí: Minulost, Současnost a Budoucnost Těžby Hnědého Uhlí V Severozápadních Čechách. (Giant Chronicle of Brown Coal: the Past, Present and Future of Brown Coal Mining in North-west Bohemia). G2 studio, Plzeň.

Vanhinsbergh, D., Gough, S., Fuller, R.J., Brierley, E.D., 2002. Summer and winter bird communities in recently established farm woodlands in lowland England. Agric. Ecosyst. Environ. 92 (2–3), 123–136.

Vicentini, F., Hendrychova, M., Tajovský, K., Pižl, V., Frouz, J., 2020. The effect of topography on long-term spontaneous development of soil and woody cover on graded and untreated overburden. Forests 11 (5), 602.

Vojar, J., Doležalová, J., Solský, M., Smolová, D., Kopecký, O., Kadlec, T., Knapp, M., 2016. Spontaneous succession on spoil banks supports amphibian diversity and abundance. Ecol. Eng. 90, 278–284.

Volf, M., Holec, M., Holcová, D., Jaroš, P., Hejda, R., Drag, L., Blízek, J., Šebek, P., Čížek, L., 2018. Microhabitat mosaics are key to the survival of an endangered ground beetle (Carabus nitens) in its post-industrial refugia. J. Insect Conserv. 22 (2), 321–328.

Watson, R., Albon, S., 2011. UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

Werner, T.T., Bebbington, A., Gregory, G., 2019. Assessing impacts of mining: recent contributions from GIS and remote sensing. Extract. Indus. Soc. 6 (3), 993–1012.

Wuczyński, A., 2016. Farmland bird diversity in contrasting agricultural landscapes of southwestern Poland. Landsc. Urban Plann. 148, 108–119.

Zhang, X.Q., 2016. The trends, promises and challenges of urbanisation in the world. Habitat Int. 54, 241–252.

Řehounková, K., Prach, K., 2008. Spontaneous vegetation succession in gravel–sand pits: a potential for restoration. Restor. Ecol. 16 (2), 305–312.

Řehounková, K., Řehounek, J., Prach, K., 2011. Near-natural Restoration vs. Technical Reclamation of Mining Sites in the Czech Republic. Faculty of Science USB, České Budějovice, p. 211.

Řehounková, K., Lencová, K., Prach, K., 2018. Spontaneous establishment of woodland during succession in a variety of central European disturbed sites. Ecol. Eng. 111, 94–99.

POST-MINING NON-PRODUCTIVE HABITATS:

TYPOLOGY

&

MANAGEMENT

The typology presented here results from our efforts to find a compromise between the requirements of the public administration authorities and solutions favored by professionals in the field of land reclamation. A number of habitat types that have advantageous so-called non-productive functions have been defined within each form of reclamation.

The establishment of small-scale habitats within planted forest stands or agricultural land fully respects the Act on Forests, which recognizes forest pastures and fields reserved for wild animals as land designated to fulfill the role of forest land. These habitats also comply with the Farming Land Resources Preservation Act, which considers non-farming land necessary for farming production as an aspect of farmland resources. One of the motivations for setting up this typology was to show that a variety of habitats can be created during reclamation which improves the environmental value of the developing reclaimed landscape. However, this range of habitats should by no means be generally referred to as, a mistake that is sometimes promoted by the media. Succession is just one means that may be used to create a certain habitat. Merely designating the target habitat as "spontaneous succession" is not enough.

Establishing a new landscape on areas formerly used for brown coal mining, on spoil heaps, and in an area of residual pits supports a land restoration concept aimed at achieving a desired level of biodiversity. When removing the adverse effects of mining activities, the objective should therefore be not only to reinstate the productive areas, as required by the Farming Land Resources Preservation Act (the socio-economic function), but also to restore the non-productive functions of the landscape. It is important to restore the aesthetic, ecological, and nature preservation functions, and to preserve individual species, communities of species, and also habitats, and to exploit the services that they provide for the environment. A combination of biotechnical processes and natural processes seems to be an appropriate and realistic approach to the creation of a new landscape that will provide support for biological, geomorphological, and other types of support. Until now, Czech legislation has fully addressed the practical application of natural processes.

Our habitat typology was created as an aid for members of the public but is also intended for people involved in the process of restoring landscapes: employees of public administration authorities and self-governing bodies, employees of environmental departments and mining authorities who authorize, approve or provide statements on reclamation projects, or who make decisions on the completion of reclamation projects. The typology will help these people to better understand the approaches in the world of nature restoration, and to set up and preserve natural or nature-close habitats to facilitate the preservation of rare, protected, or disappearing organisms, interesting features, and whole countrysides that diversify the landscape on the local and regional level, and even on a national level. The habitats described below are important not only for hosting rare species but also for serving as stepping stones for propagating common organisms in the internal part of the spoil heaps, thus supporting continual propagation, metapopulation dynamics, and the long-term survival of small isolated populations of organisms. They can have a positive effect on the local environment, and can even lead to increased farming crop production by hosting pollinators and natural pest predators, and by promoting erosion control, water retention in the landscape, etc., although the individual patches of these habitats are usually quite small. The non-productive habitats are expected to support and supplement standard reclamation projects, which indisputably support the rehabilitation of large post-mining landscapes. The specific biocenoses of transition/margin ecotonal zones (forest edges, littoral zones, balks, etc.) are highly significant. It is important to preserve various successional phases (ongoing minor disturbances or targeted management that return the community to its original state) and to create a fine landscape mosaic (a large number of small areas that are adjacent to each other).

Habitats or areas with mainly non-productive functions may be small (point) items or may have larger parameters. Here we define them in the framework of four basic reclamation methods: forest (F), agriculture (A), hydric (H), and other (O). Some habitats are universal (U) for all reclamation methods.

This Typology constitutes a methodological guide, and it has to be applied in a specific way within an implementation project for each reclamation project. All habitats are presented here with illustrative photographs. For each habitat, there is a description of its function, its purpose, the basis on which it was set up (its size, how it was established) recommended special preservation measures (territorial preservation and species preservation), and control and/or sanitation management, i.e. single interventions or repeated interventions to preserve the structure and the biodiversity of individual habitats (maintenance of early successional phases, elimination of naturally seeding plants, disc-plowing of the surface, surface plowing, etc., and often also passive management, i.e. spontaneous development). It is important to monitor the condition of the habitat and to observe the species that establish themselves. Most non-intervention habitats can be handed over for post-reclamation “use” after several years or, in some cases, together with neighboring or surrounding phases.

Code	Name	Purpose and main functions	Character and spatial parameters	Establishment and Management	Photos
F_1	A small treeless area in a compact forest stand	Sections without any planted species (forest glades, grass plots, grassy lanes) that enrich the area with open landscape species. High plant and animal species diversity thanks to the ecotonal effect. These areas may also serve as firefighting elements. They are a suitable location for small water sources (pools) for wild animals.	An irregular shape is preferred, with longer boundaries between the open area and the forest stand. A gradual transition, area 50 – 500 m^2, the lanes should be at least 10 m wide.	Areas with no planted species, embedded in the middle of forest blocks. Sow grass or herb-grass mixed seed including meadow species in a more or less treated ground, with a seed dose of 50 to 70 kg/hectare. If on flat ground, first roll the surface. Mow the grass once a year in the first two years. Later on, mow it at least once every three years. Maintain the habitat as a forest-free area, in particular by removing naturally propagating tree species.	 
F_2	Woodland meadow with solitary trees	Half-open forest-steppe areas that are rich in terms of biodiversity. Aesthetically impressive.	An irregular shape is recommended as well as longer boundaries between the meadow and a well-established forest stand, gradual transition, area 500 – 5000 m^2.	Sow grass or herb-grass mixed seed, including meadow species, in a more or less treated ground, with a seed dose of 50 kg of seed per one hectare. If on flat land, first roll the surface, and then plant shrubs and seedlings. Plant semi-saplings or saplings separately or in small groups of irregular form. The minimum tree/shrub row spacing should be 3 x 3 m. Mow the grassy area twice a year in the first two years. Later on, mow only circular spots around lower plants (not adult forest weed). Otherwise, provide standard cultivation treatment for the trees/shrubs that have been planted.	 

Code	Name	Purpose and main functions	Character and spatial parameters	Establishment and Management	Photos
F_3	An open area in compact forest stands left to spontaneous development	An environment that allows for the spontaneous spreading of tree/shrub species from surrounding stands, creation of wetlands, etc. Better diversity of wildlife species thanks to the ecotonal effect, dispersed vegetation.	Originally small grassy areas in integral forest stand blocks, area 500 – 5000 m^2.	Do no seeding, or seed a grass-herb mixture, including meadow species, on the more or less treated ground. Use a low dose of seed, 20 - 30 kg per one hectare. Roll flat areas. Support the formation of wetlands – mow minor ground depressions once a year in the two first years. Allow spontaneous processes to run free of any interventions - natural seeding can be used. However, control the spread of non-native or invasive species.	 
F_4	Area planted with tree seeds	More natural characteristics thanks to irregular or cluster-like row-spacing. Dense birch stands used on spoil banks for bird nesting, for example severely endangered birds of prey - sparrow hawk (*Accipiter nisus*).	Size 500 m^2 – 1 ha	Seed not very demanding tree species (ideal birch) in naked loosened soil in larger clusters (not in rows not in grooves) in a way that forms a mosaic of dense birch areas plus small forest-free areas. No thinning, no forest care, etc., only check for any spread of non-native or invasive species.	 
F_5	Spontaneously developed forest stands	Species-richer areas, with the occurrence of rare species, forest stands corresponding to varied habitat conditions ⇒ more stable or more resistant, e.g., to long-term changes in climate. More aesthetically attractive, more varied.	Preservation of rugged ground is important. The size of the habitat is variable depending on the situation. It may be up to several hectares subject to non-intervention management. The size should preferably be limited if on soil displaying extreme characteristics (excessively acidic soil, mostly due to coal admixture).	Spontaneous succession starts to take place and takes place without any mechanical intervention in parts of spoil heaps that are not exposed to any danger, mainly on medium-to-low trophic soils. Monitor the succession trajectory, control the propagation of non-native and invasive species. If ruderal species exhibit long-term dominance, convert the area into an F_8 habitat.	 

Code	Name	Purpose and main functions	Character and spatial parameters	Establishment and Management	Photos
F_6	Forest edge	Support for the ecotonal zone between the forest and in particular agricultural areas will improve the species diversity. Protect the forest against violent winds.	Particular, on southern edges, there should be a wider lane consisting of a herb zone (2 - 5 m), a shrub zone (5 - 10 m), and a transition zone (100 - 15 m).	The frame of these edges can be formed by planting a greater number of small tree species, e.g. common maple, mountain ash, European aspen, hazel, etc. Soon, other shrub lane species will start propagating naturally (in particular hawthorn, rose, blackberry, elder) or they may be planted (dogwood, currant, privet, birch, ash. Norway maple could appear in the transition lane, as well as wild fruit species (apple, pear, plum species). Remove naturally seeded plants from the grassy edge from time to time. Mow the grass not more than once a year, at the beginning of August.	 
F_7	Sparse forest	Thanks to the ecotone effects and exposure to sunshine, there is greater plant and animal species diversity. Sparser growths promote undergrowth (forming a shrub layer for bird nesting).	A transition community between an open landscape and a forest landscape, area 500 – 5000 m^2.	Plant seedlings quite far apart. The row spacing should be at least 3 x 4 m, with a maximum of approx. 800 seedlings per hectare. Standard forest stands care. After the seedlings become adult, stop mowing the weed areas - support natural spreading.	 
F_8	Managed succession	Acceleration of the forest stand, species of later succession phases will enrich the diversity of the habitat conditions (e.g. local soil conditions will improve thanks to better leaf fall).	This is particularly suitable for areas where no grading works have been performed. The area over 5 000 m^2.	Supplement the evolving pioneer tree species stand with species that are typical for later succession phases with high-quality leaf-fall or other soil improvement effects, e.g. oaks, hornbeam, linden, maple. Do not plant trees in all free areas. Plant only stand-alone trees, or groups of several plants, with a	 

Code	Name	Purpose and main functions	Character and spatial parameters	Establishment and Management	Photos
				maximum density of 100 trees per hectare. Standard newly-planted tree care. Mow the grass only on circular spots around the trees. All size categories of the planting material may be used (seedlings - saplings).	
A_1	Shrub belt	A way to refine the landscape mosaic, provide protection against erosion, mitigate dustiness, create an interlinking effect with other landscape elements (forest edges, hedgerows, groups of trees), and achieve improved biodiversity - natural predators eliminate pest species on farming land).	Orient the belt to follow the contour lines to prevent water erosion, and to shorten the slope. Higher structured lanes that feature an uneven upper edge are a highly-efficient tool for preventing wind erosion. Locate higher tree species in the center, and plant lower tree species along the edges, where there are several lanes. The distance between the neighboring lanes should be less than 200 m, and the minimum width should be 3.5 m, and the maximum width should be 8 m. However, wider lanes ensure greater diversify-cation of the habitat conditions.	A rich herbaceous edge (spontaneous propagation is optimal). Plant heliophilous tree species or species that are typical for forest edges. The minimum distance between trees should be 2 - 3 m. Allow for natural propagation of seeds of other shrubs (roses, hawthorn, blackthorn). The so-called Benjes hedge method can be used instead of repellent paint or fencing (cut coarse brushwood to form a heap 1 m in height that protects the trees against browsing wild animals). Allow for spontaneous division into zones e.g. from the south to a grassy edge. Form a zone of creeping plants, a thicket, or a fern and herb balk. Aim to preserve semi-permeability.	 
A_2	Herb-rich belt and fallow area	Flowering patches and temporarily non-cared areas are beneficial especially for nectar-feeding (butterflies, bees, but also for overwintering animals).	We can establish lines (minimally 3 m wide and 20 m long) or small patches (minimally 50 m^2) inside the agriculture landscape. Biodiversity is supported also through fallow land.	Flower seed or hay from surrounding meadows can be used for the establishment of herb-rich patches. Left arable land abandoned is the simplest method targeting higher biodiversity. Weeds and ruderal flowering plants will	 

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				appear spontaneously. After maximally 3 years, fallow areas can be overplowed again.	
A_3	Hedgerow	Large farming blocks are divided into plants growing wild. There is an erosion inhibiting function (if the shrub belt is set up across the slope). An environment with many species, a traditional farming landscape with a positive influence on the surrounding land (beneficial arthropods). Provides shelter after the neighboring field has been plowed, and a food source in wintertime. An interlinking effect (e.g. between solitary trees and hedgerows).	Narrow lanes (minimum 1.5 m) supplemented by tree species in some places.	Lanes without any seeding (natural propagation of species). Plant shrubs or trees (max. 20 shrubs/trees per 100 m). Provide standard newly-planted tree care. No mowing. Control the propagation of non-native species.	 
A_4	Grove	A transition area towards the surrounding field is one of the species' richest habitats in the agricultural landscape. It combines many features of forests, forest edges, and meadows (ecotonal effect).	This is suitable for creating various hedgerow shapes (elongated, compact, wedge-shaped edges), various sizes (from a few square meters to 2 - 3 ha), or orientation to cardinal points (north-south placement is more suitable for elongated hedgerows).	Plant heliophilous tree species. Provide plenty of thorny species with an abundance of fruit (as a food source for birds). The value of the hedgerows will be enhanced by stones and by dying wood. Routine planting care of newly-planted trees. Remove naturally seeding species from the edge of the grassland not more than once a year at the beginning of August.	 
A_5	Solitary trees	Small structures that improve the diversity of the landscape. A source of food and shelter. A resting place during the intermittent movement of animals through the landscape, or a clue to the source of jump dispersion of plants. An	1 – 20 tree/shrub species, the dominance of tall trees. Properly located with respect to other dispersed vegetation, so that even solitary plants or small groups of trees can facilitate the migration of	Plant the seedlings according to the standard procedure, at least 3 m apart. Routine care for newly planted tree species. In the beginning, mow circular areas around the trees. Tie half-saplings and saplings to	 

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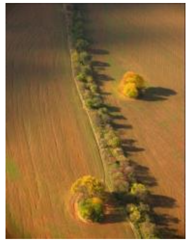
		aesthetically pleasing landscape element.	organisms through the landscape.	poles for protection against browsing.	
A_6	Tree alley	Support of landscape permeability, nesting opportunities, wind erosion control, more pollinators, positive aesthetical and hygienic effect.	lines along ways, regular tree spacing (usually 3 – 6 m), one/more species, one/both sides, single/multi-row.	Small trees are preferred (this requires changing the substrate in the hole, tying to stakes, protection against mowing, regular watering not only during planting but also during the first years).	 
A_7	Orchard	A significant source of food and shelter.	An important feature of low-trunk orchards and vineyards is the link with the surrounding dispersed vegetation, forest edges, or spontaneously growing areas (to attract natural predators and enemies of pests, and to provide nesting sites for wild pollinators). Special management is needed.	Orchards with a large distance between trees (2 - 3 m) are richer in species. When planting orchards and vineyards, plant dispersed vegetation in the surroundings (solitary trees, lanes of shrubs, etc.) Place special habitats for birds, mammals, and insects (see below, Universal habitats U). Set up flowery lanes between rows of trees. Mow every other internal lane. The rest should be mown later on, not before the end of June (when birds have left their nests in the ground), leaving some individuals to live there until the end of their lives.	 
A_8	Wet meadow and polder	Habitat for many invertebrates and rare birds. Water retention in the landscape.	A very low water level (just a few cms) or just waterlogged ground. This may be only a temporary feature (e.g. only until the beginning of the summer).	Linked to water bodies - very gradually descending shores. Small depressions within a farming area should be sown with a varied mixture of plants or should be left for spontaneous propagation. Mow from the center to the edge (to protect nesting birds	 

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				and also young mammals), or from one side to the other. Remove mown biomass from the area (do not mulch – it has an adverse effect on invertebrates). Mow in late autumn, so that the vegetation can be very low in the spring (this benefits waders nesting in these areas). Postpone the date of mowing until grass culms have formed (mid-July, to allow for bird nesting). Alternatively, when mowing for the first time (in May) leave uncut field lanes and cut them later (to protect birds nesting on the ground).	
H_1	A shallow water body in a surface depression spontaneously developed on top of a spoil bank	A habitat for protected amphibians, water birds, and invertebrates. Improvement of the small water cycle. A water source for terrestrial animals.	Several small lakes close together support the metapopulation dynamics. Spontaneous formation and extinction of lakes ⇒ different successive phases are suited to different organisms. Differences in depth, size, shores.	Spontaneously developed water bodies in the area of spoil banks. Do not carry out any ground works or any interventions. Preserve the exposure of the area (i.e. do not plant any tree species in the surroundings). Only keep out non-native species and remove any dead wood.	 
H_2	A water body spontaneously developed at the foot of a spoil bank	A habitat for protected amphibians, water birds, and invertebrates. Improves the small water cycle. A source of water for terrestrial animals.	Varying depth and size. More favorable conditions for organisms in particular further away from the soil bank. There is often a very gradual transition between the water surface and the dry ground. Undrained areas around the spoil banks.	A spontaneous process of water displacement by the weight of the spoil bank. Do not carry out any management. Maintain the exposure of the area (i.e. do not plant trees in the surroundings).	 
H_3	A tiny water body in a terrain pit or depression	A habitat for protected amphibians, birds, invertebrates, and amphibian plants (with roots in the	The depth ranges from several cms to approx. 1.5 m.	Small spontaneously-formed water bodies in ground depressions in reclaimed areas, e.g. due to the varying	

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		bottom, adapted to the alternation of water phases and dry ground phases). This habitat improves the small water cycle. A source of water for terrestrial animals.		subsidence of heterogeneous spoil bank material, or in places where the spoil bank is heaped above deposits extracted with the use of deep coal mining techniques with the collapsing ground. Excavated (by digging or by blasting) or formed by the elevation of the ground water level (in relation to the creek lowland H_4). Clay seal (mostly a natural part of the surface of the spoil bank). It is better to leave the surroundings free of planted trees (small grass plots in the area of forest husbandry reclamation). On arable land, provide several meters of protection and a buffer zone (a grassy lane, perhaps willow growth and other hygrophilous shrubs) to prevent future eutrophication or the risk of contamination by biocides used in agricultural land management. Mow grassy areas along the shores in the late autumn or in July. Keep out non-native species and remove any dead wood.	
H_4	Flood plain along drainage ditches and watercourses	Habitat for wet species, higher water retention in a landscape, it can be temporary (for example existing only during spring).	A small pool in connection to drainage ditches, 5 – 20 m^2 is sufficient area if pools repeat along the flow.	Some pools appear spontaneously as a technical mistake, but it can be made intentionally in places where ditches are not too deep, banks are not too steep and no roads will be defected by water.	 

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H_5	Drainage ditch	These are not very significant elements, because they are not filled all year round. However, they can be important in settling the spoil bank (dispersion), and they can interlink various water bodies.	Better if they are shallow and wide, not reinforced.	A way to link even small pools to this drainage element, to allow spontaneous propagation of herbaceous vegetation. Remove spontaneously propagating trees to make this element work.	 
H_6	Water reservoirs and reservoir shores	Fully non-draining reservoirs may provide living conditions for species that depend on water, including crayfish, clams, permanent bottom fauna, and insects with a several-year larva development cycle. They provide habitats for disappearing or endangered species such as leucapius fish, common loach, and bitterling. Water retention in the landscape. Macrophytic coastal vegetation, reeds, and sedge growths, including protected species of plants and animals.	There should be a shallow bed area without continuous stony reinforcement. The course of the riverbed line should be complex, with rich interlinked wet habitats. Do not implant fish. Amphibians most often live in tanks with an average depth of 1 m or more.	Embed the tank into the surrounding environment in such a way that it is not placed below the level of the surrounding ground and is not separated from the surrounding ground that is too high. Provide a link to adjacent wet meadows (a habitat for waders and rare invertebrates). The development of littoral macro-vegetation can be accelerated by the planting of initial individuals, but it is not necessary. Plant tree species preferably several dozen meters away from the reservoirs. Avoid full forestation up to the edge of the water body edge, as the trees would shade the surface of the water. This would lead to permanently colder water slowing down the development of organisms, and decomposing organic material would fall into the water and consume water-dissolved oxygen. Plant only solitary tree species and limited areas of shrubs on the shores, because the nesting of bird predators poses a threat to	 

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				the eggs of protected birds. Mow adjacent grassy areas late in the year. It is not harmful to leave the fluctuating water surface regime. Do not scrape and do not move sediments to the ramparts around the tank.	
H_7	Residual pit lake	Water retention in the landscape. Restoration of the small water cycle - a positive impact on the micro-climate	Great depth, the shores are divided into zones set up on the shores based on their uses (recreational area x nature preservation area).	Carry out technical measures such as shore anti-abrasion procedures, sealing off the bottom, water supply, etc. Prevent the introduction of nutrients into the lake (establish macro-vegetation and a sedimentation area at the inlet, and control erosion in the lake basin). Establish a rugged shore line (shape, length, slopes). The lake should be deep, but there should also be shallow areas and wetlands adjacent to the shores. Create islands, projections, reservoirs, and pools in the surrounding area. Plant solitary trees or groups of hygrophilous trees by the lake. Forest planting should not be too nearby. Do not implant fish. Mow adjacent grassy areas late in the year. Prevent eutrophication. Apply standard newly-planted tree care.	 

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H_8	Island, peninsula, and beach for birds	Habitats providing a suitable nesting environment.	Vertical (micro-terraces, depressions, gradually sloped shores) and horizontal segmentation (various shapes and sizes). Gravel surface - gravel-sand, piles of flat stones (crevices for nesting birds, the nests may be lined with small pebbles - e.g. little ringed plover).	Create islands or projections reaching the reservoirs/lakes. Create an embankment using suitable material on the surface. Create beaches, maintain forest-free areas, remove naturally propagating plants.	 
H_9	Other wetlands	Facilitating the colonization of spoil banks. Reproductive habitat.	Very shallow, small, and temporary wetlands, most often ruts or puddles on previously unpaved roads.	Form shallow grooves and other depressions. Disturb the habitat repeatedly, e.g. with the use of heavy machinery.	 
O_1	A grassland with groups of trees	Diversification of the open landscape with dispersed vegetation. A source of shelter and food, used for jump migration.	Groups of tree species, up to 0.5 ha in area.	Plant shrubs and trees. Sow 50 kg per ha of grass or leave some parts without sowing or with a limited amount of seed). Provide routine care for newly planted trees and mosaic-like mowing of grass areas, or at least mow from the center to the edge (to protect nesting birds and also mammals), or mow from one side but not from the edges to the center. Postpone the date of mowing until grass culms have formed in mid-July. This will allow birds to complete their nesting. Alternatively, mow for the first time in May, and leave uncut field lanes of varying width and mow them later. This will protect birds nesting on the ground. Exempt some areas from the second mowing cycle, which should be performed late in the spring.	 

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				Remove the mown biomass from the area (do not mulch, as the mulch has an adverse effect on some developmental phases of invertebrates).	
O_2	Xerothermic grassland	A habitat for xerophilic species typical of e.g. steppe formation on the slopes of the Bohemian Central Mountains. This habitat has a high nature preservation value.	In particular, areas that have not been reclaimed or that at least have not been sown.	Choose southern slopes, heat-containing rocks, and stones to simulate grassy and rocky steppes. Remove some of the naturally propagating seedlings in the summer after the bird nesting process is finished. Remove shrubs in winter to eliminate the developmental phases of wintering invertebrate species. Support older dying and dead trees (attract xylophagous insects). Control the propagation of non-native species. Use a combination of goats and sheep to maintain short-leaf grass with local soil loosening by grazing, or use mosaic mowing (only once a year, in July-August after natural plant sowing). However, leave high-leaf parts suitable for other organisms. Small-area winter burning to remove old plant material.	 
O_3	Area left to spontaneous development	High species diversity. There are rare species and species of early successive phases that are not found on other types of reclamation land (birds such as wheatear, stonechat, pipit, ortolan bunting). Natural character is aesthetically and more valuable.	The rugged ground shape formed by the spoil bank is preserved. No ground leveling is done. Communities spontaneously propagated on the leveled ground are usually more valuable than sown communities (see O_4). Area, more than 1 ha.	A spontaneous succession process. Control the propagation of non-native species.	 

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O_4	Area left to assisted development	A high level of species diversity. There are rare species and species of early succession phases that are not found on other types of reclamation land. The habitat has a natural character. The habitat is aesthetically varied and should be positioned in a way that is suitable for the species that live in it.	Natural appearance, an area more than 1 ha.	Spontaneously evolving areas that have been leveled, or optimally no groundwork is needed. Then plant succession phases (oak, hornbeam, maple, linden, ash, etc.) Plant only solitaires or small groups of trees (to produce local improvement of soil conditions due to better leaf-fall). Plant at most 100 trees/ha. Care for newly planted trees mainly by hand. Monitor the development of communities. Control the propagation of non-native species.	
O_5	Bare-surface site without vegetation	A habitat for thermophilic, and semi-desert species (e.g. pipit), nesting sites of solitary bees and wasps (mud daubers, tarantula hawks, andrena, hoplitis, patchwork leafcutter bees) and parasitic bees and beetles related to them (Meloidae), areas sought by rare butterflies.	Bare areas with no vegetation or covered only by a sparse herb layer	Leave young parts of the spoil heap without any sowing. Level the ground, repeatedly loosen the soil, and open it up with the use of heavy equipment. Preventing the propagation of vegetation. Repeatedly remove turf (using a bulldozer), make furrows on slopes, cautious burning (in the form of a mosaic or lanes in winter). Maintain the oligotrophy.	 
O_6	Sandy site	Protection of psamophilic species of fungi (e.g. dog turd fungus- see the photo below), plants and animals very rarely occurring in the Czech Republic (bound primarily to loose sandy soils such as sand quarries, sand dunes from the last Ice Age, gravel and sand alluvia deposited on river and creek alluvia or sandstone	A high content of sand material in the upper layers of the spoil heap It can be only a smaller area (optimally above 1000 m^2).	Create layers of sand of varying thickness and area. Create a rugged relief, maintain treeless areas, or control the vegetation cover mechanically (harrow, vehicle driving, motocross), burning, pasture, etc.	 

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		towns) that have not been subjected to reclamation - one of the most endangered habitats in the Czech Republic.			
O_7	Rubble site	Protection of communities living in rock crevices and scree	Cold scree on northern slopes, steppe rocks on southern slopes, from several m^2 to e.g. 0.2 ha in area	A by-product of drainage elements Deliver aggregate of varying fraction size (larger fractions are preferable) Natural propagation, or sparse planting of some tree species typical for scree fields (maple or ash on cold slopes, oak on warm slopes). Edges of quarries with scree material, intervention-free areas, control the propagation of non-native species.	 
O_8	Open pit walls and edges	Xeric habitats where there are rare species (e.g. sand martin), Quarry edges, sometimes hosting communities of rock crevices and stabilized debris (spalling material).	Exposed perpendicular or very steep walls (for better protection from predators, notches at the edges of quarries)	Preserve quarry walls without leveling and covering with soil. Form perpendicular exposed walls without any vegetation (cut into compacted fine-grained made-up soils), repeated disruption (removal of vegetation). Cut again in autumn.	 
O_9	Area of special importance	Research areas (including areas exposed to extreme conditions), recreational zones, geoparks, palaeontological sites, protection of geological phenomena, areas with a special water regime, etc.	Various	Created spontaneously, uncovered as a result of mining, created as attractive tourist sites. The management types depend on the use and purpose.	 

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O_10	Salty sites	There are halophilic species that are very rare in the Czech landscape. It is typical of the Ore Mountains foothill basin area, e.g. Dragon’s teeth (*Tetragonolobus maritimus*).	Salt marshes can initiate in dry polders and other reservoirs and pools with a fluctuating water surface, where minerals are oxidized to the form of salts (sulfates, chlorides) that are brought to the surface by the rising water during drought periods.	Ensure a suitable water regime (early spring rapid flooding and summer drying, dig small pools to a depth of 20 cm) Allow occasional mechanical disturbance of the soil surface - grazing, disc plowing, and shallow plowing, autocross Maintain treeless areas. Remove naturally propagating species and remove biomass, or allow grazing (mosaic structures, leaving spots without grazing), create future salt marshes in phytotoxic or sandy habitats where high salt content and extreme habitat conditions limit the growth of vegetation. However, there are some halophilic or psamophilic organisms that do not find many habitats in an intensively managed landscape. Preserve various successive phases from the initial phases of exposed areas, through salty meadows to sedge and reed species growths. Mow the grass once a year, in June. Cut down some of the reeds every few years. Rotate the grazing (1/3 of the area per year).	 
O_11	Meadow with scattered trees	Solitary trees dispersed in extensive meadows, facilitating migration through the landscape, and providing a food source and shelter. Similar to A_5, but found in more managed land (arable soil, etc.).	Random dispersion, more solitary trees, and shrubs.	Established by planting or leaving solitary trees/shrubs when technical reclamation (ground leveling) is carried out if trees have already succeeded in propagating and growing spontaneously.	 

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U_1	Shelter installations or hiding places	Promotion of biodiversity, hibernation, reproductive habitats, nesting grounds.	Small walls, birdhouses to replace hollow trees in early phases, to provide nesting places for birds, bats, and other small mammals. Piles of wood, leaves, especially for wintering (hedgehogs, etc.).	If necessary, accelerate the formation of cavities by cutting branches close to the trunk or by shortening the crown of young trees, or directly by drilling. Manage by renewal, by cleaning birdhouses, by replenishment.