UNIVERSITY OF SUSSEX

# Plant-Pollinator Relationships in a Rewilded Landscape

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## Abstract

**There has been a notable increase in awareness and concern for the state of global biodiversity in the 21st century. This has brought about the development of new conservation strategies, particularly restorative ecological approaches to land management. A method that is growing in popularity is rewilding. Rewilding is a conservation tactic aiming to restore ecosystem services through nature led processes, such as grazing. This method is often criticised by the scientific community, and certainly contains some flaws. However, the results produced in rewilded areas prove that some methods can be highly beneficial to degraded habitats such as intensively farmed marginal land. Pollinator populations are in decline globally, with habitat destruction and fragmentation driving species to extinction. Rewilding of abandoned or low-quality farmland can provide essential foraging and nesting habitats for vulnerable species through an increase in wild vegetative diversity. The objective of my study was to assess the relationship between pollinator species present at Knepp estate in West Sussex and the flowering vegetation available to them for foraging. I aimed to assess the differences in species presence and foraging choice, dependent on the vegetation type in each sample field. Pan traps were set out daily in 3 fields, at 3 sites in each in order to assess the spread of species visiting the fields. Sweep netting was carried out in each field, to collect samples of insects found foraging on flowering plants through the study period. These were later used to form species interaction plots displaying the relationship between pollinators and plants in each site. Results suggest that solitary bee species such as *Andrena* require more specific foraging resources, whereas *Bombus* and *Apis* species are more generalist, utilising a wider variety of floral plant species across the site. Floral structures with more challenging access routes to pollen and nectar, such as *Iridaceae* species, benefit large *Bombus* species. Open structures such as those of *Rubus fruticosus* are highly beneficial to a wide range of pollinators. This study suggests that a diverse range of floriferous plant species are required in order to support native pollinators.**

# 1. Introduction

### i) Biodiversity loss

It is estimated that 25% of all assessed animal and plant groups are threatened with global extinction due to human activity and climate change. This is around 1 million species across the globe (IPBES, 2009). Biodiversity has huge intrinsic value to the human population, providing food resources, medicine and oxygen production to name but a few. Most indicators of species diversity have shown a constant decline since records began. However, the intensity of pressures upon ecosystem health, such as resource consumption, invasive species introduction, and nitrogen pollution, is increasing rapidly (Butchart, et al., 2010). Soil microbial health and vegetative heterogeneity are the basis of fully functioning ecosystems, with 25% of the worlds total organisms being found in the earth (European Commission, 2010).

### ii) Pollinators

Since the 1950's, the number of wild pollinator groups in Britain has changed dramatically, with most reducing in number (DEFRA, 2014). This includes bumble bees, solitary bees, and hoverflies. Pollination is required by most angiosperms in order to fertilise reproductive organs and produce fruits or seeds. This interaction is highly valuable to both the plants and the pollinators, with an exchange of goods occurring in the form of pollen and nectar taken in return for pollination (UN, FAO, 2009). However, although wild honeybees have also been declining, the number of managed honey bee populations in the UK has increased since 2007 (Defra, 2014).

Awareness of our fundamental dependence on both wild and managed pollinators is increasing. However, numbers across the world are still in decline (Gallai, 2009). This is due to varying environmental and anthropogenic pressures, such as invasions of non-native species, a global transition from mixed farming to monoculture crops, and a lack of plant diversity in buffer zones and field margins due to broad-leaf herbicides (Boutin, et al., 2013).

The UK has undergone an intense regime of agricultural intensification since the 1940's (Zalasiewicz, et al., 2015). To accommodate the use of large industrial machinery in fields, thousands of miles of hedgerow were removed from the mid-20$^{th}$ century onwards and the vegetative diversity formally found between fields was lost (Vanbergen, et al., 2014). Semi-natural grassland was a valuable habitat for a variety of UK native species, however this has also undergone major decreases across England. It is estimated that 47% of semi-natural grassland was lost between 1967 and 2013 after being converted into intensively managed grassland and arable pasture (Ridding, et al., 2013). If current rates continue, habitat loss and fragmentation will continue to force declines in wild bee numbers. While wild pollinators are essential for the pollination and reproduction of wild vegetation, managed honey bee colonies are an essential component of agricultural systems, with enormous monetary value (Losey, Vaughan, 2006). Pollinators, both wild and managed, are responsible for the vast majority of agricultural crop pollination (Vanbergen, et al., 2014)) and were estimated to provide €153 billion worth of pollination services to agricultural crops in 2005(Gallai et al., 2005). They are an integral component of the ecosystem and provide an essential service to the industry. Particularly in the USA, some crops are wholly dependent on managed honey bee populations, such as Almonds and Avocados (FAO, 2009).

### iii) **Rewilding**

Rewilding is a modern, ecologically restorative approach to conservation (Svenning, et al., 2016). This method is based upon the archaeological and palaeontological evidence of a landscape. Rewilding methods aim to restore ecosystem functionality through reassembly of trophic levels and reintroduction of previously present large mammals (Jepson, 2015). Rewilding requires defined stages in order to identify the habitat requiring restoration, the ecosystem functions that can be restored, and identifying suitable species for reintroduction (Sandom, et al., 2013). As a concept, rewilding has increased in awareness and as a legitimate habitat restoration technique in the past 20 years. Evidence of its effectiveness, even unintentionally, is apparent in Europe, where land abandonment is increasing due to rural populations moving towards urban centres (Monbiot, 2015, Svenning, et al., 2015). The land that is left unmanaged can gradually restores itself with little to no human interference, depending on the type of habitat that is left, and the ecological influences surrounding it (Benjamin, et al., 2005). Evidence of ecological succession can be seen through pioneer species such as lichens returning (Nimis, et al., 2002), and an increase in vegetative diversity. Despite its growing popularity, very little rewilding research focuses on the effect this conservation method has on pollinator species and their interactions with flowering plants. The sensitivity of wild pollinator species such as bumble bees means they can be an interesting indicator of vegetative diversity and foraging availability in a landscape.

### iv) **Knepp Estate**

Currently, the most extensive survey which attempts to quantify the effects of rewilding on pollinators is the 2005 baseline study at Knepp Rewilding Estate in West Sussex (Greenaway, 2006). Knepp estate is a 3500-acre former dairy farm which has been transformed from traditional agricultural methods into a pioneering rewilding project over the past 20 years. Knepp was intensively farmed during the second world war and continued to undergo intensive agricultural modernisation from that time. Due to the nature of the heavy Weald clay soil found on the estate, production of crops and pasture land for cows was extremely challenging, with the land becoming impassable during heavy rain and rock hard in dry spells (Tree, 2017).

The owner of the estate initially chose to restore the Repton Park style part of the estate surrounding the castle in 2001, and having seen the success this area had, fenced off the remaining areas and halted intensive farming altogether (Lawton, 2018). Gradually, the owners introduced large herbivores in order to graze down competitive grass species and encourage smaller, less competitive native plant species.

The baseline study undertaken in 2006 identified 12 species of bee using pitfall traps. Amongst the species identified were *Bombus terrestris,* the only bumble bee caught, and 7 species of *Lassioglossum.* Due to pitfall traps being the only method used to trap insects, this record only provides a limited depiction of the bee species found at Knepp (Greenaway, 2006).

## 2. Hypotheses

The aim of this study is to assess the relationship between flowering plant species at Knepp, and the bee species that use them for foraging. I aim to assess whether the relationship differs depending on the vegetation type and field sampled. The hypotheses for this study are:

i) Increases in vegetative diversity through rewilding will increase bee abundance.

ii) Fields with a higher incidence of dicot plant species will have a greater bee population presence.

## 3. Methodology

My study was conducted in the Southern block of Knepp estate, a 3500-acre former dairy farm in West Sussex, Grid Ref: (TQ 15034 20431), between May 20th and June 14th, 2019. The southern block is around 1100 Acres overall, with fields taken out of agricultural production between 2000 and 2006. All fields in this block are undergoing rewilding methods currently, except for a few that have been kept as permanent pasture, meaning they are mowed once every 3 years to encourage grass growth and keep vegetation height low. Three fields were selected for the study, due to their differing habitat types. The fields chosen were Twenty-Seven Acres, a field set aside in 2005 which is now exhibiting the vegetative traits of a scrubland mosaic habitat. Secondly, a field called Woggs Bottom, which is primarily covered by a mixed woodland plantation planted in the 1990’s. Lastly is Wild Flower Meadow, a field set aside to permanent pasture.

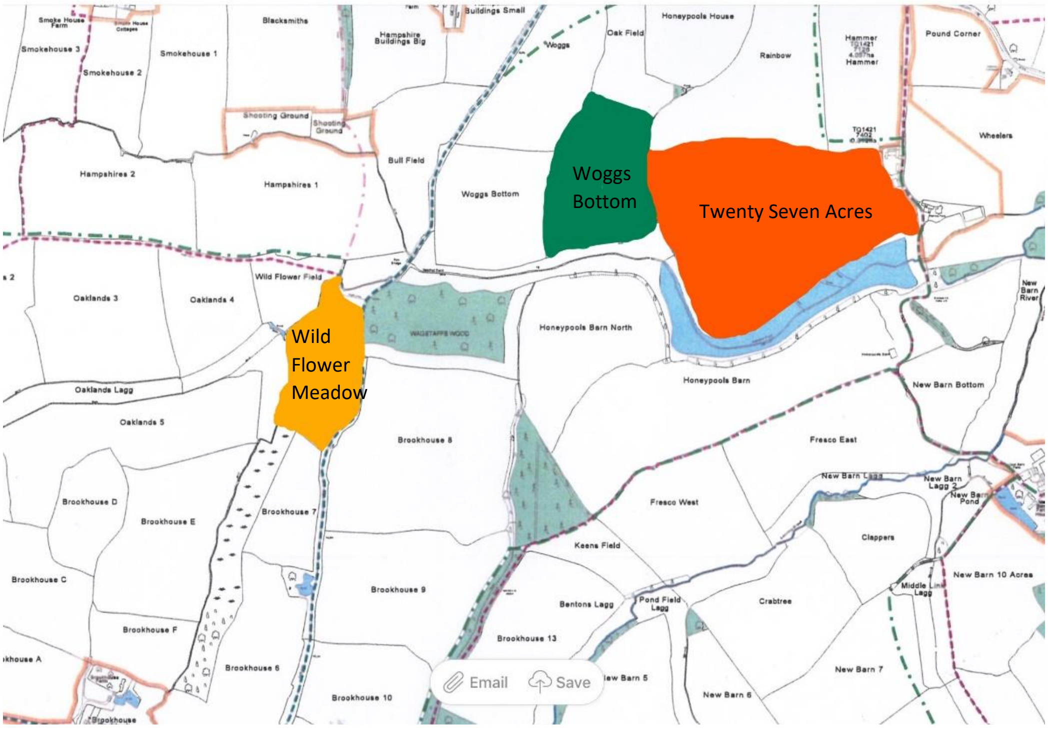


**Figure 1.**

This image illustrates field boundaries and names in the Southern block of Knepp. The 3 sample sites are highlighted, chosen due to their differing habitat types.

i) **Field Sites**

The mid-successional stage site, Twenty-Seven Acres, was chosen due to the vegetation in this field being relatively far on in the process of succession, having been given over to rewilding in 2005. Some parts of the field, particularly those closest to the Hammer Pond, are almost completely covered with tall shrubs and trees such as Hawthorn (*Crataegus monogyna)* and Blackthorn (*Prunus spinosa).*

A site primarily covered with plantation woodland, Woggs Bottom, has been primarily covered with plantation woodland since the early 1990's, however the area surrounding the woodland, a strip around 10m wide around 2 sides, has been left to restore itself since 2003. This strip of land remains open, with relatively low vegetation height and limited flowering plants, possibly due to the high incidence of herbivores found in this field grazing and sheltering their young in the woodland.

The final site, an area of permanent pasture called Wild Flower Meadow is an area of permanent pasture, undergoing systematic mowing at tri-yearly intervals. Primarily, this field comprises of low-level vegetation such as perennial grasses. There is a small fenced plantation of oak saplings towards the centre of the field. To one side there is a substantial pond, which has been left to cover with aquatic plant species such as Yellow Flag Iris *(Iris pseudacorus)*, and Horsetail (*Equisetum)*, providing an interesting factor when assessing pollinator presence.

ii) **Sampling Methods**

**Figure. 2**
**Pan Traps were set up in each field in sets of 3.**

**Pan Trapping**

Pan Traps were placed in a randomly allocated 1000m$^2$ transect in each field. They were placed in groups of 3, at 3 sites in the transect. The total number of pan traps set out each day across the sites was 27. I chose bowls 18cm in diameter and one of each colour, blue, pink and yellow, in order to attract insects that would potentially land on different coloured flowers (Saunders& Luck, 2012). Each pan was filled to around 2/3 full of water and a dash of eco-friendly washing up liquid in order to break the surface tension, enabling any light insects to sink into the water. As much foam as possible was removed from the surface as this can be used by insects to climb out of the trap. The traps were left each day for 24 hours, specimens were then collected in the morning. As my study focuses on pollinators, only bee, wasp species were collected and taken back to our base to identify. All bee species were identified to species level and pinned on a foam board for later assessment and species confirmation (Morandin& Kremen, 2013).

**Sweep Netting**

I used a triangular, extendable sweep net to sweep areas of each field site, aiming to collect samples of different pollinator species found on the sites over my sample period. I swept areas such as covered scrubland, thickets of bramble, open grassland, and flowering trees, in order to gain an indication of which plant species were being visited most, and by which species. Once an insect or group of insects were caught, they were slowly encouraged into a sample pot in order to be identified or euthanised as a pinned sample. Once an insect required for pinning was safely in the sample pot, forceps were used to pick up a roll of paper soaked in Ethyl Acetate, a strong sedative, which was then quickly dropped into a gap between the pot and its lid and closed again in order to gently euthanise the insect. Samples were then returned to our research base, identified and pinned using entomological pins.

**Static Floral Observations**

I conducted floral observations in each field site, ensuring I observed every floral species in bloom at the time. I stood for 10 minutes, observing a $1m^2$ area of flowers if possible, recording the species and number of visitations over the 10-minute period. I can then compare these, providing an indication of which floral vegetation was preferred and by which species.

**Vegetation Surveys**

To create an accurate representation of the vegetation types found in each sample site, I recorded vegetation surveys. A $1m^2$ quadrat was randomly thrown within the marked $1000m^2$ transect, and each plant species found within the quadrat was identified to species level and marked as a percentage of cover out of 100 (Baxter, 2014). I also noted down every flowering species I found in the field sites, as not all were inside the quadrats, or $1000m^2$ transect.

All sampling results have been recorded on a Microsoft Excel spreadsheet, and in tables.

## 4. Statistical Analysis

All statistical analysis was carried out using R Software (Version 3.6.1), package Bipartite. This package was used to create species interaction plots, illustrating the relationship between each pollinator and the flowering plant species they were caught on.

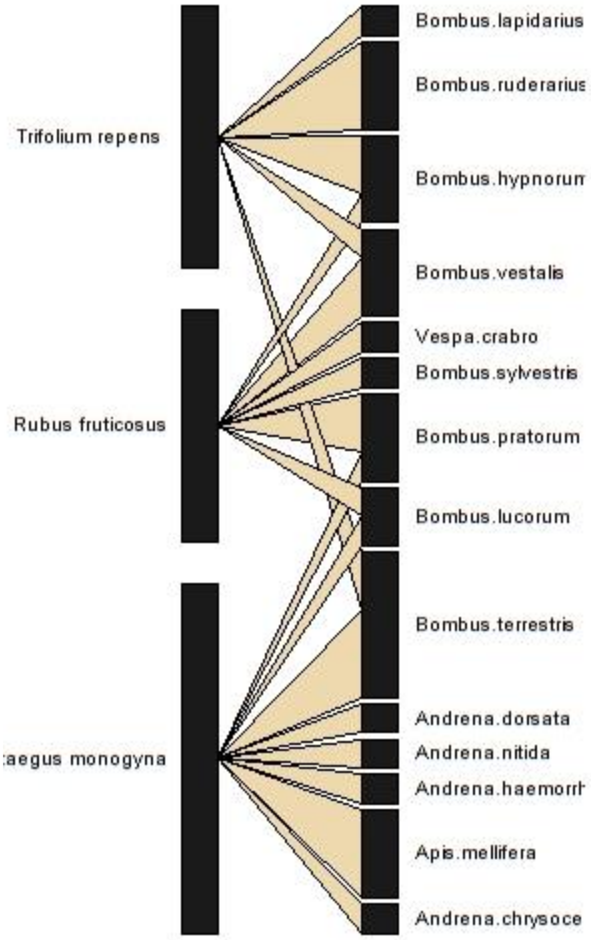


**Figure 3. Twenty-Seven Acres Interactions**

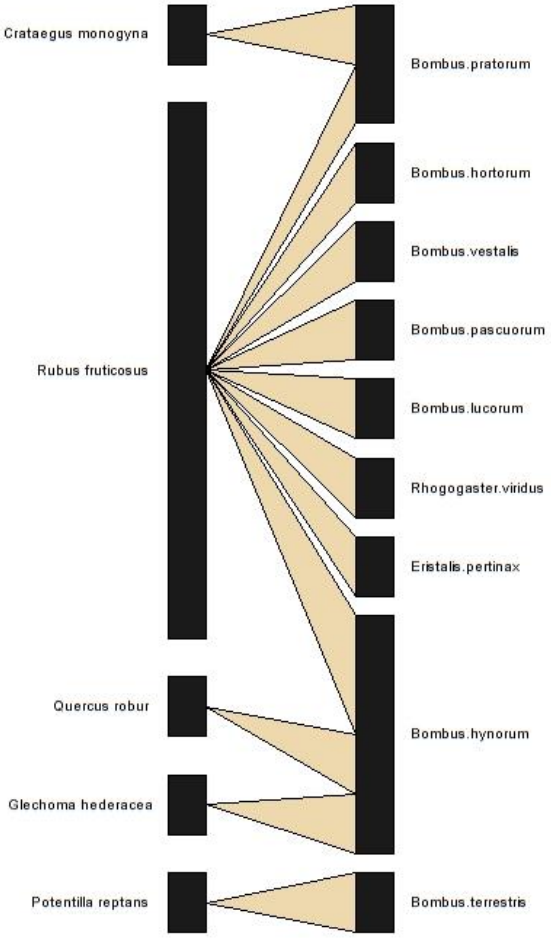


**Figure 4. Woggs Bottom Interactions**

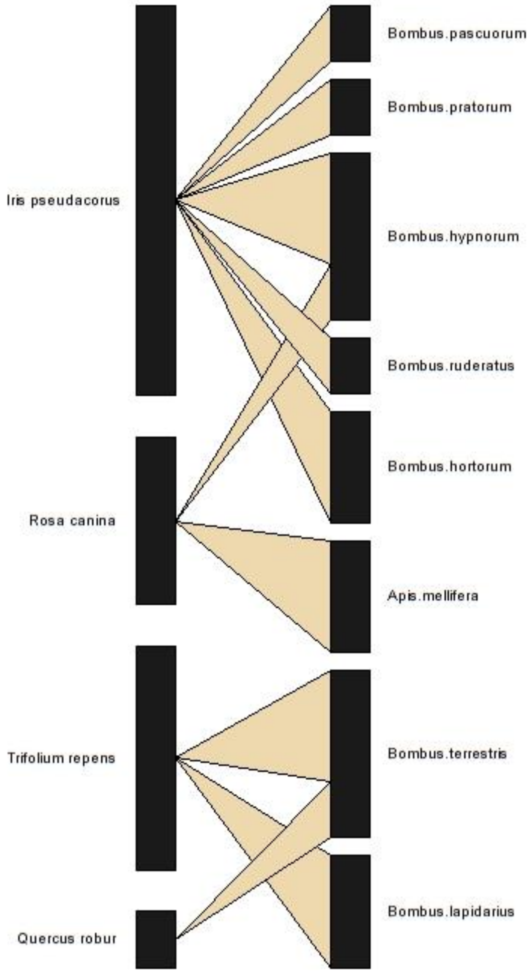


**Figure 5. Wildflower Meadow Interactions**

Species interaction plots are used to illustrate ecological relationships, particularly between pollinators and vegetation. Relationships between pollinators and the flowering species they visit is clearly defined by shaded triangles linking each insect species with the flower they were caught on while sweep netting. Each model differs substantially, both in flowering plant species present and the pollinators found on them.

Figure 3 presents the results of sweep netting in mid-successional vegetation. This site has the largest spread of species, with a relatively even distribution of captures across the three flowering plant species. However, solitary bee species such as *Andrena chrysoceles* were found solely foraging on hawthorn (*C. monogyna)* shrubs. *Bombus lapidarius* was only found foraging on white clover (*T. repens)*, indicating that this is the sole foraging resource for this species in the area.
Figure 4 presents the results of sweep netting the vegetation surrounding a mature plantation woodland. This model illustrates a high incidence of pollinators on bramble (*R. fruticosus)*, particularly *Bombus* species, and far less reliance upon hawthorn (*C. monogyna)* than figure 3. *Bombus hypnorum* was a less specific bee, found foraging on several plant species such as Ground Ivy (*Glechoma hederacaea)* underneath the trees in Woggs Bottom.
Figure 5 represents the species interactions found in the site of permanent pasture. Although this site was primarily open grazed ground, results were influenced by the pond area included

in this field. Bumble bee species favoured the Yellow Flag Iris (*Iris pseudocarus)* found in the pond margins, with a diverse range of species found foraging on the flowers throughout the study. White clover (*T. repens)* was again visited primarily by *Bombus lapidarius* on this site.

## 5. Results

In total, 58 pollinators were caught using sweep net methods. Pan traps were less specific and therefore caught non-target insect species. However, focusing on the target species, 57 pollinators were caught overall.

The most common species caught in the mid-successional site was *Bombus terrestris*, with 16 individuals caught through sweep netting and pan traps. In the site covered primarily with plantation woodland, the pollinator of highest incidence was *Bombus hypnorum,* with 5 individuals caught. Lastly, the most commonly caught species in the site of permanent pasture were *Bombus hypnorum* and *Bombus terrestris,* 3 of each being recorded. Overall, the mid-successional site, Twenty-Seven Acres, had the highest number of specimens caught and the greatest diversity of species.

### i) Sweep Net Captures

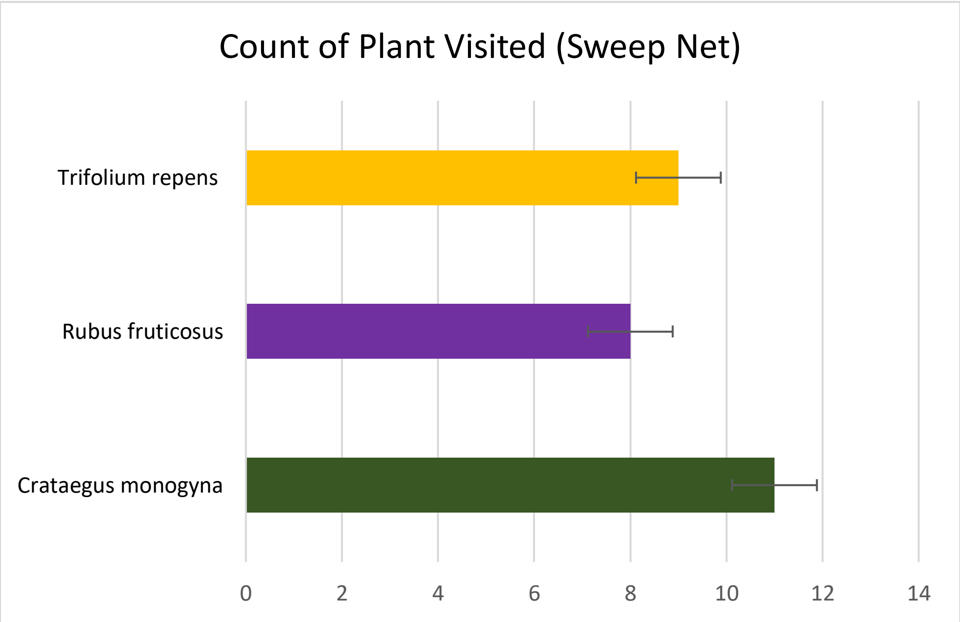


**Figure 6**. This is a count of which flowering plants were most successfully sweep netted throughout the study. The highest number of sweep net captures was on hawthorn (*C. monogyna)*, closely followed by white clover (*T. repens)* and bramble (*R. fruticosus).* Pollinators were caught on other plant species however these species had the most significant counts throughout the study. The results were partly influenced by which plant species were in flower at different times over the sample period. The relationship between hawthorn (*C. monogyna)* and pollinators is reinforced by this result.

## ii) Pan Traps

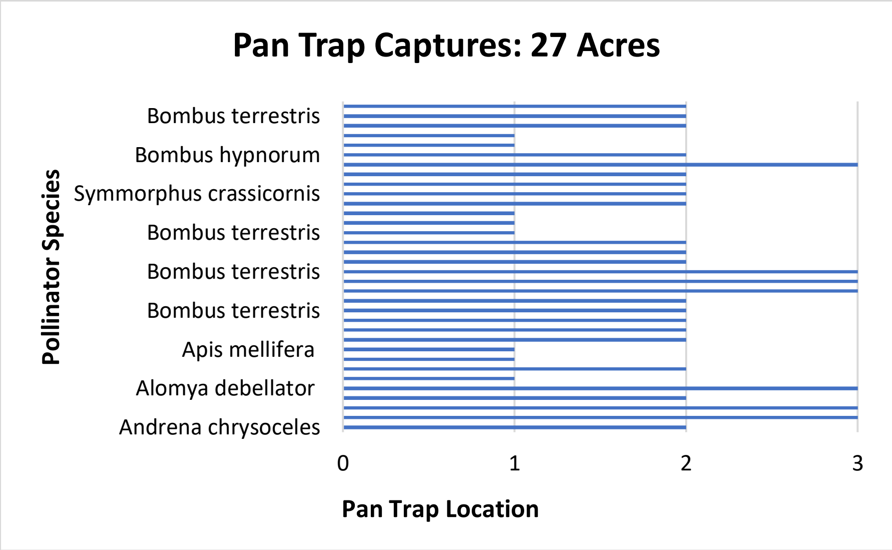


Figure 7.

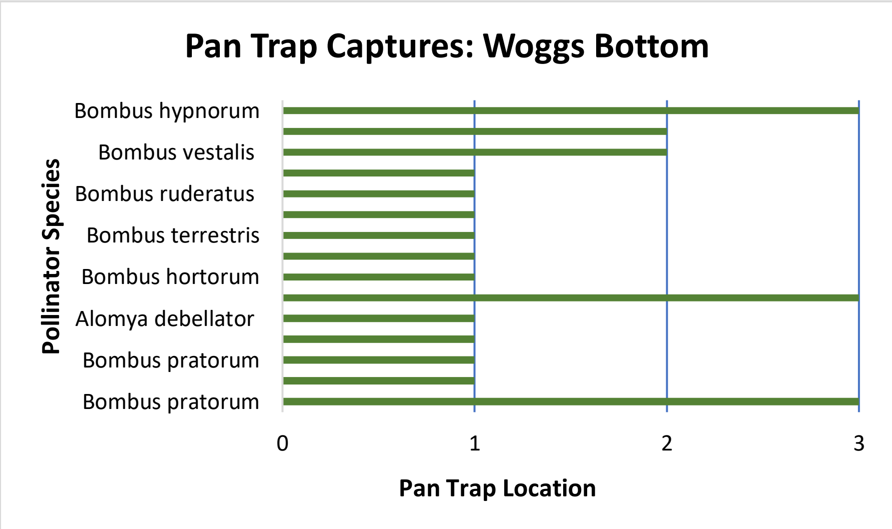


Figure 8.

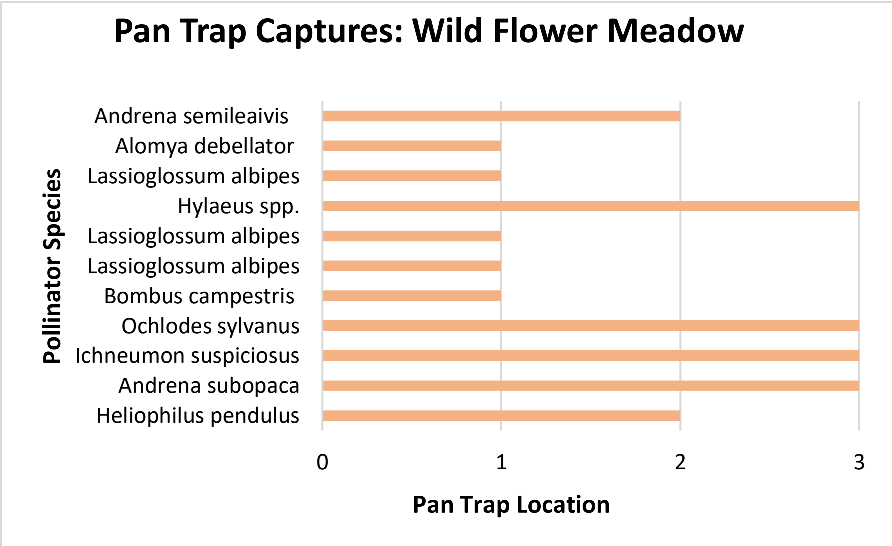


Figure 9.

Figures 7,8 and 9 illustrate the spread of species over each field by which pan trap they were found in. Figure 7 clearly illustrates the highest number of pollinator species found in the pan traps, with particular focus on pan trap 2 which was placed towards the centre of the transect. The traps in this site also have the highest rate of repeated species capture, with *Bombus terrestris* being caught 17 times. Figure 9, the site of permanent pasture, has the largest species diversity of all sites, with 9 pollinator species caught over the sample period.

## iii) Vegetation Surveys

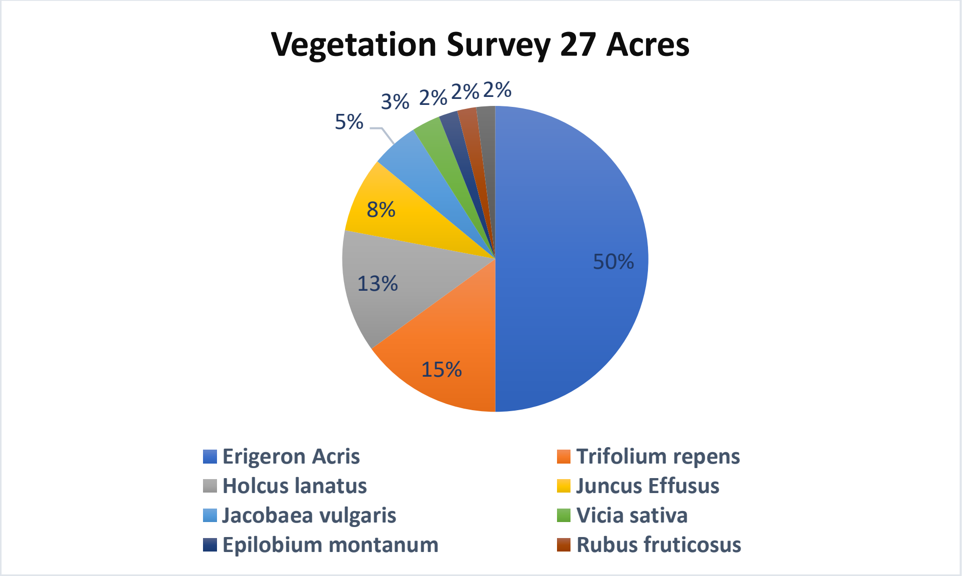


**Figure 10.**

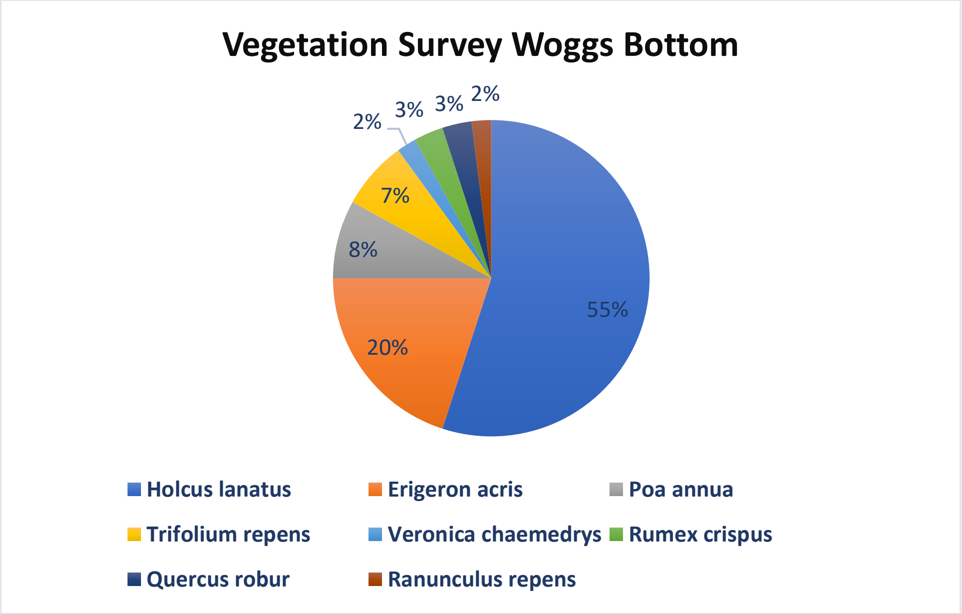


**Figure 11.**

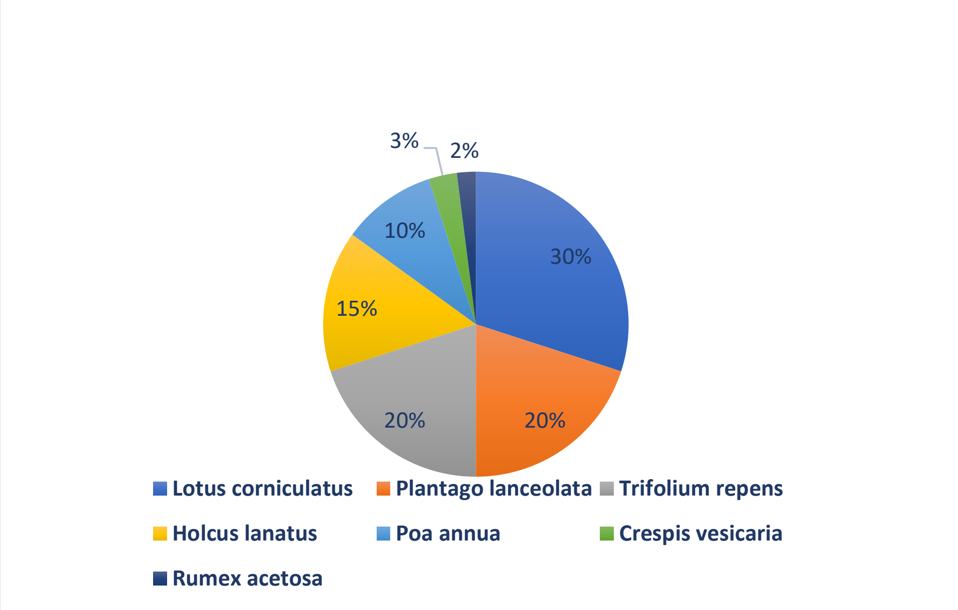


**Figure 12.**

The above pie charts illustrate the vegetative cover of plant species recorded during a quadrat survey of each field site. Twenty-Seven Acres, the site which has been undergoing rewilding processes for the longest, had relatively high plant diversity, with 9 species found here. Fleabane (*Erigeron acris)*, a pioneering, low level, successional plant was prevalent in the surveys, covering 50% of the surveyed area in Twenty-Seven Acres. Increases in vegetative diversity are found across the estate, however Yorkshire fog (*Holcus lanatus)*, a perennial grass species, remains by far the most dominant ground cover in the plantation woodland site, with 55% cover. The surveys of permanent pasture vegetation found a relatively even distribution of low-level perennials. Birdsfoot Trefoil (*Lotus corniculatus)*, ribwort plantain (*Plantago lanecolata)* and white clover *(Trifolium repens)* all possessed similar cover levels.

## iv) <u>Floral Observations</u>

I carried out static floral observations of all flowering species present in my study fields, both inside and out of the 1000$m^2$ transect used for vegetation surveys. Some flowering plants were far more regularly visited than others. No visitations were recorded to elderflower (*Sambucus nigra)*, silverweed (*Potentilla anserina)* or water violet (*Hottonia palustris*). The most regularly visited flowering species strongly correlated with which plants were most successfully sweep netted. The highest number of visitations, primarily for foraging, was on bramble (*Rubus fruticosus)* and white clover (*Trifolium repens)* later in the study period, which was foraged predominantly by red tailed bumble bees (*Bombus lapidarius).* Yellow flag iris was also used regularly for foraging, particularly by larger bumble bee species such as the common carder bee (*Bombus pascuorum)*.
The emergence of queen bumble bees increased the observed competition for foraging opportunities, particularly on bramble (*R. fruticosus)*. Throughout the observations, queen bumble bees were seen jostling for position on the blooms, pushing away workers and

smaller insects. Honey bees (*Apis mellifera),* were observed primarily on hawthorn (*Crataegus monogyna),* earlier on in the study period. Far fewer were observed once the hawthorn had begun to finish flowering, only being observed on dog rose (*Rosa canina)* on the hottest days.

There was a clear shift in reliance upon flowering plant species over time, the relationship between pollinators and their foraging preferences visibly altering through the season. *Bombus hortorum* were observed on low-level vegetation such as ground ivy (*Glechoma hederacaea)* in the plantation woodland site, remaining close to the ground for long periods of time. Smaller species such as honey bees (*A. mellifera)* were not observed on low-level vegetation, instead focusing on taller flowering plants such as hawthorn (*C. monogyna).* The site of permanent pasture, wild flower meadow, became a more integral foraging site later in the study. The emergence of white clover (*T. repens)* across the site provided a widespread resource for bumble bee species. The clover was found in areas of exposed, short grass which was regularly grazed or mown, reiterating the necessity of varied vegetative heights in the rewilded landscape.

## 6. Discussion

### Mid-Level Succession Scrub Mosaic

The site of mid-level succession, a semi-covered, mosaic scrubland habitat, had the highest incidence of sweep netted pollinators. Pan traps on this site were also the most successful, with the highest number of pollinators caught over the study period. These results indicate that this site, which has undergone rewilding practices for the longest period of time, is most favoured by pollinators. The vegetative diversity on this site provides access to foraging opportunities that are absent from the others such as widespread mature hawthorn (*C. monogyna)*. During May, few other plant species were found to be flowering around the site, suggesting that hawthorn (*C. monogyna)* was the primary foraging resource for bees. The number of honey bees (*Apis mellifera)* caught in sweep nets and observed on these shrubs displayed how vital a resource they are during early summer.

*Andrena* species were only caught on hawthorn (*C. monogyna)* earlier in the study period, reducing in number dramatically by June. Previous studies of the difference in wild solitary bee species abundance depending on land use type are sparse, however recent studies have suggested they highly benefit from an increase in vegetative heterogeneity (Wood, et al., 2016). Presence of wildflower mixes in field margins has been found to support bumble bee bee species (Carvell, et al., 2006). However, solitary bees, particularly *Andrena* and *Lassioglossum,* find these foraging resources far less beneficial and prefer an increase in diversity of native vegetation that naturally occurs in field margins and set-aside land, due to their shorter proboscis (Kells, 2001, Morandin and Kremen, 2013). The gradual decline in observed *Andrena* species may be due to their short life-cycle (Le Féon, et al., 2013). When my study was conducted there was a high presence of solitary bees, the reduction in density will most likely be temporary and a second brood will emerge and rely upon a different foraging resource.

This reinforces the theory that wild pollinators require a diverse range of flowering species that bloom gradually throughout the summer months. Bumble bee (*Bombus)* species were caught more regularly, particularly as the bramble (*R. fruticosus)* began to bloom. This was most apparent once the hawthorn (*C. monogyna)* finished flowering. There was a transfer of activity (foraging and flying) away from the scrub and higher vegetation towards lower level bramble thickets and field margins, where banks of flowering vegetation were found. This was observed in all fields but was particularly apparent in Twenty-Seven Acres.

The vegetation found to provide nectar and pollen resources for the highest diversity of species, hawthorn (*C. monogyna)* and bramble (*R. fruticosus),* have similar physiological characteristics. Bramble (*R. fruticosus)* is a woody perennial bush, growing up to 3m tall with spine coated stems. One plant can produce hundreds of flowers from spring until late summer, providing continuous pollen and nectar through the foraging season. The flowers are light pink or white, and easily visible, with an open structure (RHS.org, 2019), allowing for all flying pollinators to reach them and forage without need for specific mouth parts. Hawthorn (*C. monogyna)* is a hardy shrub, growing up to 4 metres tall. Flowers are similar to *R. fruticosus* except smaller. Emerging from late spring to early summer, the flowers are white, numerous and produced in clusters covering the shrub (RHS.org., 2019). The height and brightness of the plant enables pollinators to find it from a distance.

This field site was popular with grazing herbivores, especially deer species due to the thick vegetation providing covered resting areas. Regular browsing of the shrubs and open grassy areas of the site should ensure vegetative diversity remains. The eastern end of the field, closest to a private home, is kept free of successional shrubs, providing an ideal habitat for white clover (*T. repens)* and in turn red-tailed bumble bee (*B. lapidarius)* which was most commonly caught on this plant. From the results of this sample site, it can be assumed that a combination of natural regeneration and human-lead vegetative management provides foraging opportunities for a larger variety of pollinators.

**Plantation Woodland**

The site primarily covered in plantation woodland provided some interesting results. The vegetative structure of this field meant pollinator presence was dependent on proximity to flowering vegetation, with less species seen flying and foraging across the site. I expected to find a higher number of pollinators utilising the higher vegetation in this field, for example elderflower (*S. nigra)* flowers. However, the pan traps placed close to elderflower (*S. nigra)* were the least successful. This could be due to the nectar and pollen composition of this plant being unsuitable for the pollinator species present in the field, or due to the shaded, under-canopy position of the tree. The relationship between this tree and pollinators is yet to be studied. Far fewer specimens were caught in both sweep netting and pan traps located under the oak canopy surrounding the open margins of the site. Ground Ivy (*Glechoma hederacaea)* was occasionally foraged by *Bombus* species, particularly *B. hypnorum*.
Bramble (*R. fruticosus)* thickets surrounding the plantation, used as a separation boundary between fields, were again highly active. This fields vegetative diversity was limited by the closed canopy woodland, and some fields immediately surrounding were covered by Sallow (*Salix cinerea) (*WoodlandTrust.com, 2019). The thickets of bramble (*R. fruticosus)* found in this field therefore provide an important food resource to pollinators that require easily accessible pollen and nectar.

**Permanent Pasture**

In previous studies, fields of permanent pasture have been used as control sites due to their continuously managed state (Wallace, 2018). However, based on the data gathered from this study site, areas that continue to be managed extensively can be beneficial to pollinators. The results in this site were more positive than expected considering the level of disturbance, with the number of pollinator species recorded similar to site 2. Some pollen producing plant species were only found on this site, for example ribwort plantain (*Plantago lanceolata),* which is known to a source of pollen for bumble bees. The use of yellow flag iris (*Iris pseudacorus)* as a pollen resource by larger bee species, particularly queen bumble bees, reiterates the theory that bumble bees, which have longer proboscis, are more adaptable pollinators due to their ability to access harder to reach food resources (Cariveu, et al., 2016). Therefore, as rewilding practices increase vegetative diversity, bumble bee species may benefit from an increase in plants with larger, longer inflorescence such as *Iridaceae* species. The presence of a rewilded wetland area in this site may have created an inaccuracy in the data, as other sites of permanent pasture do not have the additional vegetative diversity provided by this habitat. Pan traps set out in the areas furthest from the pond gathered the least samples, despite being in close proximity to flowering plants used for foraging, particularly clover (*T. repens).* This may indicate that the absence of the pond would reduce pollinator numbers on this site.

**Knepp as a refuge for pollinators**

This study aimed to assess the pollinator species found at Knepp and their relationships with the flowering plants present. The techniques used to increase diversity on the estate are known as “active rewilding”. This form of rewilding aims to restore key stone species and fully functioning ecosystem services that were lost due to human encroachment and hunting (Svenning et al., 2016). During the Pleistocene era, mega fauna were present in the landscape, providing services that ensured the biodiversity of habitats continued. Evidence of the effects these large mammals had upon the landscape provides a baseline from which rewilding processes can start, a well-known example being the re-introduction of wolves to Yellowstone National Park (Lawton, 2018).

The owner of Knepp Estate has introduced large mammals in an attempt to mimic this restorative process. Tamworth pigs and Longhorn cattle were introduced into southern block from 2003 onwards, firstly in small experimental numbers. Alongside these large, impactful domestic animals, fallow, roe and red deer were introduced, and Exmoor ponies. These species were chosen due to their close behavioural comparison to herbivores that would have been found in the UK during the Pleistocene era, and their hardiness. The breeds used to actively rewild a site need to require minimal human care and survive outdoors through the winter months (Tree, 2017). The rootling nature of the Tamworth pig means areas of thatched pasture land and compacted former crop soil are turned over and excavated for invertebrates and roots regularly in winter. Seeds and less competitive plant species then have a chance to emerge in the rootled areas, increasing biodiversity and providing potential wild pollination resources. Varied grazing choices of the deer, cows and horses mean highly competitive scrub land species such as brambles are kept under control while tree saplings grow amongst them. The primary aim of the project is to monitor the vegetative succession of the estate, and how the large herbivores introduced to the land affect ecological restoration (Wallace, 2018). Pollinators have a hugely important role to play in this process, enabling the reproductive cycles of successional plant species to continue. In order for pollination services of all floral plant species to be successful, the current diversity of insect species must be protected if not improved.

**The future for pollinator populations**

Wild bee populations are decreasing worldwide, with 2 recorded extinctions of bumble bees in the UK (Vanbergen, et al., 2014). Continued intensification of agriculture in the UK reduces access to wild floral plant species. Wild bees, particularly species with smaller mouth pieces or more specific foraging preferences are further limited to fragmented areas of land with less disturbance. At the third meeting of the Convention on Biological Diversity, parties recognized and discussed the importance of pollinators, and the need to halt their decline on a global scale (CBD, 2010). The International Initiative for the Conservation and Sustainable Use of Pollinators was implemented from this meeting, aiming to promote coordinated action world-wide to reduce the impact of intensive agriculture (CBD, 2010). This action plan was a step forward, however a more proactive approach from government bodies and agricultural sectors is necessary in order to enact change. Presently, research into global pollinator populations is fragmented and sparse, with a bias towards western countries. To fully comprehend the effect of human activity on insect pollinators, more in-depth and long-term research is essential.

**Limitations of Research**

There were a few limitations to my research. Although sweep netting is an effective method with which to capture insects and identify them, there is always a risk of an element of bias. It is important to sweep areas which are likely to have an abundance of pollinators, for example a plant that is in full bloom, however there is a high likelihood of missing specimens which are not foraging at that time. Sweep nets also often catch on branches and thorns, disturbing insects in the vicinity through shaking of the vegetation, and often allowing specimens trapped inside the net to escape.

There is ongoing research as to whether the colour of a pan trap affects its efficacy (Wilson et al., 2016). The colour that an insect is attracted to may be influenced by the colour of pollen or flower it instinctively feeds from, therefore some pan traps may prove more attractive than others. Throughout my research, the blue pan traps were found to be the least effective for any insect, whereas pink was effective for trapping spider species, and yellow especially effective for pollinators. The majority of plant species in bloom at the time of data collection were white and yellow, suggesting a correlation between trap colour and florescence.

An ongoing limitation to research at Knepp Estate is the constant presence of members of the public. Human interference through destruction and removal of pan traps meant possibly valuable data was lost.

**Future Research at Knepp**

Pollination as an essential ecosystem service has gained exposure in recent years in terms of pollination of agricultural crops. However, it is just as integral to wild plant species. Rewilding advocates, such as the Burrells of Knepp, rely completely upon natural processes to spread successional plants and increase vegetative heterogeneity. Until recently, research of this site has been heavily focussed on large mammals. There is a need for continued, in-depth research of pollinator presence and habitat availability moving forward, as they are equally essential to the ecological framework as large mammals (Weiner, et al., 2014).

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