## 1. Contestants profile

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| ▪ Contestants names: | **Jakub Vácha[1] and Šimon Zeman[2] (shared 1st authorship)** |
| ▪ Contestants occupation: | Students |
| ▪ Universities / Organisations | Gymnázium Soběslav[1] and Malostranské gymnázium[2] |
| ▪ Number of people in your team: | **2** |

## 2. Project overview

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| Title: | How geodiversity influences poorly known Arthropod groups and sandpit ecosystems |
| Contest: (Research/Community) | Research |
| Quarry name: | Planá nad Lužnicí |

## Abstract

In this study, we compared biodiversity of several groups of arthropods on five sites within a sandpit near Planá nad Lužnicí (South Bohemia, the Czech Republic), each with different humidity, soil texture, penetrability and vegetation cover. With our results, we tried to explain differences in species composition by above mentioned factors. Later, we estimated biological value of each site and recommended suitable management. In our study, we focused on spiders, true bugs, beetles, planthoppers, leafhoppers and hymenopteras. Other groups of animals and plants were recorded to make species list, too. Detailed survey revealed in total 272 species of terrestrial Arthropods, 74 aquatic invertebrate species and 30 Vertebrates, of which 53 are listed in national Red-list. With results of our analysis, we argue that within different groups, different factors influence the species composition – in hymenopterans, soil characteristics (texture, penetrability) seem to be most important, while in other groups of arthropods, in most cases humidity and vegetation cover play a major role. According to our results, the biggest conservation potential provides dry sites with fine sand, which provide substitute habitats to species primarily associated with sand dunes or other warm, dry and open habitats which almost disappeared from the landscape. Brochure “Geology of Sandpits” for biologists and the project of Planá sandpit education biocenter were made and some restoration recommendations for the sandpit were proposed.

# Introduction

Sandpits are significant landscape phenomenon not only in South Bohemia, but all over the world. Besides water retention, recreation, mining and other important functions there is one more, sometimes neglected, function. It is the function of substitutional biotope for species, which used to live on river alluvial sands, sand dunes or other thermophilic open habitats. Most of those biotopes were destroyed when humans began to significantly change the landscape. Most rivers were straightened and their alluviua perished, sand dunes were either overplanted by pine forests, or began to overgrow because of higher nutrient content in the soil caused by intensification of agriculture. Number of natural inland sandy areas massively decreased, and species bound to these biotopes began to die out, slowly. Fortunately, a lot of them found refuges in similar, but man-made biotopes – sandpits.

## Sandpit Restoration

There are three main ways how to restore sandpits. If the mining is done under water level, hydric restoration is suitable. Later, the lake created in the sandpit is usually used for recreation and fishing. Technical restoration is, unfortunately, the most frequently used one. Scots pine (*Pinus sylvestris*) monocultures with low biodiversity and even low economic outcomes are grown. Sometimes, even alien species, e.g. Austrian pine (*Pinus nigra*), or Northern red oak (*Quercus rubra*) are used (Matoušková 2015). These tree plantations can be later economically productive, but nowadays, we can see that huge areas of one-age monoculture forests are vulnerable ecosystems easily affected by droughts, parasites and other unfavorable factors. Big disadvantage of this type of restoration is it´s very high price. Spontaneous succession is the least used method of restoration, but leads to the most diverse, species-rich and stable biotopes (Schmidtmayerová 2013). This kind of restoration allows nature to create ecosystems which should originate in the area. Spontaneous succession finally leads to the forest stand as well (Řehounek et al. 2015), but in this case, stable, diverse and more nature-friendly forest ecosystem is formed, and almost for free. If we want to preserve early succession stages and its specific fauna and flora, we need to perform some additional disturbations (Heneberg et al. 2016).

## Objectives

In this study, we compared species composition and biodiversity of several arthropod groups (Aranea, Auchenorrhyncha, Heteroptera, Hymenoptera, and several groups of Coleoptera) on five sites (within the sandpit) with different soil humidity, penetrability, texture and vegetation cover and argued, which factor is the main influence for species composition. Besides the five groups mentioned above we also assembled a list of other species we found in the sandpit, including birds, reptiles, amphibians and several groups of arthropods (Orthoptera, Diplopoda, Isopoda, Neuroptera, Odonata, Megaloptera, Opiliones,other Coleoptera).

With results of our research, we evaluated a biological value of studied sites and discussed reasons for such results. Moreover, we composed a list of endangered species inhabiting this sandpit to show how valuable can sandpits be for biodiversity.

We also made a brochure explaining geology of sandpits for public, mining companies and non-geological scientists interested in sandpits. A lot of people work in sandpits or visit it regularly, but many of them do not know about geological phenomena which occur in sandpits.

A project for building Planá sandpit educational biocentre has been proposed. Suggestions were formulated with special attention to both current restoration plan (GET, s. r. o. 2015) and nature conservation potential. Interactive education boards were suggested to be placed in the biocentre to create valuable multipurpose area.

## Background Information

Planá nad Lužnicí sand and gravel pit (mined since 1997) is located in South Bohemia, the Czech Republic. The subject of mining are tertiary alluvial terraces of the Lužnice river with occasional inland sand dunes. The deposit is covered with thin (0.2 – 0.5 m) layer of gleys, pseudogleys, brown earths and podzols (Hanzlík 2007).

Biological survey of mining stage two was carried during EIA process. Studied area was covered by predominantly pine forest. The survey revealed in total 88 plant species, 26 Arthropods (no spiders), 15 birds and 2 mammal species. One species (Broad-leaved helleborine – *Epipactis helleborine*) is listed as category C4 in Czech Red List (Kos 2011, Vorlová 2011).

# Methods

The sand-gravel pit was surveyed from March to July 2018. Five geologically different localities were selected for later research, each 10 x 10 m in size. Sand at locality no. 1 appeared to be very wet with fluctuating penetrability values, bigger gravel grains, and clay fraction was included. Fine, dune sand, dry on surface was found at locality no. 2, creating slopes. Locality no. 3 can be characterized as dry sand with soil mixed in, bigger grains and early stage pine restoration is found. Locality no. 4, old sedimenting basin, is similar to no. 2, but only very fine grains were present. Penetrability values predicted to be low, average water content. Locality no. 5, similar to no. 1 and 3, was chosen as typical sandpit road surface. Dry sand, bigger grains included, higher penetrability, low vegetation cover.

All three wetland biotopes present in the quarry were surveyed for aquatic fauna and later compared. Locality w1 and w3 are sandy pools, maximally 100 cm deep, located on northern and southern end of the Planá sandpit. Locality w2 is muddy littoral zone of the main lake.

## Botanical Survey

In total, 15 phytosociological relevés 1 x 1 m were made at each locality (3 per site) during July 2018. All vascular plants species were recorded, as well as bryophytes (altogether one category) and size of open sand area. During whole research, botanically interesting plant species were recorded to create the list of important plants in the pit. Red-lists by Grulich et al. (2017) for vascular plants and Kučera et al. (2005) for bryophytes were used for conservation status establishment.

## Terrestrial Arthropods Sampling

Arthropods were collected on each locality using standardized methods (sweeping, pitfall traps and individual collecting). Two pitfall traps were placed on each site (1-5), at least six meters away from each other, so that the sampling area would be larger. Traps were made out of two yoghurt cups put into each other, with punctures near edge of the upper cup and in the bottom of the lower cup, so that the rainwater collected in traps can drain away. Pitfall traps were placed in the ground so that the edge of the trap was at ground level. Traps were filled with salty water (to preserve the material) and detergent (to lower the surface tension). Material from the traps was collected each month and sorted later under stereoscopic microscope and preserved with ethanol. Sweeping was carried out each month on vegetation present on the site, with standardized number of sweeps of one hundred. Material from the sweeps was sorted with exhaustor and preserved with ethanol and ethyl acetate. Individual collecting was performed each month using exhaustor and entomological tweezers for twenty minutes on each locality. If flying insects were present, a net was used (mainly for hymenopterans and dragonflies). Material was then preserved with ethanol or ethyl acetate. Arthropods were identified either by specialists (Coleoptera – Igor Malenovský, Hymenoptera – Jakub Straka; Heteroptera in part – Petr Kment) or by Šimon Zeman and later revised by specialists (Aranea, Diplopoda, Isopoda, Opiliones – Petr Dolejš; Heteroptera in part, Orthoptera, Megaloptera – Petr Kment; Auchenorrhyncha – Igor Malenovský). Following literature was used for identification – Aranea – Nentwig et al. (2014) and Miller (1971); Diplopoda – Kocourek et al. (2017); Isopoda – Frankenberger (1959); Opiliones – Šilhavý (1971); Heteroptera – Péricart (1983, 1984, 1989a, 1989b, 1989c), Wagner (1966); Orthoptera – Kočárek et al. (2013); Megaloptera – Kratochvíl et al. (1959); Auchenorrhnycha – Biedermann et al. (2009), Kunz et al. (2011). Red-list status was assembled using Řezáč et al. (2015) (spiders) and Hejda et al. (2017) (remaining invertebrates).

In some months, we lost the material from traps (because of vandalism or deer trying to drink salt water used as conservation medium), but there was always material from at least one trap per month on each site. On every site, there was one trap missing for one month, excluding locality 5, where one trap was not included in our statistics, so that the trapdays count is the same on each site.

## Aquatic Fauna Survey

Aquatic arthropods and amphibians were captured in the funnel traps placed in littoral zones of water biotopes. Traps of two sizes, 50 x 23 x 23 cm and 80 x 28 x 28 cm with 3.5 cm and 2.5 cm entering hole reductions. Polystyrene foam was used as a floater, chicken and duck liver as a lure. Three traps were planted at locality no. 1 and 3, two traps at locality no. 2 according to the size of studied area.

Colander 30 cm in diameter was used for manual aquatic Arthropods sampling, catching 2 minutes around each funnel trap. If dragonfly adults were present, a small net was used to capture them. Amphibians were, besides funnel traps, captured manually with catching net. Vocalization hearing, frogspawns and larvae determination were done, too. Water molluscs were collected manually, later dissected, determined and stored in J. Vácha´s personal collection.

All catched invertebrates (besides Mollusca and Odonata) were conserved in ethanol for later determination by Vojtěch Kolář. Molluscs were determined using Horsák et al. (2013) and verified by Lucie Juřičková. Odonata species were determined by Michael Mikát. All amphibians were determined, documented and gently released back to the nature. Red-lists by Chobot et al. (2017) for Vertebrate and Hejda et al. (2017) for invertebrates were used.

## Statistic Methods

Data were processed using R program (version 3.5.1). PCA analysis was used (using function from library "vegan"), with data being transformed using Hellinger transformation, because of unequal abundances of each species. For biodiversity Index estimation, Simpson Index was used. Spiders, hymenopterans, planthoppers and leafhoppers, true bugs and Carabidae were processed separately. Final graphs have been modified and only selected important species were incorporated in them, because otherwise they would be too unclear. Abbreviations were created using first three letters of genus name and three first letters of specific name.

Variation coefficient was used to establish how much the penetrability differs within the locality. Soil humidity variation in time and within every locality was calculated using following method. For pointing at differences in time, absolute values of differences between two measurements on the locality in the same time were used and variation coefficient was calculated. Differences within studied localities, not considering the time, were calculated as variation coefficient of average value of two measurements at one day.

## Geological Measurements

Geophysical quantities, sand texture, humidity and penetrability, were measured at research sites no. 1-5.

Soil penetrability was measured with Humboldt Soil Penetrometer H-4200 with adapter foot, if needed, every month since April till July. Four random measurements were done at each locality and later average values were calculated.

Two mixed ~1,5kg substrate samples collected at random spots at the locality were taken at each site every month (April – July).

Standard gravimetric method was used to measure soil humidity levels (Schmugge et al. 1980). Taken soil samples were homogenized and reduced to 1000 g. 1kg samples were dried at ~105 °C until the weight of the sample stopped decreasing. Later dry soil was weighted and water content calculated.

Soil texture measurements were done in GeoTec company on certified sieves (fractions 32, 16, 8, 4, 2, 1, 0,5, 0,25 and 0,125 mm). Dried ~100g samples were made using quartation method from original ~1000g ones.

# Results

## Research Sites Characterization

Locality no. 1 represents a wet, sand-to-gravel shore and is the youngest in terms of succession age (5 years). Presence of clay particles causes higher penetrability values (average 1.8 kg/cm$^2$). Content of water is the highest among studied sites with average value of 9.4 mass % (Fig. 3). Soil at the locality is very heterogeneous and changing clay abundance causes high penetrability variation coefficient (0.9). Water content is quite stable at different parts of locality and in the time. Approximately half of the site was bare ground. Dominant plants were either graminoids (*Juncus, Cyperus* in moistier places and *Calamagrostis epigejos* in drier) or small trees (*Betula pendula, Salix* sp.*, Pinus sylvestris*)**.** On some places, relatively large cover of mosses occur. Fauna is composed mostly from hygrophilous species or generalists.

Locality no. 2, a low hill of sand near a road, is composed from fine grained sand with significant 0.25 mm fraction content (64 %) (Fig. 2). Bigger grains are very rare (1-4 mm) or absent. Soil humidity (average 6.5 %) seems to be variable at the locality, which is caused by nearby forest. Nevertheless we can say, that top layer important for non-burrowing species is quite dry. Very low penetrability average (0.2 kg/cm$^2$) and high variation coefficient (Fig. 4) are pointing to differences in values caused by local path crossing the site. This locality was abandoned 8 years ago. Approximately 28% of our site was covered by vegetation. Most abundant plant is *Calamagrostis epigejos*, but *Conyza canadensis*, *Carex* sp. and *Fillago arvensis* also occur in not negligible abundances (Tab. 2). Not many species of arthropods live in there, however those are mostly xerothermophilous specialists or very eurytopic species.

Locality no. 3 is also typical sand-gravel sediment (Fig. 2), but with higher content of bigger grain fractions (4-16 mm). Locality is very dry (3.4 % of water) and water content fluctuates a lot within the area. Penetrability is quite high (average 1,5 kg/cm$^2$) (Fig. 4). Organic component is mixed in the sand because of early stage pine restoration in the area. On this site, the vegetation was the densest from all our sites (the vegetation cover was approx. 88 %), with *Calamagrosits epigejos* being the most abundant plant. Also, a large cover of *Agrostis capillaris*, *Fillago minima* and *Fillago arvensis* occurs on the locality. From trees, *Pinus sylvestris* was present in high numbers because of forest reclamation of this site 12 years ago. A lot of ruderal plants occur on this site (*Daucus carota*, *Conyza canadensis*, *Epilobium adenocaulon*). Fauna was very rich, but mostly composed of generalists and (in a smaller amount) xerothermophilous species.

Locality no. 4, old sedimenting basin, is a unique substitute for sand dunes missing in the landscape. Technically-sorted sand consists mainly of 0.25 mm (51 %), 0.125 mm (30 %) and smaller grain fractions (Fig. 2). Penetrability level is very low (0.2 kg/cm$^2$) and homogenous. Average humidity is very low (3.6 %) and fluctuates strongly (Fig. 3), which points to area propensity to change according to weather conditions. The sedimenting basin was abandoned 15 years ago, which makes it the oldest surveyed locality. On contrary to that, on this site, there was almost no vegetation (only 20%). This can be explained by slower vegetation succession on fine and dry sand. Only *Calamagrostis epigejos*, *Pinus sylvestris* and moss occurred. As well as in locality 2, high percentage of specialists live on this site, mostly hymenopterans that nest in the sandy soil (Fig. 9).

Locality no. 5 is a pile of mixed different sandy soils with fluctuating organic content. Grains are mostly sandy with occasional gravel particles (mainly 16 mm fraction), most abundant are 0.5 and 0.25 mm fractions (55 % together) (Fig. 2). This locality is somewhere in the middle among localities no. 2 and no. 4 vs no. 1 and no. 3, speaking about soil texture (Fig. 2). Soil humidity is quite low (average 4 %) varying strongly within the locality and slightly above studied areas average, as well. Vegetation cover is approximately 40%. Surprisingly, hygrophilous species of plants were present (*Molinia* sp., *Juncus tenuis*, *Juncus effusus*). Besides them, *Calamagrostis epigejos*, *Agrostis stolonifera*, and *Agrostis capillaris* were present. In smaller abundances, *Spergularia rubra*, *Bidens frondosa* or *Conyza canadensis* were present. Fauna was mostly composed of species preferring sparsely vegetated, open and warm sites. Last significant material transport was done 14 years ago on this locality.

## Terrestrial Arthropods

In total, 272 species of terrestrial invertebrates were found in Planá quarry (Aranea 73; Hymenoptera 60; Auchenorrhyncha 22; Heteroptera 32; Orthoptera 5; Isopoda 2; Opiliones 1; Diplopoda 4; Coleoptera 72; Neuroptera 1), 24 of them included in Czech Red-list (Aranea 12 (10 LC, 2 VU); Hymenoptera 8 (6 NT, 1 VU, 1 EN); Auchenorrhnycha 2 (2 NT); Heteroptera 1 (1 EN), Coleoptera 1 (1 NT)).

From PCA, we can see that species distribution of Auchenorrhyncha, Hymenoptera, Carabidae and Aranea shows a trend of changing species composition depending either on soil characteristics, or humidity and vegetation cover. PCA analysis of other groups of arthropods hasn't shown any significant trend, but we can still see that localities have their specific species composition.

In hymenopterans (Fig. 9), this could be caused by different soil penetrability and texture. When we take a look at our graph, we can see, that the PC1 axis more or less correlates with the descent of penetrability and soil texture and it also correlates with occurrence of more specialists. Localities 1 and 3, where penetrability is similarly high, shared a lot of species – mostly generalists that are not associated with specific soil type or prefer to nest in more coarse grain soils (e.g. *Lasioglossum calceatum*, *Lasioglossum minutissimum*, *Seladonia subaurata*, *Andrena flavipes*, other *Andrena* species). On locality 1, a species *Anthophora quadrimaculata* appeared – an endangered species, but it doesn't have any specific requirements on soil texture or penetrability. On locality 1, 14 species were registered and Simpson Index is equal to 9.47, whereas on site 3, 20 species occurred and Simpson Index is very high, being 12.45 (because of low abundances of collected species). On site 5, where soil penetrability and texture are somewhat intermediate, we found mostly generalists (*Lasioglossum minutissimum*, *Lasioglossum pauxillum*), that also occur on locality 3. Also, species that strongly prefer lower penetrability and sandy soil, but don't necessarily require it, occurred on this site (*Diodontus minutus*, *Smicromyrme rufipes*, *Lasioglossum lucidulum*). 16 species were found on this site in total, Simpson Index is equal to 10.57, which is also high, but is probably caused again by low abundances of species occurring on this site. Finally, localities 2 and 4 have the lowest penetrability and the soil is mostly composed of fine sand. On these sites, a lot of fine grained sand specialists occur (e.g. *Cerceris arenaria*, *Oxybellus bipunctatus*, *Lindenius pygmaeus*, *Alysson spinosus*, *Pompilus cinereus*, *Episyron rufipes*, *Lasioglossum sexstrigatum*, *Andrena barbilabris*, *Hedychrum nobile*). Although 18 species were found on locality 2 and 22 on locality 4, those two localities had the lowest Simpson Index (6.75 on locality 2 and 4.16 on locality 4). Such low numbers are probably caused by enormously high abundances of *Lasioglossum sexstrigatum*, a species that requires very fine sand. On most localities, parasites and specialized predators also occur together with their host species or prey (*Sphecodes albilabris* on sites with *Colletes cunicullarius*; *Sphecodes pellucidus* and *Nomada alboguttata* with *Andrena barbilabris*; *Methocha ichneumonoides* with tiger beetles; *Tachysphex obscuripennis* near edges of forest with *Ectobius*; *Hedychrum nobile* with *Cerceris* and *Lasioglossum leucozonium; Sphecodes ephippius* with *Lasioglossum leucozonium* and *Lasioglossum pauxillum*). To sum it up, on sites with fine sand and low penetrability (Tab. 1), high amount of specialists (and their parasites) occurred, whereas on localities with higher penetrability and coarse grained sand more generalists occurred. Also, on localities with fine sand, higher number of Red-list species (Fig. 5) were found (4 NT and 1 VU on locality 4; 3 NT on locality 2; 2 NT and 1 EN on locality 1 and none on the rest of the localities).

In spiders (Fig. 7), rather than penetrability, humidity (in our graph PC1 axis) and vegetation cover seems to play a major role. Again, most localities have a specific composition of species, but the distribution of species is unequal – locality 1 has very specific species composition, whereas locality 3 shares most species with the rest of the localities. Locality 1 has the highest humidity and thus very specific fauna consisting mainly of species more or less associated with wet sites (*Pardosa amentata*, *Erigone atra*, *Erigone dentipalpis*, *Xysticus ulmi, Tetragnatha extensa*, *Tetragnatha pinicola*, *Pirata piraticus*, *Piratula latitans*) or even species that are strictly associated with open wet areas and considered endangered (*Arctosa leopardus*). We also found some generalist species there that also occur on localities 3 or 5 (*Agyneta rurestris, Dictyna arundinacea*, *Pardosa prativaga, Agelena labyrinthica*, *Mangora acalypha*, *Xysticus kochi*). Simpson Index is 6.75. Locality 3 is very dry, but there is a lot of vegetation which provides shadow for invertebrates inhabiting this site, thus making it easier for non-extremophilous species to survive here. Besides species mentioned above, some more generalist or vegetation requiring species inhabit this site (*Mermesus trilobatus*, *Phylloneta sisyphia*, *Zora spinimana*, *Platnickina tincta*, *Araeoncus humilis*, *Pardosa lugubris*, *Pardosa palustris*, *Zelotes subteraneus*). On the other hand, we also found species that prefer xerothermic localities there (*Centromerus incilium*, *Heliophanus flavipes*, *Sibianor aurocinctus*, *Xerolycosa miniata*, *Xerolycosa nemoralis*, *Zodarion germanicum*, *Zelotes petrensis*). Simpson Index is 3.44, being the lowest in all of our sites. It is probably caused by huge amount of *Xerolycosa miniata* spiders and by high number of spiders that were only found once on this site. Locality 4 is quite species poor and those spiders (Fig. 7), living there, are not very abundant. Locality is very dry and there is almost no vegetation (Tab. 2). Mostly xerothermophilous species occur in here (*Xerolycosa miniata*, *Zodarion germanicum*, *Talavera aperta*) or generalists (*Synageles venator*, *Tibellus oblongus*, *Xysticus kochi*), but also a few spiders that probably accidentally occurred in here (*Pelecopsis paralella*, *Erigone atra*). An interesting finding is *Singa nitidula*, which prefers wet biotopes and occurs on this locality probably because of nearby willows and a pond. Simpson Index equals to 7.21, that could be compared to e.g. locality 1, which has similar Index. Localities 2 and 5 are similar in terms of species (Fig. 7). Both have very high Simpson Index (locality 2 – 11.9; locality 5 – 12.9). They are both dry and just with a little vegetation cover. On both localities, xerothermophilous species occur (*Aelurillus v-insignitus*, *Steatoda albomaculata*, *Xerolycosa nemoralis*, *Xerolycosa miniata*). On locality two, more species associated with sandy sites occur (*Zodarion germanicum*, *Zelotes petrensis*, *Attulus saltator*) whereas on locality 5 species requiring warm, but at least a bit shaded sites occur (*Xerolycosa nemoralis*, *Talavera aperta*) and also more generalist species are found in here (*Agyneta rupestris*, *Dictyna arundinacea*, *Phylloneta sisyphia*, *Pelecopsis paralella*). In conclusion, most xerothermophilous species occurred on warm and dry localities with little vegetation (locality 5 and 2, partly 3), whereas only a small amount of species occurred on extreme locality 4. Locality 1 had its own specific fauna composed mainly from generalists or hygrophilous species. In terms of Red-list species, most of them also occurred on non-extreme warm and dry sites (1 VU and 4 LC on locality 2, 3 LC on locality 5, 1 VU and 2 LC on locality 3, 3 LC on locality 1 and 2 LC on locality 4).

For Auchenorrhyncha (Fig. 6), we can notice that with decrease of percentage of vegetation cover the number of species also declines. Besides that, distribution of species is probably caused by occurrence of host plants and differences in humidity and sun exposition on our localities. Because of low vegetation cover and just very few plant species (Tab. 2), locality 2 and 4 had extremely species poor planthopper and leafhopper fauna, there were mostly species that normally live in other nearby biotopes and occurred on this locality by accident (*Balclutha punctata*, *Errastunus ocellaris*, *Stenocranus major*, *Hardya tenuis* (which is thermophilous, but prefers shady biotopes, which is not the case of localities 2 and 4)). However, there was one species, *Psammotettix poecilus,* which requires sparse *Calamagrostis* plants on open and exposed sites. This species was very abundant on site 2 and was also present on site 4, being the only specialist on this type of biotopes. Simpson Index of both localities is low, being 1.23 on locality 2 (because of low number of species and high amount of *Psammotettix poecilus*) and 2.57 on locality 4 (because of low species number and abundances). On locality 1, species that prefer (moderately) wet habitats have been found (*Sagatus punctifrons*, *Cicadella viridis*, *Stenocranus major*, *Conomelus anceps*) or generalists inhabiting various habitats (*Javesella pellucida*, *Macrosteles laevis*, *Laodelphax striatella*). Simpson Index is 4.36. Localities 3 and 5 have similar fauna, mainly because of occurrence of species preferring warm sites with slightly sparse vegetation (*Anaceratagallia ribauti*, *Psammotettix confinis*, *Macrosteles quadripunctulatus*). Also, generalist species occur in here (*Macrosteles laevis*, *Macrosteles sexnotatus*, *Euscelis incisus*). Simpson Index is 3.11 for locality 5 (probably because of high numbers of *Marcosteles quadripunctulatus* and 7.21 for locality 3. Two NT Red-listed species were found, *Sagatus punctifrons* on locality 1 and *Psammotettix poecilus* on localities 2, 4 and 5.

For Heteroptera, no trend was observed (Fig. 8), but we can see, that localities do have specific fauna. Species composition is probably caused by humidity, sun exposition and vegetation cover rather than soil texture or penetrability. On locality 4, species associated with warm and sun exposed sites occurred (*Drymus sylvaticus*, *Acalypta marginata*) as well as generalist species that prefer other biotopes but can survive on this site as well (*Stenotus binotatus*, *Stenodema calcarata*, *Rhyparochromus pini*). Simpson Index is equal to 6. On locality 1, mostly hygrophilous species occurred (*Saldula saltatoria, Saldula pallipes, Saldula arenicola*) or generalist species (*Trigonotylus caelestialium*, *Stenodema calcarata*, *Cymus claviculus*, *Cymus melanocephalus*). Simpson Index was the lowest (4.32), this is probably caused by extremely high abundances of species strictly associated with this site (*Saldula* species). Locality 5 shares species *Cymus melanocephalus* and *Cymus claviculus* with locality 1. Mentioned species mostly prefer moist habitats with their host plant (*Juncus* spp.), but despite of rather unusual presence of *Juncus* on locality 5, they also occurred here. Another unusual and interesting finding is *Acalypta carinata* – a lace bug that lives in moist woods in moss or on dead wood. The rest of the species mostly prefer warm sunny sites with sparse vegetation (*Chlamydatus pullus*, *Chlamydatus saltitans*, *Nysius ericae/thymi*, *Lopus decolor* (this species prefers more overgrown sites, but doesn't necessarily require them), *Nabis punctatus*). Simpson Index is 5.74. On locality 2, mostly generalists appear (*Aelia acuminata*, *Lygus rugulipennis*, *Plagiognathus arbustorum*), but also species associated with warm sites (*Lopus decolor*, *Nysius senecionis*). Simpson Index is 7.36, which is quite high, but is probably caused by low abundances of all species. Locality 3 shares species with both locality 5 and 2, mostly xerothermophilous species (*Lopus decolor*, *Nysius ericae/thymi*, *Nysius senecionis*, *Chlamydatus pullus*) or generalists (*Stenodema calcarata*, *Lygus rugulipennis*, *Trigonotylus caelestialium*, *Plagiognathus arbustorum*). However, locality 3 has even more species associated with warm and at least partially exposed biotopes (*Bathysolen nubilus*, *Trapezonotus arenarius*, *Ortholomus punctipennis*). Simpson Index is 8.71, being the highest among Heteroptera. Only one Red-list species was found – *Acalypta carinata*, EN, on locality 5.

For Coleoptera, PCA and Simpson Index estimation was only performed on Carabidae family (Fig. 10), because of low abundances and species numbers of the rest of beetles. No trend was observed, but we can clearly see very specific species composition of different sites. Those differences are mostly caused by humidity and vegetation cover, but there are some sand specialists that require sandy soil (*Harpalus flavescens*, *Cylindera arenaria*). We can also notice, that with declining percentage of vegetation cover, the number of species decreases, too. On locality 1, we found a large amount of species preferring open and wet (or only wet) habitats (*Agonum sexpunctatum*, *Ocydromus femoratus*, *Bembidion quadrimaculatus*, *Chlaenius vestitus*, *Oodes helopioides*, *Elaphrus riparius*). Besides those species, sandy shores specialist occurred on this locality (*Omophron limbatum*, *Elaphropus diabrachys*). Simpson Index is 5.18, which was one of the highest and indicates stable and quite species-rich fauna. On locality 3, the second largest amount of species was found, but those species were (again) mostly eurytopic generalists (e.g. *Nebria brevicollis*, *Anisodactylus binotatus*, *Pseudoophonus rufipes*, *Harpalus affinis*, *Metallina lampros, Amara* species). Simpson Index was similar to locality 1, but it was even higher, being 5.96. On locality 5, similar species were found, mostly those able to survive on dry, arable-like land (*Pseudoophonus rufipes*, *Metallina lampros*, *Harpalus affinis*), but also one specialized psammophilous species, *Harpalus flavescens*, was found. Simpson Index was slightly lower, being 4.17, this is probably caused by smaller number of species. Locality 2 hosted also some of the generalists, but those were in low abundances (e.g. *Nebria brevicollis*). However, slightly higher abundances of psammophilous species than on locality 5 occurred (*Cicindela hybrida*, *Harpalus flavescens*). Finally, on locality 4, almost only psammophilous specialists occurred, and mostly in very high abundances (*Cicindela hybrida, Cylindera arenaria*, *Harpalus flavescens*), some steppe inhabiting species also occurred here (*Dolichosoma lineare*). *Cylindera arenaria* is very interesting and rare species, primarily occurring on gravel-sandy river banks, that nowadays almost only occurs on substitute habitats such as sedimenting basins. Both localities 2 and 4 have low Simpson Index (1.96 for locality 4 and 3.52 for locality 2), this is probably caused by low number of species (almost all of which are, however, specialists).

Five species of Orthoptera were found. Surprisingly for us, localities did have quite specific fauna. *Tetrix undulata*, a hygrophilous species, occurred in high numbers on locality 1 (one was also found on locality 5). *Tetrix tenuicornis* is more tolerant to dry habitats, therefore it occurred on localities 1, 3 and 4. *Tetrix subulata* also prefers wet habitats and was only found on locality 1. *Chorthippus mollis* preferring warm habitats with sparse vegetation, occurred on localities 3 and 5.

Remaining groups of arthropods found are not statistically processed because of the lack of data. Although some interesting species from these groups occurred in the sandpit. Isopod species, *Armadillidium vulgare*, prefers dry and sun exposed sites, which corresponds with conditions of locality 4. *Polydesmus inconstans* is a pioneer species of milipede and was found on localites 3 and 4. Interesting is the finding of *Leptoiulus proximus*, hygrophilous species, on the driest locality from all of them. It probably got there from nearby forest or nearby vegetation by water.

Following literature was used for obtaining information about ecology of mentioned species: Macek et al. (2017), Buchar et al. (2002), Nickel et al. (2003), Wachmann et al. (2004, 2006, 2007, 2008), Kočárek et al. (2013), Kocourek et al. (2017), Frankenberger (1959), Šilhavý (1971), Hůrka (2005), Tropek et al. (2011).

## Wetland Biotopes Biodiversity

All three wetland localities (w1 – w3) were surveyed from March to July, once per month, using funnel traps and 2 minutes of individual catching around the trap. Additional catching of dragonflies (Odonata) was done, if these were present. Localities w1 and w3 are shallow sandy pools and w2 is a large lake with muddy bottom.

Altogether 58 aquatic arthropod and mollusk species were found (Insecta: Odonata 10, Coleoptera 21 (1 NT), Ephemeroptera 2, Megaloptera 1, Trichoptera 1, Diptera 4, Heteroptera 12, Gastropoda: Pulmonata 3, Bivalia: Unionida 1, Cardiida 1) at w1, w2 and w3 localities. Vertebrates were represented by 3 amphibian species (Anura 2 (1 VU, 1 NT) and Caudata 1 (1 VU)), 1 reptile species (Squamata 1 (1 NT)). Seven bird species strictly associated with wetland biotopes (Anseriformes 2 (1 LC, 1 VU), Ciconiiformes 1 (1 VU), Charadriiformes 1 (1 EN), Coraciiiformes 1 (1 VU) and Pelecaniformes 2 (1 NT)) were recorded, too.

Speaking about aquatic arthropods, altogether 21 specialists for localities w1, w2 or w3 were recorded. Locality w1 (sandy pools) hosted 30 species (9 specialist – 30%), locality w2 (lake with muddy bottom) hosted 16 species (2 specialists – 12.5 %) and 34 species (10 specialists – 29.4 %) were found at locality w3 (sandy pools) (Fig. 11). Number of species specialized for sandy pools (w1 and w3) was 12. It is 26 % of total number aquatic arthropods found in the sandpit. Both specialist for locality w2 were typical pond species. 10 generalist species found at all sites were recorded.

Water beetles (Coleoptera) found in the sandpit were mainly generalists and species associated with biotopes with some vegetation were also present (16 species). Following interesting species with specific environment requirements were recorded: *Agabus sturmii* (small pools, vegetation), *Dytiscus circumflexus* (often sandy biotopes, uncommon species), *Hydroglyphus geminus* (shallow sandy biotopes), *Laccobius gracilis* (NT, sandy pools) and *Nebrioporus canaliculatus* (typical pioneer species) (Boukal et al. 2007).

Adult dragonflies (Odonata) were represented by 9 generalist species, however, *Ischnura pumilio* and *Sympecma fusca* are not very common. Five species were present at w1 and w3 sites, 4 taxa were specialist for w1 or w3 locality. *Anax imperator* larvae was found at locality w3, but no adults were collected later. Larvae of one *Coenagrion* species was the only dragonfly found at locality w2.

For amphibians and reptiles w1 and w3 biotopes seems to be more suitable than w2 site. All amphibian and reptile species (*Bufo bufo*, *Pelophylax esculentus*, *Lissotriton vuglaris* and *Natrix natrix*) were found, there. Locality w2 was inhabited only by Edible frog (*Pelophylax esculentus*). All observed amphibian and reptile species are reproducing in w1 and w3 localities.

Several bird (Aves) species were found at aquatic localities w1 – w3 including 6 Red-list species (1 LC, 1 NT, 3 VU, 1 EN). Interesting was finding of two burrowing species, Sand Martins (*Riparia riparia*) and Common Kingfisher (*Alcedo atthis*). Besides burrowing species two rare birds associated with sand shores (Common Sandpiper – *Actitis hypoleucos* (EN) and Little Ringed Plover – *Charadrius dubius* (VU)) were recorded outside our research localities.

Two Red-list plants (liverwort *Ricciocarpos natans* (LC) and bladdewort *Utricularia australis* (LC)) were recorded at locality w1.

# Discussion

On all five localities, different species with different requirements occurred. In most cases, major reasons to the distribution of the species were humidity and vegetation cover.

In hymenopterans, however, soil texture and soil penetrability seem to play a major role (Fig. 9, Fig. 5) – a lot of hymenopterans nest in burrows they dig themselves and they seem to have preferences for different soil characteristics (Srba et al. 2012). On localities 2 and 4, which both had similar soil texture (Fig. 2), mostly specialists of sand dunes occurred, sometimes in huge amount. This is caused by similarity of our localities and sand dunes, mainly due to low penetrability, dry and very fine sand and low vegetation cover. On locality 4, which is even drier and comprises the finest sand, even more species strictly associated with sand dunes occurred (*Alyson spinosus*, *Andrena barbilabris*, *Oxybelus bipunctatus*, large amounts of *Lasioglossum sexstrigatum* and *Smicromyrme rufipes*). On the other hand, localities 1 and 3 hosted only a small amount of specialists and were mainly inhabited by generalists and their parasites (e.g. *Lasioglossum calceatum*). This should be caused by higher penetrability and bigger sand grains abundance (Tab. 1). Locality 5 stands somewhere in the middle speaking about geological conditions and biodiversity. It hosts both specialists (but not too big number of them) and generalists. Because of stated reasons, we believe that localities 4 and 2 (especially number 4) have the highest potential for conservation of endangered and rare species – they are both inhabited by high number of specialists (some of them appear in Czech Red-list), whose suitable refuges are still more rare.

The rest of species were mostly distributed within the sandpit depending on the humidity and vegetation cover of selected sites. Locality 1 had almost in all groups of arthropods specific species composition, because (in comparison to other localities) it was very humid (Fig. 3). Mostly generalists or hygrophilous species occurred on this site – some of them are included in Czech red list. However, those Red-listed species on locality 1 mostly require open wet habitats, which can form basically on any kind of substrate. That doesn't mean this locality is priceless for biodiversity conservation – it means there are localities on sandpit that are of bigger value because of their specific origin. Locality 3 was extremely species-rich (Fig. 5) but was mostly inhabited by generalists. This locality had the lowest number of Red-list species, although few Red-list species occurred here – most important would be *Centromerus incilium*, but we have to bear in mind, that this species can fly long distances and was found on this locality only once, so it could be just a random visitor. Sadly, when this site overgrows with pines, even those generalists will disappear, and species richness will drop to near zero. Locality 5, again, stands somewhere in the middle. It hosts species that are either generalists or prefer warm open biotopes. Just like locality 1, this type of biotope doesn't necessarily originate from sandy soil, so its biodiversity potential is not as high as of open dry localities with fine sand (locality 2 and 4). Locality 4 was mostly species-poor (besides hymenopterans), because of its extreme conditions and almost no vegetation cover. Those few species that live here, are either generalists (in low abundances) that managed to survive even in here, or very stenotopic specialists (e.g. *Cylindera arenaria*, *Harpalus flavescens*). Locality 2 came out as the most valuable site for non-hymenopterans arthropods. Not many species were found here, but those were mostly associated with warm, dry and open habitats with very sparse vegetation that mostly occurs on sandy soils. The highest number of Red-list species were collected in there (9 species, Fig. 5). This locality seems to be the more "moderate version" of locality 4 with very low humidity, and almost missing vegetation cover which does not allow almost any species (besides hymenopterans) to survive in here. Locality 2 provides similar conditions to locality 4, but is not so dry and more shadow-providing obstacles and vegetation occur there.

Therefore, we believe that this locality is, together with locality 4, the most valuable of all sites of the sandpit. Those localities and localities similar to them should be left for the natural succession (or occasionally disturbed) and should not be technically restored in order to preserve as much biodiversity as possible.

On the other hand, locality 3 (restoration in early stage) seems to be already very poor (sandpits restored using pine plantation are generally species-poor – see Řehounek et al. 2015, Šebelíková et al. 2015). Although there was the highest amount of species (Tab. 1), almost all of them were generalists present in surrounding cultural landscape. Also, there were only 3 Red-list species present on this site, which is 3 times less than on the most valuable site (Fig. 5). This site will soon overgrow by pines and even the generalists will disappear and only few species will remain. Thus we can state that this site has the lowest biodiversity conservation potential.

Comparing our survey to a more complex study of hymenopterans in sandpits (Heneberg et al. 2012), we noticed a few differences. First of all, species *Bembecinus tridens* and *Trypoxylon minus*, which were very abundant in sandpits included in that study, didn't occur in Planá sandpit at all. Also, species *Lasioglossum sexstrigatum*, which was very abundant in our study, didn't reach such abundancies in the mentioned study – this could be caused by presence of localities with very fine sand, with which is this species associated. We argue that absence of mentioned hymenopterans might be caused by insufficient sample size (we only sampled on one sandpit). On the other hand, just like in the mentioned study, we observed high number of sand specialists (mentioned above) occurring only on localities with dry fine sand, low penetrability and sparse vegetation.

If we compare our study to extensive research of spiders inhabiting sandpits (Heneberg et al. 2014), we obtained quite similar results. Number of species was lower in Planá quarry, because our research was carried out only on one sandpit, whereas the study mentioned above examined numerous sandpits for longer time period. Just as stated in the study, only low number of species were found on localities with small amount of vegetation cover. Also, localities with the highest number of Red-listed species were from 6-15 years old and only with sparse vegetation, which corresponds with the study. Species composition of locality 3 (e.g. *Zora spinimana*, *Zelotes subterraneus, Drassyllus pusillus, Trochosa ruricola, Pachygnatha degeeri*) noticeably corresponds to species composition of reclaimed sites stated by mentioned study.

Study by Řehounková et al. (2012) examined biodiversity in nearby sandpit Cep II and thus provides a good comparison for species between Planá and Cep II sandpits. In Cep II, 81 spider species were found, which is only a slightly higher number than in Planá sandpit. Species composition was similar, but Cep II seems to host wider range of hygrophilous specialists, some of them does not occur in Planá sandpit (*Arctosa cinerea*, *Clubiona juvenis*). In contrary to that, Planá sandpit seems to host richer fauna of xerothermophylic specialists, some of them did not occur at Cep II (*Steatoda albomaculata*, *Clubiona subtilis*, *Centromerus incilium*). Similarly, psammophilous and xerothermophilous species of beetles that were not found at Cep II occurred in Planá sandpit (*Cylindera arenaria*, *Harpalus flavescens*). 73 species of Hymenoptera were found at Cep II, while 59 species were found in Planá sandpit. We believe that fauna of hymenopterans in Planá sandpit is even richer and was not sufficiently examined during our research, so carrying out another research focused on hymenopterans might discover new species to this sandpit. At Cep II, more species not associated with fine sand occurred (e.g. species of Vespidae or Apidae), but species composition of those associated with sand dunes was quite similar to the one in Planá sandpit (e.g. *Pompilus cinereus*, *Oxybelus bipunctatus*, *Alysson spinosus*, *Cerceris arenaria*). However, some species that were very abundant in Planá sandpit were completely missing at Cep II (*Smicromyrme rufipes*, *Lasioglossum sexstrigatum*) or were present in smaller abundances, but missing completely at Cep II (*Miscophus ater*, *Lindenius pygmaeus*, *Methocha ichneumonoides*). Those species are mostly strictly associated with sand dunes (or occur there in such abundances). Just like with spiders, it looks like Planá quarry (in comparison to Cep II) provides habitats for more xerothermophylic species and sand dune specialists – it seems that fine sanded sedimenting basin on locality 4 hosts unique communities of hymenopteran species associated with sand dunes, and more humid locality 2 with more vegetation serves as a good refugium for xerothermophylic species of mainly spiders and other arthropods.

Speaking about aquatic biotopes, localities w1 and w3, shallow sandy pools with some vegetation, seem to be much more important for rare arthropod species and specialists (Fig. 11). Locality w2, big lake with muddy bottom, has only about half species recorded comparing to w1 and w3, almost no specialist occurred (Fig. 11). Specialists and only Red-list species (*Laccobius gracilis*, NT) found, were present in pools with sandy bottom. All amphibian and reptile species preferred sandy pool biotopes to muddy lake. Early succession stands formed on oligotrophic soils seem to be a key factor for rare species conservation (Řehounek et al. 2015). It might be interesting to compare biotopes formed on coarse grained and fine grained sands, which were not present in the Planá sandpit, in the future.

Some bird species dependent on sandy biotopes occurred in the quarry, too. Sand Martins (*Riparia riparia*) and Common Kingfishers (*Alcedo atthis*) need sandy walls for burrowing. According to Heneberg (2009), the tunnel depth decreases with penetrability increase and fine-grained sands with low penetrability are not suitable (because of instability), either. According to our observations, average texture sands with average penetrability are the most suitable for burrowing species nesting. Burrows in fine sand piles were observed, but caused wider entrances and probably easier predation onto nests. Little Ringed Plover (*Charadrius dubius*), observed in the pit lays eggs directly onto the soil and eggs have camouflage coloring reminding gravel. We suppose, that gravel sediments (or coarse grained sands) are the most suitable substrate for Little Ringed Plover´s eggs hiding.

# Conclusions

During our research, 344 species of invertebrates (25 listed in national Red-list), 30 species of vertebrates (28 in national Red-list), 46 species of vascular plants (3 in national Red-list) and 3 species of bryophytes (2 in national Red-list) have been found in total at Planá sandpit.

This indicates that Planá sandpit is of great biological value and provides a refuge for high number of endangered and specialist species. Sandy areas with sparse vegetation (~ 70-80 % bare ground), low humidity (~ 4 wht. %) and fine sand (> 0.25 mm 80 wht. % and more) with low penetrability (~ 0.2 kg/cm$^2$) are the most valuable, providing a refuge for high number of specialists (Fig. 5) (e.g. rare and very stenotopic Tiger Beetle *Cylindera arenaria*), that primarily inhabits either sand dunes or warm and open, steppe-like biotopes. For hymenopterans, soil texture seems to play a major role in habitat preference (Fig. 9), while in other arthropod groups, mostly spiders, percentage of vegetation cover and humidity seem to be a key factor. On the other hand, a restored site (even in early stage of restoration) with planted pines hosts almost only generalist and common species that can survive almost anywhere in cultural landscape. This site will eventually overgrow with pines and biodiversity will drop to near zero, so its conservation potential is very low. In case of aquatic biotopes, both sandy pools localities host almost three times more arthropod species than the main lake with a muddy bottom. The muddy lake hosted almost no specialists and has low conservation potential, compared to ~ 30% specialists of total count of species found in sandy pools, which makes it important for nature conservation.

# Restoration Recommendations for the Planá Sandpit

Following points take local conditions and current restoration plan (GET, s. r. o. 2015) into account as much as possible. Only partial changes with small impact on landscape and restoration financing are suggested.

- Area suggested for Sand Martins (*Riparia riparia*) nesting (area F) seems to be very small (50*25 m), comparing to forest restoration (about 42 ha). We suggest preserving larger area (about 100*25 m), current localization seems to be well picked. Sand in the area is stable, medium grained and about 5m nesting wall can be created.
- The lake created at area F is nowadays very deep with steep banks. We recommend to partly fill the lake with sandy(!) substrate to make gradual banks with depth of 150 cm maximum, depth diversity is needed. Bankline of the lake should be diverse, as well. Splitting of the lake to create smaller pools is recommended.
- We recommend to use small fraction sand (from sedimenting basin or unused small fraction deposits) to create small sand dune(s) at area F. Sand dunes disappeared from the Czech landscape and many specific rare species are bonded to them (Tropek et al. 2011).
- Area F should be actively disturbed to create mosaic of different succession stages and biotopes. Additional forest reclamation of area (as suggested in reclamation plan) should not be realized.
- The option of creating Planá sandpit education biocentre in enlarged area F (Appendix 6) seems to be suitable solution for area preservation. Possibility of creating Planá biocentre will be discussed with Českomoravský štěrk company, land owner and other authorities during autumn and winter.
- The coastline of the main lake should be varied, gradual, with no organics. Creating of small individual pools (near the main lake, but not connected to it) or small islands from the lake bottom sediment is likely.
- All protected species and other rare species should be transferred to spare biotopes which should be prepared a few years before transfer. The spare biotope needs at least 2 years of spontaneous succession. Transfer of some ecosystem forming plants from wetland biotopes in the sandpit can help the process to make spare biotope suitable for animal transfers.
- Wetland biotopes (w1, w3) and sedimenting pools should stay uncovered as long as possible.
- Around areas preserved for spontaneous succession should be used mostly sandy material with low organic content values to prevent eutrophication of target oligotrophic biotopes. Fertilizers and pest repellents should not be used in areas surrounding spontaneous succession areas to create “buffer zone” at least 5 m wide.
- Repellents against *Hylobius* species should not be used at all, because no *Hylobius* parasitizing on pines was found and these repellents would be just the waste of money and unnecessary danger for the environment.
- Tree seedlings used to forest reclamation should be only native species. Northern red oaks (*Quercus rubra*) and other alien species sometimes used in forest reclamations should not be used at all.

# Refereces (see Appendix 7)

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# Appendix

1 – Maps

Fig. 1: Map of Planá sandpit with research localities marked.

2 – Results

Tab. 1: Selected locality characteristics measured during the research.

Fig. 2: XY-graph showing grain size distribution at sampled sites.

Fig. 3: Column graph showing soil humidity, its variation within localities and in the time.

Fig. 4: Column graph showing soil penetrability measured at research localities and its variation coefficient.

Fig. 5: Column graph showing total count of species and Red-list species found at research sites.

Tab. 2: Phytosociological relevés made at localities.

Fig. 6: PCA of Auchenorrhyncha species and their distribution among localities.

Fig. 7: PCA of Aranea species and their distribution among localities.

Fig. 8: PCA of Heteroptera species and their distribution among localities.

Fig. 9: PCA of Hymenoptera species and their distribution among localities.

Fig. 10: PCA of Carabidae species and their distribution among localities.

Fig. 11: PCA of aquatic Coleoptera and Heteroptera species among aquatic localities (w1 – w3).

3 – Species List of Plants

Tab. 3: List of vascular plant species found in the Planá sandpit.

Tab. 4: List of bryophyte species found in the Planá sandpit.

4 – Species List of Animals

Tab. 5: List of arthropod species found in the Planá sandpit.

Tab. 6: List of vertebrate species found in the Planá sandpit.

5 – Red-list Species

Tab. 7: List of Czech Red-list species found in the Planá sandpit.

6 – Planá Sandpit Education Biocentre

Txt. 1: Planá Sandpit Education Biocentre.

Fig. 12: Planá Sandpit Education Biocentre – area plan.

Fig. 13: Planned Sand Martins´ nesting area and Planá Sandpit Education Biocentre localisation.

Fig. 14: Contour lines of height above the sea level and supposed height of nesting wall.

7 – References

8 – Information brochure “Geology of Sandpits”

## Appendix 1: Maps

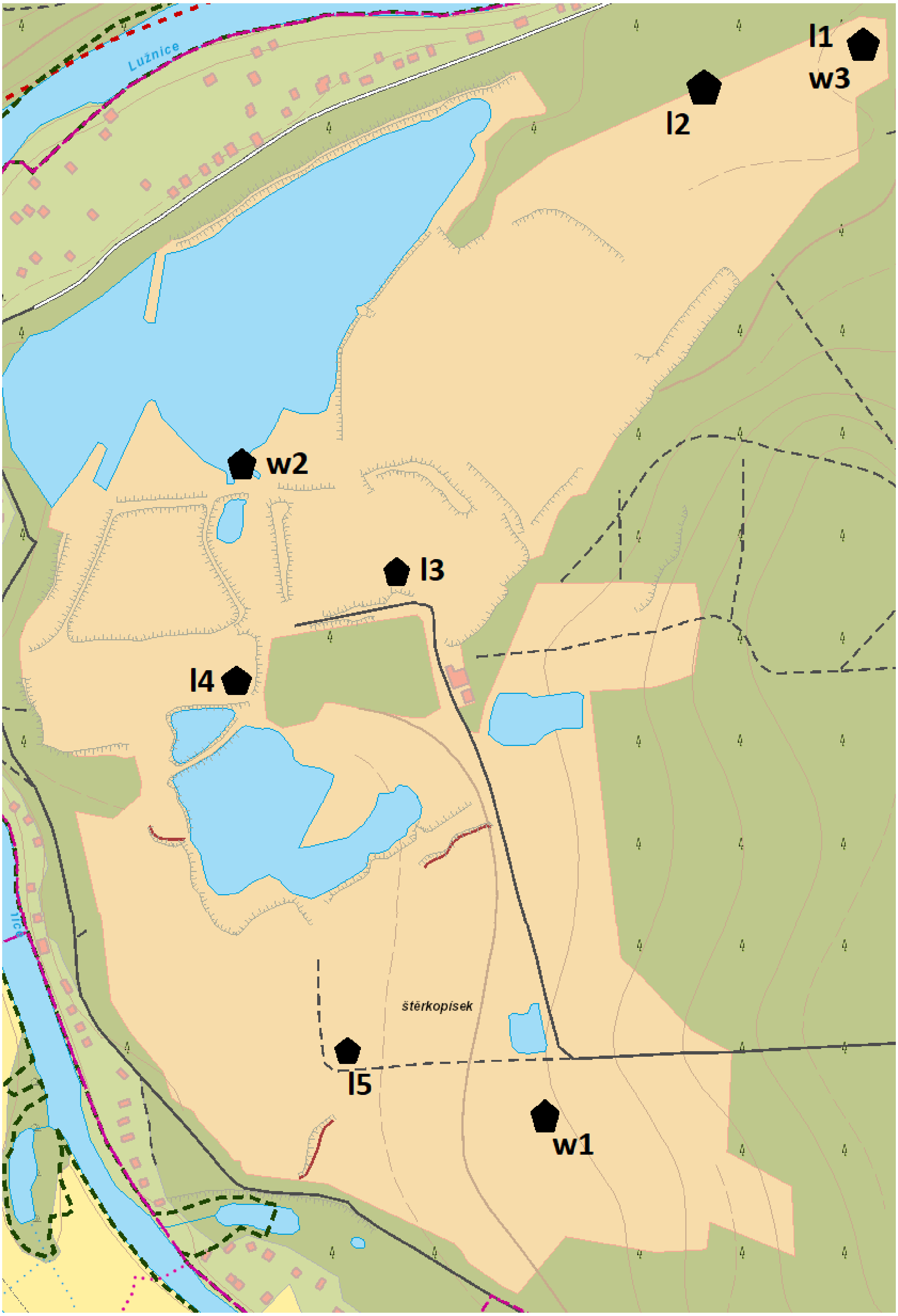



**Fig. 1**: Map of Planá sandpit with research localities marked.

Map of Planá sandpit with position of research localities (1 – 5 and w1 – w3). Author of map: ČÚZK and CENIA. Available at https://geoportal.gov.cz/web/guest/map?permalink=4431e4dc2ba35a207b437d363fc1d154.

## Appendix 2: Results

| Locality | Soil texture (mass %) | | Soil humidity (mass %) | Soil penetrability (kg/cm$^2$) | Years after abandonment | Vegetation cover (%) | Arthropod species found | Red-list species | Red-list species (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Coarse (32-1 mm) | Fine (>1 mm) | | | | | | | |
| 1 | 43 | 57 | 9.4 | 1.8 | 5 | 51 | 91 | 8 | 8.8 |
| 2 | 2 | 98 | 6.5 | 0.2 | 8 | 28 | 67 | 10 | 14.9 |
| 3 | 54 | 46 | 3.4 | 1.5 | 12 | 83 | 118 | 3 | 2.5 |
| 4 | 0 | 100 | 3.6 | 0.2 | 15 | 22 | 67 | 9 | 13.4 |
| 5 | 23 | 77 | 4 | 0.8 | 14 | 40 | 101 | 6 | 5.9 |

**Tab. 1**: Selected locality characteristics measured during the research.

Notice significant correlation between soil texture, penetrability and vegetation cover vs. Arthropod species found and Red-list species (both absolute numbers and percent).

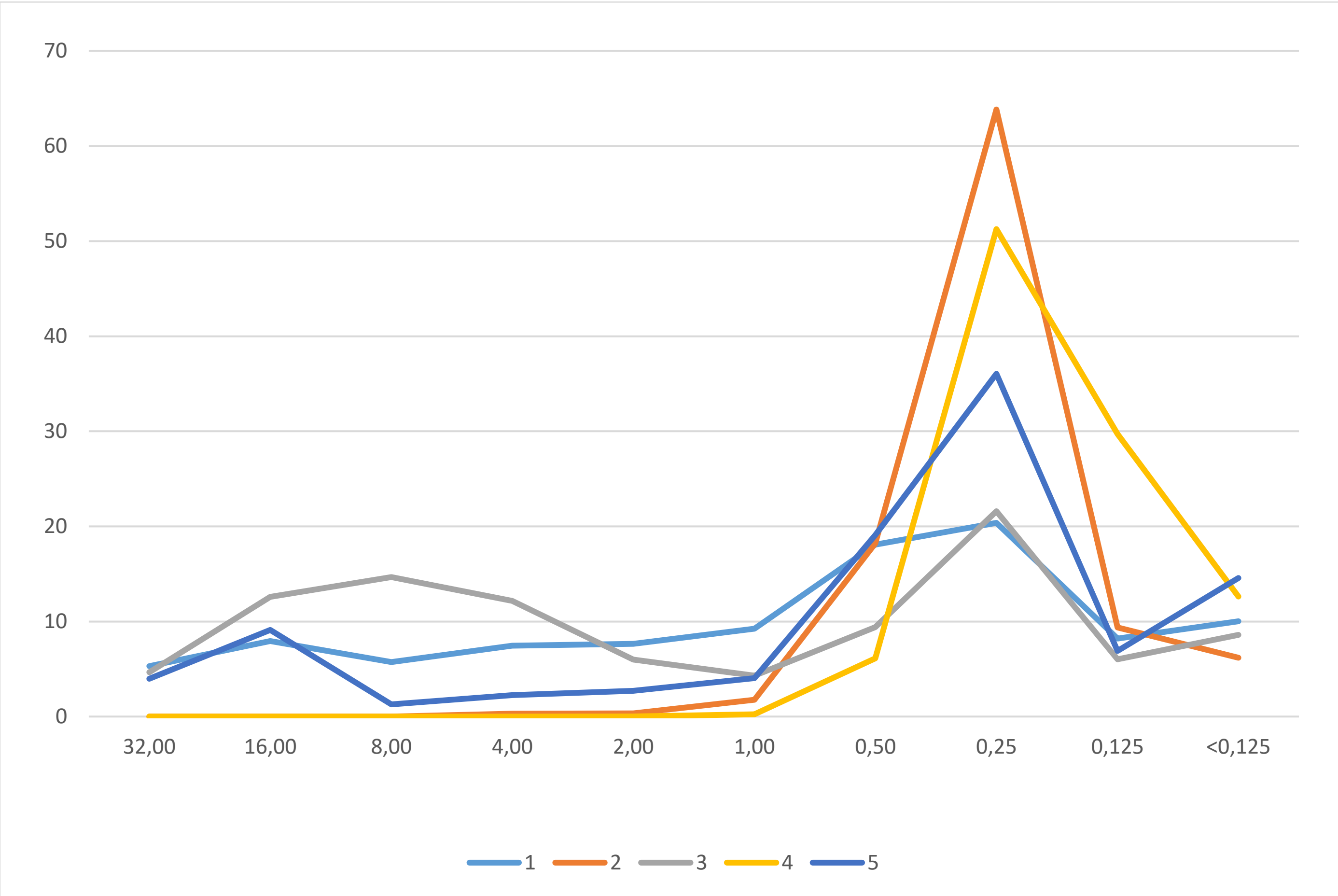



**Fig. 2**: XY-graph showing grain size distribution at sampled sites.

Graph of different fraction sizes (axis x) [mm] and its abundance (axis y) [%]. Colored lines represent localities 1 – 5. Notice missing coarse fractions at localities 2 and 4.

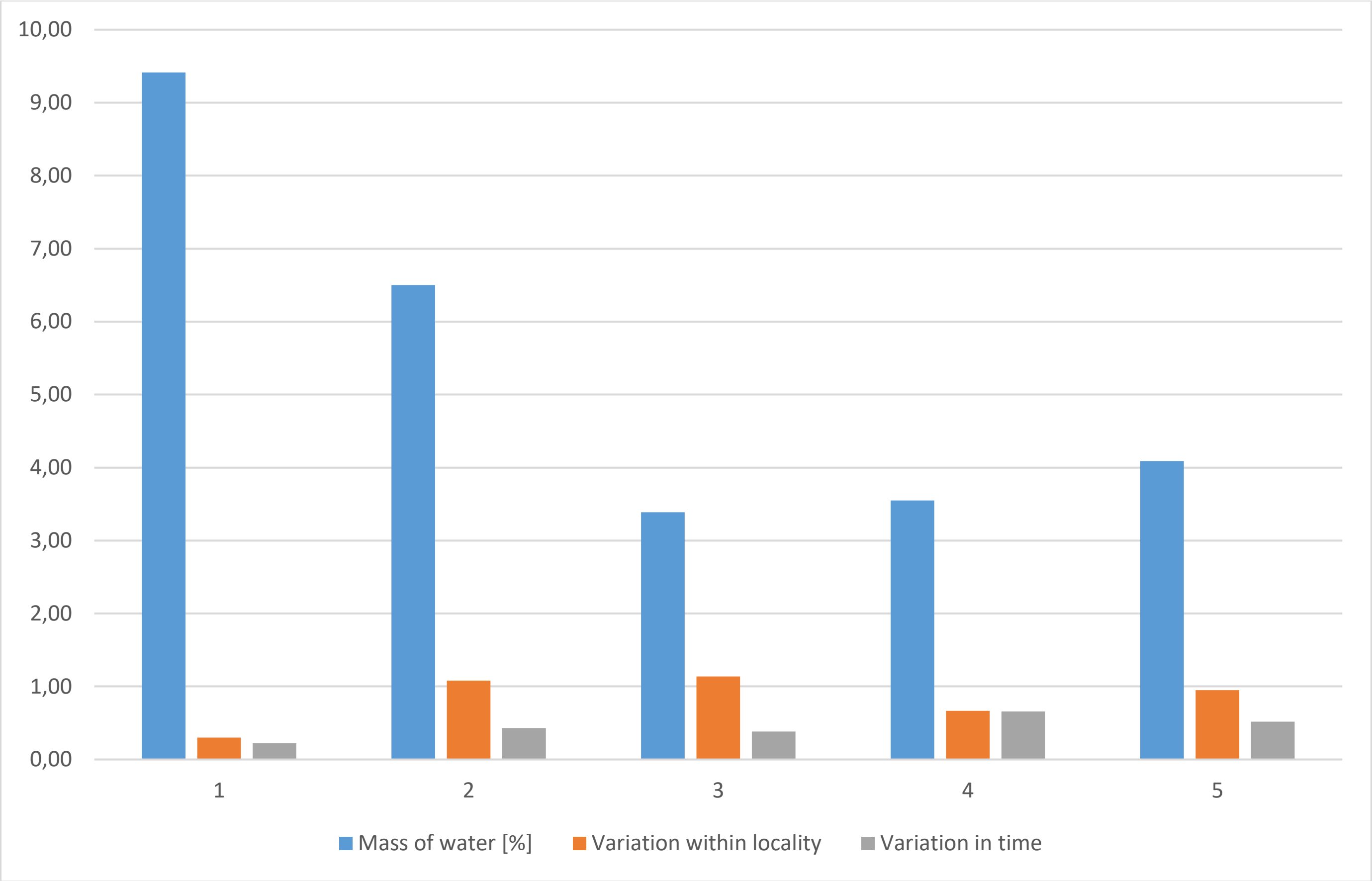



**Fig. 3**: Column graph showing soil humidity, its variation within localities and in the time.

Graph of soil humidity and its variation within localities and in the time. Localities are shown at axis x and values at axis y.

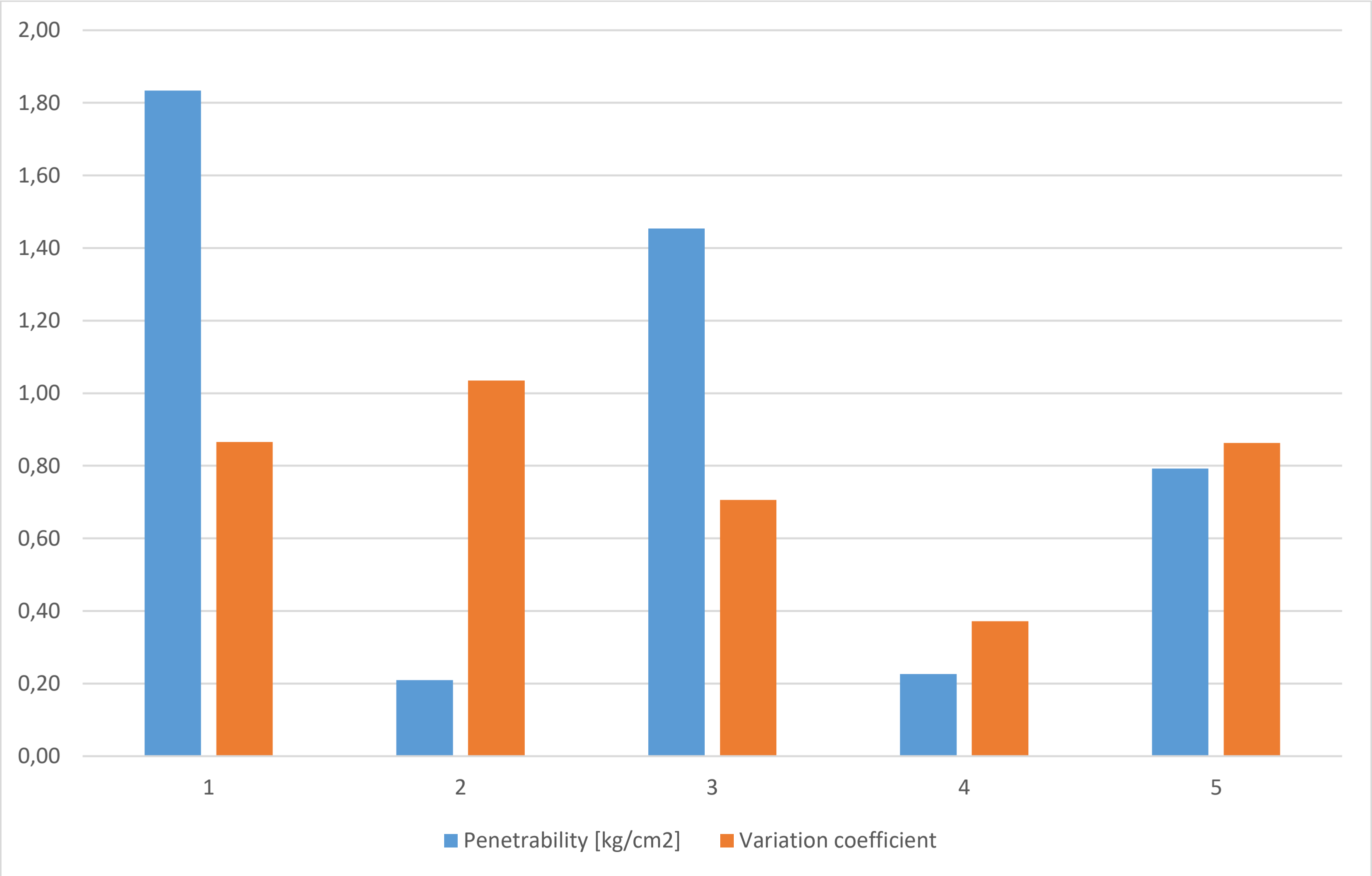



**Fig. 4**: Column graph showing soil penetrability measured at research localities and its variation coefficient.

Localities are shown at axis x and values at axis y.

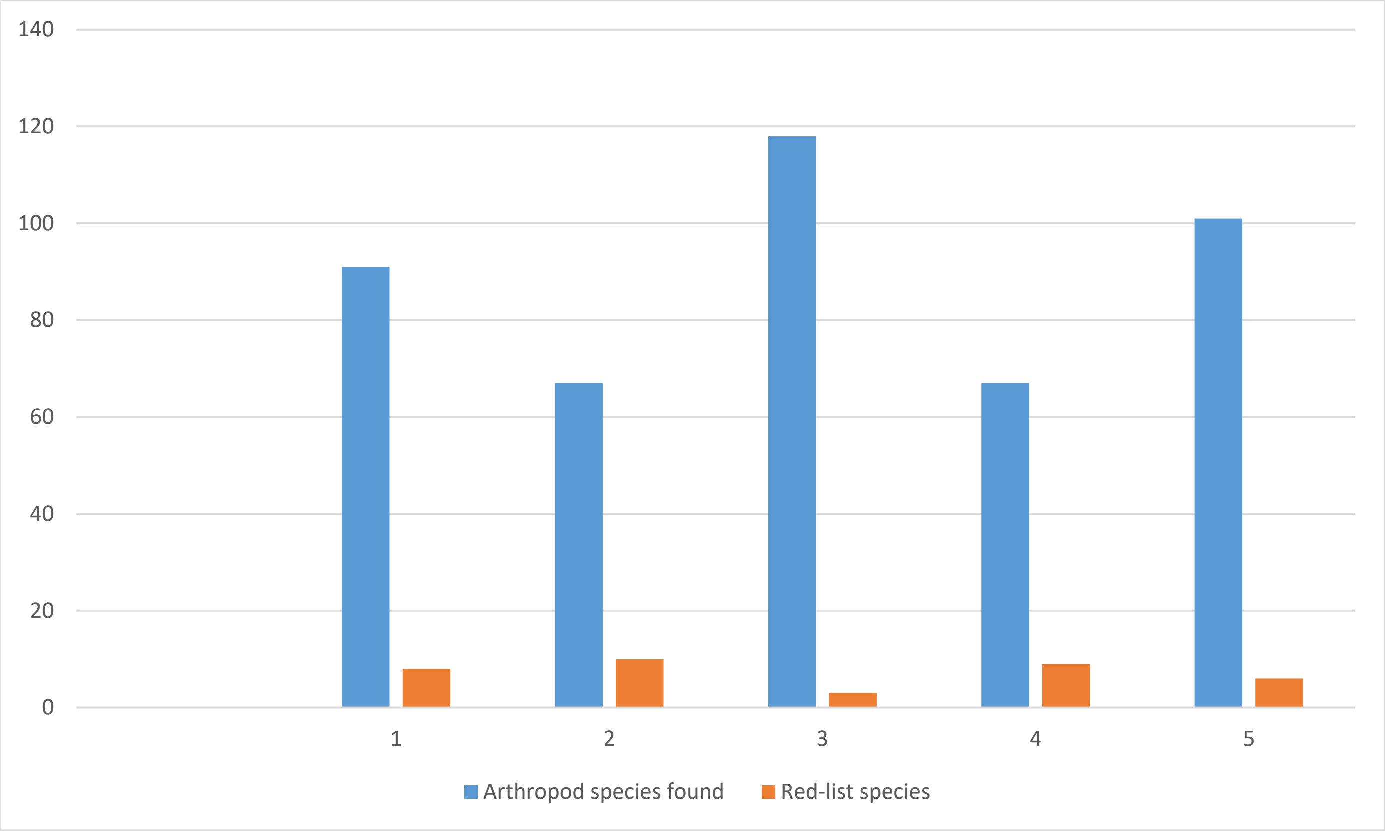



**Fig. 5**: Column graph showing total count of species and Red-list species found at research sites.

Localities are shown at axis x and numbers of species at axis y.

| Locality | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Relevé number | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Bare ground [%] | 45 | 15 | 83 | 46 | 89 | 38 | 8 | 4 | 24 | 90 | 58 | 85 | 69 | 67 | 45 |
| Obstacles [%] | | 5 | | 5 | | 38 | 12 | 4 | 8 | | | | | | |
| Species recorded [%] | | | | | | | | | | | | | | | |
| *Agrostis capillaris* | . | . | . | . | . | . | 8 | 6 | . | . | . | . | 2 | 3 | . |
| *Agrostis* sp. | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . |
| *Agrostis stolonifera* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 |
| *Alisma plantago-aquatica* | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Alopecurus aequalis* | . | . | . | . | . | . | . | . | . | . | . | . | 2 | . | . |
| *Bellis perennis* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . |
| *Betula pendula* | . | 3 | 1 | . | . | . | . | 1 | . | . | . | . | . | . | 4 |
| *Bidens frondosa* | 3 | . | . | . | . | . | . | . | . | . | . | . | 1 | 4 | 3 |
| *Calamagrostis epigejos* | 6 | 7 | . | 27 | 5 | 5 | 28 | 36 | 24 | . | 14 | 7 | 2 | 11 | 22 |
| *Calluna vulgaris* | . | . | . | . | . | . | . | 4 | 2 | . | . | . | . | . | . |
| *Carex sp.* | . | . | . | . | . | 7 | . | . | . | . | . | . | 4 | 2 | 1 |
| *Cirsium* sp. | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . | . |
| *Conyza canadiensis* | . | . | . | 13 | . | . | 4 | . | . | . | . | . | 2 | . | 1 |
| *Cyperus fuscus* | 14 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Daucus carota* | . | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . |
| *Echinochloa crus-galli* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . |
| *Epilobium adenocaulon* | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . |
| *Filago arvensis* | . | . | 4 | . | . | 9 | 8 | 22 | 16 | . | . | . | . | . | . |
| *Fragaria vesca* | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . |
| *Hieracium* sp. | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . | . |
| *Hypochaeris sp.* | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . | . |
| *Juncus effusus* | 25 | . | . | . | . | . | . | 2 | . | . | . | . | 2 | . | 13 |
| *Juncus tenius* | . | . | . | . | . | . | . | 5 | 2 | . | . | . | 6 | . | 3 |
| *Luzula campestris* | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . |
| *Lycopus europaeus* | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Molinia caerulea* | . | . | . | . | . | . | . | . | . | . | . | . | . | 7 | . |
| *Parthenocissus quinquefolia* | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . | . |
| *Pinus sylvestris* | . | 5 | 7 | . | 3 | 3 | 16 | 6 | 6 | 90 | 14 | 8 | . | . | . |
| *Poa annua* | . | . | . | . | 3 | . | . | . | . | . | . | . | 5 | . | . |
| *Rubus* sp. | . | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . |
| *Salix herbacea* | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . |
| *Salix* sp. | 3 | 2 | 3 | . | . | . | . | . | . | . | . | . | . | . | . |
| *Senecio vulgaris* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 |
| *Spergularia rubra* | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 4 | 2 |
| *Tragopogon pratensis* | . | . | . | 2 | . | . | . | . | . | . | . | . | . | . | . |
| *Trifolium dubium* | . | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . |
| *Trifolium repens* | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Tussilago farfara* | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . | . |
| *Veronica officinalis* | . | . | . | . | . | . | 4 | 6 | 2 | . | . | . | . | . | . |
| moss | . | 63 | 2 | . | . | . | . | . | 11 | . | 14 | . | . | . | . |

**Tab. 2**: Phytosociological relevés made at localities 1 – 5.

Area covered by each relevé was 1 x 1 m. For more details see Metodics.

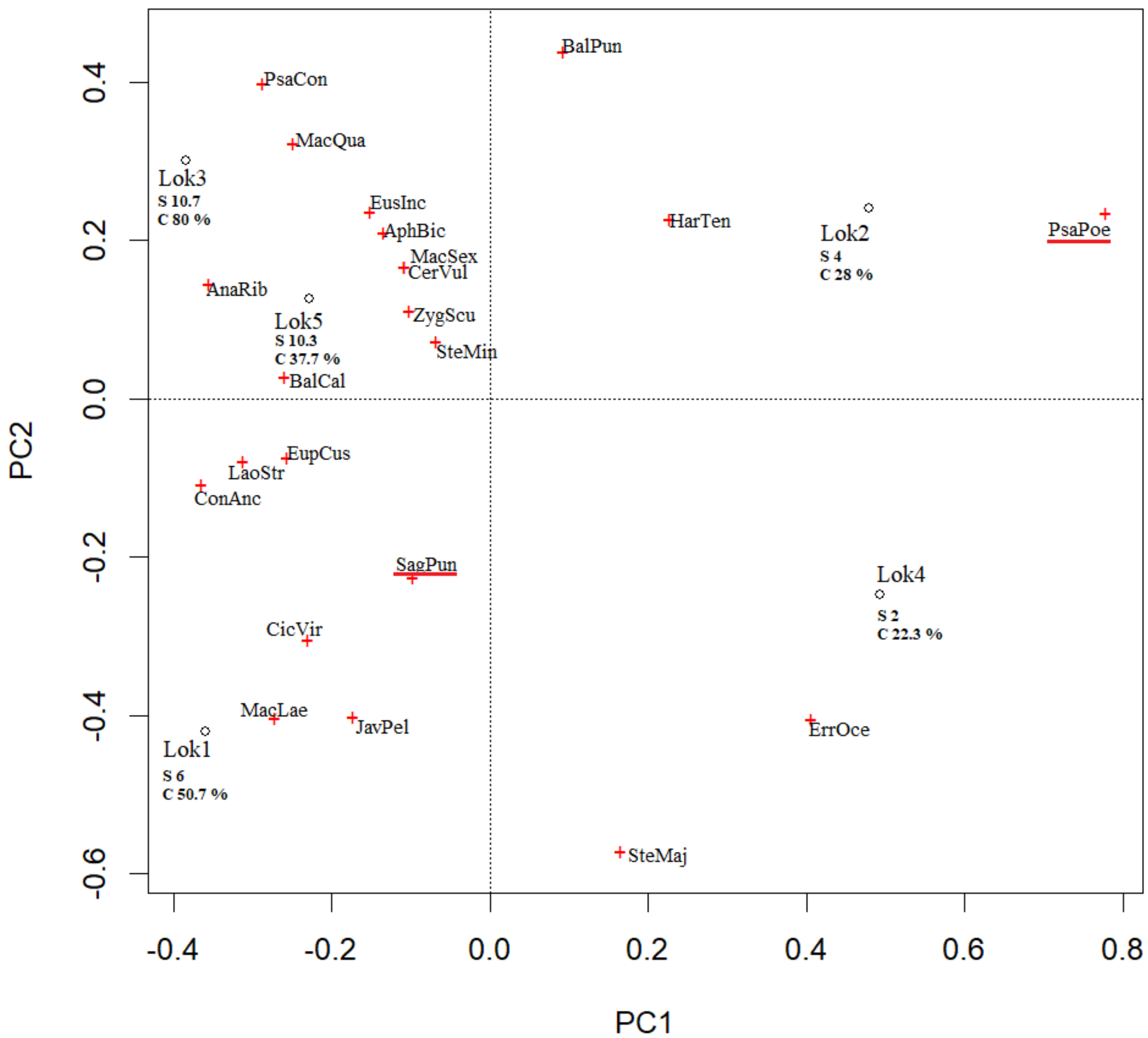



**Fig. 6**: PCA of Auchenorrhyncha species and their distribution among localities.

PCA of Auchenorrhyncha species and their distribution among localities (Lok1 – Lok5). Red-list species are underlined. Graph shows hygrophilous communities on locality 1 and high abundances of more generalist or thermophilous species on localities 3 and 5. Localities 4 and 2 host only small amount of species, but noticeable is very high abundance of *Psammotettix poecilus* on locality 2. It is worth noting how species number decline with decreasing vegetation cover percentage and number of plant species present on locality (PC1). Proportion explained PC1=46.2 %; PC2=23.2 %. Abbreviations of species names are first three letters from genus name and first three letters of species name. S = average value of species recorded in phytosociological relevés (see Appendix 4 Tab. 2), C = average vegetation cover recorded in phytosociological relevés.

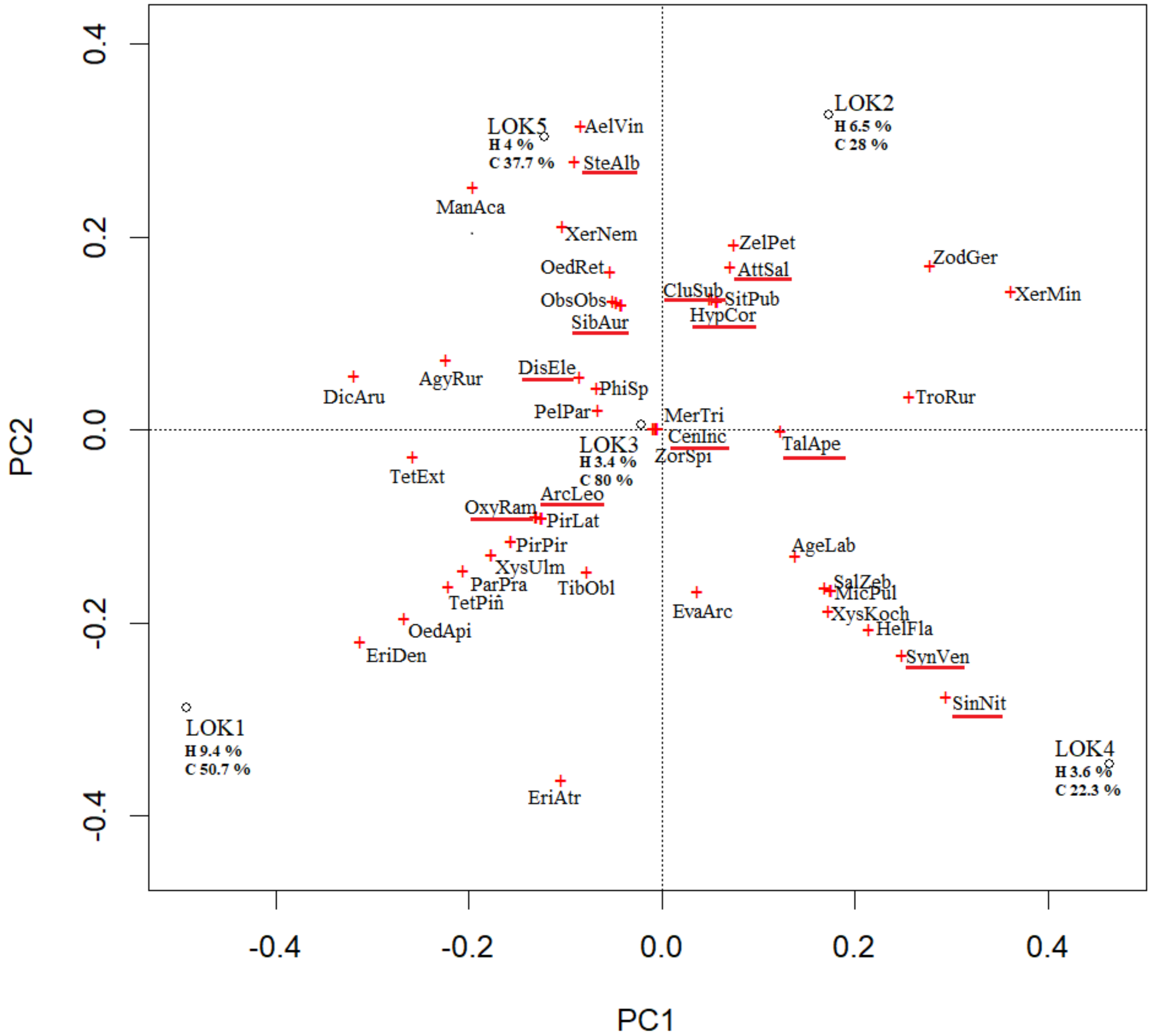



**Fig. 7**: PCA of Aranea species and their distribution among localities.

PCA of Aranea species and their distribution among localities (Lok1 – Lok5). Red-list species are underlined. Graph shows distinct spider community on very humid locality 1. Locality 3 is almost in the middle, sharing most of the species with the rest of localities. Locality 4 is relatively species poor because of its extreme conditions, localities 5 and mainly 2 host community of rare xerothermophilous species preferring warm sites with sparse vegetation. It is noteworthy how species composition changes with humidity and vegetation cover (PC1). Proportion explained PC1=33 %; PC2=26.3 %. Abbreviations of species names are first three letters from genus name and first three letters of species name. H = average value of soil humidity, C = average vegetation cover recorded in phytosociological relevés (see Appendix 4 Tab. 2). Note, that upper layer of substrate is drier than reported soil humidity average.

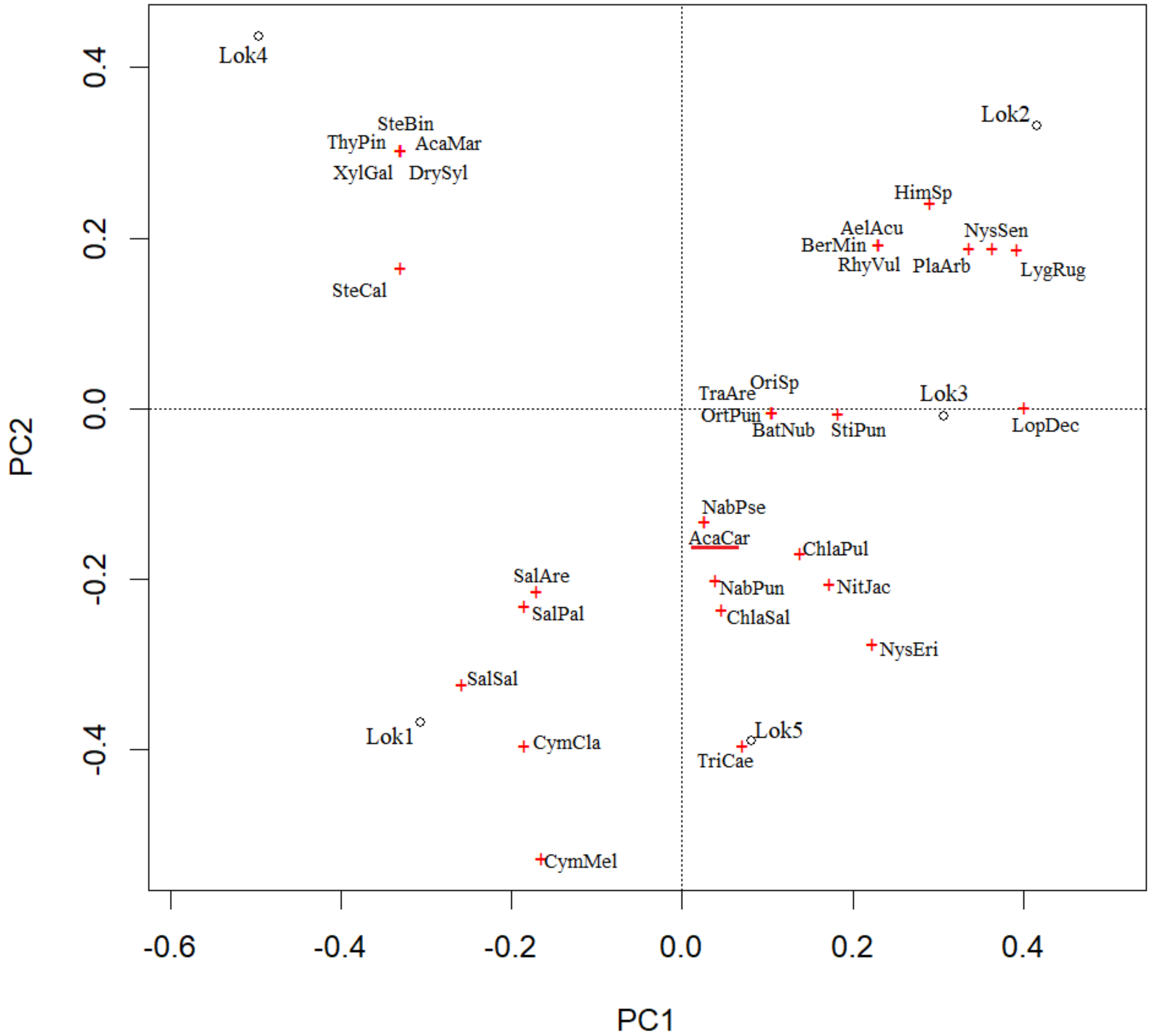



**Fig. 8**: PCA of Heteroptera species and their distribution among localities.

PCA of Heteroptera species and their distribution among localities (Lok1 – Lok5). Red-list species are underlined. Graph shows specific community of hygrophilous species on locality 1, namely *Saldula* species. Localities 5 and 3 share a lot of generalist or rather xerothermophilous species. Locality 4 is species poor, but few thermophilous specialists occur in here (*Xylocoris galactinus*). Unlike the spiders, hymenopterans and planthoppers and leafhoppers, locality 2 didn't host almost any specialists or endangered species. Red-listed species, *Acalypta carinata*, was found on very obscure place, on dry locality 5 with sparse vegetation, whereas this species occurs almost exclusively in moss of wet forests. Proportion explained PC1=33.6 %; PC2=32 %. Abbreviations of species names are first three letters from genus name and first three letters of species name.

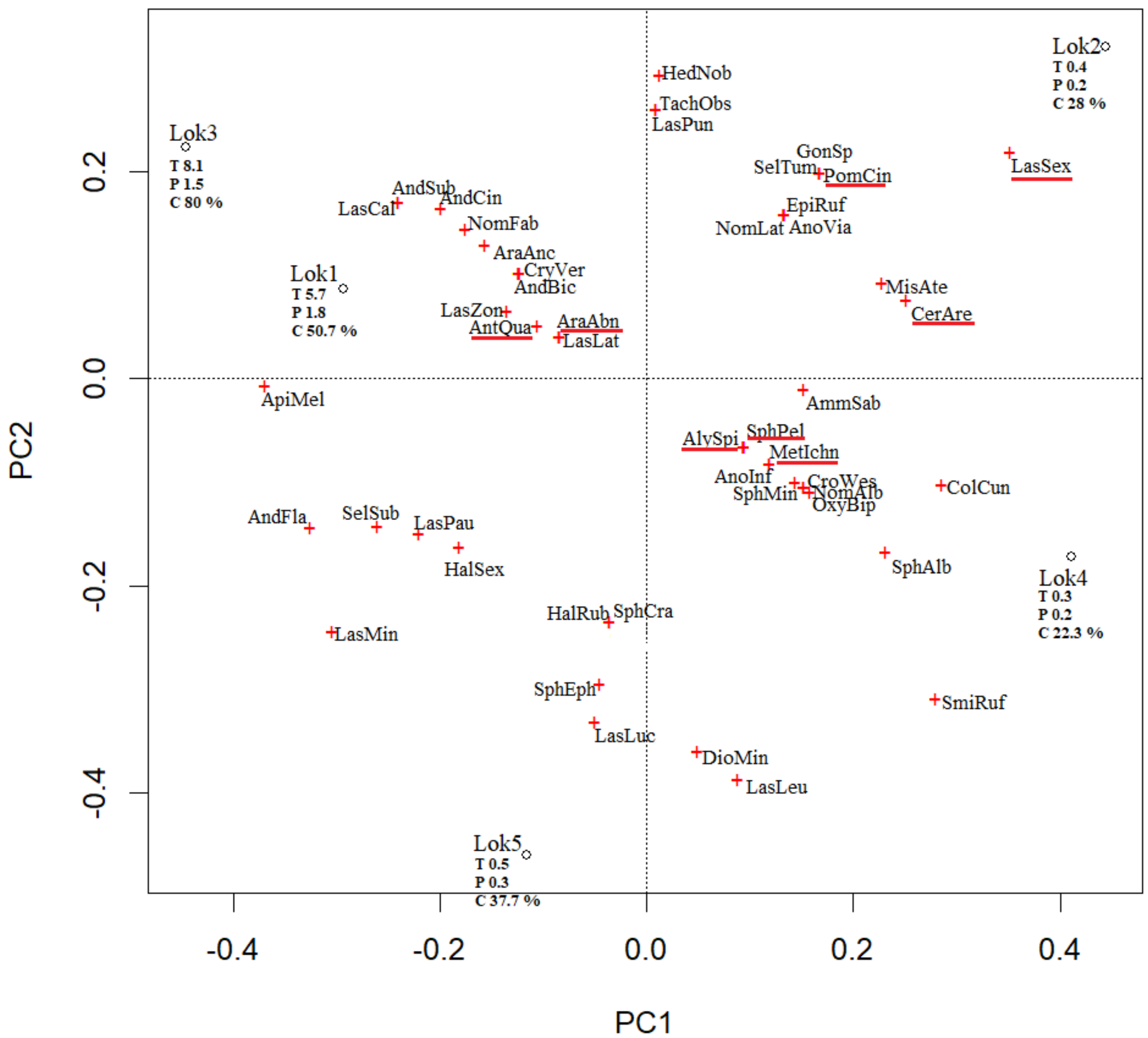



**Fig. 9**: PCA of Hymenoptera species and their distribution among localities.

PCA of Hymenoptera species and their distribution among localities (Lok1 – Lok5). Red-list species are underlined. Graph shows specific communities of rare fine sand specialists on locality 2 and (mainly) 4, where the most red-listed species were found. Locality 3 and 1 hosted similar community of generalist or coarse grain specialists, whereas locality 5 stands somewhere in between and hosts both generalist and a small amount of fine sand specialists. The trend of change of species composition and percentage of specialized and red-listed species and change of soil characteristics (PC1) is noteworthy. Proportion explained PC1=39 %; PC2=24 %. Abbreviations of species names are first three letters from genus name and first three letters of species name. T = weighted average of soil texture [mm], P = average value of soil penetrability [kg/cm$^2$], C = average vegetation cover recorded in phytosociological relevés (see Appendix 2 Tab. 2).


**Fig. 10**: PCA of Carabidae species and their distribution among localities.

PCA of Carabidae species and their distribution among localities (Lok1 – Lok5). Red-list species are underlined. Graph shows very specific and species rich communities of localities 1 and 3. However, these communities are quite different, mainly because of humidity. Locality 1 hosts hygrophilous species, whereas locality 3 mostly generalists. Localities 2, 4 and 5 have low number of species, but psamophilous specialists occur in there (*Cylindera arenaria*, *Harpalus flavescens*, *Cicindela hybrida*). We can see that number of species correlates with vegetation cover and species composition is dependent on humidity. Proportion explained PC1=39.2 %; PC2=28.2 %. Abbreviations of species names are first three letters from genus name and first three letters of species name. H = average value of soil humidity, C = average vegetation cover recorded in phytosociological relevés (see Appendix 4 Tab. 2). Note, that upper layer of substrate is drier than reported soil humidity average.

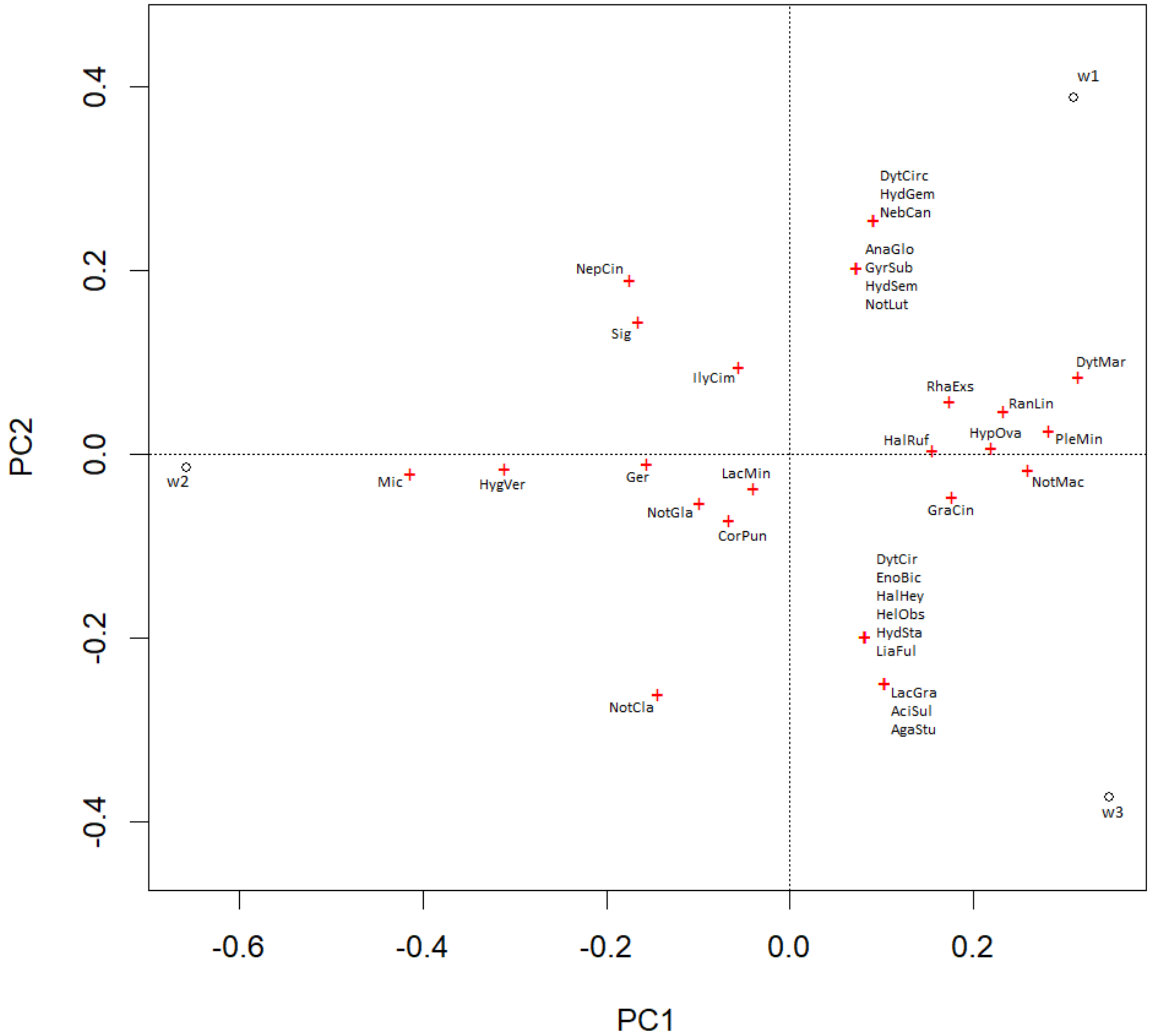



**Fig. 11**: PCA of aquatic Coleoptera and Heteroptera species among aquatic localities.

PCA of aquatic Coleoptera and Heteroptera species and their distribution among localities (w1 – w3). Graph shows specific communities of localities w1 and w3 and shared species for both w1 and w3 localities. Besides mentioned communities, mainly generalist species for all three localities occurred. Proportion explained PC1=70 %; PC2=30 %. Abbreviations of species names are first three letters from genus name and first three letters of species name.

# Appendix 3: Species list of plants

**Tab. 3**: List of vascular plant species found in the Planá sandpit.

*Agrostis capillaris*
*Agrostis stolnifera*
*Alisma plantago-aquatica*
*Alopecurus aequalis*
*Bellis perennis*
*Betula pendula*
*Bidens frondosa*
*Calamagrostis epigejos*
*Calluna vulgaris*
*Carex* sp.
*Cirsium* sp.
*Conyza canadiensis*
*Cyperus fuscus*
*Duacus carota*
*Echinochloa crus-galli*
*Epilobium adenocaulon*
*Filago arvensis*
*Filago minima*
*Fragaria vesca*
*Hieracium* sp.
*Hypochaeris* sp.
*Juncus effusus*
*Juncus tenuis*
*Luzula campestris*
*Lycopus europaeus*
*Molinia caerulea*
*Parthenocissus quinquefolia*
*Phalaris arundinacea*
*Pinus sylvestris*
*Poa annua*
*Potamogeton natans*
*Quercus rubra*
*Quercus* sp.
*Robinia pseudacacia*
*Rubus* sp.
*Salix herbacea*
*Salix* sp.
*Senecio vulgaris*
*Spergularia rubra*
*Tragopogon pratensis*
*Trifolium dubium*
*Trifolium repens*
*Tussilago farfara*
*Utricularia australis*
*Verbascum densiflorum*
*Veronica officinalis*

**Tab. 4**: List of bryophyte species found in the Planá sandpit.

*Marchantia polymorpha*
*Ricciocarpos natans*
*Sphagnum* sp.

# Appendix 4: Species list of animals

**Tab. 5**: List of invertebrate species found in the Planá sandpit.

**Spiders (Aranea)**

*Aellurilus v-insignitus*
*Agelena labyrinthica*
*Agyneta rurestris*
*Alopecosa pulverulenta*
*Araeoncus humilis*
*Araneus sturmi*
*Araniella* sp.
*Arctosa leopardus*
*Attulus saltator*
*Aulonia albimana*
*Centromerus incilium*
*Clubiona subtilis*
*Dictyna arundinacea*
*Diplostyla concolor*
*Dismodicus elevatus*
*Drassyllus lutetianus*
*Drassyllus pusillus*
*Erigone atra*
*Erigone dentipalpis*
*Euophrys frontalis*
*Evarcha arcuata*
*Heliophanus flavipes*
*Histopona torpida*
*Hypomma cornutum*
*Cheiracanthium erraticum*
*Cheiracanthium virescens*
*Leptorhoptrum robustum*
*Mangora acalypha*
*Mermessus trilobatus*
*Micaria pulicaria*
*Obscuriphantes obscurus*
*Oedothorax apicatus*
*Oedothorax retusus*
*Oxyopes ramosus*
*Pachygnatha degeeri*
*Pachygnatha* sp.
*Pardosa agrestis*
*Pardosa amentata*
*Pardosa lugubris*
*Pardosa monticola*
*Pardosa palustris*
*Pardosa prativaga*
*Pelecopsis paralella*
*Philodromus* sp.
*Phrurolithus festivus*
*Phylloneta sisyphia*
*Pirata piraticus*
*Piratula latitans*
*Platnickina tincta*
*Salticus zebraneus*
*Sibianor aurocinctus*
*Singa nitidula*
*Sittipub pubescens*
*Steatoda albomaculata*
*Synageles venator*
*Talavera aperta*
*Tenuiphantes mengei*
*Tetragnatha extensa*
*Tetragnatha pinicola*
*Tibellus oblongus*
*Trematocephalus cristatus*
*Trochosa ruricola*
*Trochosa terricola*
*Xerolycosa miniata*
*Xerolycosa nemoralis*
*Xysticus audax*
*Xysticus cristatus*
*Xysticus kochi*
*Xysticus ulmi*
*Zelotes petrensis*
*Zelotes subterraneus*
*Zodarion germanicum*
*Zora spinimana*

**Planthoppers and leafhoppers (Auchenorrhyncha)**

*Anaceratagallia ribauti*
*Aphrodes bicincta*
*Balclutha calamagrostis*
*Balclutha punctata*
*Cercopis vulnerata*
*Cicadella viridis*
*Conomelus anceps*
*Errastunus ocellaris*
*Eupelix cuspidata*
*Euscelis Incisus*
*Hardya tennuis*
*Javesella pellucida*
*Laodelphax striatella*
*Macrosteles laevis*
*Macrosteles quadripunctulatus*
*Macrosteles sexnotatus*
*Psammotettix confinis*
*Psammotettix poecilus*
*Sagatus punctifrons*
*Stenocranus major*
*Stenocranus minutus*
*Zyginidia scutelaris*

**Hymenoptera**

*Alyson spinosus*
*Ammophila sabulosa*
*Andrena barbilabris*
*Andrena bicolor*
*Andrena cineraria*
*Andrena flavipes*
*Andrena labiata*
*Andrena minutula*
*Andrena nigroaenea*
*Andrena subopaca*
*Anoplius concinnus*
*Anoplius infuscatus*
*Anoplius viaticus*
*Anthophora quadrimaculata*
*Apis mellifera*
*Arachnospila abnormis*
*Arachnospila anceps*
*Arachnospila ausa*
*Bombus bohemicus*
*Bombus pascuroum*
*Bombus terrestris*
*Cerceris arenaria*
*Colletes cunicullarius*
*Crossocerus wesmaeli*
*Cryptocheilus versicolor*
*Diodontus minutus*
*Episyron rufipes*
*Gonatopinae* sp.
*Halictus rubicundus*
*Halictus sexcinctus*
*Hedychrum gerstaeckeri*
*Hedychrum nobile*
*Lasioglossum calceatum*
*Lasioglossum lativentre*
*Lasioglossum leucozonium*
*Lasioglossum lucidulum*
*Lasioglossum minutissimum*
*Lasioglossum morio*
*Lasioglossum pauxillum*
*Lasioglossum punctatissimum*
*Lasioglossum sexstrigatum*
*Lasioglossum zonulum*
*Lindenius pygmaeus*
*Methocha ichneumonides*
*Mimumesa dahlborni*
*Miscophus ater*
*Nomada alboguttata*
*Nomada fabriciana*
*Nomada lathburiana*
*Oxybelus bipunctatus*
*Pompilus cinereus*
*Seladonia subaurata*
*Seladonia tumulorum*
*Smicromyrme rufipes*
*Sphecodes albilabris*
*Sphecodes crassus*
*Sphecodes ephippius*
*Sphecodes miniatus*
*Sphecodes pellucidus*
*Tachysphex obscuripennis*

**True bugs (Heteroptera)**

*Acalypta carinata*
*Acalypta marginata*
*Aelia acuminata*

*Bathysolen nubilus*
*Berytinus minor*
*Corixa punctata*
*Cymus claviculus*
*Cymus melanocephalus*
*Drymus sylvaticus*
*Gerris* sp.
*Himacerus* sp.
*Hydrometra stagnorum*
*Chlamydatus saltitans*
*Chlamydatus pullus*
*Ilyocoris cimicoides*
*Lopus decolor*
*Lygus rugulipennis*
*Micronecta* sp.
*Nabis pseudoferus*
*Nabis punctatus*
*Nithecus jacobaeae*
*Notonecta glauca*
*Notonecta lutea*
*Notonecta maculata*
*Nysius ericae/thymi*
*Nysius senecionis*
*Orius* sp.
*Ortholomus punctipennis*
*Plagiognathus arbustorum*
*Plea minutissima*
*Ranatra linearis*
*Rhyparochromus pini*
*Rhyparochromus vulgaris*
*Saldula arenicola*
*Saldula pallipes*
*Saldula saltatoria*
*Sigara* sp.
*Stenodema calcarata*
*Stenotus binotatus*
*Stictopleurus punctatonervosus*
*Trapezonotus arenarius*
*Trigonotylus caelestialium*
*Xylocoris galactinus*

**Bugs (Coleoptera)**
*Abax parallelus*
*Acilius sulcatus*
*Agabus sturmii*
*Agelastica alni*
*Agonum marginatum*
*Agonum sexpunctatum*
*Agonum viduum*
*Agrillus pratensis*
*Agriotes* sp. 1
*Agriotes* sp. 2
*Aleocharinae* sp.
*Amara* sp. 1
*Amara* sp. 2
*Amara* sp. 3
*Anacaena globulus*
*Anisodactylus binotatus*
*Anisodactylus signatus*
*Anostirus castaneus*
*Anotylus rugosus*
*Anthaxia* cf. *helvetica*
*Anthicidae* sp.
*Anthobium atrocephalum*
*Atholus duodecimstriatus*
*Bembidion quadrimaculatus*
*Calathus erratus*
*Cassida* sp.
*Cicindela hybrida*
*Cleonis pigra*
*Coccinela septempunctata*
*Coelostoma orbiculare*
*Coelostoma orbiculare*
*Cylindera arenaria*
*Cytilus sericeus*
*Dischyrius* sp.
*Dolichosoma lineare*
*Dytiscus circumflexus*
*Dytiscus marginalis*
*Elaphropus diabrachys*
*Elaphrus riparius*
*Elateridae* sp.
*Enochrus bicolor*
*Exochomus quadripustulatus*
*Graphoderus cinereus*
*Gyrinus substriatus*
*Haliplus heydeni*
*Haliplus ruficollis*
*Harpalus affinis*
*Harpalus flavescens*
*Harpalus rubripes*
*Harpalus* sp.
*Helochares obscurus*
*Helophorus* sp.
*Hippodamia tredecimpunctata*
*Hippodamia variegata*
*Hydaticus seminiger*
*Hydrobius fuscipes*
*Hydroglyphus geminus*
*Hydroporus erythocephalus*
*Hygrotus versicolor*
*Hyphydrus ovatus*
*Chlaenius vestitus*
*Ischnosoma splendidum*
*Labidostomis longimana*
*Laccobius gracilis*
*Laccophilus minutus*
*Lathrididae sp.*
*Lemini sp.*
*Liaphlus* cf. *fulvus*
*Lionychus quadrillum*
*Malachidae* sp.
*Margarinotus purpurascens*
*Metallina lampros*
*Microlestes minutulus*
*Nebria brevicollis*
*Nebrioporus canaliculatus*
*Nicrophorus vespillo*
*Nitidulidae* sp.
*Noterus clavicornis*
*Notoxus monoceros*
*Ocydromus femoratus*
*Oedemeridae* sp.
*Omophron limbatum*
*Onthophagus* cf. *joannae*
*Oodes helepioides*
*Paratachys bistriatus*
*Philonthus atratus*
*Princidium punctulatum*
*Protapion apricans*
*Pseudoophonus rufipes*
*Pterostichus melanarius*
*Quedius fuliginosus/curtipennis*
*Rhantus exsoletus*
*Rhinoncus castor*
*Scolytinae* sp.
*Scymnus frontalis*
*Simplocaria* sp.
*Sitona lineatus*
*Staphylinus dimidiaticornis*
*Stenolophus teutonus*
*Stenus* sp. 1
*Stenus* sp. 2
*Strophosoma capitatum*
*Tachyporus dispar*
*Tachyporus nitidulus*
*Trechus quadristriatus*
*Trepanes articulatus*
*Trypocopris vernalis*
*Tychius picirostris*

**Dragonflies (Odonata)**
*Aeschna cyanea*
*Anax imperator*
*Coenagrion puella*
*Ischnura elegans*
*Ischnura pumilio*
*Libellula depressa*
*Libellula quadrimaculata*
*Orthetrum cancellatum*
*Pyrrhosoma nymphula*
*Sympecma fusca*

**Mayflies (Ephemeroptera)**
*Ephemeroptera* sp.
*Cleon dipterum*

**Megaloptera**
*Sialis* sp.

**Caddisflies (Trichoptera)**
*Trichoptera* sp.

**True flies (Diptera)**
*Culicidae* sp.
*Chaoborus* sp.
*Chironomidae* sp.

**Neuroptera**
*Myrmeleon* sp.

**Orthoptera**
*Chorthippus mollis*
*Tetrix* cf. *bolivari*
*Tetrix subulata*
*Tetrix tennuicornis*
*Tetrix undulata*

**Isopoda**
*Armadillidium vulgare*
*Trachelipus rathkii*

**Harvestmen (Opiliones)**
*Phalangium opilio*

**Millipedes (Diplopoda)**
*Julus scandinavius*
*Leptoiulus proximus*
*Ophyiulus pillosus*
*Polydesmus inconstans*

**Pulmonata**
*Radix labiata*
*Physella acuta*
*Radix auricularia*
*Radix labiata*
*Galba truncatula*
*Cepaea hortensis*

**Unionida**
*Anodonta antina*

**Cardiida**
*Pisidium subtruncatum*

**Tab. 6**: List of vertebrate species found in the Planá sandpit.

**Accipotriformes**
*Butteo butteo*
*Milvus milvus*
*Motacilla alba*

**Anseriformes**
*Alopochen aegyptiaca*
*Anas platyrhynchos*
*Cygnus olor*

**Storks (Ciconiiformes)**
*Ciconia ciconia*
*Ciconia nigra*

**Coraciiformes**
*Alcedo atthis*

**Cuckoos (Cuculiformes)**
*Cuculus canorus*

**Charadriiformes**
*Actitis hypoleucos*
*Gallinago gallinago*
*Charadrius dubius*

**Passerines (Passeriformes)**
*Oriolus oriolus*
*Parus major*
*Phylloscopus collybita*
*Phylloscopus trochilus*
*Riparia riparia*

**Pelecaniformes**
*Ardea alba*
*Ardea cinerea*

**Frogs (Anura)**
*Bufo bufo*
*Hyla arborea*
*Pelophylax esculentus*

**Caudata**
*Lissotriron vulgaris*

**Squamanta**
*Natrix natrix*
*Lacerta agilis*

**Even-toed ungulates (Artiodactyla)**
*Capreolus capreolus*
*Sus scrofa*

**Eulipotyphla**
*Sorex araneus*

**Lagomorpha**
*Lepus europaeus*

# Appendix 5: Red-list species

**Tab. 7**: List of Czech Red-list species found in the Planá sandpit.

Red-list categories: CR - critically endangered, EN - endangered, VU - vulnerable, NT - near threatened, LC - least concern (vertebrates only)

**Liverworts**
*Marchantia polymorpha* (LC)
*Ricciocarpos natans* (LC)

**Vascular plants**
*Filago arvensis* (NT)
*Filago minima* (NT)
*Utricularia australis* (LC)

**Birds**
*Actitis hypoleucos* (EN)
*Alcedo atthis* (VU)
*Alopochen aegyptiaca* (LC)
*Anas platyrhynchos* (LC)
*Ardea cinerea* (NT)
*Ciconia ciconia* (NT)
*Ciconia nigra* (VU)
*Cuculus canorus* (LC)
*Cygnus olor* (VU)
*Gallinago gallinago* (EN)
*Charadrius dubius* (VU)
*Milvus milvus* (CR)
*Motacilla alba* (LC)
*Oriolus oriolus* (LC)
*Parus major* (LC)
*Phylloscopus collybita* (LC)
*Phylloscopus trochilus* (LC)
*Riparia riparia* (NT)

**Mammals**
*Capreolus capreolus* (LC)
*Lepus europaeus* (NT)
*Sorex araneus* (LC)
*Sus scrofa* (LC)

**Reptiles**
*Lacerta agilis* (VU)
*Natrix natrix* (NT)

**Amphibians**
*Bufo bufo* (VU)
*Hyla arborea* (NT)
*Lissotriron vulgaris* (VU)
*Pelophylax esculentus* (NT)

**Bugs**
*Harpalus flavescens* (NT)
*Laccobius gracilis* (NT)

**Hymenopteras**
*Alyson spinosus* (VU)
*Anthophora quadrimaculata* (EN)
*Arachnospila abnormis* (NT)
*Cerceris arenaria* (NT)
*Lasioglossum sexstrigatum* (NT)
*Methocha ichneumonides* (NT)
*Pompilus cinereus* (NT)
*Sphecodes pellucidus* (NT)

**Planthoppers and leafhoppers**
*Psammotettix poecilus* (NT)
*Sagatus punctifrons* (NT)

**Spiders**
*Arctosa leopardus* (LC)
*Attulus saltator* (VU)
*Centromerus incilium* (CU)
*Clubiona subtilis* (LC)
*Dismodicus elevatus* (LC)
*Hypomma cornutum* (LC)
*Oxyopes ramosus* (LC)
*Sibianor aurocinctus* (LC)
*Singa nitidula* (LC)
*Steatoda albomaculata* (LC)
*Synageles venator* (LC)
*Talavera aperta* (LC)

**True bugs**
*Acalypta carinata* (EN)

# Appendix 6: Planá Sandpit Education Biocentre

**Txt. 1**: Planá sandpit education biocentre.

The main idea of this subproject is to create area with education and nature preservation function together. Very small changes in current restoration plan (GET, s. r. o. 2015) are needed for project realization. Project is located in enlarged area F suggested for natural restoration in current plan. Actual size of planned area mainly for Sand Martins (*Riparia riparia*) nesting is 50 x 25 m (0,125 ha). Suggested enlargement would create polygon about 0,35 ha in size (Fig. 13). Biocentre would be placed next to the forest road so the whole area could be comfortably visited by public.

The dominant of the whole center would be almost 150 m long, 5 m high nesting wall for Sand Martins (*Riparia riparia*), burrowing bees (Bogush et al. 2013) and other animals (e.g. Common spadefoot toad (*Pelobates fuscus*) lives in debris cones under these walls (Vácha 2017)). Area under the wall would be full of both wetland and terrestrial biotopes. Nowadays, deep lake with steep banks is created in the area so several changes would be needed. We suggest to fill the lake with sandy or clayish material (no organic component included) to make a lot of small diverse pools. Significant part of the lake should be filled to make space for terrestrial biotopes formation. These terrestrial biotopes are very important for some aquatic species (Maštera 2012), as well (e.g. amphibian wintering). Small sand dunes can be formed in the area using material from current sedimenting basins or unused small fraction deposits. As our research shows, rare specialists of sand dunes occur in the sandpit and creating suitable spare biotope before forest reclamation of such sites is very likely. Mosaic disturbances (including pools bottom) to restart plant cover succession should be applied to reach maximal potential of the area (Řehounek et al. 2015, Boukal 2010, Řehounková et al. 2016). Also, renewal of nesting wall is needed every two years (Heneberg et al. 2007). Removed sand can be later (in winter) used by landowner (town of Tábor) e.g. for gritting raods. It is very important to cover slopes of stored soils surrounding the area to prevent area eutrophication. Oligotrophic biotopes with unique fauna and flora can be easily damaged by adding nutrients into the soil (Tropek et al. 2012). We can prevent this damage by covering slopes leading in the area with clayish soils. Creating a zone composed of deciduous trees only around the biocentre is very likely to make natural border between pine restoration and biocentre. This “buffer zone” should be at least 5 m wide. Some geocaches can be placed in the area to support additional disturbances.

In the area could be installed several interactive information boards showing e.g. genesis of natural sand dune, Sand Martins (*Riparia riparia*) or Common kingfisher (*Alcedo atthis*) nesting, or other both geological and biological phenomenons present in the biocentre.

Planá sandpit education biocentre can be a target location for protected and rare species transferred from forest reclamation areas in the sandpit. Suitable ecosystems for all target species would be created in the biocentre.

If the project is successful, some education trips in cooperation with South Bohemian University or local museums can be easily realized in the biocentre. It is very important to popularize effective nature preservation in real conditions mainly to young people. Planá sandpit offers ideal space and both geological and geomorphological conditions for education biocentre emplacement.

**Fig. 12**: Planá Sandpit Education Biocentre - area plan.

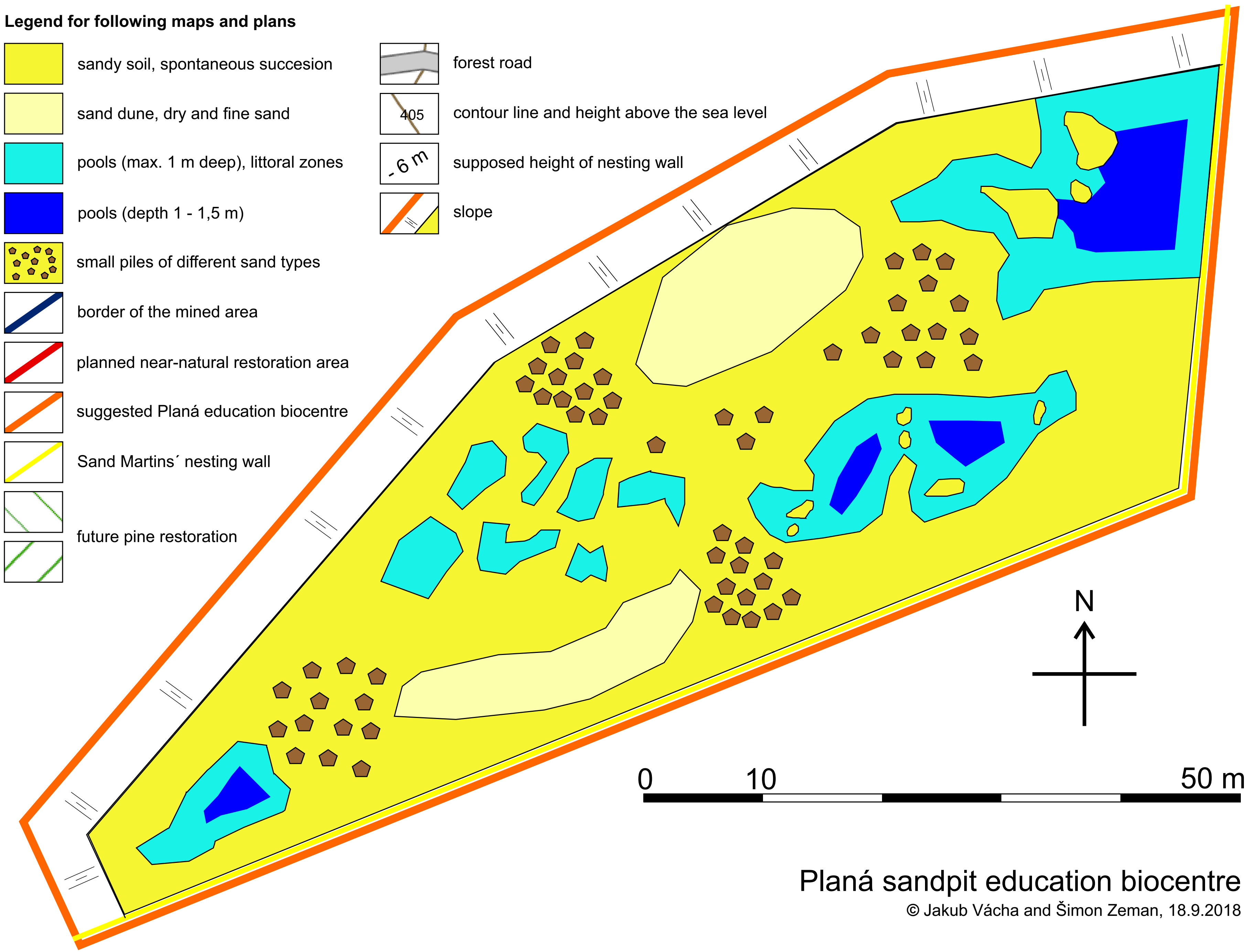
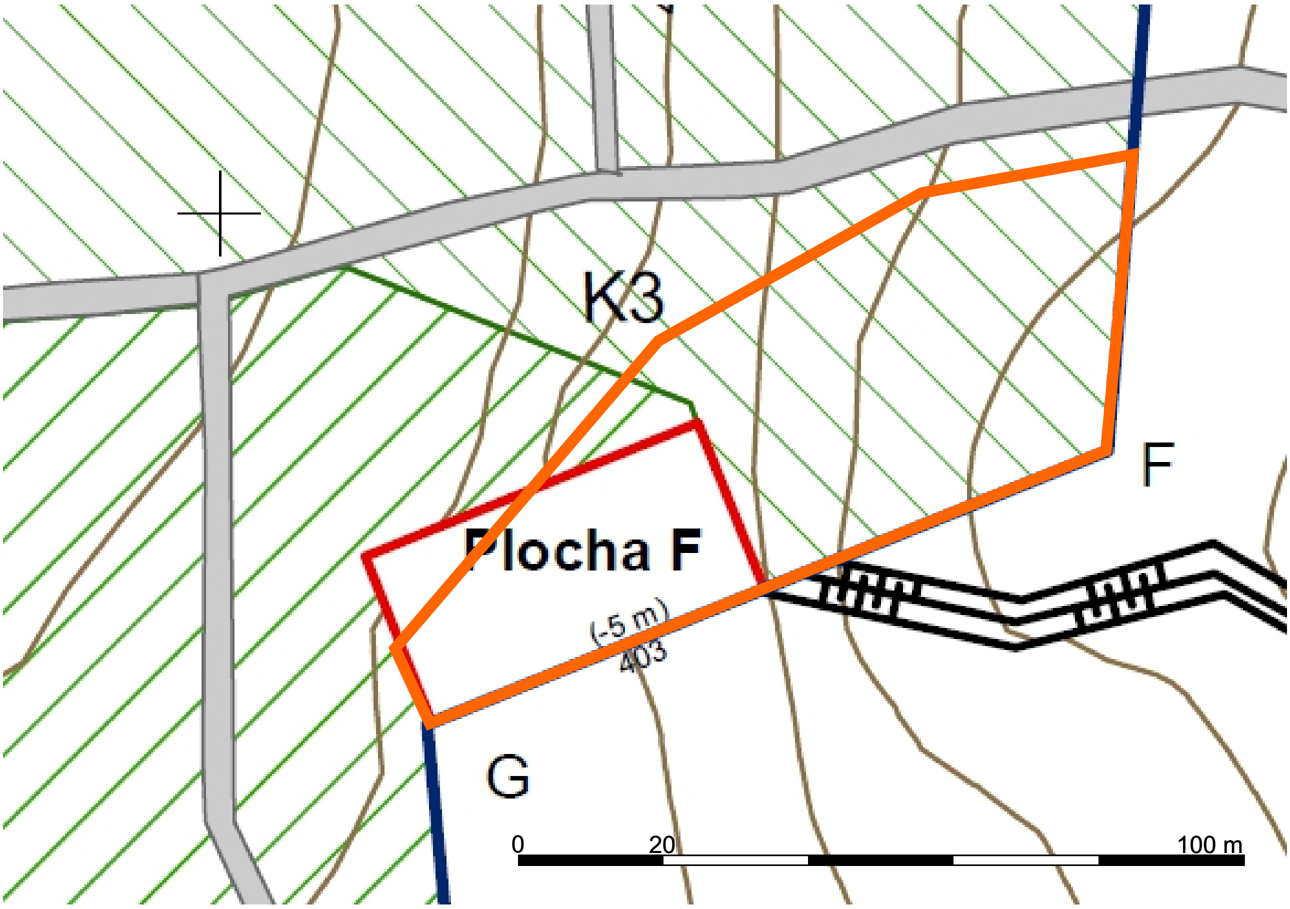
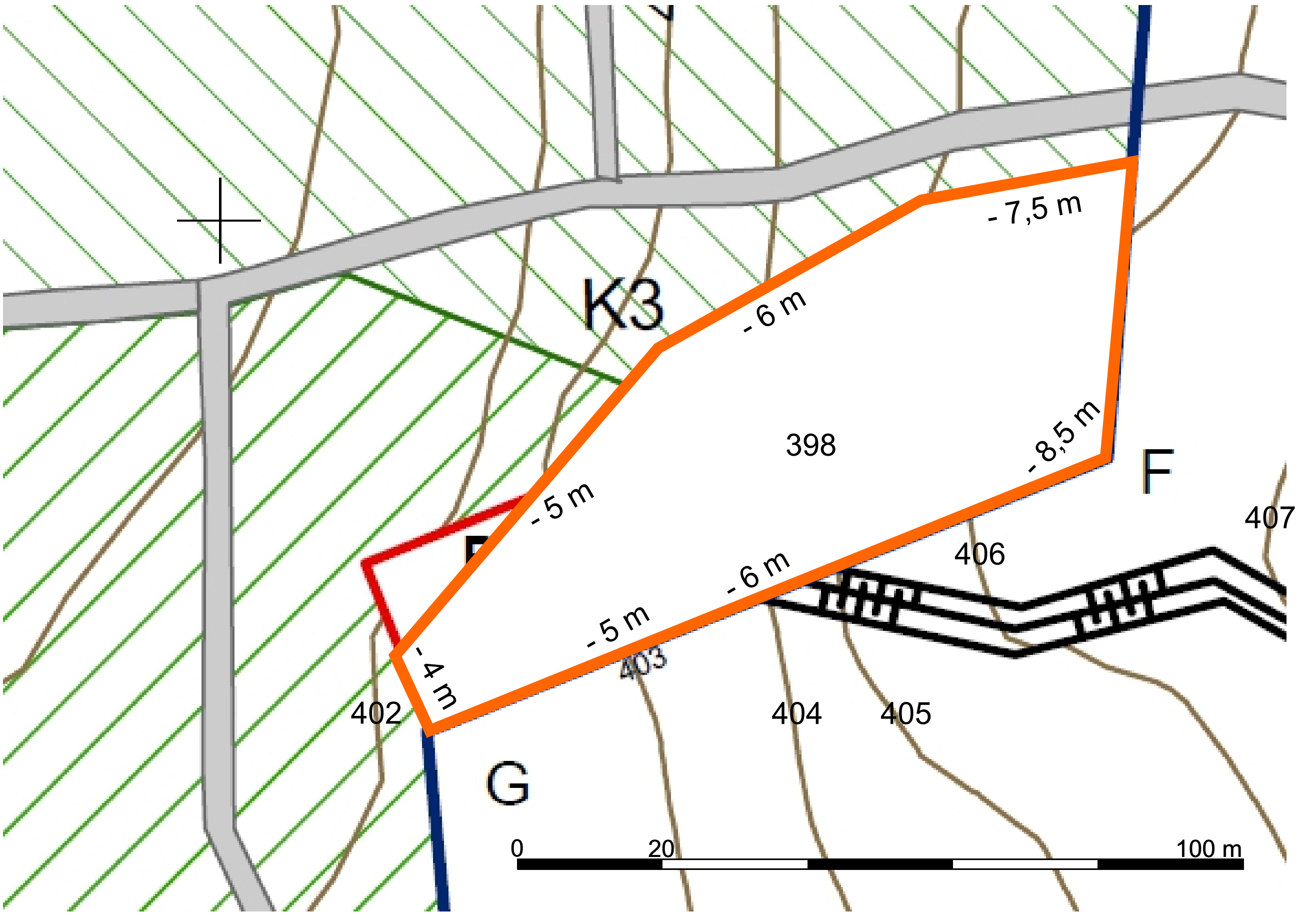


**Fig. 13**: Planned Sand Martins´ nesting area and Planá Sandpit Education Biocentre localisation.




Map by GET, s. r. o. (2015); modified.

**Fig. 14**: Contour lines of the height above the sea level and supposed height of the nesting wall.




Map by GET, s. r. o. (2015); modified.

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# Geology of Sandpits

Moldavite (40 mm) in situ, Vrábče, Czech Republic. Photo I. Doležal

## Introduction

Sandpits are like a huge treasure chests that collect material from the large area. Most of mined sand deposits are of river origin, so they contain objects collected by the water flow. A sandpit can be full of local rock fragments, interesting mostly heavy minerals, fossils and other items. Heavy minerals are concentrated in the river sand deposits in the amount that can be even mined, there. In the past, a lot of animals and plants fell in the river. They were buried in the sand deposit and they await their discovery. Each sandpit hides a lot of secrets, information about weather conditions in the past and a lot more. So, let's discover it.

## Origin of the Sand Deposit

Matrix is in the beginning. If matrix erodes, sand is created. Later, it can be transported away in multiple ways. There are three main transporters: wind, river (water flow) and sea.

**Wind-transported sand deposit** (also known as sand dune) is a pile of fine-grained sand located near to primary (river/sea) sand deposit, where the material comes from.

**Sea sand deposits** can contain various material collected usually nearby and can be useful in researches of former storms. Some deposits, for example around the Baltic sea, contain amber, numerous fossils etc.

**River sand deposits** are the most interesting ones. River deposit is often untouched and layers aren't mixed up. Deposit like this can be formed in the meander or in the river mouth (delta is ideal). Size of grains in specific layers can give us information about flow strength, which can be related to huge rains. Thickness helps with duration establishment. Organic remains can be used for carbon-dating of the layer, as well as some specific fossils.

Layered river sediment (photo width 50 cm). Photo J. Vácha

## Geolomorphological Phenomenons

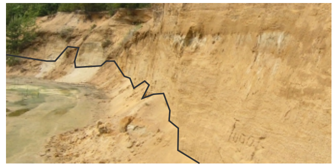
In each sandpit we can find some geological structures formed in sand. Common are **rain gullies**, furrows formed by water in sandy slopes. Under sand walls are located **debris cones**, piles of sand which felt down from the walls. These can host a lot of animals from amphibians to the smallest Arthropods.

**Dreikanters** are stones with sharp edges grinded by sand transported by wind during ice ages. Dreikanters are found in river-sand deposits, where they were formed.

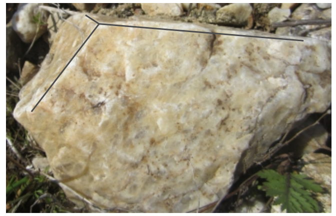
Sand or gravel can be bonded with calcite, limonite, quartz, manganese oxides etc. Formed stone is called **concretion**. The most common one is limonite concretion, where gravel or sand is bonded by iron oxides.

**Frostwedge** is soil formation created during ice age. The water expanded in the small crack in the sediment, creating wedge crack, sometimes tens of meters tall. Crack was filled with the soil from surface. Age of wedge can be estabilished from pollen in the soil.

Rain gully (width 30 cm). Photo J. Vácha



Debris cone (wall height 4 m). Photo J. Vácha



Quartz dreikanter (12 cm). Photo J. Vácha

Limonite concretion (7 cm). Photo J. Vácha

Frostwedge (30x10 cm), Dřenice sandpit, Czech Republic. Photo I. Doležal

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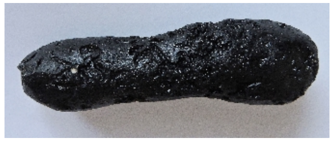
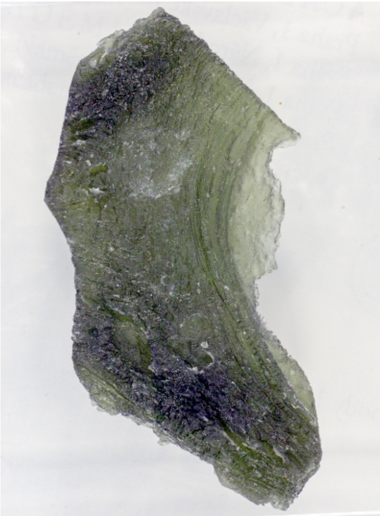
## Tektites

Tektites are a specific group of rocks formed from sediment melted during meteorite impact. There are several tektite species, each specie created by different impact. Species of tektites are usually named after area, where they are found. The most known species are **indochinites**, **philippinites** or Czech **moldavites**.



*Indochinite (105 mm), Mao Ming, China. Photo I. Doležal*



*Moldavite (80 mm), Bartelov, Czech Republic. Photo P. Rajlich*

*Moldavite „drop" (67 mm), Bartelov, Czech Republic. Photo P. Rajlich*

**Design and text:** Jakub Vácha
**Proofreading:** RNDr. Petr Rajlich, PhD., CSc.

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## Minerals

Many interesting minerals can be found in sandpits. Some heavy minerals concentrated in sand sediments are sometimes mined there and even used in the gem industry. Typical precious heavy minerals found in sandpits can be **saphires (corunds), spinels, garnets, topases** or even **diamonds**. **Gold** and other metals can be found, too. Common are findings of **quartz crystals** (many varietes) or **chalcedony** pieces. Also, different **tourmalines** are likely to be found in sandpits. Lucchesiite, the new tourmaline species, was discovered in river sediments in Sri Lanka.


*Native gold, Czech Republic. Photo O. Jaroš*


*Saphire, Czech Republic. Photo O. Jaroš*

*Native gold and cinabarite, Czech Republic. Photo O. Jaroš*


*Garnet (pyrope), Czech Republic. Photo O. Jaroš*

*Tourmaline in pegmatite, Planá sandpit. Photo J. Vácha*

## Rocks

All kinds of **local rocks** can pop out if we search them in the pit. These rocks can be helpful, if we want to know where the material came from. Some kinds of rocks (e.g. limestone) can also change the soil chemistry.

Rarely, we can find special rock called **varvite**. This is rock formed from local sediments, where each layer (with slightly different color) represents one year of sedimentation. Study of varvite layers is an important geochronological method.

*Orthogneiss (23 cm). Photo J. Vácha*

*Varvite (picture width 100 cm), Polanka sandpit, Czech Republic. Photo D. Bystroň.*

## Fossils

Fossils, especially quartzified specimens, are sometimes found in sanpits, too. Common are findings of **petrified wood**, less common are **mammal teeth**, **bones** or even **mammoth tusks**. Fossil **pinecones** or different parts of flora are found rarely, too.

*Mammoth tooth (23 cm), Hulín sandpit, Czech Republic. Photo S. Veselá*

*Petrified wood (4 cm), Hulín sandpit, Czech Republic. Photo J. Hanuš.*

*Seashell in flint (2 cm), Žabčice sandpit, Czech Republic. Photo Z. Galba*

**Project tags (select all appropriate):**

This will be use to classify your project in the project archive (that is also available online)

Project focus:

- ☐Beyond quarry borders
- ☒Biodiversity management
- ☒Cooperation programmes
- ☒Connecting with local communities
- ☒Education and Raising awareness
- ☐Invasive species
- ☒Landscape management
- ☐Pollination
- ☒Rehabilitation & habitat research
- ☒Scientific research
- ☒Soil management
- ☒Species research
- ☒Student class project
- ☐Urban ecology
- ☐Water management

Flora:

- ☒Trees & shrubs
- ☐Ferns
- ☒Flowering plants
- ☐Fungi
- ☒Mosses and liverworts

Fauna:

- ☒Amphibians
- ☒Birds
- ☒Insects
- ☐Fish
- ☒Mammals
- ☒Reptiles
- ☒Other invertebrates
- ☒Other insects
- ☐Other species

Habitat:

- ☐Artificial / cultivated land
- ☐Cave
- ☐Coastal
- ☐Grassland
- ☐Human settlement
- ☐Open areas of rocky grounds
- ☐Recreational areas
- ☒Sandy and rocky habitat
- ☐Screes
- ☐Shrub & groves
- ☐Soil
- ☐Wander biotopes
- ☒Water bodies (flowing, standing)
- ☒Wetland
- ☐Woodland

Stakeholders:

- ☒Authorities
- ☐Local community
- ☐NGOs
- ☒Schools
- ☒Universities