Quantification of the attractiveness of bee-friendly plants to bees

Which ‘bee-friendly’ plants attract the most bees?

   

Studied over five years from 2014 to 2018

Rosi Rollings - 02 February 2019

Plants pictured: Helenium Autumnale ~ Calamintha Nepeta ~ Echium Vulgare ~ Geranium ‘Rozanne’

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1 Summary of study

Plants and pollinators have co-evolved over millenniums to produce a rich diversity and also a co-dependence. Bees are responsible for the pollination, and the survival, of 30% of all plant species. Reduced pollination is a threat to continued biodiversity. One of the main factors causing the current mass loss of pollinators is the near elimination of their natural habitat. This makes it vitally important that we invest in providing as many flowering plants as possible, wherever space allows. Bees are the powerhouse of pollination and so the focus of this study.

But which plants should we plant? There are many lists available of plants that are likely to beneficial for pollinators. But most of these list are only based on anecdotes and experienced observation. The purpose of this study is to quantify how attractive various plants are to bees and provide a better basis for plant recommendations.

The plants in the study were chosen for their reported or observed potential to be highly attractive to bees. Many of these plants are recommended by leading horticultural or wildlife organisations. The study covered **111 plants** including:

- 90 perennials, 6 biennials and 15 annuals
- 30 native plants, 81 non-native

The majority of the plants have at least two years' worth of data and 63 have 3 years or more.

1.1 Findings

The following finding are based on 7 years, hunting for the best plants and 5 years for quantification analysis. Each year has added to my understanding of the subject but most of the findings have stayed very consistent from the first year.

- The primary finding is that the number of bees each plant attracts varies hugely. Some attract surprisingly few, even supposedly 'bee-friendly' plants. This variation is significant for anyone wanting to maximize the amount of bee-food any area of land can provide.
- Weather has a major impact on both bees and plants causing them to thrive much more in some years than others. Yet, both are also very resilient and how attractive a plant is to bees should not be judged on a single year let alone a single observation.
- Both native and non-native plants are equally attractive to bees. Except where there is some unique inter-dependency, most bees show no favoritism to native plants and seek food where they can access it.
- Healthy plants with more flowers attract more bees. The old gardeners' adage of 'right plant for the right place' is important for both a sustainable garden and more bee-food
- Different plants attract different bees and so to ensure that food is supplied to a wide range of bees its best to have a wide range of flowers available. Although plant structure has a bearing on which plants each bee prefers, it is not the only factor. Hopefully, this study can help guide some plants choices.

One further comment relates to honey bees. Although not proven, many of my observations show that honey bees out-compete other bees for food; if you introduce c.50,000 additional bees into a local population then you must be increasing pressure for food resources. Beekeepers should consider how to increase local floral resources to avoid negative impact on wild bees

Summary chart of the top performing plants for bees, by type of bee, over the 5 years of our study and 'rationalised' to equalise the weighting of each bee group.

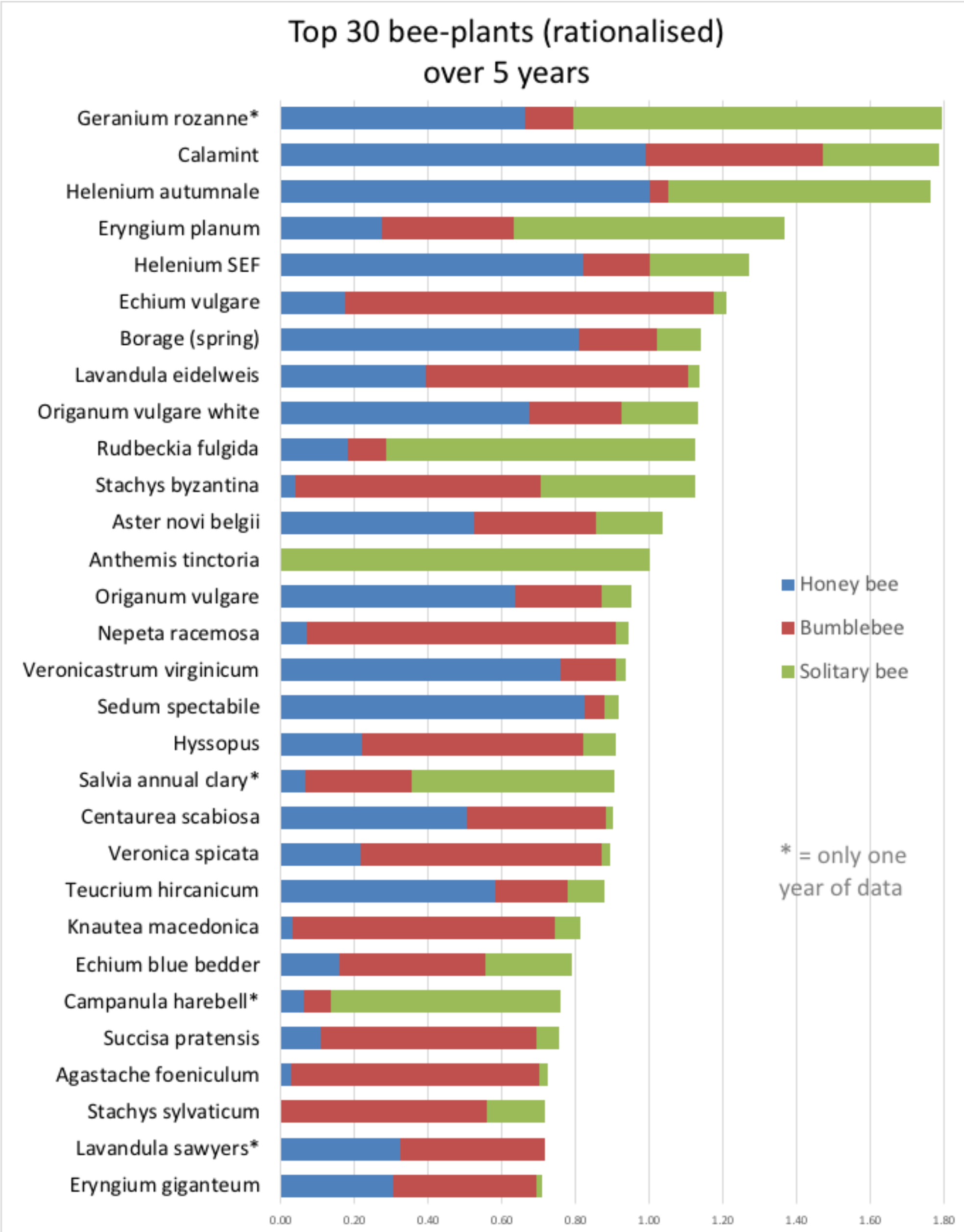

Figure 1 - Top bee-plants (rationalised over 5 years

For more details please refer to full research results at www.rosybee.com/research.

2 Introduction

This report summarises the findings from 5 years of research aimed at quantifying how attractive many 'bee-friendly' plants are to bees.

Clearly, there are many hundreds of trees, shrubs and herbaceous plants that could be tested. The focus of this research has been on herbaceous plants and sub-shrubs that are easily added to any garden or small area of available space. Plants were chosen for inclusion based on their reported or observed potential to be highly attractive to bees, in many cases, these are plants that appear on lists of recommendations from leading horticultural or wildlife organisations and, in some cases based on my own observations.

- The study covered **111 plants** including:
  - 90 perennials, 6 biennials and 15 annuals
  - 30 native plants, 81 non-native

The study evolved over the years starting with 45 plants. Each year a few more were added and 7 were dropped after only one year as it was obvious they offered very little value to bees. The majority of the plants have at least two years' worth of data and 63 have 3 years.

The research was conducted at our plant nursery site in south Oxfordshire (51.636634, -1.389445), (rosybee.com). Over time, we have been developing the six-acres of former pasture land has been developed as a 'bee haven. There are areas of wildflowers, naturalising hedges and an acre of annual borage and phacelia to provide more nectar and pollen. We also keep honey bees and sheep.

All of this activity probably increases the total bee populations on the site. But this should not distort the main findings of the research which concern <u>relative</u> attractiveness of plants to bees

The nursery is sited on the edge of a village in the Thames floodplain. Approximately 80% of the surrounding land is arable farming, with field margins and hedgerow boundaries. The remaining 20% is a mix of houses with domestic gardens, paddocks and some small areas of woodland around the village. The aerial photo shows the large arable fields which offer little bee-forage unless the crop includes oil-seed rape or field beans.

The natural soil is a very heavy clay over a gravel layer. The soil in the research borders has been improved with the addition of organic material, to resemble the local garden soil. The soil tends to be slow to warm up in spring causing the plants to be slightly later to develop than other southern counties. It also becomes very dry in midsummer as the study areas have no irrigation systems. The plants were only watered occasionally by hose during very dry conditions.
This sort of research takes time as each plant must be grown to maturity before we can representative results. After the first two years of study, it became clear that that more years of data would help to provide more robust results. There are still many more herbaceous perennials and sub-shrubs to quantify. However, as the focus has been on those most likely to be attractive to bees, so we have made a good progress in this work.

3 Research method

(Full details of the method can be found in section 10 Appendix 1 – Research method*)*

The research methods have remained the same: each plant was given a square meter of ground and allowed to mature, then bees and other pollinators are counted on each plant, at least weekly, for the period each plant was in flower. This gives a basic 'bees per square meter' calculation. The counting used the 'snapshot' method: all the bees that are on the plant at the moment of observation are counted. We only count on days when the bees are flying i.e. when it's not raining, blowing a gale or below 10 degrees.

The main outputs are:

1. The average number of bees, per square meter for each plant
2. The number of weeks each plant flowers for

We also capture weather and other factors that may have a contextual influence on the results, such as the health of the plant. Where possible, honey bees and bumblebees were recorded at species level. Solitary bees were recorded as a single group with notes of probable species as its often very difficult to identify them in flight.

4 Ratings logic

Both length of flowering' and 'number of bees attracted', contribute to the value each plant can provide to bees and other pollinators. Some plants such as *Erysimum* 'Bowles Mauve' flowered for an average of 17 weeks (including an amazing 34 weeks in 2017) yet it tends to only attract 1 or 2 bees at any one time. Compare this with a classic bee-plants such as lavenders, they tend to flower for only 3 and 6 weeks (depending on the specific plant cultivar) but attract an average of 5+ bees at a time.

Our hypothesis, and the basis of our ratings is that both have equal importance as indicators of the bee-food value of the plant and hence:

- 10 bees at a time for 3 weeks = 3 bees at a time for 10 weeks

We calculate a measure for each plant and from this, it is possible to rank the plants. We also calculate these ratings separately for honey bees, bumblebees and solitary bees. When recombining these figures, we have given each bee family equal weighting. As there are so many species in the bumblebee and solitary bee groups, this is a significant simplification but it helps to avoid honey bees dominating the data.

5 Contextual findings

5.1 Weather

Weather over the 5 years has varied considerably. Both wind and temperature have a direct impact on the number of bees flying and foraging each day. Periods of cold and rain may inhibit or increase flowering, as may periods of drought. Different bee species react differently to these challenges as do the plants.

We do not count bees on cold or wet days and so the weather we recorded at the times of our observations do not entirely reflect the season. However the temperatures do correlate closely with bee behavior.

No two years were alike, there were similarities that allow for some simplification:

- 2014 and 2015 were both mild and warm;
- 2016 was cold and wet through the early summer and hot in August
- 2017 and 2018 were both much hotter during the early part of summer

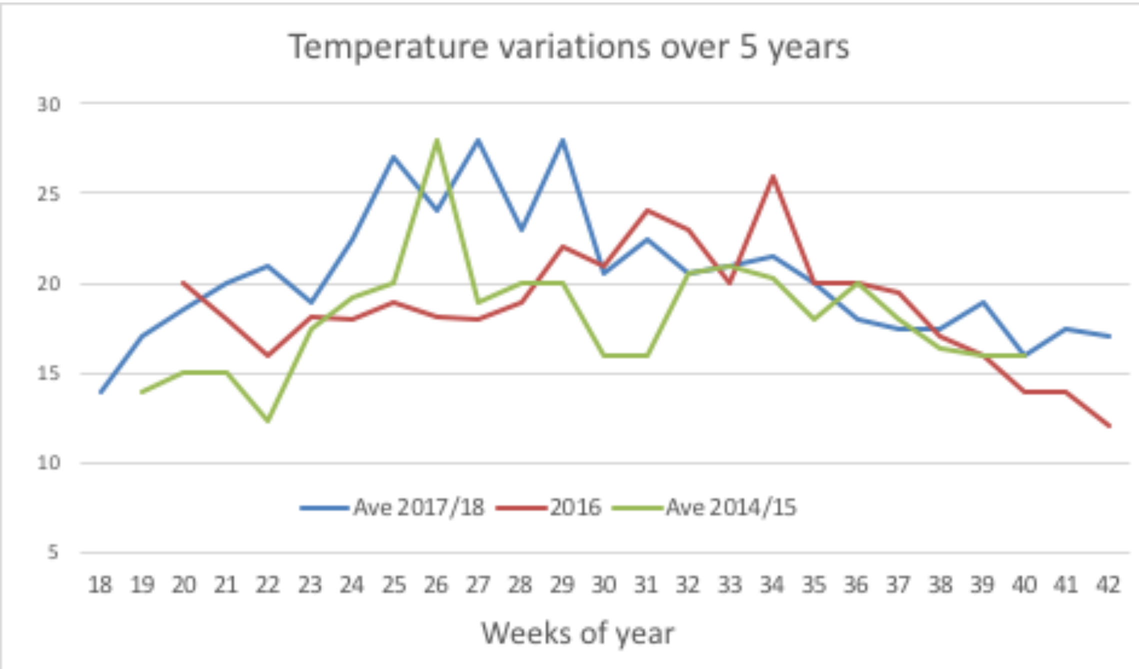

Figure 2 - Temperature variations over 5 years

5.2 Bee numbers

The average bees numbers per square meter increased since the first year although in the last two years honey bee numbers increased considerably. Bumblebee numbers have decreased. There appear to be multiple reasons for this pattern. Solitary bee numbers have increased four-fold since 2014 but still only represent around 10% of all bees sighted even though this group has the highest number of species seen. Some of the increase in solitary bees may be due to increased identification skills on my part.

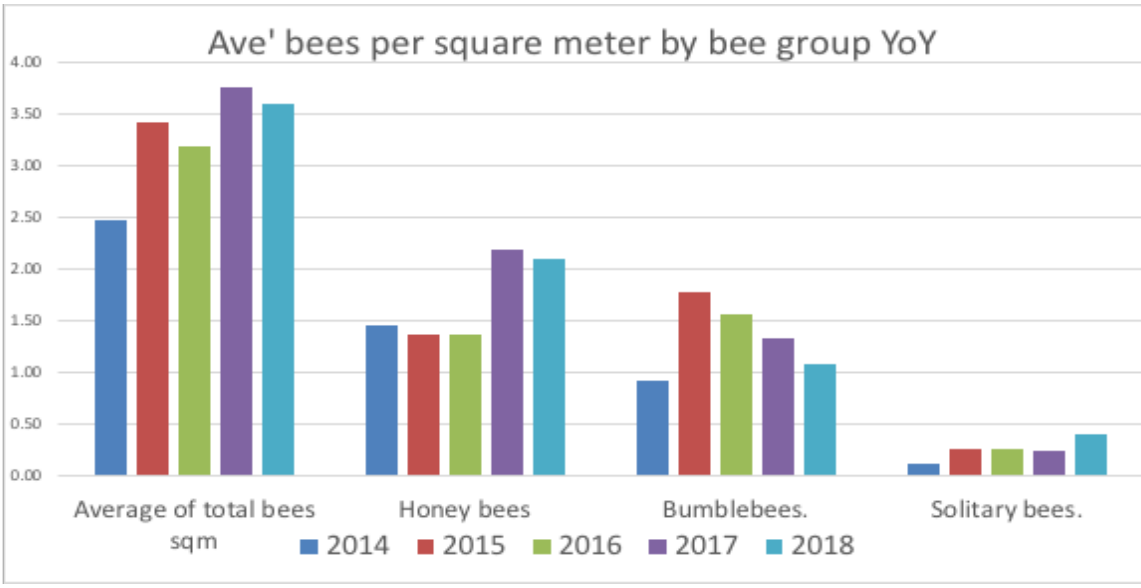

Figure 3 - Average bees per square meter by bee group YoY

Over the 5 years, honey bees have made up between 41% (2015) and 58% (2017 and 18) of all bees sighted. Although their high numbers probably due to the proximity of our nearby apiary, the patterns of increase and decrease appear to reflect changes in weather and available food rather than the number of bees in the apiary. There appears to be no direct correlation between good honey bee years - when the hives are healthy and producing a good flow of honey - and the numbers observed in the research beds.

The two charts below attempt to show the relationship between bumblebee numbers, honey bee numbers and the most influential of the weather conditions: temperature. (Note that rain will most effect on bee abundance but we don't do counting on rainy days as there will be none!)

I have selected 2015 as being a typical, cooler year with a mild spring, one very hot day in week 24 (mid-June). Temperatures over the summer varying between 16 and 21 degrees. This also demonstrates the typical pattern we observe of having peak bumblebee numbers in June with a second smaller peak in August. Honey bees typically take longer to arrive on the herbaceous perennials (previously foraging in the trees and hedgerows) and then peak from mid-July to the end of August.

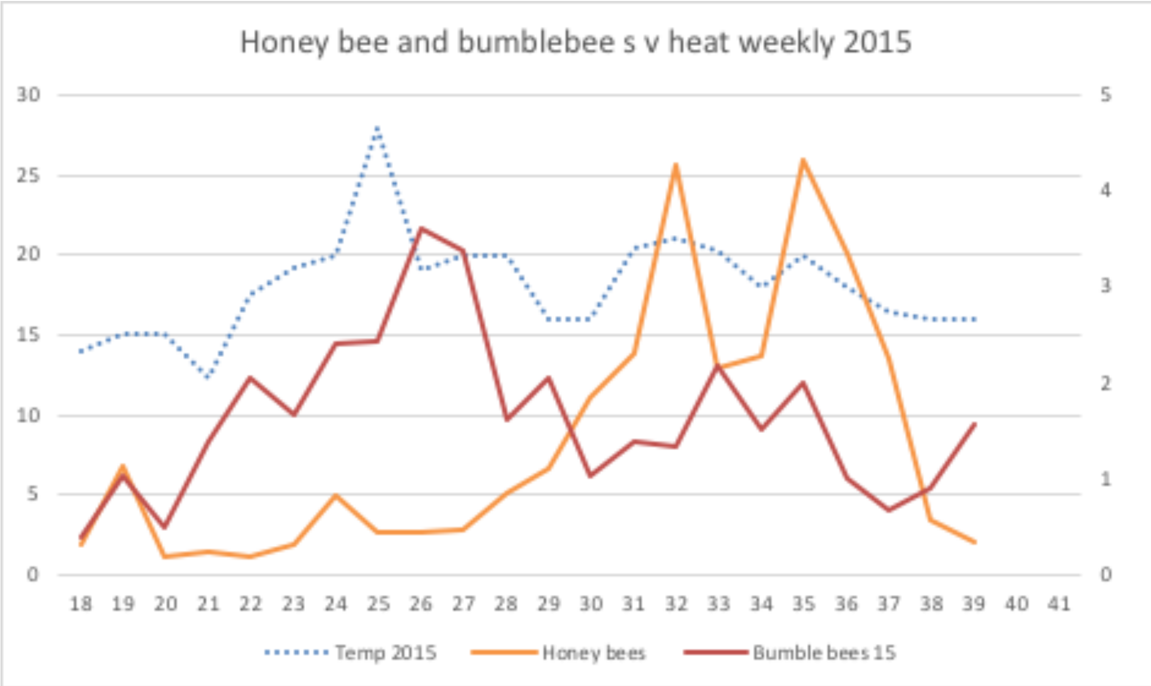

Figure 4 - Honey bee and bumblebees vs. heat weekly 2015

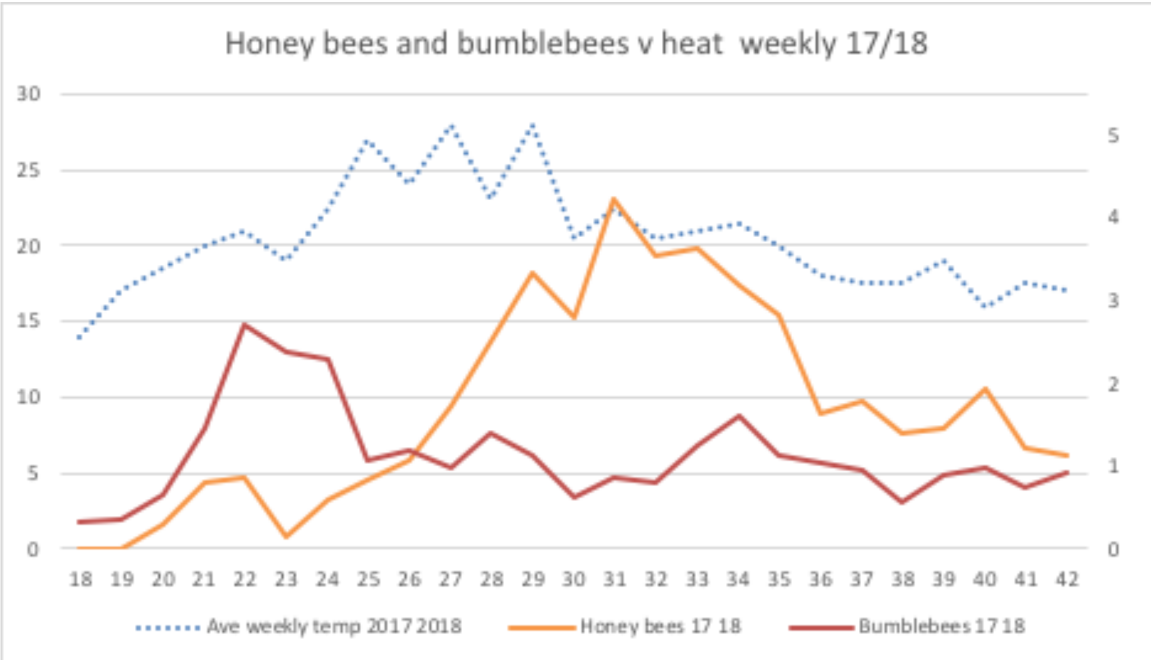

Figure 5 - Honey bees and bumblebees vs. heat weekly 17/18

2017 and 18 were both much hotter than the previous 3 years through June, July and into early August when temperature were above 20 degrees for 10 weeks. Bumblebee numbers are significantly reduced as soon as the temperature rises above 25 degrees in June. Conversely, the honey bee numbers built up sooner, with an average of 3 per square meter being achieved in week 29 versus a more typical week 31

It is possible that the increase in honey bee numbers actively contributes to the reduction in bumblebee numbers. Note how the peaks and dips coincide on both charts. It is likely that the hotter weather suits the honey bees better but both more honey bees and heat adversely affected the bumblebees.

There is one further factor that is likely to have contributed to the reduction in bumblebee numbers which can be observed when they are seen at a species level.

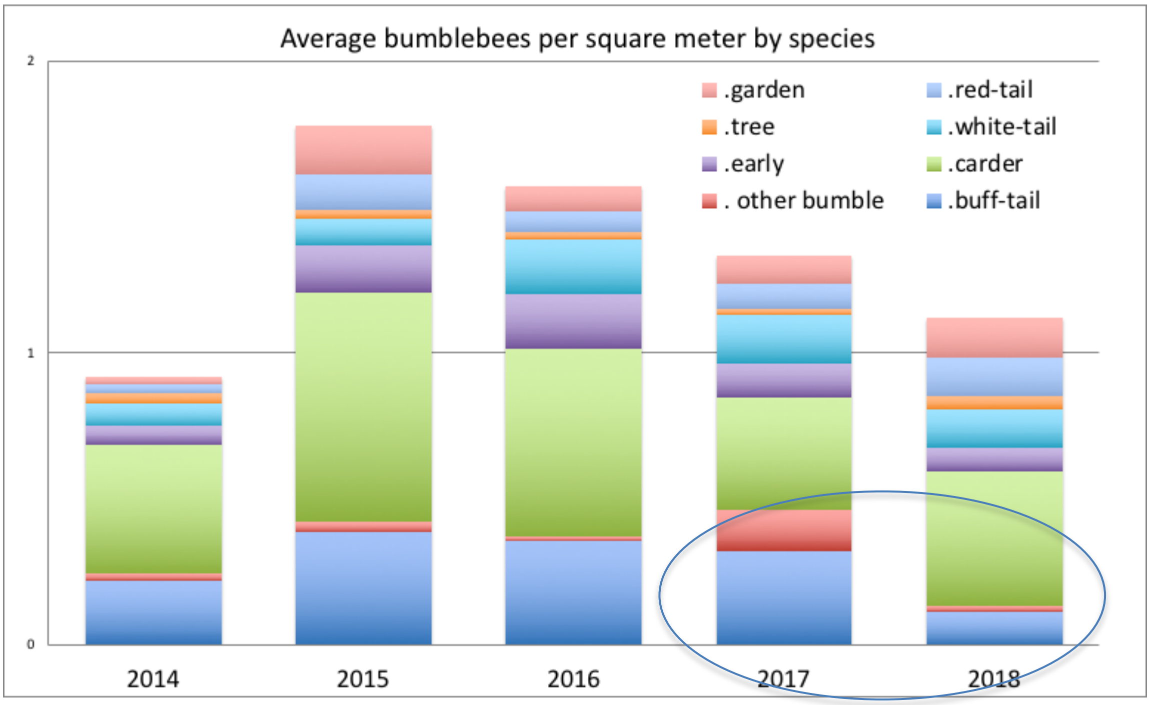

Figure 6 - Average bumble bees per square meter by species

In 2017 a significant number of *Bombus vestalis* (Other bumblebee: red) were observed. These that acts as a cuckoo to buff-tail bumblebee (blue). The dramatic reduction in Buff-tails (*Bombus terrestris*) in 2018 and also of the cuckoo bumblebee is likely to be due to a rebalancing between these two species. This may account for some of the reduction in the last year but does not account for the reduction of most of the other bumblebees species since 2015.


Figure 7 - Bombus vestalis on echinacea


Figure 8 - Eryngium giganteum attracting honey bees

5.2.1 Indicators of honey bee competition and dominance

In 2017, bees accounted for 85% of all pollinators but honey bees accounted for 50% of that total, up by 68% of previous years. In fact, honey bees were so dominant this year that those plants that are particularly attractive to honey bees tended to rise up the rankings overshadowing plants that are valuable to attract wild bees; 8 out of the top 10 rated plants are mainly attracting honey bees. This pattern continued into 2018.

There are some indications that, when honey bees are strongly attracted to a plant, they actively discourage foraging by other bee. I have observed bumblebees and solitary bees on plants when they begin to flower. But then as it reaches full flower, the honey bees arrive and other bee species disappear. *Eryngium giganteum*, *Calamint*, and *Helenium 'Sahins 'early flowerer'* are examples of where I noted this pattern.

5.2.2 Solitary bee observations

Over the 5 years of this study, I have seen an increase in solitary bees both in terms of total number and number of species. I now keep a species list which now runs to 67 bee species of which 54 are solitary. The most commonly sighted groups are various *Osmia, Andrena* and *Lasioglossums* and we now also see their associated parasitic bees.

Some of the increase in species recorded is almost certainly due to my growing experience in spotting new ones. But I am optimistic that this is also due to the increasing range of plants on offer for them.

6 The Results

Plants vary in how they behave, flowering more in some years than in others. Bees also vary in how well they thrive. Often these variations are driven by weather conditions. For these reasons, we continued this study over 5 years in order to have more reliable results.

6.1 Bee-plant ranking

The basic building blocks of our ranking have not changed over the 5 years and is:

Average number of bees per square meter	X	Weeks in flower

This gives a very simple rating of each plant and allows comparison between plants and between years. Based on this we can determine relative attractiveness in the form of a ranking.

Until this last year (2018) *Helenium autumnale* consistently had the highest ranking, attracting significant numbers of honey bees and solitary bees. As it also flowers for an average of 13 weeks, making it also an excellent garden plant. However, 2018 was so hot and dry that the heleniums suffered from the lack of water resulting in a reduced flowering time of only 9 weeks.

Simultaneously *Calamintha* nepeta, a Mediterranean herb that has been rising in the rankings, had a superb year attracting not only honey bees and bumble bees but many *Lasioglossum* solitary bees. The *Calamintha* averaged 10.6 bees per sq meter and flowered for 15 weeks. This was enough to not only put it as the overall top performer for 2018 but in the cumulative results too.

Annual ratings for all 111 plants tested to date can be found in section 11 Appendix 2 – Ratings for all plants studied per year

However when the data was examined at the level of bee-group (honey bee vs. bumblebees vs. solitary bees) found that the local abundance of honey bees was causing those plants that attract honey bees to rise up the rankings. As it is unlikely that honey bees normally make up 49% of the bee population, they probably ‘skew’ the results. So, to avoid honey bees dominating rankings, I have now ‘rationalised’ the data to give each bee-group equal weighting by

1. Produce separate plant rankings for each bee-group
2. Recombine the ratings giving equal weighting to each bee-group

This has the effect of boosting the results for those plants that attract solitary bees and slightly demotes those attracting honey bees. Although this is a bit artificial, no national data is available for the actual proportion of each bee-group and so this seems to be a fair solution.

In this 'rationalised' ranking, the top performer tentatively becomes *Geranium* 'rozanne'. I say 'tentative' because I only have one year of data for this plant and it may not perform so well in cooler years. Having said that, this plant is certainly very popular with gardeners for its long flowering period.

The charts below show firstly the simple combined ratings and then the rationalised ratings.

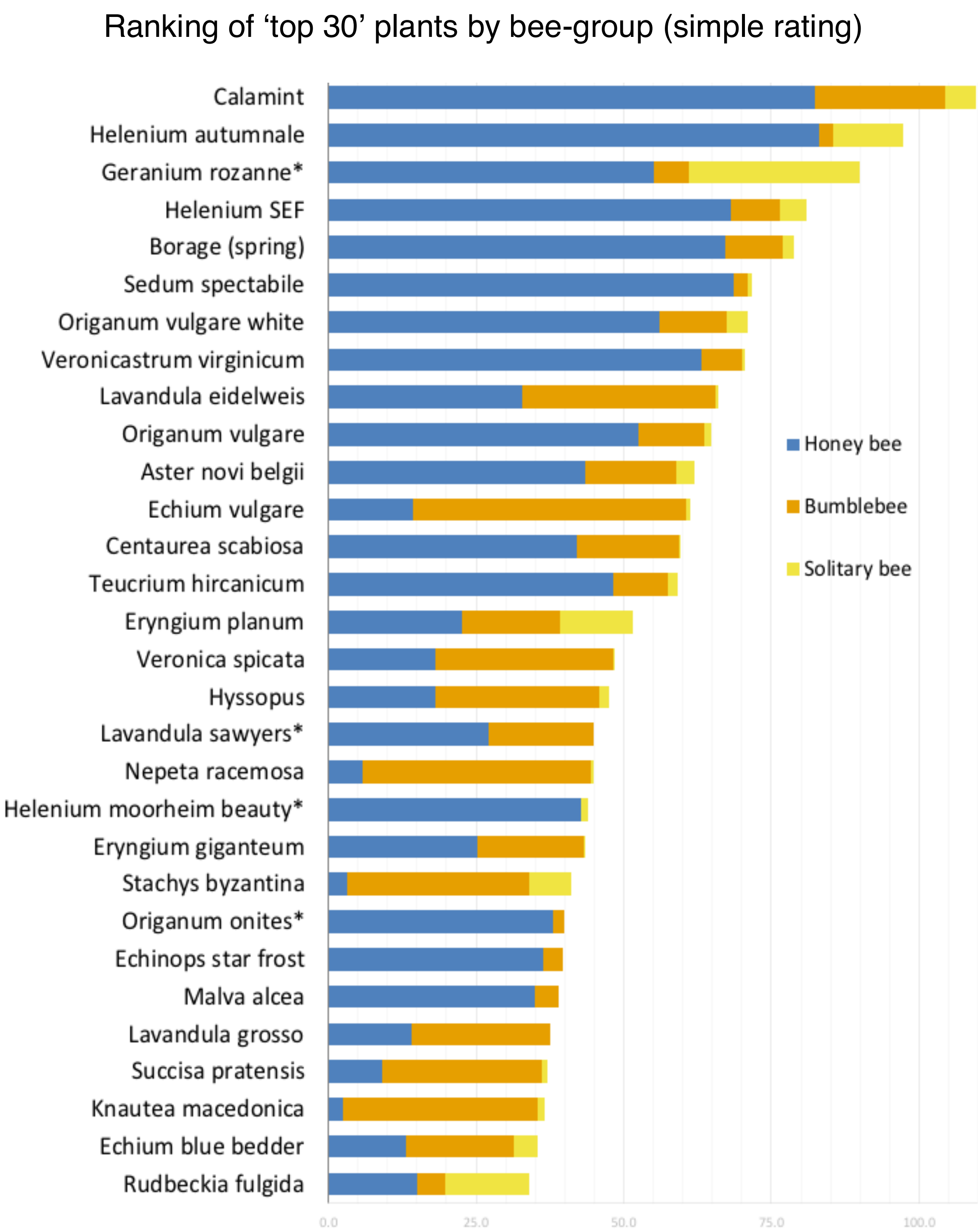

Figure 9 - Top 30 bee-plants by bee type over 5 years (simple ratings)

The dominance of the honey bees is quite clear in the first chart. The rationalised version below, has the advantage of more clearly showing how different plants attract different types of bees.

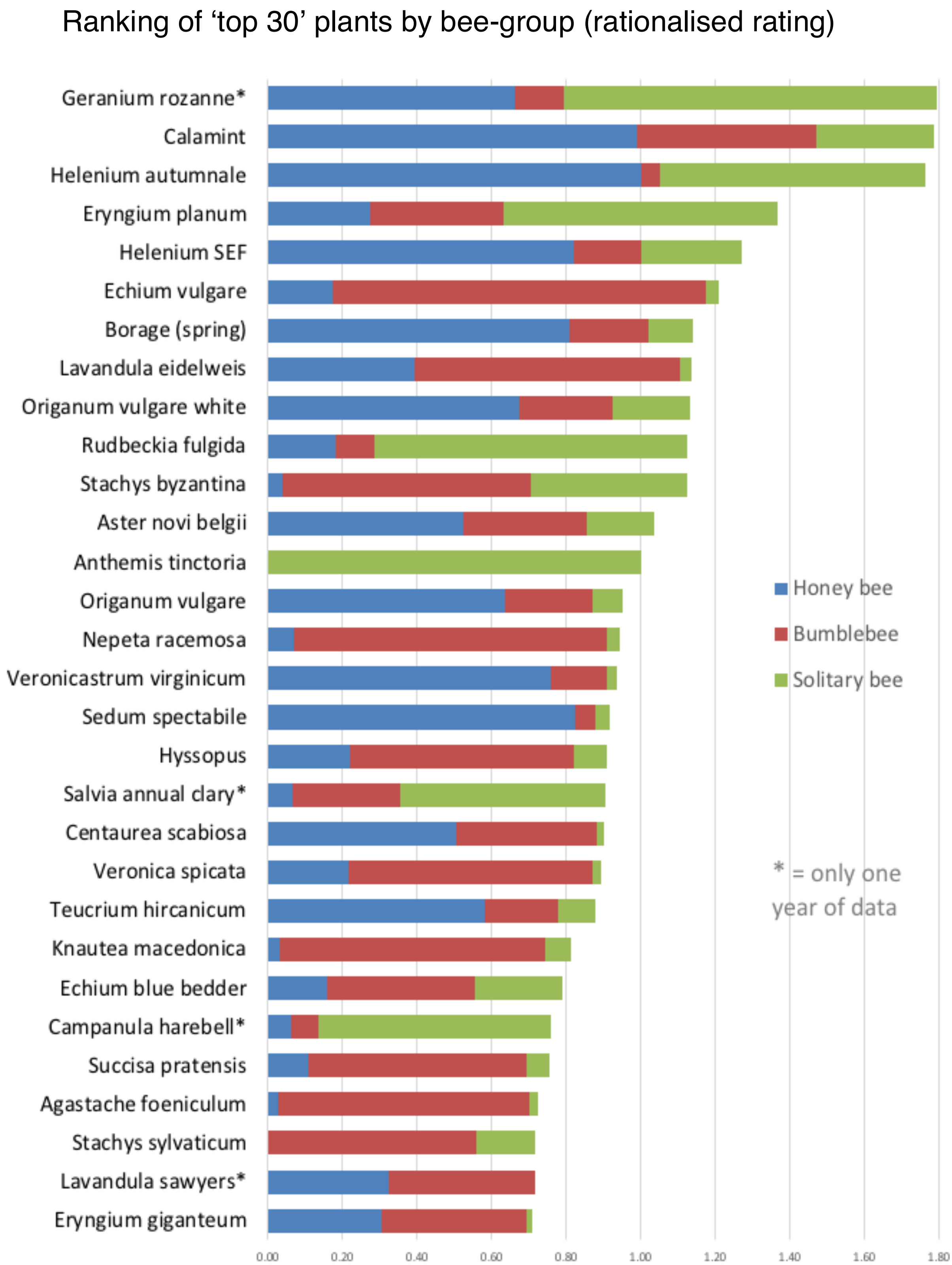

Figure 10 - Top 30 bee-plants (rationalised) over 5 years

6.2 Rankings by bee group

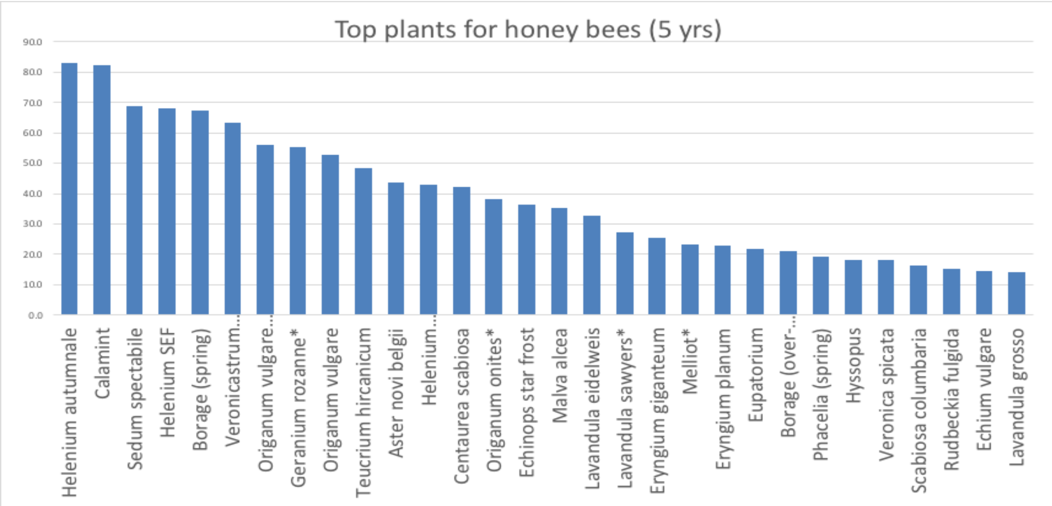

Figure 11 - Top plants for honey bees (5 yrs)

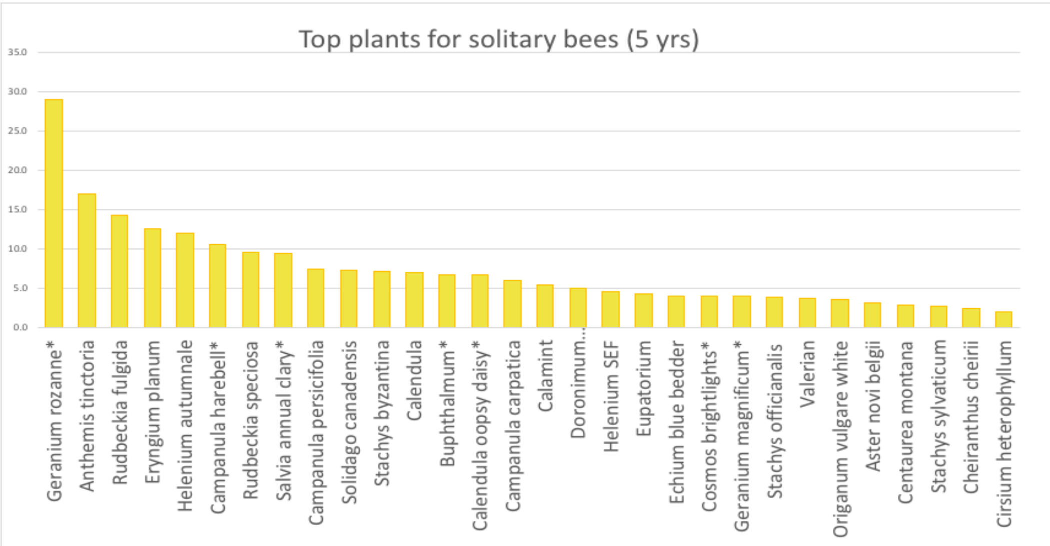

Figure 12 - Top plants for solitary bees (5yrs)

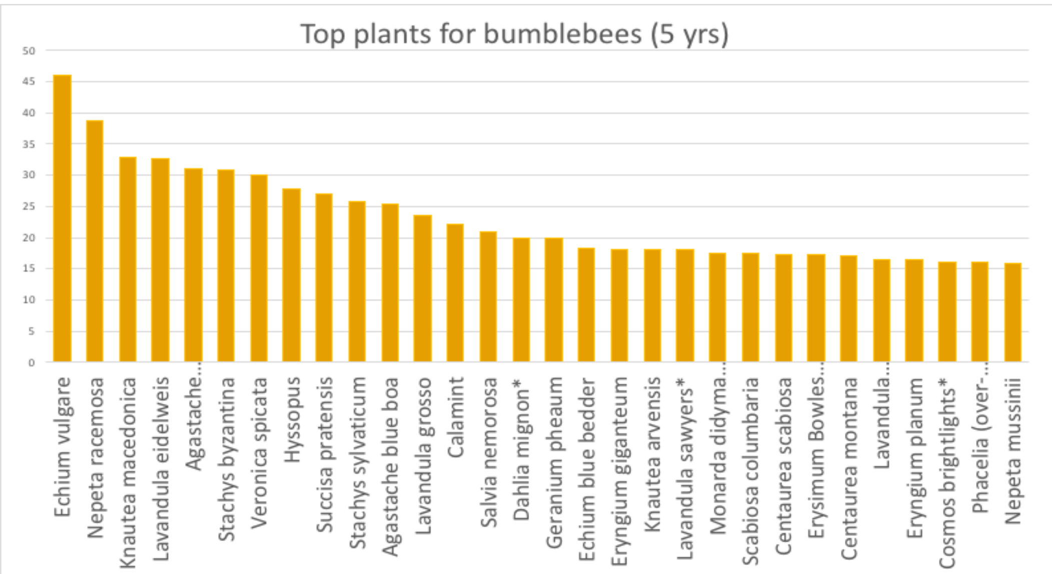

Figure 13 - Top plants for bumblebees (5yrs)

6.3 Different plants attracting different bees

By studying the plants that attract the different groups of bees separately, another finding has emerged. There is very little overlap between the plants that attract the most bumblebees and the two other groups. This is likely to be because bumblebees have much longer tongues and, although tongues of solitary bees vary the majority are small. It is well documented that tongue length relates to the flowers that bees choose. But it is still interesting to see it generally reflected in this data.

The chart below attempts to plot the 'top 30' plants (based on simple ratings) on a spectrum of both tongue length and bee groups. It should be noted that very few plants attract only one group of bees. If the proportion of a secondary group is lower than 5% I have chosen to show it as attracting only one group for simplicity of display.

'Top 30' plants arranged by tongue length and grouped by bee-group

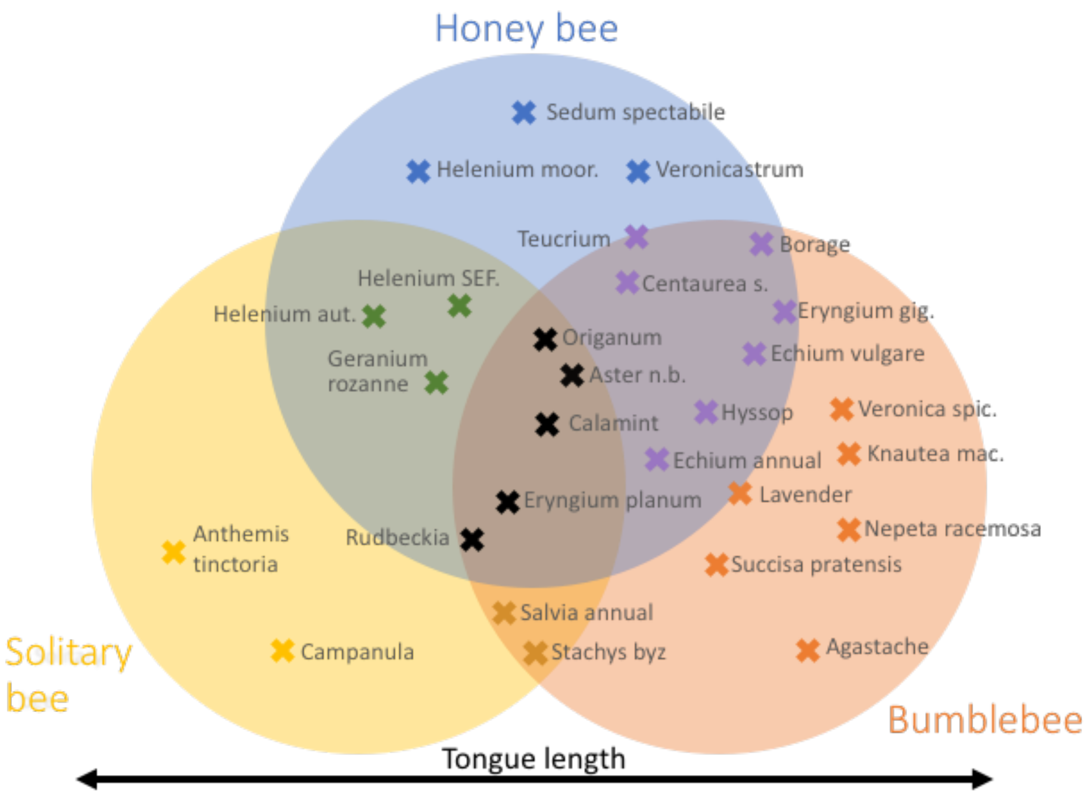

Figure 14 - Which bees the top 30 plants attract

There are fewer plants in the 'top 30' that attract more solitary bees than other types. In part this will relate to the fact that the total number of solitary bees sighted is far fewer, being only 11% of all bees observed. As solitary bees have the shortest average tongue length it's not surprising that there is little overlap between those plants and the ones attracting much longer-tongued bumblebees. Where there are overlaps between plants attracting solitary bees and other bee-types, the specific solitary bees are usually a larger species, e.g. *Stachys byzantina* attracts wool carder bees and buff-tail of bumblebees but wool carders are some of our larger solitary bees.

6.4 Similar flowers attracting different bees

The chart above shows the common understanding that bees are attracted to plants that their tongues can accommodate. Yet it appears to be a bit more complicated than that. Some plants would appear to be very similar in structure yet regularly attract different bees. A good example of this is the differences in the bees attracted to the various large 'daisies' in the study. All have a simple open composite flower head and very similar dimension of the individual flower sections that make up the cone-shaped center. Therefore they would appear to all be very accessible for a wide range of short-tongued bees. Yet the variation in bees attracted is quite significant and quite consistent over multiple years. The bumblebees attracted range from medium-sized buff-tail, red-tail through the slightly smaller common carders. The most common solitary bee attracted by the *Rudbeckia* and *Heleniums* is an assortment of *Lasioglossums*. Yet larger solitary bees such as ivy mining bees are also recorded. The *Anthemis*, showing no apparent differences structurally seems to only attract solitary bees and species that I have not observed on any other plant including a few *Andrena* and *Halictus* species.

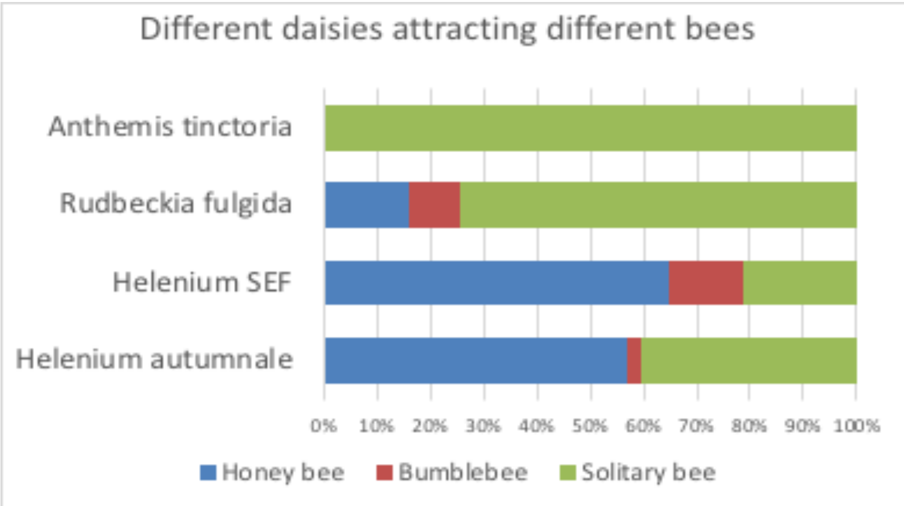

Figure 15 - Different daisies attracting different bees

The variety in bees attracted must indicate that something else is differentiating the flowers other than just their structure: perhaps the nature of the nectar or pollen.

6.5 Native vs. non-native plants

Another clear finding is that there is very little difference in bee-attraction between native and non-native plants.

The chart below shows the average number of bees (per square meter) each week on the native and non-native plants. The two lines follow each other quite closely except for the early weeks; until week 19 (early May) only non-native plants flowered and until week 22, those native plants that were in flower attracted few bees compared with the non-native plants flowering at that time. White *Origanum*, was the only non-native plants flowered after week 41.

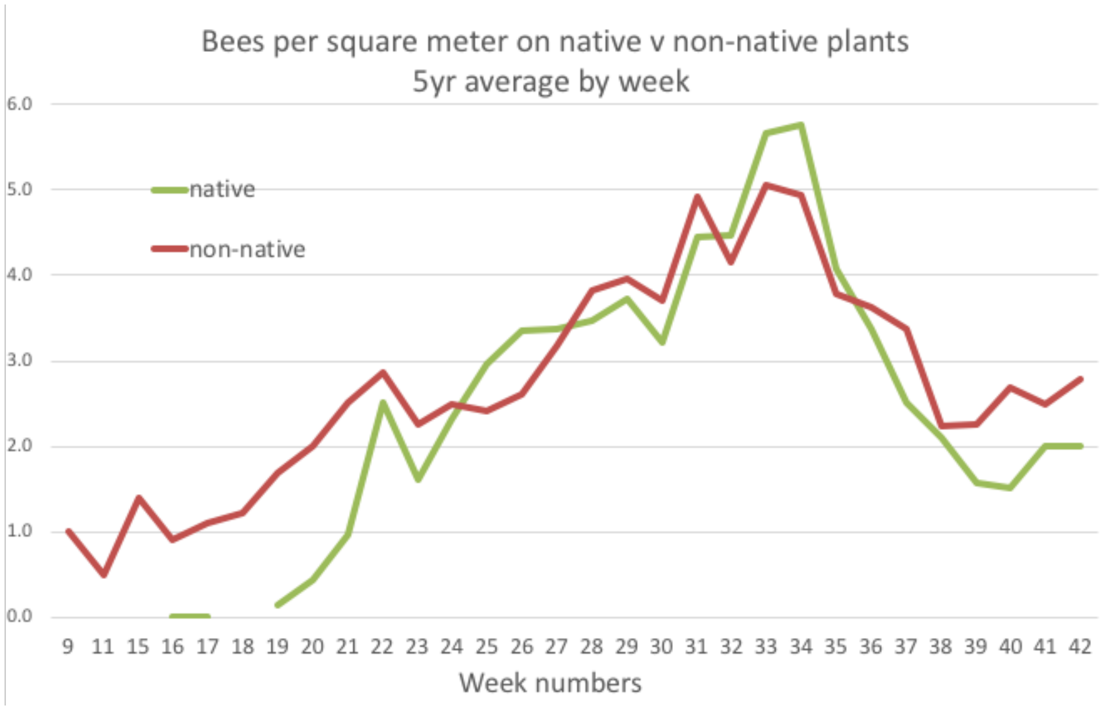

Figure 16 - Bees per square meter on native vs. non-native plants (5yr average by week)

The biggest difference between the native and non-native plants still seems to be that the non-native plants begin to flower earlier. This reflects that they respond to light triggers earlier in the year even though the UK climate is cooler than their regions of origin. Within this research, the non-natives that regularly flowered from week 9 onward included *Erysimum* 'Bowles Mauve', *Nepeta mussinii*, and *Centaurea montana*, All of these are of Mediterranean or middle eastern in origin. (Effectively, they flower early because no-one has told them they are not up a Turkish mountain!)

The non-natives extend the bee-food supply but in spring and autumn. However, in spring, very few bees are flying to benefit from any herbaceous perennials until week 18. But, those late flowerers are very useful to extend the season while bees are still flying. These included *Aster novi-belgii*, *Dahlias* and some cosmos'.

6.6 Annuals

Throughout this study, I have made a conscious effort to try and find annuals that attract bees. This is important as many people love the vibrant colour that annuals tend to provide in the garden. Also, when grown from seed, they are easy and cost effective.

It is well documented that most of the typical "six-pack" annuals sold by garden centers attract very few pollinators. Many are sterile and grown through hydroponics. To check this, in 2014, I did a specific test of a selection of common garden center annuals. As was expected, very few pollinators were observed foraging. A few such as stock and nicotiana must attract night-flying pollinators as they developed seed pods but I never saw any pollinators on them. The only bought annual that attracted any bees was a lobelia.

Each year I have also tried a few different seed-sown annuals, choosing those that are sold with a 'plants for pollinators' logo or specifically state they attract bees. Again these, although fully viable plants, have had very mixed results and most have been disappointing as bee-food sources. The table below lists the seed-sown annuals in ranked order.

Rank	Plant	Pollinators attracted
5	Borage (spring germinated)	Honey bees and some bumblebees
29	Echium blue bedder	Good mix
32	Phacelia	Bumblebees and honey bees for pollen
36	Salvia annual clary	Solitary and bumblebees
40	Borage (over-wintered)	Honey bees and some bumblebees
41	Cosmos	Solitary and bumblebees
42	Dahlia mignon	Bumblebees
49	Cosmos brightlights	Solitary and bumblebees
69	Cerinthe major	Bumblebees
77	Calendula	Solitary bees
85	Calendula oopsy daisy	Solitary bees
86	Limnathes douglasil	Occasional honey bee
91	Aeratum	Hoverflies
107	Forget me not	Occasional solitary bee and flies
109	Cleome	Occasional wasp

Table 1 - Seed-sown annuals in ranked order

From our data, it would appear that few of the annuals attract as many bees as the perennials and biennials tested. Borage is the only annual that competes well. Having said that, phacelia is so easy to grow from seed (by simply scattering it on the soil surface) that it is probably more valuable for pollinators than these figures show.

Cosmos is regularly recommended by many leading wildlife organisations, as a good plant for bees, but I did not find it so. Over 3 years of testing it did not seem to be very attractive to bees and at many observation times no bees were recorded at all.

7 Other patterns and observations

7.1 Sterile plants can have value for pollinators

Several of the longest flowering plants in this study are sterile as the result of breading. They all have the ability to generate nectar but not seed. But these plants are apparently unaware of this so they just keep generating more flowers in a futile attempt to reproduce.. The result of this – and presumably this was the plant breeders intentions – is that they continually flower for many more weeks than their fertile relatives. This long-flowering also means they tend to score well in our ratings.

All this - contradicts the standard advice that sterile plants are not beneficial for bees. Sterile plants in this study included:

Sterile plant name	Rank out of 111
Helenium ‘Sahins early flower’	4th
Lavundula ‘Eidelweis’	9th
Agastache ‘Blue boa’	36th
Erysimum ‘Bowles mauve’	42nd

Table 2 - Ranking of sterile plants

It may be coincidence but this list includes plants that also extend the flowering season. Erysimum ‘Bowles mauve’ starts flowering very early – sometimes in March providing nectar for emerging solitary bees. Helenium ‘Sahins’ early flowerer’ will repeat flower – at a low level - into September keeping the season going for bumblebee queens that have not yet gone into hibernation

Figure 17 - Helenium ‘Sahin’s early flowerer’ flowering September with ivy mining bee

7.2 Impact of common gardening practices to extend flowering

Gardeners commonly employ some practices that are aimed at extending the flowering season of suitable perennials. These include:

- ‘dead-heading’ plants i.e. removing flower heads that have finished flowering.
- ‘Chelsea chop’: cutting some of the flowering stems in half typically end of May/early June before they have fully opened their flowers.

Both of these practices cause the plant to generate more flower for a longer period. These techniques mimic grazing animals and the plants respond by growing more flowers to ensure they generate enough seed. However, by generating more flowers my observation is that this also provides more bee-food. On some perennials, for example, the *Helenium* ‘Sahins early flowerer’, I tend to dead-head and remove the entire top of the flowering stem quite carefully after the first set of flowers; it responds by generating new flowering side branches and more flowers. This is a sterile plant and would generate some repeat flowers even if not cut but having tried cutting only half the patch. It was clear that the effect of trimming generate more flowers than if left alone. More importantly the half not cut attracted fewer bees.

7.3 Happy plants attract more bees

There are several plants that I suspect would be much better attractors of bees if they were grown in better soil. The following plants are ones that I have either struggled to grow at all or believe they are surviving but not 'happy' in our heavy clay:

- ***Agastache foeniculum*** – in some years, one or two plants will rot away and need to be replaced which tells me it is not ideally suited to the conditions. It survives with lots of added compost and a thick winter mulch of leaves to help it. In years where it grows strongly, it attracts more bees. The sterile *Agastache* 'blue boa' appears to be a bit hardier but not as attractive to bees as '*foeniculum'* in a good year.

- ***Perovskia*** – I have seen this growing well and covered in bees in RHS Wisley but cannot get it to thrive enough to fill a square meter. The best result I have had was from a single plant that had been chucked in the compost heap and left for dead where it grew and flowered happily from July onwards last year attracting a nice range of bees. Sadly I did not notice it in time to record viable data.

- ***Monarda*** – these plants are known for liking damp soil so when our clay dries out in mid-summer these struggle. They always produce some flowers but in dry years they seem not to produce much nectar and so fail to attract any bees; yet in wet summers they attract honey bees and bumblebees.

8 Conclusions from five years

After 7 years of hunting for plants that are highly attractive to bees and quantifying that, I am confident that these findings are meaningful. Each year has added to my understanding of the subject but most of the findings have stayed very consistent from the first year.

- The primary finding is that the number of bees each plant attracts varies hugely. Some attract surprisingly few, even supposedly 'bee-friendly' plants. This variation is significant for anyone wanting to maximize the amount of bee-food any area of land can provide.

- Weather has a major impact on both bees and plants causing them to thrive much more in some years than others. Yet, both are also very resilient and how attractive a plant is to bees should not be judged on a single year let alone a single observation.

- Both native and non-native plants are equally attractive to bees. Except where there is some unique inter-dependency, most bees show no favoritism to native plants and seek food where they can access it.

- Healthy plants with more flowers attract more bees. The old gardeners' adage of 'right plant for the right place' is important for both a sustainable garden and more bee-food

- Different plants attract different bees and so to ensure that food is supplied to a wide range of bees its best to have a wide range of flowers available. Although plant structure has a bearing on which plants each bee prefers, it is not the only factor. Hopefully, this study can help guide some plants choices.

Figure 18 - Osmia bicornis on dandelion

9 Future Research Plans

Having now completed this study there are still more plants to investigate. However I find far fewer new ones now than when I started. When I visit great gardens with well stocked herbaceous borders, I tend to only find one or two plants that offer strong potential for bees. Recommendations by email are also reduced. Even so, I will continue to seek out more plants that may be beneficial to pollinators, and to test them. But will publish these on an adhoc basis rather than commit to an annual report

Winter flowering plants and bulbs may be worth a specific study.

Through this experience, I have become more aware of other pollinators but I have really got the bug (ha ha!) for solitary bees and would like to invest some time identifying specific bee-plant interdependencies. I will continue to invest the many hours it takes to identify solitary bee species'.

In 2018 I also became an Bumblebee Trust 'beewallker' which involves walking the same route regularly and recording what bees were observed. This was an easy extension of what I have been doing and feels like a good way to link my data with something national.

Ideally, it would be good to attempt similar testing of plants in other locations to compare results. In 2015 I had a couple of volunteers who managed as small scale count over one summer – and I am very grateful to them - but it is difficult other to find the time to do this consistently. If anyone living on either peat or sandy soil would like to undertake a small-scale study, I would be delighted to engage with them.

Figure 19 - Lasioglossum albipes on Erysimum 'Bowles mauve'

10 Appendix 1 – Research method

Observations are taken at least once a week from the time that the first plants begin to flower and it is warm enough for the first bees to fly. This may be as early as March but has more often been late April or May. Observations continue until either there are no more flowers or it is too cold for bees; typically early October.

Observations are taken at times of day varying between 1100 and 1600. Days when it was either raining or extremely windy were avoided as there would simply have been no bees to observe in those conditions. This sometimes results in the gap between observations being either as little as 4 days or as great as 10 days but the plants were still observed on 25 days out of 30 weeks with the majority at weekly intervals.

The following variables are captured:

- Pollinator family group: honey bee, bumblebee (by species), solitary bees, hoverflies, butterflies/moths
- Weather: temperature, wind, sun/light levels
- Flowering fullness for each plant: Full, partial or marginal

10.1 Recording pollinator visits to plants

The method used for recording the numbers of bees and other pollinators that visited the flowers of each plant replicates the method established by Mihail Garbuzov and Francis Ratnieks at the Laboratory of Apiculture and Social Insects (LASI) at the University of Sussex during their research in 2011-12.

By following the same snapshot method, it is possible to make a fairly direct comparison between the insect visits recorded in this research and the results found by LASI.

Each week bees and other insects were simply counted as a snapshot. The observer approached each plant slowly and avoided casting any shadows that might disturb the insects, then quickly counted all insects observed noting the type. The counting on each plant area lasted no longer than approximately 20 seconds which minimised the risk of counting a single insect more than once.

If the number of insects exceeded 8, or if they were moving too fast to reliably count, it was found that the risk of counting the same insect twice increased or bee movement was simply too great to monitor as they moved between flowers. In these cases a second count of that plant would be made approximately 5 minutes later and an average of the two counts recorded.

In some cases, telling the difference between some visually similar bumblebees could not be done reliably without getting too close to avoid disturbing the bees and so photographs were sometimes taken and studied later for confirmation.

Flowering stage was also recorded and was defined relative to the maximum flowers for that plant, in that square meter. Even when in full flower, some plants naturally produce more flowers than others at the same time e.g. the flowers of a field scabious (*Knautea averensis*) tend to be very loose and on the end of long stems with up to 30cm space between flowers, where heleniums present a packed display, where the flowers are almost touching, producing a solid mass of colour. The actual density of productive flowers within the square meter was not recorded.

Where some plants could not be considered mature or did not grow to fill a full square meter the area was recorded as being only 0.5 of a square meter or an appropriate adjustment and bee numbers were then pro-rated to equate to a square meter. The same was applied where plants grew more than expected and, when in full flower splayed out to fill more than their allocated space.

The bees were recorded by each of the main groups: honey bees, bumblebees and solitary bees. Non-bee pollinators were grouped by butterfly/moths, hoverflies and a general bucket of 'other pollinators' for any other insects. Within the bumblebees an attempt was made to identify the most common species: *Bombus' terrestris, Lucorum, Paturom, Pascuirum, Hororum, Lapidaries* and 'other bumblebees'.

10.2 Origanums in this study

For the first 3 years of this study the patch of origanums was a mix of both a pink and white forms although I had no idea how this happened. But in 2017 I separated them and studied them separately. The result confirmed my suspicions that the white performed slightly better pink form. I was fairly certain the pink form was the native *Origanum vulgare* but I then had to work out where the white one had come from and so was not certain of its identity.

Having searched my records the most likely candidate seemed to be a purchase of some *Origanum onities* plugs which should be white flowering. So I bought some more only to find it flowered pink not white too. After several more tests it transpired that the one they sold me as common pink 'vulgare' actually flowered white! My supplier now agrees that they must have had some seed and naming confusion for some years.

Anyway the upshot of all this is an apology to readers of previous years results and the data has now been corrected to show the labels *Origanium vulgare* 'white' and *Origanum vulgare*, the latter being the common pink form. This matters because they consistently flower at different times and attract different numbers of bees. The data has now been corrected as much as possible and the blend for 2014-16 has been catergorised as the native pink vulgare as that was the majority with in the mixed patch.

11 Appendix 2 – Ratings for all plants studied per year

Rating value = average bees per square meter x weeks of flowering

Plant	2018	2017	2016	2015	2014	Average
Calamint	159.1	116.7	94.0	67.2		109.2
Helenium autumnale	97.6	90.0	78.0	152.0	69.0	97.3
Geranium rozanne	90.0					90.0
Helenium SEF	73.0	95.8	90.7	94.0	51.0	80.9
Borage (spring germinated)		84.0		55.0	97.7	78.9
Origanum vulgare white	53.0	89.0				71.0
Veronicastrum virginicum	78.0	105.0	40.0	99.0	30.0	70.4
Sedum spectabile	79.0	66.0	32.0	145.4	15.0	67.5
Lavandula eidelweis	67.0	95.0	47.0	55.0		66.0
Echium vulgare	34.2	36.0	66.6	113.4	70.0	64.0
Origanum vulgare	67.0	36.0	84.0	84.1	41.7	62.5
Centaurea scabiosa	80.0	43.0		56.0		59.7
Teucrium hircanicum	63.2	57.0	61.0	84.0	28.0	58.6
Aster novi belgii	103.0	41.0	28.0			57.3
Eryngium planum	58.0	58.0	76.0	30.0	26.4	49.7
Veronica spicata	41.8	44.0	44.0	67.0	46.0	48.6
Hyssopus		43.0	35.7	49.0	62.0	47.4
Lavandula sawyers	45.0					45.0
Nepeta racemosa	49.0	35.0	48.0	48.0		45.0
Helenium moorheim beauty	52.0	36.0				44.0
Eryngium giganteum	82.0	30.0	24.0	38.0		43.5
Stachys byzantina	0.0	54.2	40.0	70.0		41.0
Origanum onites	40.0					40.0
echinops star frost	36.0	66.0	17.0			39.7
Malva alcea	28.0	50.0				39.0
Lavandula grosso	47.0	28.0				37.5
Knautea macedonica	28.5	61.0	42.0	39.0	14.4	37.0
Succisa pratensis	44.0	28.1	14.0	56.3		35.6
Echium blue bedder		40.0		25.1	40.0	35.0
Scabioius columbaria	18.0	39.0	19.0	75.0	18.0	33.8

Plant	2018	2017	2016	2015	2014	Average
Agastache foeniculum	30.0	52.0	22.0	45.0	17.0	33.2
Phacelia SG		17.0	20.0	47.0	46.5	32.6
Rudbeckia fulgida	39.2	33.3	36.3	36.0	13.0	31.6
Melliot		30.0				30.0
Stachys sylvaticum	18.0	36.0	31.3			28.4
Salvia annual clary	28.0					28.0
Agastache blue boa		36.0	44.0	4.0		28.0
Eupatorium	18.0	3.0	32.0	54.0		26.8
Lavandula munstead	15.0	26.7	34.0			25.2
Borage (over-wintered)				26.3	22.8	24.6
Cosmos	21.3	33.0		18.0		24.1
Dahlia mignon		24.0				24.0
Erysimum Bowles Mauve	17.0	9.3	15.0	62.7	15.1	23.8
Verbena bonariensis	6.0	11.0	24.0	44.0	33.3	23.7
Lavandula angustifolia				33.0	14.0	23.5
Salvia nemorosa	22.7	32.0	9.0	37.0	14.0	22.9
Monarda Jacob Cline		18.7	26.7			22.7
Geranium pheaum	22.0	15.0	24.0	29.7		22.7
Cosmos brightlights	22.0					22.0
Knautea arvensis				30.0	14.0	22.0
Nepeta mussinii		31.7	5.0	30.0	21.0	21.9
Valerian	22.7	20.0				21.3
Echinacea purpurea	16.0	34.0	18.0	36.0	2.0	21.2
Rudbeckia speciosa		21.4	23.0	19.0		21.1
Centaurea montana	30.0	22.0	14.0	17.0	19.0	20.4
Chicory	20.0					20.0
Campanula harebell				34.0	4.0	19.0
Echinacea white	13.3	24.0				18.7
Stachys officianalis	15.0	12.0	19.0	27.0		18.3
Geranium pratense	12.0	22.0	20.0	16.0	19.0	17.8
Malva moschata	11.0	18.0		32.0	9.0	17.5
Anthemis tinctoria	10.7	26.0	14.0			16.9
Monarda didyma pink				25.3	7.0	16.2
Centaurea nigra				16.0		16.0

Plant	2018	2017	2016	2015	2014	Average
Geranium magnificum	16.0					16.0
Dahlia bishops	7.0	22.0				14.5
Verbascum sixteen candles	20.0	9.0				14.5
Allium schoenoprasum	29.0	15.6	6.0	15.0	4.0	13.9
Cerinthe major	13.0	14.0				13.5
Geranium macrorrhizum	10.0	8.0	8.7	24.0		12.7
Allium nectaroscordum	12.0					12.0
Cirsium heterophyllum		12.0				12.0
Geranium cantabridgense	10.0	6.0	12.0	18.2		11.5
Solidago canadensis	21.0	6.7	2.0	15.0		11.2
Doronimum caucausicum				20.0	2.0	11.0
Digitalis		2.0	13.0	21.0	6.0	10.5
Calendula	22.7			6.0	2.0	10.2
campanula carpatica			10.0			10.0
Campanula perscifolia	21.3	9.3	5.3	11.0	3.0	10.0
Lavandula stoechas			7.0	20.0	2.0	9.7
Geranium spinners	9.3					9.3
Allium roseum	11.0	12.0	6.8	10.0	4.0	8.8
Lavandula little lottie	10.0	6.7				8.3
Buphthalmum		8.0				8.0
Calendula oopsy daisy		8.0				8.0
Limnathes douglasii	8.0					8.0
Pulmonaria		8.0	10.0	6.0		8.0
Scabious japonica	6.7	12.0	3.3	8.0		7.5
Anemone hupehensis	10.0	4.0				7.0
Aster amellus				12.0	0.0	6.0
Ageratum		5.3				5.3
Cirsium rivulare	4.0	6.7				5.3
Sweet William	11.0	0.0	0.0	10.0		5.3
Cheiranthus cheirii	10.0		5.3	2.0	2.0	4.8
Teasel			5.0	9.0	0.0	4.7
Salvia bienial clary	6.7			2.0		4.3
Centaurea dealbata			4.0			4.0
Geranium oxonianum	4.0					4.0

Plant	2018	2017	2016	2015	2014	Average
Kniphofia				4.0		4.0
Monarda didyma red				4.0	4.0	4.0
Erysimum Winter joy				2.0	4.0	3.0
Verbascum phoeniceum				4.0	2.0	3.0
Papaver orientale			1.0	2.0	4.0	2.3
Allium unifolium	4.0	2.0	2.0	2.0	1.0	2.2
Leucanthemum vulgare		2.0	1.0	5.0	0.0	2.0
Thymus vulgare		2.0				2.0
Forget me not	3.0	2.0	0.0	2.0		1.8
Centranthus rubra				2.0	1.0	1.5
Cleome	0.0					0.0
Red Campion				0.0		0.0

Table 3 - Ratings for all plants studied per year

12 Appendix 3 – Rosybee species sightings

12.1 Bee species sightings

Location: East Hanney, Oxfordshire, OX12 0FH (51.636634, -1.389445)

Bees	Species	Common name	Last seen
Andrena	bicolor	Gwynnes Mining	2018
Andrena	chrysosceles	Hawthorn Mining	2018
Andrena	cineraria	Ashy Mining	2018
Andrena	dorsata	Short Fringed Mining	2018
Andrena	flavipes	Yellow Legged Mining	2018
Andrena	fucata	Painted Mining	2017
Andrena	haemorrhoa	Orange Tailed Mining	2018
Andrena	labialis *	Large Meadow Mining	2018
Andrena	nigroaenea	Buffish Mining	2018
Andrena	nitida	Grey Patched Mining	2018
Andrena	scotica	Chocolate Mining Bee	2018
Andrena	wilkella	Wilke'S Mining	2018
Anthidium	manicaturm	Wool Carder	2018
Anthophora	furcata	Fork-Tailed Flower Bee	2018
Anthophora	plumipes	Hairy Footed Flower	2018
Anthophora	quadrimaculata	Four-Banded Flower	2018
Apis	mellifera	Honey bee	2018
Bombus	barbutellus	Barbuts Cuckoo	2018
Bombus	campestris	Field Cuckoo	2018
Bombus	hortorum	Garden	2018
Bombus	hypnorum	Tree	2018
Bombus	lapidarius	Red Tailed	2018
Bombus	lucorum	White Tailed	2018
Bombus	pascuorum	Common Carder	2018
Bombus	pratorum	Early	2018
Bombus	ruderarius	Red Shanked Carder	2017
Bombus	ruderatus	Large Garden	2018
Bombus	rupestris	Red Tailed Cuckoo	2018
Bombus	terrestris	Buff Tailed	2018
Bombus	vestalis	Vestal/Southern Cuckoo	2018

Bees	Species	Common name	Last seen
Chelostoma	campanularum	Small Scissor Bee	2018
Chelostoma	florisomne	Large Scissor Bee	2018
Coelioxys	elongata	Dull-Vented Sharp-Tail	2018
Colletes	daviesanus	Davies'	2018
Colletes	hederae	Ivy Mining	2017
Colletes	similis	Bare-saddled	2017
Halictus	rubindicus	Orange Legged Furrow	2017
Halictus	tumulorum	Bronze Furrow	2018
Hylaeus	communis	Common Yellow Face	2018
Hylaeus	confusus	White Jawed Yellow Face	2018
Hylaeus	dilatatus	Chald Yellow Face	2018
Hylaeus	hyalinatus	Hairy Yellow Faced	2018
Lasioglossum	albipes	Bloomed Furrow	2018
Lasioglossum	calceatum	Common Furrow	2018
Lasioglossum	fulvicorne	Chalk Furrow	2018
Lasioglossum	leucopus	White-Footed Furrow	2018
Lasioglossum	leucozonium	White Zoned Furrow	2018
Lasioglossum	morio	Green Furrow Bee	2018
Lasioglossum	pauxillum	Lobe-Spurred Furrow	2018
Lasioglossum	smeathmanellum	Smeathman's Furrow	2017
Lasioglossum	villosulum	Shaggy Furrow Bee	2018
Megachile	centuncularis	Patchwork Leafcutter	2018
Megachile	ligniseca	Wood-carving leafcutter	2018
Megachile	versicolor	Brown footed	2018
Megachile	willughbiella	Willughby'S	2017
Nomada	flava	Flavous	2018
Nomada	goodeniana	Goodens Nomad	2018
Nomada	lathburiana	Lathbury's	2018
Nomada	marshamella	Marsham's	2018
Nomada	panzeri	Panzer's	2017
Nomada	ruficornis	Forked-jawed	2018
Osmia	aurulenta *	Gold-fringed	2018
Osmia	bicolor	Red-Tailed Mason Bee	2018
Osmia	bicornis	Red Mason	2018

Bees	Species	Common name	Last seen
Osmia	caerulescens	Blue Mason	2018
Osmia	leaiana	Orange-Vented Mason	2018
Sphecodes	ephippius	Bare Saddled Blood Bee	2018
Sphecodes	geoffrellus *	Geoffroys Blood Bee	2018
Sphecodes	monilicornis	Boxed-headed	2018

Table 4 - Bee species sightings

12.2 Butterfly & Moth sightings

Butterfly / Moth	Common name	Last seen
Butterfly	Brimstone	2018
Butterfly	Brown argus	2018
Butterfly	Comma	2018
Butterfly	Common blue	2018
Butterfly	Gatekeeper	2018
Butterfly	Green veined white	2018
Butterfly	Holly blue	2018
Butterfly	Large heath	2018
Butterfly	Large skipper	2018
Butterfly	Large white	2018
Butterfly	Marbled white	2018
Butterfly	Meadow brown	2018
Butterfly	orange tip	2018
Butterfly	Painted lady	2017
Butterfly	Peacock	2018
Butterfly	Red admiral	2018
Butterfly	Ringlet	2018
Butterfly	Small copper	2018
Butterfly	Small heath	2018
Butterfly	Small skipper	2018
Butterfly	Small tortoiseshell	2018
Butterfly	Small white	2018
Butterfly	Speckled wood	2018
Moth day	Cinnibar	2018

Butterfly / Moth	Common name	Last seen
Moth day	Clouded border	2017
Moth day	Common swift	2018
Moth day	Ghost moth	2018
Moth day	Hummingbird hawkmoth	2017
Moth day	Mint moths	2018
Moth day	Mother Shipton	2018
Moth day	Narrow bordered 5-spot burnet	2018
Moth day	Red underwing	2017
Moth day	Scarlet tiger	2018
Moth day	Silver Y	2018
Moth day	Small magpie	2018
Moth day	Small yellow underwing	2018
Moth day	White ermine	2018
Moth day	Yellow underwing	2018
Moth night	Angle shades	2018
Moth night	Euthrix potatoria	2018
Moth night	Feathered thorn	2017
Moth night	Green brindled crescent	2017
Moth night	Pale november	2017
Moth night	Secaceous hebrew	2017
Moth night	The drinker *	2018
Moth night	Triangle plume moth	2018
Moth night	White plume moth	2018

Table 5 - Butterfly and Moth sightings

13 Appendix 4 – About rosybee

13.1 About Rosi and the nursery

Having been a passionate plantswoman and gardener all my life, in 2010 my husband and I became honey bee keepers. Naturally, we did a bit of reading about bees and quickly became aware that they appeared to be under threat that they are an essential part of our eco-system and so their health is important stuff.

The horticulturalist in me wanted to know which plants to grow to help the bees and so I started to seek out information. I found lists but not much guidance or many suppliers. So, we decided to set up our own supply as well as a site for trialing plants to see which plants the bees seem to like best. That was the beginning of the research we are now publishing.

The nursery has been trading since 2012 and is a source of both plants and advice to meet the growing interest in bees from both gardeners and landowners. The business trades mainly through the website and we sell our plants in trays of 6 or 10 to encourage planting in blocks because that's what the bees prefer.

We pride ourselves on only selling plants that we believe will help gardeners to maximize the support they can give to bees.

14 Appendix 5 – Personal note about this study

Over the years of this study I have found that my attitudes to plants have changed and that I can no longer appreciate plants on a purely aesthetic basis when there are so many beautiful and viable plants available. I hope that plant breeders and judges will also consider pollinators more in the future when developing new plants.

Also, as a keeper of honey bees, I am now planning to keep fewer bees because I am concerned that, in times of flower shortages, honey bees out-compete wild bees. Honey bees are not a viable substitute for the full range of specialist pollination services that wild bees provide, so it's important that we do not add any further pressure on wild bees' ability to thrive. More research is required to understand this balance but provision of more flowers as food for all pollinators will never be a bad thing!

If you are a honey beekeeper please consider the local floral resources and how many other hives are in the vicinity before deciding to add more. There is currently no clear advice or policy on how many bee-hives per square mile but it's now acknowledged that intensive farming has depleted many traditional forage resources and so to avoid causing catastrophic harm to our native bees, 5 hives per square mile may be a sensible limit.

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