1. Contestant profile

▪ Contestant name:	**Oskar Lövbom and Hampus Jarhede**
▪ Contestant occupation:	Students
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2. Project overview

Title:	How to make wild bees thrive in environments affected by quarrying
Contest: (Research/Community)	Research
Quarry name:	Slite

Abstract

Wild bees provide one of the most important ecosystem services we have: pollination. Unfortunately, pollinators all over the globe are declining and wild bees are no exception. One explanation to this decline is that natural habitats for wild bees are diminishing. Therefore it is of increasing importance to protect and create new habitats for wild bees. Fortunately, quarries have been found to provide suitable habitats for many species of wild bees. With the right actions many quarries could become thriving environments for wild bees helping to counteract the decline of wild bees. The aim of this study was to try to understand what actions are advisable to carry out in quarries. A variety of factors thought to influence number of species, diversity and abundance of wild bees was explored, this in order to figure out what actions that would best support wild bees in quarries. These factors were: flower distribution and the creation of artificial nesting sites in areas highly affected by quarrying and in control areas. What we found was that creating nesting sites in quarry areas did not have a different effect compared to control areas ($p > .1$). However, we could observe nesting at 5 out of 6 sites and wild bees at all sites. Flower distribution was found to be significantly correlated to the number of species ($p < .1$), diversity ($p < .01$) and abundance of wild bees ($p < .001$). From our study and earlier research we develop some simple and direct methods on how to safeguard wild bees. We conclude by presenting guidelines for: (1) Flower management, (2) Creation of nesting sites, (3) Ground management and (4) Other actions.

1 Introduction

One of the most important interactions between organisms on the planet is the interactions between insects and plants. One specific interaction, also called pollination, is necessary for approximately 80% of all plant reproduction (Schowalter 2016). To us humans' pollination also has an immense economical value, since 35-76% of our crops are pollinated by insects (Schowalter 2016; Willmer 2011). The value of the global pollination by insects has been estimated to 153 $ billions/year (Gallai et al. 2009).

One of the more important groups of pollinating insects are the wild bees. Bees live only of nectar and pollen during their whole life-cycle, which is unique amongst pollinators (Falk 2015; Willmer 2011). Bees are found in many different sizes and shapes all around the world. Currently 20 000 species have been described but the true number is believed to be several times higher (Falk 2015). The most commonly known and widely spread bee is the domestic honey bee (*Apis mellifera*) (Frankie and Thorp 2009). However, non-domestic bees, often referred to as wild bees, are not to be forgotten. Wild bees are actually a very important group of pollinators, especially now when populations of domestic pollinators, such as the common honey bee, are declining (Devillers and Pham-Delègue 2005). Another problem is that honey bees and wild bees compete for the same pollen and nectar, which in worst case can lead to honey bees outcompeting wild bees (Herbertsson et al. 2016; González-Varo and Vilà 2017; Steffan-Dewenter and Tscharntke 2000). If wild bees disappear from an area, species of the local flora might also disappear (Willmer 2011). Wild bees are also often more efficient at pollinating many crops and plants compared to honey bees (Cobert et al. 1991, referred in Klein et al. 2003; Falk 2015; Willmer 2011). The reason behind this is that many species of wild bees are highly specialized in their foraging for plants. Honey bees are instead generalists and can forage nectar from many different types of flowers (Westerkamp 1991). This specialization in plant choice have made many wild bees into very efficient pollinators, which further highlights wild bees important role in both agriculture and in the wild (Willmer 2011).

In Sweden there are about 250 species of wild bees, 177 lives on Gotland and about 16% of these are nationally red listed (SLU n.d.a). Many of these wild bees lives solitary (bumble bees being the large exception), which honey bees do not. Wild bees varies a lot in their nesting preferences, about 70% nests below sun-exposed ground and the rest nests in wood or in other plant material, for example in reeds (Linkowski et al. 2004).

However, this important ecosystem service (pollination) that wild bees and other insects provide us with is currently under threat. A study by Hallenman et al. (2017), that investigated the abundance of insects in nature reserves in Germany, showed a decline in insect biomass by 77% during the last 27 years. Several other studies confirm that the same pattern is true for bees, as bees seem to decline in both density and diversity (Devillers and Pham-Delègue 2005; Ollerton et al. 2014; Winfree et al. 2009, Woodcock et al. 2016; Potts et al. 2010; Goulson et al. 2008). Earlier studies have also found a number of factors that are thought to be the cause of this worrisome decline. Some of these factors are changes in agricultural and livestock management, excessive use of pesticides as wells as diminishing habitats and pests (Exeler et al. 2009; Frankie and Thorp 2009; Garibaldi 2009; Goulson et al. 2015; Roszko et al. 2016; Schowalter 2016).

When agriculture, cities and industries expand they often do so at the cost of natural habitat of wild bees (Aizen and Feinsinger 1994; SBA 2004). Therefore, it is of utmost importance to protect and restore suitable habitats for wild bees. One area where wild bees have been found to sometimes thrive is in quarries (Krauss et al. 2009; Heneberg et al. 2012: Nilsson 2010). Both active and inactive quarries have under the right circumstances been found to be a suitable habitat for a variety of species (Krauss et al. 2009; Sydenham 2012). Some threatened species even heavily rely on quarries as a habitat, and there are three threatened bee species on Gotland that does so *Melitta melanura*, *Megachile lagapoda* and *Coelioxys obtusispina* (Krauss et al. 2009; Karlsson and Larsson 2011; Nilsson 2010; Sydenham 2012).

By doing some simple, inexpensive and low-maintenance work the suitably of quarries as a wild bee habitat can easily be increased. For example by planting flowers and creating suitable nesting sites, these actions would likely yield an effective response as well as helping other organisms

(Soldinger Almefelt et al. 2015; Nilsson 2010). We have chosen to explore the difference in affect that artificial nesting sites have in quarry and control areas and also how flower distribution affects the diversity, number of species and number of observed wild bees (the abundance) of wild bees. Because natural habitats, where wild bees normally nests, often are at risk of either becoming overgrown or removed entirely (SBA 2004). Man-made nesting sites such as: sun exposed piles of sand and bee hotels can therefore play an important role for wild bees and by creating nests the number of wild bees in an area should increase (SBA 2004). Hopefully these man-made nesting sites could function as a counteraction to the detrimental effects of habitat loss. Another factor that probably influences the number of bees in quarries are the flower distribution. The interaction between flower distribution and wild bees has been poorly studied in quarries but have been shown important in other habitats (Kruess et al. 2002; Krauss et al. 2009; Holzschuh et al. 2008; Ebeling et al. 2008).

We think that with the right preparations, further expansion of quarries doesn't necessarily need to pose a threat to the local wild bee population, especially if similar actions as described earlier are taken together with a few additional measures. In this study we hope to see the same positive results as other studies have seen, which performed similar measures for wild bees in urban and agricultural landscapes (Fortel et. al. 2016; Winfree, 2010). If so, it might be possible that habitat loss by further quarrying could be replaced by creating new nesting sites nearby, allowing wild bees to quickly resettle in new areas. If these efforts are done correctly, it is possible that the biological value in the area might be higher after quarrying than before.

Our ambition with this study is to collect important data to make the quarries at Slite and Smöjen better homes for wild bees, thus safeguarding a threatened and very important cornerstone of biodiversity. We also aim to raise awareness amongst Cementa and the local citizens around the quarries at Gotland about this important ecosystem service. We plan to do this by producing a short movie about our project (posted on the QLA-blog), contacting local news media and putting up signs with information about wild bees at our locations. We also wish to demonstrate that humanly-disturbed areas like quarries could, with a few simple actions, become homes to a great variety of wild bees thus helping to counteract the negative global trends. To aid in this matter we plan to develop some global guidelines on how to make wild bees thrive in quarries. In order to understand what actions that should be recommended we will research the following questions: (1) Is there a difference in diversity, number of species and abundance of wild bees between quarry and control areas with artificial nesting sites? (2) Are the diversity, number of species and abundance of wild bees correlated to the flower distribution?

2 Methods

2.1 Nesting sites

Using piles of sand for below ground nesting wild bees and bee hotels for above ground nesting wild bees, we created six nesting sites in six different locations at Gotland, Sweden (Appendix 1). Where sites 1 and 2 were located near the File Hajdar Quarry, 3 and 4 near the Western Quarry and 5 and 6 near the Smöjen Quarry (Appendix 1). Three sites (2, 4, and 6) were created in areas affected by quarrying. The nesting sites were chosen within areas where they would not be affected by the ongoing quarrying, making it safe for us to inventory. The other three nesting sites (1, 3, and 5) were created in less disturbed areas and were used as control sites. All control nesting sites were placed outside of quarries. However, due to the soil properties of Gotland and since groundwater levels are high in spring, we had to limit the placements of nests to areas easily accessed by roads. At each site one bee hotel and one sand pile were placed. The quarry and control sites were located at least 800m from each other, so that no interactions would occur (Linkowski et al. 2014). All nesting areas were placed facing south, so that they would be exposed to the sun for the majority of the day.

The bee hotels we built measured 80x60x20 cm and consisted of one third natural birch wood, one third with blocks of untreated fir wood and one third of bamboo and reed. In the fir and birch wood we drilled approximately 200 holes varying between 2,5-12 mm in width and about 15-19 cm deep. The bamboo and reed was cut into suitable lengths of 15-20 cm. By doing so the reed and the bamboo provide excellent nests since they by nature are hollow. The reason behind the variation

of hole size was to accommodate nests for as many different species of wild bees as possible.

For the piles of sand, we used 2 cubic meter of sand with a grain size of 0.06-2 mm, which Cementa helped us transport to the locations. The piles of sand were then placed in sun exposed areas of 2x2 meters near the bee hotels. By doing this simple action the below ground nesting bees will be able to dig their own holes directly in the sand.

During large scale actions flowers are normally planted to provide sufficient amounts of nectar and pollen for wild bees. However, in our study this was not done due to two reasons. First, we wanted to study the difference in effect of only creating nesting sites in the two different types of habitats. Second, we did not want to plant any new, potentially alien species in the areas before we had a better understanding of the local plant composition. The endangered flower *Pulsatilla patens* has also been found in areas close to the File Hajdar quarry and we did not want to create any potential new threats to its survival.

2.2 Inventory methods

To find out how successful the constructed nesting sites had been, we surveyed the areas for wild bees using three different inventory methods: (1) transect inventory, (2) nesting site inventory and (3) an inventory of the whole site and its surroundings. All bees that were found during the inventories were noted either with the species name or with an ID:number for later identification. We chose to do three inventories in order to cover the entire flying season of wild bees in Sweden.

The transects were inventoried using a well-tested method that the Swedish University of Agricultural Sciences (SLU) have developed for fieldwork on bumblebees (Glimskär et al. 2018). The transects were placed in a square surrounding the man-made nests. Each transect was 20m long, the start and the end of each transect was marked with GPS (WGS84). Some requirements of the chosen method is that the weather cannot be too windy (maximum of 8m/s), too cold (minimum air temperature of 17 degrees C) or too cloudy (the sun had to be shining all time). The transects was walked in a set tempo of 4 min/100 m and at each transect average flower distribution was noted (‰).

The nest site inventories were done in order to see if any wild bees were nesting in our constructed nests. During the nest site inventories we first sat by the pile of sand for 10 minutes and then by the bee hotel for another 10 minutes, during this time we noted all bees, other hymenopterans, predators such as birds/spiders and parasites at the nest. The condition (e.g. if damage and mold was present) of the nests were also noted.

Last, we searched the area surrounding the nesting site for 10 minutes. This inventory was used as a complement to the two prior inventories, for a more complete species list of the areas and in order to gain an accurate understanding of what could be done to improve the quarries.

2.3 Statistics

All statistical analyses were made in either Excel 2016 or Rstudio (Version 1.0.136). The diversity index (Shannon-Wiener diversity index) was calculated using Excel and was done for each area. The calculated diversity indexes were then used as a measurement of bee diversity in the sites and used in a number of tests. For analyzing if the abundance, number of species and diversity differed between the two habitats we did three paired t-tests in Rstudio. To analyze if abundance, number of species and the diversity was correlated with flower distribution three regression analysis were made in Rstudio.

3 Results

125 wild bees and a total 30 species were observed during our inventories (Appendix 2).16 species were new sightings for Slite, nine were new for File Hajdar and seven species were new for Smöjen. At all 6 sites bees were observed. However, during the inventories nesting were only observed at 5 sites.

3.1 Differences in diversity, number of species and abundance of wild bees when comparing Quarry sites to Control sites.

When analyzing the abundance of species we found that area 2, 4 (Quarry) and 3 (Control) had the highest number of different species with 15, 11 and 14 species respectively (Figure 1B). However,

when comparing the different area types, we found no significant difference ($p > .1$) in number of species. During the different times of inventories, we observed most bees during our visits in late June and mid-July (Appendix 3).

When we analyzed the abundance we found again that sites 2, 3 and 4 had the highest number of sightings (Figure 1A), while sites 1, 5 and 6 had the lowest. However, no significant difference ($p > .1$) in abundance of wild bees was found between control and quarry sites. The same pattern, no significant difference ($p > .1$), was seen when analyzing the difference in diversity between quarry and control sites (Appendix 3).

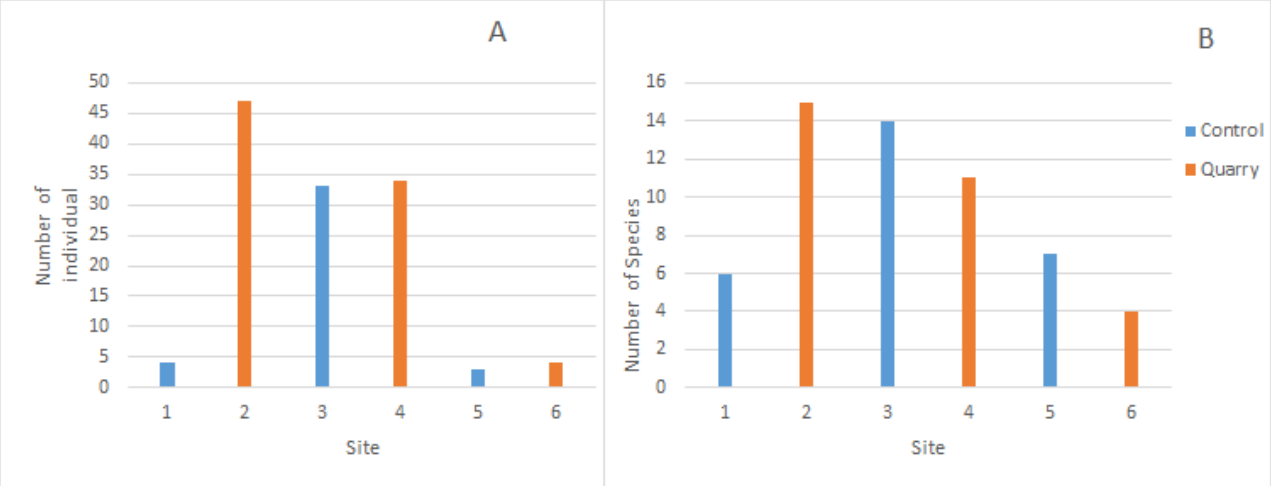

Figure 1. A) The total number of bees found at each study site. Site 1-2 are located near the File Hajdar Quarry, 3-4 near the Western Quarry and 5-6 near the Smöjen Quarry (Appendix 1). B) The total number of different species found at the different locations, with the same sites as in A).

3.2 Effect of flower distribution

The regression analyses showed that the number of species ($R^2 = .554$, $F(1,4) = 4.968$, $p < .1$) and the abundance of wild bees ($R^2 = .9795$, $F(1,4) = 191$, $p < .001$.) (Figure 2 and Figure 3) was significantly correlated with the flower distribution. The same could be seen when analyzing the correlation between diversity of wild bees and flower distribution ($R^2 = .85$, $F(1,4) = 22.67$, $p < .01$; Appendix 3)

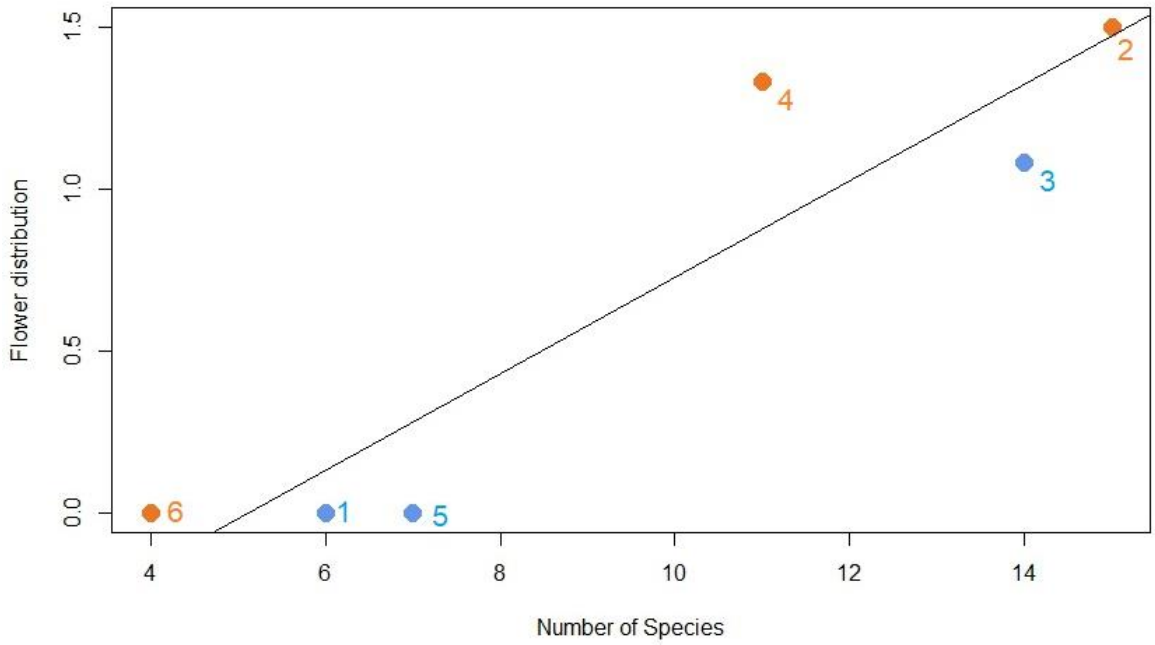

Figure 2. Number of species correlated with flower distribution. Each circle represents a study site (Blue=Control, Orange=Quarry) and site 1-2 are located near the File Hajdar Quarry, 3-4 near the Western Quarry and 5-6 near the Smöjen Quarry (Appendix 1).

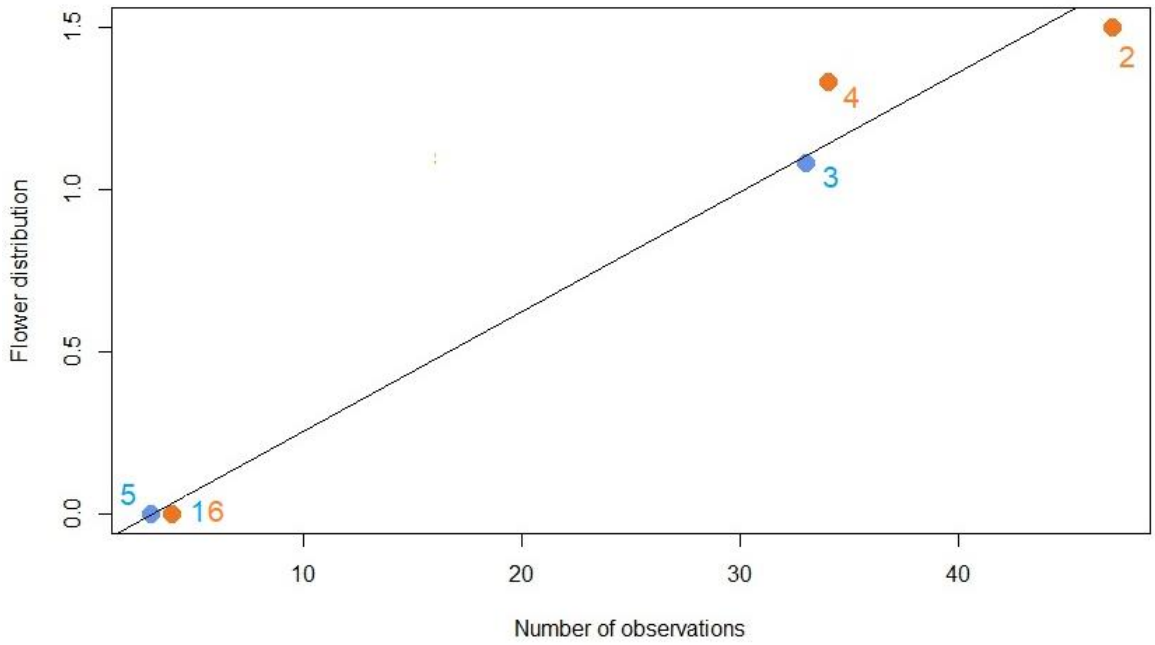

Figure 3. Number of observations correlated with flower distribution. Each circle represents a study site (Blue=Control, Orange=Quarry) and site 1-2 are located near the File Hajdar Quarry, 3-4 near the Western Quarry and 5-6 near the Smöjen Quarry (Appendix 1).

4. Discussion

4.1 Effects on abundance, number of species or diversity of bees

During our inventories we found a total of 30 species of wild bees and many of these were new to their location (SLU n.d.a). However, due to our relatively small searching areas it is probable that many more species could be found with further efforts.

We argue that there might be a number of possible scenarios explaining why no significant difference in abundance, number species or diversity of bees were found between the quarry and the control sites. First, there might not actually been any difference between the study sites. If this is the case, wild bees will to the same degree find and nest in man-made nesting sites regardless if the area is quarried or not. Another possibility is that our control plots did not differ enough in disturbance from the quarry plots, due to limitations of placement. We could not place our nesting sites in optimal locations due to practical reasons, for example: ground-water levels and not obstructing the path of vehicles down in the quarries. The number of replicates could also be a possible explanation as to why we did not find a significant difference. Too few replicates might have caused a too large variation of bees found in quarry and control plots, resulting in our analyses not being strong enough to detect a difference.

Even though our results showed no significant difference, between quarry and control areas, we argue that our nesting sites did work and probably benefited the local bee fauna. During the inventories nesting was observed at 5 out of 6 sites, concluding that creating man-made nesting sites actually creates environments where bees can nest. However, some modifications to the nesting sites are in order. After gaining an increase knowledge about wild bees, we argue against creating large bee hotels, as we did. We do not recommend this due to an increased risk of parasites and disease in large bee hotels (MacIvor and Packer 2015; Moenen 2012). A phenomenon that we also observed during our inventories. Large numbers of cells hosted parasites and many birds used the higher concentrations of insects around the bee hotels as a way of getting an easy meal. Instead we think that other options should be used (see 2. Nesting sites, Guidelines).

We argue for creating more natural habitats, which we think would favor the local wild bees and could also benefit some more rare species, such as the nationally red listed wild bee *Megachile lagopoda* (Nilsson 2010). For example one could create nesting sites from already overburden soil taken from the quarry to not add new material with other properties (for more information see Guidelines; Soldinger Almefelt et al. 2015). If done correctly these new natural areas would also be excellent habitats for other species and could increase the diversity of birds, insects, wood living fungi and species connected to them (Soldinger Almefelt et al. 2015; SLU n.d.b; Hedengren 2014; Moenen 2012)

We also think that another factor heavily have influenced the results, this factors being flower distribution. We observed that in the three areas where we had the highest distribution of flowers we also had the highest numbers of species and individuals of wild bees (Figure 2; Figure 3). When analyzing the correlation between the abundance, the number of species and the diversity of wild bees with the distribution of flowers we found it to be significant. The same pattern is also supported by other studies, which have found that with a high flower diversity the abundance of wild bees is increased (Dauber et al. 2003; Krauss et al. 2009; Warzecha et al. 2017). This might not be that surprising since wild bees feed of the nectar and pollen from flowers. Meaning that when creating new habitats for wild bees it is essential to focus on flower distribution and use the local flora as a guideline, for example *Centaurea scabiosa* or *Succisa pratensis* would be a fitting choice for Slite (For more see Appendix 4). If alien species are used there is a risk that the local plant community will dramatically change and as a consequence, probably alter the local diversity of wild bees in an undesired way (Gurevitch and Padilla 2004). Benefiting the local flower distribution could also have a positive effect on other local organisms, such as beetles, hymenopterans and butterflies, e.g. *Maculinea arion and Parnassius apollo* in Slite (See Appendix 4; Nilsson 2010).

4.2.1 Global guidelines for managing wild bee populations in quarries

The following guidelines are important in order to safeguard wild bees in quarries. Guidelines for other organisms (such as: birds, plants, fungi and other insects) are often similar in their advices. Therefore if our guidelines are followed wildlife as a whole, around and in the quarries, will be greatly favored. For more specific guidelines regarding Slite, see Appendix 4.

1. <u>Plant management</u>

Flowers are necessary for wild bees to thrive in an area. The more diverse the flora in an area is, the more species of wild bees are normally found there. Therefore it can be of great value to increase the plant diversity in and around quarries. Ideal timing of establishing new plant communities depends on the plant species. We recommend that new plant communities are established using a combination of the following methods (NAM 2016; Nilsson 2010; Petterson et al. 2004; SBA 2016; SBA 2018; Soldinger Almefelt et al. 2015):

- A good starting point is often to reuse overburden soil material which has the soil qualities and the seeds that are desired. If stored correctly the overburden soil could hold a local seed bank alive for over a year and when used again be a direct source of local plant species.
- If time is an issue and no overburden soil is available, topsoil donations from areas not too far away can be used instead. The donation area should be similar to the targeted habitat, both in soil properties and in flora.
- Topsoil should be spread thinly (maximum of 2.5cm) over the area, so that the seed bank in the soil can be activated.
- Plants can be established in meadows or as flower beds.
- Plants can be established in the area by spreading locally sourced seeds or by moving and replanting locally sourced full grown plants or by planting seedlings grown in greenhouses from locally sourced seeds.
- If time is not an issue plants can be allowed to self-colonize prepared areas (areas cleared from current vegetation, see 3. Ground management). This method often is the cheapest.
- It is advisable to create a habitat where there are blooming flowers present during the whole growing season. If a broad variety of local plants are used this normally solves itself.
- If rare species of wild bees are present in the area extra effort should be put into making sure that the preferred plants for those species are established.
- Meadows and flower beds has to be maintained and not allowed to become overgrown by e.g. Unwanted trees, bushes and grasses. For further instructions see 3. Ground management.

2. <u>Creating nesting sites</u>

Bees need to have some place to nest in order to inhabit an area. By creating nesting sites, together with other actions, the diversity and abundance of wild bees in the area will increase. Wild bees either nest above or below ground, therefore it is important to create both types of nesting habitats. Nesting sites can be created any time of the year, the following guidelines are advised:
MacIvor and Packer 2015; Moenen 2012; Nilsson 2010; SBA 2016; SBA 2018; Soldinger Almefelt et al. 2015; Svensson 2012).

Above ground:
- We recommend placing dead wood in the area instead of using bee hotels. The dead wood should be drilled, creating holes 2-13 mm in width and about 15-19 cm deep, since it resemblance how wild bees naturally nests. Dead wood should be sourced locally and treated wood should never be used.
- Sites should be placed so that they are exposed to the sun for the majority of the day.
- If bee hotels are to be used we strongly recommend that they have to be small in size (less than 30x30cm) and placed well distributed over the whole area.
- Using large bee hotels heavily increases the risks of parasites, diseases and bird attacks.
- Above ground nesting sites often increase in biological value first after a few years.

Below ground:
- Nesting sites for ground nesting wild bees should always be placed where it is exposed to the sun for the majority of the day but preferably not too exposed to the wind.
- We recommend using local overburden as material for the nesting sites.
- If no local overburden is available and external material has to be used we recommend doing an

analysis of the material first, assessing the soil properties and risk of alien plant species.
- When creating piles of sand for below ground nesting bees it is important that the sand is of a varied grain size. The sand piles needs to contain some silt or mud particles so that the tunnels dug by the bees will not collapse.
- Other material like piles of gravel and cobble should also be available as it is needed by some species of wild bees as nesting material.
- A pile should at least be 2x2m and contain $2m^3$ of material, but preferably larger. Piles should be well distributed over the whole area.
- Disturbing the ground (3. Ground management) is also an effective way of creating nesting sites for ground nesting wild bees.
- Sun facing screes and slopes of different material can be of great value to ground nesting bees, especially if almost vertical and made of sandy material. This screes and slopes should not to be remove or become overgrown. If possible, the creation of sandy screes and slopes is a very good alternative to sand piles.
- Creating these types of habitats could also increase the biodiversity of e.g. beetles and birds.

3. <u>Ground management</u>

Plants that grows in and around quarries are often favored by disturbance. Therefore ground disturbance is necessary if these plants are not to be outcompeted of existence by generalist. Without the disturbance favored plants many depending organisms, including bees, would also risk to disappear. Many ground nesting bees are also dependent on ground disturbance in order to find suitable nesting spots (NAM 2016; Potts et al. 2003) SBA 2016; SBA 2018; Soldinger Almefelt et al. 2015; Willmer 2011). Some suitable methods of ground disturbance are:

- Areas suitable for ground management are hills of overburden soil, screes, slopes, parts of meadows and grasslands.
- Harrowing and scraping the ground with e.g. bulldozers or tractors could be used to expose soil and remove vegetation. By harrowing the soil is loosen up and recreates suitable nesting sites for wild bees and could also active the seed bank of disturbance favored plants.
- Mowing, low intensity grazing and controlled burning of meadows and flower beds can be used to keep them from getting overgrown. For optimal effect a combination of these methods should be used in the area to create slightly different habitats. However, any of these methods can make a huge difference.
- Grazing has to be done with care and with low intensity. If too many animals are placed in a too small area grazing can have a very detrimental effect on insect diversity.
- Grazing by goats and sheep should be done extreme caution since they easily overgraze areas.
- Mowing should only be done in early spring and/or in late autumn, when there are no or almost no flowers blooming. The mowed vegetation is then to be left for 1-2 weeks for seeds to drop and should then be removed to not return nutrients to the soil.
- The cheapest method is often to use controlled burning of the vegetation, this since no material has to be transported away afterwards. Burning is recommended in early spring. We also recommend that the meadows are only partly burned, e.g. half of the meadow is burned one year and the other half the following year.
- One should never use alien soil that differ in quality from the local soil. For example: In an area with nutrient poor soil, nutrient rich soil should never be introduced.

4. Other actions

Other actions than previously mentioned could also be important, such as raising awareness about quarries and not filling the entire quarry with water (Kraus et al. 2009). If done correctly these actions would also help the wild bees. Therefore, the following things should be considered:

- Activities can be made together with e.g. local schools, companies and other organizations, to raise awareness about quarries role as an important habitat for wild bees. Some suitable activities are seed sourcing and spreading, planting flowers and building nests.
- Excursions and lectures could also be important for engaging the local wildlife enthusiasts.
- One should never water fill entire quarries. However, creation of smaller ponds can be beneficial for insects.
- We recommend leaving large parts of a quarry untouched by actions when the quarrying ends. This since many species of wild bees already thrive in quarries even without any actions taken.

5 Conclusions

What we observed was that wild bees chose to nest in man-made nesting sites, showcasing that creating nesting sites could work as an action for protecting the local wild bee diversity. However, we could not prove that creating nesting sites had different effects if placed in quarry or control areas, there are a number of possible explanations to this (earlier discussed in 4.1). Contrary to our initial beliefs we now argue that bee hotels might not be optimal for large scale actions, this based on our own observations and on other studies.

We did find that abundance, number of species and the diversity of wild bees were significantly correlated to flower distribution, proving that plant management is an important focus when creating habitats for wild bees in and around quarries.

We also managed to develop some general and specific guidelines that could hopefully aid in safeguarding wild bees both nationally and globally. With this study we hope that Cementa at Slite, Sweden and HeidelbergCement will have gotten a deeper understanding about wild bees that are living in and near their quarries.

To be kept and filled in at the end of your report

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