Predation risk of artificial ground nests in a post-mining landscape after opencast brown coal mining in the Czech Republic

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Abstract

Context

Opencast mining of minerals has a considerable impact on the landscape and local ecosystems including bird communities. Suitable landscape restoration methods can replace habitats lost due to mining activities.

Objectives

Our study aimed to identify how factors such as restoration management, spatial distribution and vegetation characteristics of restored habitats can affect the risk of bird nest predation.

Methods

In 2018 and 2019 we conducted a field experiment using 726 artificial ground bird nests installed on four spoil heaps and in the surrounding landscape of North Bohemian Brown Coal Basin in the Czech Republic.

Results

Nests on the post-mining sites suffered from a significantly higher risk of predation (75.4%) than nests in the surrounding landscape (60.3%), especially on technically reclaimed sites (71.8%) compared to near-natural habitats (64.7%). A generalized linear mixed model confirmed a statistically significant impact of horizontally more heterogeneous but vertically not very diversified vegetation cover of the site on a higher risk of predation of nests installed both inside and outside post-mining sites. The risk of predation of nests adjacent to the spoil heaps decreased with increasing distance of the nest from the heap.

Conclusions

We consider spoil heaps as centres and sources of nest predation. We interpret the significant impact of the vegetation structure on risk of predation as result of post-mining rehabilitation approach. The higher risk of nest predation on post-mining sites reflected the character of technically reclaimed habitats. We recommend a greater extent of natural restoration methods in current rehabilitation policy.

1. Introduction

Opencast mining of minerals has a considerable impact on the landscape, on local ecosystems and on communities of organisms, including birds. Subsequent restoration of the landscape creates new ecosystems, which are gradually integrated into the existing environment. Suitable rehabilitation methods can to a certain extent replace habitats lost to bird communities due to mining activities, and can thus partially compensate the decrease in the biological diversity of the communities caused by the loss of the original nesting sites (e.g. Gould 2011).

The North Bohemian Brown Coal Basin (NBBCB) in the Czech Republic is one of the largest regions in Europe to have been greatly impacted in the past by opencast brown coal mining. Mining activities are still transforming the local landscape (Hendrychová and Kabrna 2016). As in other European coal-mining regions, reclamation practice in the restoration of the local post-mining territories has traditionally worked with four basic types of technical reclamation based on the intended final use of the territory, mainly for production or for recreation: agricultural, sylvicultural, hydric and other reclamation. Near-natural methods for rehabilitating or restoring the locality, which allow and support natural development, e.g. leaving the locality to spontaneous succession (Prach et al. 2011; Hendrychová et al. 2020), have been used only sporadically. The vegetation on sites restored by near-natural methods develops in a different way than on technically reclaimed sites. Vegetation cover is more diverse, and there is much greater diversity of species (e.g. Hodačová and Prach 2003; Šebelíková et al. 2019), including local communities of birds that are related to the environment (Hendrychová et al. 2009; Šálek et al. 2010; Šálek 2012). The greater species richness, species rarity and higher ornithological value of the communities on post-mining sites was associated with the existence of a mosaic of habitats with greater heterogeneity of the vegetation cover (Hendrychová et al. 2009; Šálek et al. 2010; Šálek 2012; Moudrý et al. 2021). In addition to higher natural value of the resulting habitats, near-natural methods, especially leaving the site to spontaneous natural development, can be significantly more economically advantageous (Prach and Pyšek 2001).

The quantity and also the diversity of the species on post-mining sites can be significantly impacted by nest predation, which is generally considered to be the main cause of unsuccessful nesting of birds (e.g. Martin 1993). Higher levels of nest predation are related to fragmentation of the original habitats in a cultivated landscape and a growing share of ecotonal habitats (e.g. Andrén 1995; Stephens et al., 2004) with the impact of the edge effect on nest predation, i.e. the level of predation is higher when the nest is nearer to the border of the habitat (e.g. Gates and Gysel 1978; Paton 1994; Lahti 2001; Batáry and Báldi 2004). Some studies have proved a possible impact on the risk of predation of the structure of the immediate habitat (units to tens of meters) around the nest (e.g. Cristescu et al. 2012; Sánchez-Oliver et al. 2014; Bellamy et al. 2018), or of hiding the nest in vegetation (Borgmann and Conway 2015). Different nest predation patterns may also result from the range of nest predators present in the landscape (e.g. Chalfoun et al. 2002).

Very little information is available about the mechanism of nest predation on post-mining sites. However, the predation mechanism may work differently in newly-created ecosystems than in a normal, stabilized landscape. Some earlier studies (e.g. Purger et al. 2004a; Purger et al. 2004b) have detected an impact of the edge effect on the predation of artificial or real nests on post-mining sites, but other studies did not find any influence of the edge effect (e.g. Gressler and Marini 2015). The results of studies of the impact of the vegetation structure on successful nesting are similarly ambiguous (e.g. Graves et al. 2010 compared to Hill and Diefenbach 2013).

There is still insufficient knowledge of the effect of nest predation on the NBBCB bird communities in dependence on the rehabilitation approaches that are used. Our study presented here is aimed at extending current knowledge. Our intention was (1) to compare the possible risk of nest predation inside and in the surroundings of reclaimed post-mining sites, and to study any interaction between them, i.e. to determine the role of reclaimed ecosystems in the landscape not directly affected by mining; (2) to assess the effect of post-mining territory management: technical reclamation versus near-natural restoration; (3) to identify possible factors affecting the risk of predation from the point of view of the structure of habitats, with a view to setting up further studies that will suggest efficient ways to support and protect bird communities in these unique post-mining sites.

2. Materials And Methods

2.1 Study area

The study area consists of four separate study sites – the territory of four external spoil heaps (used for depositing the overlying spoil from near opencast brown coal mines) and their surroundings – located in the North Bohemian Brown Coal Basin (also known as the Mostecká Basin) in the Czech Republic (Fig. 1). The spoil heaps were (or some still are) reclaimed mainly technically, with the use of agricultural, sylvicultural, hydric and other reclamation methods. There are also some larger and smaller sites that have been left entirely or mostly to natural development (Table S1 in the Supplementary Information).

In almost all cases, technical reclamation involved landscaping (earth moving) and fertilization of the upper layers of the soil. In the biological phase, permanent grasslands were formed by sowing clover-grass mixtures low in species diversity, or homogeneous monoculture forest plantations were frequently established. Near-natural restoration involved leaving the site entirely to spontaneous succession or making only small interventions. The near-natural localities most often consisted of later succession stages of forests, or open forest-steppes. The near-natural localities had a very diverse surface microrelief with a large number of water features of various sizes, and patches with bare surfaces or covered by sparse vegetation. The vegetation communities were significantly diversified in species, age and spatial composition (Fig. S1-S4 in the Supporting Information).

2.2 Field experimental design

The research study was designed as a two-year field experiment using artificial ground nests, taking into account limitations due to the fact that the level of artificial nest predation does not reflect the real level of natural nest predation. Artificial nests may be more attractive for predators than natural nests; there may be different species predating on artificial nests and on natural nests, due to the absence of parental activity on artificial nests, etc. (e.g. Major and Kendal 1996; Pärt and Wretenberg 2002). However, artificial nests make it possible to study the relative rate and patterns of nest predation, so that possible environmental factors affecting the predation of real nests can be identified (Bravo et al. 2020).

The nests were installed on pre-planned (1) spoil heap-border line transects (n = 5–6 per spoil heap) and located approximately on the border and then at distances of 50, 100, 250 and 500 m towards the inside and the outside of the spoil heap, and (2) on one or more inner/outer line transects pre spoil heap (> 500 m from spoil heap border, min. 50 m distance between neighbouring nests) (Fig. S1-S4). The nest sites (located by GPS station) were different in 2018 and in 2019 and covered all types of local habitats.

An artificial nest simulated the nests of ground-nesting birds in the form of a shallow hole with a radius of approx. 10 cm, lined with dry plant materials of local origin. Each nest was stocked with two Japanese quail *Coturnix japonica* eggs as a bait for predators and one plasticine egg of a dull colour, resembling a quail egg in size and in shape, and fixed to the ground (Suvorov et al. 2014). The plasticine egg served for collecting prints of the beak, teeth or claws of the predator of the nest, and for capturing predation of the nest even by small predators (Maier and Degraaf 2000). In order to minimize the smell of humans, all materials were aired in an open space for two weeks before use, and latex gloves were used when the nests were being installed (Whelan et al. 1994).

The site was marked with a dull-colour textile strip (Major and Kendal 1996). The nest was not revisited again until two weeks (common incubation period of local songbirds) later (Major 1990). We used camera traps located on the Radovesická spoil heap to monitor a separate group (Krüger et al. 2018) of experimental nest.

2.3 Data collection

For each nest, the recorded data included the study season in which the nest was used (referred to as the Season), the study site in which it was installed (Study site), and the locality within the site: (1) inside (inside nests) or (2) outside (outside nests) the spoil heap (Locality).

In order to describe the character of the vegetation cover, by direct monitoring and reading from orthophotomaps, we divided the vegetation on a circular area with a radius of 25 m, centred on the nest, into six vegetation level categories: (1) high forest – woody vegetation reaching over 15 m; (2) low forest – woody vegetation from 5 m to 15 m high; (3) bush level – woody plants of max. 5 m; (4) high herbs – open growth of grasses and herbs reaching over 0.15 m; (5) low herbs – open growth of grasses and herbs of max. 0.15 m, and (6) no vegetation – places without vegetation or containing very sparse vegetation cover. For each nest, we recorded the vertical heterogeneity of the vegetation cover (Layers) as the number of categories that were present; the horizontal heterogeneity of the vegetation cover (Patches) as the number of individual patches consisting of vegetation of each category; and the ratio of the woody plant cover to open patches in the site as a percentage of the surface of the circle covered by the first three categories (Woods).

By means of a circular reading label (Bibby et al. 2000), we determined optometrically from the photos the level of concealment by vegetation of each nest (Concealment) from the inclined top view from the side, from four different directions, as the percentage of the covered surface of the label (average value of all five readings). In the geoinformation system (GIS), we read (the “Near” function) the actual distance of each nest from the border of the spoil heap (Border).

From documentation provided by the operators of the spoil heaps, we determined the type of management on the nest site (Management) in the category of (1) technical reclamation or (2) near-natural rehabilitation, and also the age of the locality (Age), i.e. the number of years that had passed from the first phase of technical reclamation (earth moving and the beginning of biological reclamation), or from depositing the materials and leaving the site for natural development. For outside nests, we did not consider the Management and the Age, because the landscape had been continuously used for agricultural purposes for a long time, and no particular moment for the beginning of its development could be determined.

The fate of the nest (Fate) was recorded as (1) non-predated; or (2) predated (if at least one egg had been removed from the nest or had been damaged). If a nest had been destroyed in a way obviously other than by predation, e.g. by human activity, or if it had not been found during the inspection, it was removed from the experiment. The probable predator of the nest was determined on the taxonomic level of mammal *Mammalia* or bird *Aves*.

2.4. Statistical analysis

The data were analysed in the R programme, version 4.1.0 (R Core Team, 2021). The detected predation rates were analysed by the chi-squared test for goodness of fit, and the Pearson chi-squared test with the Yates continuity correction for 2 x 2 contingency tables.

The probability of predation of the experimental nests was analysed in the generalised linear mixed model (GLMM) (“lme4” package), where the explained variable (see the previous chapter for a description of the variables) was the Fate with binominal classification (1 = predated, 0 = non-predated). Random variables included the Season and the Study site. Fixed variables included the Age Layers, Patches, Woods, Concealment, and Border, and their mutual 2-way interactions. In order to capture any specifics applicable to localities inside and outside the spoil heaps, we built two separate models for inside nests and outside nests. The outside nests model did not contain the variable Age (see section 2.3). Because of the big range, the values of the fixed variables were logarithmically transformed. The interaction of the fixed variables was interpreted by visualization using plotting (“interactions” package).

In all statistical analyses, a minimum probability level of $P < 0.05$ was accepted.

3. Results

During the two seasons of the study, we installed 726 experimental nests, out of which 44 were lost or were removed from the experiment. As a result, we collected data from a total of 682 nests.

3.1 Predation rates

The number of predated nests in all types of monitored localities was statistically significantly higher than the number of non-predated nests (Table 1). Inside nests were statistically significantly exposed to a higher risk of predation than outside nests. Inside nests had a higher risk of predation on technically reclaimed surfaces than nests on near-natural sites, but the difference was not statistically significant (Fig. 2, Table S2).

Table 1
The numbers of predated and non-predated nests in each type of studied locality (Locality). Differences in detected numbers within the relevant locality were statistically tested by chi-squared test for goodness of fit

Locality/Management	*Total nests*	*Non-predated nests*	*Predated nests*	*P*
Outside nests	343	136	207	< 0.001
Inside nests	339	105	234	< 0.001
- near-natural site nests	133	47	86	0.001
- technically reclaimed site nests	206	58	148	< 0.001

3.2 Predator rates

For 361 experimental nests, we determined the probable predator. In the whole experiment, nests probably predated by birds prevailed statistically significantly (Table S3). The same result was also detected for each studied type of locality. However, the result was statistically significant only in the case of inside nests, and on technically reclaimed sites (Table 2). The differences in the prevailing predators between monitored localities and between post-mining managements were not statistically significant. However, the difference between near-natural localities and technically reclaimed localities was almost statistically significant (Fig. 3).

Table 2
Information about the number of nests where the probable predator was identified for the whole experiment and for each type of study site and site management. Differences in the number of nests within each locality were statistically tested by the chi-squared test for goodness of fit

Locality/Management	*Identified predators*	*Birds*	*Mammals*	*P*
Experiment	361	212	149	0.001
Outside nests	168	92	76	0.217
Inside nests	193	120	73	0.001
- near-natural site nests	77	41	36	0.569
- technically reclaimed site nests	116	79	37	< 0.001

In 55 cases, the camera traps recorded the presence of a possible bird nest predator; in 96 cases a possible mammal nest predator was recorded (Table S4). The prevailing bird active in the study locality was clearly the Eurasian jay *Garrulus glandarius* (n = 44). The most frequent mammal was the wild boar *Sus scrofa* (n = 39), followed by the European pine marten *Martes martes* (n = 23) and by small rodents *Rodentia* (n = 19). In 40 cases, a predation event was recorded and the predator was identified equally between birds and mammals (n = 20 to 20). The most active bird predator was again the Eurasian jay (n = 15); among the mammals, there was again more evenly spread activity. The difference in the proportion between birds (n = 7) and mammals (n = 15) in the case of ground nests (n = 22) approached statistical significance ($\chi 2$ = 2.91, df = 1, P = 0.088). In the case of elevated nests (n = 18), the proportion in favour of birds (n = 13) over mammals (n = 5) was on the border of statistical significance ($\chi 2$ = 3.56, df = 1, P = 0.059). The difference in the rate of representation of taxons between ground nests and elevated nests was statistically significant ($\chi 2$ = 4.95, df = 1, P = 0.026).

3.3 Generalized linear mix models (GLMMs)

An inside nests model (Table 3, Table S5, Fig. S5-S7) proved statistically significantly the impact of horizontal heterogeneity of the vegetation cover (Patches), the interaction between the vertical and horizontal heterogeneity of the vegetation cover (Layers-Patches), and the interaction between the vertical heterogeneity of the vegetation cover and the rate of woody vegetation cover (Layers-Woods). As the value for the horizontal heterogeneity of the vegetation cover of the site grows, the predation risk also increases, especially in the interaction with lower values of the vertical heterogeneity of the vegetation cover of the site. However, the interaction with higher and average values of the vertical heterogeneity lowered the predation risk. The interaction between the vertical heterogeneity of the vegetation cover and the growing ratio of woody vegetation showed a slight decrease in the risk for average vertical heterogeneity values. The decrease in the predation risk was more significant when the vertical heterogeneity values were low; however, the predation risk increased slightly when the vertical heterogeneity values of the vegetation were high.

An outside nest model showed a statistically significant effect of the vertical (Layers) and horizontal (Patches) heterogeneity of the vegetation cover, the distance of the nest from the border of the spoil heap (Border), and the interaction between the distance and the horizontal heterogeneity of the vegetation (Patches-Border). The predation risk grew with lower vertical heterogeneity of the vegetation cover and with greater horizontal heterogeneity of the vegetation cover. The risk also increased with less distance of the nest from the spoil heap. The interaction between less distance and greater horizontal heterogeneity of the vegetation cover raised the level of risk, and greater distance in connection with lower horizontal heterogeneity of the vegetation reduced the risk.

Table 3
Results of GLMMs for an analysis of the impact of each of the variables and their interactions on the probability that the experimental nests inside and outside the spoil heaps will be predated

Inside nests	*Estimate*	*Std. Error*	*df*	*P*
Patches	20.46	8.55	1	0.013
Layers-Patches	-5.85	2.63	1	0.025
Layers-Woods	5.11	2.50	1	0.037
Outside nests	Estimate	Std. Error	df	P
Layers	-14.44	6.50	1	0.024
Patches	9.95	3.92	1	0.006
Border	-1.81	0.86	1	0.024
Patches-Border	-2.86	1.16	1	0.008

Estimate – regression coefficient estimate, *Std. Error* – standard error of the regression coefficient. For the sake of efficiency and arrangement, the table shows only those variables, and the interaction between them, in cases where the impact on the probability of nest predation proved to be statistically significant ($P < 0.05$)

4. Discussion

The reclamation of post-mining localities in the NBBCB has usually resulted in land use similar to the land use in the surrounding fragmented cultivated landscape (Hendrychová and Kabrna 2016; Hendrychová et al. 2020) with a significant predominance of productive habitats over non-productive habitats. Our study has monitored the risk of predation of artificial nests from the point of view of the role of reclaimed post-mining areas in the original landscape not affected by mining, the management of those territories and possible factors influencing the risk of predation. Our results indicate that post-mining sites had been incorporated by surrounding landscape, as similar factors of artificial nest predation appeared in our experiment on both types of localities.

The higher risk of predation of experimental nests on spoil heaps and in the surroundings of spoil heaps was reflected primarily on sites divided horizontally into several patches with few layers of vegetation. This kind of environment on the spoil heaps is interpreted as a combination of mainly artificially established grasslands with woody plants or other non-productive habitats, i.e. an environment with fragmented habitats and with a possible impact of the edge effect (see again Gates and Gysel 1978) and/or an ecotonal effect or a matrix effect (Lidicker 1999) on the predation of the experimental nests. The character of these biotopes corresponds to the biotopes in normal landscapes, where the edge effect on predation has already been detected, i.e. a combination of a matrix in the form of agricultural land with fragments of forest cover (Andrén 1995; Sánchez-Oliver et al. 2014), non-production elements of vegetation such as hedges (e.g. Ludwig et al. 2012), or mown lawns and meadows disrupted by patches of ruderal covers or wetland covers (e.g. Suvorov et al. 2014). An environment of this type may have been more attractive for predators than the homogeneous interior parts of agriculturally reclaimed areas or forest monocultures, due to an increased amount of potential sources of food (e.g. real nests) near to and on the border between different habitats (Gates and Gysel 1978), or the use of these habitats as transport corridors for moving around the environment (Gehring and Swihart 2003; Šálek et al. 2009). Various predators, typical for certain neighbouring sites, may have interacted with each other, thus increasing the risk of predation of the experimental nests in the edge habitats (Lidicker 1999; Svobodová et al. 2012).

A question that remains to be answered is whether environments that increase the risk of predation include near-natural sites within reclaimed spoil heaps. In woody covers, the risk tended to be higher in vertically differentiated growths, which are more typical for succession forest covers. However, this could well also apply to aged or more nearly-natural and more structured forest covers with multiple layers of vegetation. These forest habitats have higher species diversity of local birds, including potential nest predators, such as those appearing in the post-mining forest localities of the NBBCB, as mentioned above: Eurasian jay, great spotted woodpecker, red-backed shrike and carrion crow (Hendrychová et al. 2009). An attractive environment and a greater presence of predators may have led to the higher risk of predation of the artificial nests located there than of nests located in homogeneous forest covers. The opposite effect, a significantly decreasing trend in the risk of predation of experimental nests, resulted from their location on the vertically and horizontally diverse sites associated with near-natural sites, especially with succession localities covered by forest-steppe vegetation with a varied mosaic of patches without vegetation, grass and herbs, and woody plants of various ages and species growing both solitarily and in groups (Prach and Pyšek 2001; Moudrý et al. 2021). The lack of predation pressure may have been caused by the greater complexity of the local habitat, which provides better concealment of the experimental nests from predators (e.g. Martin 1993). In the context described above, the detected lower rate of predation of nests in the near-natural sites than in the technically reclaimed sites could be explained, but it should be noted that the difference was not statistically significant.

The risk of predation of the experimental nests was statistically significantly higher on the territory of the spoil heaps than in the surrounding landscape, and the risk decreased statistically significantly with growing distance from the border of the spoil heap. This means that the post-mining sites were a source of predation pressure in the original landscape. Nest predators may regard the spoil heap as some kind of refuge in the surrounding landscape, with no permanent presence of people and with comparatively favourable site conditions: the landscape is more diversified than the non-mined landscape, which is mostly extensively agricultural. The prey of the predators may also have regarded the spoil heap in the same way. Especially birds, for which, compared to other organisms, the recolonization of post-mining sites is often the most successful in terms of population density, species richness and diversity or spatial distribution (Cristescu et al. 2012; Šálek 2012). Greater amounts of prey can attract larger numbers of predators. These might include species that are not ordinarily nest predators, but that might predate a randomly found and unprotected, poorly concealed or inappropriately located experimental nest, thus increasing the risk of incidental predation of a nest found when looking for some other prey (Hulbert et al. 1996; Arbeiter and Franke 2018). All these influences resulted in an increase in the risk of predation of experimental nests on post-mining sites in comparison with nests located in the surrounding landscape. If, as a result, the same pattern applies to the predation of real nests, the post-mining sites could be a sort of ecological and/or reproduction trap for birds nesting there (Gates and Gysel 1978; Robertson and Hutto 2006).

We mentioned above that the higher risk of predation on spoil heaps was connected with more diversified habitats, e.g. edge habitats and non-productive habitats. By means of these habitats, the predators, especially those that are more mobile, could have moved from the spoil heaps to their surroundings without recognising the border between the post-mining landscape and the original environment (Gehring and Swihart 2003; Šálek et al. 2009). This may have caused the demonstrably detected more probable predation of experimental nests in similar habitats near spoil heaps.

We observed that the prevailing probable predators of experimental nests were birds. However, we believe that this result must be taken with some caution. In the case of almost one fifth (18.4%) of the nests, no probable predator was identified, and the experimental nests and/or plasticine eggs could, in some cases, have been subject to secondary predation and, as a result, to incorrect identification of the predator (Krüger et al. 2018). Our recordings of predation events by camera traps and also some other studies (e.g. Ludwig et al. 2012) have shown that, in the case of artificial ground nests, a greater representation of mammal predators should probably be considered. The structure of the species of the recorded predators corresponds to Central European conditions (Weidinger 2009) and to current knowledge of the dominant position of corvids *Corvidae* among bird predators in agricultural landscapes and in forest covers (Purger et al. 2004b; Krüger et al. 2018; Bravo et al. 2020).

5. Conclusions

Our research using artificial ground nests has shown that the probability of predation of experimental nests on post-mining localities and in their surroundings in the NBBCB landscape was influenced by similar factors, especially by the level of vertical and horizontal heterogeneity of the vegetation cover on the relevant site. However, the post-mining sites were demonstrably riskier than the surrounding landscape for the experimental nests. The risk of predation decreased with the distance of the nest from the post-mining locality. In the landscape context, we therefore consider the role of restored post-mining areas as a potential centre and source of predation pressure on nesting birds.

A significant impact on the increase in the risk of predation of experimental nests on post-mining sites was observed mainly in sites with more horizontally diversified but vertically non-heterogeneous vegetation cover, which are interpreted as a combination of technically established habitats, especially within the framework of agricultural and sylvicultural reclamation of the site. However, the richly horizontally and vertically diversified sites, the character of which best corresponds to the areas left mainly or entirely for natural development, with open forest-steppe habitats, tended to reduce the risk of predation of experimental nests, although this tendency was slightly opposite in the case of a forest with a closed canopy and bush habitats. The results for the impact of management methods thus remain ambiguous.

With regard to the above, and because post-mining sites, especially near-natural localities, provide alternative habitats for rare and endangered bird species and for more biologically valuable bird communities, we think it is essential, in order to provide protection and support for the bird communities, to study and monitor the real nest predation, focusing on the following issues: (1) determining and comparing the level of nest predation in post-mining sites and in their surroundings, along with a description of local communities of predators. This will provide a definition of the role of post-mining localities in the landscape, primarily with regard to their function as a possible source of predation pressure and as a reproduction trap for nesting birds; (2) determining the real nesting predation on post-mining sites from the point of view of a comparison of the management approach to the restoration of these sites – technical reclamation vs. near-natural restoration, and (3) from the point of view of the character and structure of restored habitats, primarily with regard to their arrangement, size, fragmentation and the presence of edge habitats, in order to identify the “hot spots” of higher predation and also the “refuges”, where there is a lower risk of nest predation. We believe such knowledge would be useful not only for supporting and protecting local bird communities in the North Bohemian Brown Coal Basin, but also as a more general contribution to the rehabilitation of post-mining landscapes and to the protection of birds in other post-mining landscapes.

The richly horizontally and vertically diversified habitats which tended to reduce the risk of predation of experimental nests can be established by the both approaches – technical reclamation and near-nature methods. However, based on our results and generally in regard to higher natural value and lower implementation costs we already recommend improve the existing rehabilitation policy more in favour of near-natural approaches.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

Both authors contributed to the study conception and design, material preparation, data collection and analysis. The first draft of the manuscript was written by Jakub Novák and Markéta Hendrychová commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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Figures

Figure 1

Location of the study area (a), and the location of the study sites (b)

HOR – Hornojiřetínská spoil heap, RAD – Radovesická spoil heap, RUZ – Růžodolská spoil heap, VEL – Velebudická spoil heap, OM – Ore Mountains (Krušné hory), CBH - Central Bohemian Highlands (České středohoří), pit – open pits of active brown coal mines, towns of Most, Bílina and Litvínov

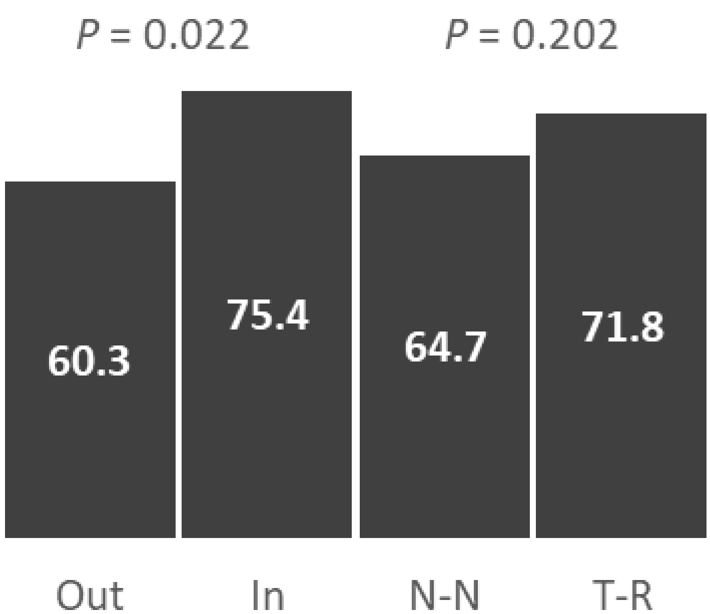

Figure 2

A comparison of the detected rates of predation of the experimental nests [%] between individual study territories (Locality) and restoration methods (Management)

Out – outside nests; In – inside nests; N-N – near-natural restored sites; T-R – technically reclaimed sites. The difference in predation rates was statistically tested by a Pearson chi-squared test with the Yates continuity correction for 2 x 2 contingency tables

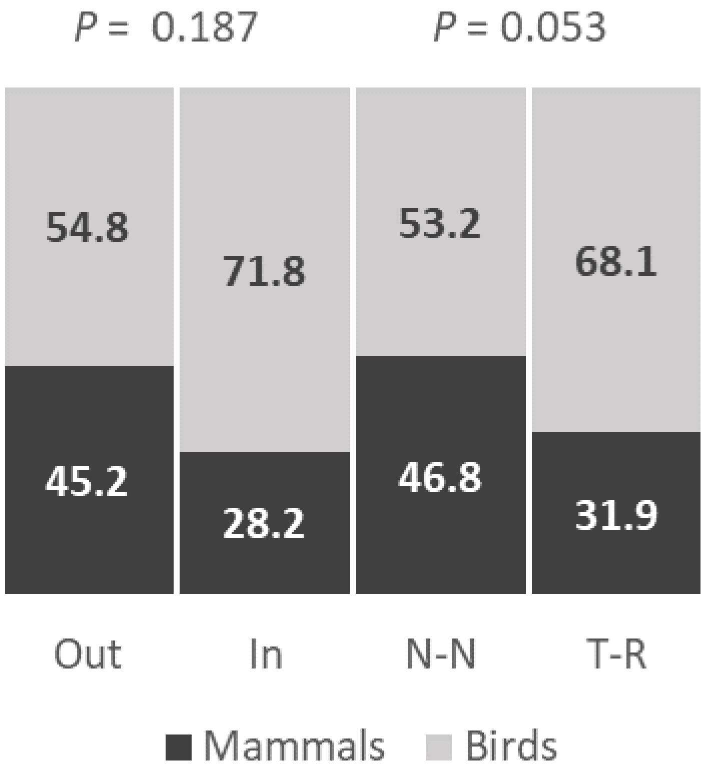

Figure 3

The proportion [%] of nests predated probably by birds and of nests predated probably by mammals in each study territory (Locality) and on the basis of the restoration method (Management)

Out – outside nests; In – inside nests; N-N – near-natural restored sites; T-R – technically reclaimed sites. The difference in proportional representation between the types of localities was statistically tested by the Pearson chi-squared test with the Yates continuity correction for 2 x 2 contingency tables

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