

Seasonal activity of honeybee colonies in relation to the biodiversity of quarries

The Quarry Life Award 2018 Project



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Final Project Report

1. Contestant profile

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2. Project overview

Title:	Seasonal activity of honeybee colonies in relation to the biodiversity of quarries
Contest: (Research/Community)	Research
Quarry name:	Mokrá near Brno

Abstract

Aims: Is the quarry Mokrá suitable environment for pollinators? Can the quarry offer sufficient food resources for insects during the whole growing season? Can we determine some differences between active quarry, abandoned quarry and cultural landscape? Can the seasonal activity of honey bees indicate the density of solitary bee populations? Is it possible to measure and compare the nesting activity of solitary bees among localities? Does the honey analysis reflect characteristics of the environment?

Methods: The quarry of Mokrá represented a target locality, two other localities (abandoned quarry Hády and a small village Lažánky) were considered as reference localities for a data comparison. We installed two honeybee hives at hive scales at each locality and measured the weight and temperature outside and inside the hives at 5–15min intervals from April to July 2018. Collected data were immediately sent to the data server, and they were available online on the web. Consequently, we installed five special solitary bee traps at each locality. Due to the better compatibility of obtained results, we also recorded phenological data about the start of flowering, full flowering and end of flowering for selected plant species. We asked for the analysis of metals in the honey in an accredited laboratory.

Results: Honey income fluctuated due to the weather and nectar productivity of plants. The most balanced weight curve was observed at the locality Hády, the most extended time-distance between honey flows have been found at the locality Lažánky. Nesting activity of solitary bees was comparable at all localities till May 15th. After this date nesting activity at the locality Lažánky almost stopped, while it intensively continued at all other two localities till the end of June. Localities Lažánky and Mokrá were phenologically later than the locality Hády for about 5-7 days. Then the phenological difference between Mokrá and Hády lowered. Honey analysis has shown the presence of higher concentrations of some elements in the sample from Mokrá. Pesticides were not identified at a measurable level anywhere.

Discussion: The monitoring of weight changes of beehives showed differences between localities, which may be well interpreted by the landscape structure and species diversity. Nesting activity of solitary bees had the similar pattern. Solitary bees are more sensitive to the food deficit and the use of pesticide in the cultural landscape. Therefore, their late spring populations are more endangered than socially living insect pollinators (honey bees and bumble bees). The interesting gradual decreasing of phenological difference between localities Hády and Mokrá was probably affected by the effect of Thermal Island considering the large mining area. Higher dust pollution of active quarry affected the higher level of some compounds in the Mokrá quarry, but they were not above levels considered as a health risk for consumers.

Conclusion: Our project demonstrated an application of several innovative approaches (hive scale, bee-hive monitoring, solitary bee traps), which are useful worldwide. Despite a small data sample, research results showed significant differences between localities and they could be an inspiration for the improvement of the limestone quarry reclamation quality concerning insect pollinators.

Introduction

The main task of our project was to explore forage sources of insect pollinators in surroundings of the quarry. Although the intensive monitoring of life nature in Mokrá quarry started in the nineties of the last century, no scientific study of this diverse group of insects has been done here yet. We also wanted to warn by this project that the insects as an essential component of the food pyramid in the wild nature of Europe fastly disappear (Hallman et al. 2017).

As one of possible outcomes, an extreme decrease of insect pollinator populations could endanger survival and successful reproduction of flowering plants soon. The insect at least partly pollinates almost two-thirds of the native flora of Central Europe (Kühn et al. 2004). Many various groups of fauna are the secondary consumers, and they are also dependent on the insect biomass level. We do not know it precisely in numbers, but the lack of insect may be one of the most important reasons for their disappearing.

Activity and density of insect pollinators are usually measured, e.g. using colour pan traps or Malaise traps. The disadvantage of these methods is in their destructive impact on current populations (Campbell & Hanula 2007). Additionally, their informational content may be limited for some specific groups as pollinators of trees (Cane et al. 2001).

We decided to apply an entirely new approach and tried to measure the diversity of food resources for pollinators indirectly by quantitative methods of monitoring of two model groups of organisms with different behaviour. The first was the monitoring of weight changes of honeybee colonies (*Apis mellifera*), the second considered monitoring of nesting activity of solitary bees.

The honey bee is one of few domesticated insect species. Beekeeping in the Czech Republic is a common hobby or employment. In 2017 about 58,500 beekeepers with 637,000 bee colonies were officially registered (Anonymus 2017), what represents enormous potential of collected experiences about the behaviour of this insect species. The honey bee is a generalist forager (Butz Huryn 1997; Coffey and Breen 1997). This species can pollinate about

40,000 vascular plant species over the World (Crane 1990). The nutrition of honeybee colonies depends on the food resources of the hive surroundings. The amount of nectar and pollen collected by bees corresponds approximately to the proportion of natural grasslands and broad-leaved forests, while a cultural landscape influences their production negatively (Donkersley et al. 2014).

Large limestone quarries in the Czech Republic as Mokrá or Hádý are presented as the biodiversity hotspots (Tichý 2005). Active quarry Mokrá near Brno is known for its species-rich flora (Tichý unpubl.) and as one of the very species-rich localities for butterflies at the southern Moravia (Laštůvka 2014). Therefore, we wanted to know, how the bee-hive weight increase will differ from the other two selected reference localities.

Honey bees are very efficient in collecting nectar and pollen. However, their competition with other wild bees is not so strong (Steffan-Dewenter & Tscharntke 2000). While the territory of honey bees can be a circle with the radius of about several kilometres (Beekman & Ratnieks 2001), solitary bee populations have more local character. The distance between the nest and forage of solitary bees usually does not exceed 250 m (Gathmann & Tscharntke 2002). We would like to know if the availability of forage resources measured independently by the collection efficiency of honey bees will be in agreement to the activity of solitary bees. Then we investigated a nesting frequency of solitary bees quantitatively using solitary bee traps.

Our aim for this project was to answer these following questions: (1) Is the quarry Mokrá suitable environment for pollinators? (2) Can the quarry offer sufficient food resources for insects during the whole growing season? (3) Can we determine some differences between active quarry, abandoned quarry and cultural landscape? (4) Can the seasonal activity of honey bees indicate the density of solitary bee populations? (5) Is it possible to measure and compare the nesting activity of solitary bees among localities? (6) Does the honey analysis reflect characteristics of the environment?

Methods

Monitored localities

The Mokrá active limestone quarry (1) was selected as a target locality of our project (1). This large mining site managed by Českomoravský cement company considers the area of 2.65 km². Semi-natural oak and oak-hornbeam forests and species-rich dry grasslands at its edges host many endangered species. However, large areas with only sparse and species-poor vegetation cover currently mining area. When we decided to measure forage resources for insect pollinators by the entirely new approach, we needed to compare the obtained results with other

localities. Therefore, we selected (2) large, abandoned and previously reclaimed limestone quarry Hádý near Brno as an example of diverse post-industrial landscape with a high concentration of naturally valuable localities. (3) Additionally, we considered a small village Lažánky as the second reference locality representing the current rural landscape of the Czech Republic. This village is surrounded by large arable fields with high agricultural intensity. However, the whole region remained partly traditional, the country roads are with fruit trees, and broad-leaved forests cover a part of the landscape. The

general comparison of biodiversity of these three selected localities is shown at the Fig. 1.



Fig. 1. Visual characteristics of 2x2 km surroundings of selected localities (source of satellite images: Google Earth, 05th December 2017). Species-rich areas (shrubland, abandoned fields, dry grasslands, gardens, extensive orchards and forest edges) are marked by green colour, less species-rich areas (forests, overgrown parts of quarries, residential areas) are marked by yellow colour, while the species-poor sites with low density of vegetation (arable fields, industrial areas, railway station, mining area etc.) are marked by red colour. Two circles represent the distance of 500m and 1000m from monitored hives.

It is evident from the figure that the largest area of species-rich vegetation exists at the locality Hády. Mokrá has a medium species richness considering almost the desert for pollinators at mining sites. The most complex area is in surroundings of the Lažánky village, where residential part of the settlement with gardens and orchards offers many opportunities to insect pollinators, but the rest of the agricultural landscape is currently very deficient in available forage resources.

Weight changes of honeybee colonies

Field measurements were not possible without some preparatory phase lasting from July 2017 to March 2018. Firstly, we constructed and calibrated three pieces of electronic equipment developed especially for this project. Three hive scales based on Arduino micro-computer platform developed at that time were prepared for recording and online presentation of weight changes of beehives, the temperature inside the colony and air temperature of closed surroundings of hives. The photography of our prototype is at the Fig. 2. The scheme of necessary components is shown at the Fig. 3. The weight and temperature measurements and their storage at the server are supported by the software programmed individually for each locality. Also, the locality Mokrá needed a unique construction and software changes due to the absence of a plug-in connection.

At the start of growing season (from 25th March to 3rd April) we installed monitoring system and a pair of beehives with wintered honeybee colonies of the similar size at each of our three selected localities. The parallel monitoring of two hives at the same location helped us to make the results more objective during the whole period of measurement. Data sampled in intervals from 5 to 15min were immediately sent to the internet server. Therefore, it was possible to check online the functionality of all scales and changes of the hive weights.

We had to solve three defects of the system during all the time of measurement. Thanks to the online connection it was easy to determine the technical problem and repair it immediately. Therefore, the time-series from all localities are complete.



Fig. 1. Hive scale for the Mokrá quarry with a Li-Pol 30 000 mAh power bank, which is possible to measure and send online data continually every 15 minutes during three weeks.

We stopped the measurement 31st July – three weeks after the first artificial feeding of honeybees by the sugar. In that time bee colonies are not usually able to search for sufficient nectar and pollen sources in dry landscape without blossoms, and the subsequent monitoring would not bring any new information.

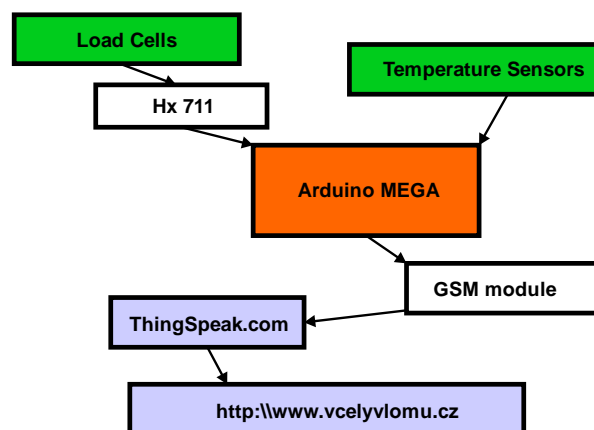


Fig. 2. Scheme of beehive scales and data transfer.

We focused on the standardised design of all locations, hives and manipulation techniques: bee colonies were in the same type of hives, and they were managed comparably in intervals of 1–2 weeks. The success of the monitoring depended on the suppression of two serious threats – the destruction of the system by vandalism and swarming of any bee colony. However, these threats were successfully eliminated – beehives in Mokrá quarry were fenced, and we managed all apiaries in such a way that they were not able to swarm all the season. The increase of the temperature over 35 °C is critical for swarming preparation (Seeley & Tautz 2001). Therefore we had to control the swarming even according to the

temperature measurement of the brood area inside the hive.



Fig. 3. Beehives in early spring located at a unique base with an integrated load cell and temperature sensors.

Estimation of landscape pollution

The honey extracted from monitored bees became an interesting by-product. We decided to ask for a complete honey analysis for the content of selected metals (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Te, Ti, Tl, V, Zn, Zr), and about hundred types of pesticides for an accredited laboratory to compare its quality. We selected samples of honey from the second honey extraction (end of June/start of July).

Monitoring of solitary bee activity

We suggested and created special solitary bee traps of standardised size and design. We drilled three times the lime trunk of the 25cm diameter and 30cm length. 40 plastic straws filled each hole with a diameter of 4 cm and length 26cm with a diameter of 5mm and the length 24cm (Fig. 5). Each trap contained 120 nesting opportunities altogether.



Fig. 4. Standardised solitary bee traps prepared for installation. They have a natural look of a lime trunk with three holes by 40 black plastic straws.

We installed five traps at each from three monitored localities (Mokrá, Hády, Lažánky) at similar places in different distances from honeybee hives (15–350m). The front side of traps was situated to the south at a sunny position at the height of 0,7–1,2m above ground. Their installation was finished 23rd March 2018, just after last strong frosts. Traps were monitored to the middle of July in approximately two-week intervals. We analysed the obtained results in the software Statistica (Dell Software 2015).

Phenological investigation

We recorded three different phenological stages of reproductive organs of plants selected as essential producers of nectar, or pollen (Hagrasim 2013): start flowering date (about 10% of opened blossoms), full flowering date (more than 50% of opened blossoms) and the end of flowering (more than 90% of faded blossoms). Then we compared phenological records with the weight increase of bee colonies. Also, we were able to compare exact phenological differences between monitored localities summarising records of the same species and same phenological stage.

Statistical analyses were done in R-project (R Development Core Team 2017).

Results

Weight changes of honeybee colonies

We collected altogether almost 80,000 records about weight and temperature of hives and their closed surroundings from 25th March to 31st July 2018. Raw data from sensors are available at the data server here: <http://www.vcelylomu.cz>. Modified data (after removal of weight changes affected by beekeeping) are shown in Fig. 6. Weight records were combined with phenology of six the most important plants producing a high amount of nectar, which occur at all three localities.

First height increase was recorded with the start of the flowering of blackthorn (*Prunus spinosa*; around 15th April). At this time also many other fruit trees started to flower, such as apple trees, cherries,

plums and common pears, so till the end of Hawthorn flowering, all three localities were comparable. Later the locality Hády differed from others by almost continual weight increase, which was interrupted significantly only once by the period of nectar drought between 15th and 30th May. Both other localities (Mokrá and Lažánky) showed an irregular pattern in nectar income, which was interrupted more frequently. Periods of the dearth were the longest at the locality Lažánky, where higher honey flow was concerned to four short episodes followed by the long period of stagnation or even deficiency. The period of hive weight increase finished at all three localities around 20th June, and in total, they considered only 65 days. Some honeydew appeared for a short time around

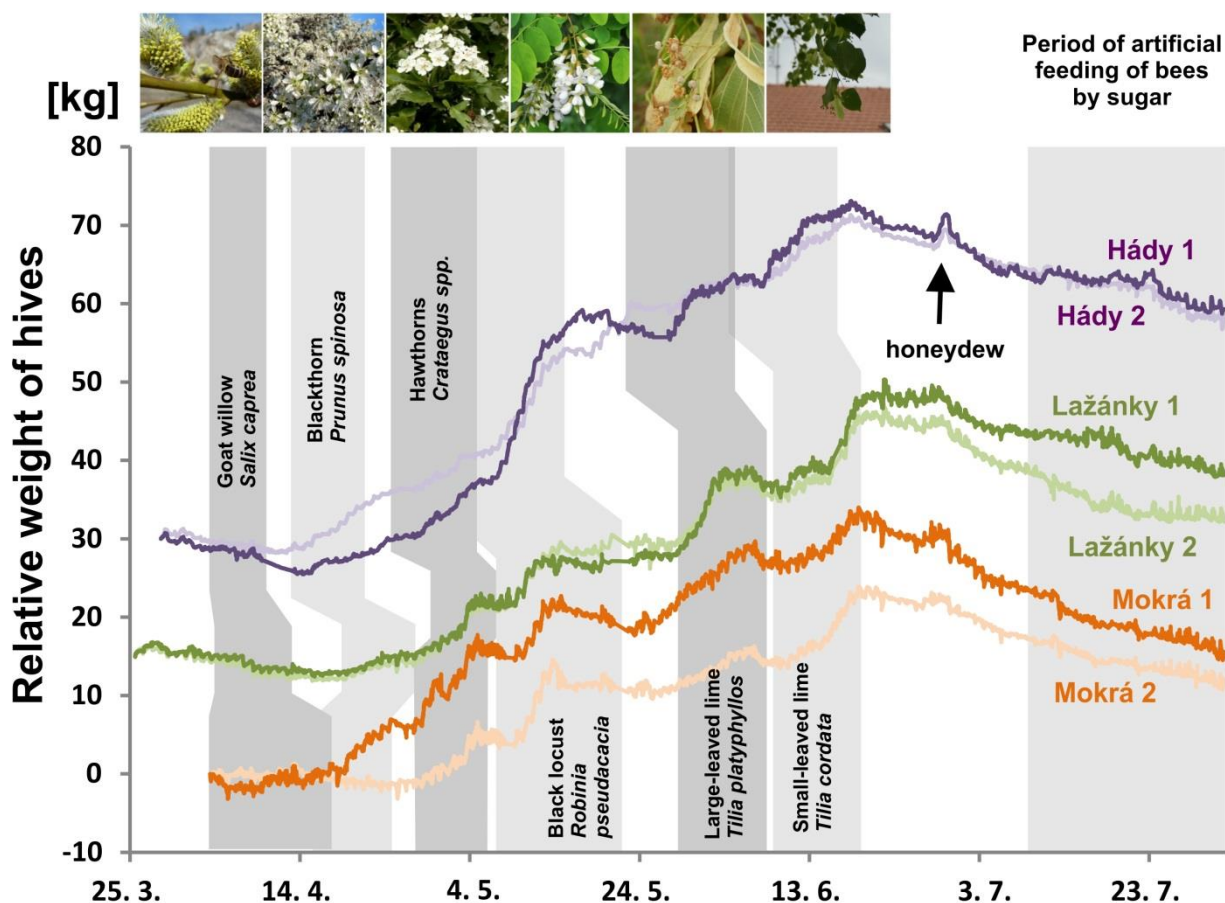


Fig. 5. The chart presents relative weight changes of honey bee colonies from 25th March to 31st July 2018. The starting weight of Mokrá was artificially set to 0 kg, Lažánky to 15 kg and Hády to 30 kg to distinguish and visualise all relative differences in honey flow. Periods of flowering of six the most important tree nectar producers, which grew at all three localities, were displayed.

27th June, but their income was marginal and remained unimportant.

The lowest amount of storage was found around 15th April, the maximum relative weight of the hives was recorded around 20th June. The maximum difference between the maximum and minimum weight (see Fig. 7) was 27–48kg. Part of this amount was consumed by bees or left for the rest of the growing season. Therefore, about 15–25kg of honey was collected from one hive. During the period from 4th April to 10th July (in total 97 days) 53–64 days with the weight increase were recorded. Bee colonies were artificially fed from 10th July, because natural honey flow stopped without any chance to continue.

	Total No. of records	Days with recording	Days with weight increase from 4.4. to 10.7.	Absolute weight difference (max-min) (kg)	Number of honey extractions	Total amount of extracted honey (kg)
Mokrá 1	16202	120	53	37.2	2	14.4
Mokrá 2			55	27.1		
Hády 1	22803	126	63	47.7	2	22.8
Hády 2			64	43.1		
Lažánky 1	39498	128	54	35.2	3	20.7
Lažánky 2			59	37.9		

Fig. 6. Basic characteristics of monitored bee colonies.

Temperature measurement inside beehives shown prevailed temperature of 34.5°C, which is advanta-

geous for the brood survival. Only in a few short episodes, the temperature rose to over 35°C, but it fell quickly back. Thanks to efficient ventilation the temperature inside hives fell even below 25°C, and it probably decreased the danger of colony to swarm.

	Mokrá (mg/l)	Hády (mg/l)	Lažánky (mg/l)	Maximum (45 samples) (mg/l)	Limits and recommendations (various informal sources) (mg/kg)
Al	5.6	<2.0	<2.0	9.6 (Dolní Rožínka)	5
Cu	0.43	<0.20	<0.20	1.2 (Pržno)	max. 2.5 (DDD)
Fe	2.3	2.3	<1.0	4.94 (Pržno)	max 15.0 (DDD)
Mn	5.19	0.69	2.29	15.0 (Čerenčany)	max. 9.0 (DDD)
Ni	0.67	<0.50	<0.50	0.707 (Sebranice)	1
Zn	4.22	1.57	2.03	2.58 (Zvole)	max. 10.0 (DDD)

Fig. 7. Selected elements of the honey determined by the accredited laboratory. Values of other elements were below the detectable level. First three columns show results from our honey, the last column considers the maximum value from 45 randomly selected Czech and Slovak honey (Matějková 2015). The fifth column shows some limits and recommendations for the food. Honey is classified as food for a special dietary. Therefore, its quality (instead of heavy metals, pesticides and antibiotics) is not officially limited (DDD – rec. daily consumption; 1l of honey = 1.4kg).

Estimation of landscape pollution

Most of the element concentrations were below the detection level. Therefore, it was not able to compare localities in all selected parameters. Elements, which concentration was precisely determined at least at one locality, were considered to the table at Fig. 8. For these components, the Mokrá has every time higher values than other localities. The value for zinc seems to be rather high because it overcomes al-

most two times the highest value mentioned in the bachelor thesis of K. Matějkové (2015), who analysed 45 samples of Czech and Slovak honey.

No pesticide was detected in our honey over the level of resolution and all honey samples suited to hygienic standards.

Monitoring of solitary bee activity

Design, parameters and functionality of solitary bee traps were successfully evaluated in the field. Only three traps remained unsettled, and the total occupation of individual clusters (a set of 40 straws in one hole) sometimes exceeded even more than 50%.

	Max. number of occupied nests		
	Mokrá	Hády	Lažánky
Trap 1	31 (31)	30 (21)	0 (0)
Trap 2	5 (4)	11 (11)	4 (0)
Trap 3	7 (6)	0 (0)	18 (4)
Trap 4	3 (1)	9 (2)	0 (0)
Trap 5	23 (23)	8 (6)	2 (2)
Sum	69 (65)	60 (40)	24 (6)

Fig. 9. The total sum of all occupied straws and the number of all straws occupied after 20th May (in brackets) by solitary bees at three monitored localities.

Total absolute number of occupied straws in individual localities is summarized at the Fig. 9. A time sequence of continuous occupation of straws by solitary bees is displayed in Fig. 10. While in both quarries (Hády, Mokrá) the number of occupied straws increased continually, the Lažánky showed another pattern. After the early spring period with the increase of nest numbers, which was comparable with other localities the nesting almost stopped after 20th May. It resulted in more than two times less total number of occupied straws than in the other two localities.

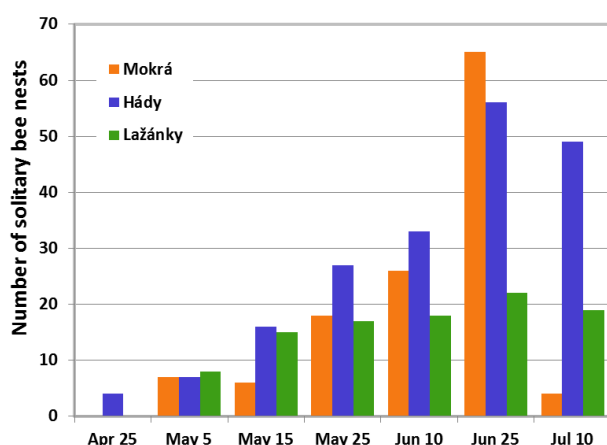


Fig. 10. Total number of actually occupied straws at each locality from 25th April to 10th July 2018.

We did not confirm a direct competition of honey bees with solitary bees. The distance between hives and solitary bee trap was not in any significant relationship (linear regression; $R^2=0.065$, $p=0.36$, $y=13.8805-0.0215x$). Regression slope was even negative, because two traps in front of hives (Trap 1,

Hády and Mokrá; Fig. 9) showed the highest number of occupied straws. Therefore, nesting activity of solitary bees was not affected by the distance from honeybee populations.

The straws started to be occupied approximately from 20th April, about one month after their installation. After the period of rapid early spring increase, their number started to stagnate. The increase was then recorded in late May and early June at both Mokrá a Hády locality. Later the number of occupied straws decreased probably due to hatching or nesting parasitism.

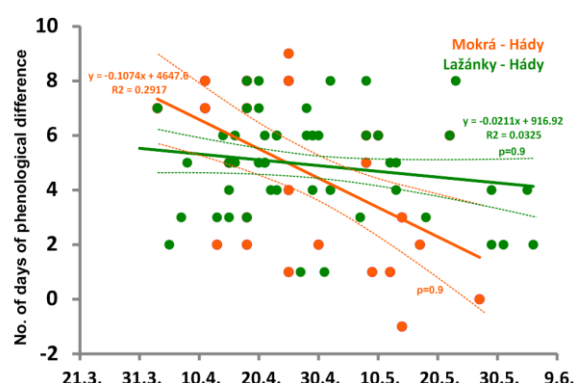


Fig. 11. Phenological difference between the same phenological stage at the locality Hády and one of the other localities. Each circle represents the difference of one species at one phenophase.

Concerning the fluctuation of the number of occupied nests, the total difference among localities is not statistically significant (Mood's median test; $p=0.15$). However, if we focus only at the number of nests after 15th May, the difference between locality Lažánky and two other localities (Mokrá, Hády) is statistically significant (Mood's median test; $p=0.03$). In both quarries, even after this date, the number of nests increased while Lažánky remained almost without any solitary bee activity.

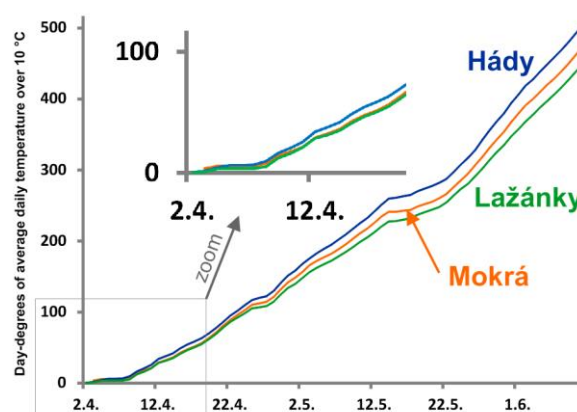


Fig. 8. Total sum of day-degrees of average daily temperature over 10 °C. First part of the season is zoomed to visualise almost no difference between Mokrá and Lažánky at this time.

Some nesting straws were occupied by other insects, as spiders (order Araneae) and earwigs (order Dermaptera), but their frequency nor the competitive potential for solitary bees were not tested.

Phenological investigation

During the spring season (March–June) we recorded phenology of 58 plants at one to three localities at one to three phenological stages (start of flowering, full flowering, end of flowering). In total, we collected 229 records about the species, locality, date and stage. The fastest spring develop was observed at Hády. Next two localities were phenologically comparable till the middle of April (Fig. 11).

At localities Mokrá and Lažánky in comparison to Hády, the vegetation is delayed 6–7 days in early spring. However, this difference significantly de-

creased only in Mokrá. The start of later flowering plants was 2–3 days faster than in Lažánky. A similar pattern can be seen at the Fig. 12 with the number of day degrees of average daily temperature over 10 °C. While the starting difference of day-degrees between Lažánky and Mokrá is negligible, it increases from the second half of April so, that Mokrá os on the half-way between Hády and Lažánky.

Thanks to phenological investigations we also had a chance to check, which species are the most important for honey bees. These most important species were included in the Fig. 6.

Discussion

Weight changes of honeybee colonies

This spring was climatically very unusual. The honeybee colonies were not able to grow so fastly, and the brood consumed most of the nectar. One from colonies in Mokrá showed even the weight decrease in the second part of April. In comparison to solitary bees, which collect mainly pollen resources, honey bees (*Apis mellifera*) are dependent on a nectar production of few vascular plants because of their storage potential. Also, the distance between the hive and forage resources is different – at poor localities, they can fly to 9.5km (Beekman & Ratnieks 2001), and so they are not dependent on the only local nectar resources. However, most honey bees collect nectar and pollen to the distance of 800m from the hive (Hagler et al. 2011). The closed vicinity of bee-hives is the most important for them, what is evident even from our data.



Fig. 9. Example of trap occupation at the site Mokrá (Trap 1, 19th June 2018) about 20m from honeybee hive.

Mokrá. Even though the amount of extracted honey was the lowest, the nectar flow during the season was more stable than at Lažánky. It seems that the periods of dearth are shorter, what is probably influenced by the higher biodiversity at this locality. Mokrá shows more suitable environment than an average cultural landscape.

Hády. Positive weight changes at this locality were registered during prevailed part of the spring season.

Moreover, they were more stable than at both two other localities, because the diversity of vascular plants at Hády is extraordinary. Honey bees have many opportunities to find a sufficient amount of nectar and pollen. It was obvious that insect pollinators may benefit from a correctly reclaimed limestone quarry.

Lažánky. We recorded high fluctuations in nectar flow indicating the dependence of honey bees at few nectar producents at the species-poor landscape. The weight increases (the success of the beekeeper at the exact year) depend mostly on crops grown at arable fields in surrounding of hives. The absence of nectar and pollen in more extended spring periods combined with bad weather and other worse conditions (parasite infestation, viruses) may be one of the essential reasons of bad survival of bee colonies in last years. Honeybee colonies must be frequently fed artificially by the beekeeper, and the amount of extracted honey is frequently less than the sugar added by the human. Other wild insect pollinators have no such opportunity. Therefore, such a landscape is risky and limiting for the survival of their populations.

Estimation of landscape pollution

When the chemical analysis is sufficiently precise, the honey is a useful indirect indicator of the environment quality (Buldini et al. 2001). We showed that the honey from our localities is safe and does not contain significant levels of heavy metals (Pb, Cd, Hg, Sn) and pesticides over the hygienic limits proposed by European Commission (Commission Regulation No. 1881/2006). However, it is necessary to select an accredited laboratory carefully. The precise analysis may have still an informative content nevertheless the values are deeply below any limits. Unfortunately, our current data consider only a few compounds with slightly higher levels over detectable laboratory level, and so the differences of localities are only intimated.

Despite this, the analysis showed expectable results: Higher dust pollution in the active limestone quarry contaminates nectar of flowering plants which is collected by honey bees. However, such contamination does not exceed tolerated hygienic limits generally for the human nutrition (no official data are available

specifically for the honey). Contrary, the honey is not a good indicator for the pesticide contamination of nature. We could expect that the cultural landscape will have higher levels of at least some pesticides, but no sample contained concentrations higher than detectable. The honeybees are rather efficient at filtration of toxic compounds, and the honey is filtered several times before it matures as a supply for long-lived winter bees (du Rand et al. 2015).

Monitoring of solitary bee activity

Our investigations did not show any direct competition between solitary bees and honeybee colonies, which would limit a nesting success of solitary bees (Fig. 13). Similar results were also supported by the study of Steffan-Dewenter & Tscharntke (2000). Therefore, during the study of solitary bees, it is not necessary to pay attention to the position of honeybee apiaries.

Following text analyses differences of studied sites:

Mokrá. Nesting activity of solitary bees was found at all installed traps. Number of occupied straws at two traps highly increased mainly during June, most of the nests were left at the start of July. It is possible to estimate that it was a single species, which occupied these nests and found sufficient forage resources at the edge of the quarry. No areas with the application of pesticides are in closed surroundings.

Hády. Although the nesting activity of solitary bees was found at four traps, it showed high intensity and fewer fluctuations during the whole spring period. The locality supports probably balanced forage resources for solitary bees all the spring season because the southern slope of Hády hill is heterogeneous and biologically diverse. Some areas with small private gardens may be a source of few pesticides, but it did not probably influence our data.

Lažánky. We can explain more than twice less number of occupied straws and the absence of any nest in two from five traps at this site by the fewer nutrition sources during more extended periods and by the frequent use of pesticides in a rural agricultural landscape. While first wild shrubs (e.g. willows – *Salix* spp.), weedy and ruderal plants (coltsfoot, dandelion) and fruit trees provide the sufficient forage resources, after rape flowering (start of May) the landscape almost stops to flower. Maize and other wind-pollinated crops overgrow arable fields, herbicides kill weeds, and insecticides suppress the life at arable fields. The food potential for insect pollinators strongly decreases in that time also due to species-poor extensively managed biotopes (see the Fig. 1). It is probably the reason of the absence of late spring and summer solitary bees in the cultural landscape, as it can be concluded by Hallman et al. (2017) in one of the most frequently cited scientific entomological pa-

pers (45 citations for the first nine months; source: PLoS ONE). These authors found an insect decrease of 76%, and this decrease was even higher (82%) during the summer months.

Found differences correspond with data, which we are collected from the weight increase of honeybee colonies. In Central European conditions after the flowering of black locust (*Robinia pseudacacia*) and before the flowering of large-leaved lime (*Tilia platyphyllos*) there is a transitional period of nectar dearth even for commercial beekeepers. While the site Hády has this period shorter, it was more distinctive at Mokrá and the longest and most influencing the activity of honey bees at Lažánky.

It would be rather interesting to investigate the species richness of solitary bees at individual localities, which needn't be trivial. The shape and used material for closing nests of straws suggest that it could be several different species. More than 600 species of bees live in the Czech Republic (Macek 2010), and some part can colonise similar straws as we used in our project. For example, the study of species richness of nesting traps, which have been done in France (Fortel et al. 2016) recognised in total 24 different species of solitary bees. Therefore, we decided to cultivate and determine surviving brood in straws by the expert (ing. Antonín Přidal, MENDELÚ Brno; beyond the QLA project scope), but we will know the result during the winter.

Phenological investigation

In comparison to the average dates of full flowering of many tree species at the period 1991–2010, which are published in Atlas of phenological conditions of the Czechia (Hájková 2012) we found a much faster phenological development of nature in the year 2018 at all monitored localities. It was about one week at the start of growing season, but this difference increased to two, and later to three weeks. At the same time, the phenological difference between localities shortened. We frequently observed a very untypical situation, when some tree species, which generally flower distinctively, flowered together at the same time. This situation was also supported by almost the absence of cold periods frequently slowing the phenological development during early spring.

The phenological difference between sites Hády and Mokrá decreased significantly, while the same difference between Lažánky and Hády remained comparable. Higher heterogeneity of the Mokrá locality can explain this situation, but probably the main reason is the heat island of the active quarry, which appears every spring and summer with the increasing insolation. We consider the shortening of phenological development of plants during the spring as an interesting observation, which has not been described yet.

Conclusions

The monitoring of honey bees and solitary bees was a technically tricky pilot project, for which we were not able to expect the success before its full termination. Therefore, we considered the project as very successful, because we obtained coherent and interpretable data. The monitoring of weight changes showed the differences between localities, which can be interpreted by the nesting activity of solitary bees.

The activity of honeybee colonies respected the character of closed surroundings of hives. We were able to show notable differences among all monitored sites. We can conclude that it is possible to describe the quality and distribution of forage resources for pollinators from the monitoring of beehive weight changes. Even though honeybee colonies show a slightly different pattern than the nesting activity of solitary bees, it is possible to describe the relationship of both independent measurements. It seems that localities with discontinuously distributed forage resources are not suitable for solitary bees. Approximately in between 15th and 30th May, we can see a distinct period of nectar dearth in conditions of Central Europe. The group of solitary bees is probably

more sensitive to the use of pesticides in the cultural landscape because every adult individual in the population is exposed to their impact. Honeybee colonies have only about 10–20% of individuals collecting nectar and pollen out of the hive. Even the massive infestation of flying honey bees gives a higher chance for the whole colony to survive, because it may easily regenerate. Therefore, the lack of wild solitary pollinators is evident, especially after 15th May.

Used solitary bee traps were considered as a suitable non-destructive tool for a quantitative evaluation of solitary bee activity. Even though the relatively small number of used traps we were able to distinguish the density of nesting populations statistically at monitored localities, which also corresponds with other tested parameters (species/habitat diversity and weight changes of honeybee colonies). Besides, we evaluated that the location of installed traps need not consider into account the distance from commercial apiaries. Due to a broad distribution of wild bees (*Apoidea*, about 20,000 known species), the proposed methods are probably applicable worldwide.

Popularisation of the project

We tried to disperse project results among a maximum number of people. We regularly actualised web pages of the project <https://quarrylifeaward.com>, where almost 90 news considering the life of solitary bees, honey bees, beekeeping and project realisation were published. All these news are also available at our Facebook 'Včely v lomu'. We needed some platform for the presentation of online records of hive weights. Therefore we established another web <http://vcelyvlomu.cz>, which started to be frequently visited by some other beekeepers who have no hive scales (more than 4000 accesses, about 15 unique accesses daily). We presented the project at a large information board, which was installed in the eco-centre Lamacentrum Hády, where about 15,000 visitors come yearly. We organised there a presentation of the beekeeping and honey on 10th June. The similar presentation was organised on 8th September in cement factory Mokrá, where more than 2000 visitors came (Fig. 14).



Fig. 10. Presentation of the project, beekeeping and many types of honey from the World at an event in cement factory Mokrá 8th September 2018 by our team.

We also published a print release on 27th June about the worse situation of solitary bees in our countryside. It was accepted and published in various news and internet sources (iDnes, BrněnskoDnes, Český svaz včelařů, Naše voda, Envivweb, Jihomoravské novinky, ZO ČSV České Budějovice a První zprávy).

Project outcomes

Evaluation of new research methods

During the project, we proposed, constructed and evaluated electronic equipment for the on-line monitoring of honeybee hives. We verified that such a tool could be assembled cheaply and with relatively low operating costs even in localities without a direct plug-in connection. We can see a big potential of this electronic equipment, because it is useful for many other environmental purposes. After small changes (sensor, software), it is possible to record, e.g. fluctuation of water level in drill holes and wells, actual water flow, or other quantitative characteristics useful

for online analysis and presentation. This tool is therefore perfect for long-term presentation of the environmental quality.

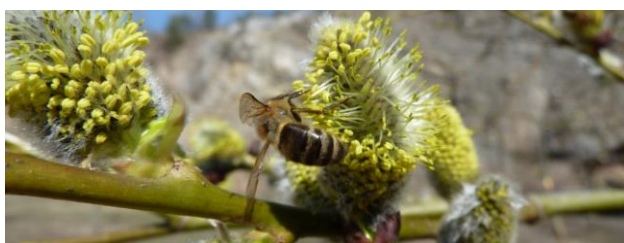
Also, the honey may be an excellent cheap tool for evaluation of the environmental quality in the case when we have sufficient amount of analysed samples from other localities. However, in respect to our few experiences, it is not clear, how different is a honey extracted during different parts of the growing season.

Another important outcome of this project was the proposal and evaluation of new standardised solitary bee traps. The project showed that these traps are (1) frequently occupied by bees in a suitable environment, (2) they have standardised shape useful for scientific research, and (3) they are not destructive for bee populations.

Proposal for improvement of reclamations

We may conclude from our project observations that for insect pollinators the occurrence of common, but insect-pollinated species is more important than the presence of rare and endangered species. However, this simple and obvious fact is not usually accepted in current reclamations. We will show here some examples of our native plants, which are crucial producers of pollen and nectar, but they are usually missing in reclamation plans:

Goat willow (*Salix caprea*). This widely distributed willow with a natural dispersal is frequently removed from reclaimed areas as a weed species. This dioecious plant has male and female individuals. While females offer only nectar, males are important producers of sugar in nectar and proteins in a high amount of pollen. They are fully occupied by butterflies, beetles, bees and other insects in that time. Although it is easy to reproduce it by cuttings, as we know, this species has not been used in reclamations yet. If it would be necessary to prevent future incident dispersal, it is possible to plant only males, which do not produce seeds.

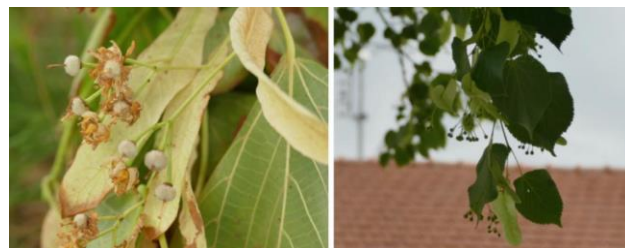


(Wild) Fruit trees (e.g. apples, pears, cherries, plums). They are used in reclamations rarely, but the combination of species and cultivars of fruit trees may prolong the availability of nectar sources to several weeks. Cultivars are frequently characterised by their difference in fruit ripening, which is preceded by

a different time of flowering. Moreover, some types of restorations may help in the preservation of those old cultivars of fruit trees, which are endangered by extinction. For the higher variability of phenological stages of individual species, it could help to take the differences in topography into account during construction of reclamation plans.



Small-leaved lime & large-leaved lime (*Tilia cordata* & *T. platyphyllos*). They are two visually similar native trees with similar ecological requirements. They mainly differ in the flowering dates. Large-leaved lime is two weeks earlier than the other species. It starts to flower in the middle of June and flowers usually 7–10 days. However, these two species usually are not distinguished in plantations. Their differentiation would help to prolong the flowering time of limes to almost three weeks.



It would also be another significant benefit for insect pollinators to support dispersal of insect-pollinated species and restore diverse grasslands, shrublands and forests with many flowering plants.

These small corrections of restoration plans could help to increase this part of diversity, which is usually neglected – concerning insect species, which are dependent on plants as forage producers. Moreover, beekeepers would be happy for the higher honey production and quality.

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Project tags (select all appropriate):

This will be used 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