Sand pit for Biodiversity at Cep II quarry

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Březen – září 2012

Abstract

We compared the effect of restoration status (technical reclamation, spontaneous succession, disturbed succession) on the communities of vascular plants and assemblages of arthropods in CEP II sand pit (Třeboňsko region, SW part of the Czech Republic) to evaluate their biodiversity and conservation potential. We also studied the experimental restoration of psammophytic grasslands to compare the impact of two near-natural restoration methods (spontaneous and assisted succession) to establishment of target species. The sand pit comprises stages of 2 to 30 years since site abandonment with moisture gradient from wet to dry habitats. In all studied groups, i.e. vascular pants and arthropods, open spontaneously revegetated sites continuously disturbed by intensive recreation activities hosted the largest proportion of target and endangered species which occurred less in the more closed spontaneously revegetated sites and which were nearly absent in technically reclaimed sites. Out results provide clear evidence that the mosaics of spontaneously established forests habitats and open sand habitats are the most valuable stands from the conservation point of view. It has been documented that no expensive technical reclamations are needed to restore post-mining sites which can serve as secondary habitats for many endangered and declining species. The experimental restoration of rare and endangered plant communities seems to be efficient and promising method for a future large-scale restoration projects in abandoned sand pits. The restoration project must be prepared with respect to habitat demands of many endangered species bounded to such rare habitats and should be studied within detailed scientific research to evaluate the success of proposed restoration.

Introduction

Mining of gravel and sand is important phenomenon highly affecting the landscape in many parts of the Czech Republic. The Czech land reclamation policies require that disused mining sites must be reclaimed to their previous use, i.e. to forests or agrarian use. Forest use is often interpreted as planting with conifers, mostly Scots pine (*Pinus sylvestris*). State forest agencies are often required to create plantations that generate economic benefit through timber production. Agrarian use is interpreted mostly as a conversion to arable land. Reclamation to a water body is performed in sites where the gravel-sand was mined to below the groundwater table. The estimated average costs for reclamation of 1 ha is about 1.5 million Czech crowns (i.e. about 60 000€) depending on the type of reclamation (Kavina 2004). At present, spontaneous succession is not considered as a regular rehabilitation method for post-mining landscapes. Practically all mining sites for sand have 100% potential to be restored by spontaneous succession or near-natural restoration (including also assisted succession and management treatments). We assumed that the minimum intervention inherent in spontaneous succession in the case of suitable site conditions, especially if the site is surrounded by (semi-)natural vegetation, could be an effective and economical option for establishing species rich assemblages with high conservation potential (e.g. Novák et Konvička 2006, Řehounková & Prach 2008, Tropek et al. 2010). Nevertheless, including the approaches into restoration projects should be based on detailed survey of the locality and also reflect the spontaneous establishment of organisms during the mining sites and therefore the precise scientific evaluation of different restoration method used from the biodiversity and conservation point of views is necessary.

Objectives

In this study, we compared the effect of technical reclamation and spontaneous succession on the communities of vascular plants and assemblages of arthropods in abandoned areas of sand pit to evaluate their biodiversity and conservation potential. Moreover, we continued in research of experimental restoration of psammophytic grasslands focused on comparing spontaneous and assisted succession (the experimental trial was established in 2009).

The results of this study should contribute to practical restoration proposal of mining sites abandoned in September 2012. For this site we also suggest to establish unique large-scaled scientific experiment, not realised all over the world in similar site up to now, cover both slopes and also coastal areas and differed in restoration status (reclamation and vegetation succession), heterogeneity and moisture. Large areas left for spontaneous succession will go through the coastline up to the slope that is in contrast to the current situation, i.e. belts with spontaneous succession located only along the coastline.

Finally, we also proposed a text part for information board about flora, fauna, habitats and restoration in Cep II sand pit.

Background information

CEP II sand pit belongs to mining areas with very low biological knowledge of this site within the Třeboňsko region. No detailed biological survey has been ever conducted there, so there are available only

some smaller surveys or findings of particular species. Regarding vascular plants, there is only one paper focused on localities of the Smooth Cat's Ear (*Hypochaeris glabra*) in the South Bohemia (Lepší & Lepší 2011) because CEP II sand pits belongs to one of the localities where this critically endangered species occure. This paper was based on the fied surveys done by Jan Blahovec. In 1998, Jan Máca conducted research of invertebrates in the CEP II, however, this data are available ony only as a manuscript. Further information (especially about vertebrates) can be found in the UNDOP faunistic database. However, there is lack of information from this locality (Zdeňka Neudertová unpublished). References to the CEP II sand pit can be also found in literature devoted to the ecological restoration after mining (see for example Řehounková K., Řehounek J. a kol. 2010).

In 2009, Klara's island (48°54'59"N, 14°52'40"E) was used in an experimental trial to restore psammophytic grasslands in the sand pit and this experiment continues up to date. Since this vegetation type has become very rare and fragmented in the whole region, there is a chance to support the establishment of this vegetation type on suitable new sites such as abandoned sand pits. Raking was used as a method to harvest seeds and cryptogam material. Although some target species may locally establish spontaneously (Řehounková & Prach 2008), raking probably speeds up the process substantially and includes more species.

Methods

The sand pit was surveyed from April to half of September in 2012. The history of particular sites was reconstructed on the basis of official records from mining company and by interviewing local administrators (Administration of Třeboňsko Protected Landscape Area). All representative sites were selected, each of them with restoration status: i.e. spontaneous succession (spontaneously revegetated sites without further disturbances by recreation activities), disturbed succession (spontaneously revegetated sites continuously disturbed by intensive recreation activities), wet reclamation (wet reclaimed sites covered by organic material and planted by *Alnus glutinosa*) and dry reclamation (dry and mesic reclaimed sites covered by organic material and planted with *Pinus sylvestris*). The period since abandonment (age) ranged from 2 to 30 years. Red List species of vascular plants were determined according (Procházka et al. 200), arthropods according (Farkač et al. 2005, Plesník et al. 2003).

Vegetation sampling

All sufficiently large sites were sampled. Phytosociological relevés 5 m x 5 m (see Appendix 3 – Table 2) were recorded in the centre of each of the site (in the littoral stands the dimensions were adjusted to the total area about 25 m^2) in the July 2012. In this way, 28 relevés were obtained, 25 of which were used in analyses (wet reclamation was not included because of small area located only in one part of sand pit). Percent cover for vascular plants species and total cover of bryophytes and lichens were estimated in each relevé. The inclination of all sites where the relevé were recorded was between 0° and 30°. Water table depth in each site was estimated according the water table in large water body and consulted with local mining authorities.

All vascular plant species in were recorded the whole sand pits during the whole vegetation season to create overall list of species, further separated to particular lists of species for spontaneously revegetated sites (both disturbed and undisturbed sites because of unclear history of several smaller areas) , dry reclamation and wet reclamation.

Experimental design

In September 2009, an experiment focused of rare restoration psammophytic grasslands was established in the Klara's island (48°54'59"N, 48°54'59"E). Almost 1000 litres of raking material with seeds and cryptogames (lichens, bryophytes) was gathered in two types of habitats (sand dunes, floodplain terraces) in the Třeboň Basin where rare and retreating psammophytic communities still occur and transferred on the island. Phytosociological relevés were made on the donor sites (sand dunes, terraces) including inventory of mosses and lichens. Three variants (control, two different types of donor sites) were realized in a complete block design with five replicates. A ratio of 1:1 for donor and receptor sites was used. All permanent experimental plots were analyzed by phytosociological relevés prior to and a year after the experiment started and soil samples were collected. Vegetation sampling is made annually in second-third of September and therefore it was not possible to include data from 2012 to analyses (only results based on data from 2009- 2011 are presented).

Sampling of arthropods

Altogether 23 plots were sampled (see Appendix5-Table4), 18 of which were used in following analyses. Because the reclamation on wet sites occurred only in one relatively small area in sand pit, it was not included into analyses and following comparison of different restored sites.

Three quantitative methods including pitfall traps, yellow pan traps and sweeping were applied to sample arthropod assemblages. Pitfall traps with ethylenglycol were used to sample ground-dwelling arthropods. The traps were active from early April till the half of September; samples were collected every 2 – 3 weeks. Yellow pan traps were used to sample flower visiting arthropods. They were placed near a respective pitfall trap for ~3 days in April, June and July. Sweeping samples (50 sweeps around each pitfall trap) were collected twice in early July and late August. This method was aimed mainly on orthopteroid insects, although other insects were also sorted and identified. Each plot are charecterized by percent cover of vegetation layers (E0- moss, E1-herbs,E2-shrubs, E3-trees), age of site, water table level and restoration status.

To sample rare taxa or taxa not targeted by above methods additional methods of individual (qualitative) sampling were used, including sweeping, beating, trapping insects with water net, and light traping. Data on dragonflies, butterflies and vertebrates were collected mainly by direct observation; photos were used for additional determination when needed.

Statistical analyses

Vegetation, arthropod and environmental data were analysed using multivariate methods in CANOCO version 4.5 (ter Braak & Šmilauer 2002). Determination of alien species follows Pyšek et al. (2002). The target vascular plant species were classified according to their affiliation to the vegetation classes typical of open sand and clay habitats and a criterion according to (Chytrý & Tichý 2003) was applied.

Species data were logarithmically transformed and rare species downweighted. Using unimodal methods was justified by the length of the gradient in DCA, which was in all analyses higher than 4 SD-units (Lepš and Šmilauer, 2003). Ordination diagrams were produced using the CanoDraw programme (ter Braak and Šmilauer, 2002). Forward selection was conducted with all environmental variables using the Monte Carlo permutation test with 999 permutations: environmental variables used in vegetation pattern- inclination, age, water table, restoration status (spontaneous succession, disturbed succession and dry reclamation) , in arthropod pattern- age, water table, E0, E1, E2, E3. Subsequent analyses contained only the significant variables ($P<0.05$). Environmental variables were fitted to the DCA as passive variables. In analysis focused on experimental restoration of psammnophytic grasslands, the permutation of plots corresponds to complete block design was applied.

Differences in species richness /number of target species/Red List species of vascular plants, arthropods and particular arthropod taxa, between sites restored in different ways were tested with the non-parametric Kruskal- Wallis test using the R 2.9.2 programme (R Development Core Team, 2010). The taxa of arthropods with low presence in sampled sites were excluded from the analyses.

Results

Vegetation pattern

In total, 183 species of vascular plants were recorded during botanical survey within the whole sand pit (i.e. reclaimed, spontaneously revegetated and disturbed sites), 177 of which on sites restored by spontaneous succession (i.e. both disturbed and undisturbed sites), 44 on dry and mesic reclaimed sites, which were covered by organic material and planted with *Pinus sylvestris* and 56 on wet reclaimed sites, which were covered by organic material and planted by *Alnus glutinosa* (see Appendix2 –Table1).

Altogether 43 species typical of open sand and clay habitats were classified as target species within the whole pit. We recorded 31 target species in sample sites, 44 species of them occurred in both types of spontaneously revegetated sites and 10 in dry and mesic reclaimed sites and 6 in wet reclaimed sites. In total, 12 species are included on the national Red List (6 species were recorded on sampled plots), 12 species of which in spontaneously revegetated sites, two in dry and mesic reclaimed sites and 2 species in wet reclaimed sites (for summary see Appendix 7- Table 6). Because the reclamation on wet sites occurred only in one relatively small area in sand pit, it was not included into analyses and following comparison of different restored sites 83 species of recorded vascular plants occurring within the sand pits preferred grassland habitats with the highest proportion in spontaneous sites and lowest in wet reclaimed sites, 45 woodland woodland habitats dominated in undisturbed and reclaimed sites and 23 species wetland habitats. In total, 47 species of undesirable species (i.e. ruderal, alien) occurred in the sand pit, about 27 of which can

be classified as ruderal and 20 species as alien species. Number of ruderal species was only slightly higher in spontaneous sites (25 species), the lowest number reached in wet reclaimed sites (7 species). The alien species were successful mostly in spontaneous sites (19 species) and the least in reclaimed sites (4 species). Cover of undesirable species decreased in the course of vegetation succession (see Appendix3 – Table2).

Because the DCA and CCA ($\lambda_{1:}$ 0.503, $\lambda_{1:}$ 0.288) showed basically the same pattern, only DCA graphical outputs are displayed. The results of DCA species ordination are shown in Appendix 7 –Fig. 4).The first axis explained 73.5% of variability in vegetation data and can be easily interpreted as a gradient of site moisture. The second axis explained 54.6% of variability and could be interpreted as time since site abandonment but effect of variable Age was not significant (P>0.05) and therefore not presented. Type of restoration status (reclamation, disturbed succession, spontaneous succession) and site moisture appeared as significant explanatory variables (P<0.05). Site moisture explained 39% of the vegetation variability, restoration status 28.2%.

Among the species best fitted the model are the target species (including some species from national Red List) typical of prevailingly open sand and clay habitats on the right hand site of the ordination biplot which were overgrown by common shrubs and trees in mesic undisturbed spontaneously revegetated sites during the 30 years since site abandonment. On wet undisturbed sites led spontaneous vegetation succession to the *Typha* and reed beds. The vegetation in reclaimed sites is dominated by planted trees *Pinus sylvestris* accompanied by only rarely spontaneously established shrubs and trees (e.g. *Picea abies, Betula pendula*) with very poor herb layer (cover less than 10%) and only several common species.

Appendix 7 -Fig 7a,b shows continual transitions from open spontaneously revegetated disturbed sites with rather high species richness and many target and rare species towards more closed spontaneously revegetated sites still providing suitable conditions for some target and rare species (especially in wetter sites) to species poor reclaimed sites nearly without target species.

Experimental restoration of psammophytic grasslands

The first preliminary results indicate that three-quarters of higher plants and cryptogames typical of psammophytic grasslands (vascular plants 20 of 27 species, cryptogames 13 of 17) successfully established, (see Appendix7- Table7).

The ordination analysis (DCA, $\lambda_{1:}$ 0.802, $\lambda_{1:}$ 0.634) shows the close similarity in vegetation composition on donor (i.e. sand dunes, floodplain terraces) and receptor sites (island in the CEP II sand pit). The results show that during two years the sites with assisted succession and transferred material converged in species composition toward the species composition in donor sites (i.e. sand dunes, terraces). The trajectory of vegetation development in spontaneously revegetated sites (i.e. control plots) was relatively short in comparison to assisted successional plots and the course of vegetation succession is still unclear (see Appendix7- Fig. 6).

Pattern of arthropods

In total, we recorded 507 species of animals (including arthropods, reptiles, birds, amphibiants, during survey within the whole sand pit (Appendix 4- Table3)

Out of 467 species of arthropods recorded in 23 detailed sampled sites, 118 are considered as target species typical of open habitats and 26 are included in national Red List . Total numbers of target and red-listed species in differently restored study sites are summarized in (see Appendix 7 – Table 8). Because the wet reclamation occurred only in one relatively small area in sand pit, it was not included into analyses and following comparison of different restored sites. In total, one undesirable invasive species ladybird beetle *Harminia axyridis* occurred in the sand pit.

The result of DCA species ordination is shown in Appendix7- Fig. 7. The first axis explained 61.8% of variability in vegetation data and could be interpreted as a gradient of vegetation cover in studied sites but the impact of vegetation structure (E0, E1, E2, E3) was not significant and therefore it was not presented (P>0.05). The second axis explained 34.1% of variability but was not clearly interpretable. The direct ordination analyses CCA ($\lambda_{1:}$ 0.483, λ_2: 0.405) revealed similar general pattern as DCA and therefore it was not presented. In CCA analyses of the restored sites, only the type of restoration status was significant explanatory variables (21.3%).

Among the species with significant responses, target species of beetles, orthopteroids and hymenopteroids (including several red listed species) preferred open disturbed sites on the right hand site of the ordination biplot. The spectrum of target species decreased in the spontaneously revegetated sites during vegetation succession but still some of them (especially hymenopteroids and spiders) are typical of such not

completely closed vegetation with woody trees (Appendix7-Fig. 8). The woodland generalists were significantly connected with reclaimed sites.

Biodiversity and conservation potencial

The data on vascular plant species and selected taxa of arthropods are summarised in Table (Appendix 7 – Table 9). The richness species was higher in disturbed sites than on other restored sites, for particular studied taxa it was higher for ladybirds beetles, dipterous insect, hymenopteroids, crabronid wasps, halictid bees and orthopteroids (Appendix7-Fig. 9a). Similarly, the number of target species (Appendix7-Fig.9b was higher in disturbed sites than on other studied sites, for particular studied groups it was higher for vascular plants, spiders, beetles, dipterous insects and hymenopteroids. The number of red list species (Appendix7-Fig. 9c) was higher in the disturbed sites than on other studied sites, for particular groups it was higher for vascular plants, beetles and hymenopteroids.

None of the analyses revealed positive impact of technical reclamation in comparison to disturbed spontaneous succession. The effect of more closed spontaneously revegetated sites to species richness, target species and red listed species was not significant.

Discussion

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Restoration of target species and groups in the sand pits by processes of spontaneous vegetation succesion can be successfully achieved in a reasonable time. Moreover conservation value of spontaneously revegetated areas is higher in contrast to technically reclaimed sites (Prach& Hobbs 2008). Especially young or continuosly disturded open sites with natural development on nutriet poor substrate offer suitable environmental conditions for many organisms including many red listed species and provide them refuges in the eutrophicated landscape. A similar conclusion has been reported from gravel-sand pits (Řehounková & Prach 2008), dumps (Hodačová & Prach 2003, Tropek et al. 2012) and limestone quarries (Beneš et al. 2003, Novák & Konvička 2006, Tropek et al. 2010).

It is likely that the target assemblages may be well restored via natural colonization in those sand pits that are adjacent to (semi-)natural habitats, that can act as seed and species source for many target organisms. Concerning vegetation, long-distance dispersal mostly by epizoochory besides seed sources in the surroundings, may also be importatnt for the establishment of wetland vegetation including some rare species (Krahulec & Lepš 1994). Colonization of spontaneously revegetated areas in the sand pit by target and end endangered species was high despite the fact that our study site is surrounded by relatively species poor and homogenous forest dominated by *Pinus sylvestris* with very few small and narrow open sand areas outside the pit land located only on forest trails. The creation of secondary habitats for rare and declining species of open habitats was documented also from other post-mining landscapes left for spontaneous succession (Řehounková et al. 2011). Spontaneous vegetation succesion is pushing back towards the most valuable open habitats via countinous disturbances connected with recreation activities, which enable to create heterogenous mosaics of microhabitats such are open grasslands, open sands, areas with scattered trees and shrubs and woodland areas still not completely closed. Such heterogenity is key for the coexistence of many species declining from their original nutriet poor environments (e.g. Aculeata Hymneoptera -Heneberg et al., in press).

Alien species may be able to colonize the site early after a disturbance but the altering of succession from target towards undesirable asembladges is not probable in this site (Prach et al. 2011). The lower importace of ruderal and alien species in site located in relatively colder and wetter region and surrounded by woodland landscape corresponds with the fact that more Central European ruderal and alien species require drier and warmer sites than those in the local flora (Pyšek et al. 1995, Řehounková et Prach 2008). Alien plant *Robinia pseudacacia* found on the locality is easily dipersed vegetatively and by seeds over a short distance. The effect of *R. pseudacacia* on species composition of the field layer through nitrogen fixation is likely to be strongest on poor sandy soils where nitrogen is the main lifting soil resource. This species reaches optimal environmental conditions for growth and spreading in warm and dry regions resulting in the considerably rise of nitrophilous and ruderal species. Such undesirable change of natural development is associated with dry sites in Moravian or central Bohemian lowlands which provide suitable conditions for this alien species and up to date it is not documented from sand pits in colder and wetter Třeboňsko region (Řehounková and Prach 2006). However, it is generally recomended to implement some management treatments focused on eredication of *Robinia pseudacacia* into the restoration plan (Řehounková and Prach 2008).

The trasfer of raked materials with seeds and cryptogames to the experimental plots on island seems to be successful. All dominant cryptogames established successfully on assisted succession sites. After only two years the composition of vegetation on experimental plots is very similar to donor sites. However, the expansion of leguminous plant *Lotus cornuculatus* may potentially divert ssuccession. Therefore it is still not sure if the experiment will be successful in a longer perspective.

10 species of **vascular plants** are listed in the national Red List of Endangered Species. Five of them, namely Morison's Spurry (*Spergula morisonii*), Smooth Catsear (*Hypochaeris glabra*), Small Cudweed (*Filago minima*), Shepherd's Cress (*Teesdalia nudicaulis*), Common Thrift (*Armeria vulgaris*) and Common Centaury (*Centaurium erythraea*), occur only on open sands and dry grasslands. Especially the first of above mentioned species is a dominant on continuously disturbed areas during spring aspect. Trailing St John's Wort (*Hypericum humifusum*) occur quite commonly on wet open sands. Wetland plants are represented by Common Club-rush (*Schoenoplectus lacustris*), Long Stem Waterwort (*Elatine triandra*) and Marsh Willowherb (*Epilobium palustre*). For all above mentioned plants applies that for their long-term existence on the CEP II sand pit I is necessary to maintain the intensity of disturbances because they are species typical of early successional stages.

It must be noted that two more species from the Czech Red List occur in the CEP II sand pit, namely Hedge-hyssop (*Gratiola officinalis*) and American Shoreweed (*Littorella uniflora*). Both species are very rare and endangered, however they were introduced into the sand pit from the collection of wetland plants of the Institute of Botany, Academy of Sciences. These two species are therefore not included into the overall species list and analyses because it would influence the results. While the Hedge-hyssop does not spread too much, the American Shoreweed colonizes the sand pit on suitable habitats quite successfully.

A potential danger for development of plant communities could be invasive species, particularly Black Locust (*Robinia pseudacacia*). Therefore we proposed to eliminate this species in two sites. Other invasive species occurring in the CEP II sand pit are *Erechtites hieraciifolia*, Shorthair Goldenrod (*Solidago canadensis*), Canadian Horseweed (*Conyza canadensis*), etc. Unlike the Black Locust, these species usually disappear during the course of succession so they are not a major risk.

Ectomycorrhizal macrofungi are indispensable for tree community development both in natural and artificial regeneration of sand pits under oligotrophic condition. Nearly 50 % of macrofungi found during a one-shot survey on September 2012 were ectomycorrhizal fungi The area of artificial regeneration of the sand pit highly prevails the area of spontaneous regenerarion. Therefore the Scots pine plantations (*Pinus sylvestris*) exhibit the highest number of the macrofunal species. Thinning as the practice of foresty introduced higher amount of decaying wood into the canopy and caused a significant deal of wood decaying fungi. The relatively small area of spontaneous regeneration exhibits lower numbers of both ectomycorrhizal and lignicolous species. Saprotrophic species, on the other hand prevailed in natural regeneration stand in comparision to pine plantations, namely in wet series. The complete list of the species revealed 51 taxons with two redlisted species, *Leccinum holopus*, ectomycorrhizal with birch in wet conditions and *Diplomitoporus flavescens*, wood decaying species of pine stumps. Both species are more common in the South Bohemia then in other part of the Czech Republic.

The conservation value of the recorded **spider community** is tremendous and rather unusual. In total, 81 species of spiders were identified, including 4 nationally endangered species. The most important for regional biodiversity are records of three species so far not known in the whole South Bohemia region: *Gibbaranea bituberculata*, a rare spider of warm and dry open habitats; *Clubiona comta*, a rare spider preferring colder habitats of peat bogs and well-preserved forests; and *Clubiona juvenis*, a nationally endangered specialist of wetlands and littorals which is known from the only other locality in the whole Bohemia. A nationally endangered wolf spider *Arctosa cinerea*, a declining specialist of gravel river banks, is also known to occur exclusively in the sandpits of Suchdol nad Lužnicí in the whole region. Additionally, two other nationally endangered species, *Micaria silesiaca* and *Sitticus saltotor*, and several other rare and declining spiders were recorded. As a consequence of habitat heterogeneity among the studied plots, an important combination of spiders with totally opposite habitat preferences was revealed – from spiders of forests or peat bogs in colder areas (e.g., *Gnaphosa montana*), through species of wetlands (e.g., *C. juvensis*) or dry grasslands (e.g., *M. silesiaca*), to specialists of open sands (e.g., *S. saltator*). The studied sandpit is thus a good example how can a single locality significantly increase the regional biodiversity. Although a majority of the recorded rare spiders are specialized to warm and dry habitats, the conservation potential of the locality can be preserved only by supporting of the current habitat mosaic by heterogeneous management and diversified restoration approaches.

Species important for conservation listed in the Czech Red List and occurring in the CEP II are also among **Dragonflies (Odonata)**. Namely they are the Yellow-Spotted Whiteface (*Leucorrhinia pectoralis*),

the Common Darter (*Sympetrum striolatum*), the Scarce Blue-tailed Damselfly (*Ischnura pumilio*) and the Spearhead Bluet (*Coenagrion hastulatum*). However the first above mentioned species (which is also protected on the European level within the Natura 2000 network) was recorded only once so it may be just a random occurrence. The conditions are not very suitable for the dragonflies because there are only few small water pools in the CEP II sand pit.

In total 13 species of **Orthopterous insect** was found during the survey. They were mostly widespread and abundant representatives of this group. Rare species with local occurrence in the Czech Republic, such as the Heath Grasshopper (*Chorthippus vagans*), the Mottled Grasshopper (*Myrmeleotettix maculatus*) and the Two-spotted Groundhopper (*Tetrix bipunctata*), deserve particular attention. These species occur exclusively in sparse pine forests on sands, heath lands and similar biotopes. Potential occurrence of other species which have not been found yet, such as the Slender Blue-winged Grasshopper (*Sphingonotus caerulans*) or the Cepero's Groundhopper (*Tetrix ceperoi*), is still possible in the future. Maintenance of broad spectrum of species with representation of habitat-sensitive species is dependent on appropriate management of the site that should be aimed to creation a mosaic of bare or sparsely vegetated areas and insolated edges of water bodies.

From other monitored groups two species of Scorpionflies (Mecoptera), two species of Cockroaches (Blattodea), one species of Snakeflies (Raphidioptera) and four species of **Neuropterous insect** were recorded. Most of these species are widespread and common but the Antlion *Myrmeleon formicarius* from the Neuroptera order deserves our attention. Its occurrence on the locality requires the same management measures as the Orthoupterous insect.

Butterflies (**Lepidoptera**) are not a priority group in our survey. We can mention protected the Poplar Admiral (*Limenitis populi*) as one of more interesting species. Other interesting species are the Green Hairstreak (*Callophrys rubi*), the Sallow Kitten (*Furcula furcula*) or the Garden Tiger Moth (*Arctia caja*).

The order **Diptera** comprises many species with varied life strategies. Only some target groups from the Cep II sand pit have been currently determined. Adults of some families, e.g. Syrphidae, are heliophilous (seeking insolated places), thus often common at the sand pits; they are good flyers and their development often takes place in different habitats. The species of Asilidae and Therevidae are bound to the xerothermous places both as adults and larvae; both stages are predaceous, adults are often stenophagous; the asilid (robber fly) *Rhadinus variabilis* (critically endangered species in the Czech Republic) is the most important finding. Dolichopodidae are also predaceous, often hygrophilous but some species are xerophilous. Bombyliidae are floricolous as adults but their larvae are parasitoids of bees, sphecoid wasps etc., thus dependent on the xerophilous prey; *Anthrax varius* is a rare species, previously known from some south Bohemian sand dunes but not collected there during the last 30 years. Some Sarcophagidae have the same life strategy, two of the recorded species (*Metopia staegerii* and *Taxigramma hilarella)* prefer vast sandy areas. *Nephrotoma scurra* (Tipulidae), *Antlemon brevimanum* (Keroplatidae) and *Pherbina coryleti* (Sciomyzidae) are markedly thermophilous, but the details of their biology are poorly known. Hygrophilous Diptera occur in some parts of the locality but some otherwise common hygrophilous species or even groups (Limoniidae, Ephydridae, Muscidae: Coenosiinae etc.) are poorly represented or absent. Also some xero/thermophilous dipterans, known from some other sandy localities of southern Bohemia, have not been collected and the finding of *Orchisia maculata* (Muscidae) (collected in the quarry Cep II in 1998) has not been repeated. The management should mainly seek to create favourable conditions for the occurrence of aculeate hymenopterans, serving as prey of some important dipterous species.

Hymenoptera – Aculeata use to be one of the most important groups of animals or insects in sandpit fauna, and many species are strictly bound on sandy localities. The locality represents a very good site for obligatory specialists nesting in sand dunes (e.g. spider wasps *Anoplius concinnus*, *Episyron rufipes* and *Pompilus cinereus*, digger wasps *Alysson spinosus*, *Bembecinus tridens*, *Cerceris arenaria*, *Crabro scutellatus*, *Oxybelus argentatus*, *O. bipunctatus* and *Tachysphex obscuripennis*, and the bee *Halictus sexcinctus*) and cuckoo bees and wasps invading their nests (*Hedychrum nobile*, *Nysson maculosus*, *N. niger* , *Nomada rufipes* and *Sphecodes longulus*). Marshes and littoral vegetation are important for other rare species (*Melitta nigricans* and *Lasioglossum zonulum*). The locality is quite warm (confirmed by the occurrence of species of warm sites, e.g. all sandy specialists and *Lasioglossum malachurum*) but in cooler region with forests (confirmed occurrence of mountain forest species *Bombus jonellus* and *Lasioglossum rufitarse*), which makes its fauna interesting. Since most of the species recorded occur in open biotopes with open sand without dense grass or shrub cover, most important is to provide management measures maintening the locality as a mosaic of open sand patches, spots of vegetation, shrubs, little pools, etc. Very good is presence of vertical sandy slopes orientation to SW and few sand heaps for nesting of species specialized on very early successional stages. It is necessary to cut shrubs every year and to put the top 30

cm of the ground away on several patches every few years (depending on the situation). The parts with open ground must be on sun most of the day. Then the locality would be inhabited by other rare species of aculeate Hymenoptera and help to sandy-site species in their critical situation.

Representatives of terrestrial species prevail among beetles **(Coleoptera)** whereas there are only few representatives of water beetles due to minimal number of suitable habitats. In total 12 species form the Czech Red List were found in the locality, mostly specialists on oligotrophic habitats, and 4 species protected under Czech legislation which are not too endangered. Ground Beetles (Carabidae) are the most interesting group in the sand pit. Four species of Ground Beetles found in the sand pit are listed in the Czech Red list. Ground Beetles *Acupalpus brunnipes* and *Bembidion modestum* are rare species disappearing within the Czech Republic but occurring in the sand pits of the Třeboň basin. The Ground Beetle *Nebria livida* occurs locally exclusively on sandy or loam-sand shores of unpolluted water bodies. The most interesting finding is a Ground Beetle *Bembidion testaceum* which is very rare species disappearing all over the territory of Bohemia and occurring only locally in Moravia on original sandy shores of bigger rivers. Other important psamobiotic species occurring exclusively on sandy habitats are *Amara fulva*, *Dyschirius politus*, *Harpalus autumnalis*, *Lionychus quadrillum* and *Omophron limbatum*. All the above mentioned species are specialists on sandy and loam-sand sites around rivers and they find suitable secondary habitats in the sand pits. Jewel Beetles are another important family from the conservation point of view in the CEP II sand pit. Even if there are not many species present in the sand pit, two of them are listed in the Czech Red List namely *Anthaxia chevrieri* which lives on Scotch Broom (*Cytisus scoparius*) and *Buprestis octoguttata* from scarce pine stands. Four species of Reed Beetles from the family of Leaf Beetles living in wetland habitats are worth mentioning two red listed species - *Donacia versicolorea* and *Donaciella cinerea*.. Other endangered species of beetles are the Violet Oil Beetle (*Meloe violaceus*) which larvae parasites in nests of Hymenopterous insect and *Morychus aeneus* from the Byrrhidae family which is a specialist on sandy biotopes. Click Beetle *Cardiophorus nigerrimus* is listed in the Czech Red List but it lives also in managed forests in the Czech Republic. We can find also other species typical of open oligotrophic habitats among terrestrial beetles. Conservation of these habitats in sufficient size can provide long-term survival for endangered beetles in the CEP II sand pit.

Eight species of **water beetles** were found during the inventory of the Cep II sandpit area. This number of species is very low and all the species except *Dryops luridus* are widespread or even euryecious (Boukal et al. 2007). This finding reflects, along with the lack of a more thorough inventory, the absence of suitable habitats that could be colonized by water beetles. Most water beetles, like other aquatic insects, require shallow water bodies with gradually sloping shores. If such habitats became available, the sandpit could host various species restricted to early successional stages and requiring water bodies without vegetation and plant debris as is the case the nearby reclaimed area of Cep I sandpit (with, e.g., populations of the diving beetle *Nebrioporus canaliculatus* and of the water scavenger beetle *Laccobius gracilis*). Two individuals of the critically endangered diving beetle *Graphoderus bilineatus* were also found in an old pool there in April 2011 and 2012 (D. Boukal, unpublished data). We thus expect that various rare species of water beetles, including habitat specialists that find only few suitable habitats in the surrounding landscape, will occur in the Cep II area after a creation of small pools and their spontaneous succession.

During the biological survey of the sand pit the occurrence of **vertebrate** species was also recorded. 6 species of amphibians, 4 species of reptiles and 7 bird species are listed in the Czech Red List (mostly in lower categories). We can mention for instance Little Ringed Plover (*Charadrius dubius*), Common Raven (*Corvus corax*) or Common Adder (*Vipera berus*) as interesting species.

Conclusion

The mosaics of spontaneously established forests habitats and open sandy habitats are the most valuable stands from the conservation point of view. Open non-forested sands (either young succesional stands or older stages pushing back towards the young open stands through continuous disturbances connected with recreation activities) can serve as a refuge for many endangered species declining from their natural habitats. Spontaneous vegetation succession led usually to the development of contaneous vegetation cover within 10 years and stabilized late succesional stages are reached relatively fast in about 20 years. More closed successional woodland stands usually hosts less species of various groups of organisms but still provide suitable conditions for some target species in contrast to technical reclamation colonized by generalists. Alien species such *Robinia pseudacacia* should be eredicated both in the locality and also in the close vicinity because if invasive species occur on the post-mined site, they are colonizers from the close surroundings.

Observation time of the experimental restoration of psammophytic grasslands was too short to analyze success of the restoration experiment. However, it appeared that this method of restoration of rare and endangered plant communities seems to be efficient and promising for a future large-scale restoration projects in abandoned sand pits.

The restoration scheme for mining sites must be prepared with respect to habitat demands of many endangered species (e.g.arthropods, amphibians, birds, reptiles) bounded to such rare habitats. Therefore close collaboration between botanists and zoologist is necessary.

Mining companies should promote research in their localities and strike to put the results of restoration studies into practice.

Implication for practices

Recommendations for management of already reclaimed areas

1. Open sands on slope below the round road (GPS: 48° 55' 33.36"N, 14° 52' 35.64"E): We recommend selective tree cutting of adjacent pine monocultures that shade the slope. In the future it would be desirable to maintain open vegetation and good insolation of the slope.
2. Alder cars with pools (GPS: 48° 55' 34.80", 14° 52' 32.82"):We propose selective tree cutting around small water pools because several protected species of amphibians and endangered invertebrates occur in this habitat.
3. Coastal areas with ecological restoration (GPS: 48° 55' 19.62", 14° 52' 19.50"): Currently no interventions are necessary. However in the future restoration of some small water pools or creation of new ones and disturbance of closed vegetation in areas without intensive recreation activity will be appropriate. Selective tree cutting of spontaneously established woody plants (especially pines) is recommended in some places.
4. Stands with spontaneously established trees on the west from the large beach (GPS: 48° 55' 39.00", 14° 52' 20.46"): In this area invasive species Black Locust (*Robinia pseudoacacia*) should be eradicated not to divert the course of succession towards Robinia groves accompanied by nitrophilous species. The most suitable method of eradication of the Black Locust seems to be a combination of mechanical removal and contact herbicide e.g. Roundup.
5. Island in the lake (GPS: 48° 54' 58.89", 14° 52' 39.59"): The island should be further left for the scientific experiment focused on restoration of psammophytic grassland by assisted succession.

Recommendations for restoration of other areas abandoned in close future

Based on the conducted research, modern knowledge of ecological restoration and experience of authors of the project, we propose the following recommendations for restoration of areas where active mining will be finished in close future:

1. It is necessary to use ecological restoration (spontaneous succession, assisted succession, management measures) on the maximum possible area. The CEP II mining area can become good example for similar mining sites in the Czech Republic, if newest scientific knowledge is used and maximum possible area is left to natural processes.
2. We propose to use the forestry reclamation only rarely in a mosaic with ecologically restored areas. Covering the surface by nutrient rich organic material in mined sites in inappropriate in any cases including reclamation. With regards to the scientific research it would be appropriate to create the moisture gradient from the coastline of the lake to the upper edge of the sand pit especially for spontaneous succession. Larger strips on the slopes left to the spontaneous succession are also important for good insolation of habitats (pine monocultures will very quickly shade smaller areas along the coast left to the spontaneous succession).
3. We recommend to modify the coast of the lake as maximally heterogeneous as possible (good example are areas with spontaneous succession on the west coast of water body).
4. It is desirable to create a series of small water pools in the coastal part of the water body that will not be connected with the water body and will serve as a suitable habitat for many target aquatic organisms. These pools will be also used for study focused on spontaneous succession of plant communities and communities of aquatic invertebrates in oligotrophic water pools. Creation of pools should be consulted with specialists.
5. The areas left to spontaneous succession should be connected with small drainage ditches in adjacent forests. In this way we will create a set of biologically valuable habitats that will be maintained

without any management (e.g. erosion ravines, small “floodplains”, sediments of fine material, small beaches along the slopes, etc.).

6. It is necessary to leave certain part of the slopes with steep slopes. Vertical faces will serve as nesting areas for endangered species of Aculeate Hymenoptera. At least some of these sites will be maintained in a good condition without any management, only due to erosion. Various inclination of slopes is one of the important restoration measures how to ensure diversity of habitats in the sand pit. Moreover, flat areas and moderate slopes would be formed together with steeper slopes. We further recommend divided the area by system of small ridges.
7. We propose to create other islands in the lake. Clay material can be used for their creation. We recommend to put at least layer of sand (e.g. half of metre of sand on the basis of clay material) on their surfaces.
8. Extensive recreational activity (swimming, fishing, etc.) is desirable in the sand pit (even though currently it is illegal) and after finishing the mining activities it will be one of a few options how to maintain suitable habitats for species demanding open treeless habitats. Building infrastructure for vacationers is however strictly not recommended (perhaps with the exception of garbage bins in the most exposed places). Current character of recreational activities should in our opinion be maintained.
9. With regards to the results of research focused on spontaneous and assisted succession we do not recommend use the newly restored areas for sewing, seeding or planting of endangered plant species that could influence the results of scientific research. In the first place this applies for species that are not native in Třeboňsko region.
10. Other biological survey of the area is highly needed. We propose to establish a scientific experiment in the CEP II sand pit comparing the slopes and the coast reclaimed with traditional forestry reclamation and areas with spontaneous succession. The best design will be large areas (at least 50 m x 50 m) with different restoration status (i.e. spontaneous succession, reclamation, directed succession) each of them differed also in heterogeneity (large flat areas, heterogenous areas with system of ridges, gentle slopes and steeper slopes) and moisture (large hallow flooded sites, wet area on ecotones between flooded and dry sites on slopes, dry sites) (Appendix 10).The results should also serve as practical test of the proposed restoration and enables to measure restoration success and improve alternatively the suggested restoration measures. For the same purpose the ongoing experiment on the island focused on experimental restoration of psammophytic grasslands via assisted succession could be used.
11. The attention of specialists should be paid to CEP II sand pit also in future. In this respect a potential of nearby University of South Bohemia could be employed.

References (see Appendix)

Acknowledgements: Jan Bláhovec, Jaroslav Blízek, Jaroslav Bosák, Dušan Čudan, Zdeněk Hanč, Miroslav Hátle, Petr Heneberg, Josef Hlásek, Tereza Kušnírová, Martin Lepší, Zbyněk Kejval, Zdeněk Kletečka, Rudolf Macek, Petra Konvalinková, Jiří Migl, Zdeňka Neudertová, Ladislav Rektoris, Jan Řehounek, Karel Spitzer

Appendix:

1. Maps

Fig.1. Map of CEP II san pit- year of site abandonment is shown.
Fig. 2. Location of phytosociological relevés in differently restored sites within the CEP II sand pit.
Fig 3. Location of pitfall traps in differently restored sites within the CEP II sand pit.

2. List of vascular plant species

Table 1. List of vascular plant species found in the CEP II sand pit.

3. Phytosociological relevés

Table 2. Phytosociological relevés (restoration status: R- dry and mesic reclamation, W-wet reclamation, D- disturbed succession, S- spontaneous succession)

4. List of animals

Table 3. List of animals found in the CEP II sand pit
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5. List of arthropods in sampled sites

Table 4. List of arthropods in sampled sites (restoration status: R- dry and mesic reclamation, W-wet reclamation, D- disturbed succession, S- spontaneous succession)

6. Red listed species

Table 5. List of red listed in the CEP II sand pit.

7. Results

Table 6. Summary data for the restored sites within the sand pits included in the study (vascular plants).
Fig. 4. Unconstrained ordination (DCA) of species and significant environmental factors (vascular plants).
Fig.5. Unconstrained ordination (DCA) of vegetation samples from reclaimed sites, spontaneously revegetated and disturbed sites (vascular plants).
Table. 7. Proportion of target species (vascular plants, cryptogames) which established successfully on the island in plots with site assisted succession and spontaneous succession (i.e. control plots).
Fig. 6. DCA ordination of species and samples (experiment).
Table 8. Summary data for the restored sites within the sand pits included in the study (arthropods).
Fig.7. Unconstrained ordination (DCA) of species and significant environmental factors (arthropods).
Fig.8. Unconstrained ordination (DCA) of samples from reclaimed sites, spontaneously revegetated and disturbed sites (arthropods).
Fig.9. Differences in number of species (Kruskal-Wallis test) according to the given variables (species richness, number of target species and number of red listed species) and restoration status (reclamation, spontaneous succession, disturbed succession).
Table.9. Results of site restoration impact on vegetation composition and studied taxa of insect community.

8. List of Ectomycorrhizal Macrofungi.

Table 10. List of Ectomycorrhizal Macrofungi found in the CEP II sand pit

9. References

10. Maps with restoration proposal for sites abandoned in close future (first part in autumn 2012)

11. Information board

Appendix 1.Maps

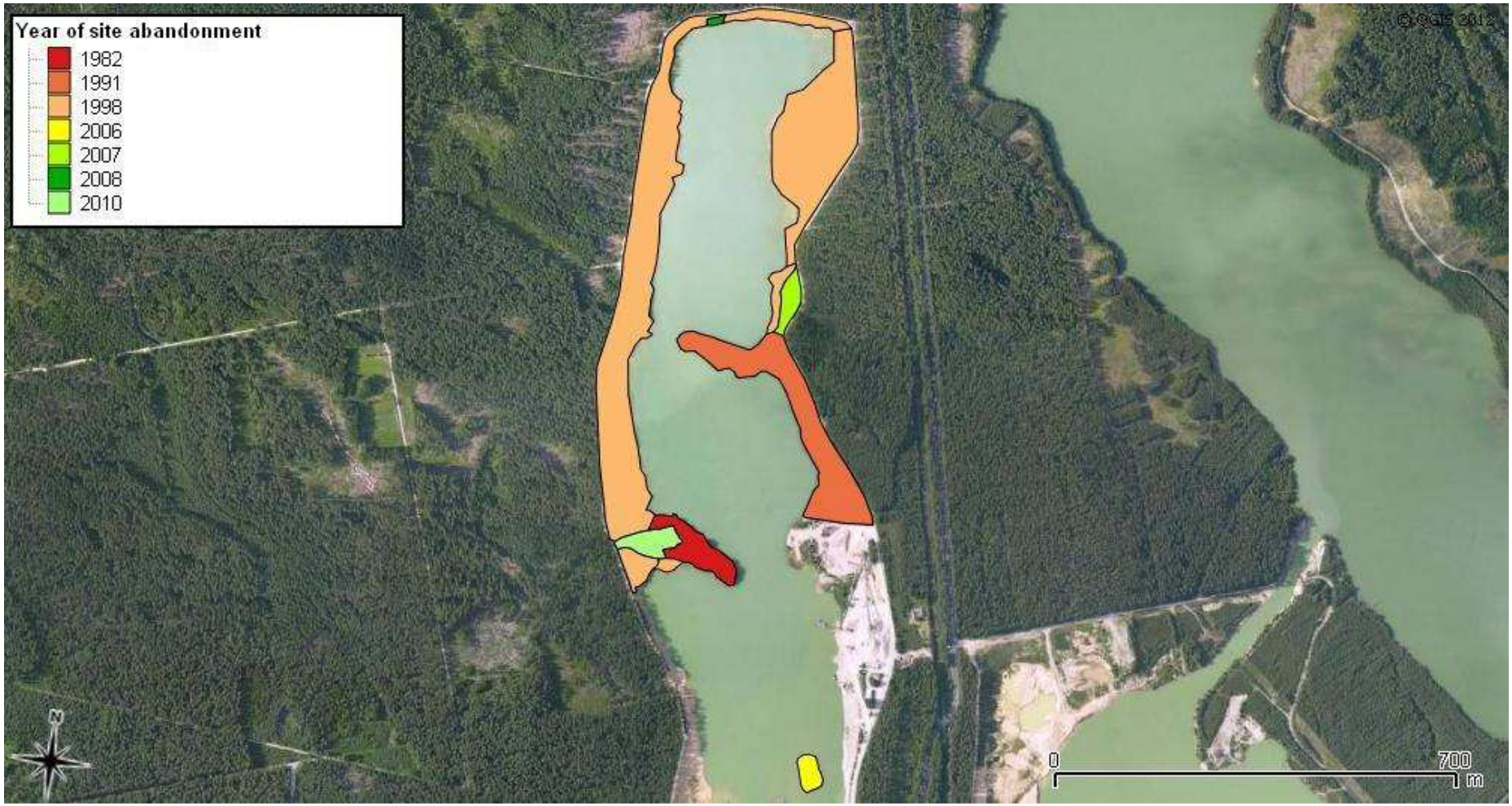


Fig.1. Map of CEP II sand pit- year of site abandonment is shown.

Fig. 2. Location of phytosociological relevés in differently restored sites within the CEP II sand pit.

Fig 3. Location of pitfall traps in differently restored sites within the CEP II sand pit.

Appendix 2. List of vascular plant species.

Table 1. List of vascular plant species found in Cep II sand pit.

Aegopodium podagraria
Agrostis canina
Agrostis capillaris
Agrostis scabra
Agrostis stolonifera
Achilea millefolium
Ajuga reptans
Alisma plantago-aquatica
Alnus cinerea
Alnus glutinosa
Alnus incana
Alopecurus geniculatus
Antennaria dioica
Anthoxanthum odoratum
Arabidopsis thaliana
Armeria vulgaris
Arrhenatherum elatius
Artemisia vulgaris
Athyrium filix-femina
Avenella flexuosa
Betula pendula
Bidens frondosa
Calamagrostis arundinacea
Calamagrostis epigejos
Calamagrostis villosa
Callitriche palustris
Calluna vulgaris
Campanula patula
Campanula rapunculoides
Carduus species
Carduus vulgare
Carex brizoides
Carex canescens
Carex caryophyllea
Carex hirta
Carex leporina
Carex nigra
Carex pilulifera
Centaurium erytracea
Cerastium holosteoides
Cirsium arvense
Cirsium palustre
Convonvulus arvensis
Conyza canadensis
Crepis bienis
Cytisus nigricans
Cytisus scoparius
Dactylis glomerata
Daucus carota
Deschampsia cespitosa
Dianthus deltoides
Digitaria ischaemum
Elatine triandra
Eleocharis acicularis
Eleocharis palustris agg.
Epilobium angustifolium
Epilobium montanum
Epilobium palustre
Equisetum arvense
Erechtites hieraciifolius
Erigeron acris
Fagus sylvatica
Festuca rubra
Ficaria verna
Filago minima
Fragaria vesca
Frangula alnus
Fraxinus excelsior
Galeopsis species
Galium album
Galium aparine
Galium palustre
Geum urbanum
Glyceria fluitans
Gnaphalium sylvaticum
Gnaphalium uliginosum
Gratiola oficinalis (planted)
Hieracium pilosella
Hieracium sabaudum
Holcus lanatus
Holcus molis
Hypericum humifusum
Hypericum perforatum
Hypochaeris radicata
Chelidonium majus
Jasione montana
Juncus articulatus
Juncus bufonius
Juncus bulbosus

Juncus conglomeratus
Juncus effusus
Juncus filiformis
Juncus squarrosus
Juncus tenuis
Lamium maculatum
Leontodon autumnalis
Leontodon hispidus
Littorella uniflora (planted)
Lotus corniculatus
Luzula campestris
Luzula luzuloides
Luzula multiflora s.lat.
Luzula pilosa
Lycopus europaeus
Lychnis flos cuculi
Lychnis viscaria
Lysimachia numularia
Lysimachia vulgaris
Medicago lupulina
Mentha arvensis
Molinia arundinacea
Molinia caerulea
Myosotis palustris agg.
Oenothera bienis
Orthilia secunda
Peplis portula
Persicaria hydropiper
Persicaria lapatifolia
Phedimus spurius
Phragmites australis
Picea abies
Pimpinela minor
Pinus sylvestris
Plantago lanceolata
Plantago major
Plantago uliginosa
Populus alba
Populus nigra
Populus tremula
Potamogeton natans
Potentila reptans
Potentilla erecta
Prunus avium
Vicia craca
Viola reichenbachiana
Pteridium aquilinum
Pyrus sp.
Quercus robur
Ranunculus flamula
Ranunculus repens
Robinia pseudacacia
Rosa sp.
Rubus fruticosus agg.
Rubus idaeus
Rumex acetosa
Rumex acetosella s.lat.
Sagina procumbens
Salix aurita
Salix aurita x *cinerea*
Salix caprea
Salix cinerea
Salix purpurea
Salix triandra
Sambucus nigra
Scleranthus annus
Scutellaria galericulata
Sedum sexangulare
Senecio fuchsii
Senecio sylvaticus
Senecio viscosus
Schoenoplectus lacustris
Sorbus aucuparia
Spergula morisonii
Spergularia rubra
Spiraea salicifolia (planted)
Symphytum officinale
Tanacetum vulgare
Taraxacum sect. *Ruderalia*
Teesdalia nudicaulis
Trifolium repens
Tussilago farfara
Typha angustifolia
Typha latifolia
Urtica dioica
Utricularia australis
Vaccinium myrtillus
Vaccinium vitis-idaea
Verbascum chaixii ssp. *austriacum*
Veronica officinalis

Appendix 5. Phytosociological relevés.

Table 2. Phytosociological relevés (restoration status: R- dry and mesic reclamation, W-wet reclamation, D- disturbed succession, S- spontaneous succession)

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
E3:	10	30	0	0	3	0	0	0	5	65	0	80	5	0	0	5	50	50	0	0	0	10	70	0	0	50	0	0
E2:	45	4	2	4	17	4	5	5	45	3	20	5	2	3	3	30	5	3	10	3	3	5	5	10	0	5	1	0
E1:	30	6	10	10	12	3	4	15	4	4	10	4	3	40	60	15	4	4	10	10	5	7	5	4	15	3	30	10
E0:	5	5	5	5	5	3	90	10	60	5	40	3	0	2	15	10	3	5	40	50	2	5	2	5	2	10	20	1
Type of restoration	S	R	D	S	S	D	W	W	W	R	S	R	D	D	S	S	R	R	D	D	S	S	S	D	D	R	D	D
Agrostis canina	.	.	.	.	.	.	.	0.1	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	7	0.1
Agrostis capillaris	0.1	0.01	0.1	.	.	.	.	.	0.1	0.1	0.1	.	0.1	.	.	0.1	.	0.1	0.1	0.1	.	0.1	0.1	0.1	1	0.1	0.1	5
Agrostis scabra	.	.	2	.	.	0.1	0.1	0.1	.	.	0.1	.	.	.	0.01	0.1	.	.	.	.	0.1	.	.	.	0.1	.	.	.
Agrostis stolonifera	.	.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.
Alisma plantago-aquatica	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alnus glutinosa	.	.	.	.	.	.	0.1	1	5	5	0.1	2	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	1	.
Alopecurus geniculatus	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anthoxanthum odoratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.
Avenella flexuosa	5	5	.	7	5	.	.	.	.	0.1	.	0.1	0.1	.	.	.	.	0.1	.	.	0.1	0.1	0.1	0.1	0.1	0.1	.	.
Bellis perennis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01
Betula pendula	6	1	.	0.1	1	0.1	.	.	0.1	0.1	2	2	.	.	0.1	2	15	0.1	4	0.1	0.1	.	75	1	0.01	9	0.01	0.01
Bidens frondosus	.	.	0.1	.	.	.	.	0.1	.	.	0.1	.	.	0.1	.	.	.	.	0.01	0.1	.	.	.	.	0.1	.	0.1	.
Calamagrostis epigejos	5	0.01	0.1	.	.	.	0.1	0.1	0.1	.	0.1	.	0.1	.	2	0.1	.	.	1	.	.	.	0.1	1	0.1	0.1	1	0.1
Calamagrostis villosa	.	.	.	.	.	.	.	.	0.1	0.1	.	0.1	.	.	.	0.1	1	.	.	.	.	1	1	.	.	0.1	.	.
Callitriche species	.	.	0.1	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calluna vulgaris	5	.	.	.	.	.	.	.	.	.	0.01	.	.	.	.	1	.	.	0.1	.	0.1	0.1	.	.	.	0.1	.	.
Campanula rapunculoides	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carduus species	.	.	.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex brizoides	0.1	0.1	.	.	.	.	.	.	.	0.1	.	0.1	.	.	.	0.1	2	.	.	.	0.1	.	.	.	.	.	.	.
Carex canescens	.	.	.	.	.	.	0.1	0.1	.	.	.	.	0.1	.	.	.	.	.	.	1	.	.	.	.	0.1	.	0.01	.
Carex leporina	.	.	0.1	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	0.1	.	0.1	.	.	.
Carex nigra	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex pilulifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	0.1	.	.	.	1
Carex species	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.

Cirsium arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	0.01	.	.	.
Cirsium species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.
Conyza canadensis	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	0.1	.	.	.	0.1	.	0.01	0.01	
Cytisus scoparius	.	.	.	0.01	7	0.1	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Deschampsia cespitosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	
Elatine hexandra	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Eleocharis acicularis	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Eleocharis palustris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	
Eleocharis palustris agg.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Epilobium angustifolium	1	.	.	.	0.1	.	.	.	.	0.1	.	.	.	.	.	0.1	.	0.1	0.01	.	0.01	0.1	.	.	.	.	.	.	
Epilobium lamyi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	
Epilobium palustre	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	
Epilobium species	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Erigeron acris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	
Festuca ovina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
Festuca rubra	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	
Filago minima	.	.	0.1	.	.	0.1	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	0.1	.	.	0.1	0.1	.	0.1	0.1	
Frangula alnus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	4	.	.	
Galium palustre	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Geum urbanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	
Glyceria fluitans	.	.	.	.	.	.	.	0.1	.	.	.	.	.	0.1	.	.	.	.	.	2	.	.	.	.	.	.	.	.	
Gnaphalium sylvaticum	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	
Gnaphalium uliginosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01	.	
Hieracium pilosella	.	.	.	.	.	0.1	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	0.1	
Hieracium sabaudum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	
Holcus lanatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	
Hypericum humifusum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	
Hypochaeris radicata	.	.	0.1	2	.	0.1	.	.	0.1	.	0.1	.	.	.	1	0.01	.	.	0.1	.	.	.	.	1	0.1	.	10	3	
Juncus articulatus	.	.	.	.	.	.	.	0.1	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Juncus bufonius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	
Juncus bulbosus	.	.	0.1	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	2	.	.	.	.	1	.	.	.	
Juncus effusus	.	.	1	.	.	.	0.1	0.1	0.1	.	0.1	.	.	0.1	5	0.1	0.01	.	5	1	0.1	.	.	.	10	.	3	.	
Juncus filiformis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	0.01	.	.	
Juncus squarrosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	
Juncus tenuis	.	.	0.1	.	.	0.1	.	0.1	0.1	.	0.1	.	0.1	.	.	0.01	.	.	.	.	.	.	.	0.1	.	.	5	2	

Leontodon autumnalis	.	.	.	.	.	.	.	.	.	.	0.1	.	0.1	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Littorella uniflora	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.
Luzula campestris	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1
Luzula luzuloides	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.
Luzula multiflora s.lat.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.
Luzula pilosa	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.
Lycopus europaeus	.	.	0.1	.	.	0.1	0.1	0.1	.	.	0.1	.	.	0.1	0.1	.	.	.	.	.	.	.	.	.	.	0.1	.	1	.	.	.	.
Molinia caerulea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	0.1	.	.	0.1	.	.	0.1	.	.	.	.	.	.	.	.
Myosotis palustris agg.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peplis portula	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phedimus spurius	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phragmites australis	.	.	0.1	.	.	.	.	.	.	.	.	.	.	35	50	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.
Picea abies	1	0.01	.	.	.	.	.	.	0.1	.	0.1	0.1	.	.	0.01	1	5	0.1	1	.	.	.	.	.	.	2	.	.	.	.	.	.
Pinus sylvestris	47	30	0.1	2	10	1	.	.	5	60	10	80	5	0.1	0.1	30	35	35	2	0.1	0.1	10	.	5	0.1	40	0.01	0.01	.	.	.
Plantago lanceolata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01
Plantago major	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	0.1	.	0.1
Polytrichum species	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Populus tremula	.	0.1	0.01	.	1	0.1	0.1	0.1	0.1	0.1	1	.	.	.	.	.	2	.	0.1	.	.	2	.	.	.	1	.	.	.	.	.	.
Potamogeton natans	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentila norvegica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.
Potentilla erecta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01
Pteridium aquilinum	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	0.1	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.
Quercus robur	1	1	.	.	.	.	.	.	.	.	.	1	.	.	0.01	.	0.1	0.1	.	.	.	1	0.1	.	.	5	.	.	.	.	.	.
Ranunculus flamula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.
Ranunculus repens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.
Robinia pseudacacia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubus fruticosus agg.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	5	1	.	.	.	.	.	.	.	.
Rubus idaeus	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubus species	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rumex acetosa	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rumex acetosella s.lat.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	0.1	.	.	.	.	.	.	.
Salix caprea	.	.	0.1	.	5	.	.	.	.	.	.	.	.	.	1	2	.	.	5	1	0.1	2	.	5	.	2	.	.	.	.	.	.
Salix cinerea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	0.1	.
Salix species	.	.	0.1	0.1	.	0.1	5	2	40	0.1	5	.	.	1	.	.	.	.	0.1	.	.	.	.	0.01	.	.	.	.	.	.	.	.
Sedum sexangulare	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Senecio sylvaticus	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio viscosus	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.
Sorbus aucuparia	.	0.1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Spergularia rubra	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1
Sphagnum species	.	.	.	.	.	.	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tanacetum vulgare	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Taraxacum sect. Ruderalia	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.01
Trifolium repens	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tussilago farfara	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	0.01	.	.	.	.	.	0.01	.	.	.	.	.	0.01	.			
Typha latifolia	.	.	2	.	.	.	.	1	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.			
Vaccinium myrtillus	8	0.1	.	0.1	0.1	.	.	.	.	.	0.1	0.1	.	.	.	5	0.1	0.1	0.1	.	0.1	0.1	2	.	.	.	.	.			
Vaccinium vitis-idaea	1	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.			
Verbascum chaixii ssp. austriacum	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Veronica officinalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1			
Viola reichenbachiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.			
Viola species	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.			

Appendix 4. List of animals

Table 3. List of animals found in the CEP II sand pit.

Spiders (Araneae)

Dysderidae
Harpactea lepida

Theridiidae
Robertus lividus

Linyphiidae
Abacoproeces saltuum
Erigone atra
Erigone dentipalpis
Gongylidiellum vivum
Neriene clathrata
Oedothorax apicatus
Oedothorax fuscus
Tallusia experta
Walckenaeria alticeps
Walckenaeria antica
Walckenaeria atrotibialis
Walckenaeria mitrata

Tetragnathidae
Pachygnatha degeeri
Pachygnatha listeri

Araneidae
Gibbaranea bituberculata
Hypsosinga pygmaea
Mangora acalypha

Lycosidae
Alopecosa pulverulenta
Arctosa cinerea
Arctosa leopardus
Aulonia albimana
Pardosa alacris
Pardosa amentata
Pardosa lugubris
Pardosa palustris
Pardosa prativaga
Pardosa pullata
Pirata hygrophilus
Pirata tenuitarsis
Piratula latitans
Trochosa ruricola
Trochosa terricola
Xerolycosa miniata

Pisauridae
Dolomedes fimbriatus
Pisaura mirabilis

Oxyopidae
Oxyopes ramosus

Zoridae
Zora spinimana

Agelenidae
Histopona torpida
Inermocoelotes inermis
Malthonica campestris

Hahniidae
Hahnia nava

Amaurobiidae
Amaurobius fenestralis

Miturgidae
Cheiracanthium erraticum

Liocranidae
Agroeca brunnea

Clubionidae
Clubiona comta
Clubiona frutetorum
Clubiona juvenis
Clubiona lutescens
Clubiona subsultans
Clubiona terrestris

Corinnidae
Phrurolithus festivus

Zodariidae

Zodarion germanicum

Gnaphosidae
Drassodes pubescens
Drassyllus lutetianus
Gnaphosa montana
Haplodrassus silvestris
Haplodrassus soerenseni
Micaria fulgens
Micaria pulicaria
Micaria silesiaca
Zelotes apricorum
Zelotes clivicola
Zelotes petrensis

Sparassidae
Micrommata virescens

Philodromidae
Philodromus collinus
Tibellus oblongus

Thomisidae
Ozyptila atomaria
Xysticus kochi
Xysticus ulmi

Salticidae
Aelurillus v-insignitus
Evarcha arcuata
Evarcha falcata
Heliophanus flavipes
Phlegra fasciata
Salticus scenicus
Sitticus caricis
Sitticus floricola
Sitticus saltator
Talavera petrensis

Dragonflies (Odonata)

Aeshna grandis
Anax imperator
Calopteryx virgo
Coenagrion hastulatum
Coenagrion puella
Cordulia aenea
Enallagma cyathigerum
Ischnura elegans
Ischnura pumilio
Lestes sponsa
Leucorrhinia pectoralis
Libellula quadrimaculata
Platycnemis pennipes
Sympetrum danae
Sympetrum sanguineum
Sympetrum striolatum
Sympetrum vulgatum

Cockroaches (Blattodea)

Ectobius lapponicus
Ectobius sylvestris

Grasshoppers, crickets and katydids (Orthoptera)

Acrididae
Chorthippus biguttulus
Chorthipus brunneus
Chorthippus paralellus
Chorthippus vagans
Euthystira brachyptera
Myrmeleotettix maculatus

Gryllotalpidae
Gryllotalpa gryllotalpa

Tetrigidae
Tetrix bipunctata
Tetrix subulata
Tetrix tenuicornis
Tetrix undulata

Tettigoniidae
Tettigonia cf. viridissima

Earwigs (Dermaptera)
Forficula auricularia

Megaloptera
Sialis cf. *lutaria*

Snakeflies (Raphidioptera)

Raphidia notata

Net-winged insects (Neuroptera)

Chrysopa commata
Chrysopa perla
Chrysoperla carnea
Myrmeleon formicarius

Scorpion flies (Mecoptera)

Boreus hyemalis
Panorpa communis
Panorpa germanica

Butterflies and moths (Lepidoptera)

Pieridae
Anthocharis cardamines
Gonepteryx rhamni
Pieris rapae
Pieris napi

Nymphalidae
Aglais urticae
Araschnia levana
Inachis io
Limenitis populi
Polygonia c-album
Vanessa atalanta
Vanessa cardui

Lycaenidae
Callophrys rubi
Polyommatus icarus

Satyridae
Aphantopus hyperanthus
Maniola jurtina

Hesperiidae
Thymelicus lineola

Lasiocampidae
Lasiocampa trifolii

Lymantriidae
Euproctis similis

Notodontidae
Furcula furcula

Arctiidae
Arctia caja

True flies, mosquitoes and gnats (Diptera)

Tipulidae
Nephrotoma scurra

Limoniidae
Molophilus ater

Bibionidae
Dilophus febrilis

Keroplatidae
Antlemon brevimanum

Rhagionidae
Rhagio lineola
Rhagio scolopaceus

Bombyliidae
Anthrax varius

Tabanidae
Hybomitra micans
Tabanus mikii

Stratiomyidae
Chloromyia formosa

Dolichopodidae

Neurigona quadrifasciata
Sciapus sp.
Xanthochlorus ornatus

Syrphidae
Chrysotoxum arcuatum
Chrysotoxum bicinctum
Episyrphus balteatus
Eupeodes corollae
Helophilus pendulus
Helophilus trivittatus
Microdon analis
Scaeva pyrastri
Volucella pellucens

Lauxaniidae
Lauxania cylindricornis

Platystomatidae
Rivellia syngenesiae

Dryomyzidae
Dryomyza flaveola
Neuroctena anilis

Sciomyzidae
Pherbina coryleti

Drosophilidae
Drosophila kuntzei
Drosophila transversa
Scaptomyza pallida

Scathophagidae
Americina medium

Muscidae
Mesembrina meridiana
Phaonia pallida

Hippoboscidae
Lipoptena fortisetosa

Therevidae
Thereva microcephala
Thereva sp.

Asilidae
Dioctria hyalipennis
Lasiopogon cinctus
Neoitamus socius
Neomochtherus pallipes
Rhadinus variabilis

Sarcophagidae
Macronychia sp.
Metopia argyrocephala
Metopia staegerii
Sarcophaga carnaria
Sarcophaga similis
Sarcophaga variegata
Senotainia conica
Taxigramma hilarella

Asteiidae
Asteia amoena

Psilidae
Loxocera aristata

Bees and wasps (Hymenoptera: Aculeata)
Ampulicidae
Dolichurus corniculus

Andrenidae
Andrena carantonica
Andrena flavipes
Andrena haemorrhoa
Andrena helvola
Andrena nigroaenea
Andrena nitida
Andrena praecox
Andrena vaga

Apidae
Apis mellifera
Bombus jonellus
Bombus lapidarius
Bombus pascuorum
Bombus sylvestris
Bombus terrestris
Nomada fabriciana
Nomada flava
Nomada flavoguttata

Nomada fucata
Nomada lathburiana
Nomada leucophthalma
Nomada rufipes

Colletidae
Colletes cunicularius

Crabronidae
Alysson spinosus
Bembecinus tridens
Cerceris arenaria
Crabro scutellatus
Diodontus minutus
Gorytes laticinctus
Nysson maculosus
Nysson niger
Oxybelus argentatus
Oxybelus bipunctatus
Oxybelus trispinosus
Passaloecus singularis
Philanthus triangulum
Tachysphex obscuripennis
Tachysphex pompiliformis
Trypoxylon minus

Halictidae
Halictus sexcinctus
Halictus tumulorum
Lasioglossum aeratum
Lasioglossum leucozonium
Lasioglossum lucidulum
Lasioglossum malachurum
Lasioglossum morio
Lasioglossum pauxillum
Lasioglossum punctatissimum
Lasioglossum rufitarse
Lasioglossum villosulum
Lasioglossum zonulum
Sphecodes longulus

Chrysididae
Cleptes pallipes
Hedychrum nobile
Trichrysis cyanea

Megachilidae
Stelis minuta

Melittidae
Melitta nigricans

Pompilidae
Anoplius concinnus
Anoplius infuscatus
Anoplius viaticus
Arachnospila anceps
Arachnospila minutula
Arachnospila spissa
Arachnospila trivialis
Episyron rufipes
Evagetes pectinipes
Pompilus cinereus
Priocnemis hyalinata
Priocnemis perturbator
Priocnemis pusilla

Sphecidae
Ammophila sabulosa

Vespidae
Vespa crabro
Vespula rufa
Vespula vulgaris

Beetles (Coleoptera)
Carabidae
Abax parallelepipedus
Abax parallelus
Acupalpus brunnipes
Acupalpus flavicollis
Acupalpus meridianus
Acupalpus parvulus
Agonum fuliginosum
Agonum gracile
Agonum muelleri
Agonmj versutum
Agonum viduum
Amara aenea
Amara communis
Amara fulva
Amara plebeja
Amara tibialis
Bembidion articulatum
Bembidion bruxellense

Bembidion dentellum
Bembidion femoratum
Bembidion illigeri
Bembidion lampros
Bembidion modestum
Bembidion punctulatum
Bembidion quadrimaculatum
Bembidion testaceum
Bembidion tetracolum
Bembidion varium
Calathus erratus
Calathus micropterus
Carabus arcensis
Carabus auronitens
Carabus hortensis
Carabus nemoralis
Carabus violaceus
Cicindela campestris
Cicindela hybrida
Cicindela sylvicola
Cychrus caraboides
Demetrias monostigma
Dyschirius globosus
Dyschirius politus
Harpalus autumnalis
Harpalus luteicornis
Harpalus rufipalpis
Harpalus rufipes
Harpalus tardus
Harpalus luteicornis
Leistus ferrugineus
Lionychus quadrillum
Loricera pilicornis
Nebria brevicollis
Nebria livida
Notiophilus palustris
Omophron limbatum
Oodes helopioides
Oxypselaphus obscurus
Paranchus albipes
Platynus assimilis
Poecilus lepidus
Pteristichus aethiops
Pterostichus diligens
Pterostichus minor
Pterostichus niger
Pterostichus oblongopunctatus
Pterostichus strenuus
Stenolophus mixtur
Stenolophus teutonus
Syntomus foveauts
Tachyta nana
Tachyura quadrisignata
Tachyura parvula

Haliplidae
Haliplus flavicollis

Dytiscidae
Agabus sturmii
Ilybius fuliginosus
Ilybius guttiger

Hydrophilidae
Anacaena lutescens
Helochares obscurus
Hydrobius fuscipes

Silphidae
Nicrophorus humator
Nicrophorus interruptus
Nicrophorus vespilloides
Oeceoptoma thoracica
Phosphuga atrata

Geotrupidae
Anoplotrupes stercorosus
Trypocopris vernalis

Scarabaeidae
Aphodius prodromus
Melolontha hippocastani
Ontophagus ovatus
Oxythyrea funesta
Phylloperta horticola

Byrrhidae
Byrrhus fasciatus
Morychus aeneus

Dryopidae
Dryops luridus

Buprestidae
Anthaxia godeti
Anthaxia chevrieri

Anthaxia helvetica
Anthaxia similis
Anthaxia quadripunctata
Buprestis octoguttata
Buprestis rustica
Trachys minutus

Elateridae
Actenicerus siaelandicus
Agriotes lineatus
Agriotes obscurus
Agrypnus murinus
Ampedus balteatus
Athous subfuscus
Athous zebei
Cardiophorus nigerrimus
Cardiophorus ruficollis
Pheletes aeneoniger
Sericus brunneus

Dasytidae
Dolichosoma lineare

Coccinelidae
Adalia bipunctata
Coccinela quinquepunctata
Coccinela septempunctata
Exochomus quadripustulatus
Harmonia axyridis
Hyperaspis campestris
Propylea quatuordecimpunctata
Scymnus frontalis
Scymnus nigrinus

Oedemeridae
Chrysanthia cf. geniculata

Anthicidae
Notoxus monoceros

Meloidae
Meloe violaceus

Tenebrionidae
Melanimon tibiale
Prionychus melanarius

Cerambycidae
Corymbia rubra
Gaurotes virginea
Oberea oculata
Pogonocherus fasciculatus
Rhagium bifasciatum
Rutpela maculata
Spondylis buprestoides
Stenurella melanura

Chrysomelidae
Agelastica alni
Altica sp.
Bromius obscurus
Calomicrus pinicola
Cassida rubiginosa
Chrysolina fastuosa
Chrysolina polita
Clytra laeviscula
Crepidodera aurata
Cryptocephalus bipunctatus
Cryptocephalus hypochoeridis
Cryptocephalus moraei
Cryptocephalus ocellatus
Donacia bicolor
Donacia versicolorea
Donacia sp.
Donaciella cinerea
Galeruca tanaceti
Gastrophysa polygoni
Linaeidea aenea
Lochmaea capreae
Neocrepidodera transversa
Oulema gallaeciana
Oulema melanopus
Phratora laticollis
Phratora vitellinae
Phyllotreta nigripes
Phyllotreta vittula

Curculionoidea
Acalyptus carpini
Anthonomus phyllocola
Bagous tubulus
Brachonyx pineti
Brachyderes incanus
Catapion seniculus
Ceutorhynchus obstrictus
Curculio rubidus

Datonychus arquata
Dorytomus dejeani
Ellescus scanicus
Hylobius abietis
Ischnopterapion virens
Otiorhynchus ovatus
Pachyrhinus mustela
Phyllobius arborator
Pissodes castaneus
Pissodes pini
Polydrusus cervinus
Polydrusus pallidus
Protapion apricans
Protapion fulvipes
Rhinoncus bruchoides
Rhyncolus ater
Sitona lineatus
Sitona striatelus
Sitona sulcifrons
Strophosoma capitatum
Tachyerges pseudostigma
Temnocerus nanus

Trogossitidae
Ostoma ferruginea

Lagriidae
Lagria hirta

Melandryidae
Orchesia ustulata

Amphibians (Amphibia)
Bufo bufo
Lissotriton vulgaris
Mesotriton alpestris
Rana dalmatina
Rana esculenta synkl.
Rana temporaria

Reptiles (Reptilia)

Lacerta agilis
Lacerta vivipara
Natrix natrix
Vipera berus

Birds (Aves)

Anseriformes
Anas platyrhynchos
Aythya ferina
Aythya fuligula

Ciconiiformes
*Ardea cinere*a

Accipitriformes
Buteo buteo

Charadriiformes
Charadrius dubius

Columbiformes
Streptopelia turtur

Passeriformes
Carduelis flammea
Corvus frugilegus
Corvus corax
Corvus corone cornix
Erithacus rubecula
Fringilla coelebs
Garrulus glandarius
Hirundo rustica
Miliaria calandra
Motacilla alba
Parus caeruleus
Parus major
Phoenicurus ochruros
Phylloscopus collybita
Riparia riparia
Sylvia atricapilla
Turdus merula
Turdus philomelos

Mammals (Mammalia)
Apodemus sp.
Capreolus capreolus
Crocidura sp.
Lepus europaeus
Sus scrofa

Appendix 5. List of arthropods.

Table 4. List of arthropods in sampled sites (restoration status: R- dry and mesic reclamation, W-wet reclamation, D- disturbed succession, S- spontaneous succession). Numbers of individuals are shown.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Restoration status	S	R	S	R	W	W	W	W	W	R	S	D	D	S	R	R	D	D	S	S	D	S	D
Coelotes inermis																3		0			1		
Histopona torpida															1			0		3			
Malthonica campestris			1					1					1	4				0			1	1	
Amaurobius fenestralis																		0				1	
Gibbaranea bituberculata							1				1							0					
Hypsosinga pygmaea											1							0					
Mangora acalypha																		0			1		
Clubiona comta				2														0					
Clubiona juvenis			1															0					
Clubiona lutescens										1								0					
Clubiona subsultans												1				1		0					
Clubiona terrestris															1			0					
Phrurolithus festivus										1								0					
Harpactea lepida										1								0					
Drassodes pubescens	1				6	1	1											0					
Drassylus lutetianus					2													0					
Gnaphosa montana			1															0					
Haplodrassus silvestris																1		0		2			
Haplodrassus soerenseni																		0		1			
Micaria fulgens								1										0					
Micaria pulicaria							1	1										0					
Micaria silesiaca											1			1				0					
Zelotes apricorum																1		0					
Zelotes petrensis	2		1								1							1					
Hahnia nava														1				0					
Abacoproeces saltuum										1								0					
Erigone atra												2					1	0					
Erigone dentipalpis												1						0					
Gongylidiellum vivum											1	1						0					
Neriene clathrata															1			0		1			
Oedothorax apicatus																	2	0					
Oedothorax fuscus						1												0					
Tallusia experta					3			3	1									0					
Walckenaeria alticeps			1			1			1		1							0					
Walckenaeria antica			1															0					
Walckenaeria atrotibialis			0			1												0					
Walckenaeria mitrata			0															0				1	
Agroeca brunnea		3	0			4				4						1		0				4	
Alopecosa pulverulenta			0		2			2	1									0	1				
Arctosa cinerea			0								1							0					
Arctosa leopardus			0		1			2				2					9	0					
Aulonia albimana			0		1													1					
Pardosa alacris		1	0			8	1		1									0	2				
Pardosa amentata			0		1							1						0					1
Pardosa lugubris		18	1			127	1	1	21	34					3	3		0		2		2	
Pardosa palustris			0								1	2						0					
Pardosa prativaga			0		14	32	30	35	12	1		4		1			1	0					
Pardosa pullata			0		7	1	9	16	2	2	3	1		2		1		0	1				

Pirata hygrophilus			0		1			1					2				0						
Pirata tenuitarsis			0		1			3			1					5	0						
Piratula latitans	1		0		26	2	3	3	3	2	3			4			1	0					
Trochosa ruricola	7		0		4	4	2	7	3	3	3	3		1			5	0				1	1
Trochosa terricola	9		3	3	2		1	1	1			1	4	2	1	4	3	2	3	2	2	5	
Xerolycosa miniata	2		2			1				2		11	4	5		2	31	21			2	9	8
Cheiracanthium erraticum			0			1												0					
Oxyopes ramosus			0						1								1	0					
Philodromus collinus			0									1						0					
Tibellus oblongus	1		0														1	1			1		
Dolomedes fimbriatus			0															1					
Pisaura mirabilis			0						1		1							0			1		1
Aelurillus v-insignitus	1		0										1					1			1		
Evarcha arcuata			0		2						2						3	2					2
Evarcha falcata			0	1														0					
Heliophanus flavipes			0									1						0					
Phlegra fasciata	1		0															0					
Salticus scenicus			0														1	0					1
Sitticus caricis			0						1									0					
Sitticus floricola			0									1						0					
Sitticus saltator			1															0					
Talavera petrensis			0									2		1				0	1				
Micrommata virescens			0															1					
Pachygnatha degeeri	1		0								1				1		3	0					
Pachygnatha listeri			0		1	4	1	1		2		2					1	0					
Robertus lividus			0	1														0					
Ozyptila atomaria			1															0					
Xysticus ulmi			0				1			1		1						0	1				
Zodarion germanicum	1		1			1					2	1		2				0					
Zora spinimana	2	1	0		2	2	2	3	5	3	2		1	1			1	0					
Ectobius lapponicus		1	0						1									0					
Ectobius sylvestris			0	1					1									0	1				
Notoxus monoceros			0															0			4		2
Anthaxia chevrieri			4		1		1				1		1					0					
Anthaxia godeti			1										5					0			1		1
Anthaxia helvetica	2		3										8	1				1			1		2
Anthaxia quadripunctata	1		2										8	1				2			3		2
Anthaxia similis			1															0					
Buprestis octoguttata			1															0					
Trachys minutus			0														1	0					
Byrrhus fasciatus			0										1					0					1
Morychus aeneus	43		2									1					6	14					
Abax parallelepipedus			0					1							1			1					
Abax parallelus			0													1	1	0					
Acupalpus brunnipes			0														2	0					3
Acupalpus flavicollis			0														1	0					1
Agonum fuliginosum			0			1	1		1						2	2		0					
Agonum muelleri			0			1												0					
Agonum viduum			0						1									0					
Amara aenea			0			1											1	0					1
Amara communis			0															0		1			
Amara fulva			0										1					0			1		
Amara plebeja			0															0				1	
Amara tibialis			0				1										1	1					

Bembidion bruxellense			0		1												0							1
Bembidion femoratum			0													1	0							
Bembidion illigeri			0								1						0							
Bembidion lampros			0			1											0							
Bembidion quadrimaculatum			1														0							
Calathus erratus	4		34						1	1		10	9		3		21							4
Calathus micropterus	1		3	5				1		2	1				1		32	1						
Carabus arcensis			1	1				1										0						
Carabus auronitens			0	2						1					3			0						
Carabus hortensis			0	5			1		1						1			0					2	
Carabus nemoralis		1	0	2			1			2								0	1	1				
Carabus violaceus			0	1	1				1					1				0	1					
Cicindela hybrida			1										2				1	0					2	3
Cychrus caraboides		3	0		1										3			0						
Demetrias monostigma			0					1										0						
Dyschirius globosus	3	1	2	2		1	1	1		1				1			1	0						2
Harpalus autumnalis			0															0						1
Harpalus rufipalpis			0										1					0						
Harpalus rufipes			1															0						
Leistus ferrugineus		2	0															0						
Lionychus quadrillum	1		0															0						4
Loricera pilicornis			0		1	1				1								0						
Nebria brevicollis			0			2				1		2						0						
Notiophilus palustris			0			1												0						
Oodes helopioides			0				1	1		1								0						
Oxypselaphus obscurus		1	0			7												0						
Platynus assimilis			0								1							1						1
Poecilus lepidus			1															0						
Pterostichus aethiops			0															1						
Pterostichus diligens			0			2			2								1	0						
Pterostichus minor			0			3					1							0						
Pterostichus niger		8	1	13	2	2	4	3	5	5	2		1	10	20	1	1	0			1			
Pterostichus oblongopunctatus		1	0	3		2				1								0	1			1		
Pterostichus strenuus			0			1												0						
Stenolophus mixtus			0														4	0						
Syntomus foveatus			1															3			1			
Tachyura parvula			0															0						1
Pogonocherus fasciculatus		1	0															0						
Pogonocherus fasciculatus			0												1			0						
Stenurella melanura			0															0			1			
Agelastica alni			0			4	3	1	1		4						1	1						
Chrysolina fastuosa			0															0						1
Chrysolina polita			0			2												0						
Clytra laeviscula			0															1						
Cryptocephalus bipunctatus			0															1						1
Cryptocephalus ocellatus			0															0						1
Galeruca tanaceti			0															0						1
Linaeidea aenea			0			1	1											1						
Lochmaea capreae			0		9		3	2	20									0						1
Oulema melanopus			0														1	0						
Adalia bipunctata			0								1	2		1			2	1						2
Coccinela septempunctata	1		0					1			1							1						

Coccinella quinquepunctata			0															0					1
Exochomus quadripustulatus			0															1					
Gastrophysa polygoni			0									1						0					
Harmonia axyridis			1		1						1	1						0					1
Hyperaspis campestris			0										2					1					
Propylea quatuordecimpunctata			0															0			1		
Scymnus frontalis			0															1					
Scymnus nigrinus			0										1					0					
Acalyptus carpini			0															0					1
Anthonomus phyllocola			0	1									1					0					
Bagous tubulus			0														1	0					
Brachonyx pineti			0										1					0					
Brachyderes incanus			1										2			2	1	0					
Catapion seniculus		1	0															0					
Curculio rubidus			0														1	0					
Datonychus arquata			0			1												0					
Dorytomus dejeani			0															0		1			
Ellescus scanicus			0															0	1				
Hylobius abietis			0							1						2		27			1	2	
Ischnopterapion virens			0									1						0					
Otiorhynchus ovatus			0								1							0					
Phyllobius arborator			0												1			0					
Pissodes castaneus			0								1							0					
Pissodes pini			0	1														0			1		
Polydrusus cervinus			0															0					1
Polydrusus pallidus		1	0										1					0					
Protapion apricans			0							1		1						0					
Protapion fulvipes			0														1	0					
Rhinoncus bruchoides			0															0					1
Rhyncolus ater			0															0		2			
Sitona lineatus			0															1					
Sitona striatelus	1	1	1								1						1	2					
Sitona sulcifrons			0									1					1	0					
Strophosoma capitatum		3	2	1											1	1	1	0	2			2	1
Tachyerges pseudostigma			0									1						0					
Temnocerus nanus			0						1									0					
Dolichosoma lineare			1															0					1
Agriotes lineatus			0					1										0					1
Agriotes obscurus			0															0	1				
Agrypnus murinus			0														1	0					
Anoplotrupes stercorosus			3	15										1				0	1				
Trypocopris vernalis	12		1	3		1			1									0					
Orchesia undulata			0				1											0					
Chrysanthia cf. geniculata	1		0															0					
Anoplotrupes stercorosus			0	2														0					
Aphodius prodromus			0										1					0					
Ontophagus ovatus			0															0			2		
Phyllopertha horticola	1		0										1					0			1		1
Nicrophorus humator			0	1														0					
Nicrophorus interruptus		1	0	1														0					
Nicrophorus vespilloides	1	16	1	7			1											0	3				
Oiceoptoma thoracica			0	1														0					
Oiceptoma thoracica		7	0															0					

Phosphuga atrata	1	1	0	1												0	1	1				
Melanimon tibiale	2		0													1						
Lagria hirtaLagriidae	1	3	1	1			1				1					0	1	2				1
Forficula auricularia			0													0					1	
Dioctria hyalipennis	1		0						1							0						1
Lasiopogon cinctus	1		0													0						
Neoitamus socius			0										1			1						
Neomochtherus pallipes			0								1					0						
Rhadinus variabilis			0												1	0						
Asteia amoena			0				7									0						
Dilophus febrilis			0			1						1			1	0			3			
Anthrax varius			0									1				0						
Neurigona quadrifasciata	1		0	1											1	0						
Sciapus sp.			0													0						1
Xanthochlorus ornatus			0	1												0						
Drosophila kuntzei			0	2												0						
Drosophila transversa			0					1								0						
Scaptomyza pallida			0				2									0						
Dryomyza flaveola			0													0		2				
Neuroctena anilis			0	6												1						
Lipoptena fortisetosa			0		1											0						
Antlemon brevimanum			0													0			1			
Lauxania cylindricornis			0				1									0	1		1			1
Molophilus ater			0						2							0						
Mesembrina meridiana	1		0													0						
Phaonia pallida			0	1												1						
Rivellia syngenesiae			0													1						
Loxocera aristata			0													0						1
Rhagio lineola			0													1						
Rhagio scolopaceus			0					1								0						
Macronychia sp.			0													0						1
Metopia argyrocephala			0													0	1					
Metopia staegerii			1													0						
Sarcophaga carnaria			0								1					0			1			
Sarcophaga similis			0								1					0						
Sarcophaga variegata			0													0		1				
Senotainia conica			1												1	0			3			2
Taxigramma hilarella			0													0						1
Americina medium			0					1								1						
Pherbina coryleti			0													0						1
Chloromyia formosa			0				1									0			1			
Chrysotoxum arcuatum			0									1				0						
Chrysotoxum bicinctum			0													0			1			
Episyrphus balteatus			0	1	1						1				2	0						1
Eristalis tenax			0									1				0						
Eupeodes corolae			0		1										2	0			1			2
Helophilus pendulus			1													0						
Helophilus trivittatus			0												1	0			1			
Microdon analis			0					1								0						
Scaeva pyrastri			0												2	0						1
Volucella pellucens			0										1			0						
Thereva microcephala			0				1	2								0						
Thereva sp.			0													0			1			
Dolichurus corniculus			0													0			1			

Andrena carantonica		0											0			1			
Andrena haemorrhoa		0											0			1			
Andrena helvola		0											1						
Andrena nigroaenea		0						1	1				0			1			
Andrena nitida		0											0			1			
Andrena praecox		0											0			1			
Andrena vaga		0											0			1			
Apis mellifera		0										1	1						
Bombus jonellus		0					1					1	0			3		1	
Bombus lapidarius		0				1							0						
Bombus pascuorum		0											0					1	
Bombus sylvestris		0								1			0						
Bombus terrestris		0	1										1		1	1			
Nomada fabriciana		0		1									0						
Nomada flavoguttata		1											0						
Nomada fucata		0										1	0						
Nomada lathburiana		1											0						
Nomada rufipes		1											0						
Cleptes pallipes		0											0		1				
Hedychrum nobile		0							3				0			2			
Trichrysis cyanea		0											0					1	
Alysson spinosus		0						1					0						
Bembecinus tridens		0											0					1	
Cerceris arenaria		0							5				0			2			
Crabro scutellatus		0			2				1			1	0						
Diodontus minutus		0											0					1	
Gorytes laticinctus		0											1						
Nysson maculosus		0							3				2						
Nysson niger		0							1				1						
Oxybelus argentatus		0							4				0			1		1	
Oxybelus bipunctatus		0										1	0						
Oxybelus trispinosus		0											0			1			
Passaloecus singularis	1	0											0						
Philanthus triangulum		0											0			3			
Tachysphex obscuripennis	1	0					2		4			1	1			16		1	
Tachysphex pompiliformis		0										1	1						
Trypoxylon minus	1	0	1						2	3			1						
Halictus sexcinctus		0											0			2			
Halictus tumulorum		0											0	1					
Lasioglossum aeratum		1											0						
Lasioglossum leucozonium		0						1				2	0					1	
Lasioglossum lucidulum		0											0					2	
Lasioglossum malachurum		0							1				1						
Lasioglossum morio		0											0			2			
Lasioglossum punctatissimum		0							1				0					1	
Lasioglossum rufitarse		0							1				0						
Lasioglossum zonulum		0										1	0						
Sphecodes longulus		1											0						
Stelis minuta		0							1				0						
Melitta nigricans		1											0						
Anoplius concinnus	3	0					3					1	0						
Anoplius infuscatus	4	0					5	2		3		1	1					1	

Anoplius viaticus			2									2				0			1			
Arachnospila anceps			0									1				1						
Arachnospila minutula			1												1	0	1					
Arachnospila trivialis			1													0						
Arachnospilla spissa			0												1	0						
Episyron rufipes			0												2	0						
Evagetes pectinipes			0												1	0						
Pompilus cinereus			0						1			1				0			1		2	
Priocnemis hyalinata			0													1						
Priocnemis perturbator	1		0	1		1						1		1	1	1			1		1	
Priocnemis pusilla			0													1			1			
Ammophila sabulosa			1									3				0			5			
Vespula rufa			0							1					1	0						
Vespula vulgaris			0		1											0					1	
Boreus hyemalis			1													0						
Panorpa communis	1	1	1	2												0		1				
Panorpa germanica			1	1												0						
Sialis cf. lutaria			0							1					1	0						
Chrysopa commata			0													0			1			
Chrysopa perla			0						1							0						
Chrysoperla carnea			0	1			1	1								0			2		1	
Chorthippus biguttulus	2		0							3		2				0			2		2	
Chorthippus brunneus			0							4						0			1			
Chorthippus parallelus			0						1							0						
Chorthippus vagans			0									1				0			2		1	
Euthystira brachyptera			0									1			2	0					1	
Myrmeleotettix maculatus			0						4	3		4			2	0						
Gryllotalpa gryllotalpa			0						1	1				1	1	0						
Tetrix bipunctata	2		0													0						
Tetrix subulata			0				2								3	0					1	
Tetrix tenuicornis			1						2							1						
Tetrix undulata			1				1	1	1	2		6			59	3					7	
Tettigonia cf. viridissima			0													0					1	
Raphidia notata			0													1						

Appendix 6. List of red listed species

Table 5. List of red listed in the CEP II sand pit.
Red list categories (plants): C1 – critically endangered, C2 – endangered, C3 – vulnerable, C4a – lower risk
Red list categories (fungi, animals): CR – critically endangered, EN – endangered, VU – vulnerable, NT – near threatened, LC – least concern (only vertebrates)

Plants:
Antennaria dioica C2
Armeria vulgaris C4a
Centaurium erythraea C4a
Elatine triandra C2
Epilobium palustre C4a
Filago minima C3
Hypericum humifusum C3
Hypochoeris glabra C1
Schoenoplectus lacustris C4a
Spergula morisonii C4a
Teesdalia nudicaulis C2
Verbascum chaixii subsp. *austriacum* C4a

Fungi:
Leccinum holopus NT
Diplomitoporus flavescens EN

Spiders:
Arctosa cinerea EN
Clubiona juvenis EN
Micaria silesiaca EN
Sitticus saltator EN

Dragonflies:
Coenagrion hastulatum NT
Ischnura pumilio NT
Leucorrhinia pectoralis VU
Sympetrum striolatum NT

Diptera:
Rhadinus variabilis CR

Aculeate Hymenoptera:
Bembecinus tridens VU
Cerceris arenaria VU
Crabro scutellatus EN
Nysson maculosus VU
Nysson niger EN
Oxybellus argentatus EN
Tachysphex obscuripennis VU
Halictus sexcinctus VU
Lasioglossum aeratum VU
Sphecodes longulus VU
Hedychrum nobile VU
Stelis minuta VU
Melitta nigricans VU
Episyron rufipes VU
Pompilus cinereus VU

Beetles:
Acupalpus brunnipes VU
Bembidion modestum VU
Bembidion testaceum EN
Nebria livida NT
Meloe violaceus VU
Morychus aeneus NT
Cardiophorus nigerrimus NT
Anthaxia chevrieri VU
Buprestis octoguttata VU
Donacia versicolorea EN
Donaciella cinerea EN
Datonychus arquata NT

Amphibians:
Bufo bufo NT
Lissotriton vulgaris NT
Mesotriton alpestris NT
Rana dalmatina NT
Rana esculenta synkl. NT/VU
Rana temporaria NT

Reptiles:
Lacerta agilis NT
Lacerta vivipara NT
Natrix natrix LC
Vipera berus VU

Birds:
Ardea cinerea NT
Carduelis flammea NT
Charadrias dubius VU
Corvus frugilegus VU
Corvus corax VU
Corvus corone cornix NT
Hirundo rustica LC

Appendix 7. Results

Table 6. Summary data for the restored sites within the sand pits included in the study (vascular plants): age (time since site abandonment), water table depth, total number of species, number of target species, number of red listed species, proportion of woodland, wetland, ruderal and alien species.

	Spontaneous succession	Dry reclamation	Wet reclamation
Age	2 - 30	14 -21	14
Water table depth	0.3 - 15	1 - 6	0 - 1
Total number of species	175	55	44
Number of target species	44	10	6
Number of red listed species	12	2	2
Number of grassland species	81	21	11
Number of woodland species	42	19	23
Number of wetland species	22	6	2
Number of ruderal species	25	8	7
Number of alien species	19	4	4

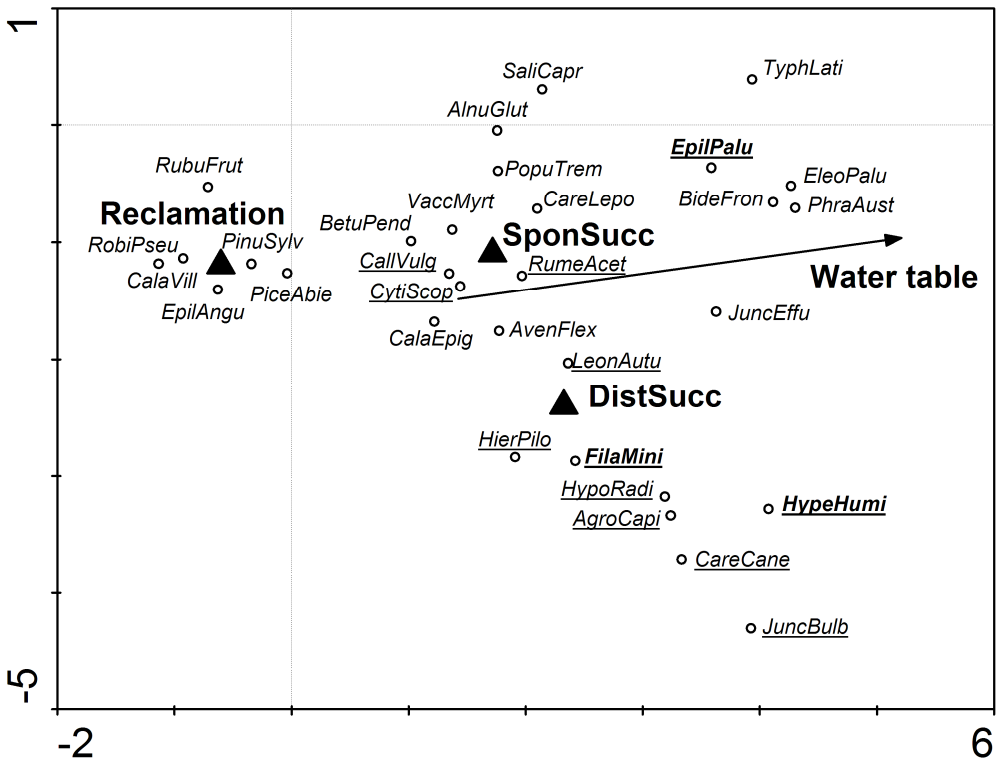


Fig. 4. Unconstrained ordination (DCA) of species and significant environmental factors (vascular plants, P<0.05). The restoration status (Reclamation, SponSucc- spontaneous succession and DistSucc-disturbed succession) and site moisture (P<0.05) were fitted *ex post* as passive variables. Species best fitted to the model are shown. Target species are underlined, red listed species are in bold. Species abbreviations used are composed of the first four letters of the generic and species names.

AgroCapi- *Agrostis capillaris*, AgroScab – *Agrostis scabra*, AlnuGlut – *Alnus glutinosa*, AvenFlex – *Avenella flexuosa*, BetuPend – *Betula pendula*, BideFron – *Bidens frondosa*, CalaEpig – *Calamagrostis epigeios*, CalaVill – *Calamagrostis villosa*, CallVulg – *Calluna vulgaris*, CareCane – *Carex canescens*, CareLepo – *Carex leporina*, CytiScop – *Cytisus scoparius*, EleoPalu – *Eleocharis palustris*, EpilAngu – *Epilobium angustifolium*, EpilPalu – *Epilobium palustre*, FilaMini – *Filago minima*, HierPilo – *Hieracium pilosella*, HypeHumi – *Hypericum humifusum*, HypoRadi – *Hypochaeris radicata*, JuncBulb – *Juncus bulbosus*, JuncEffu – *Juncus effusus*, LeonAutu – *Leontodon autumnali*, PhraAust – *Phragmites australis*, PiceAbie – *Picea abies*, PinuSylv – *Pinus sylvestris*, PopuTrem – *Populus tremola*, RobiPseu – *Robinia pseudacacia*, RubuFrut – *Rubus fruticosus*,

RumeAcet – *Rumex acetosella*, SaliCapr – *Salix caprea*, TyphLati – *Typha latifolia*, VaccMyrt – *Vaccinium myrtillus*

a) **b)**

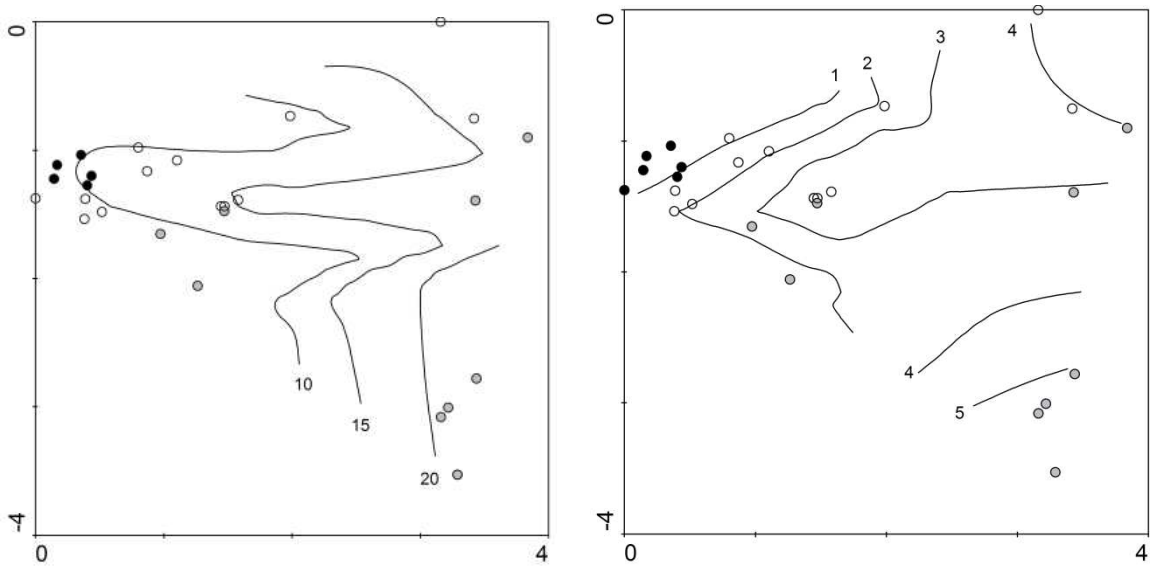


Fig.5. Unconstrained ordination (DCA) of vegetation samples from reclaimed sites (black dotted), spontaneously revegetated (white dotted) and disturbed sites(grey dotted). Isolines represent (a), total number of species (b) and number of target species.

Table.7. Proportion of target species (vascular plants, cryptogames) which established successfully on the island in plots with site assisted succession and spontaneous succession (i.e. control plots). Two variants were distinguished within site assisted succession- plots with transferred material from sand dunes and from terraces. The number of species is shown in the brackets.

Type of method	**Assisted succession**			**Spontaneous succession**
Number of target species	**Total established**	**Sand dunes**	**Terraces**	**Control**
Vascular plants (27)	75% (20)	48% (13)	67% (18)	18% (5)
Cryptogames (17)	76% (13)	76% (13)	59% (10)	0.06% (1)

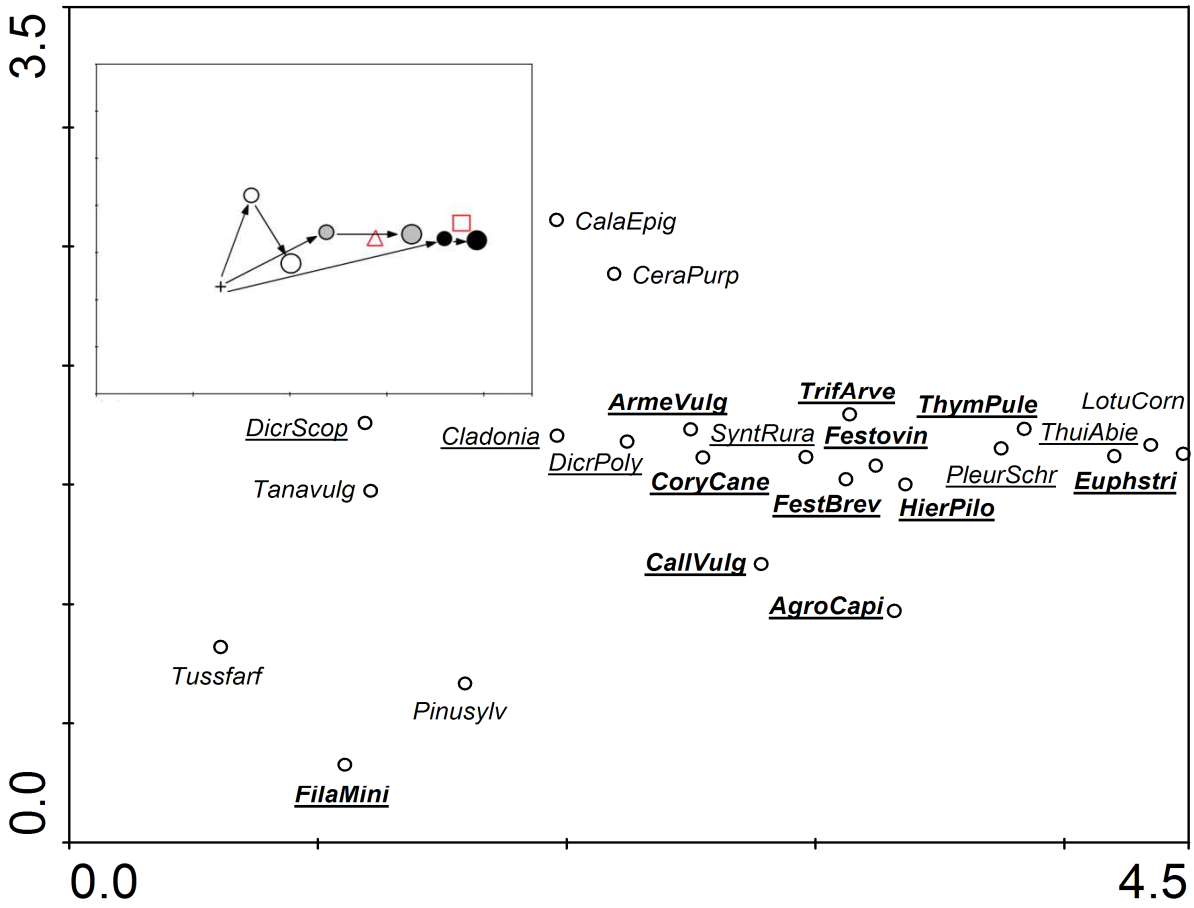


Fig. 6. DCA ordination of species and samples (experiment). The inset diagram shows the direction of succession in particular sere (spontaneous succession, assisted succession with raked material from terraces, assisted succession with material from sand dunes) using centroids for each age group. Increasing size of symbols corresponds to increasing age (cross is used for the year 2009 when the experiment was established). Species best fitted to the model are shown. Underlined- target species, bold- red listed species. Species abbreviations used are composed of the first four letters of the generic and species names.

Table 8. Summary data for the restored sites within the sand pits included in the study (arthropods): range of age (time since site abandonment), range of water table depth, total number of species, number of target species , number of red listed species.

	Disturbed Succession	Spontaneous Succession	Dry Reclamation	Wet Reclamation
Age	2 - 14	6 - 30	14, 21	14
Water table depth	0.3 -15	0.5 - 12	1 - 6	0 -1
Total number of species	215	136	87	101
Number of target Species	82	50	6	24
Number of red listed species	17	13	0	3

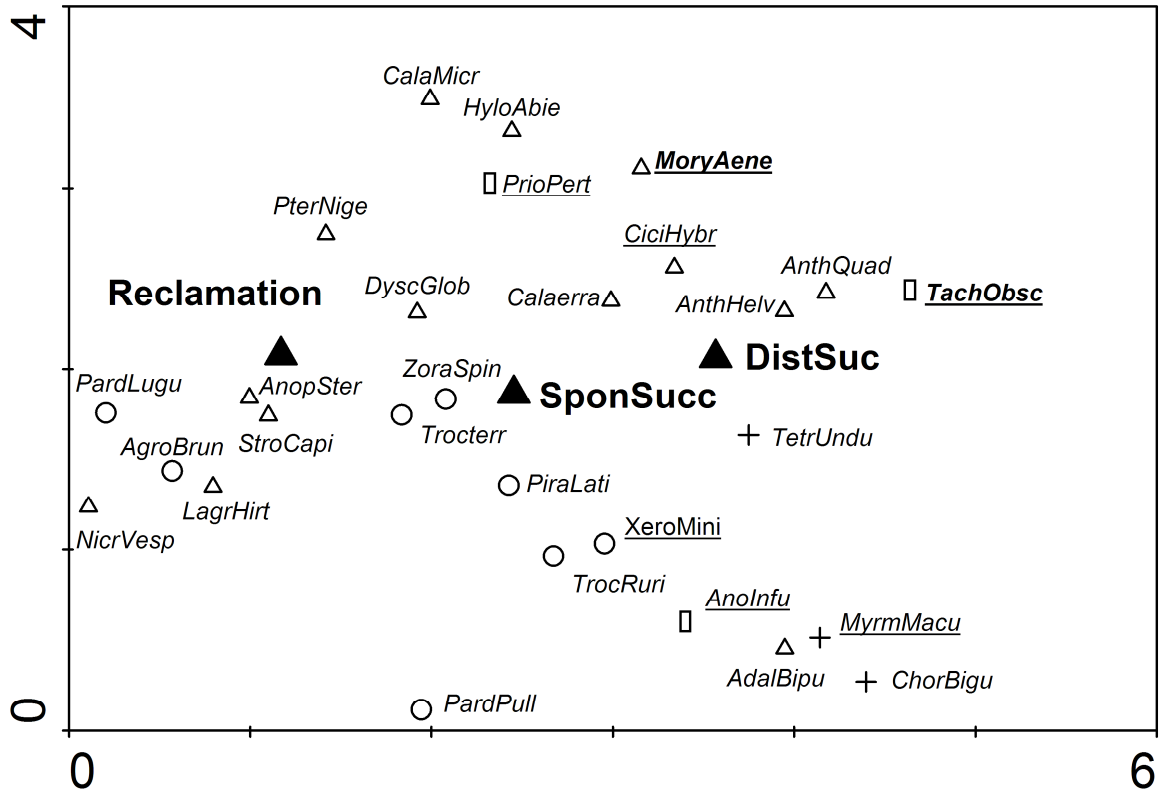


Fig.7. Unconstrained ordination (DCA) of species and significant environmental factors (arthropods). The restoration status (Reclamation, SponSucc- spontaneous succession and DistSucc- disturbed succession) was fitted *ex post* as passive variable. Species best fitted to the model are shown. Target species are underlined, Red listed species are in bold. Species abbreviations used are composed of the first four letters of the generic and species names. Circle- spiders, Triagle – beetles, Cross- Orthopteroids, Box – Hymenopteroids.

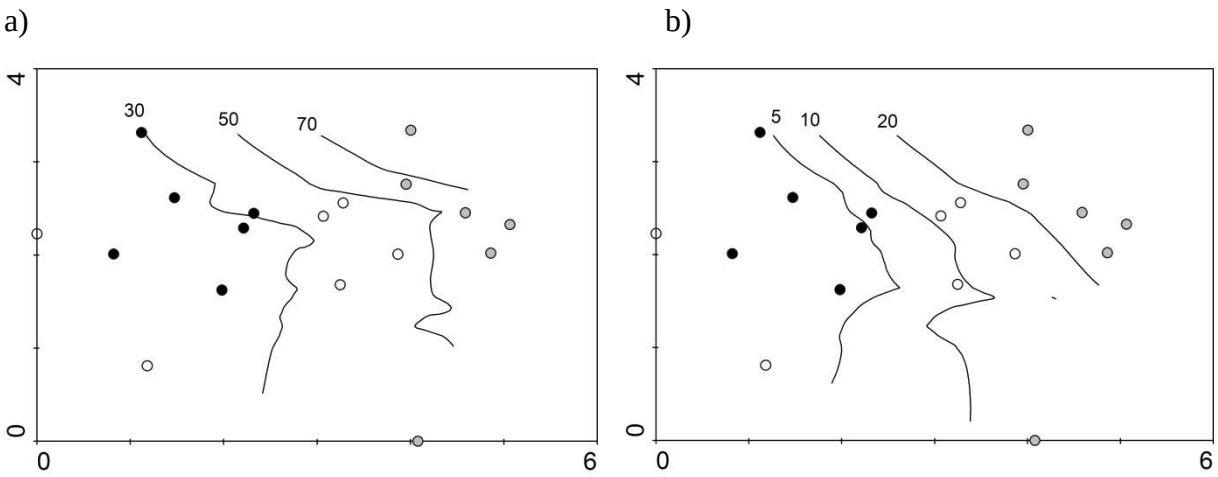
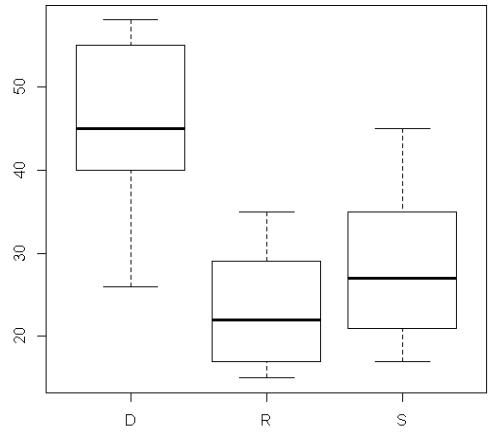


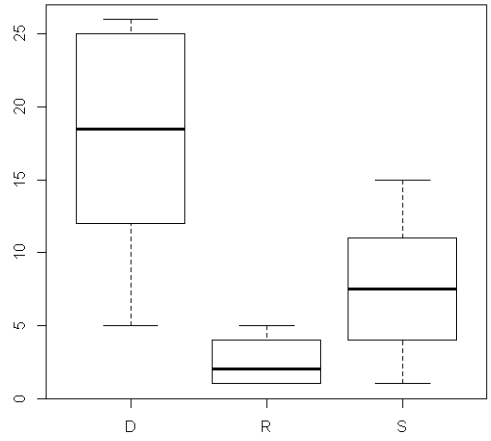
Fig.8. Unconstrained ordination (DCA) of samples (arthropds) from reclaimed sites (black dotted), spontaneously revegetated (white dotted) and disturbed sites (grey dotted). Isolines represent (a), total number of species (b) and number of target species.

A) arthropods

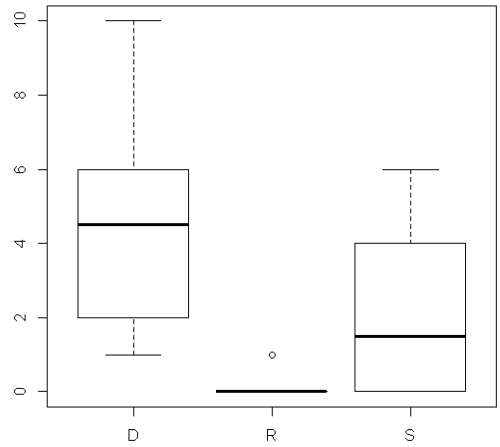
a) species richness (P<0.05)



b) target species (P<0.001)

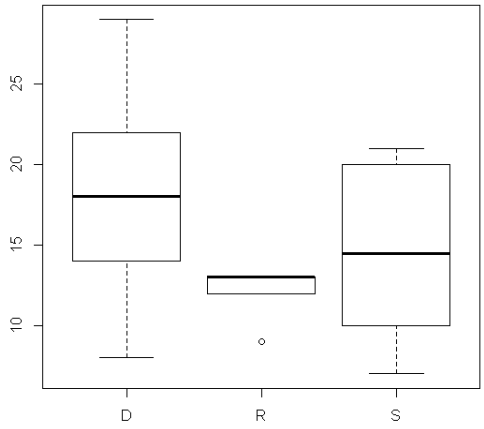


a) red listed species (P<0.01)

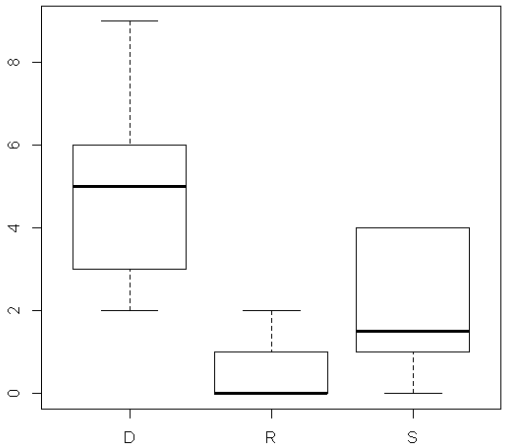


B) vascular plants

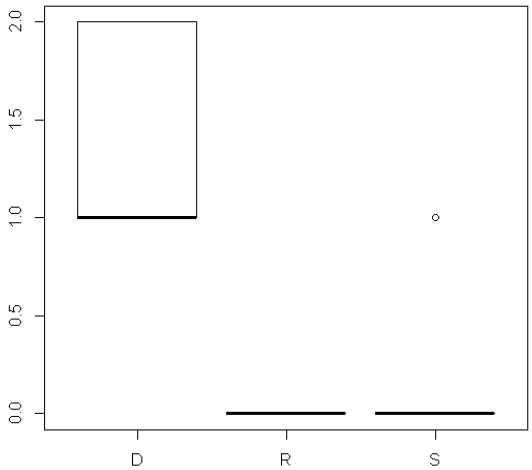
ns



(P<0.01)

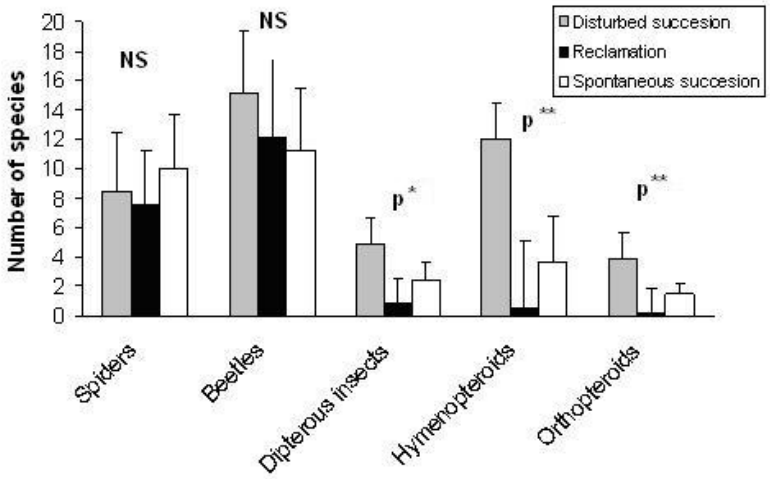


(P<0.01)



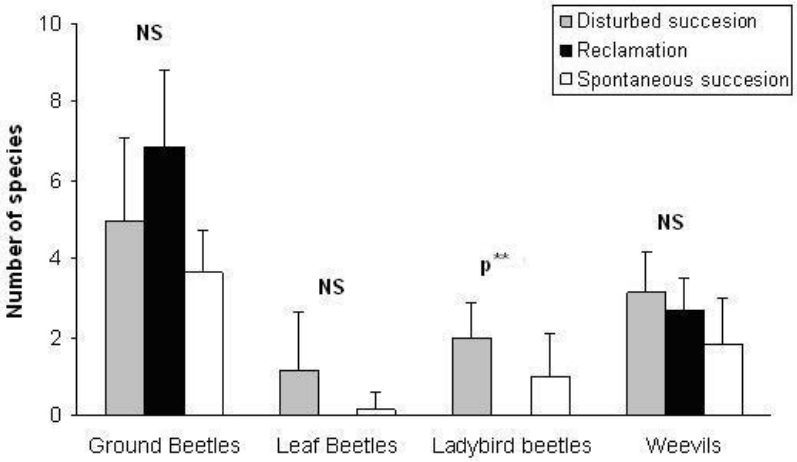
C) selected orders of arthropods

a) species richness



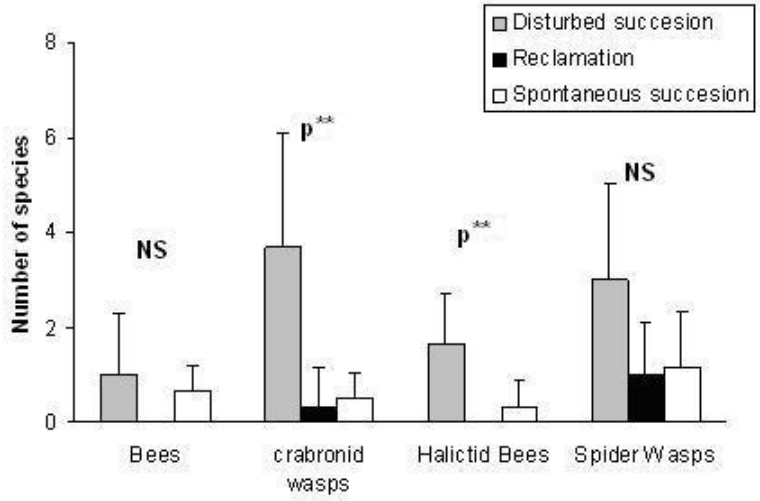
D) selected families of beetles

a) species richness



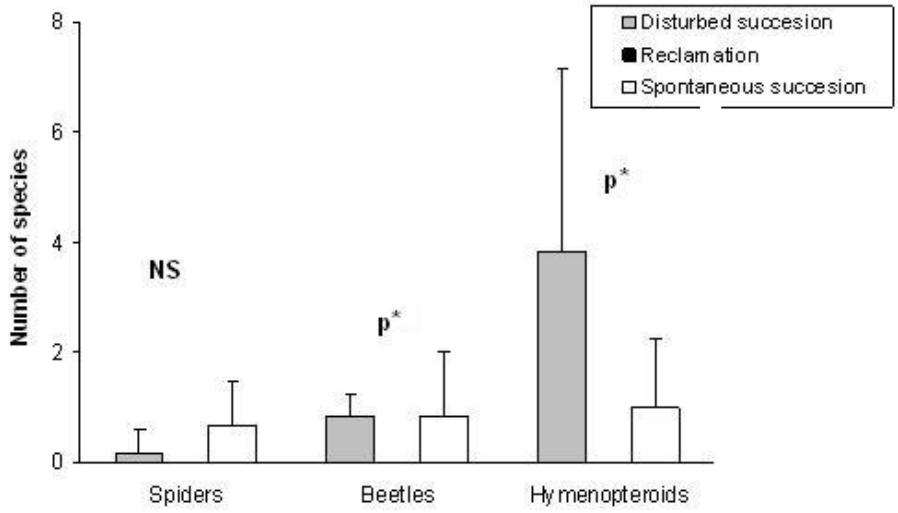
E) selected families of Hymenopteroids

a) species richness



C) selected orders of arthropods

b) target species



b) red listed species

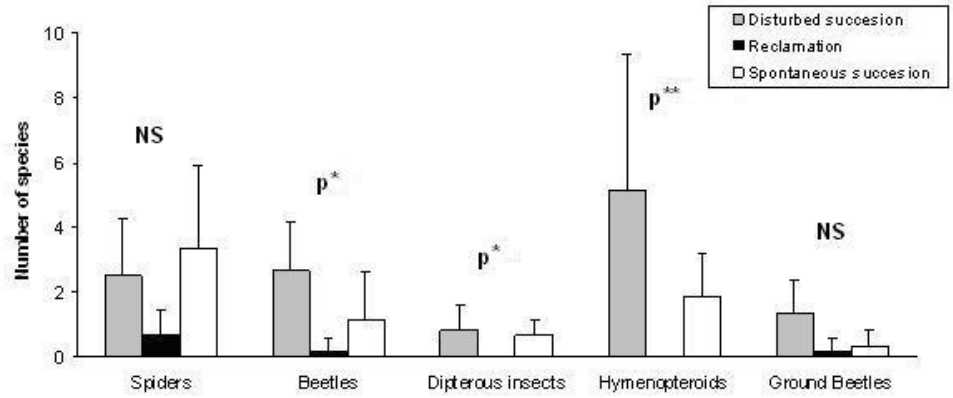


Fig.9. Differences in number of species (Kruskal-Wallis test) according to the given variables (species richness, number of target species and number of red listed species) and restoration status (reclamation, spontaneous succession, disturbed succession). A) arthropods, B) vascular plants, C) selected taxa of arthropods, D) selected taxa of beetles, E) selected taxa of Hymenopteroids (Mean ±SD are shown). P value: *(P<0.05), **(P<0.01), ***(P<0.001).

Table.9. Results of site restoration impact on vegetation composition and studied taxa of insect community. a)species richness, b) number of target species, c) number of Red List species. Significant differences between differently restored sites are marked by different letters – the same letters indicate homogeneous groups according to the Turkey test at $p < 0.05$ Average number with standard deviation are shown.

Species richness	**Disturbed succesion**	**Reclamation**	**Spontanous succesion**	**P values**
Arthropods	44,8±11,5^{a}	23,3±7,9^{b}	28,7±10,1^{bc}	0.024
Spiders	8,5±6,1	7,5±3,8	10,0±4,7	ns
Beetles	15,2±3,5	12,2±5,8	11,3±4,0	ns
Ground beetles	5,0±2,1	6,8±2,5	3,7±1,0	ns
Leaf beetles	1,2±1,5	0,00	0,2±0,4	ns
Ladybird beetles	2,0±0,9^{a}	0,0^{b}	1,0±1,1^{ab}	0.004
Weevils	3,2±1,0	2,7±0,8	1,8±1,2	ns
Dipterous insects	4,8±3,0^{a}	0,8±2,0^{b}	2,5±1,2^{ab}	0.018
Hymenopteroids	12,0±7,5^{a}	0,5±0,5^{b}	3,7±1,6^{bc}	0.001
Bees	1,0±1,3	0,00	0,7±0,5	ns
Crabronid wasps	3,7±2,4^{a}	0,0^{b}	0,8±1,2^{bc}	0.008
Halictid Bees	1,7±1,0^{a}	0,0^{b}	0,3±0,5^{bc}	0.008
Spider Wasps	3,0±2,0	0,5±1,0	1,7±1,0	ns
Orthopteroids	3,8±0,8^{a}	0,2±0,4^{b}	1,5±1,9^{bc}	0.005
Vascular plants	18,0±7,4	12,0±1,6	15,0±5,7	ns
Red listed species				
Arthropods	4,7±3,2^{a}	0,2±0,4^{b}	2,2±2,4^{ab}	0.010
Spiders	0,2±0,4	0,00	0,7±0,8	ns
Beetles	0,8±0,4	0,00	0,8±1,2	0.028
Hymenopteroids	3,8±3,3^{a}	0,0^{b}	1,0±1,3^{ab}	0.013
Vascular plants	1,0±0,5^{a}	0,0^{b}	0,0±0,4^{bc}	0.001
Number of target species				
Arthropods	17,5±8,3^{a}	2,5±1,6^{b}	7,7±5,2^{bc}	0.006
Spiders	2,5±1,8	0,7±0,8	3,3±2,6	ns
Beetles	2,7±1,5^{a}	0,2±0,2^{b}	1,2±1,2^{ab}	0.013
Dipterous insects	0,8±0,8^{a}	0,0^{b}	0,7±0,5^{ab}	0.037
Hymenopteroids	5,2±4,2^{a}	0,0^{b}	1,8±1,3^{ab}	0.003
Vascular plants	5,0±2,4^{a}	1,0±0,8^{b}	2,0±1,7^{bc}	0.005

Appendix 8. List of Ectomycorrhizal Macrofungi.

Table 10. List of Ectomycorrhizal Macrofungi found in Cep II sand pit.

Amanita fulva
Amanita muscaria
Amanita rubescens
Cantharellus cibarius
Cortinarius causticus aff.
Cortinarius croceus var. *porphyrovelatus*
Cortinarius semisanguineus
Gomphidius roseus
Inocybe lacera
Laccaria laccata
Lactarius obscuratus
Lactarius pubescens
Leccinum aurantiacum
Leccinum griseollum
Leccinum holopus (IUCN NT)
Leccinum scabrum
Paxillus involutus
Russula atrorubens
Russula grisea aff.
Trichaptum fuscomarginatum
Gomphidius roseus
Microcollybia cirrhata
Ampulloclitocybe clavipes
Coprinus sp. 1 (copricolous)
Cystoderma amianthinum
Galerina sp. 1, (with ring zone)
Galerina sp. 2 (pruinate stem)
Scleroderma citrinum
Suillus bovinus
Suillus luteus
Suillus variegatus
Thelephora trerrestris
Daedaleopsis confragosa
Diplomitoporus flavescens (IUCN EN)
Fomitopsis pinicola
Gymnopilus hybridus
Hypholoma fasciculare
Phaeolus schweinitzii
Pholiota alnicola
Pholiota tuberculosa
Piptoporus betulinus
Ramaria apiculata
Skeletocutis carneogrisea
Trametes hirsuta
Trametes versicolor

Gymnopus dryophilus
Mycena galopus
Mycena pura
Rhodocollybia prolixa
Rickenella fibula
Setulipes androsaceus

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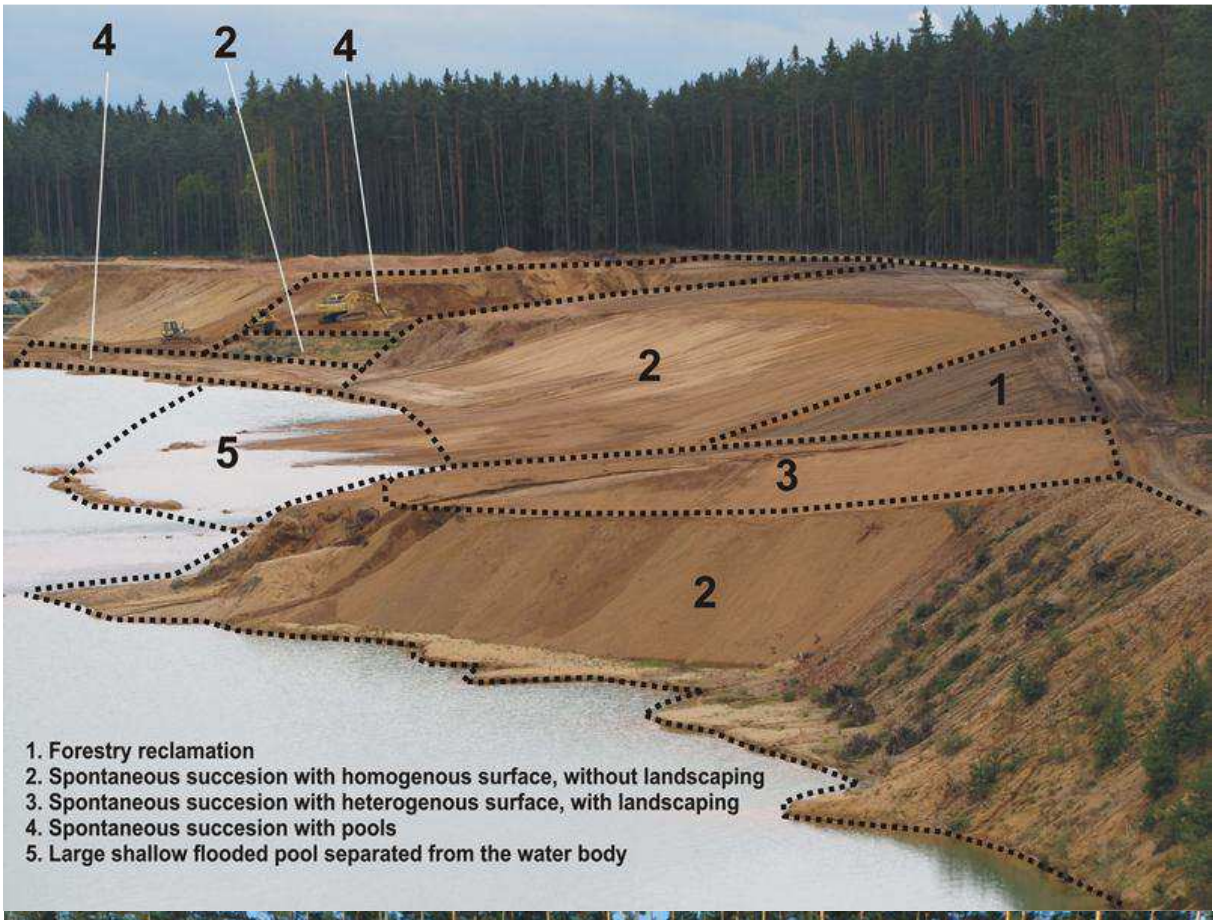
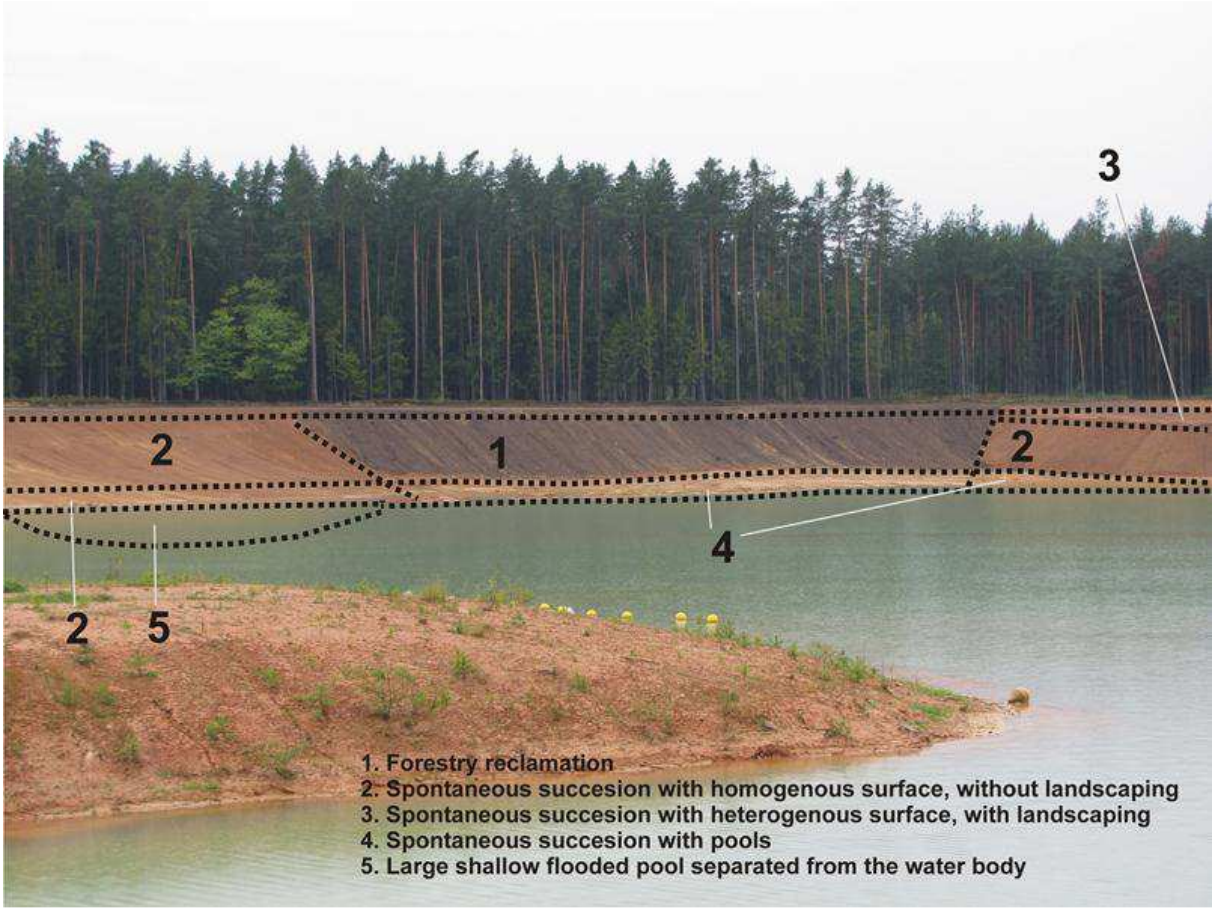
Appendix 10. Maps with restoration proposal for sites abandoned in close future (first part in autumn 2012)





Appendix11. Information board (pdf. file, see also
www. http://www.quarrylifeaward.com/project/sand-pit-biodiversity-cep-ii-quarry/update/new-information-board-sand-pit-nova-informacni)

THE CEP II SAND PIT

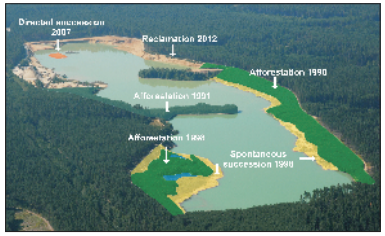
How did the lake appear here?

The lake in the CEP II sand pit is very young. It was created after the sand mining which started in 1980. The extraction takes place in the former riverbed so that the lake has elongated shape. The extracted Quarternary sediments and the Mesozoic clays forming impermeable layer of under bed are typical of almost the whole Třeboň basin. The mining of sand is carried out mostly by floating technology. The sand is used in concrete, asphalt mixtures and for other construction purposes.

Floating suction excavator

Why does the lake look like this?

The slopes around the lake have been gradually reclaimed during the progress of mining. The first forestry reclamations took place in 1991 (see the map below). The northern part of the lake was reclaimed mainly in 1998 and part of the banks was left to the near-natural restoration. Shallow bays and small water pools were created on the shore of the lake and left to the spontaneous succession. The latest reclamation began in summer 2012 (see the orthophoto).



Overview of performed reclamations, 2008

Forestry reclamation, 1991

Plantation of pine trees around a water pool, 1998

Landscaping of the shore for further reclamation, 2012

Why are the sand pits biologically interesting?

1. The soil in sand pits is nutrient poor. These sites are rare in our eutrophicated landscape and are suitable for plants that prefer low nutrient level and are weak competitors to other species.

2. In sand pits there are newly created open areas, for instance open sands, dry grasslands or nutrient poor wetlands. Many endangered species of plants and animals require these early successional stages.

3. Sand pits and other mining sites increase diversity of landscape and consequently biodiversity because there is usually established a mosaic of habitats in mining areas.

4. Sand pits are also inhabited by "ordinary" species. Their abundance decreases in landscape and mining sites are suitable secondary habitats for them.

Twin Spot Longhorn Beetle (*Oberea oculata*)

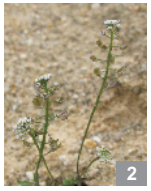
Near-natural restoration vs. forestry reclamation

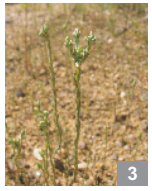
Most of the mining areas are still reclaimed technically for forest or agriculture use in the Czech Republic. Sand pits in the Třeboňsko region are created mostly in forests therefore the reclamation plans usually concern the forestry reclamation. Pine monocultures (*Pinus sylvestris*), which are usually planted, are not very biologically valuable. The forest could be, however, restored "on its own" with the use of natural processes and usually it is more valuable from both conservation and biodiversity point of views. One of the reasons is that many open sands areas and grass strips maintain in this forest that can be inhabited by the most endangered species in sand pits.

What can you find in the CEP II sand pit?

Open sands and dry grasslands

These are probably the most biologically interesting habitats in the sand pit because organisms living here have had to adapt to extreme environmental conditions. These include psammophytic plants - the Trailing St John's Wort (*Hypericum humifusum*), the Small Cudweed (*Filago minima*), the Shepherd's Cress (*Teesdalia nudicaulis*), the Common Thrift (*Armeria vulgaris*) – and especially many insect species – Ground Beetles, Tiger Beetles, Aculeate Hymenoptera, Mole Crickets, Antlions etc.





1 Trailing St. John's Wort (*Hypericum humifusum*), 2 Shepherd's Cress (*Teesdalia nudicaulis*), 3 Small Cudweed (*Filago minima*),
4 Violet Oil Beetle (*Meloe violaceus*), 5 European Mole Cricket (*Gryllotalpa gryllotalpa*),
6 Digger Wasp *Cerceris arenaria*, 7 Little Ringed Plovers (*Charadrius dubius*)

Wetlands

Wetlands are other interesting habitat in the sand pit because of their low nutrient level and open water area that are suitable for many species of plants and animals. From the rarer species we can mention the Yellow Bladderwort (*Utricularia australis*), the Common Club-rush (*Schoenoplectus lacustris*) or the Threestamen Waterwort (*Elatine triandra*), from the common species for instance the Common Water Plantain (*Alisma plantago-aquatica*). Water insects and protected amphibians reproduce in small water pools, for example the Alpine Newt (*Triturus alpestris*), the Smooth Newt (*Triturus vulgaris*) or Agile Frog (*Rana dalmatina*). The Grass Snake (*Natrix natrix*) preys in the water pools.

1 Yellow Bladderwort (*Utricularia australis*), 2 Common Water Plantain (*Alisma plantago-aquatica*), 3 Smooth Newt (*Triturus vulgaris*), 4 Grass Snake (*Natrix natrix*)

Areas with spontaneously established trees

In areas where the overgrowing advanced, stands of various spontaneously established trees are formed, mainly pine trees, alders, poplars, willows or birches. Many endangered species preferring insolate habitats disappear quickly from such shaded habitats. However we can find here for example striking butterfly Poplar Admiral (*Limenitis populi*), Jewel Beetle *Buprestis octoguttata*, Jewel Beetle *Buprestis rustica* or the Adder (*Vipera berus*).

1 Poplar Admiral (*Limenitis populi*), 2 Jewel Beetle *Buprestis rustica*

Pine monocultures

Pine trees (*Pinus sylvestris*) are planted on slopes around the water body in order to restore the forest that was here before the mining started. Shading and small spatial diversity of these dense stands are the reason why only few species occur there. Plants can be found prevailingly only in at least slightly open areas on the edges or in intersection, such as for instance the Sidebells Wintergreen (*Orthilia secunda*).

Sidebells Wintergreen (*Orthilia secunda*)

Text: Jiří Řehounek, Klára Řehounková, Petra Konvalinková
Photos: Jiří Řehounek, Petra Konvalinková, Michal Koupý, Českomoravský štěrk, a.s.