Technical report D2

The effects of restorations in Sand Life on flora and fauna

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Summary

Introduction

Sand Life aimed at restoring flora and fauna in southern Swedish sand dunes and grasslands. In Sand Life, parts of pine plantations were reopened to favour threatened species, and to facilitate access from the public. Restoration actions included removal of pine (mainly the exotic species mountain pine) and Japanese rose, soil perturbation, topsoil removal prescribed fires and grazing. To analyse the initial development of the conservation status of target habitats, we identified species and species groups likely to respond within the project time, and with a close connection to the favourable conservation status of the sandy habitat types.

Methods

The current conservation status was measured both by repeated surveys of the same locations before and after the conservation actions took place, and by comparing treated areas with nearby non-treated control areas.

Plants

Many of the actions were made rather shortly after the actions and vegetation was still in an early succession. We observed a positive trend over time for plants with high conservation value as well as nectar and pollen sources after creating bare sand in all habitat types. And in calcareous and dry grassland the proportion of red-listed species were higher compared to the control. Burning had less strong influence on vegetation within the time frame measured, but reduced lichen and moss cover.

Birds

Areas cleared from mountain pine were rapidly inhabited with several open-habitat species and had higher number of red-listed bird species than surrounding pine areas. A trend break was observed for the very threatened tawny pipit; for the first time an increase in the Swedish population was observed, from 33 to 40 territories. Most of the territories were within, or adjacent to benefit areas. We observed a positive trend for nightjar after removal of pine and other actions in dune and grassland. For woodlark the picture was more complex, we observed an overall negative trend, but in a specific survey were pines had been removed, the density of woodlark was significantly higher in the created glades.

Insects

In general, removing of pine and creation of bare sand increased the proportion of sand specialists for all groups of insects, and for spiders. For bees and wasps, the effects were strikingly clear: a more complex fauna of bees and wasps in created sand plots and open areas with higher abundance, higher species richness, more red-listed species, more sand specialists, and more predators and parasites. The pattern was similar for dunes and grasslands. For beetles, we observed a positive trend over time in restored dunes, especially for sand specialists. In grasslands, the number of red-listed beetles increased. For butterflies, we observed that many species, including the red-listed large blue occurred in sand plots, but mostly in lower numbers than in surrounding areas. In dune areas, creating sandy glades by

removing mountain pine created new habitat for many sand specialists among moth species, while pine specialists dominated in the surrounding pine areas.

Conclusions

The vegetation succession in restored areas was not complete when the survey was made, but the positive trend over time for red-listed plant species, species of conservation value and nectar and pollen sources show that restoration actions had a positive effect and that succession moves towards communities typical for many Natura 2000 habitats. The response in insects was very fast and positive in most cases. The restorations in all habitat types had a positive effect for the overall insect diversity in the areas, and that they already provide areas with a better status for threatened species. As might be expected, the response was most positive for those species favoured by areas of bare sand. Thus, already at an early stage the bare sand favours those species of bees and wasps, beetles and spiders that prefer habitat with open sand. Sand specialists among moth species depend on host species in open habitats, often different types of grasses, and it was clear that these already showed a positive response after mountain pine removal. The response in nectar and pollen feeding species, such as butterflies and some bees, showed less of a positive response. This may be due to that densities of flowers can still be higher in areas before restoration, although subordinate to other species. Therefore, nectar and pollen feeding species should be paid special attention in future monitoring. Among the birds, it will be of special interest to follow the population trends for tawny pipit, and if it can spread to restored areas, where it still not occurs.

Sammanfattning (swedish)

Inledning

Syftet med Sand Life var att återställa flora och fauna i sydsvenska sanddyner och sandiga gräsmarker. I projektet motverkades igenväxning för att gynna hotade arter och för att underlätta tillgängligheten för allmänheten. Restaureringsåtgärderna innefattade borttagning av tallskog och vresros, skapande av bar sand, bränning och att införa betesdrift. För att mäta effekterna av restaureringen och habitatens bevarandestatus identifierade vi arter och artgrupper som sannolikt kommer att reagera inom projekttiden, och som indikerar god bevarandestatus hos sandiga Natura 2000-habitat.

Metoder

Den nuvarande bevarandestatusen mättes både genom upprepade undersökningar av samma platser före och efter åtgärderna och genom att jämföra behandlade områden med närliggande obehandlade områden.

Växter

Inventeringen genomfördes kort tid efter åtgärderna och vegetationen var fortfarande i en tidig succession. Vi observerade en positiv trend över tiden för växter med högt bevarandevärde, samt nektar- och pollenkällor, efter att ha skapat sandiga områden i alla typer av habitat. Och i gräsmarker var andelen rödlistade arter högre jämfört med kontrollytor. Bränning hade mindre stark effekt på vegetationen inom den uppmätta tidsramen, men minskade lav- och mosstäcket.

Fåglar

Områden där bergtall och tall tagits bort var snabbt bebodda av flera fågelarter knutna till öppna livsmiljöer, och hade ett större antal rödlistade fågelarter än omgivande tallskogar. Ett trendbrott konstaterades för den mycket hotade fältpiplärkan och för första gången observerades en ökning av den svenska populationen, från 33 till 40 revir. De flesta av reviren var inom eller intill områden restaurerade inom Sand Life. Vi observerade en positiv trend för nattskärra efter borttagning av tall och andra åtgärder i sanddyner och gräsmarker. För trädlärkan var bilden mer komplex, vi observerade en övergripande negativ trend, men i en specifik undersökning där tallar togs bort, var tätheten av trädlärka högre i röjda områden än i omgivande tallskog.

Insekter

I allmänhet ökade andelen sandspecialister för alla grupper av insekter och för spindlar där tallskog tagits bort och/eller sandytor skapats. För steklar var effekterna uppenbara: en mer komplex stekelfauna i restaurerade områden med högre mängd, högre artrikedom, mer rödlistade arter, mer sandspecialister och fler rov- och parasitsteklar. Mönstret var liknande för sanddyner och gräsmarker. För skalbaggar observerade vi en positiv trend över tiden i restaurerade sanddyner, särskilt en ökning av sandspecialister. I gräsmarker ökade antalet rödlistade skalbaggar. Vi såg att många arter fjärilar, inklusive den rödlistade svartfläckig blåvinge, förekom i sandytor, men mestadels i lägre antal än i omgivande områden. I sanddyner var det tydligt att gläntorna som bildades efter att bergtall tagits bort skapade nya livsmiljöer för många sandspecialister bland nattfjärilar, medan tallskogsarter dominerade i den omgivande tallskogen.

Slutsats

Vegetationen i restaurerade områden var i ett mycket tidigt stadium när undersökningen gjordes, men den positiva trenden över tid för rödlistade arter, bevarandevärden och nektar- och pollenkällor visar att restaureringsåtgärderna hade en positiv effekt på habitatkvalitén och att successionen rör sig mot samhällen typiska för många Natura 2000-habitat. Insekterna svarade snabbt på åtgärderna och i de flesta fall positivt. Restaureringarna i alla typer av livsmiljöer hade en positiv effekt på den totala mångfalden av insekter i områdena och bättre status för hotade arter. Som kunde förväntas var svaret mest positivt för de arter som gynnas av områden med bar sand. Således gynnar den bara sanden redan i ett tidigt skede de arter av steklar, skalbaggar och spindlar som föredrar livsmiljöer med öppen sand. Sandspecialister bland nattfjärilar lever ofta på olika arter av gräs, och det var klart att dessa redan visade ett positivt svar efter borttagning av bergtall. Nektar- och pollenberoende arter, som fjärilar och vissa bin, visade mindre positivt svar. Detta kan bero på att tätheter av blommor fortfarande kan vara högre i områden före restaurering, även om de där är tillbakaträngda av andra arter. Det kan vara särskilt viktigt att följa dessa arter under kommande år. För fältpiplärkan blir det intressant att se om den nu kan hitta tillbaka till ännu fler områden som den försvunnit ifrån, nu när de har restaurerats.

Introduction

Habitats on sandy soils support a richness in species that is among the highest found in any habitat in Europe (Gazenbeek 2005; Warren et al. 2007; Jentsch et al. 2009). Although there is a large variation in habitat types on sandy soils, ranging from coastal sand dunes to inland grasslands and calcareous grasslands, they share similar abiotic characters and hence, the threats to biodiversity is similar in most habitats on sandy soils.

On sandy soils, wind, water and fire – together with human activities – modulate the ground and vegetation. The result has been a heterogeneous landscape in constant change with temporary areas of open sand. In Sweden, afforestation and other methods to stop sand migration have dominated management during the last two centuries. The mosaic created by drifting sand is disappearing all over Europe when dunes stabilize (Riksen et al 2004, 2006). The ongoing encroachment threatens biodiversity and the distinctive flora and fauna of sandy habitats. If no actions are taken, the conservation status of these habitats will deteriorate, and in the long run their characteristic species may be lost.

During the last century, scots pine and exotic species like Japanese rose and mountain pine, were planted in large dune areas to prevent entrainment. Other dunes have been used for farming or otherwise exploited. Finally, eutrophication has contributed to overgrowth. Areas of open sand dunes have therefore been reduced, and species attached to these areas have become rare.

Sand Life aimed at restoring flora and fauna in southern Swedish sand dunes. In Sand Life, parts of the plantations were reopened to favour threatened species, and to facilitate access from the public. Restoration actions included removal of pine plantations and Japanese rose, soil perturbation, topsoil removal and grazing. To measure the initial improvement of the conservation status of target habitats, we identified species and species groups likely to respond within the project time and with a close connection to the favourable conservation status of the sandy dune habitat types (2120, 2130, 2140, 2180, 2320, 2330), heath habitat type on sandy soils (4030) and grassland habitats (6120, 6210 and 6270) in the Natura 2000 network. To measure the effect of project actions in terms of ecosystem services, we evaluated population trends for plants that act as nectar resources and therefore can promote a high abundance and diversity of pollinating insects in the landscape.

The monitoring of insect diversity was an important factor in understanding the restoration success of the project, since the combined feeding and nest building demands of insects put pressure on the quality of target habitats. Wasps, ground beetles, butterflies and moths were chosen because the four different groups of insects differ in dispersal pattern and the way they benefit from a heterogeneous habitat with areas in earlier succession stages.

The current conservation status was measured both by repeated surveys of the same locations before and after the concrete conservation actions took place, and by comparing treated areas with nearby non-treated areas. The latter strategy is particularly relevant for conservation actions that aim to create small-scale variation and for indicator organisms with relatively small home ranges.

In this report, after a description of survey methods common to all organism groups, each of these groups is assigned its own chapter. In each chapter, the organism group is introduced, method details specific to the group are described, results are presented by habitat and analysed. Finally, the report is wrapped up by an overall discussion based on the outcome of all surveys on the effects of Sand Life restoration actions on flora and fauna indicators.

Restored open dune at Gropahålet.

Methods

The surveys were made following two different designs: (1) before compared to after actions and (2) control areas compared to treated areas. Both these methods are suitable for statistical analysis using paired t-test. Here we describe the common design for vascular plants, bees and wasps, butterflies, beetles and spiders. Specific method details for each group of organisms are described in the corresponding chapter. The design of bird and moth surveys differed from the setup for other groups and are therefore described directly in those chapters.

Before and after restorations

The survey was performed at 16 sites with a total of 25 monitoring grids in dunes and calcareous grasslands (Table 1). Grids were designed according to Bengtsson (2010) for dunes and Haglund & Vik (2010) for grasslands (Fig. 1). In dunes, the positioning of grid systems and transects within them were chosen to cover different stages of dune succession. Each grid contained 12 monitoring squares for vascular plants and habitat structures (see Ahlstrand et al. 2018), or three parallel transects for insect and spider surveys.

Table 1. Monitoring was performed in 9 dune sites with a total of 17 monitoring grids and 6 grassland sites with a total of 8 monitoring grids, as listed below. The grids were placed according to Figure 1a in dunes and according to Figure 1b in grasslands.

Sand dunes	Grids	Calcareous grasslands	Grids
Friseboda SE0420136	3	Marknadsplatsen SE0420077	2
Gropahålet SE0420137	1	Möllegården SE0420157	1
Ängelholms strandskog SE0420233	2	Lyngby SE0420234	1
Sandhammaren SE0430093	2	Åby sandbackar SE0330103	1
Bödakusten västra SE0330119	2	Gårdby sandstäpp SE0330102	2
Bödakusten östra SE0330121	2	Skede mosse SE0330104	1
Laholmsbuktens sanddynsreservat SE0510006	2		
Haverdal SE0510020	2		
Falsterbo skjutfält SE0430111	1		

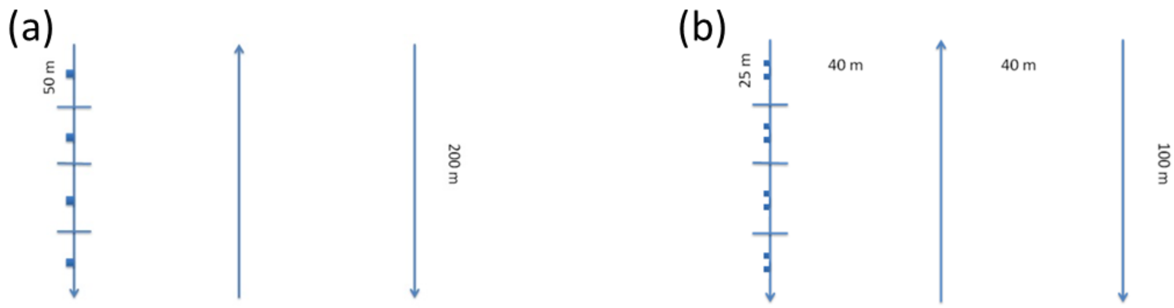


Figure 1. (a) Monitoring in dune grids. Three 200 m long transects parallel to the shore line were placed in each grid, and each transect was divided into four 50 m long segments. Transect positions were chosen to cover different stages of dune succession. A 5 x 5 m monitoring square was placed at the middle of each segment, for a total of 12 squares in each grid. (b) Monitoring in grassland grids. Three 100 m long transects were placed in each grid, and each transect was divided into four 25 m long segments. Transects separation was 40 m.

Control and restoration areas

A total of 25 sand plots were selected for a common setup (referred to as the common setup) for surveying bees and wasps, butterflies, spiders, beetles and plants. Of these, 15 plots were located at three Dry Grasslands sites at Revingefältet and 5 plots at a Dune site at the Falsterbo peninsula, all of them in Scania in southern Sweden, and finally 5 sand plots at two Calcareous Grasslands sites on the eastern side of the island Öland in southeast Sweden. For each sand plot a control plot with the same size and shape was placed in a random direction with a separation of 10 m from the sand plot, for a total of 50 plots in the survey. Once placed, the positions of the controls were fixed and the same controls (referred to as common controls) were used for all surveyed species. The survey method for each organism group is described in the corresponding chapter. For plants, in addition to the common setup, further sand plots as well as other action areas of the project, were surveyed using a control/action design; details are given in the corresponding chapter.

Analysis of results by habitat

Using both before/after and control/action surveys, we assessed the effects of restoration actions for each organism group and present the results by habitat. For simplicity, all habitat types were divided into three main categories as follows:

Dunes refers to all habitats in the dune series (2110, 2120, 2130, 2140, 2170, 2180).

Dry Grasslands at large equals Fennoscandian Lowland Species-Rich Dry to Mesic Grasslands (6270). The category also includes a few sites with other habitat types, but these were only surveyed for vascular plants.

Calcareous Grasslands includes the two habitat types Semi-Natural Dry Grasslands and Scrubland Facies on Calcareous Substrates (6210) and Xeric Sand Calcareous Grasslands (6120). When present, Xeric Sand Calcareous Grasslands normally doesn't cover a full site, but instead is part of a mosaic with the two habitat types interspersed.

Statistical Analysis

In all surveys, the following was analysed: abundance and species richness of all species, red-listed species and sand specialists, together with parameters specific to the organism group. All p-values refer to two-tailed pairwise t-tests (with before/after or control/action as pairs), with *** for $p<0.001$, ** for $p<0.01$, * for $p<0.05$ and NS (no significance) for $p\geq0.05$.

Vegetation survey at Åby sandbackar.

Vascular Plants

Introduction

The habitats on sandy soils in southern Sweden support a plant species richness among the highest of any habitat in Europe, with a very special flora. The habitats mostly stretch along the coastline of the three project counties Skåne, Halland and Kalmar, but also include some inland sand dunes and dry grasslands. These areas are now the living remnants of a historical landscape marked by traditional management methods including crop rotation with long periods of fallow. This special history together with the mixture of lime-rich and dry soils has resulted in that the vegetation consists of very specialized species. The project area covers a large proportion of the Natura 2000 sites with coastal sand dunes in southern Sweden with habitat type 2110, 2120, 2130, 2140, 2170, 2180 and 2190, as well as Xeric Sand Calcareous Grasslands (6120), a habitat type rapidly declining in Europe and with an unfavourable and deteriorating conservation status.

Today many of these habitats are overgrown with either pine forests or, due to the low intensity management, dense vegetation including bushes and scrubs, but this has not always been the case. Since the withdrawal of the last period of land ice, the areas have continuously been affected by human activities and in the 18th century, the intensified management of sandy soils led to wind erosion and severe sand drift affecting areas in the landscape far from where the sand originated. Many of the forests that today grow on the appointed areas originate from this era and were planted to prevent the sand drift. Today we no longer experience any problems of drifting sand and due to the modernisation of the agriculture sandy soils are no longer prioritized for farming since heavier soils are far more productive. The abandonment of cultivation on sandy soils have led to a continuous invasion of trees, bushes and tall dense vegetation of grass and herbs, and a degradation of the flora. Where we today have pastures, the grass production is favoured to ensure sufficient food for the grazing animals. This has led to a loss of flowering herbs, which increases the risk of severely diminishing populations of the fauna connected to these habitats. In addition, the abandonment of farmland practice on these low productive soils and thereby an end to the repeated cultivation, has led to lime leaching from the upper layers of soils, drastically degrading the biodiversity of these rare habitats in southern Sweden. This project was launched at a time when great efforts are required to restore these habitats, to maintain and develop the environment for the species of the dune and grassland habitats on sandy soils.

The progression of the plant community is a crucial feature to monitor after restorations as they lay the foundation of each habitat type and many plants serve as key species for insects or otherwise regulate ecosystem functions. At least three different aspects should be considered when surveying plants: (1) if they are rare or threatened themselves, (2) how they influence the physical environment and (3) how they can serve as host species for insects and other organisms by providing nectar, pollen or other resources.

Method details specific to Vascular Plants

(1) Before/after

As previously described, a total of 12 monitoring squares (in this chapter referred to as quadrats) with the size 5 x 5 m were placed in each grid. All 17 dune sites were surveyed before (summer 2013) and after (summer 2018) actions were implemented.

(2) Control/action

The setup differed between dunes and grasslands. In dunes, a 5 x 5 m quadrat was randomly placed inside the surveyed action plot (sand plot, ploughed plot, mountain pine clearing, removal of Japanese rose, prescribed burning etc.) and an identical quadrat was placed in a random direction in the control area with a separation of 5 m from the plot (Fig. 2a). In grasslands, a 10 x 10 m monitoring frame was placed inside the plot, an identical monitoring frame was placed in a random direction in the control area with a separation of 5 m from the plot, and finally five 0.5 x 0.5 m monitoring quadrats were placed inside each monitoring frame (Fig. 2b). For the 25 sand plots in the common setup, a third monitoring quadrat/frame was randomly placed inside the common control, i. e. with a separation of 10 m from the action plot. When needed, the 5 m controls are referred to as standard controls to distinguish them from the common controls. In all cases, every quadrat was surveyed for presence of selected graminoids and all other vascular plant species and percentage cover of nectar and pollen species. Finally, a full plot survey (identification of all plant species in the entire plot) was performed.

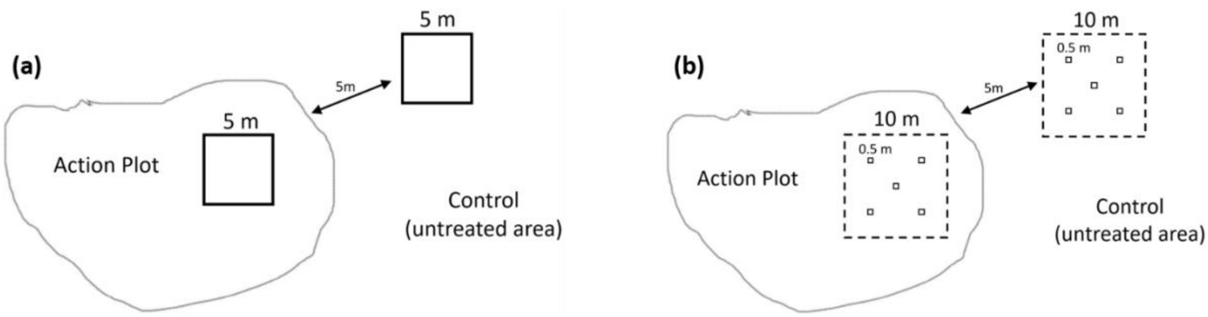


Figure 2 Monitoring with quadrats. (a) In dunes, a 5 x 5 m quadrat was randomly placed inside the action plot and an identical quadrat was placed in a random direction in the control (untreated) area with a separation of 5 m from the plot. (b) In grasslands, a 10 x 10 m monitoring frame was randomly placed inside the action plot, an identical frame was placed in a random direction in the control (untreated) area with a separation of 5 m from the plot, and five quadrats (0.5m x 0.5m) were systematically placed inside each frame. In both dunes and grasslands, for sand plots in the common setup, a third quadrat/frame was placed in the common control.

Species measures

Besides measures common to all organism groups, vascular plant species were evaluated by two other means. Firstly, the share of nectar and pollen species, and secondly, conservation values.

Nectar and pollen species were defined according to Bengtsson (2010), namely all as plants belonging to any of the eight families Asteraceae, Boraginaceae, Campanulaceae, Dipsacaceae, Ericaceae, Fabaceae, Lamiaceae and Salicaceae.

The conservation value for each species was taken from a list developed in 2013 by museum curator Torbjörn Tyler in Lund. This list includes all vascular plant species in southern Sweden, and the conservation value is based on a wide range of traits including tolerance to disturbance, abundance trend, longevity, xeric sand affinity and dependence on bees, wasps and butterflies for pollination. The list was developed to serve as a decision basis for order of priority between sites or as, in this case, evaluations of actions based on the frequency, quality and rarity of, and threats against, recorded species.

In addition, red-listed species according to Gärdenfors (2010) were recorded.

Analyses

In control/action surveys of vascular plants, each trait (for instance conservation value) was analysed in four different ways. First, we can analyse the quadrat mean or full plot values, and secondly, we can sum over all species or use species means. Thus, for each trait, in total four different analyses are possible, as follows:

Plot Totals (for instance total conservation value of the plot). Reflects the total value of the plot summed over all present species, increases with every additional species.

Quadrat Totals (for instance total conservation value per quadrat). This value is always lower than, or equal to, the plot total and reflects how well spread all species of the plot (but mainly those with high values) are. In a fully homogenous plot (where every species in the plot is also present in each quadrat) the quadrat total would equal the plot total.

Plot Means (for instance mean conservation value of all species in the plot). Reflects the mean quality of species in the plot, and depending on their quality, additional species could either bring up or pull down this value.

Quadrat Means (for instance average over quadrats of mean conservation value per species). Reflects how well spread the quality of the plot is. This value can be either lower or higher than the plot mean. With conservation values as example, quadrat mean lower than the plot mean indicates that of all species having reached the plot, those with high conservation values are less spread than others, and vice versa.

In summary, those four numbers highlight different aspects of the development of the plot. When comparing plot and control values, some caution is suggested. Quadrat totals and quadrat means are fully comparable with controls, plot means and quadrat means are to scale but as described above reflect different characters, while plot totals are not directly comparable with controls or any of the other measures. However, they are still fully comparable between years (see temporal surveys below).

In addition to this, for plots surveyed several years, temporal analyses (looking at the progress over years) were made. In those, only plots with identical survey years were included. In other (non-temporal) analyses, when plots with different number of visits were included, yearly values were averaged for each plot before averaging over all plots.

Results Vascular Plants in Dunes

The analysis of dune systems included both before/after monitoring of grid systems, and control/action surveys. We used the conservation value to evaluate the success of the actions and found that even though the vegetation became sparser, in all parts of the dunes the proportion of species with high conservation value was higher after implementation of project actions than before (Fig. 3).

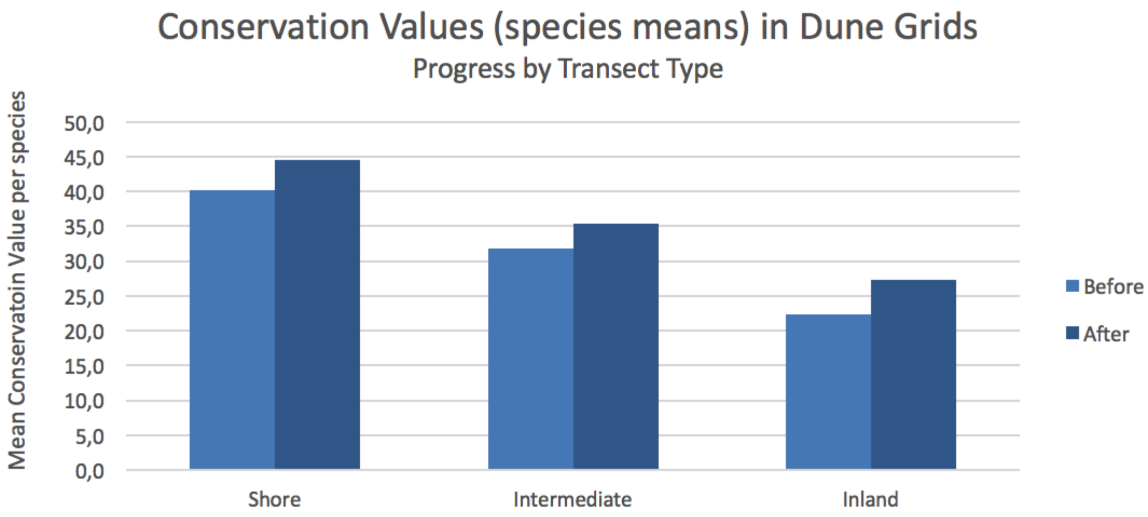


Figure 3. Mean Conservation Value per species (weighted by coverage) in shore, intermediate and inland transects before and after implementation of project actions in Dunes (number of grids = 17, number of monitoring quadrats per transect type = 68).

The share of nectar and pollen sources also increased during the project time presumably as an effect of the restoration actions taken, and this increase was particularly distinct in the inner parts of the dunes (Fig. 4).

Having established this increased vascular plant quality in dune grids subject to a wide range of restoration actions but dominated by mountain pine clearings, control/action surveys gave us a chance to examine the effects at a smaller scale, particularly with respect to the creation of sand plots. As in the before/after survey, sand plots created during the last few years still have a less dense vegetation, but nevertheless total conservation values in these new settings reached the control mean by the second survey year (Fig. 5). Simultaneously, full plot values continue to increase, illustrating a parallel colonization by new species into the sand plots, and a spread over more parts of each plot of those already present (Fig. 5).

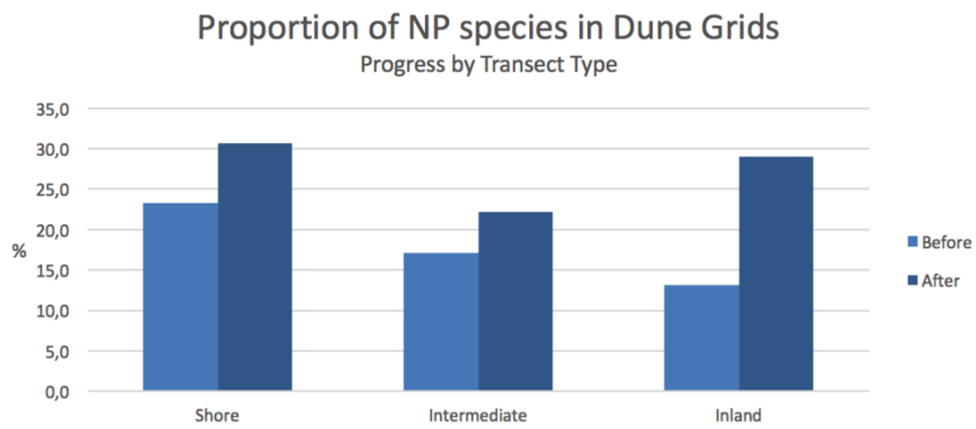


Figure 4. Share (weighted by coverage) of all species in shore, intermediate and inland transects listed as Nectar and Pollen (NP) species before and after implementation of project actions in Dunes (number of grids = 17, number of monitoring quadrats per transect type = 68).

The mean conservation value per species outpaced controls already in the first year and continues to increase (Fig. 6). The quadrat mean was slightly higher than the full plot mean, which means that of all species having reached the plot, those with high conservation values spread just as well as more ordinary species (Fig. 6).

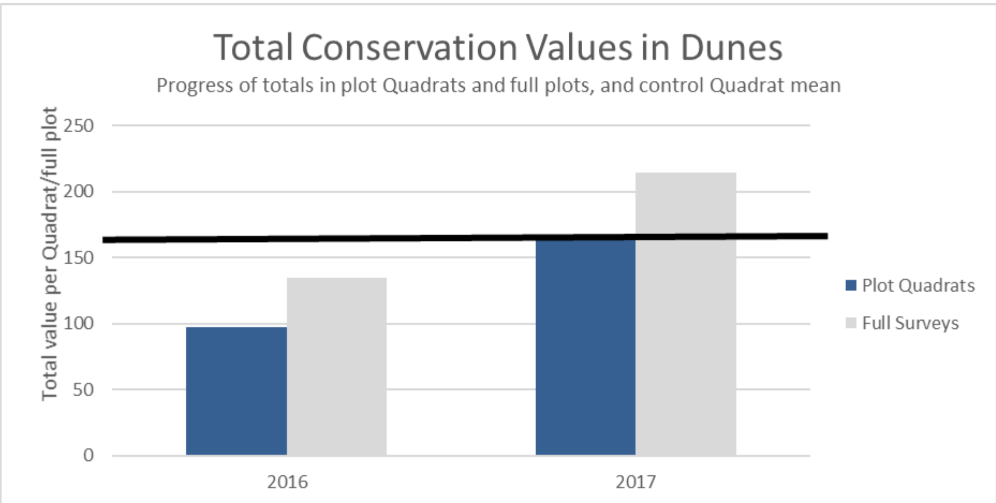


Figure 5. Total conservation values (plant considered of high conservation value) in sand plots in dunes surveyed the last two years of the monitoring. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 18, number of quadrats = 40).

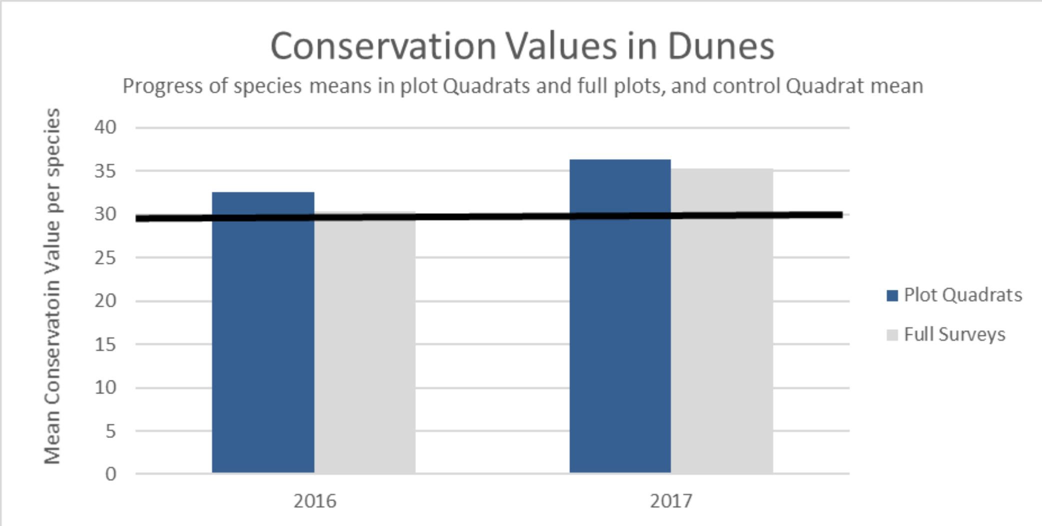


Figure 6. Mean Conservation Value per species in sand plots in Dunes surveyed the last two years of the monitoring. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 18, number of plot monitoring frames = 40).

Results Vascular Plants in Dry Grasslands

In this habitat, we surveyed the effect on the plant community of two different disturbance actions: the construction of sand plots and ploughed plots. We focused on the set of 24 sand plots surveyed all years and the 14 ploughed plots surveyed at least the two last years. For sand plots, this amounts to 120 plot quadrats or up to 240 quadrats in total per year, or a total of 685 surveyed quadrats over the years. Similarly, the survey of ploughed plots was based on a total of 245 surveyed quadrats.

Table 2. Progress of species richness, total conservation value, number of nectar and pollen (NP) species and number of red-listed species. Averages in dry grassland sand plots surveyed all years (n=24) and ploughed plots surveyed the last two years (n=14). Yearly values for plot quadrats and full plots, with control quadrat values averaged over all years.

TOTAL VALUES		Quadrats (0.5m × 0.5m)				Full Plots		
		2015	**2016**	**2017**	**Contr.**	**2015**	**2016**	**2017**
Species richness	Sand	1.0	1.9	3.1	**5.5**	19.8	20.9	26.2
	Ploughed		1.8	4.4	**4.8**		24.8	34.6
Conservation value (sum over all species)	Sand	12.5	41.4	77.1	**98.6**	450	610	780
	Ploughed		30.8	128.1	**139.8**		620	940
Number of NP Species	Sand	0.1	0.4	0.9	**2.6**	5.9	7.5	10.9
	Ploughed		0.7	1.7	**2.5**		9.0	14.4
Number of Red-listed species	Sand	0.00	0.11	0.27	**0.28**	0.8	1.5	2.0
	Ploughed		0.01	0.11	**0.40**		1.1	1.8

For both actions, the vegetation in the last survey year was still sparser in plots than controls but there was also a distinct difference between the actions, with more species in ploughed plots, and a distinct increase over the years for both action plot types. Total species richness also increased over the years in both sand and ploughed plots (Table 2).

Conservation values increased steadily over the years in both plot types. In sand plots surveyed all years, species means in quadrats outpaced the control in the second year (Fig. 7). Species means were always higher in full plots than quadrats, but the rise over years was less dramatic (Table 3).

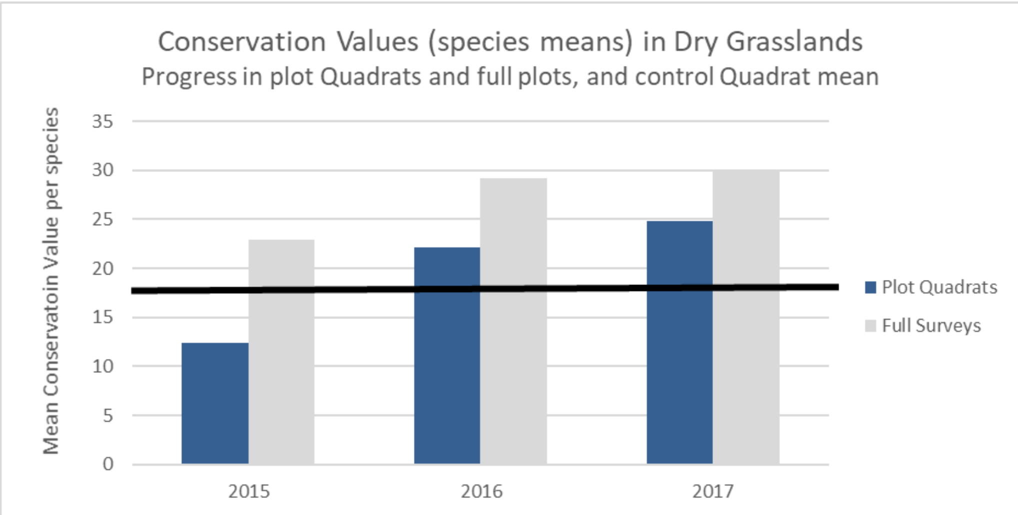


Figure 7. Mean conservation value per species in Dry Grassland sand plots surveyed every year. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 24, number of plot monitoring frames = 72, number of plot quadrats = 360).

Ploughed plots saw a similar pattern with quadrat species means increasing to meet the controls by 2017, and full plots means increasing at a slower pace (Table 3). Thus, for both actions, the mean conservation value per species was initially much lower in quadrats than full plots, illustrating that species with a high conservation value, although present in the plot, didn't spread as well as more ordinary species. But as seen, this pattern weakens with time, meaning high value species are now catching up.

Table 3. Progress of mean conservation value per species, proportion of nectar and pollen (NP) species and red-listed species. Averages in dry grassland sand plots surveyed all years (n=24) and ploughed plots surveyed the last two years (n=14). Yearly values for plot quadrats and full plots, with control quadrat values averaged over all years. Note that all values for sand plots are also illustrated in graphs (Fig. 7-9).

SPECIES MEANS\ SHARES		Quadrats (0.5m × 0.5m)				Full Plots		
		2015	**2016**	**2017**	**Contr.**	**2015**	**2016**	**2017**
Conservation value (species mean)	Sand	12.4	22.1	24.9	**17.9**	22.9	29.2	29.9
	Ploughed		16.7	29.0	**29.1**		25.0	27.1
Share of NP species (%)	Sand	14.5	23.0	31.8	**47.9**	31.3	39.1	45.1
	Ploughed		40.3	38.1	**53.0**		36.3	41.5
Share of Red-listed species (%)	Sand	0.0	6.2	9.3	**5.1**	4.2	7.6	7.9
	Ploughed		0.8	2.4	**8.3**		4.3	5.2

Since the total number of species also increased with time, total conservation values grew even faster than means, both per quadrat and in full plots, even though they hadn't yet reached the control by the last surveyed year (Table 2).

The number of nectar and pollen (NP) species was lower in sand and ploughed plots than controls but all varieties of the measure saw steep gains over years (Table 2). Turning to proportions, the share of species listed as nectar and pollen sources increased every year in sand plot quadrats, but by the last survey year had not yet reached the control mean (Fig. 8). The share was lower in quadrats than in full plots, illuminating that of all species having reached the plot, those listed as nectar and pollen species were less spread than others, but this gap was also closing over the years. The result in ploughed plots deviated from the outcome in sand, with only a small increase in full plot surveys and a slight decrease in plot quadrats (Table 3).

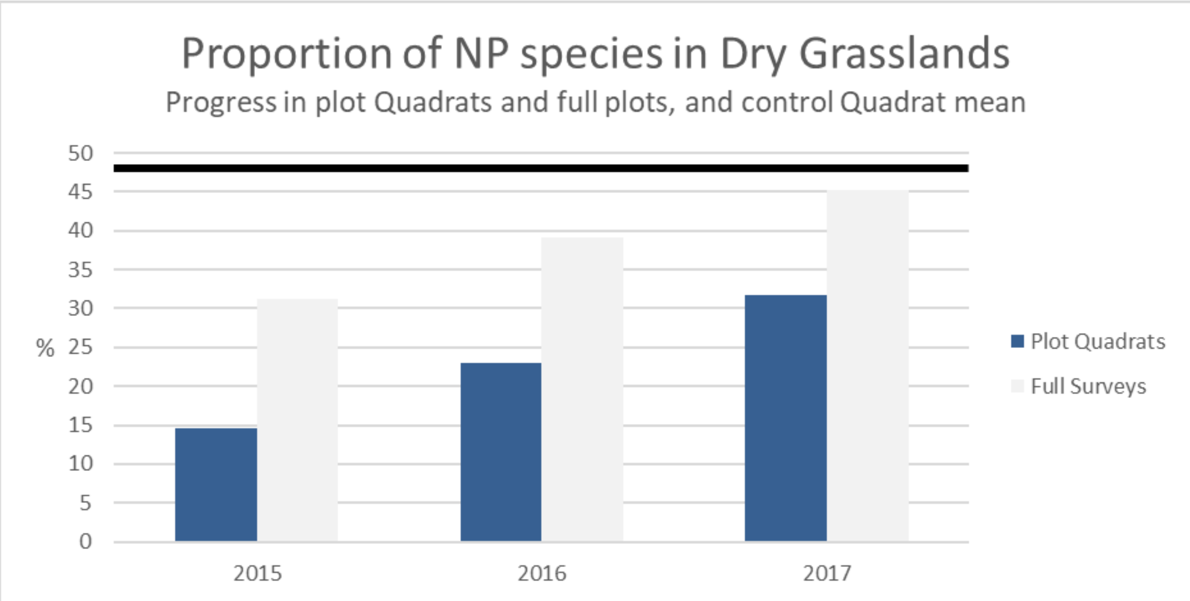


Figure 8. Proportion of species listed as nectar and pollen (NP) species in Dry Grassland sand plots surveyed every year. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 24, number of plot monitoring frames = 72, number of plot quadrats = 360).

Despite only about half as many species were found in sand quadrats compared to controls, the number of red-listed species advanced to almost reach the control mean the last year. The total number of red-listed species per sand plot also increased with time and more than doubled from 2015 to 2017. In ploughed plots, despite higher overall species richness, the number of threatened species was considerably lower than in sand, although distinctly increasing with time (Table 2).

Turning to proportions, already in the second survey year the share of red-listed species in quadrats was higher in sand than controls, and this disparity was further emphasized the last year (Fig. 9). Full plot shares also increased every year (Table 3). Compared to sand, the proportion of red-listed species was much smaller in ploughed plots, even though this proportion also gained with time (Table 3).

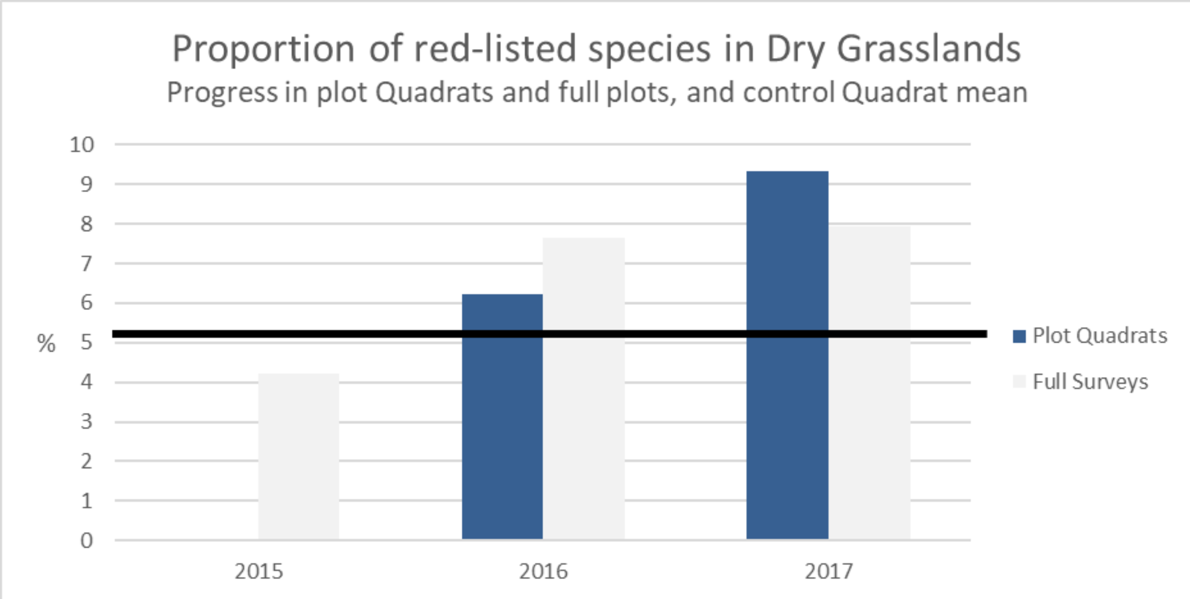


Figure 9. Proportion of species included in the Swedish national red list in Dry Grassland sand plots surveyed every year. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 24, number of plot monitoring frames = 72, number of plot quadrats = 360).

Results Vascular Plants in Calcareous Grasslands

In Calcareous Grasslands, surveying focused on sand plots and prescribed burnings. For sand plots, the following analysis is based on the six plots in this habitat type surveyed with quadrats all years. Note that full plot surveys were not implemented the first year, and hence this value is missing in all tables. As in Dry Grasslands, the number of species per plot and their spread over the plot increased with time, but plot quadrat values were still far below controls (Table 4).

Table 4. Progress of species richness and conservation value in sand plots in calcareous grasslands. Quadrat means with control quadrat mean for comparison, and full plot means (n = 6).

		2015	2016	2017	Control Mean
Average species richness	Quadrat	0.2	0.2	0.4	1.0
	Plot	---	19.2	23.8	---
Total Conservation Value	Quadrat	1.3	4.3	8.3	10.6
	Plot	---	600	680	---

Despite this, total conservation values almost reached control means the last year (Table 4) and the mean conservation value per species exceeded controls already in the second year (Fig. 10).

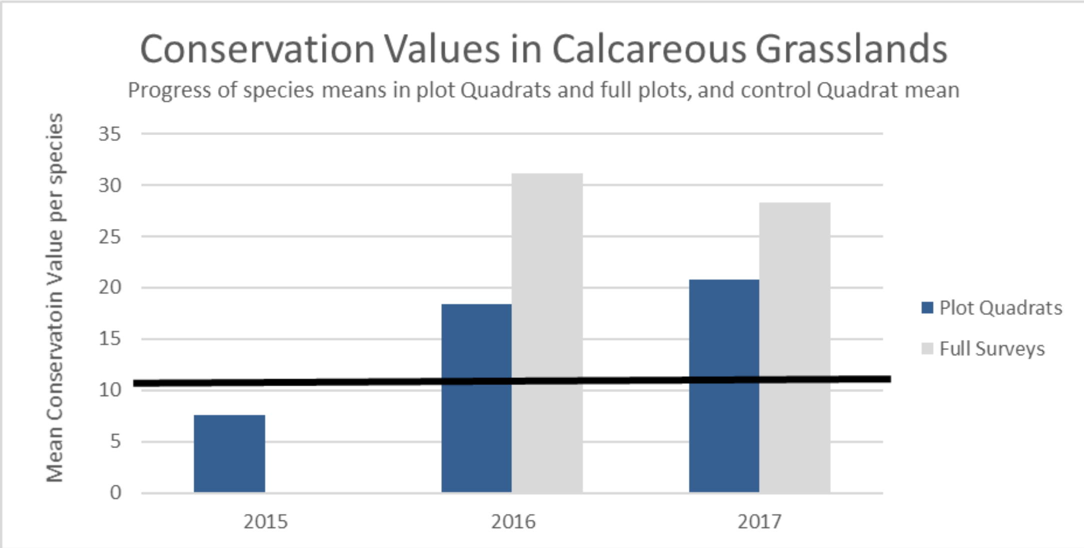


Figure 10. Mean conservation value per species in Calcareous Grassland sand plots surveyed every year. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 6, number of plot monitoring frames = 18, number of plot quadrats = 90). Note that the Full Survey value for 2015 was excluded since not all plots were surveyed in this manner that year.

Thus, we observed that plants colonised treated plots relatively fast after restoration actions. And we could also see a progress in the right direction, both when it comes to species of conservation value and nectar and pollen sources (Fig. 11).

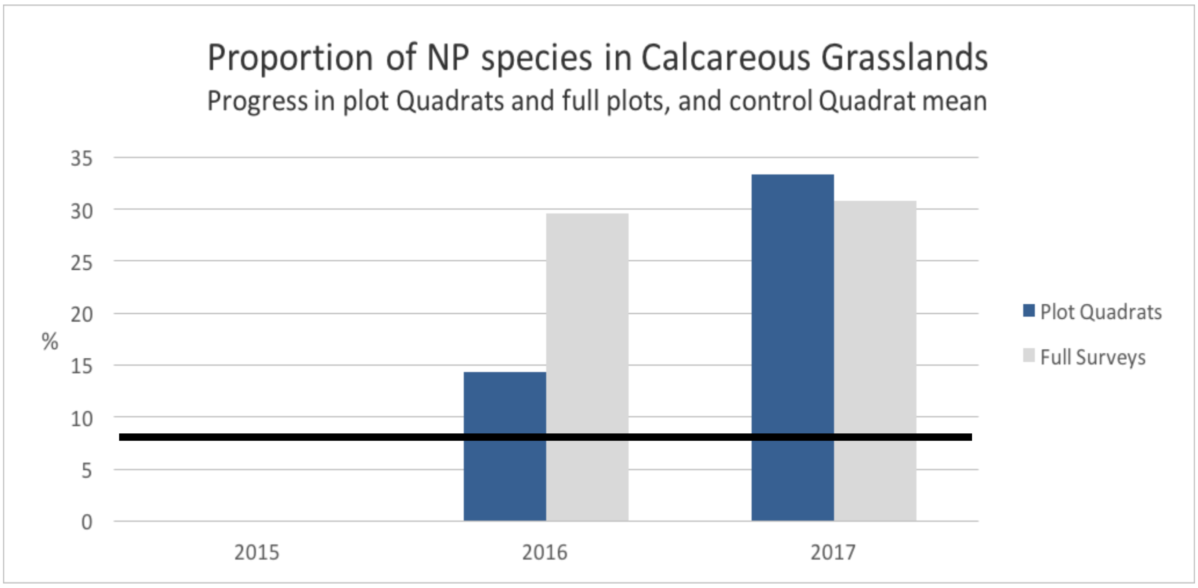


Figure 11. Proportion of species listed as Nectar and Pollen species in Calcareous Grassland sand plots surveyed every year. Progress in plot quadrats and full plots with line = control quadrat mean (number of plots = 6, number of plot monitoring frames = 18, number of plot quadrats = 90). Note that the Full Survey value for 2015 was excluded since not all plots were surveyed in this manner that year.

Prescribed burning was used in several calcareous grasslands. The effects were never obvious, but we detected in several surveys that mosses and lichen cover was reduced and there were indications of positive effects on specialists typical for xeric sand calcareous grasslands (Fig. 12).

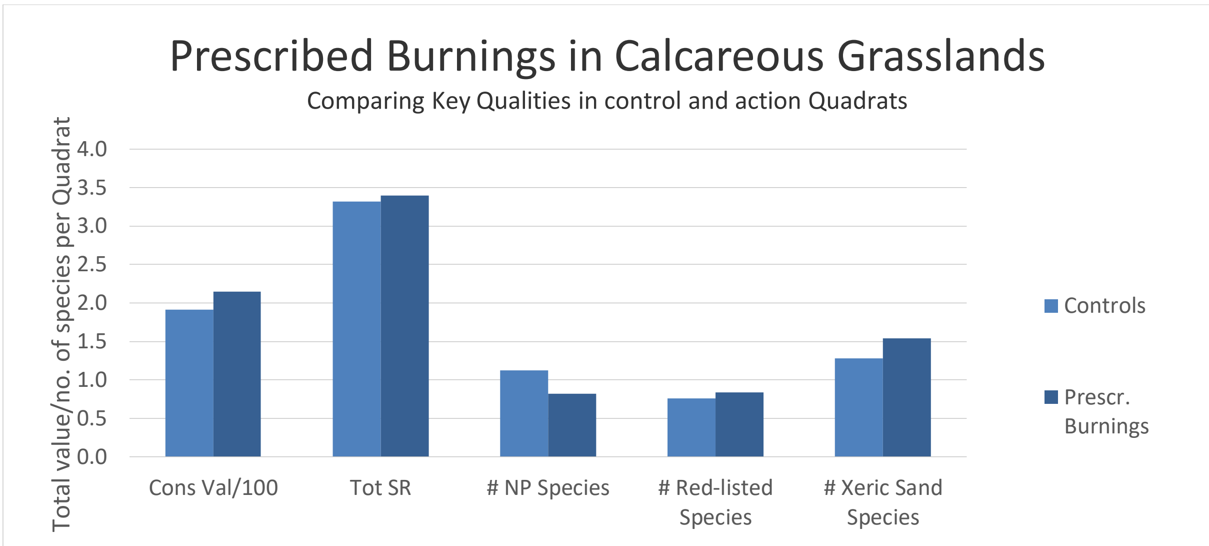


Figure 12. Mean total values per control and plot quadrat for a set of key measures in prescribed burnings in Calcareous Grasslands. From left to right: Total Conservation Value/100 (note that this value was divided by 100 to bring it to scale with the other measures), total Species Richness, number of Nectar and Pollen Species, number of Red-listed Species and number of Xeric Sand Species (number of prescribed burnings = 5, total number of monitoring frames = 11, total number of quadrats = 55).

Discussion Vascular Plants

Sand plots and ploughed plots were constructed to add the disturbance sought by target species. As these plots were initially virgin, fewer as well as less spread species at least during the first years is not surprising, and the first concern is about what kind of species first colonize the plots rather than total numbers. Clearly, many of the pioneer species in these new settings have high ecological values such as a rich supply of nectar and pollen and at this early successional stage, these values continue to increase rapidly with corresponding species conquering more interior parts of the plots over the years. For instance, already in the first year, conservation values for full plots was high but at the quadrat scale still very low, but with time this has changed and more parts of the plots now mirror the variation initially seen only at the full plot scale. Moreover, note that not only have more species entered each plot and each fraction of the plots, but of all those that did, the mean conservation value has also increased, and the same pattern is seen in almost every trait analysed in this report, such as supply of nectar and pollen and inclusion in the Swedish national red list.

Comparing actions, the establishment of new species and spread of those was much faster in ploughed plots compared to sand, presumably reflecting that ploughing is a less drastic disturbance than the construction of plots of barren sand in Dry Grassland habitats. While the swift increase in nectar and pollen sources and species with high conservation values obtained in ploughed plots is of course desirable, on the other hand results in this report indicate that acquired resources as well as the acquisition of even more values to the plots might last longer in sand plots, as trends for some traits in ploughed plots already are underway to flatten out, at least for species means at the full plot level.

As these sand and ploughed plots are still in early succession, the articulated trends in conservation values, abundance of herbs listed as good nectar and pollen sources and number of red-listed species rapidly increasing over the years and still accelerating rather than levelling off, anticipates further addition of value in impending years and continued monitoring would be worthwhile to reveal further details of the establishment of vascular plants in these Dry Grassland plots, in particular the preferred timing and magnitude of disturbance to maintain a mosaic representing all stages of succession in a sandy habitat.

Thymus serpyllum, red-listed according to the 2015 list, established in a sand plot in Gropahålet.

Birds

Introduction

Bird populations in the open, sandy landscape have decreased during many years in Sweden. Many of the birds connected to sandy soils are insectivores and needs a high production of insects and a high insect-production is favoured by the occurrence of bare sand. However, some of these bird species are favoured by larger patches of bare sand than many other organism groups and monitoring the bird fauna was made to give us further information on habitat quality and an answer if the restoration and management actions are sufficient. Bird monitoring was mainly carried out in coastal areas with larger areas of open or tree-covered sand dunes, habitats that are favourable for many bird species connected to sandy habitats. The focus species were nightjar (*Caprimulgus europaeus*), tawny pipit (*Anthus campestris*) and woodlark (*Lullula arborea*). Tawny pipit is a bird species that is typical for habitat types such as 2120, 2130, 2180, but also found in 2320, 2330, 6120. Breeding of tawny pipit is one of the conservation targets for habitat type 2120 and 2130. It is also, together with woodlark and nightjar, included in the species of the Special Protection Areas (SPA) of the Birds Directive in the project (Sandhammaren, Falsterbo-Foteviken and Laholmsbuktens sanddynsreservat).

Bird territories in restored dune habitats

Method

In 2017, a bird survey was carried out in three Sand Life dune areas. The comparative study of birds was performed in three areas were restoration measures had been carried out (mountain pine removal and creating areas of bar sand) and on areas that were not restored, so-called control areas. The survey was made in Haverdal and Laholmsbuktens sanddynsreservat (Tönnersa and Hökafältet). In each of Haverdal, Tönnersa and Hökafältet, two routes were surveyed, each of them 2 km long. One route in restored and one in control area for each area. The transects were surveyed on three occasions from early May to mid-June. The methods followed ”Fåglar revirkartering, generell metod” (Naturvårdsverkets handledning för miljöövervakning, version 1:1 2012-06-21; bilaga 5). For a more detailed description of results, see report in Swedish by Patrik Olofsson (2013; 2017).

Results

The control areas were dominated by pine forests, while the restored areas were dominated by newly created dune heath, with significant areas of bare sand. There was a tendency for higher bird territory density in control areas and significantly higher species richness in the control. There was a clear tendency for higher number of territories of red-listed bird species in restored areas, mean values of 9 compared to only 2 in control areas (Table 5).

Table 5. Number of territories and species richness as calculated as mean for the three routes in control areas and three in the restored areas (n=3). The mean values were compared using paired t-test.

	Control	Restored	p
Territores per route	73.7	56.3	0.13
Species richness per route	28.3	25.7	0.015*
Red-listed territories per route	2.0	9.0	0.16
Red-listed species per route	1.7	3.0	0.46

The results for the woodlark (*Lullula arborea*), which is listed in the listed in the Birds Directive (79/409/EEC), is included in Table 6 together with the results for the nationally red-listed species. The woodlark had significantly higher territory numbers in restored areas. The same was the case for the red-listed yellowhammer (*Emberiza citronella*). Five of the red-listed species occurred only in the restored areas, while two occurred only in control areas.

Table 6. Number of territories of all red-listed species and woodlark as calculated as mean for the three routes in control areas and three in the restored areas (n=3). The mean values were compared using paired t-test.

Species	Red-list	Control	Restored	p
Lullula arborea	LC	0.33	3.3	0.035*
Alauda arvensis	NT	0	2.0	0.23
Emberiza citrinella	VU	0	4.3	0.039*
Anthus pratensis	NT	0	2.0	0.23
Dendrocopos minor	NT	0	0.33	0.42
Saxicola rubicola	EN	0	0.33	0.42
Dryocopus martius	NT	0.67	0	0.18
Regulus regulus	VU	1.3	0	0.057

Discussion

The results show that the actions already have had a significant effect on the bird fauna. Many open-habitat species have colonized the areas where actions have been taken. The red-listed species in the control areas where typical forest species, which both have rather good populations in the area. It is worth to note that also one red-listed forest species like the little woodpecker only was noted in restored areas. In addition to the red-listed species, those that increased were mostly typical open-habitat species.

Overall, the bird territory survey shows that the actions have changed the bird community into one with more open-habitat species, with many of them being red-listed. It is still early stage after restoration, and it is therefore partly surprising that the cleared areas already hold qualities enough for many threatened species.

Tawny pipit

Introduction

Tawny pipit (*Anthus campestris*) belongs to the open sand dunes and sandy grasslands. The species was a common bird in Skåne until the beginning of the 20th century, and then bred in large parts of southern Sweden. During the last 100 years, the area and quality of the open sandy habitats have been drastically reduced, for example due to changed land use and planting and spread of species such as mountain pine or Japanese rose. The development has been devastating for tawny pipit, which today is rare and only occurs scarcely in eastern Skåne. The population of tawny pipits in Sweden has been followed through many surveys, all of which have shown a downward trend with time (Larsson and Fritz 2016).

Method

Tawny pipits in southern Sweden was surveyed in 2013 (before Sand Life actions) and 2017 (after actions). The 2017 survey started in mid-May, and most of the field work was commenced in mid-July. During late July and the whole of August, additional visits were made to follow up later breeding and check for fledglings. The total time in field was approximately 180 hours. As in 2013, 36 selected areas were surveyed, all areas that hosted tawny pipits during at least one of the earlier surveys in 2001, 2008 or 2013, but sites with recordings of tawny pipits from the 1980s and 1990s were included. The size of the surveyed areas was highly variable, from small sandpits and smaller sandy areas of a few hectares, to large areas such as Ravlunda military ground and the coast of Hanöbukten. The largest areas were divided into smaller subareas.

The inventory was carried out through "Förenklad revirkartering för jordbruksmark" (according to the Swedish Environmental Protection Agency's standards, Version 1: 1, 2012-05-28). In cases where no birds were noted visually, the vocal song recordings were played using tape recorders to provoke birds present to start sing. The observations of birds were mainly of two categories; singing males and pairs with some breeding criterion. All observations were recorded with GPS (RT90). The weather during the inventory period was initially relatively stable with dry, but sometimes windy and cold days, whereas in June and July it became unstable with relatively many rainy days. The season was characterized by unstable weather, and lacked longer coherent periods of warm and stable weather.

Results

The inventory of tawny pipits in Skåne 2017 resulted in 40 territories with a total of 23 breeding pairs. The number of tawny pipits has increased by about 20% since the previous inventory 2013, when 33 territories and 21 breeding pairs were noted. The results for 2017 is approximately at the same level as the corresponding inventory in 2008, when 42 territories were found (Fig. 13). In 2017, all tawny pipits were found in Skåne, and no breeding occurred in Halland.

Most of the tawny pipits occurred in areas that were subject to actions in Sand Life. Also in areas outside the Sand Life project there was an increase in number of territories compared with 2013, but these areas did not recover compared with the numbers in 2008, as was the case for the Sand Life areas.

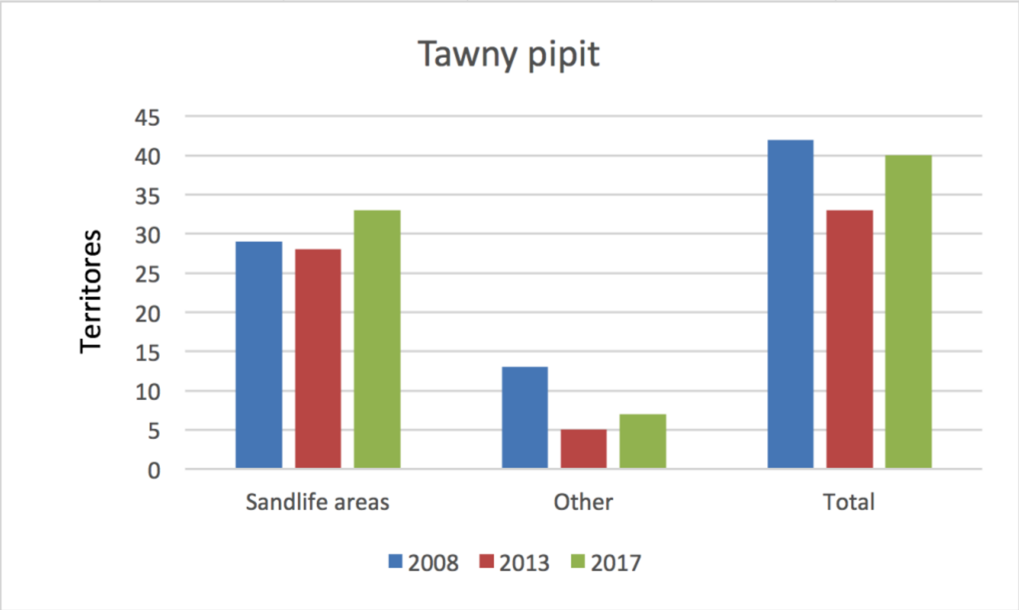


Figure 13. The number of territories of tawny pipits in Sweden from 2008 until 2017. Most of the breeding pairs are in Sand Life areas.

During the inventory in Skåne 2017, tawny pipits occurred at 11 places in Skåne, which is an increase with three places compared with 2013. The result is an extension of the range of the species; to the north (Bäckaskog grustag), to the northwest (Everöd's airport) and to the south (Vårhallarna). These places lacked tawny pipits in 2013, had the species in 2008. Although the results for 2017 and 2008 are close to each other, they differ in terms of the extension area. During the 2008, birds were found on 19 places, several of which were located along the south-eastern Skåne coastline and at Revingefältet, areas that still lack tawny pipits. However, a new breeding occurred in 2018 in Sandhammaren on the south-eastern Skåne coastline and where restoration actions within Sand Life had been made.

Discussion

Between 2013 and 2017 there has been a densification of the territories at Ravlunda military field, where the population has increased from 9 territories to 14 and the site now houses 35% of the whole population. Even the Drakamöllan with surrounding nature reserve has had a positive development with a new pair compared to 2013.
There is a very large proportion of the population of tawny pipits within a barely square mile area in eastern Skåne. Within the five sub-areas: Ravlunda military field, Vitemölla, Kiviks marknadsplats, Drakamöllan with nearby nature reserves, and Brösarps norra backar host 70% of the total number of known territories in Sweden. Large areas outside the present population have been restored within Sand Life, and the coming years it will be very interesting to see if tawny pipit can spread to these areas. One very positive observation in 2018 was that a new territory was established in the Skåne south coast, in restored areas of Sandhammaren. An important spreading of the population range.

Nightjar and woodlark

Introduction

Both woodlark and nightjar breeds in areas were sandy areas are connected to pine trees or forest. Nightjar is connected to the forest areas, but often prefer glades in the forest. Woodlark, on the other hand, prefer mainly open habitats, as far as there are some trees in the area. These species were not target species in the restoration actions, but were monitored since they are SPA species of the Birds Directive.

Method

Birds were surveyed by nesting range monitoring for target species, following the national monitoring program. For woodlark, we surveyed Verkeån, Friseboda, Gropahålet, Klammersbäck, Rinkaby, Sandhammaren, Böda västra, Böda östra, Laholmsbuktens sanddynsreservat and Haverdal. For nightjar, we surveyed Friseboda, Gropahålet, Rinkaby, Sandhammaren, Böda västra, Böda östra, Laholmsbuktens sanddynsreservat and Haverdal.

The areas for woodlark and nightjar were selected since they were expected to have relatively large populations of these species within or just outside benefit areas. The surveys were made in spring and summer 2014 and 2017.

Results

The survey of nightjar showed an increase in the benefit areas during the project period (Table 7). Many of the new territories of nightjar was found in areas where gaps have been created in the pine forest, such as in the Böda area on Öland. Woodlark, on the other hand decreased during the period. To check up for this, we also analysed data from Species gateway in all benefit areas. The data here indicated an increase in woodlarks between 2012 when 37 territories were noted to 2017 when there were 46 territories registered.

Table 7. The number of territorial males and females before and after the actions.

Species	2014	2017
Nighjar, males	33	40
Nightjar females	15	22
Woodlark males	53	41

Discussion

The positive results for nightjar show that a landscape with less dense pine stands are positive for this species. Indeed, many territories were observed in glades created during the project. The actions in the project have not been specifically targeting the nightjar, but it is interesting to note that this species that is depending on pine was favoured during the project time.

For the woodlark, the results are less clear. The woodlark was surveyed together with the nightjar, since it is active also during the night. It might be a better idea to survey the woodlark early in the spring when they first arrive. The results from the regular survey indicated a decrease, but on the other hand, the data in species gateway indicated an increase. And more importantly, the bird territory survey in dune habitats found a significant higher density of woodlark in restored areas compared to controls. Overall, we cannot conclude about the success for woodlark for the moment, but future surveys are recommended to follow the woodlark in benefit areas.


Tawny pipit, fledgling.

Bees and Wasps

Introduction

Bees and wasps (Hymenoptera) is the largest insect order in Sweden, with about 8,000 named species, and includes nectar and pollen feeders, predators and parasites. Many bees and wasps have well-developed parental care: some species build a larval chamber where the egg is laid together with a supply of food for the larva to consume after hatching, other feed their larvae directly right through to pupation. Some bee and wasp species are social with large communities with individual specialisations such as nectar and pollen collectors, larva feeders, guards, polishers etc, but most are solitary, even though many of these still prefer to aggregate their nests into colonies.

Many bees and wasps need patches of vegetation-free, bare sand to dig and lay egg. At the same time, they need nectar and pollen sources for foraging. Wild bees have been recognized to be very important as pollinators within agriculture and an effect of favouring bee-populations within the project is that important ecosystem services are improved (Breeze et al. 2011). Increasing populations of bees will also favour bee parasites.

Monitoring in this project focused on bees and wasps in the infraorder Aculeata (bees and "stinging wasps"), and surveyed species include all the ecological variation described above (Table 8). The high prevalence of predatory and parasitic relationships between wasps and bees might be pictured listing just those interactions involving surveyed species (Fig. 14). Sphecoid wasps are mainly parasitized by emerald and vespoid wasps, while bees are predated by sphecoid wasps and parasitized by other bees, notably the genera *Sphecodes* and *Nomada*.

Table 8. Overview of ecology in surveyed species of infraorder Aculeata.

Common Name	Taxon	Ecology
Bees	Apoidea – Apiformes	Flower Visitors, Parasites
Sphecoid Wasps	Apoidea – Spheciformes	Predators
Emerald Wasps	Chrysidoidea – Chrysididae	Parasites
Vespoid Wasps	Vespoidea	Predators, Parasites

Sand specialists are found in all functional groups and many surveyed taxa including nectar and pollen collectors such as mining bees *Andrena* and *Panurgus*, plasterer bees *Colletes* and sweet bees *Lassioglossum*, parasites such as cuckoo bees *Nomada*, blood bees *Sphecodes* and cuckoo\emerald wasps Chrysididae, and finally predators such as spider wasps Pompilidae and sphecoid wasps Crabronidae and Sphecidae.

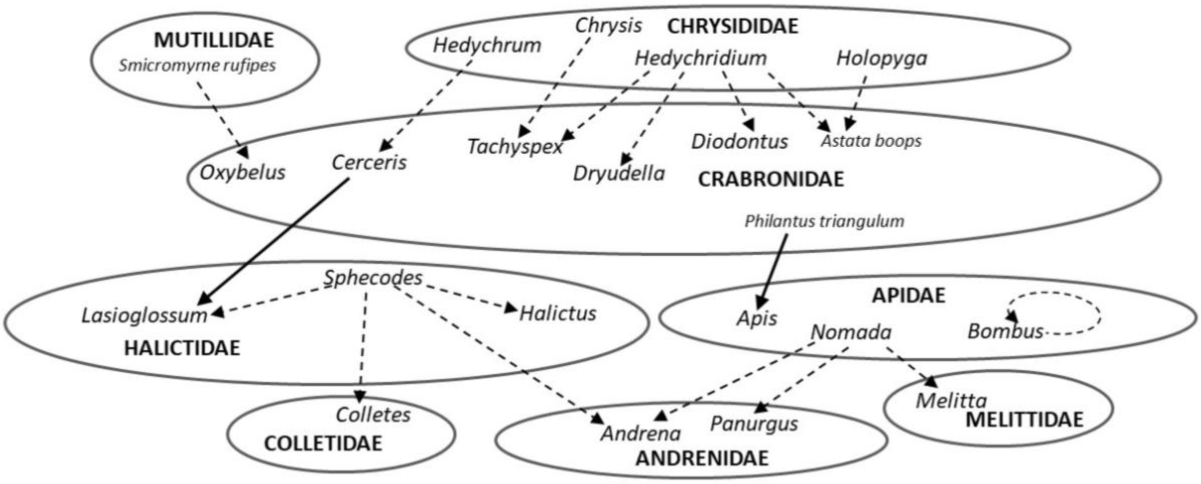


Figure 14. Predator-prey (solid lines) and parasite-host (dashed lines) relationships involving surveyed genera. Circles correspond to families. In some cases where only one surveyed species in the genus is involved in relations, the full species name is written out instead of just the genus.

Sandy habitats are preferred by bees and wasps for various reasons. The coarse structure of the sand makes it well drained, easy to dig in and thus useful for building larval chambers. For some species (referred to as Barren Sand species), the sand is even more attractive if it's covered only by sparse vegetation or no vegetation at all, since it is then more easily accessible. Barren sand also absorbs more solar radiation which creates a warm microclimate preferred by the larvae of many species. For predatory and parasitic bees and wasps, the open areas of exposed sand serve as hunting grounds, and those species are often seen ambushing around their host's or prey's nest. Other bee species are dependent on vascular plants confined to sandy habitats for nectar and pollen feeding or as material for nest building. In many bee and wasp species, several of these needs are combined which makes them even more vulnerable. For instance, the mason bee *Osmia maritima* needs *Louts corniculatus* or *Lathyrus japonicus* to collect nectar and pollen for herself and her larvae, stable sun-exposed sand free of vegetation as nesting ground and leaves preferably from *Viola canina* to construct larval chambers. Evidently, for predators and parasites, the requisite of a high abundance of their prey or host is combined with their own nest building demands.

In Sand Life mountain pine stands were cleared to increase the abundance of flowering plants and sand plots were constructed to attract bees and wasps with a preference for sandy habitats. Immediately after construction the plots are barren, but with time vegetation will grow into them, and each successional stage of the plots benefits different species. The monitoring of bees and wasps in Sand Life includes both before/after and control/action surveys of clearings and sand plots in dunes and grasslands.

Method details specific to Bees and Wasps

Before/after

At each visit, every transect was walked slowly and all bees and wasps observed within two meters from the transect were recorded (or if necessary caught for later species identification). In total, 10 grids at six different dune sites and 7 grids at five different grassland sites were surveyed in the summer both before (July 2013) and after (July 2017). In addition to this, four of the dune sites were also surveyed in the spring both before (April 2014) and after (April 2017) implementation of Sand Life restoration actions.

Control/action

All 25 sand plots and their controls in the common setup were surveyed twice (once in June and once in July) during the summer of 2017, using both sweep netting and observation. The results from both visits and both methods were summed into a single value for each plot or control.

For bees and wasps, in addition to the common setup, another survey was carried out to examine the combined effect of mountain pine clearings and creation of sand plots. Five areas at three sites in southern Halland on the west coast of Sweden were surveyed for selected bee and wasp species. Each area included both a control plot with remaining mountain pine and a nearby sand plot in a recently cleared territory (Fig. 15). In each sand or control plot, three white plastic bowls were placed in early/mid-July 2017 and collected two days later, and this was repeated about three weeks later for a total of four trap nights per bowl. All collected bees and wasps of the infraorder Aculeata were identified and counted.

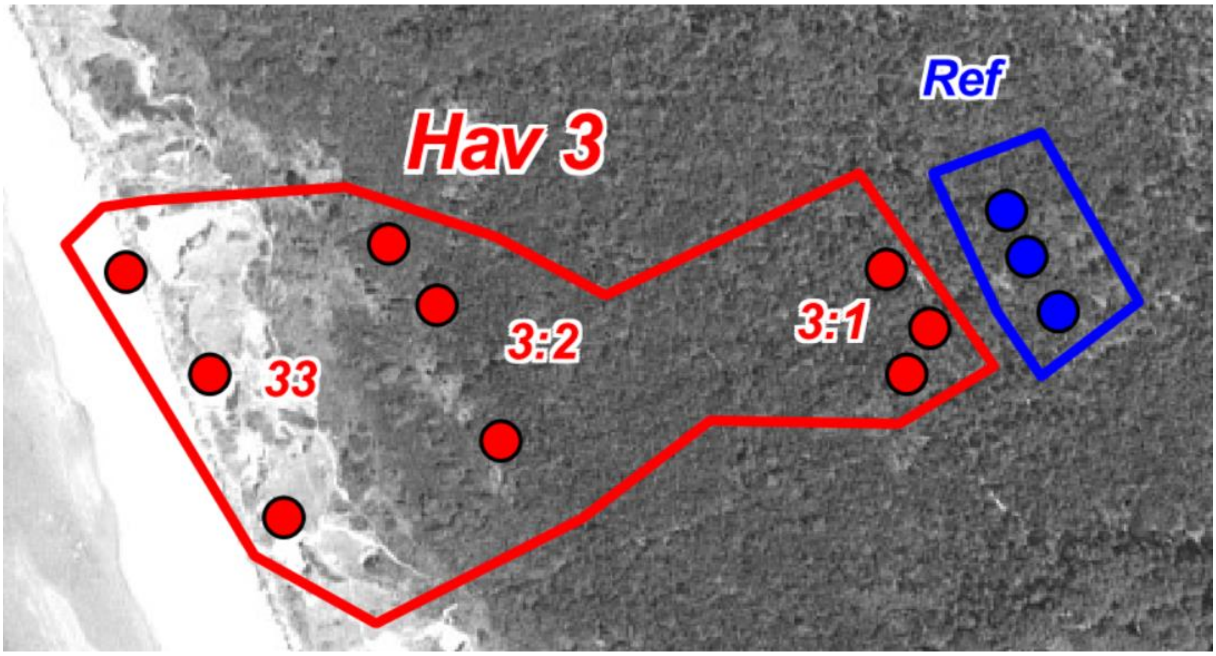


Figure 15. Set up of plastic bowls in one of the five surveyed areas. The red polygon represents newly cleared territory with sand plots, and the blue polygon is the control plot in remaining stands of mountain pine. Dots (red or blue) represent plastic bowls: 3 in sand plots and 3 in the control plot. Note that, in the action plot only the capture in the three bowls closest to the control plot (marked 3:1) was used in this analysis.

Species classification

Species were classified without knowledge of the results according to ecology, nest building demands and sand affinity by entomologist Mikael Sörensson at Lund University, as follows:

Ecology: *Flower visitor*, *Parasite*, *Predator*.
Nest Building Demands: Each species was assigned one of six classes based on its demand on properties of the soil, vegetation etc. crucial for its nest building. *Barren Sand* (dependent on patches of sand with almost no vegetation cover), *Veg Sand* (partly overgrown is

acceptable), *Arid Meadow, Arid Ground, Plant Material, Others* (none of the above demands).
Diet specialization: Flower visitors only. *Narrow-oligolectic, Intermediate-oligolectic, Broad-oligolectic, Polylectic.*
Overall sand affinity: Combining ecology, diet specialization and nest building demands, each species was listed as either of the following three: *Sand Specialist* (confined to sandy habitats), *Sand Favoured* (promoted by and attracted to sandy habitats, but also occurring in other xeric soil types) or *Other Bees and Wasps* (not promoted by presence of sand).

Results Bees and Wasps in Dunes

Bees and wasps in dunes were surveyed in three different ways. As mentioned, before/after surveys demonstrate the effect of clearings and prescribed burnings, the control/action survey in the common setup covers the effect of creating sand plots, and the additional small-scale control/action survey of areas with remaining mountain pine as well as cleared areas with sand plots, illustrates the combined effect of both these actions.

Overall abundances and Species richness

In the before/after survey in dunes, 363 bees and wasps of 37 species were recorded, with one red-listed species: the leafcutter bee *Megachile leachella*. In the common setup control/action survey, a total of 114 bees and wasps of 27 species were recorded, with 2 red-listed species: sickle-jawed blood bee *Sphecodes puncticeps* and moss carder bee *Bombus muscorum*. In the small-scale control/action survey of the combined effect of clearings and sand plots, 33 bees and wasps of 19 species were collected.

In the before/after survey, the average number of collected bees and wasps per grid was higher before than after implementation of the actions (15.5 compared to 10.4), but there was a large seasonal bias to this: in the spring the average number of specimens per grid increased (from 6.7 to 17.5) whereas in summer this number decreased sharply (from 19.0 to 7.6). In the common setup control/action survey, the average number of bees and wasps per plot was significantly higher in sand, 15.2 compared to only 7.6 in controls.

Total species richness was higher before implementation of the actions, but this also varied distinctly with the time of the year: in the spring eight species were recorded before and seven species after, whereas the number of collected species in the summer was only 13 after compared to 22 before implementation of the actions. In the common setup control/action survey of sand plots in dunes, species richness was higher in sand than controls both measured as mean species richness per plot (7.4 in sand compared to 5.6 in controls, NS) and total species richness (21 species were recorded in sand plots compared to 16 in controls, amounting to 11 species confined to sand, 6 to controls and 10 species found in both treatments).

However, since the before/after survey has the obvious bias of varying weather conditions, to which bees and wasps are extraordinary sensitive, with a glimpse of sunshine modifying abundances in minutes, and the control/action survey with its proximity of treatments is subject to a risk of including attraction effects, the most straightforward assessment of differences in abundances and species richness between treated and non-treated areas is, despite its small scale, probably to be sought in the small-scale action/control survey of the combined effect of clearings and sand plots, since this survey isn't handicapped by either of the above tilts.

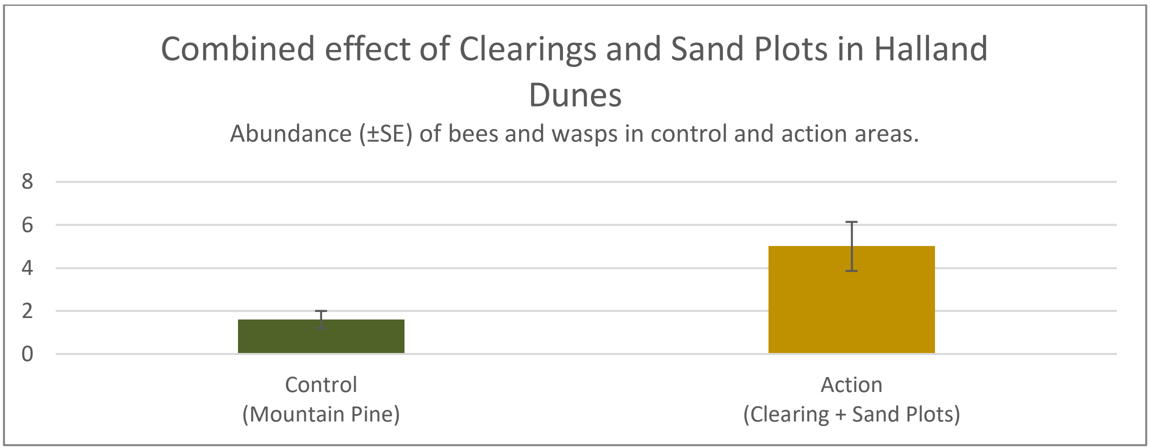


Figure 16. Combined effect of Clearings and Sand Plots in Halland Dunes. Average abundance (±SE) of bees and wasps per control and action area (action > control, *).

In this survey, more species and specimens were collected in action than control areas. The mean capture per area was 5.0 in actions compared to 1.6 in controls (Fig. 16) and mean species richness per area was 3.8 in actions compared to 1.4 in controls (Fig. 17), and both these results were significant.

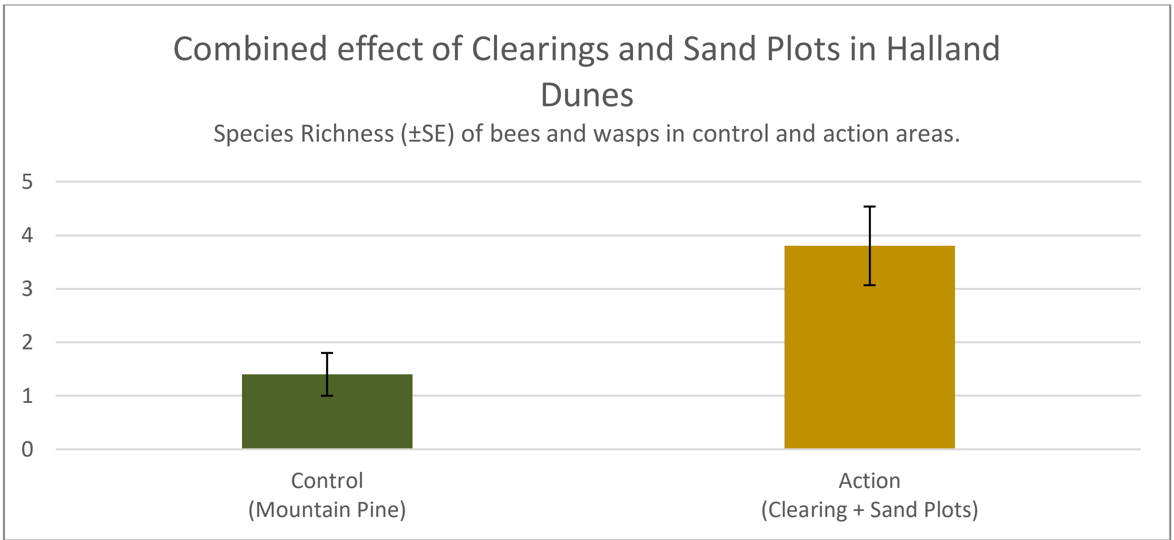


Figure 17. Combined effect of Clearings and Sand Plots in Halland Dunes. Average species richness (±SE) of bees and wasps per control and action area (action > control, *).

Sand Affinity of Bees and Wasps in Dunes

In the before/after survey, the share of sand favoured species saw a more than six-fold increase, with sand specialists almost doubling (Fig. 18). A seasonal variation was registered with higher abundances of species with sand affinity in the spring than in the summer, but the share of both sand specialist and sand favoured bees and wasps nevertheless increased during both seasons.

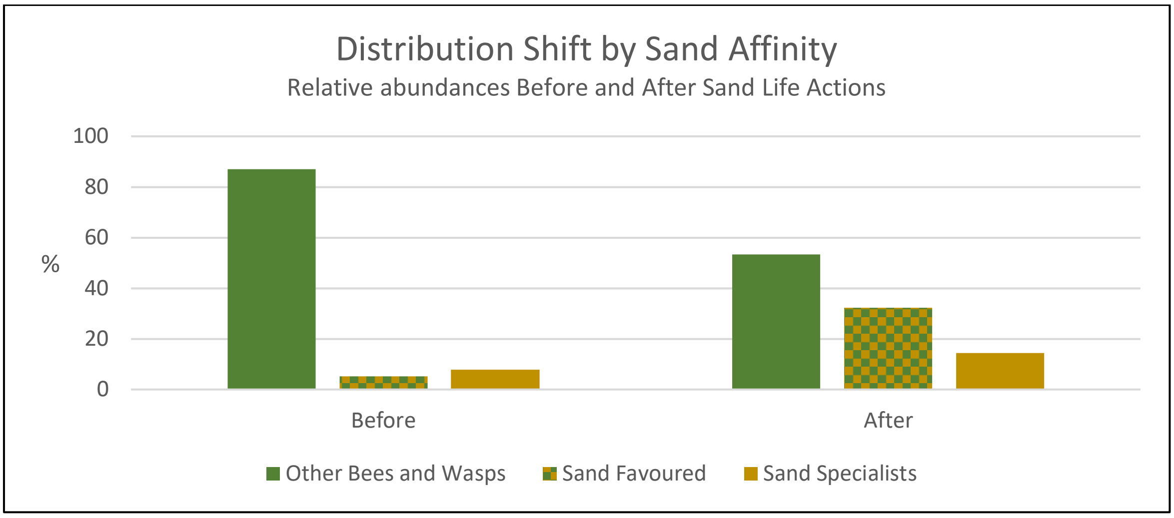


Figure 18. Abundances of Other, Sand Favoured and Sand Specialist Bees and Wasps as percentages of total abundance before and after implementation of Sand Life Actions.

The distribution of bees and wasps shifted inland with the realization of Sand Life actions (Fig. 19). Further scrutinizing this pattern, even though sand specialist and sand favoured species increased their share in all transect types, the shift was most remarkable in intermediate transects which saw an increase in bees and wasps with sand affinity (sand specialists or sand favoured) from 12.3% to 60.3%.

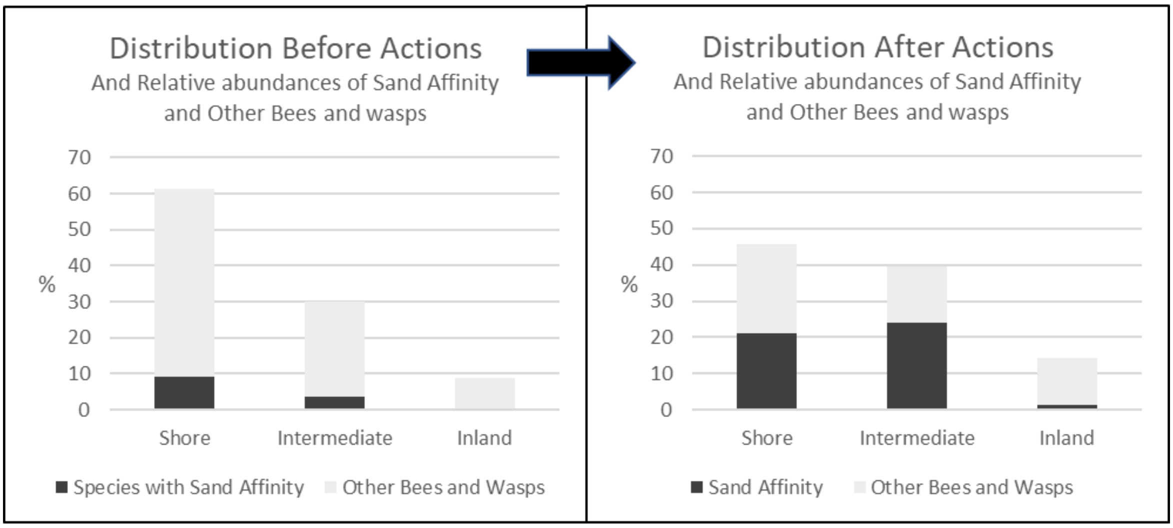


Figure 19. Distribution and sand affinity of Bees and Wasps before and after implementation of Sand Life actions.

Table 9. For each species group, number of species confined to sand plots, found in both treatments and confined to control plots. And mean species richness in sand and control plots, and significance of the difference between treatments.

	Number of species			***Avg. species richness / plot***		
	Sand	*Both*	*Control*	*Sand*	*Control*	*Sign.*
Sand Specialists	5	1	-	2.2	0.6	*
Sand Favoured	3	4	2	2.8	1.6	NS
Others	3	5	4	2.4	3.4	NS

The pattern in the before/after survey with bees and wasps with a high sand affinity clearly favoured by actions, reappeared in the common setup control/action survey. In this survey, five out of the six sand specialist species were confined to sand plots, with other species rather evenly distributed between treatments (Table 9). Not surprisingly, species richness and abundance per plot (Fig. 20) of sand specialist and sand favoured bees and wasps were also significantly higher in plots than controls

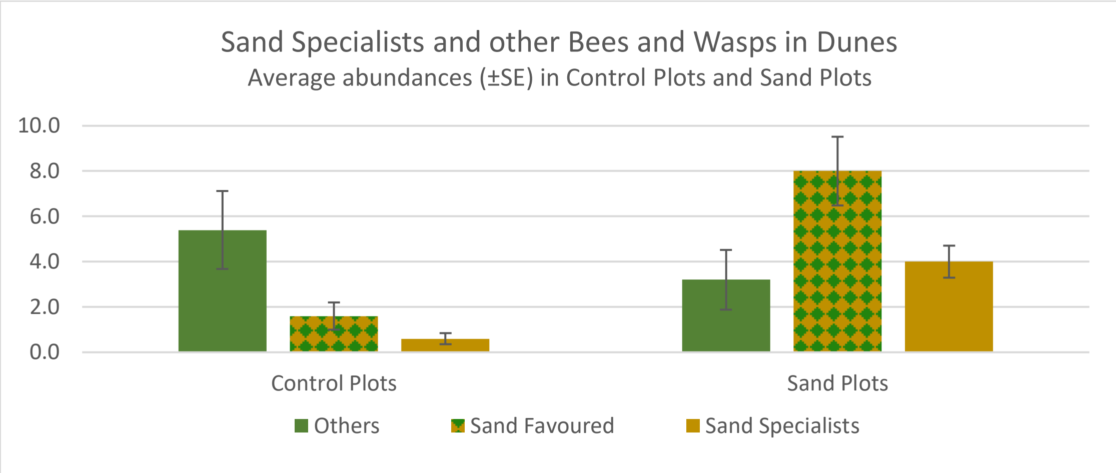


Figure 20. Comparing species composition by sand affinity in control and sand plots. From left to right average abundances (±SE) per plot of Other Bees and Wasps (NS), Sand Favoured (sand>control, **) and Sand Specialists (sand>control, *). Grouping all species with sand affinity (Sand Specialists and Sand Favoured), significantly (***) more were found in sand.

All six sand specialist species recorded in the common setup control/action survey were more abundant in sand than controls, and a similar pattern was seen in the number of sand and control plots each species was found in (Fig. 21).

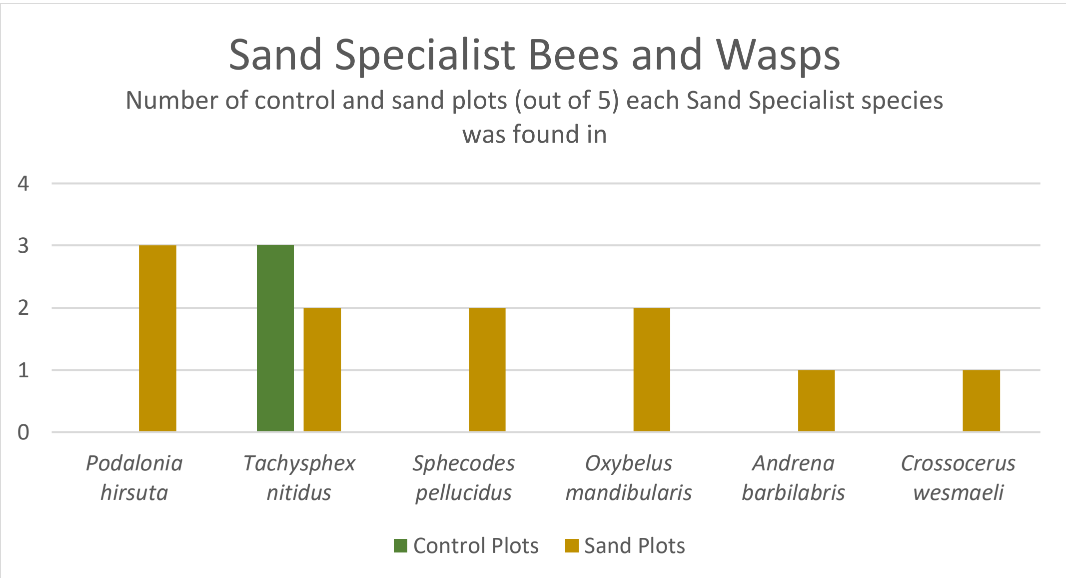


Figure 21. For each Sand Specialist species found in the survey, number (out of five) of Control Plots and Sand Plots it was found in.

Nest Building Demands of Bees and Wasps in Dunes

Investigating what drives sand specialists to the plots, the common setup survey discerns nest building demands as a key factor. In this survey, 3 out of 4 Barren Sand species and 5 out of 10 Veg Sand species were confined to sand, but in all other groups, species were almost equally split between treatments (Table 10) and abundances parade a similar pattern (Fig. 22)

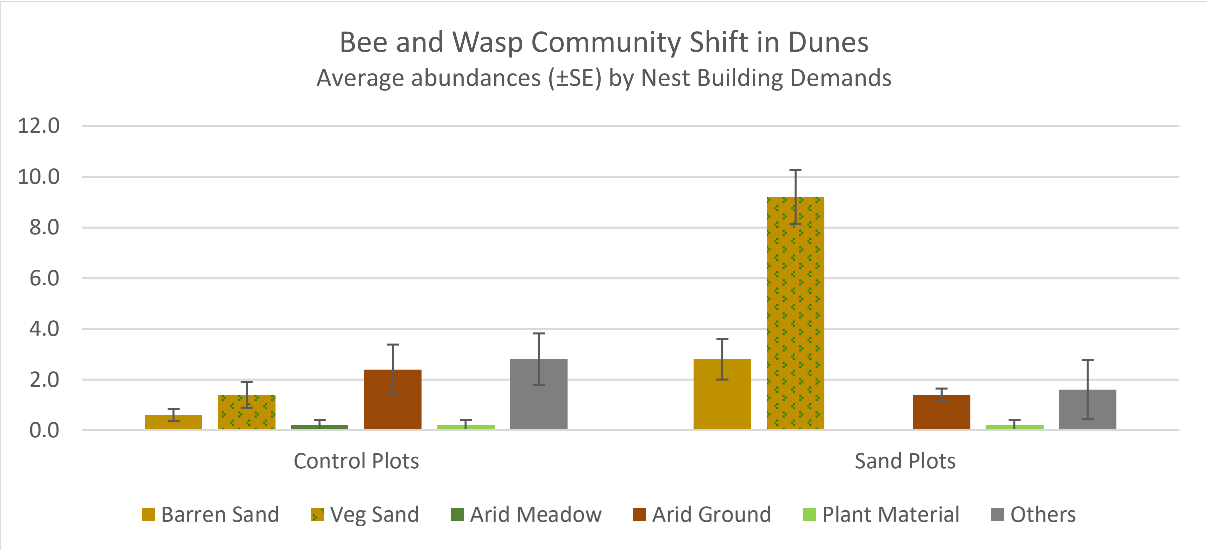


Figure 22. Comparing Bee and Wasp communities divided by Nest Building Demands in control plots and sand plots. From left to right average abundances (±SE) per plot of bees and wasps classified as Barren Sand species, Veg Sand species, Arid Meadow species, Arid Ground species, Plant Material species and Others.

Table 10. For each Nest Building Demand class, number of species confined to sand plots, found in both treatments and confined to control plots. Also, for each class, its relative contribution to total species richness and proportion of all specimens recorded in the survey.

	Sand	*Both*	*Control*	***Species***	***Specimens***
Barren Sand	3	1	-	15%	15%
Veg Sand	5	4	1	37%	46%
Arid Meadow	-	-	1	4%	1%
Arid Ground	1	2	1	15%	17%
Plant Material	-	1	-	4%	2%
Others	2	2	3	26%	19%

Flower-visiting, predatory and parasitic Bees and Wasps in Dunes

So far, most results have been independent of survey method, but for functional groups – that is, the share of flower visitors, predators and parasites – a striking difference between the before/after and control/action surveys, was identified. In the before/after survey, flower visitors increased their share (from 80.2% to 90.1%), while predators declined sharply (from 16.6% to 4.1%). However, in the common setup control/action survey, parasitic bees and wasps were almost ten times more common in sand than controls, while flower visitors had a higher abundance in controls (Fig. 23), and the distribution of species between treatments in this survey (Table 11) confirms this pattern. Finally, in the small-scale control/action survey of the combined effects of clearings and sand plots, both species richness and abundance of all functional groups was richer in action than control areas (8 flower visitor species in actions compared to 4 in controls, predators 7 species compared to 3 and the only parasite species was found in an action plot).

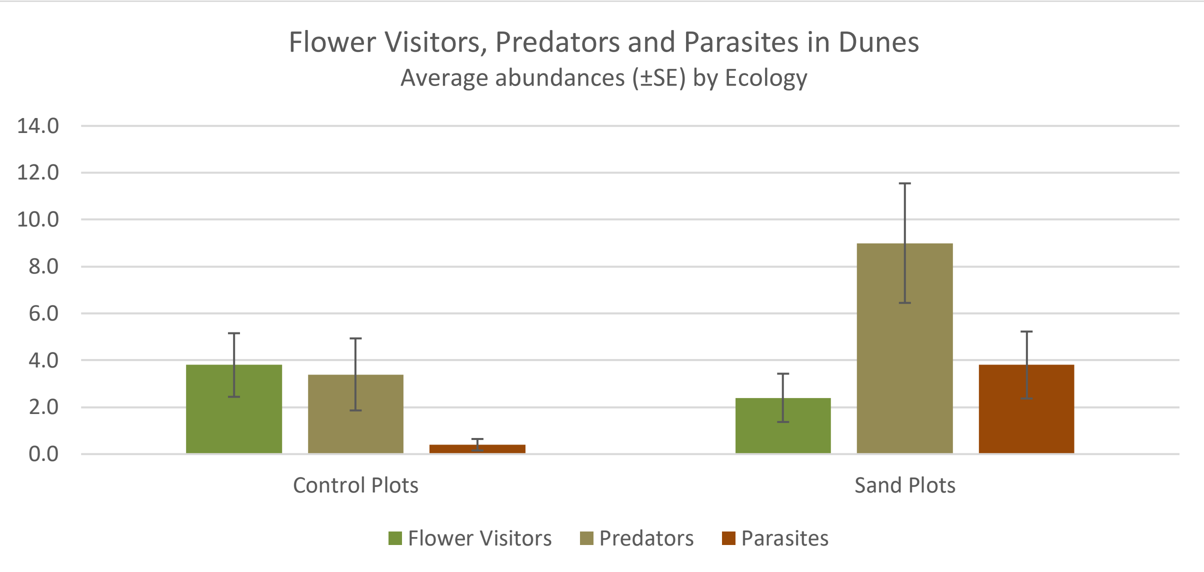


Figure 23. Comparing mean abundances of Flower Visitors (NS), Predators (sand>control, *) and Parasites (sand>control, *) in control and sand plots.

Table 11. For each functional group, number of species confined to sand plots, found in both treatments and confined to control plots.

	Sand	*Both*	*Control*
Flower Visitors	4	3	6
Predators	4	6	-
Parasites	3	1	-

Bees and Wasps in Dunes – results by Taxonomy

In the before/after survey, four out of six bee families increased their share, with the most positive effects seen in plasterer bees (Colletidae, increased from 8.8% to 30.1% of all recorded specimens) and mining bees (Andrenidae, increased from 1.8% to 11.6%). Mason or leafcutter bees (Megachilidae) and Melitidae also increased while sweet bees (Halictidae) decreased in relative numbers, but the most dramatic decline was seen in the most abundant family Apidae, which fell from 68.7% to 51.4% of all recorded bees and wasps. The most favoured genera in the before/after monitoring in dunes were mining bees *Andrena* and plasterer bees *Colletes*, with *Andrena barbilabris* and *Colletes cunicularius* being the most favoured species.

In the common setup control/action survey, the genus most favoured by sand in terms of highest increase in mean species richness per plot was the genus of parasitic bees *Sphecodes* (blood bees), followed by the sphecoid wasp genus *Ammophila*, while *Bombus* showed the opposite pattern although this difference was not significant (Figure 24).

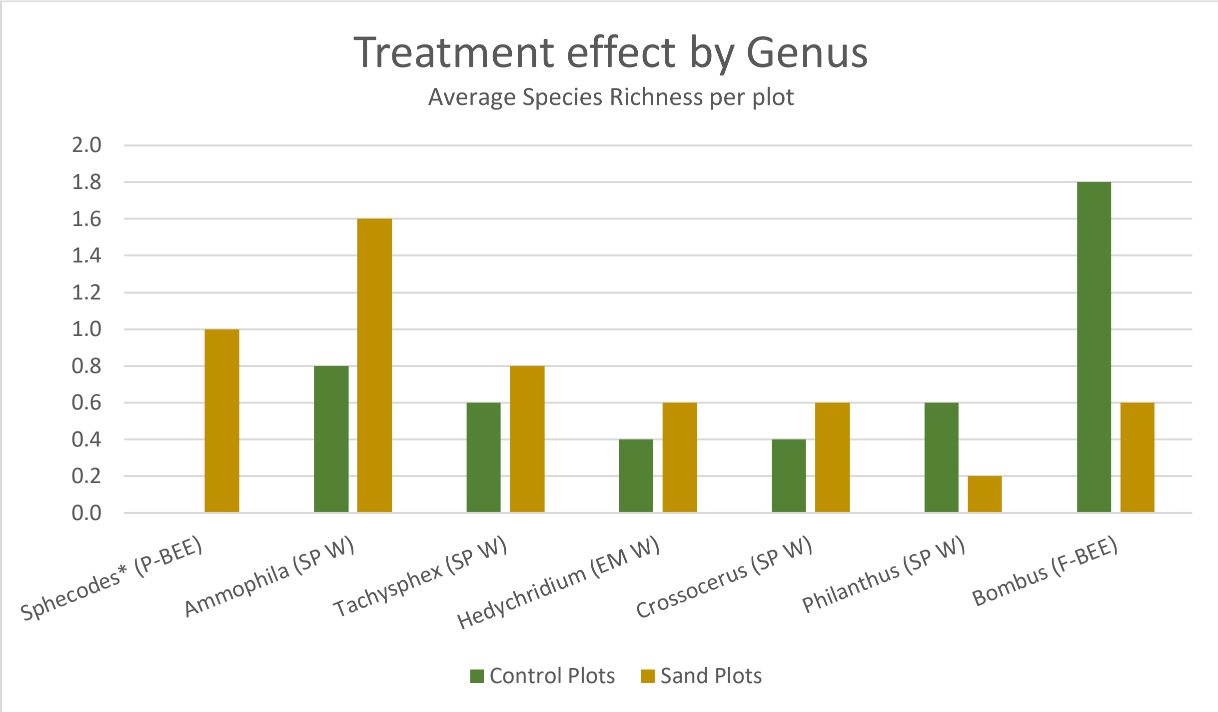


Figure 24. Average species richness per genus in control and sand plots for the seven most abundant genera in the survey. In parentheses, taxonomic and ecological group with F-BEE = Flower Visiting Bees, P-BEE = Parasitic Bees, SP W = Sphecoid Wasps and EM W = Emerald Wasps. Note that in the genus *Bombus* with both flower visiting and parasitic species, none of the latter were recorded in this survey, justifying the chart label. The only genus (*Sphecodes*) with significant difference (sand>control, *) between treatments in mean species richness per plot marked with *.

Finally, combining taxonomy and ecology, results from the common setup survey reveals that not only predatory and parasitic wasps but also parasitic bees benefit from actions, with both abundance and mean species richness higher in sand for all groups except flower visiting bees (Fig. 25).

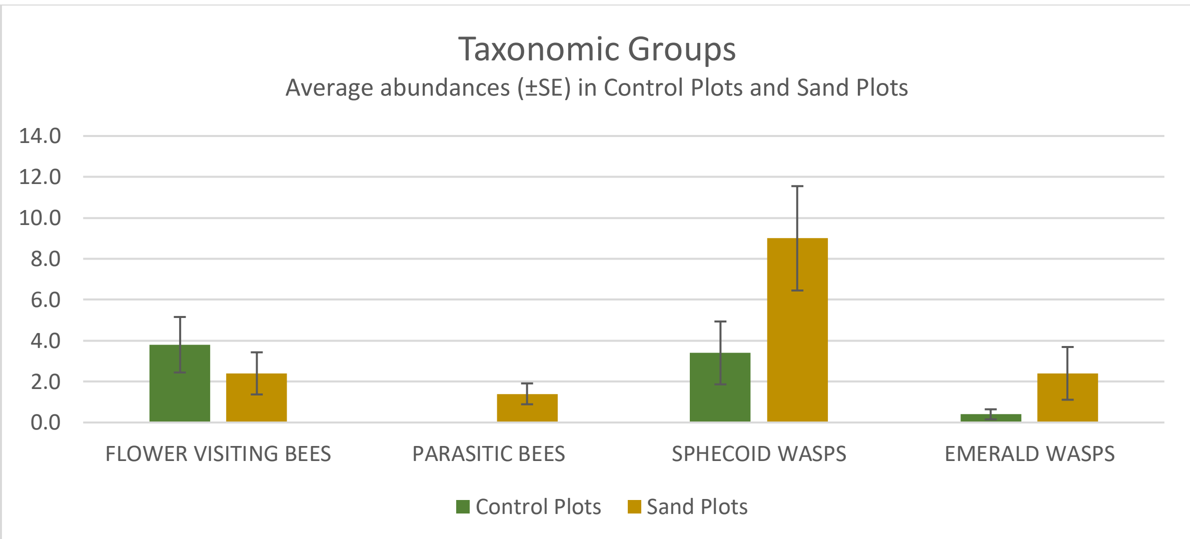


Figure 25. Average abundances by taxonomic groups, with bees split by ecology.

Results Bees and Wasps in Dry Grasslands

The results for bees and wasps in dry grasslands are based on the 15 plots of the common setup control/action survey that were in this habitat.

Overall abundances and Species richness

In total, 587 bees and wasps of 90 species were found in the survey, with 15 red-listed species. The average number of bees and wasps per plot was higher in sand (27.0 compared to 12.1 in controls, ***) and the same pattern was seen in mean species richness per plot (16.4 in sand compared to 7.3 in controls, ***) and in total species richness: 69 species were recorded in sand plots compared to 50 in controls, amounting to 40 species confined to sand, 21 to controls and 29 species found in both treatments.

Sand Affinity of Bees and Wasps in Dry Grasslands

A total of 129 Sand Specialist bees and wasps of 15 species and a total of 186 Sand Favoured specimens of 25 species, were recorded in the survey. Twelve out of 15 Sand Specialist species were confined to sand and the other three occurred in both treatments, thus no Sand Specialist species was found only in controls. Also, more than half of the Sand Favoured species were confined to sand, but of species with no sand affinity, more were confined to controls than sand. Mean species richness per plot was significantly higher in sand than controls for all three species groups (Table 12).

Table 12. For each species group, number of species confined to sand plots, found in both treatments and confined to control plots. And mean species richness in sand and control plots, and significance of the difference between treatment.

	Number of species			***Species richness / plot***		
	Sand	*Both*	*Control*	*Sand*	*Control*	*Sign.*
Sand Specialists	12	3	-	4.1	0.7	***
Sand Favoured	13	9	3	5.3	2.0	***
Other Bees and Wasps	15	17	18	7.0	4.7	**

For both Sand Specialists and Sand Favoured, average abundance per plot was significantly higher in sand than controls, while species with no sand affinity as a group were equally common in both treatments (Fig. 26).

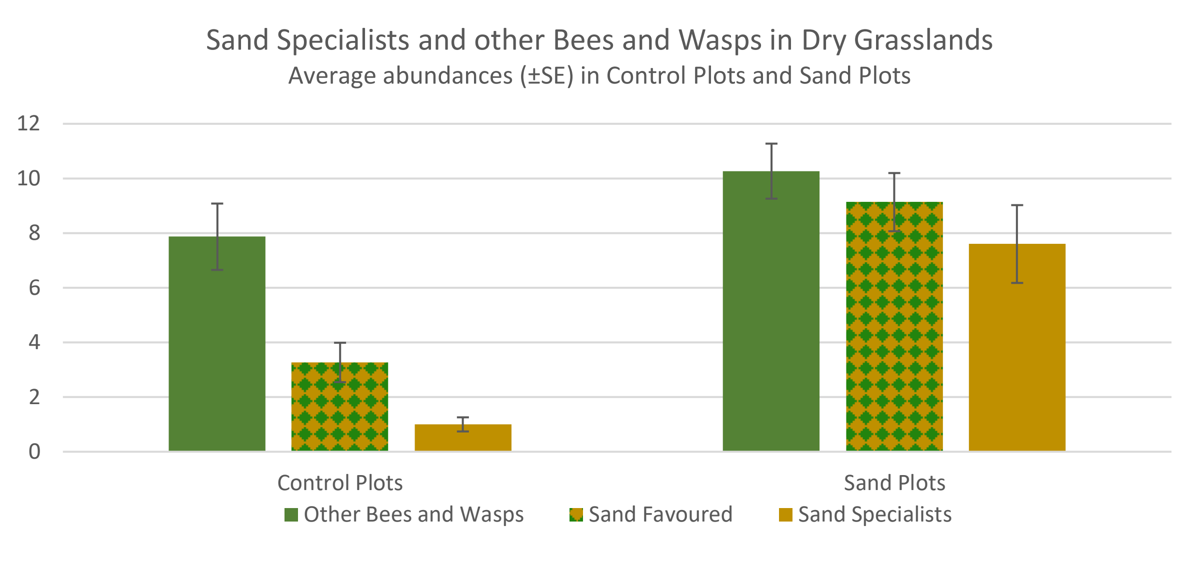


Figure 26. Comparing species composition by sand affinity in control and sand plots. From left to right average abundances (±SE) per plot of Other Bees and Wasps (NS), Sand Favoured (sand>control, ***) and Sand Specialists (sand>control, ***).

Out of the 15 Sand Specialist species recorded in the survey, 14 were more abundant in sand than controls, and the same pattern was seen in the number of sand and control plots each species was found in (Fig. 27).

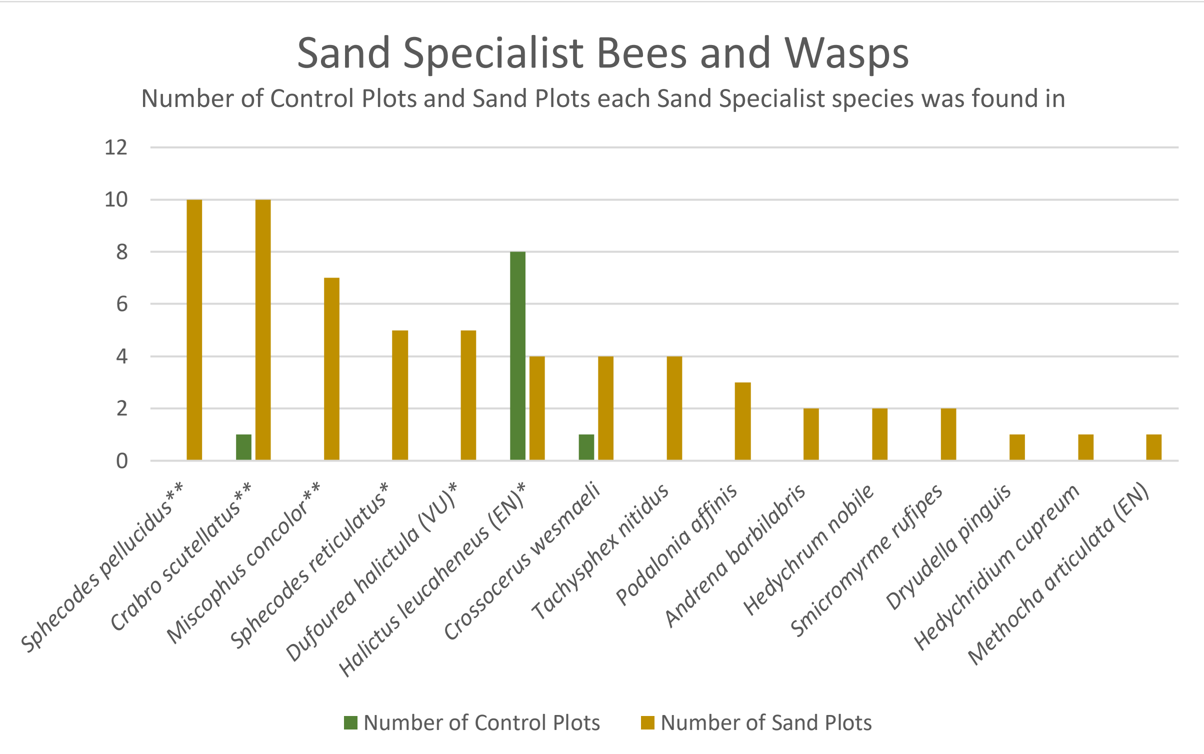


Figure 27. For each Sand Specialist species found in the survey, number (out of 15) of Control Plots and Sand Plots it was found in. Species with significant differences between treatments in average abundances per plot (all except *Halictus leucaheneus* with sand>control) marked with ** or * according to the level of significance.

Nest Building Demands of Bees and Wasps in Dry Grasslands

Turning to Nest Building Demands, average abundance per plot was significantly higher in sand than control for Barren Sand, Veg Sand and Arid Ground species (Fig. 28). Comparing species richness by treatment, 9 out of 11 Barren Sand species and more than half of Veg Sand and Arid Ground species were confined to sand, but on the contrary, five out of six Plant Material species occurred only in controls (Table 13). Species richness per plot was significantly higher in sand than control for Barren Sand (***), Veg Sand (***) and Arid Ground (***) species.

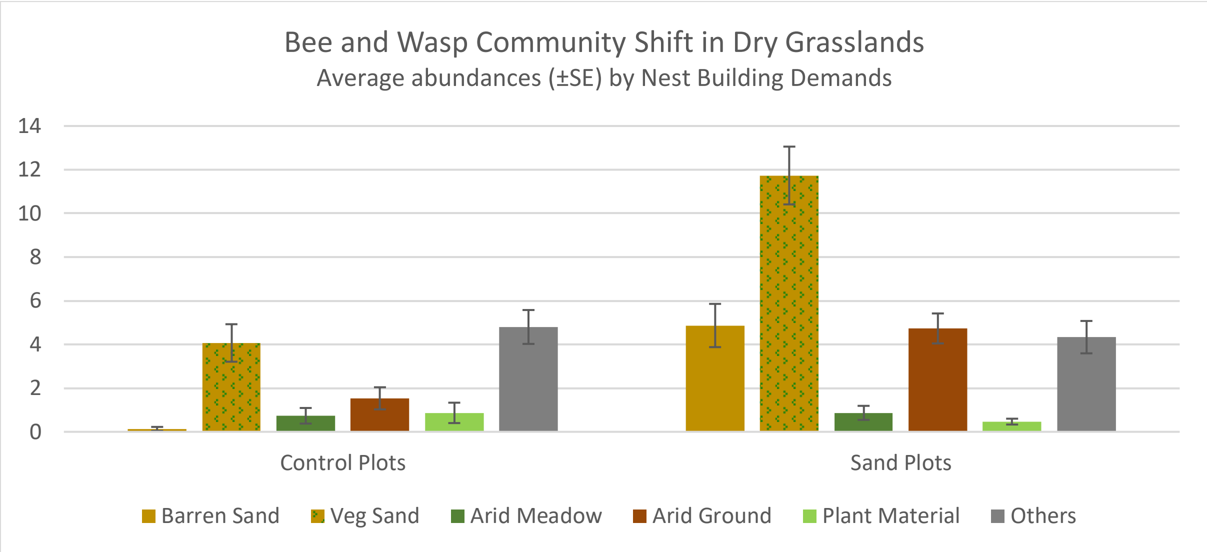


Figure 28. Comparing Bee and Wasp communities divided by Nest Building Demands in control plots and sand plots. From left to right average abundances (±SE) per plot of bees and wasps classified as Barren Sand species, Veg Sand species, Arid Meadow species, Arid Ground species, Plant Material species and Others. Significant differences between treatments (sand>control) for Barren Sand (***), Veg Sand (***) and Arid Ground (**).

Table 13. For each Nest Building Demand class, number of species confined to sand plots, found in both treatments and confined to control plots. Also, for each class, its relative contribution to total species richness and proportion of all specimens recorded in the survey.

	Sand	*Both*	*Control*	***Species***	***Specimens***
Barren Sand	9	2	-	12%	13%
Veg Sand	16	9	3	31%	40%
Arid Meadow	1	4	-	6%	4%
Arid Ground	9	6	2	19%	16%
Plant Material	-	1	5	7%	3%
Others	5	7	11	26%	23%

Flower-visiting, predatory and parasitic Bees and Wasps in Dry Grasslands

Both predatory and parasitic bees and wasps were more than five times more common in sand, while flower visitors had a slightly higher abundance in controls (Fig. 29). Almost half of predatory and more than half of parasitic species were confined to sand plots. Despite very low overall abundances for these functional groups in controls, many of the predatory and parasitic bee or wasp species were recorded only in controls and not sand (Table 14), but mean species richness per plot was nevertheless significantly (***) higher in sand for both groups.

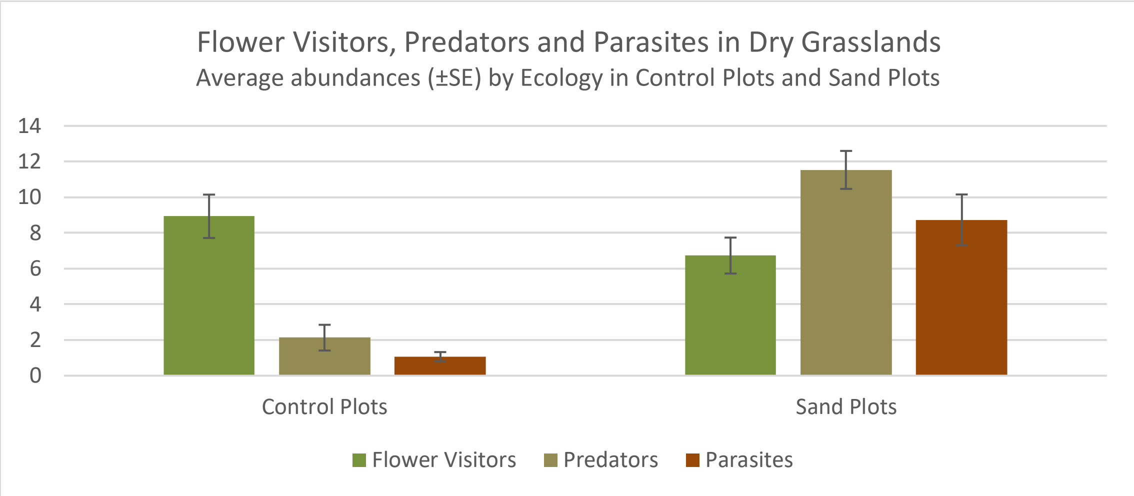


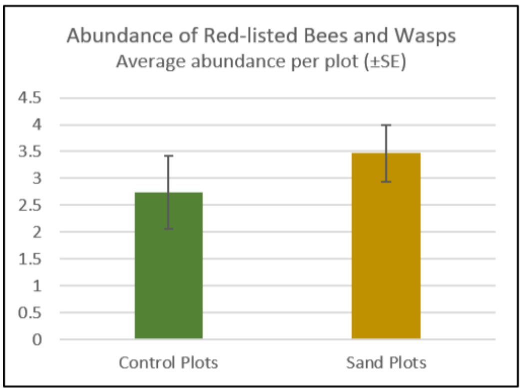
Figure 29. Comparing mean abundances of Flower Visitors (NS), Predators (sand>control, ***) and Parasites (sand>control, ***) in control and sand plots.

Table 14. For each functional group, number of species confined to sand plots, found in both treatments and confined to control plots.

	Sand	*Both*	*Control*
Flower Visitors	11	15	12
Predators	12	9	4
Parasites	17	5	5

Red-listed Bees and Wasps in Dry Grasslands

Red-listed bees and wasps were equally abundant in both treatments (Fig. 30), but mean species richness per plot (Fig. 31) was higher in sand, as well as total species richness per treatment: 12 red-listed species were recorded in sand plots compared to 8 in controls, amounting to 7 red-listed species confined to sand, 3 to controls and 5 found in both treatments.



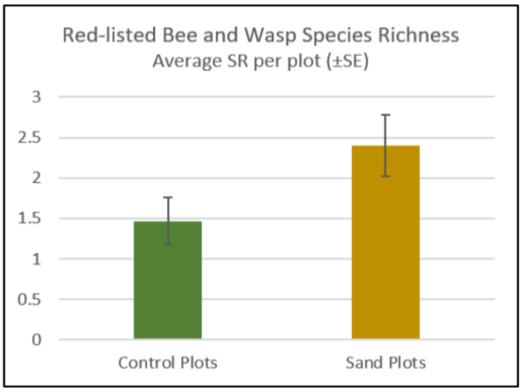


Figure 30-31. Average abundance (NS) and species richness ($p<0.05$) per plot (±SE) of Red-listed Bees and Wasps in both treatments.

Bees and Wasps in Dry Grasslands – results by Taxonomy

Highlighting treatment effects by taxonomic groups, abundance was higher in sand for all groups except Flower Visiting Bees (Fig. 32), and mean species richness was higher in sand for all groups.

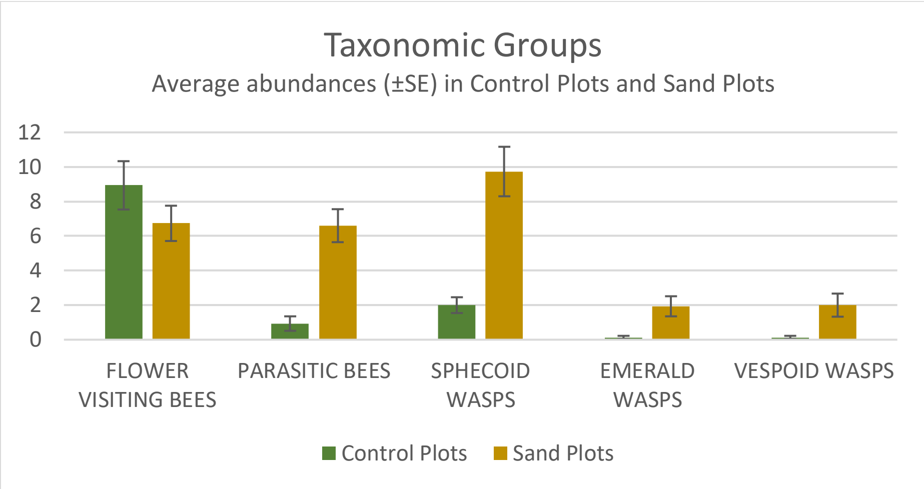


Figure 32. Average abundances by taxonomic groups, with bees split by ecology.

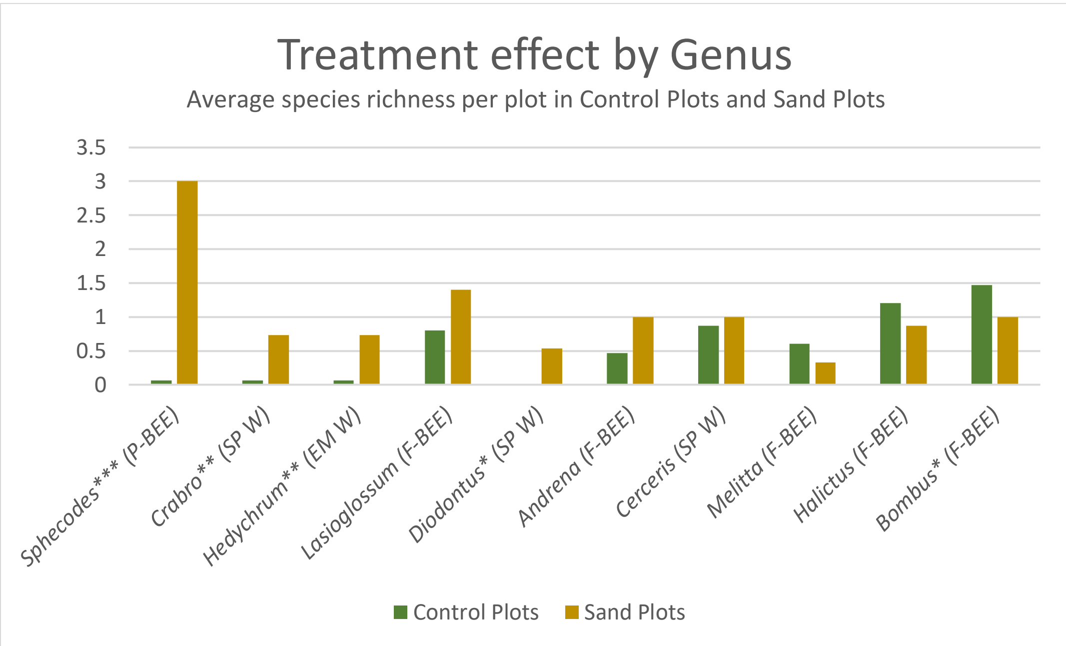


Figure 33. Average species richness per genus in control and sand plots for the ten most abundant genera in the survey. In parentheses, taxonomic and ecological group with F-BEE = Flower Visiting Bees, P-BEE = Parasitic Bees, SP W = Sphecoid Wasps and EM W = Emerald Wasps; none of the ten most abundant genera were Vespoid Wasps. Note that in the genus *Bombus* with both flower visiting and parasitic species, those have been treated separately, with only flower visitors represented in this chart. Genera with significant differences between treatments in mean abundance per plot (all except *Bombus* with sand>control) are marked with ***, ** or * according to the level of significance.

The genus with highest difference between treatments in both average abundance and mean species richness per plot was the genus of parasitic bees *Sphecodes* (blood bees), followed by the sphecoid wasp genus *Crabro* and the emerald wasp genus *Hedychrum*. Listing significant differences, of the ten most abundant genera in the survey, both parasitic and two out of three predatory were more common in sand, while one of the five flower visiting bee genera had a higher average abundance in controls (Fig. 33).

Results Bees and Wasps in Calcareous Grasslands

Bees and wasps in dunes were surveyed using both before/after and control/action surveys. As mentioned, the before/after survey generally captures the effect of large-scale actions such as clearing of heather or prescribed burnings, while the common setup control/action survey in this habitat exposes the effect of creating sand plots.

Overall abundances and Species richness

In the before/after survey, a total, 687 bees and wasps of 34 species were recorded, with five red-listed species. The capture frequency was more than ten times higher than in the corresponding survey in dunes (250 bees and wasps recorded per kilometre in grasslands compared to only 22 in dunes). The average number of collected bees and wasps per transect was higher before than after implementation of the actions: 56.0 compared to 42.1, but both overall species richness (23 compared to 22) and mean species richness per transect (6.6 compared to 6.3) were slightly higher after. Red-listed species increased both in total and relative abundance (from 3.1% of all recorded bees and wasps before to 5.4% after actions were implemented), as well as in total and mean species richness (3 red-listed species were collected with a mean of 0.7 such species per transect before compared to a total of 4 and a mean of 1.1 after).

In the control/action survey, a total, 152 bees and wasps of 42 species were found, with 6 red-listed species. The average number of bees and wasps per plot was higher in sand (23.2 compared to 7.2 in controls, *) and the same pattern was seen in mean species richness per plot (12.2 in sand compared to 5.2 in controls, **) and in total species richness: 33 species were recorded in sand plots compared to 17 in controls, amounting to 25 species confined to sand, 9 to controls and 8 species found in both treatments. A total of 13 red-listed bees and wasps of six species were recorded in the survey, and of those four were more common in sand and the other two in controls. One recorded species - *Pterocheilus phaleratus* – was listed as Endangered (EN) and this species was found in two sand plots and one control plot.

Sand Affinity of Bees and Wasps in Calcareous Grasslands

In the before/after survey, sand specialists almost doubled their relative abundance from 2.8% to 4.7% of all collected bees and wasps. Sand Favoured species, however, decreased drastically from 15.6% to 3.4%. However, more than the full difference is explained by the caught of a single species (the mining bee *Dasypoda hirtipes*), and almost at a single grid (Åby Sandbackar at Öland). Instead looking at observations per species, 3 out of 4 Sand Specialist species and 4 out of 6 Sand Favoured species increased with the accomplishment of actions. And looking at the geographical distribution of observations, after actions Sand Affinity (Sand Specialists and Sand Favoured) species were recorded at all five sites (and at all seven grids), compared to only two sites (the two Öland sites) before.

In the control/action survey, a total of 42 Sand Specialist bees and wasps of 12 species and a total of 36 Sand Favoured specimens of 10 species, were recorded in the survey. Ten out of 12 Sand Specialist species were confined to sand and the other two occurred in both treatments but no Sand Specialist species was found only in controls (Table 14). The average number of Sand Specialist species per plot was seven times higher in sand than controls (Table 14).

Table 14. For each species group, number of species confined to sand plots, found in both treatments and confined to control plots and mean species richness in sand and control plots, significance of the difference between treatments.

	Number of species			*Species richness*		
	Sand	*Both*	*Control*	*Sand*	*Control*	*Sign.*
Sand Specialists	10	2	-	4.2	0.6	*
Sand Favoured	5	1	4	2.4	1.6	NS
Other Bees and Wasps	10	5	5	5.6	3.0	NS

The average number of Sand Specialist specimens was almost ten times higher in sand than control plots, even though this result was slightly non-significant (Fig. 34).

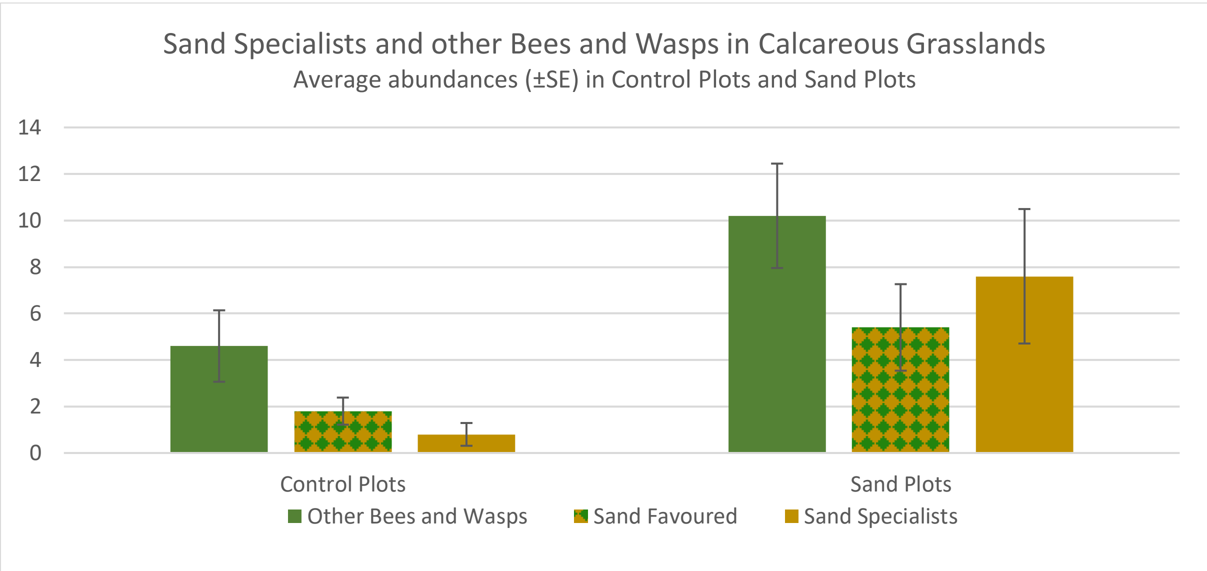


Figure 34. Comparing species composition by sand affinity in control and sand plots. From left to right average abundances (±SE) per plot of Other Bees and Wasps, Sand Favoured and Sand Specialists.

All 12 Sand Specialist species recorded in the survey were more abundant in sand than controls, and a similar pattern was seen in the number of sand and control plots each species was found in (Fig. 35).

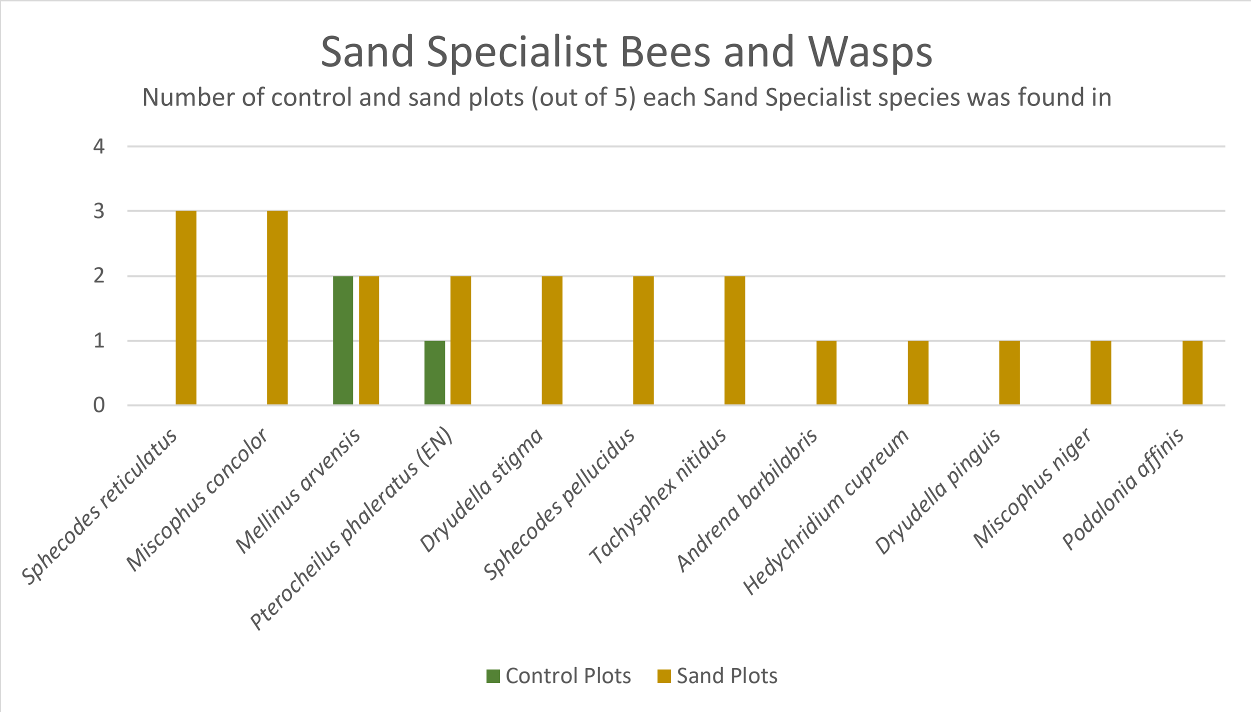


Figure 35. For each Sand Specialist species found in the survey, number (out of 5) of control and sand plots it was found in.

Nest Building Demands of Bees and Wasps in Calcareous Grasslands

Turning to Nest Building Demands, in the control/action survey, average abundance per plot was more than five times higher in sand than control for Barren Sand, Veg Sand and Arid Ground species, while Arid Meadow and Plant Material bees and wasps were more abundant in controls (Fig. 36). Comparing species richness by treatment, 7 out of 9 Barren Sand species and more than half of Veg Sand and Arid Ground species were confined to sand, but on the contrary, two out of three Plant Material species occurred only in controls (Table 15). The average number of Barren Sand species per plot was five times higher in sand than controls.

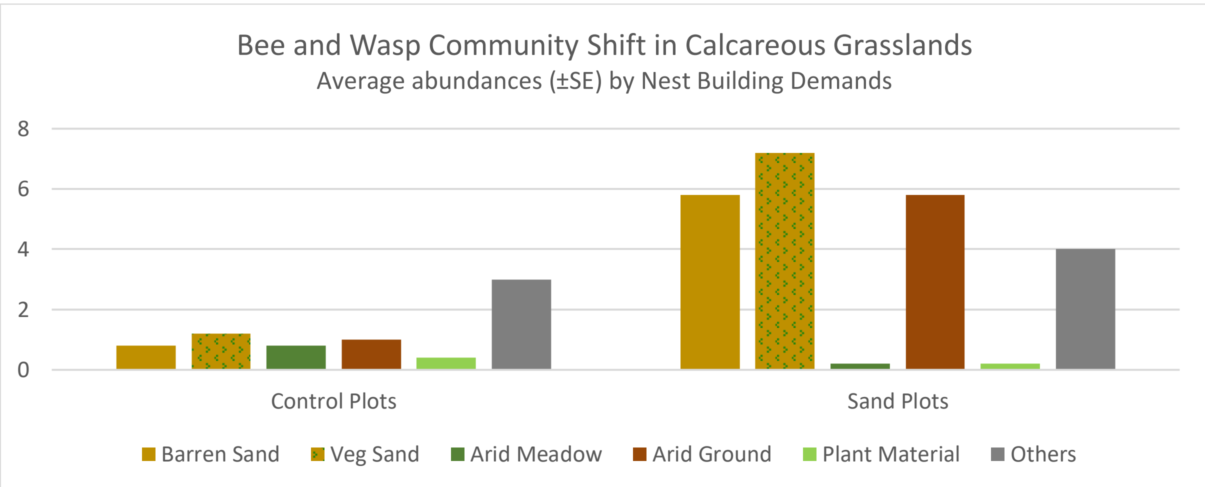


Figure 36. Comparing Bee and Wasp communities divided by Nest Building Demands in control plots and sand plots. From left to right average abundances per plot of bees and wasps classified as Barren

Sand species, Veg Sand species, Arid Meadow species, Arid Ground species, Plant Material species and Others.

Table 15. For each Nest Building Demand class, number of species confined to sand plots, found in both treatments and confined to control plots. Also, for each class, its relative contribution to total species richness and proportion of all specimens recorded in the survey.

	Sand	*Both*	*Control*	***Species***	***Specimens***
Barren Sand	7	2	-	21%	22%
Veg Sand	8	1	3	29%	28%
Arid Meadow	1	-	2	7%	3%
Arid Ground	5	1	-	14%	22%
Plant Material	1	-	2	7%	2%
Others	3	4	2	21%	23%

Flower-visiting, predatory and parasitic Bees and Wasps in Calcareous Grasslands

In terms of functional groups, in the before/after survey, predators almost tripled their relative abundance from 5.6% to 14.9% of all recorded species, and the share of parasites was more than six times higher after than before (increase from 0.5% to 3.4%). Consequently, flower visitors dropped from 93.9% to 81.7% (Figure 37). Despite this drop in relative abundance, corresponding to a decrease with more than a third in absolute numbers for flower visitors, mean species richness per transect for this group decreased only slightly from 4.7 to 4.3.

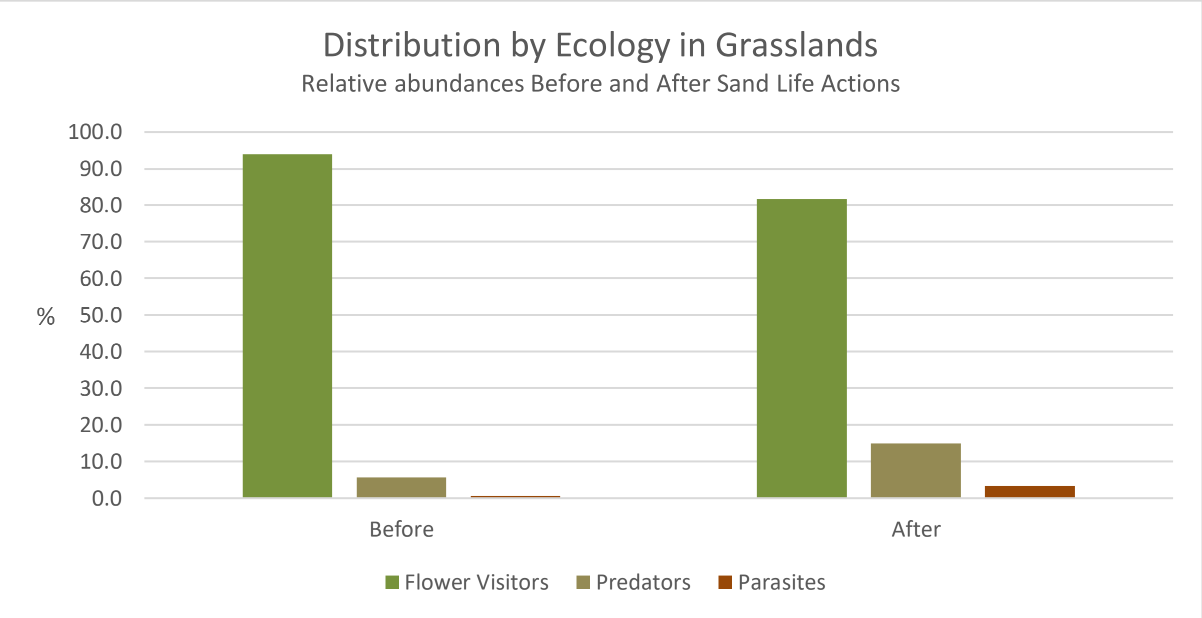


Figure 37. Abundances of Flower Visitors, Predators and Parasites as percentages of total abundance before and after implementation of Sand Life Actions.

In the control/action survey, both predatory and parasitic bees and wasps were more than ten times more common in sand than controls, mean species richness per plot was significantly (*) higher in sand for both groups and 17 out of 21 predatory or parasitic species were confined to sand. In contrast, Flower Visitors were equally split between treatments, both in numbers and species richness (Fig. 38 and Table 16).

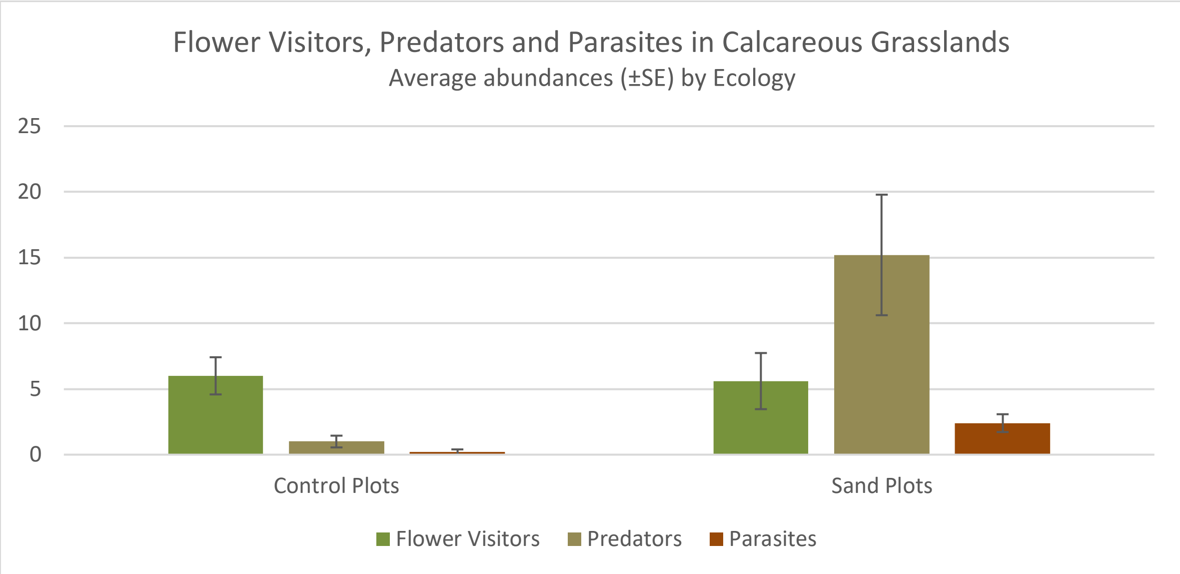


Figure 38. Comparing mean abundances of Flower Visitors (NS), Predators (sand>control, *) and Parasites (sand>control, *) in control and sand plots.

Table 16. For each functional group, number of species confined to sand plots, found in both treatments and confined to control plots.

	Sand	*Both*	*Control*
Flower Visitors	8	5	8
Predators	11	3	-
Parasites	6	-	1

Bees and Wasps in Calcareous Grasslands – results by Taxonomy

In the before/after survey, the two genera with the highest increase in species richness were bumble bees *Bombus* (from 8 species before to 11 after) and mining bees *Andrena* (no species before and two after), but the single species most distinctly favoured by actions was *Philantus triangulum*. In the control/action survey, the genus with highest difference between treatments in mean species richness per plot was the genus of parasitic bees *Sphecodes* (blood bees), followed by the sphecoid wasp genus *Philantus*, and both these differences were significant (Figure 39).

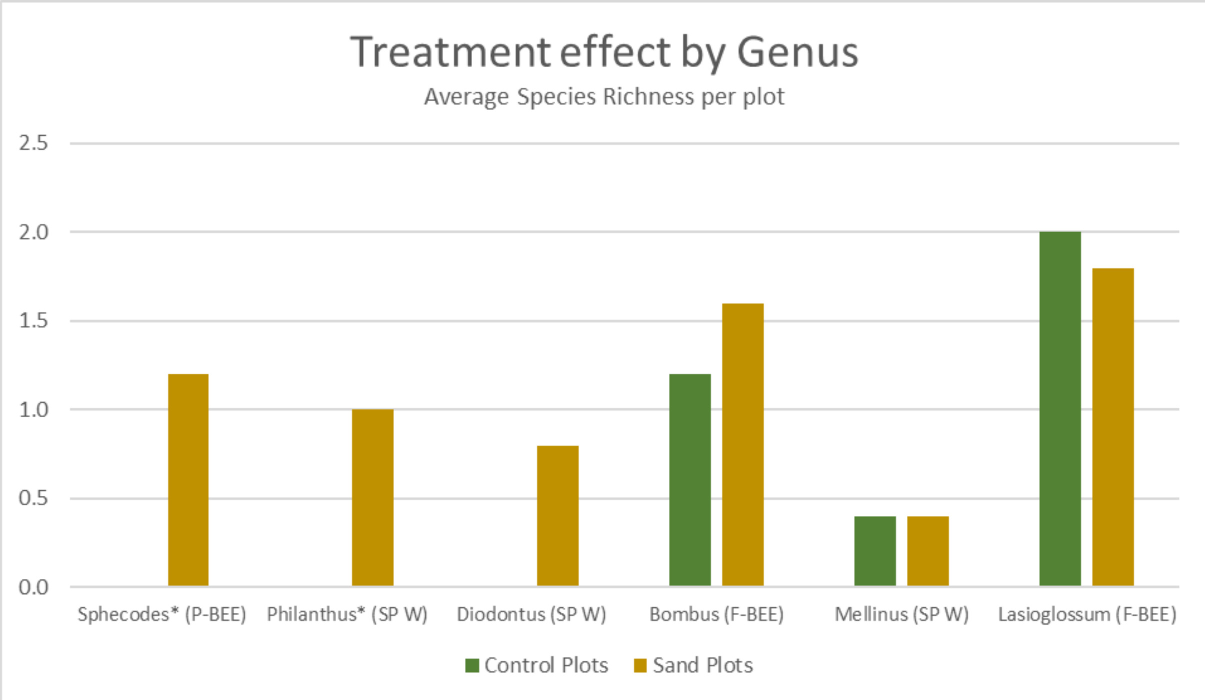


Figure 39. Average species richness per genus in control and sand plots for the six most abundant genera in the survey. In parentheses, taxonomic and ecological group with F-BEE = Flower Visiting Bees, P-BEE = Parasitic Bees and SP W = Sphecoid Wasps; none of the six most abundant genera were Emerald Wasps or Vespoid Wasps. Note that in the genus *Bombus* with both flower visiting and parasitic species, none of the latter were recorded in this survey, justifying the chart label. Genera with significant differences between treatments in mean abundance per plot (both these with sand>control) are marked with *.

As for major taxonomic groups, in the control/action survey, both abundance and mean species richness was higher in sand for all groups except Flower Visiting Bees (Fig. 40).

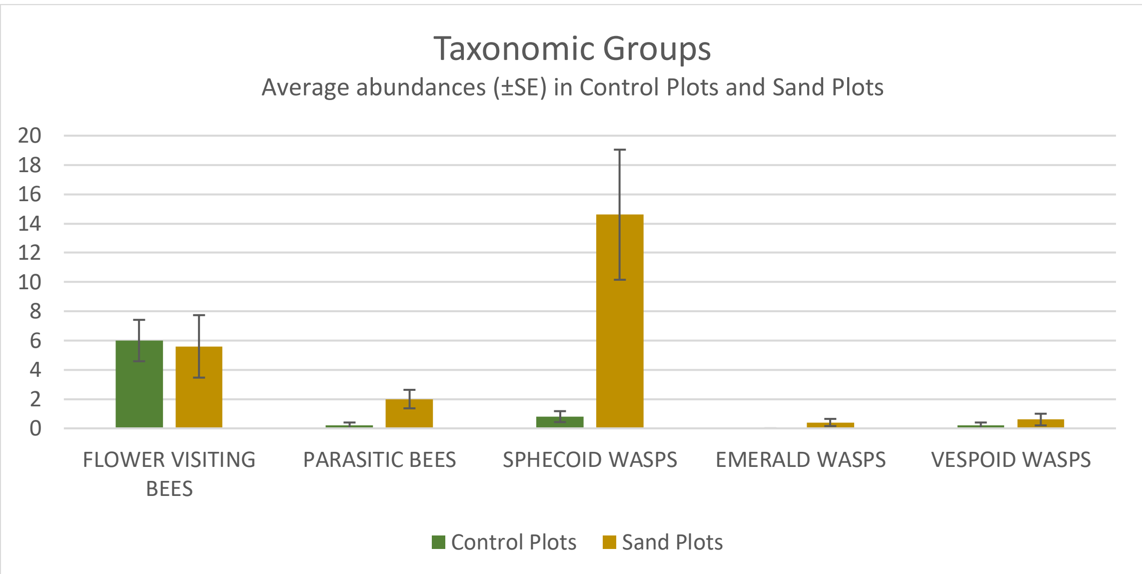


Figure 40. Average abundances by taxonomic groups, with bees split by ecology.

Discussion Bees and Wasps

Sand specialist bees and wasps were distinctly favoured in all habitats and in all survey types, both in the before/after monitoring and in the control/action surveys, and the results are consistent throughout families. In grasslands, the newly created patches of barren sand have clearly favoured species with a high sand affinity, and in dunes, this group has benefitted from the open landscape resulting from mountain pine clearings, although the species are not always the same. Interestingly, as in beetles, arid meadow species with no sand affinity as a group is essentially unaffected, again pointing out the specificity of the actions.

Moreover, actions led to an overall increase in both species richness and the number of red-listed species. In dunes, while the proportion of sand specialists increased in all parts, the distribution shifted inland to intermediate and inner dunes where most actions were carried out.

In sand plots, predators and parasites were the most distinctly favoured groups and this pattern was consistent throughout genera, with not only wasps but also parasitic bees favoured, while in mountain pine clearings, the highest increase in abundance was seen in flower visitors. Presumably, this is a combined effect of the original environment in the surveyed area and the type of action carried out. Grassland surveys focused on sand plots created in an area already relatively rich in pollen and nectar sources, and hence the added value of good nesting grounds in the sand will be the main determinant of the effect on the community structure. Many bee and wasp species take advantage of the coarse structure of the warm, well-drained and easily accessible sand in the plots to build larval chambers, but predators and parasites benefit even more since they also use the open areas of exposed sand as hunting grounds. In dunes however, large-scale clearings of mountain pine and other exotic trees dominated, and the introduction of nectar and pollen sources to a previously forest dominated tract naturally attracts flower visitors.

At the taxonomic level, in line with project aims, among the most favoured were bee genera with many sand specialist species, such as *Andrena*, *Colletes*, *Lasioglossum* and *Sphecodes*. Interestingly, in sand plots, the genus with the most distinct gain was blood bees *Sphecodes*, which are predators of four other surveyed bee genera, and in grasslands, the European beewolf *Philanthus triangulum* increased significantly in both survey types, illustrating parts of the foodweb in being with higher trophic levels benefitting from the increased abundance and species richness of flower visitors.

Sand plots as well as mountain pine clearings and areas with prescribed burnings or other restoration measures are still in early succession. At this stage, the actions have not only distinctly favoured sand specialists but also promoted an overall richer bee and wasp fauna. With time this mosaic with virgin patches of barren sand and later more vegetated stages is expected to develop further and continue to meet demands for both nectar and pollen sources as well as suitable nesting grounds. Some patches in a degenerated stage could be beneficial, but eventually some disturbance is required. As today many bees and wasps specialized on sandy habitats are threatened by overgrowth due to lack of grazing or mowing, abandonment of convertible husbandry, exploitation, afforestation, pit restoration and atmospheric deposition of nitrogen, the need for a continued active management of sandy habitats, with substantial efforts to ensure a sustained continuous access to areas of bare sand for bee and wasp species with this need, is clear

Philanthus triangulum, a predatory wasp.

Beetles

Introduction

Many of the ground beetles are related to early succession stages of the habitat and may quickly respond to changes in habitat quality in sandy soils, which make this an important group for quantitative monitoring after restoration actions to determine restoration success.

Beetles (Coleoptera) is globally the most numerous organism order with almost half a million named species and in Sweden we have over 4,000 species, thriving in many different environments from wood to water. Sand specialist species are found among *Harpalus*, *Amara* and other ground beetle genera, among true weevils, darkling beetles and in other beetle families. The sandy habitats are preferred for various reasons: phytophagous larvae confined to sand specialist plants, as hunting ground for ground beetles and other very mobile species, because of the high temperature and good drainage of the sand, as an easily-dug day refuge for nocturnal beetles or simply because of competitive release due to lack of sand life adaptions in competing species.

Many endangered beetles are associated with the early successional stages after soil disturbance, and some of them directly with the occurrence of patches of bare soil and sand (Cizek et al. 2012; Ödman et al. 2011). Tiger beetles are indicator species in dunes and sandy grassland because of their preference for disturbed habitats and bare sand, and the fact that they are threatened by vegetation encroachment (Knisley 2011). A good example of this is the tiger beetle *Cicindela hybrida*, which persists on military fields in Germany (Warren and Büttner 2008).

Within Sand Life, the monitoring of ground living beetles is important since it is recognised that many of these species are red-listed. At the same time, they may prove to be important initial indicators of restoration success in sandy grasslands, especially since the ground beetles might respond rapidly to changes (Perner and Malt 2003).

The aim of the surveys during 2013 was to establish grid systems in dune areas where restoration actions will be implemented during the project. In Sand Life, we created sand plots in Calcareous Grasslands to attract beetles with a preference for sandy habitats. With time, vegetation will grow into the sand plots to create a more complex habitat but remaining patches of bare sand will still attract many beetle species.

To assess the importance of access to bare sand for beetles, we performed a comparison between sand and control plots using pit traps. This study aims at mimicking the conditions before and after actions were implemented but without the complications of varying weather conditions.

Method details specific to Beetles

Before/after

Three dune grids (Gropahålet and both grids in Laholmsbuktens sanddynsreservat) were surveyed both before (2013) and after (2017) implementation of Sand Life restoration actions. At each visit, 10 pitfall traps were placed along each segment, for a total of 40 traps per transect, or 120 traps per grid. All traps were collected one week later, and trapped beetles were identified and counted.

Control/action

20 of the common setup sand plots (15 in dry grasslands and 5 in calcareous grasslands) with controls were surveyed for beetles. At the end of June 2017, five pitfall traps were placed along the edge of each plot, all traps were collected five days later and all trapped beetles were identified and counted.

Species classification

Classification of Sand Specialist beetles was implemented without knowledge of the results by entomologist Christoffer Fägerström at Lund University.

Results Beetles in Dunes

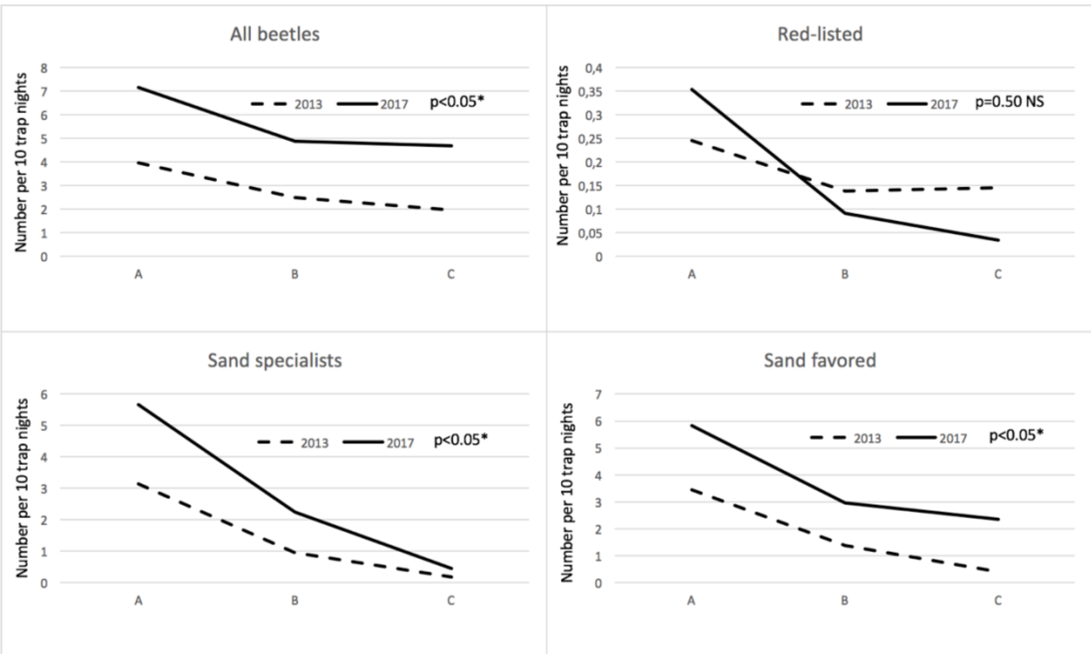


Figure 41. Total abundance, number of red-listed beetles, sand specialist beetles and sand favoured beetles per transect type in dune grids (values per 10 trap nights). A is the outer dunes, B intermediate and C is the innermost dunes. Mountain pine was removed from all three zones, but between the two visits of this monitoring (2013 and 2017) more from zone B and C. Differences between years were tested with paired t-test (n=9).

In total, the number of trapped beetles increased markedly between 2013 and 2017 in all three zones, but most markedly in the inner dunes where number of trapped beetles increased with more than 100% (Fig. 41). The number of red-listed beetle species was rather low, and it increased in the outer dunes, but decreased in the inner dunes. However, none of these results were significant. The decrease in the inner dune was totally dependent on one species (*Carabus convexus*) in one grid (the northern grid of Laholmsbuktens sanddynsreservat). This is a species that thrives in forest.

The sand specialists also increased, but the numbers were still low after the restoration. The proportion of sand favoured, however, increased markedly in inner dunes, where most of the restoration was performed. The increase in sand favoured species was less pronounced in the outer dunes.

Results Beetles in Dry Grasslands

In total, 1295 beetles of 97 species were found in the survey, with eight red-listed species. The number of beetles was almost equally split between sand and control plots, but total species richness was higher in sand plots (78 compared to 66).

Average abundance of sand specialist beetles was significantly higher in sand plots than in control plots in the surrounding grassland, but in contrast, arid meadow beetles not dependent on access to sandy habitats were equally common in both treatments (Fig. 44). A total of 17 sand specialist beetle species from 5 different families were found in the survey, all had a higher total abundance in sand plots than in control plots, and 14 out of 17 were found in more sand plots than control plots (Fig. 44).

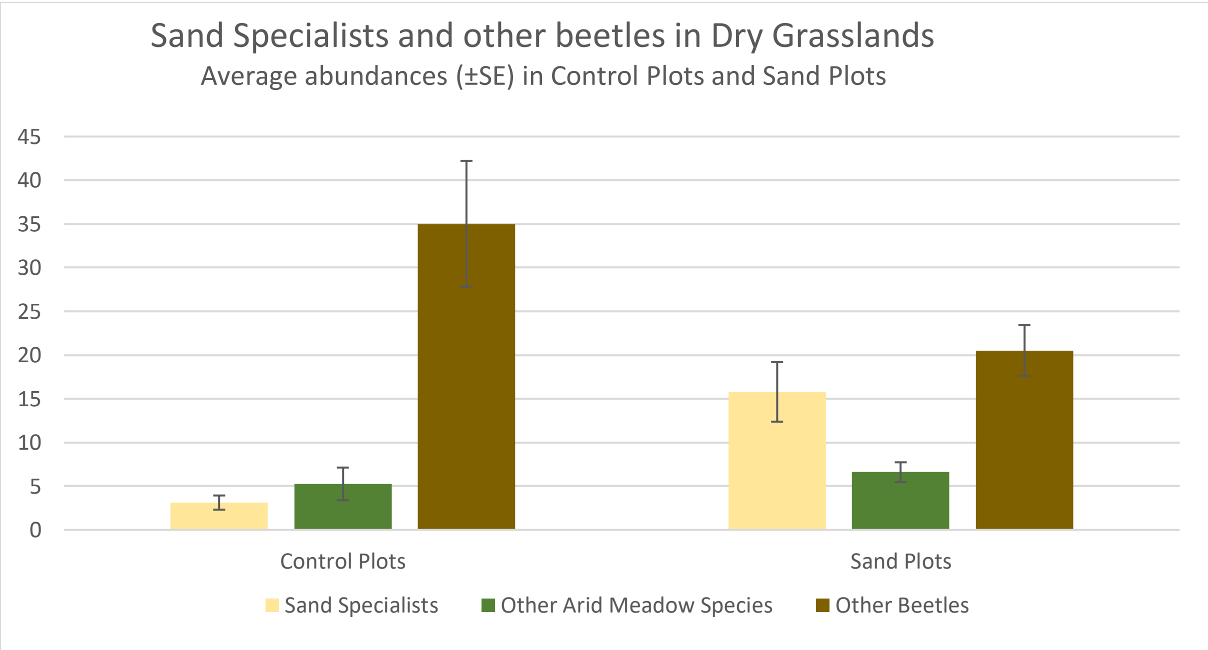


Figure 44. Comparing species composition in Control Plots and Sand Plots. From left to right average abundances (±SE) per plot of Sand Specialists (sand > control, **), Other Arid Meadow Species (NS) and Other Beetles (control>sand, *).

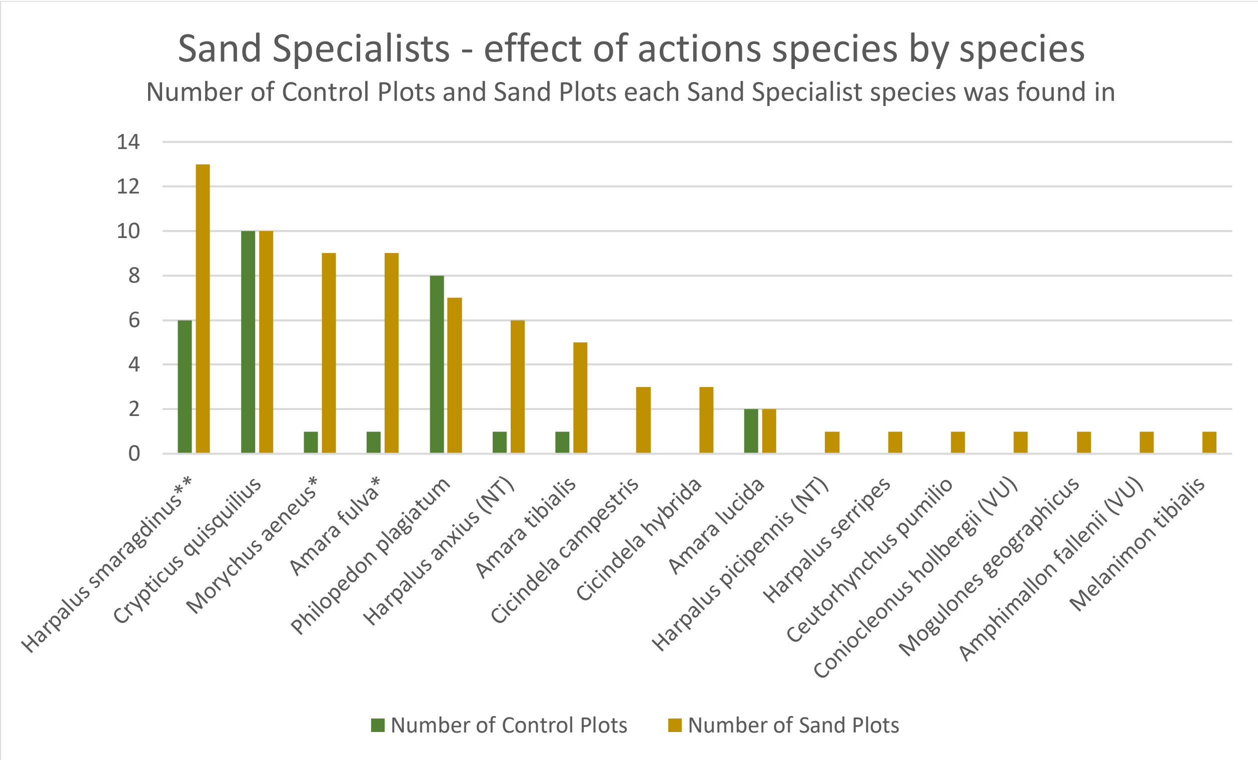


Figure 45. For each Sand Specialist species found in the survey, number (out of 15) of Control Plots and Sand Plots it was found in. Species with significant differences between treatments (all with sand>control) in average abundances per plot marked with * (for p<0.05) or ** (for p<0.01).

Sand plots harboured 31 red-listed beetles of 7 species, all of which were more common in sand plots than control plots, with 6 of these confined to sand, including the three beetle species recorded in the survey listed as vulnerable (VU). All four red-listed sand specialist species recorded in the survey were found in sand plots with a total of 24 beetles compared to a single beetle in control plots. Of the other four red-listed species, three were found in sand plots with a total of 7 beetles compared to a single beetle in control plots. Thus, in total control plots harboured only two red-listed beetle species, each with one observed beetle. Average abundance and species richness of red-listed beetles per plot was significantly higher in sand plots than in control plots (Fig. 46).

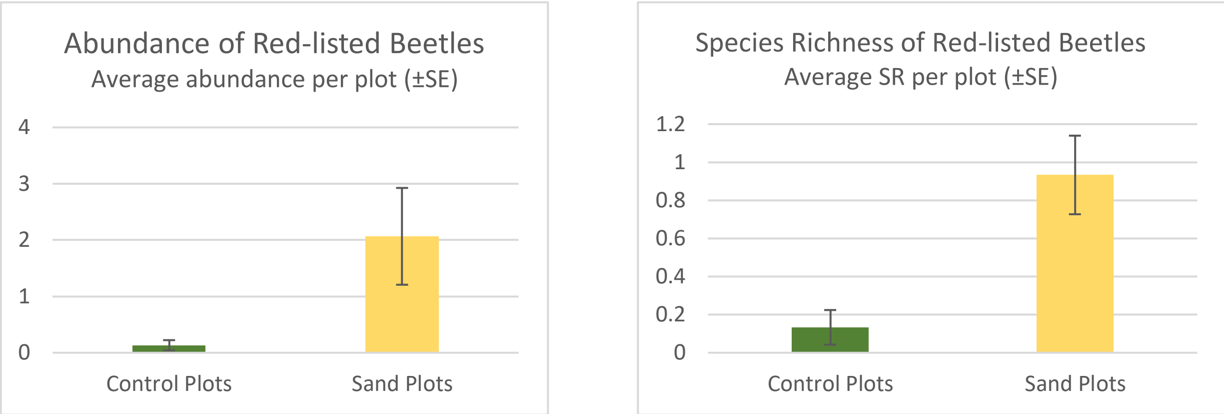


Fig 46. (a) Average abundance (±SE) of red-listed beetles in control and sand plots (sand>control, *). (b) Average Species Richness (±SE) of red-listed beetles in control and sand plots (sand>control, **).

Results Beetles in Calcareous Grasslands

In total, 60 beetles (for an average of 0.24 beetles per trap and night) of 24 species were found in the survey, with two red-listed species. The number of beetles was higher in control plots (36 compared to 24) but total species richness was higher in sand plots (16 compared to 12).

A total of 9 sand specialist beetles of 6 species from four different families were recorded in the survey. Of these, 5 species with a total of 8 beetles were confined to sand plots, compared to a single sand specialist beetle found in control plots (Figure 1 and 2). In contrast, other arid meadow species were equally common in both treatments and for other beetles (neither sand specialists nor arid meadow species), numbers were more than twice as high in controls as in sand (35 beetles compared to 16) and looking at mean values per plot this difference was significant (Fig. 42).

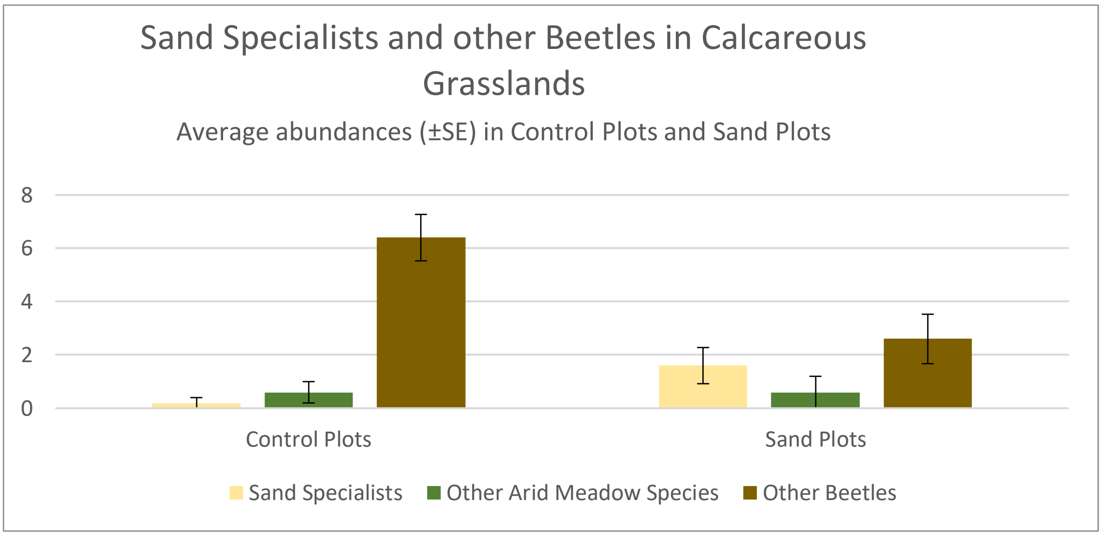


Figure 42. Comparing species composition in Control Plots and Sand Plots. From left to right average abundances (±SE) per plot of Sand Specialists (sand>control, NS), Other Arid Meadow Species (sand=control) and Other Beetles (control>sand, *).

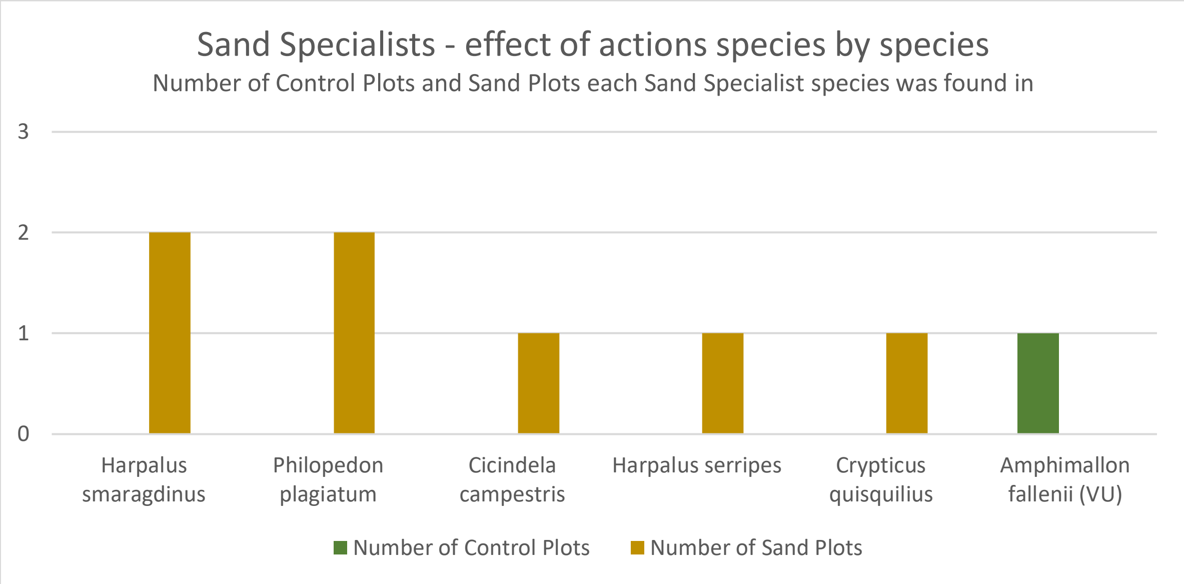


Figure 43. For each Sand Specialist species found in the survey, number (out of 5) of Control Plots and Sand Plots it was found in. As seen, all 6 species were confined to either treatment.

Only two red-listed species were found in the study (one listed as VU with one beetle and the other listed as NT with 8 beetles), both belonging to the family Scarabaeidae and both confined to control plots (Fig. 43). The beetle listed as VU was also a sand specialist, and thus the single such beetle found in control plots.

Discussion Beetles

In dunes, we expected the largest effects to occur in the inner parts of the dunes where the actions of pine removal were most drastic. However, results from the before/after monitoring shows that the actions affected all zones and it is promising to see such large numbers of beetles, including sand favoured species, at such an early stage after restorations. The number of red-listed species were still low and the focus of future monitoring should therefore be to reveal if red-listed species immigrate when the areas come to a later stage of the open dune succession.

In dry and calcareous grasslands, the control/action survey illustrates the effect of creating sand plots. Since the plots were created during the last few years, they are in early succession and the vegetation is still very sparse. Beetles highly specialized on the early successional stages of sandy habitats were clearly favoured by the actions, and the results were accordant across different beetle genera and families. Interestingly, arid meadow species with no sand affinity seemed to be essentially unaffected, pointing out the specificity of the actions.

Since half of the red-listed species recorded in the control/action survey were sand specialists, the higher number of threatened beetles in sand than controls was not surprising. Still, five red-listed sand specialist species with two of them listed as vulnerable is evidence that sand plots created in this project can serve as an important refuge even for some of the more susceptible sand specialist beetles. Moreover, the prosperity of rare sand specialists does not seem to be at the expense of other rare beetles, since numbers for these were also higher in sand than controls.

Comparing the two grassland habitat types, the average number of beetles per trap night was more than five times lower in calcareous grasslands than in dry grasslands. Thus, numbers from calcareous grasslands alone were often too low to obtain significant results, but some clear pattern could still be seen. First, the main outcomes with sand specialist distinctly favoured by the sand plots and an overall higher beetle diversity in plots than controls, were the same in both habitats. However, in dry grasslands total abundances were the same in sand and controls, but in calcareous grasslands more beetles were found in controls. Also, while six out of eight red-listed species in dry grasslands were confined to sand, both red-listed species in calcareous grasslands were confined to controls.

What are the most feasible explanations for this difference? Reports from the field worker indicate that the low number of collected beetles in calcareous grasslands could be due to cold and rainy weather during survey days. It seems likely that this could also explain the contrasting results with more beetles in sand plots in dry grasslands but the opposite pattern seen in calcareous grasslands, since sand plots are more sensitive to weathers than the less exposed microhabitat in the proper grassland. Heavy precipitation may force beetles to seek shelter in less exposed positions and so results from the two surveys together simply illustrate the shifting role played by sand and vegetation under different weather conditions and further stress the importance of a mosaic of habitat types not only to harbour a variety of beetle species, but even for single beetles to thrive, rain or shine.

In conclusion, the sand affinity of sand specialists and a higher overall species richness in sand plots than control plots are outcomes resisting weather shifts, whereas the bulk of beetles in more generalist species seems to favour different microhabitats depending on precipitation and/or temperature.

As for the future of these recently restored sandy habitats, each successional stage has its own specialists, so as open dunes reach later successional stages and vegetation colonizes sand plots, remaining patches of sand will continue to harbour the sand specialists initially favoured – including many ground beetles – while more vegetated areas will attract other types of beetles. However, with lack of ground disturbance – after a few decades – eventually the vegetation closes to an extent no longer suitable for sand specialists and thus repeated restorations actions are required prior to this.

As today many beetles specialized on sandy habitats are threatened by overgrowth due to lack of grazing or mowing, abandonment of convertible husbandry, exploitation, afforestation, pit restoration and atmospheric deposition of nitrogen, the need for a continued active management of sandy habitats, with substantial efforts to ensure a sustained continuous access to areas of bare sand for species with this need, is clear.

Butterflies

Introduction

Butterflies are among the most threatened insects in Europe today and many of the species populations have decreased rapidly and are now severely fragmented. There are several nationally threatened species and also one species in the Habitat Directive. The dependence of butterflies on both plant hosts and nectar sources make them particularly vulnerable, and some of the species, such as the Large Blue, also depend on symbioses with ants. The loss of specific habitats such as sandy grassland and a lack of nectar sources in the landscape have caused the decline of butterflies in the landscape. It may also already have caused extinction of many species (Dunn 2005).

Method details specific to Butterflies

Before/after

At each visit, every transect was walked slowly and all butterflies observed within two meters from the transect were recorded. In total, 11 grids in dunes and 4 grids in calcareous grasslands were surveyed both before (2013) and after (2017) implementation of Sand Life restoration actions. In addition, two routes in dune landscape were surveyed 2014 and 2017.

Control/action

Of the sand plots in the common setup, all in dry grasslands were surveyed once and all in calcareous grasslands were surveyed three times. At each visit, all butterflies observed in the plot/control during four minutes, were recorded.

Species classification

Species were classified without knowledge of the results according to sand affinity (Sand Specialist, Sand Favoured or Other) by Lars Pettersson and Marcus Franzén.

Results Butterflies

Before/after routes in dunes

The two routes surveyed in Böda showed higher butterfly abundance in 2017 compared to 2014 (Fig. 47). In Böda W, no actions had been performed in 2017 and the effect is thus due to between year variation. The increase in abundance was particularly high in Böda E, mainly due to an impressive occurrence of heath fritillary (*Melitaea athalia*) in the dunes where pines had been cleared and the vegetation partly had been subject to burning.

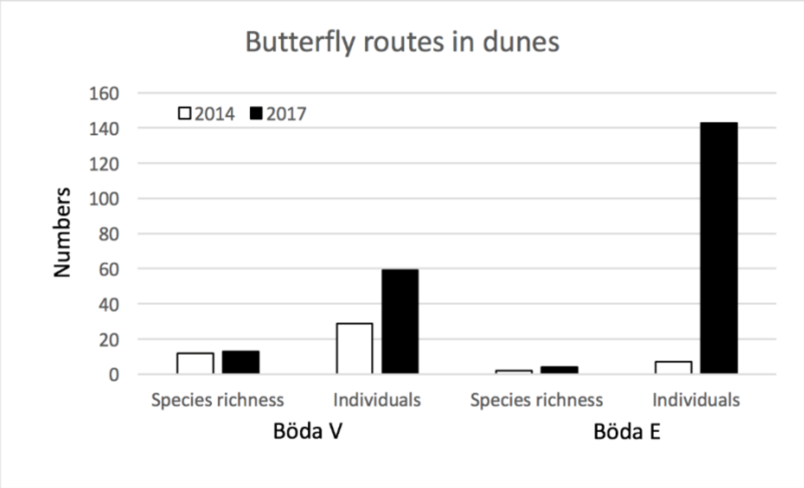


Figure 47. Number of butterflies in dune habitats in the areas Böda östra and Böda västra.

Before/after Grids

The survey of butterflies in grid systems were done in 2013 and 2017. Species richness was lower in both dunes and grassland in 2017 compared to 2013 (Table 17). The abundance in dunes was higher in 2017 compared to in 2013 before the actions, while the opposite was found for grasslands.

Table 17. Butterfly abundance and species richness before and after actions in dunes and grassland.

		2013	**2017**
Dunes	**Species richness**	**17**	**13**
	Abundance	**111**	**157**
Grassland	**Species richness**	**13**	**11**
	Abundance	**106**	**27**

The increase in butterfly abundance in dunes (Fig. 48) was mainly because of large numbers om heath fritillary (*Melitaea athalia*) flying in the dunes. Their abundance was high both in outer dunes where burning had favoured nectar sources and in the inner dunes where pines had been cleared.

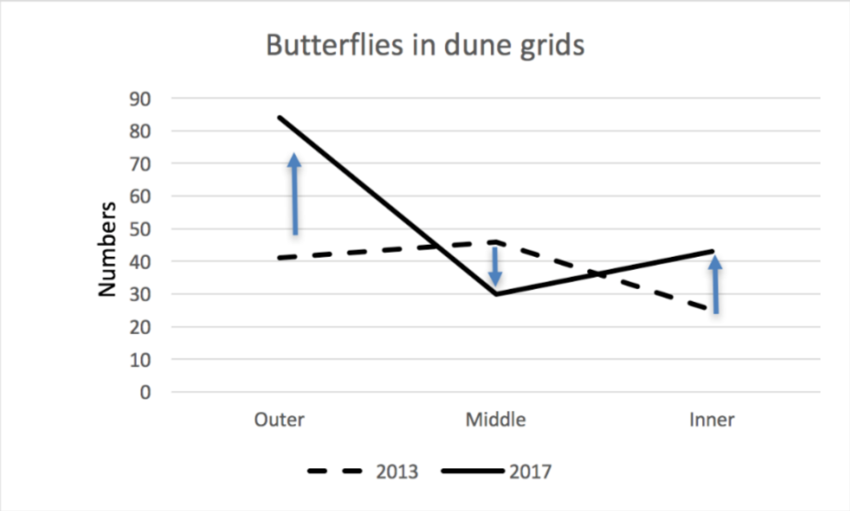


Figure 48. Butterfly abundance in the three sections of the grid systems in dunes.

Control/action

The control/action analysis showed higher abundance and species richness in sand plots compared to control plots. In dry grassland, however, the abundance and richness was higher in control plots (Table 19).

Table 18. Butterfly abundance and species richness in control/action plots in different habitat types.

		Controls	Sand plots
Dunes	Species richness	0.60	1.0
	Abundance	0.80	1.8
Calcareous grassland	Species richness	2.2	3.2
	Abundance	3.6	4.2
Dry grassland	Species richness	3.1	2.5
	Abundance	5.7	3.9

When dividing the butterflies up in three categories: sand specialists, sand favoured and others, it turned out that in calcareous grassland it was the sand specialists and favoured that increase the most, while in dry grassland no such pattern could be seen (Fig. 49).

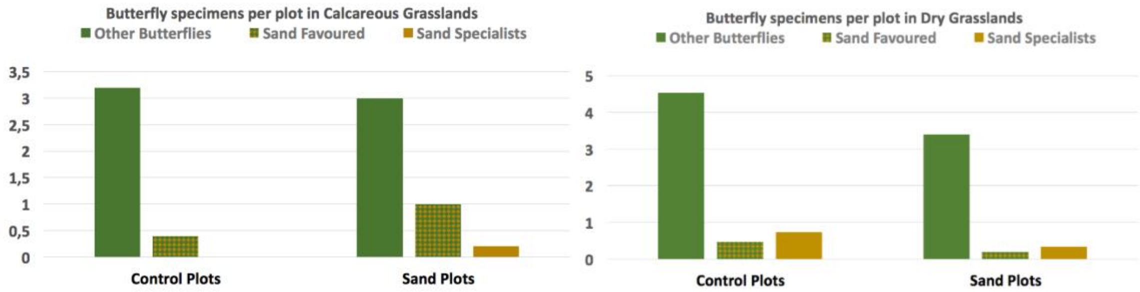


Figure 49. The number of sand favoured butterflies in control/action plots in calcareous and dry grassland.

Discussion Butterflies

Overall the butterflies gave few positive responses on the actions. This may have been explained partly by two different explanations. The first is that 2017 was a particularly bad year for butterfly survey. The season when most of the surveying was planned was cold and cloudy, especially the period between May to mid-July. Another explanation may be that succession in treated areas were still in very early succession. The proportion of nectar sources had increased in many areas, but the density was still low and in an early succession. And this may not be optimal for butterflies.

The species that increased the most was heath fritillary, not a typical sand specialist. We have no good explanation for this response, and it did not show a good trend overall in Sweden during 2017. Maybe this is a species that can be favoured very early after clearing woodland.

Moths

Night-flying Lepidoptera, generally called moths, is a species rich group with around 2600 species in Sweden. Of these are around 1000 so called macromoths and 1600 micromoths. The larvae feed on the vegetation and can specific to certain host species. The adult moth is to varying degrees dependent on nectar sources.

In Sand Life, we made clearings in the pine plantations in dune habitats. The aim is to create more open space, and to reduce the exotic species mountain pine and keep the native species scotch pine. With time, the cleared spaces will be inhabited with dune grasses and forbs that can be important nectar sources.

To get a picture of the occurrence of moth species in cleared habitats, we performed a comparison between pine woodlands and clearings by using light traps. Since in most places all mountain pine was removed, we cannot compare in most cases with how it was before the mountain pine was removed. Instead we evaluate the newly created habitats by comparing with adjacent scotch pine forests.

Methods Moths

The survey was performed in late July 2017. We used a set-up including six different restored dune habitats. In each of these we selected 2-3 restored clearings and 2-3 pine forests in a paired design. In each spot, we placed a moth trap, a heath trap (Watkinson & Doncaster, UK) with 6W actinic light tube. Traps were left for one night and in the morning after all specimen were counted and photographed and then released live. In total the survey contained 30 trap nights. All results refer to a unit of 1 trap night. We analyzed moth numbers, species richness, density of red-listed species and the numbers of sand specialists and sand favoured (less strict definition that includes also the sand specialists) species (judged by experts not aware of the results in this data set). As earlier mentioned, this method differs from the common setup used for most other organism groups.

Results Moths

In total, we counted 1262 moths of 176 species in the survey, 115 species of macro moths and 71 species of micro moths. Five of these species were red-listed. The number of moths per trap night was similar between the two types of habitats, around 40 individuals per trap night.

For macro moths, the number of moths was slightly higher in clearings compared with in pine woodland, while species richness was the same (Fig. 50). There was a tendency for higher proportion red-listed, sand specialists and sand favoured macro moths in clearings, but these results were not statistically significant.

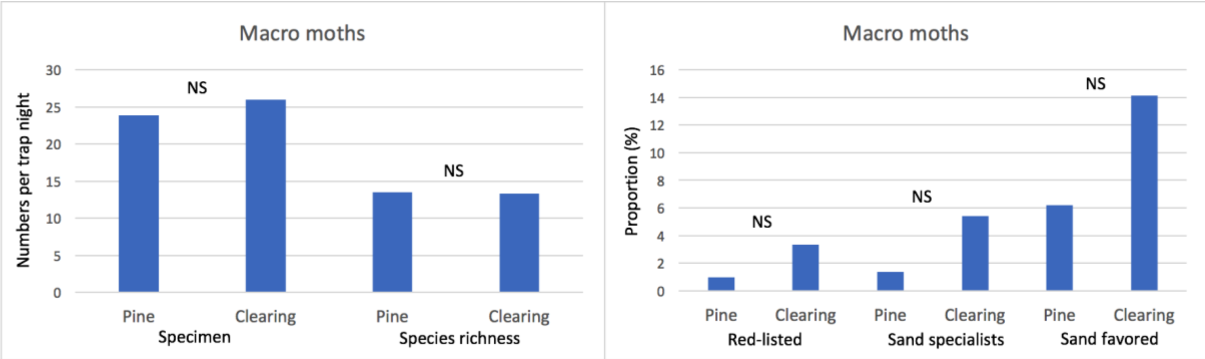


Figure 50. Average macro moth numbers (no per trap night) and richness in pine woodland (n=11) and clearings (n=14) created in the Sand Life project. Each location was placed approximately 50-100 m from a clearing. The proportion of red-listed, sand specialist and sand favoured species are also given. A t-test was used to test for differences between pine forest and clearings and NS indicates no significant difference between pine and clearing (p>0.05).

For micromoths, the number of moths was slightly higher in pine forest compared with in clearings, while species richness was almost the same (Fig. 51). There was significantly higher proportion sand specialists and sand favoured micro moths in clearings.

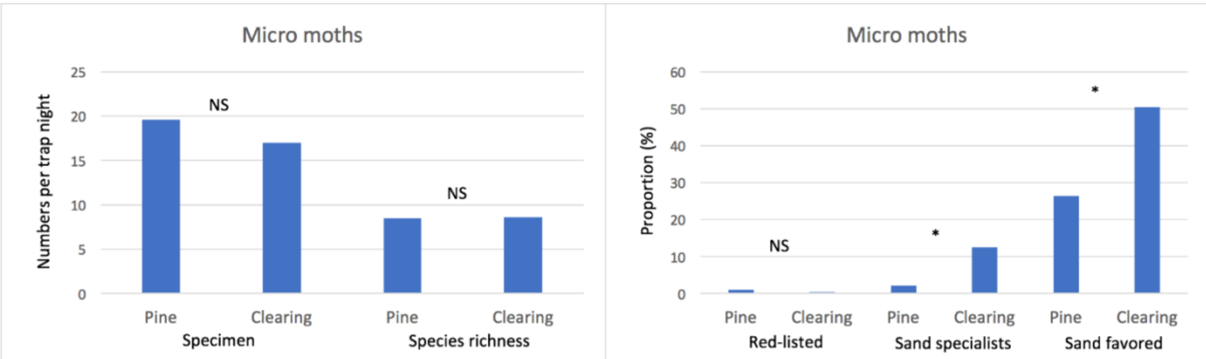


Figure 51. Average micro moth numbers (no per trap night) and richness in pine woodland (n=11) and clearings (n=14) created in the Sand Life project. Each location was placed approximately 50-100 m from a clearing. The proportion of red-listed, sand specialist and sand favoured species are also given. A t-test was used to test for differences between pine forest and clearings and * indicates significant difference between pine and clearing (p<0.05), while NS indicates no significant difference.

The number and richness of macro moths was slightly higher than for micro moths. The proportion of sand specialists was on the other hand clearly higher for micro moths. Reaching above 50 % of sand favoured in the clearings.

Discussion Moths

Many of the restored clearings are still in an early succession, with very low density of nectar and host species. Still it is clear that the clearings add values to these dune habitats, where pine still is dominating in most cases. The clearings add to the biodiversity by favouring sand specialists and sand favoured species.

The number of red-listed species were relatively low, illustrating that sites are still in early succession. Close to these habitats there are other places that harbour a higher density of red-listed species, but these were not included in the present study.

A rich moth fauna in the sand habitats is not surprising, and the number of pine specialists were indeed high. In the surroundings, some of the dune habitats also contain significant amounts of deciduous woody vegetation, adding further to the moth density. And the locations in pine forest were never far from the sandy clearings, explaining why specialists for open sandy habitats were also found there in them. And it should be highlighted that the pine forests probably are much richer habitats than the mountain pine plantations that gave place for the new clearings.

In conclusion, clearings already have added to the moth diversity in the dune habitats by benefiting sand specialists and thus increasing the overall diversity in these dune habitats.

Hemistola chrysoprasaria (EN), found during moth survey in Gropahålet.

Spiders

Method details specific to Spiders

Before/after

Three dune grids were surveyed both before (2013) and after (2017) implementation of Sand Life restoration actions. At each visit, 10 pitfall traps were placed along each segment, for a total of 40 traps per transect, or 120 traps per grid. All traps were collected one week later, and trapped spiders were identified and counted.

Control/action

Five of the common setup plots and their controls in dry grasslands were surveyed. In June 2017, five pitfall traps were placed along the edge of each plot, for a total of 50 traps. All traps were collected one week later, and trapped spiders were identified and counted.

Species classification

Classification of sand specialists, xerophilic and thermophile species was implemented without knowledge of the results by spider expert Lars Jonsson at Kristianstad University, Sweden.

Results Spiders

In total, 1111 spiders of 35 species were found in the survey. The number of trapped spiders was more than twice as high in controls than sand, but species richness was still almost the same in both treatments (28 in controls compared to 27 in sand).

In absolute numbers, almost twice as many Sand Specialists were found in sand as controls and in relative numbers this ratio was four. The average proportion per plot of spiders classified as sand specialists was 18.1% compared to 4.9% in controls, and this difference was significant (Figure 52).

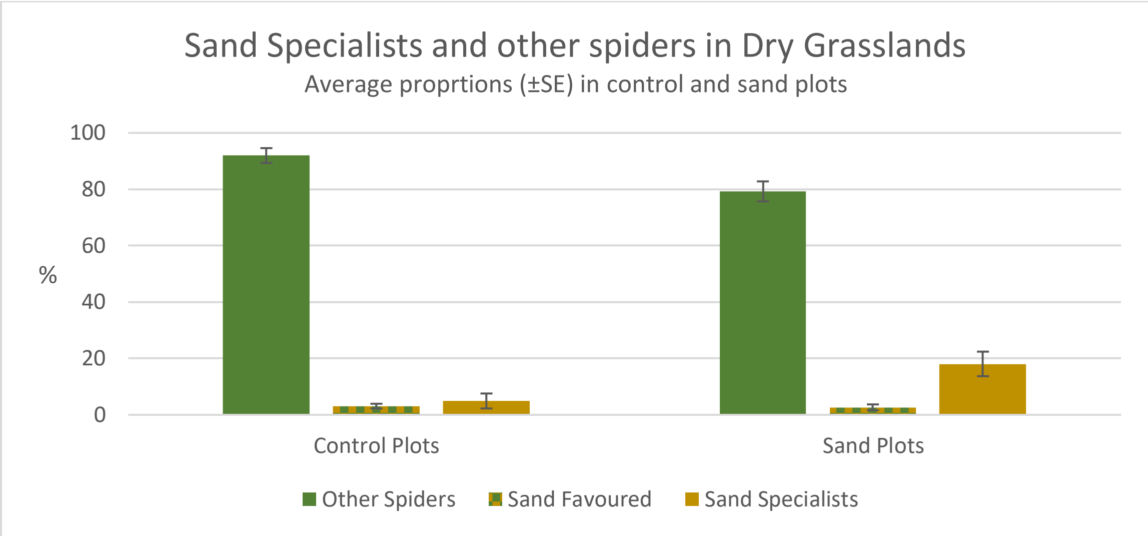


Figure 52. Sand affinity in control and sand plots. From left to right average proportion per plot (±SE) of Other Spiders (control > sand, *), Sand Favoured (NS) and Sand Specialists (sand > control, *).

Discussion Spiders

Although spider densities were in general higher in control areas, the most specialized species were the favoured ones. Control areas were dominated by common forest species, that still occur to a large extent in the surrounding landscape.

Conclusions

At this early stage of succession after implementation of restoration measures, several very promising results can already be seen. The most conspicuous outcome is perhaps the increased populations of tawny pipit after several decades with a decline, but other threatened bird species also build nests in newly cleared areas rather than remaining stands of pine forest and virgin sand plots are increasingly colonized by a high proportion of nectar species and red-listed plants, as well as sand specialists and sand favoured species among insect groups such as ground beetles, bees and wasps and moths. We conclude that most indication are positive already this early after restorations. Key species do find their way into restored habitats and become a more dominant part of the communities in benefit areas.

The responses in insects and other arthropods was very fast and positive in most cases. The restorations in all habitat types had a positive effect for the overall insect diversity in the areas, and provide areas with a better status for threatened species. As might be expected, the response was most positive for those bees and wasps, beetles and spiders favoured by areas of bare sand. Sand specialists among moth species depend on host species in open habitats, often different types of grasses, and it was clear that these already showed a positive response so soon after mountain pine removal. The response in nectar and pollen feeding species, such as butterflies, was less clear. This may be because the flower densities have not yet fully recovered after clearings, prescribed burnings or other actions to open-up the landscape. Compared to insects, the succession of vascular plants is a much slower process, and restored areas are therefore in a very early stage, but the makeup of the dawning plant communities already shows positive trends for red-listed species, species of high conservation value and nectar and pollen sources, and succession moves towards communities typical for many Natura 2000 habitats.

While project actions have already created large new areas of sandy habitats and added value to those already present, the threats of encroachment remain and continued restoration measures are evidently required. With respect to current results, in the future it would be especially interesting to follow the continued colonization of restored areas by sand specialist vascular plants, the progress of nectar and pollen feeding insect species and the population trends for tawny pipit to see if it can spread to restored areas, where it still not occurs.

Continued monitoring of the same groups as surveyed in this project will give an important decision basis for the future management of restored areas.

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Partners

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Life+ Nature

Sand Life has been funded through LIFE + Nature, which is part of the EU's funding for major environmental and nature conservation projects in Europe. The purpose of Life + Nature is to implement the EU Birds Directive and the Habitats Directive mainly within the Natura 2000 European Network. The measures to be implemented in the area of LIFE + Nature should be well-proven and ensure that species and habitats achieve favorable conservation status.

Natura 2000

The sites included in Sand Life do all consists of Natura 2000, which is a network with valuable nature within the EU. The purpose of the network is to eliminate the eradication of animals and plants and to improve their habitats. In Sweden, there are just over 3 500 Natura 2000 sites, which are the most valuable natural areas in the country. Most of the sites are protected as a national park or nature reserve.

Read more about Life + and Natura 2000 on the website of the Swedish Environmental Protection Agency and the EU Commission.

www.sandlife.se