UNIVERSITY OF GOTHENBURG

DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES

THE FORGOTTEN GOLDEN SAND BEE:

A follow up on the status of the golden sand bee *Andrena marginata* in Municipality of Mark, a decade later

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Andrena marginata ♀ *on Succisa pratensis. Photo: Wilhelm Osterman*

Content

Abstract

Over a decade ago, a conservation project aimed at preserving the endangered golden sand bee (*Andrena marginata*) populations in the Storån valley of the municipality of Marks was initiated. The species, red-listed in Sweden as well as in many other European country, specializes in pollen from Devil's bit. However, due to a limited financial period of three years, the current status of the sites remained unknown. This follow-up study addresses the knowledge gap, aligning with the recognized importance of ongoing assessments for threatened species conservation. Objectives encompassed: (1) investigating the current number of the golden sand bee and the abundance of Devil´s bit in the area, (2) assessing the sites' present status, (3) determining the necessity for new conservation measures, and (4) leveraging the study for public awareness and support conservation. The method utilized inventory of the bees was a "no-kill" using a sweeping net or by survey walks. Management measures for habitats of the golden sand bees were found in existing literature. Inventory results revealed a correlation between Devil's bit abundance and observed golden sand bee numbers. Overgrowth by Bushgrass emerged as a predominant threat, primarily attributed to weak disturbances, and at one site competition with the honey bee was especially pronounced. The overarching conclusion underscores that consistent, suitable management is crucial for site and population sustainability, whereas neglect or excessive changes jeopardize their viability. The study has proactively communicated inventory results, identified threats, and proposed actions to landowners, leasers, and the Marks municipality, with ongoing supportive engagement. Observed species has been reported to the Swedish Species Information Center (Artportalen). Encouragingly, the study has garnered local media attention, with an article in Markposten highlighting how wild bees, including the golden sand bee, can be preserved.

Keywords: Golden sand bee, *Andrena marginata*, Devil´s bit scabious, *Succisa pratensis*, Oligolectic bees, Inventory, Meadow land, Conservation

Abbrevations:
CAB – Country Administration Board
CEC - Centre for Environmental and Climate Science
EPA – Environmental Protection Agency
GBIF - Global Biodiversity Information Facility
SMHI - Swedish Meteorological and Hydrological Institute
STA - Swedish Transport Administration

Background

During an inventory of the natural environments along the Storån in Marks municipality in 2007, several interesting species of wild bees were found. One of them were the golden sand bee *Andrena marginata*, which at the time only was known from about twenty areas in Sweden and listed as threatened on the red list. The discovery led to a preservation project; Project Golden sand bee and was carried out by the environmental office in the municipality of Mark, between year 2009 – 2012, with funds from the Action program for threatened species. Its purpose was to preserve the small populations of the threatened golden sand bee *Andrena marginata* that occur in Storån valley (Figure 1), and the goal was to find measures that work in the long term and that improve the living conditions for the golden sand bee. Several measures were tried out such as vegetation control, burning, digging etc. and during the three-year period the number of observed golden sand bee females in the area increased from 8 to 46. The golden sand bee population, which was judged to be weak in 2009, increased during the course of the project and was considered to be stable at the end of the project in 2012, provided that the environments continue to be managed appropriately. As the occurrence of Devil´s bit and the golden sand bee increased during the project period, which correlated with the increased number of Devil´s bit stems, it is likely that this increase was an effect of implemented measures (Nolbrant 2012).

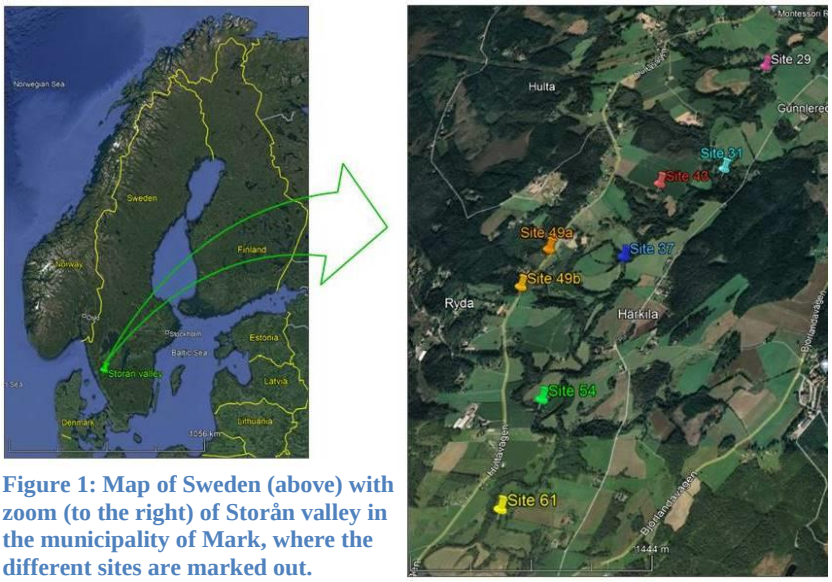


Figure 1: Map of Sweden (above) with zoom (to the right) of Storån valley in the municipality of Mark, where the different sites are marked out.

The golden sand bee

The golden sand bee *Andrena marginata* was discovered by Fabricius in year 1776 (GBIF). *A.marginata* is a medium-sized bee; females can be up to 11 mm, while the male is slightly smaller. The female's head and middle body are black and the hind body can vary from completely dark to completely dull carrot red, all intermediates can occur, however the first hind body segment (tergite) is always black. The hair is light brown to whitish on the head and middle body, the hind legs (the hips) have heavy hair, the long hairs, flocculi (Figure 2) are curved and form the pollen basket (scopa) where pollen is gathered (Figure 3) (Larsson 2006; Falk & Lewington 2015). The golden sand bee is an oligolectic species, which means that pollen is only collected from a limited number of plant species, in this case from scabiouses. Devil´s bit (*Succisa pratensis*) (Figure 3) is the main pollen source in Sweden.

Figure 2: The golden sand bee (♀), with visible flocculi on the hips.

Figure 3: The golden sand bee (♀) loaded with white pollen from its host plant Devil´s bit. Photo: Peter Nolbrant

A. marginata belongs to the family Andrenaidae, also called digger bees. They live solitary but can occur in aggregations (colonies), depending on the quality of the habitat and the availability of suitable substrate. As solitary bees, they dig their nest tunnels in the ground; the entrance to the nest is surrounded by a characteristic tumulus, a volcano-like elevation that surrounds the nest. The species is univoltine, i.e. has a one-year life cycle and has its flight period during the time that *Succisa pratensis* flowers; roughly between the end of July until the middle of September. The males appear a little earlier and have a shorter flight time when they fertilize the female and then die (Larsson 2006; Falk & Lewington 2015).

Devil´s bit Scabious

The golden sand bee populations in the Storån valley mainly collect pollen from Devil´s bit Scabious (*Succisa pratensis*). *S. pratensis* belongs to the family Dipsacacae, and is an herbaceous wildflower that thrives on sandy or gravelly soils where there is moving ground water, and prefers open grasslands, moist pastures, meadows and heaths. Populations of *S. pratensis* are composed of females and hermaphrodites, as they are so-called gynodioecious, which means that some plants bears only female (pistillate) flowers (Figure 4 A) or both male (staminate), and female (pistillate) flowers (Figure 4 B) on other plants. Pollen is only produced in hermaphroditic flowers (Larsson 2006).

Figure 4 A: Female (pistillate) flowers

Figure 4 B: Hermaphrodite with both female and male (staminate) flowers.

Occurrence and Red list classification

With data on 2343 occurrences of *Andrena marginata*, Sweden tops the list of occurrences in Europe (Figure 5) (GBIF). Despite that the golden sand bee is red listed as "Near Threatened" (NT) in Sweden since 2020, and a decline is ongoing or is expected to be, due to reduced habitat quality and decreased geographical range. Over the past decade the rate of reduction for this bee has been ranging from 10% to 20%, which is a similar reduction rate as for its host plant Devil´s bit scabious, which has had a 15% decrease over a 10-year period. The rate of decline, as well as for the estimated values for the occurrence area, is in close proximity to the threshold for "Vulnerable" (VU) for the Swedish population (Swedish Species Observation Centre 2023). *A.marginata* is classified as "Vulnerable" in Norway (Norwegian Biodiversity Information Centre 2023) and as "Endangered" (EN) in Denmark (Danish Nature Data Centre 2023). In Finland, *A. marginata* has transitioned from being "Vulnerable" (VU) in the year 2000 to being classified as "Critically Endangered" (CR) in 2010 and 2019 (Finnish Biodiversity Information Facility 2023). In England, the species has seen a significant decline in almost all areas, similar to *Andrena hattorfiana*, which also collects pollen from Dispaceae (Falk & Lewington 2015). In Ireland, the bee is categorized as "Critically Endangered" (CR) (National Biodiversity Data Centre, Ireland 2023), and in Germany as Highly threatened (German Red List Center).

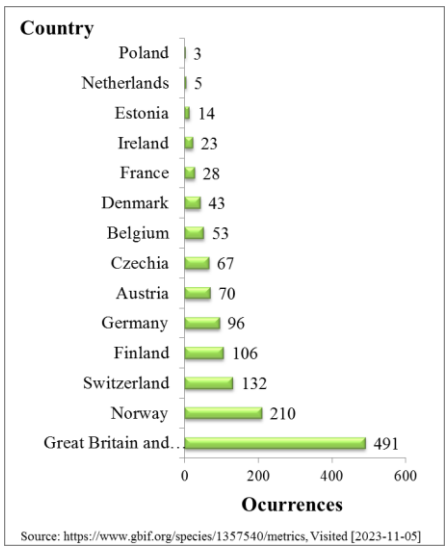


Figure 5: Occurrences of *A. marginata* in European countries

Objectives

In 2012, Project golden sand bee in Mark was completed and today there is no information about the current status of the premises. The report emphasizes the importance of management, which might not has happened but the golden sand bees (along with other wild bees that benefited from the project's efforts) might have had to fend for themselves. In the Swedish Environmental Protection Agency's latest guidance for wild pollinators, follow-ups are recommended in the longer term, around 10 years, in areas where measures have been taken. Experiences from such follow-ups can contribute to an increased knowledge base (Swedish EPA 2023). There has been no follow-up at these sites, but there was a need of one. Thus is the purpose of this study to examine: 1) current status of seven sites in the Storån valley for comparison with the status achieved at the end of the project in 2012; 2) current status, with regard to the presence of females of the golden sand bee *Andrena marginata* on the sites in Storån valley, 3) current status, with regard to the presence of Devil´s bit, *Succisa pratensis*, on the sites in Storån valley; 4) assessment of the sites – are they in need of new conservation measures; what threats exist, what measures may need to be taken and who can be assumed to carry them out?

In addition to increased knowledge, there was also a hope that this study can rekindle the interest in preserving these populations, which at the time of the project existed among both landowners, the County Administrative Board (CAB) of Västra Götaland, the Environment Office in Mark's municipality as well as among the residents of the municipality.

Methods

A large number of published studies and reports related to wild bees, oligolecty and global change have been read. Parallel with this study I also made a literature study where the subject is; Oligolectic bees and global change impacts on oligolectic bees (Böttcher 2024). Scientific articles have been searched via global databases; Web of Science, ScienceDirect, Google Scholar, etc. Reports and some facts originate from established intuitions or authorities such as Artportalen, the County Administrative Board, the Swedish Environmental Protection Agency, Swedish Universities, Personal communication with the Swedish entomologist and bee expert Björn Cederberg has also formed the basis for certain parts of this study. It should be noted that so called “grey literature” has been used; grey literature typically refers to sources or information that falls outside the traditional academic publishing channels and may not undergo the same rigorous peer-review process. This "grey literature" includes reports, working papers, government documents, theses, and other materials that are not formally published in mainstream academic journals or books. Grey literature can be valuable as it often contains data, information, or perspectives that might not be available through conventional academic sources. However, since it hasn't undergone the same level of peer review, its reliability and quality may vary.

Inventories

In accordance with the Swedish Entomological Society's ethical guidelines for insect studies, no-kill was conducted: hand raking with direct observation and field determination. This is because traps can exterminate threatened species locally, as these species' population sizes are often small and failing. The initial plan was to inventory (number of stems) *Succisa pratensis* on at least three occasions during the period 7 – 31 August (weeks 32 – 35) and at the same time count all golden sand bee females. The time period is adapted to the golden sand bee's flight time, which is synchronized with when the *S. pratensis* blooms (around July 25 to September 15), and the *S. pratensis* blooms at the bee´s peak during August. Inventories should be carried out during the day, preferably on warm and sunny days with relatively calm weather (Larsson & Franzén 2007).

However, the present year's poor weather conditions resulted in inventories being carried out when the opportunity arose and only a few of the inventories were carried out under optimal conditions. A number of different inventory methods were used; 1) capture; 2) “hot spot” survey and 3) survey walks. On four occasions, all female golden sand bees that were seen were captured with a sweep net and kept in test tubes (with air holes in the lid) in a shady location until the entire area had been searched. The premises sometimes had to be divided into sub-areas out of consideration for the golden sand bee. Inventorying the entire site, with bees stored in test tubes, would put the bees at risk as keeping a bee in a test tube for too long can be harmful, and it might even die from overheating. The hot spot method was used on one occasion. The method consists in monitoring, in this case, a small area with Devil´s bit for a certain period of time and recording the number of visits by female golden sand bees. The other inventories (survey walks) were carried out by walking slowly through the entire population of Devil´s bit and counting the number of golden sand bee females seen at the same time as the number of Devil´s bit stems were counted with the hand tally counter. At one of the sites (at sub site 61 D) an area with a relatively homogeneous distribution of a large amount of Devil´s bit, the number was calculated from five randomly selected sample squares. The randomization was carried out by throwing colourful reflex rollers rolls (facing away from the area and with the wrong hand). Before the throw, the directions (west and south) were determined from which 1 meter long bands were laid out so that the area corresponding to 1 square meter. The number of Devil´s bit was counted for each square meter with a hand tally counter, the sums were added up and divided by five. The number of stems/sq. m. was then multiplied by the total area measured with the infrared distance meter.

Material

- Sweep net
- Test tubes with air holes in the lid
- Hand tally counter
- Thermometer
- Infrared distance meter
- Camera
- Insect binoculars
- Maps of the sites
- 5 colourful reflex rollers
- 4 bands, 1 meter in length

Use of data

Data was analysed in Excel, using R package.

Results

Abundance

This year's inventory of the golden sand bee found the bee in four of the seven sites (Figure 6) that were inventoried during the project period.

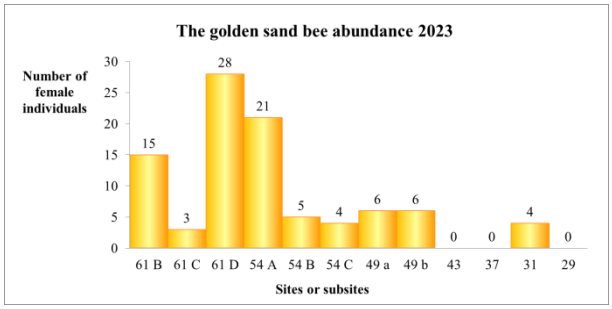


Figure 6: The abundancy of the golden sand bee (number of ♀) at the sites, year 2023

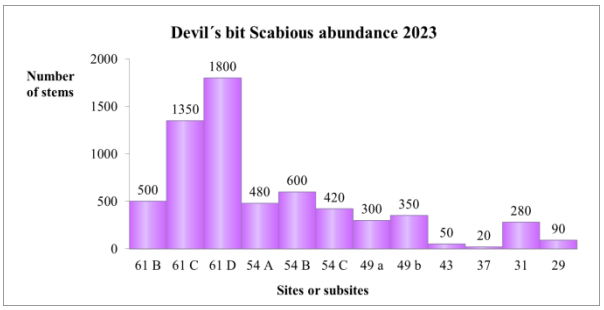


Figure 7: The abundance of the Devil´s bit (number of stems) at the sites, year 2023

The abundance was especially rich in site 61 and 54; these both sites were divided into subsites. A similar trend could be seen in the inventory results of the Devil´s bit (Figure 7).

Change in abundance

To see the change in abundance the results from the project were compared to this year´s results. The results showed a huge increase of both the golden sand bee and Devil´s bit at site 61 and 54, a smaller increase were found in site 49, whereas the other sites showed decreases in both the golden sand bee and Devil´s bit (Figure 8 and 9).

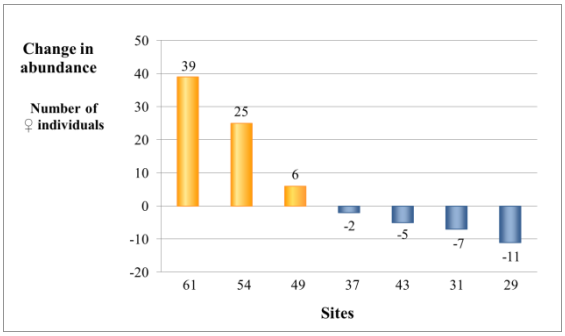


Figure 8: The change in abundance of the golden sand bee at the sites between 2012 and 2023.

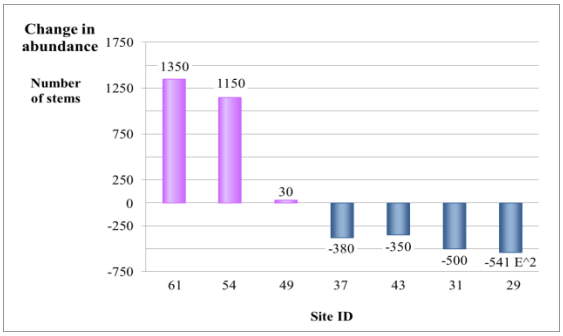


Figure 9: The change in abundancy of Devil´s bit at the sites between 2012 and 2023.

Spearman's Rank Correlation

To see how the relationship is between the golden sand bee and Devil´s bit a statistic test was performed. The Spearman's Rank Correlation Coefficient is a statistical test that examines the degree to which two data sets are correlated. The correlation between the proportional changes in abundancy of variable 1 relative to the changes in variable 2 and ranges from -1 to 1. For example, if species A has a correlation value near one, negatively or positively, on species B node, we conclude that species A correlates strong with species B. However, if the correlation is close to zero, the species does not correlate.

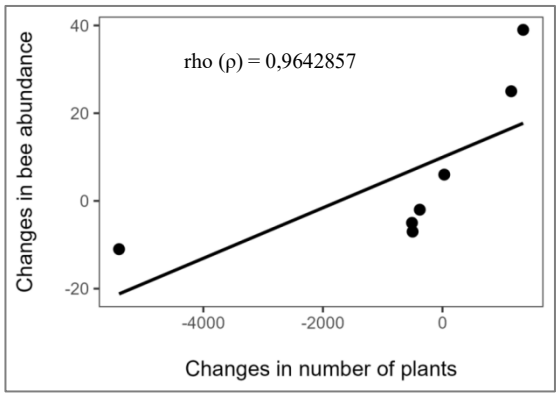


Figure 10: The Spearman´s Rank Correlation test gave the result S = 2, p-value: 0,002778, ρ: 0,9642857, which shows strong positive correlation.

The result of the statistical test showed that there is a strong positive relationship between the abundance of the golden sand bee and the abundance of Devil´s bit (Figure 10), as the value of rho (ρ) = 0,9642857. This means that a change in abundance of Devil´s bit affects the number of golden sand bee female individuals.

Current status

The current status is here only briefly described but a full description is found the section Site descriptions. In site 29, areas that in year 2012 had around 5500 stems of Devil´s bit has been replaced by a dense vegetation of young trees and bushes, due to lack of management, and no golden sand bee were found. In site 31 there has been a reduction in the number of Devil´s bit and areas are grazed by sheep, leaving very few flowers. A smaller number of the golden sand bee was found though. At site 37 there has been a huge change as the old tractor road has been altered into a road consisting of macadam and crushed gravel. The surrounding areas are overgrown with young lignose vegetation. A few stems of Devil´s bit were found but there was no sign of any golden sand bee. Regrowth has also occurred at site 43 resulting in decreases in flower abundancy and no golden sand bee were seen. Site 49 is this year divided into 49 A+B and 49 a (which makes the total number of sites to eight). 49 A+B has some sporadic stems of Devil´s bit but in 49 both Devil´s bit and golden sand bee had increased, although the increases were not large. The situation was similar at site 49 b. In sites 54 and 61 the results were astonishing, probably due to maintenance performed and cow grazing. Both sites are made up by mosaic structure where Devil´s bit and sand patches for nest holes are available at several different places (Figures 11 a-e).

Figures 11 a - e: The mosaic structure in site 54.

Threats identified

Bush grass

Bush grass (*Calamagrostis epigejos*) overgrowth is a threat to three of the eight sites; 49 a, 54 and 61. Bush grass (Figure 12) is a robust and tall perennial grass species that forms extensive stands through its creeping rhizome. Its leaves are broad, hard, and grey-green, and it features a grey-brown stipule. The plant often has a dusty appearance where it thrives. This species is distributed throughout almost the entire country and is commonly found in dry sandy areas, such as road verges, embankments, and beaches. Bush grass thrives best in semi-shady locations with moderately nutritious soil. Characteristic of overgrown areas, this grass exhibits high competitiveness in areas that are not regularly managed. Bush grass rapidly spreads vegetatively through its well-branched rhizomes, forming widespread stands. Bush grass is grazed by both horses and cattle, while sheep mainly consume tender leaf parts from young plants. Similar to other tall grass species, Bush grass is sensitive to disturbance and only becomes problematic in areas with poor or no management (CAB of Blekinge 2004).

Figure 12: Bush grass at site 49 a.

Competition

There was high abundance of honey bees at site 61. In August the occurrence of honey bees did not seem to cause any competition whereas in September an indication of likely competition was to be seen. It expressed itself as reduced abundance of the golden sand bee in areas having the highest abundance of Devil´s bit, where the numbers of honey bees were totally uncountable. The golden sand bee was only to be seen in the edges of areas with high abundance of honey bees. The honey bees showed a "rude" behavior towards all other insects (as well as to the human performing the inventory), but not towards each other. There are at least three farms having several hives of honey bees within one kilometre from site 61. In a research investigation exploring food overlap, it was observed that honey bees swiftly deplete forage resources, potentially resulting in the local extirpation of wild bee populations. These findings offer valuable parameters for decision-making in the management of honey bee colonies within regions inhabited by threatened species. Notably, the study identifies *Andrena marginata* as one of six distinct oligolectic bee species facing threats, demonstrating a food overlap exceeding 70% with honey bees (Rasmussen et al. 2021).

Raise of awareness

The aims in were to contribute to available data of the studied species, to raise awareness of the general threat to wild bees and to what can be done to mitigate their survival. Here are some points on how the results of the study shall be or have been utilized.

- Landowners / Leasers
    - All results and for some, suggestions of new measures, will be shared with the landowners and leasers.
- New landowners
    - The new landowners (site 29) will receive additional suggestions of measures that would mitigate a return of the golden sand bee.
- Swedish Transport Administration
    - Results have been shared together with a suggestion of; 1) changed management 2) consideration of a rise in classification of the roadside`s value.

- Swedish Species Observation System
    - Species and abundancy has been reported.
- County Administrative Board of Västra Götaland
    - The result will be shared with the County administration board of Västra Götaland as the golden sand bee is subject to action programme of threatened species.
- Article in the Local newspaper (Markposten)
    - The study has garnered local media attention, with an article in Markposten highlighting how wild bees, including the golden sand bee, can be preserved
- (Strömma Agriculture High school)
    - An attempt to contact has been taken without any response.

Discussion

As the surveys for the golden sand bee were conducted under suboptimal conditions, it is conceivable that the observed number of females might underestimate the actual population. Additionally, there could be females present at the sites that were not detected during this study. It is essential to note that not all females engage in pollen collection simultaneously, as they often return to their nest holes and arrange brood cells. Furthermore, during peak solar intensity, some individuals may refrain from pollen collection, possibly due to heat-related factors (personal communication with Cederberg, B.), impacting the recorded count of golden sand bee females. The likelihood of misidentification of species is minimal, as potential confusion species were thoroughly examined before the inventory, and reference materials were brought to the field. The two species most susceptible to confusion with *A. marginata* based on appearance are the large blood bee (*Sphecodes albilabris*) and *Andrena labiate* (due to the fact that *A. marginata* can have black tergites together with carrot red tergites). However, the large blood bee is a kleptoparasitic species that does not engage in pollen collection, and *Andrena labiata* has its flight period in the spring.

Even though the number of golden sand bees has significantly increased at two locations, it should be emphasized that, unfortunately, it appears that the number of locations with golden sand bees has decreased from seven to four. The greater the distance between locations with golden sand bees, the higher the risk that these populations may decrease over time due to isolation. Given its relatively small size, to be optimal the distance between suitable habitats and areas abundant in Devil´s bit for the golden sand bee should not exceed 200 meters. This distance is considered the maximum flight range between the nest and the flowers (Nolbrant 2012). The detailed aspects of a species' distribution, such as the identification of newly established individuals, their flight range, the rate of advancement, the speed of colonization, and the number of attempts required for successful establishment, remain largely unknown and necessitate further investigation through research (Linkowski et al. 2004). Studies on the pollen requirements of the golden sand bee have revealed that in areas with appropriate nesting substrates, a consistent presence of approximately 185 densely flowering individuals of the food plant Devil´s bit is necessary for a small population (≤ 20 females) of the golden sand bee to thrive (Larsson 2006). Storån valley is highly valuable as the geomorphology and soil types in the Storån valley provide highly favourable environments for the golden sand bee and other insect species. The valley contains deep layers of fine-grained sediments deposited by water flowing into the sea during the melting of the last ice sheet. In numerous areas, sandy and moist soils create suitable conditions for nesting for many wild bee species (Nolbrant 2012).

It has been shown that extinction vulnerability is strongly increased in bees flying in late summer, with a statistical model that included flight time, habitat preference, and duration of activity correctly predicting the vulnerability status of 85% of the species (Hofmann et al. 2019). Devil's bit serves as a food source for numerous late-flying pollinators, especially during exceptionally warm summers, when premature blooming of various other flower species may occur. Consequently, Devil's bit has the potential to undergo a second flowering, providing nectar and pollen accessible to a wide range of pollinators. A comprehensive survey should be conducted to identify other wild bee species present in the Storån valley. There is e.g. a possibility that *Andrena humilis*, listed as vulnerable in the Swedish Red List by the Swedish Species Observation Center, was found in Hulta gravel pit. Although, this could not be confirmed due to the image's lack of clarity (Figure 13). It is inferred based on the observation that *Andrena humilis* extensively collects pollen from the subfamily Cichorioidae.

Figure 13: A bee found at Hulta gravel pit, possibly the vulnerable *Andrena humilis*.

Conclusions

The overarching conclusion underscores that consistent, suitable management is crucial for site and population sustainability, whereas neglect or excessive changes jeopardize their viability. For the long-term survival of the species, a network of suitable habitats with different moisture levels within dispersal distance is required, meaning that other suitable areas near existing habitats also need to be managed.

The sites necessitate periodic monitoring, preferably at intervals of no more than five years, and a comprehensive inventory of wild bees in the Storån valley should be conducted. Identification and protection of floral reserves along Storån valley should be conducted; a series of habitat patches containing plants of the threatened golden sand bee would allow migratory pollinators to move between patches of plants, which are critical for preserving the populations in the long term.

Acknowledgments

I am deeply grateful for all the help and time that Peter Nolbrant (BioDivers, Nature Conservation Consultant, and author of the report "Project Golden Sand Bee in Mark 2009-2012") has generously provided in responding to my (numerous) questions and guiding me through the various locations in the Storån valley. I would also like to express my gratitude to my supervisor, Julia Osterman, who consistently and methodically clarified any uncertainties I had and demonstrated a genuine interest in fieldwork, which has been invaluable and motivating for me. A warm thank you also extends to the landowners who warmly welcomed me to the survey sites. The fact that several landowners have continued conservation efforts for the golden sand bee even after the conclusion of the project in 2012 is hopeful. I would like to thank the Entomological Society in Stockholm for awarding me a scholarship for the purchase of a book on wild bees and an insect binocular. Last but not least, I want to express my gratitude to Åslög Dahl for accepting the role of examiner and to course leader Charlotta Kvarnemo, who has been consistently available for my numerous inquiries.

Site descriptions

Here, the various sites of the project period 2009 – 2012 are described, current status and (if any) measures needed to be taken. All information referring to the project period 2009-2012 is taken from the project report; "The golden sand bee in Mark" (Nolbrant 2012).

Site 29

In 2012, the largest number of golden sand bees was found at site 29 (together with site 31), which was eleven females. This year, not a single golden sand bee was found, and the amount of Devil´s bit that in 2012 amounted to around five thousand, there was now only a few percent left.

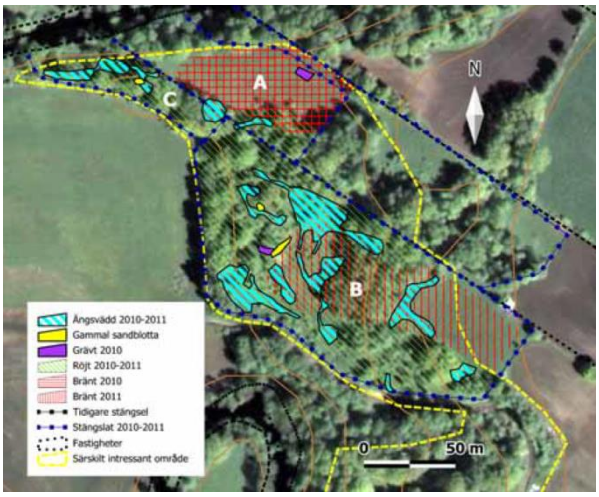


Figure 14: Site 29, Ekeberget 600 m V, Coordinates: O12.4413, N57.5865 (WGS84)

The site (Figure 14) were described in 2012 as a 3.1 ha large, varied area, with south-west facing brinks and slopes. There is both a sandy hill and a slope with sandbars, suitable as nesting sites for golden sand bees. In 2009, there were several thousand stems of Devil´s bit indicating that suitable habitats were the limiting factor. During the course of the project, clearing and felling of birch, hornbeam, hazel and younger aspens and oaks was carried out. A sand patch of 50 m^2 was excavated in subarea A and two of approx. 2-3 m^2 each in subarea B. In subarea B, hazel bushes were also dug up with their roots as this shaded an existing sand patch.

Today, subarea A is mostly grass, although it still has some flowers. However, the area is grazed by sheep in late summer, which means that the bare sand that was dug during the project is mostly still there. Around the premises, you can also see plenty of badger burrows, which also contribute to several smaller areas of exposed sand, suitable for nesting sites. The remaining areas are overgrown with small oak, aspen, raspberry bushes and other trees belonging to early succession stages. The areas that were cleared so that the Devil´s bit received light radiation are today heavily shaded; see the turquoise-striped figures in figure 14. The premises are rich in wild bees and among the species that were seen and could be identified with certainty were three longhorn bees, two white sand bees, six white sand bees, four splendid trouser bees and a fur bee.

The premises consist of two different properties and the land with subareas B and C has recently acquired new owners. The information that their land was a location for the golden sand bee was met with delight and they showed great interest in restoring these areas for the benefit of the golden sand bee and other wild bees. That landowners are willing to get involved is basically a prerequisite for saving our wild bees. It will require a lot of measures followed by appropriate care and for this Jenny Pleym, biologist, employed by the municipality of Mark, was contacted. She stated that the municipality can help with the establishment of a suitable management plan and that the landowners can apply for grants for initial restoration measures. Actions that will need to be carried out are the clearing of sloughs so that the light ingress increases and the burning of the grass that has been added in the absence of appropriate management, which will increase the occurrence of Devil´s bit. In the management plan, it is likely that the land will be fenced in so that horses and/or yearlings can be grazed. Split oak posts should preferably be used, being more environmental friendly than impregnated ones. For the purchase of fences, grants can be sought from the municipality.

Figure 15: Site 29, where areas that are suggested to take measures within, are marked.

For a comprehensive assessment and formulation of an overarching restoration and management strategy, it is advisable to establish contact with Jenny Pleyme at the municipality of Mark. However, for preliminary considerations, several minor interventions may be contemplated to improve the habitat for various wild bee species, including the golden sand bee. In regions denoted as area a and c (Figure 15), characterized by steep slopes facing southward, selective removal of vegetation such as trees and shrubs could enhance solar exposure. If grazing activities, particularly involving cattle, are implemented, the resulting trampling may inadvertently create favourable bare sand patches. In the case of area b, which currently encompasses a 10 sq. m sand patch, it is recommended to establish a pinfold enclosure around the sandy area and the Devil's bit plant. The pinfold structure, designed with an openable side, would allow controlled grazing by cows before and after the Devil's bit flowering period, aligning with approximate dates of July 1 and September 15.

Site 31

Site 31 was visited on two occasions and it was mainly subareas C and D that were examined. The total number of golden sand bees in 2012 was eleven females and one male. On the first visit this year, four females and one male were seen in sub-area D (see orange marking in figure 16), which were seen right at the beginning of the search. Then came fresh gusts in close succession and no more golden sand bees were seen. There were then 279 stems of Devil´s bit in the same area where around 500 grew in 2012. On the second visit two days later, there had been mushroom pickers there and probably they were also the ones who picked a substantial bouquet of Devil´s bit and trampled many nest holes. There were 110 stems of Devil´s bit left and not a single golden sand bee was seen.

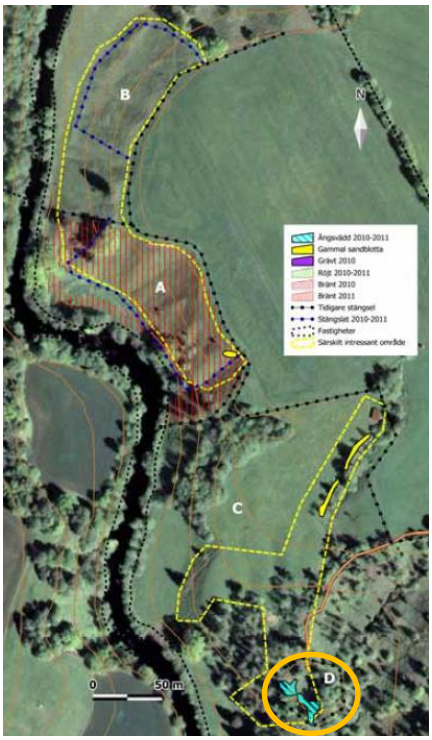


Figure 16: Site 31, Apelskog 240 m NNV, Coordinates: O12.4424, N57.5771 WGS84. The orange circle indicates subarea D.

Site 37

Site 37 (Figure 17) was prioritized away based on the fact that the number of golden sand bees had not increased during the project period, this year's very weak stock of Devil´s bit and the lack of suitable soil material for nesting sites. If there had been time, the premises would have been visited once more as the premises housed plenty of bees and even a small number of Devil´s bit can house a smaller population. In 2012 two female golden sand bees were seen but this year none were seen at all.

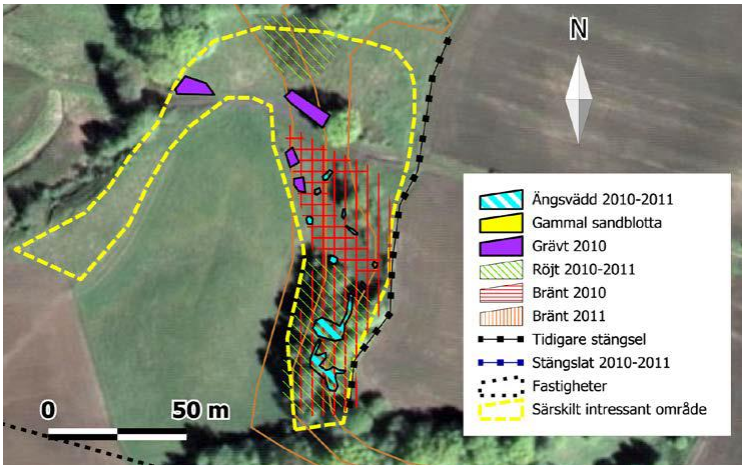


Figure 17: Site 37, Tomten 300 m VNV, Coordinates: O12.4336, N57.5698 WGS84

The premises are approximately 0.7 ha, there is a west facing slope and an old tractor road leads through the area. As the area was overgrown with trees in both the northern and southern parts with old grass in between, approx. 0.6 ha was cleared and 140 m2 of sandbars were dug at the beginning of the project period 2009-2012. Burning had to be carried out every year when the horses did not graze the more difficult-to-access areas in the southern part. Through the measures, the number of flowering Devil´s bit increased, from 65 to 400, on an area of approx. 100 m^2, despite this, the number of golden sand bees did not increase.

A possible reason could be that the material in the area has a higher proportion of soil content and is finer grained than sand, which does not appeal to the golden sand bee. However, other, smaller wild bees with other preferences dug hundreds of nest holes where the horses' tramps had exposed soil along the tractor road as seen in figure 18.

Figure 17: The picture is from 2012 with hundreds of nests of wild bees

Figure 19: The picture is from 2023 with several layers of crushed gravel/macadam.

Today this premises is completely changed, the tractor road is now covered by several layers of crushed gravel/macadam (Figure 19). Macadam and crushed gravel are used today as surface layers in several different road-related contexts and represent lesser-known threats to biological diversity.

The fine-grained material has been replaced by a ground cover where no wild bees can create their nests. (Swedish EPA 2021). The soil masses from the old tractor road now instead cover a large part of the open area of the slope (orange marking in figure 20) and have buried the Devil´s bit that grew there before. The area does not appear to have been grazed for a long time as open areas had old grass and there are no trodden paths. In the upper parts of the slope, a lot of raspberries and blackberries are now growing, in the more southern parts (marked in blue in figure 20) where all the Devil´s bit grew, it is now completely overgrown, and only eleven Devil´s bit could be found despite a careful search. The northern part (marked in green in figure 20) is overgrown with aspen and blackberry and no traces could be found of the dug sandbars on the premises. Despite this, there is an abundance of different wild bees in the area and some species of bees seen are one female and three male Long-horned Bees (*Eucera longicornis*), Large Scabious Mining Bee (*Andrena hattorfiana*) (NT) and one *Lassioglossum sp*. No golden sand bees were seen on the visit on 1 August, which is not so surprising as there was only one Devil´s bit that was in flower, the rest were in the bud stage.

Figure 20: Site 37

Site 43

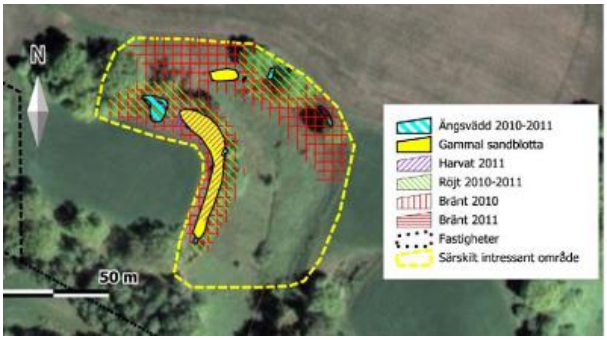


Figure 21: Site 43, Apelskog 460 m V
Coordinates: O 12.4358, N 57.5755 WGS84

Figure 22: Site 43

In 2012, five females of the golden sand bee were seen at site 43 (Figure 21), but this year no golden sand bees were seen at all. Of the maximum number of Devil´s bit of 550 during the project period, it was now only possible to find a maximum of 48 Devil´s bit.

This site was heavily overgrown as the area had not been grazed, cleared or harrowed since 2012. Despite this, there were plenty of wild bees and other pollinators. Under the broad-crowned oaks (blue object in figure 22) there are now about twenty young oaks and many raspberry bushes growing. The large patch of sand in the western part (green object in figure 22) is largely overgrown, but in the north-eastern part there is plenty of exposed sand as one or more badgers diligently digs holes. Harebell (*Campanula rotundifolia*), Germander Speedwell (*Veronica chamaedrys*), Rough Hawkbit (*Leontodon hispidus*) (NT) and Field scabious (*Knautia arvensis*) also grow there in abundance. The rest of the room, between the two figures in the picture and to the south, is completely covered with Queen of the meadow (*Filipendula ulmaria*) and some wild angelica (*Angelica sylvestris*). The highest number of stalks of Devil´s bit was counted on 10 August at 48 (which is about 10% of the 2011 stock).

No Devil´s bit had then begun to flower but was in the bud stage. It is a rather late bloomer, probably due to all the small trees that have grown up to create shade. No golden sand bees have been seen. In the Field scabious, five Large Scabious Mining Bee, *Andrena hattorfiana* (NT) were seen on one occasion, about ten Field scabious (*Knautia arvensis*) also had a second bloom at the end of August. Other bees seen at the site are blood bees (*Sphecodes* spp.), Gold-tailed Melitta (*Melitta haemorrhoidalis*), *Lassioglossum* sp., Yellow-Loosestrife Bee (*Macropis europaea*), sweat bees, honey bees and a great diversity of bumble bees and other pollinators.

Based on the great diversity of pollinators seen here, this locale is certainly worth saving. Small oak, raspberry and other young trees need to be cleared in the south-eastern part (blue figure), burning may also be relevant. To deal with all moose grass, grazing by sheep and goats is a good solution, cattle and horses unfortunately do not graze moose grass, but their trampling can disturb the growth. Depending on how moist the ground is (so the tractor doesn't sink down and get stuck), the moose grass could also be mowed repeatedly when flowering. The owner of this land leases out the area as they are not in a position to take care of it themselves, they would not mind if measures were taken on the premises provided the lessee (who owns the land where premises 54 is located) does not think otherwise.

Site 49 A + B

In 2012, seven golden sand bee females were seen at location A. In this inventory, area A (figure 23) has been divided into 49 A and 49 a respectively. Subareas A and B are used today for cattle grazing and no golden sand bees were seen in these parts. In area A, almost all the trees have been removed and the area is now completely open, occasional Devil´s bit grew in the pasture before the cattle were let in for grazing. The cattle create numerous large and small sand patches on the south and west facing slopes (B) and in many places you could see nest holes made by insects. Area B is also cleared regularly and the material is removed. The abundant flowering that existed during the project period could not be found again, there were now only single flowers growing and a total of twenty-one Devil´s bit were counted along the entire slope. The Large Scabious Mining Bee *Andrena hattorfiana* (NT) was seen in two specimens on the slope in subarea B.

Site 49 a

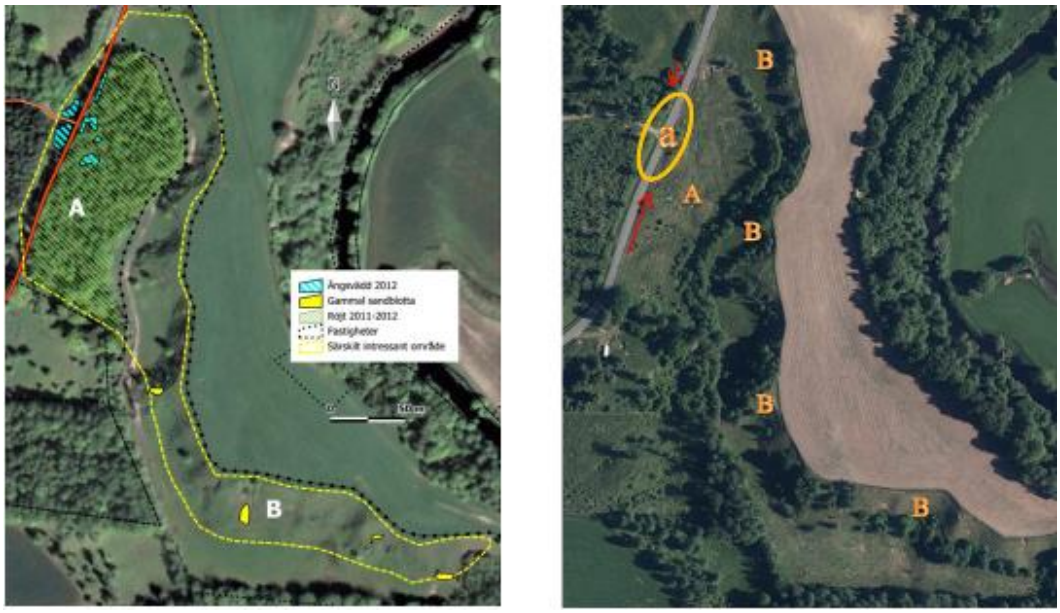


Figure 8: Site 49 a, Häljesgården 800 m N, Coordinates: O12.97743, N63.87839, WGS84. The red arrows in the right picture are position indicators for where the strong spread of bush grass threatens the abundance of Devil´s bit.

A maximum of seven golden sand bee females were seen at location 49 A in 2012, approximately half of those were seen in area 49 a. This year, five females were seen on August 13 and six females on August 29. However, these two occasions do not correspond to when the Devil´s bit blooms the most, but rather are at the beginning and end of the greatest bloom. It can therefore be assumed that it is possible to see more than six golden sand bees on this site if they are counted at an optimal time. Also based on the number of flowering Devil´s bit scabious and the fact that areas with suitable for nesting are located within flying distance, it is reasonable to assume that there are more golden sand bees than results presented in this study. There are also plenty of other pollinators on the site.

Site 49 a, is now completely in a sunlit position as all the trees have been felled in area A, which has benefited the presence of bush grass on both sides of the road. The roadsides are not cut during July to September, which allows Devil´s bit to flower. The Devil´s bit is, however, threatened by bush grass on both sides of the road (red arrows in the right picture above). Bush grass is disadvantaged by mowing and grazing and since none of these disturbances occur, this grass has been able to establish itself and is now spreading. Single lupines are also present on the site and these should be removed before they increase in number. The premises are located along a popular cycle path and thus contribute to recreation and tourism, which contributes to the fact that conservation measures should be taken. In total, it is about 20 square meters of bush grass that needs to be cut 1-3 times a year, grazing is not possible and the measure must probably be carried out with a clearing saw. The Swedish Transport Administration is responsible for these roadsides and will be informed of the situation (read more under local 49 b).

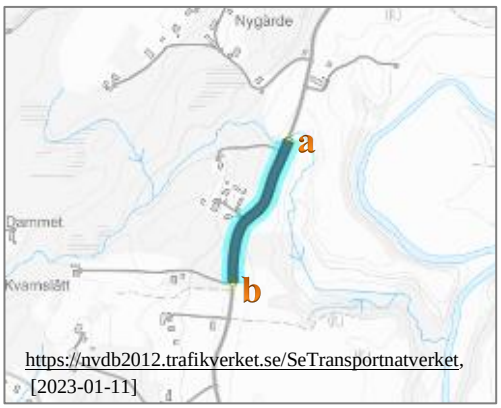
Site 49 b

Local 49 b is located roughly 300 m further south from local 49 a, this local also consists of roadsides with rich abundance of Devil´s bit (see figure 24). In 2012 two females of golden sand bee were seen here, this year at most six females were seen. The area seems to be taking care of itself and the only measure is to inform the traffic authority not to cut the roadsides before September 15, if possible. This is because the golden sand bee has its flight time up to about that time, but also so that the Devil´s bit will have time to seed. On the premises there were many other pollinators, in particular bumblebees. The venue is located along the same popular tourist route as 49 a, so these two populations most likely belong to the same meta population. And if individuals can move between subpopulations of a meta population, this can support long-term survival and adaptability.

Figure 24: Site 49 b, Häljesgården 500 m N, Coordinates: O12.4227, N57.5675 WGS84

Backäckra, Kvarnslätt, ID: AV3382

Site 49 a and 49 b are positioned at a so called species rich road side (Figure 25) where the management is handled by the Swedish Transport Administration. When reading the data description of this road side (NVDB 2023-11-01) and compared it to the qualifications of specifications (Lindqvist 2012) several indications of potential discrepancies between the observed biodiversity and the categorization in the document were found. Therefor an update to the road description is suggested, emphasized the current biodiversity and the importance of preserving and promoting beneficial species for the local insect population. Contact has since then been taken with Mats Lindqvist, Environmental Specialist at the Swedish Transport Administration and in the reply he informed that the Swedish Transport Administration will perform an inventory at this operating area during June/July 2024. They will go through older material as well as the results of this inventory supplied by this study, so that adjustments can be made. An example of found error is: 4.2.5 E. Abundant flowering and substrate plants for insects: Particularly valuable is abundant flowering of substrate plants for insect fauna, such as Field Scabious and Devil´s bit Scabious, which it is, despite it being categorized under AV3382 D-Abundant flowering as: Not.



https://nvdb2012.trafikverket.se/SeTransportnatverket, [2023-01-11]

Figure 25: Species rich roadside (ID: AV3382) where 49 a and 49 b is included, the figure is extracted from NVDB, Swedish Transport Administration.

Site 54

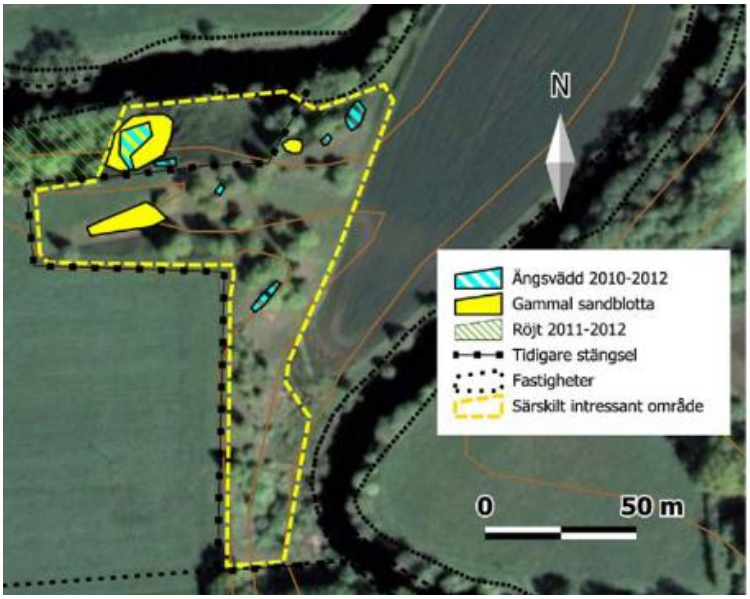


Figure 26: Site 54, Ryda 300 m ONO
Coordinates: O12.4293, N57.5606 WGS84

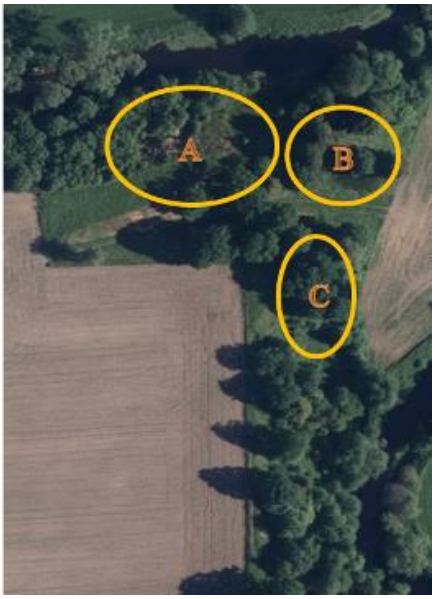


Figure 27: Site 54

In 2012, at site 54 (Figure 26 and 27), a maximum of five female golden sand bees were observed. This year, on a single occasion during which only sub-area A was surveyed, more than four times as many golden sand bees (21 individuals) were recorded. During this observation, the golden sand bees were carefully captured and temporarily housed in test tubes equipped with air holes, placed in a shaded location until the inventory of subarea A (see Figure 27) was completed. To safeguard the well-being of the golden sand bee population, the premises were subdivided into three distinct subareas. Conducting a comprehensive inventory of the entire area, with bees confined in test tubes, posed a potential risk to the bees' health.

Prolonged containment in test tubes can lead to overheating and, consequently, harm or mortality in bees. The overall abundance of Devil´s bit has approximately tripled, exhibiting a relatively even distribution across subareas A, B, and C (see Figure 27).

The size of site 54 is about 0.7 ha and consists of a north-facing, an east-facing and a south-facing slope. The north-facing one, which slopes down towards the Storån, is very steep and there are both Devil´s bit and patches of sand, in the east-facing one there are Devil´s bit as well as some minor patches of sand and in the south-facing one almost half the surface is a sand patch, but very few Devil´s bit. The area between the north-facing and south-facing is made up of a plateau where Devil´s bit grows on the eastern half. The north-eastern part of the premises (subarea B) is divided from the plateau where two large oaks form a natural passage. In subarea B, Devil´s bit grows abundantly and there are also smaller patches of sand.

The topographical variation of the site creates a mosaic of diverse habitats, rendering it highly suitable for conservation efforts. There is access to sunlit Devil´s bit during all daylight hours and when it is very windy it is usually one of the surfaces that protected from the wind. During the morning, subareas B and C are in direct sunlight as there is a field to the east of them and thus there are no shading trees. Even during the afternoon, these areas are largely exposed, area B gradually ends up in shadow at 3:30 to 4 p.m., while subarea C has sunlight for at least another hour. The plateau in subarea A is mostly shaded during the morning hours and the northern slope is completely in shadow. The plateau is then sunlit until sunset; the North Slope also has evening sun but not as long. The western part of, where there is a really large patch of sand, is shaded today by the trees that have grown up after the clearing that was carried out during the project period. Birch, oak and hornbeam are the dominant tree species, but pine and rowan also occur.

The ground temperature, in the part of the northern slope that is not shaded, seems to last for a long time and by half past six is up to one degree higher than the ground temperature on the plateau, which has been exposed to sunlight for several hours. Possibly this is due to the northern slope being leeward of the prevailing wind direction. The southern slope is also relatively protected and has evening sun for a longer time, which means that the ground temperature there can be more than two degrees higher than on the plateau well into the evening. Subarea B, which is not reached by the evening sun, can already at four o'clock have a ground temperature two degrees lower than that prevailing on the plateau. The area's sandbars are kept open by grazing tramples and by wild animals that moves in the area. Especially by wild boar that frequently move through the area to the surrounding cornfields, where they often stay during the day. The large sand patch in the western part of the steep North Slope, which lies outside the pasture, is probably kept open primarily by erosion.

In the eleven years that have passed, looking at the whole, the premises have not undergone any major changes. The area is managed by the landowner letting his cattle graze there and also removing trees that have grown too large. But there are also threats to the area and it is mainly the spread of rock pipes that in some places have already taken over from the Devil´s bit. In area B, the greatest amount of Devil´s bit grows in the eastern part, and there grows a lot of bush grass. Bush grass often spread in pastures with low grazing pressure and they can form large stands through root shoots. In area C, bush grass seems to have already displaced most of the Devil´s bit abundance on more than ten square meters. Some occasional Devil´s bit is visible therein, likely exceptionally strong individuals as they have to put extra energy into becoming taller than the surrounding bush grass. In the same area, small oak also threatens the population of Devil´s bit, mainly in the southern part. In the brink outside the pasture, the shading, as mentioned earlier, is probably the reason why only half of the Devil´s bit that grew here in 2012 remains today. However, this reduction is largely compensated for by the fact that Devil`s bit (at least 150 stems) is now growing on the upper half of the slope inside the pasture.

Figure 28: Steep sandy slope at site 54.

Unfortunately, small oaks and other small pioneer trees have started to claim this part of the northern slope. There are instances of steep sandy grounds, occasionally with clay admixture, that can maintain openness through natural erosion alone. Erosion (and to some extent trampling by animals) is also keeping the southern sandy slope open (Figure 28). These areas necessitate minimal or no management and are among the most species-rich, harbouring numerous burrowing species (Linkowski et al., 2004).

Recommended measures for premises 54 include prioritizing the control of bush grass growth. Bushgrass, being sensitive to disturbance, would not pose a challenge with higher grazing pressure, especially by cattle, as they consume young plants and restrict spread through trampling. However, elevated grazing pressure could also impact Devil's bit. Early grazing might be considered, contingent on the growth timing of bush grass relative to Devil's bit. Alternatively, a simpler approach involves clear-cutting 1-2 times during the season (depending on the pasture schedule) and removing the material. However, the most effective measure, albeit requiring physical effort and material costs, entails erecting fences around the stocks to enable increased cattle grazing in the area. Other measures encompass periodic clearing of small oaks and slush every five or ten years, accompanied by material removal. Thinning and removal of birch, holm oak, and small oak west of the sandy part of the northern slope are recommended, while pine and rowan should be preserved. The lower half of the area west of the sandy brink should be conserved to provide shade to Storån, preventing a rise in water temperature that could adversely affect aquatic organisms. The trees along Storån are crucial for various bird species and should be retained.

Of the eight sites, site 54 with its great variety of habitats is probably one of the best candidates for conservation measures and a long-term management plan should be drawn up. The area, with its mosaic of habitats, is not only favourable for the golden sand bee and the Devil´s bit, but also for the large number of pollinators found here, both for diversity and also for diversity. Other important species found at the site are; Large Scabious Mining Bee *Andrena hattorfiana* (NT), Pasque flower *Pulsatilla vulgaris* (VU), Grass snake *Natrix natrix* (LC), Golden eagle, *Aquila chrysaetos* (NT), Dove hawk, *Accipiter gentilis* (NT) and Blue kingfisher, *Alcedo atthis* (VU). These species would also benefit from conservation. The area's mosaic of sand patches scattered in different places and different habitats for Devil´s bit makes the premises more prepared for sudden events, such as prolonged drought or heavy downpours. The sand material on the premises has a very small proportion of soil, which is preferred by many burrowing wild bees and other insects. There also appear to be no invasive plants on this site. In late summer, the area fulfils an important function for many late-flying wild bees, bumblebees and other pollinators, especially during summers with prolonged drought and when many flowers have bloomed too early and/or for too short a period. The roadsides along the nearest road are cut in early September after a long summer break. These flower-rich roadsides are an important source of nectar and pollen and when they had been mowed, a large increase in mainly bumblebees was noticed on the site. During the late summer the area is completely secluded as it is surrounded by tall growing corn, there is not even a path leading there, which means that human impact during this period is minimal.

During this fieldwork, the site has given rise to new reflections and insights about the golden sand bee. During the visit on September 7th, the "hot spot" method (counting the number of visitors to a flower or cluster of flowers during a certain time) was tried. A suitable (with a good overview, so that none of the golden sand bees were double-counted), sunlit, clump of Devil´s bit was selected and monitored for an hour. It passed seven females of the golden sand bee, but more interesting is the fact that all seven females rejected the only three Devil´s bit having pink flower colour, in contrast to the other pollinators that included the pink ones in their foraging "route".

At the same visit, a golden sand bee was also studied for five minutes to see how many flowers the bee visits during a certain period of time, the result was twenty-two this time. In subarea B, also on September 7th, a very large abundancy of so-called crab spiders was noted at many of the Devil´s bit. The spider kills insects that visit the flower (they hide under the sepals). Only two females were found at that time and both were killed by a crab spider. No more golden sand bee females were seen, but two were found in the Devil´s bit (48 pcs) which grew more scattered a little further to the west in area B. Where the two live ones were seen, the sun was shining while the large cluster was in shadow. This raises the question of whether bees can "know" that a certain area of Devil´s bit is dangerous to visit because many crab spiders or if it was just because the crab spider area was in the shade (it was more than 20^0 C in the air).

Site 61

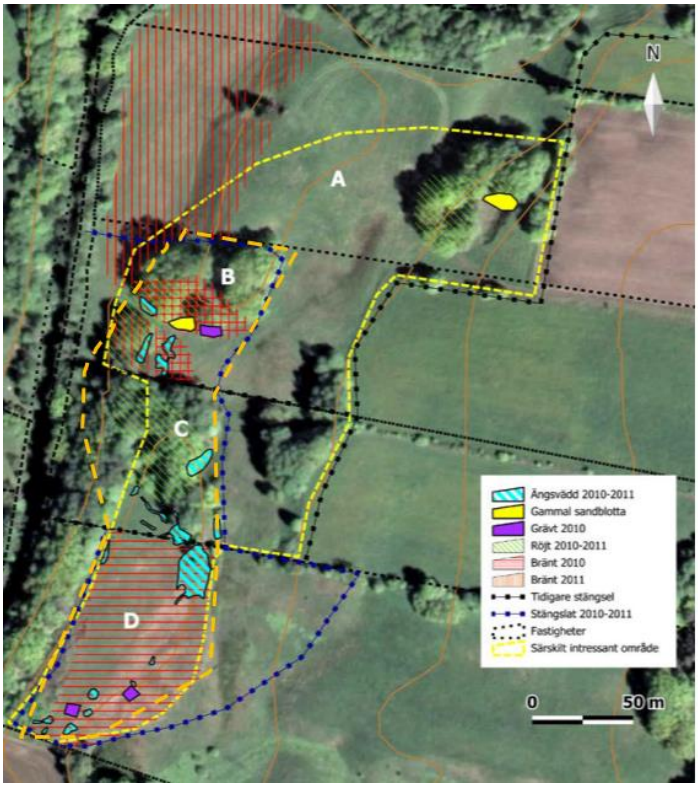


Figure 29: Site 61, Gunnarstorp 630 m VSV
Coordinates: O12.4287, N57.5534 WGS84

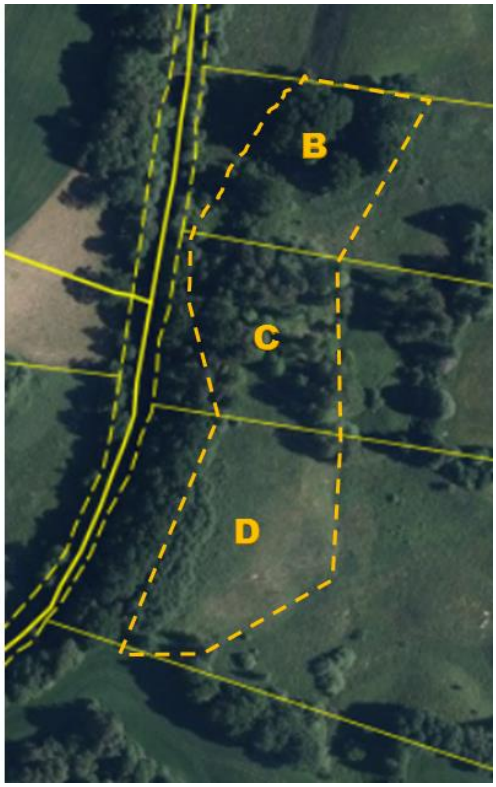


Figure 309: Site 61

At site 61 (Figure 29) a total of 46 golden sand bee females were seen in subareas B, C and D. this year, which is a great increase compared to the seven females seen in 2012. The occurrence of Devil´s bit has also increased, from 2300 stems during the project period to 3650 stems this year. During the project period, a lot of measures were carried out on this 3.1 ha premises. Smaller pioneer trees were removed, large areas were burned, sand patches were dug and fences were erected to divide the pasture into paddocks so that it was possible to have regulated cattle grazing. Subarea A has been excluded for inventory this year as no Devil´s bit grows where the golden sand bee can be inventoried. The inventories carried out on August 17 (subarea B) and August 19 (subarea D) (Figure 30) took place under near-optimal conditions. Unfortunately, a comprehensive inventory of the sub-areas could not be carried out as the test tubes brought ran out and there was also a concern about the health of the bees. Attempts were made to keep two females in the same test tube, but in some of them disputes arose and in order not to risk any bee being harmed, the inventory was ended.

This happened in both sub-areas when approximately 80% of the Devil´s bit was inventoried. Subarea C (Figure 30) was visually inventoried under less favourable conditions and the maximum number of golden sand bee females seen was three. In this sub-area three males were also seen on one occasion. In area B, there is plenty of Devil´s bit growing in the southern part, while those that grew in the western part are almost gone, only single specimens were seen growing among all the bush grass that have invaded the surface. Even the south-facing sand flats are largely covered by small oaks and bush grass, especially the dug flat located east of the old one.

In the old sandy patch there are plenty of nest holes and many new arrivals could be seen at every new visitation. The grazing pressure in the sub-area is far too weak, which has resulted in bush grass and small oak being able to spread, and since the grazing animal are sheep, the spread of bush grass cannot be limited by trampling, which cattle grazing does. Subarea C forms together with subarea D the paddock where cattle are released to graze in September. The late introduction of grazing animals results in a weak grazing pressure, which favour the growth of aspen, birch and small oak, but also contributes to an increasingly thicker grass cover and moss growth. Subarea D, which has a really high incidence of Devil´s bit and which alone had the largest number of golden sand bee females seen, is threatened in the western part by the many small aspens that have started to spread. The sand patches that were dug are partly overgrown, but in several places there is exposed sand where badgers and/or possibly foxes have been digging (Figure 31).

Figure 10: Sand exposed by wild animals.

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