PLAN FOR HONEY BEE HEALTH AND WELL BEING

The Sussex Plan

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In many parts of the world, including Britain, Europe and North America, the honey bee is in decline. Although still a very common insect the number of hives has reduced greatly. It is important to reverse this trend to maintain honey production and pollination. But how do we do this?

As a beekeeper and researcher trained in honey bee biology at Cornell University and head of LASI, the Laboratory of Apiculture and Social Insects, in 2008 I decided to make a contribution by focusing the greater part of LASI's efforts towards applied research and outreach aimed at helping the honey bee and beekeeping. We called this the Sussex Plan for Honey Bee Health and Well Being. Over the following years the Sussex Plan picked up speed as funds were raised, postdoctoral researchers, PhD students and research technicians were hired, and projects were begun. The projects we set out to do were those that we felt would be most likely to have clear benefits to bees and beekeepers. Many of the topics were chosen following discussions with the British Beekeepers' Association (BBKA) and other beekeepers. The purpose of this article is to let British beekeepers know what we have been up to and what we have achieved so far.

Honey Bee Pests and Diseases

Honey bees have many pests and diseases. Successful beekeepers must control these but it is not always an easy task. Most varroa mites, for example, are now resistant to fluvalinate, the active ingredient in Apistan® strips, which for many years gave very good control.

LASI's research on pests and diseases has two main strands. The first of these is on hygienic behaviour which is a natural defence against brood diseases where worker bees uncap cells containing brood that is dead or infected. In this way, diseases such as chalkbrood, American foul brood and varroa can be fully or partly controlled.

Although hygienic behaviour is natural it is not common. Surveys of colonies, in which patches of capped brood are freeze-killed with liquid nitrogen to quantify the rate at which the dead brood is uncapped and removed, typically show that only 10% of colonies are fully hygienic, meaning that they remove 95% or more of the dead brood within two days. Hygienic behaviour is not something that bees learn. Rather, it is an inherited trait. At LASI we have been able to breed a line of fully hygienic bees that remove 95% or more of the freeze-killed brood. We hope that in the future, funding permitting, we can make this stock available to British beekeepers. We have also run many workshops at LASI showing beekeepers how to carry out the freeze-killed brood assay so that they can screen their own bees and use them in queen rearing and breeding.

An update on current LASI research projects at the University of Sussex

LASI's research on hygienic behaviour has shown that hygienic colonies do not mistakenly remove healthy brood, meaning that it will not be costly to the colony. In addition, we have shown that hygienic colonies do not sting more or show reduced calmness during hive inspections. We have also shown that open-mated queens reared from highly hygienic colonies give rise to highly hygienic colonies. In particular, it is not necessary to mate queens via instrumental insemination to have highly hygienic colonies, which makes things much simpler for beekeepers and queen rearers. Our research, for example, shows that queen rearers in Britain could supply open-mated hygienic queens bred from locally adapted bees.

What about disease control via hygienic behaviour? In 2013, we did an experiment that showed that the one-year build up of varroa mites in fully hygienic colonies (>95% removal of freeze-killed brood) was less than half that of less hygienic colonies. In addition, the worker bees in these fully hygienic colonies showed no symptoms of deformed wing virus (DWV), which can be transmitted by varroa. But DWV was seen in approximately one-third of the non-hygienic colonies. These results show that hygienic behaviour can play an important role in controlling varroa and the viral diseases it transmits.

The second strand of our research on pests and diseases is on the control of varroa mites. We have quantified carefully the effectiveness of two methods that can be used by beekeepers. One of these is drone brood trapping. Varroa mites are particularly attracted to drone brood and, in one experiment, we have been able to show that half a frame of drone comb placed into a hive in early spring, when the first batch of drones are being reared, can trap about half of the varroa in the colony.

Even more encouraging is our research on oxalic acid. Although oxalic acid has been used by beekeepers for several decades to kill varroa, we realised that no proper study had ever been done to determine the effectiveness of different doses and application methods on mite and bee mortality. In an experiment using 110 hives we filled this gap. We compared three application methods and three doses. Hives were treated in early January when they had no brood (as oxalic acid does not kill varroa in cells, only those on the worker bees). We determined the proportion of mites killed by washing the mites off a sample of approximately 300 worker bees immediately before and ten days after treatment with oxalic acid. We also determined the number of bees killed at the time of treatment and colony mortality and strength four months later, in spring.

Our results came to a very clear and encouraging conclusion. Application of oxalic acid via sublimation, in which oxalic acid is applied in pure form by vaporising the crystals with a special heated tool, was superior to application as a solution via either spraying or dribbling. Sublimation gave greater kill of varroa at lower oxalic acid doses and no increase in bee mortality. In fact, four months after treatment, the colonies treated via sublimation had more brood than our ten untreated control colonies. The sublimation method is also quick and easy, as the hive does not need to be opened. To be sure of our results we retested the sublimation method one year later, this time just before Christmas in broodless colonies. An amazing 97% of the varroa mites were killed by using 2.25 g of oxalic acid per hive, and colony survival three months later in spring was close to 100%.

LASI researchers treated broodless hives with oxalic acid in January 2013 using a range of methods. The sublimation method involves inserting a heated tool through the hive entrance

Honey Bee Foraging

Even if we could control all honey bee pests and diseases our problems would not be over because the bees still need to eat! The main reason why the number of colonies in Britain has declined is almost certainly that their food supply, flowers providing nectar and pollen, has declined. Agricultural intensification has reduced the abundance of flowers in the countryside. Among other things, arable fields have fewer weeds, grazing land has less clover, heather moors are reduced and hay meadows have almost vanished. These changes affect not just honey bees but a huge range of British wildlife including other bee species, butterflies, birds and wild flowers.

As with our disease research, LASI's research on honey bee foraging also has several strands. One of these, dance decoding, takes advantage of a unique honey bee behaviour – the waggle dance. On returning to the hive, a honey bee forager working a profitable patch of flowers will make waggle dances to tell her nest mates its location (direction and distance) from the hive. By keeping colonies in glass-walled observation hives, we can video the dances and then decode them, eventually mapping out and analysing the actual foraging locations as indicated by the dances. In essence, we eavesdrop on what the bees are saying to each other to study their foraging.

The research began by developing better methods for decoding and mapping the dances. This took quite a long time and resulted in two scientific papers that will be used by scientists around the world who are studying the waggle dance and using it to investigate foraging. We then used these new methods to analyse two years of dances that we had videoed using observation hives at LASI. Following bee dances over the whole foraging season had never been done before. In one project, we compared foraging month by month to examine seasonal trends. In early spring, average foraging distances were less than 1 km but they increased to 2 or 3 km in summer before dropping again in the autumn.

Honey bees are smart when it comes to foraging and do not fly long distances if they do not have to. So what this project showed is that summer is actually a more challenging season for bees to find high quality flower patches than spring or autumn. In spring, a huge range of flowers is in bloom and forage is abundant. In the autumn one key plant, ivy, is in bloom and is very abundant. (In another project we showed that 90% of the pollen collected by honey bees in the autumn is from ivy.) The summer may have more days of good foraging weather but there are also many more bees competing for flowers. In addition, many of the agricultural habitats that had abundant summer flowers, such as hay meadows and heather moors, are now scarcer. One encouraging result of this project is that we now know when more flowers are needed to help the bees. As a result, efforts to increase flower abundance can be focused better. It is easier to increase the food supply for two months, in July and August, than for the whole 8–9 month foraging season.

Using the same dance data, a second project investigated the actual land types that bees were foraging in. This showed that there was no preference for urban versus rural areas, but that areas of agricultural land under higher level stewardship received more foraging. In addition, two hot spot areas that had the most foraging both included nature reserves. These had been set up for the benefit of wild flowers and butterflies, not bees.

Dance decoding tells us where the bees are foraging, but not the exact habitat or the flower species. Following on from the results of the dance decoding, we have been examining one of the hot spots indicated by the dancing bees to determine which particular habitats and flower species have the most foraging insects. It turns out that field boundaries, including the hedge and adjacent tall vegetation, are the location with the most foraging insects and that the most attractive wild flowers are well-known common species: bramble, hogweed and knapweed. In addition, there were many kinds of insects on the flowers, including bumblebees, hoverflies and butterflies. Importantly, this shows that honey bee dance decoding highlights locations that are also good for other pollinating insects.

Because honey bees can forage at long distances, by decoding waggle dances made from hives in a single location, it is possible to survey up to 100 square kilometres of the surrounding landscape to determine the areas most valuable, not just for honey bees but for flower-visiting insects in general.

Another major strand of the work on foraging is aimed at helping flower-visiting insects in urban gardens and parks. In Britain there are about 30,000 beekeepers but there are millions of gardeners, not to mention many other types of landowners including local town councils. Helping bees and insects in their own gardens is probably the most widespread opportunity for the general public to help bees.

Gardens are normally planted with ornamental flowers that can be attractive to bees. Although many lists of bee- and insect-friendly plants are available, there is a need to put the process of making recommendations onto a firmer scientific basis. In one project we planted a special experimental garden on the Sussex University campus with 32 varieties of summer-flowering plants. (We chose summer-flowering plants as the dance decoding research had shown that summer is the season when additional flowers will be most valuable.) For two years we then repeatedly counted and identified the insects foraging on each patch. The results showed that there was a 100-fold range in the numbers of insects attracted. This means that gardeners can make a real difference by selecting insect-friendly plants, which are just as pretty to look at and easy to grow. Approximately 85% of the insects counted were bees, with bumblebees the most abundant and honey bees next. So, if you plant flowers in your garden, the bees will come! Honey bees routinely fly several kilometres to flowers in the summer and can fly ten kilometres or more.

We then went on to survey a local park, Southover Grange Garden in Lewes, which to the eye looks like it should be bee heaven as it is full of flowers in August. But the reality was that of 79 varieties in full bloom, only three were highly attractive to insects. We saw no insects at all on 30% of the varieties and 45% had very few. Using similar methods we also made a survey of over 200 aster varieties at the national collection at Picton Garden in Worcestershire. Asters are a widely grown ornamental that flower mainly in the autumn. This study also showed that most varieties attracted few insects, but some attracted many.

Overall, these studies of ornamental flowers are very encouraging as they show that there is great potential for improving the value of gardens and parks to bees and other flower-visiting insects simply by making better plant choices. There is no need to spend more money or to stop having flowers that are attractive to the human eye. There is a huge range of varieties available to choose from. It is actually very simple to count the bees and other insects on the flowers and we have made videos showing people how to do this. These videos are on the LASI YouTube channel 'LASI Bee Research & Outreach'.

The final project on bee foraging I want to mention also concerns a local park, the Saltdean Oval in Brighton. The Parks Department had decided to allow the grass in one half to grow long and we worked with them to determine how this affected the numbers of flowers and flower-visiting insects. There was a huge increase in both. Nothing was planted. Wild flowers were already there in the grass waiting for a chance not to be cut down. We also surveyed the opinions of local people using the park. Most were very much in favour of helping the flowers and insects, especially as the Parks Department had also left plenty of short grass. This project makes an important point. When it comes to wild flowers, in many cases they are already present and don't have to be planted.

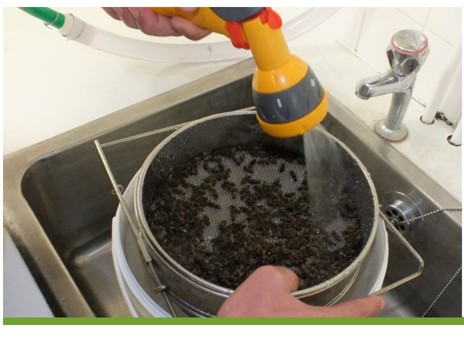
The same thing applies to farmland. If areas not being cultivated are cut once or twice per year they are likely to have many wild flowers. I advised one farmer to try this and he came back a year later to say how surprised he was at all the wild flowers, bees and butterflies that resulted, without seeds being planted.

Neonicotinoid Insecticides

The third area of the Sussex Plan concerns a topic much reported in the media: neonicotinoid insecticides. These have been widely blamed for killing bees. Since December 2013, the EU has put in place a moratorium on the use of certain neonicotinoid insecticides as seed dressings on crops with insect-attractive flowers, such as oilseed rape. There is concern that the small residual amounts of insecticide present in the pollen and nectar may be harming individual bees or their colonies, leading to a reduction in bee populations.

The whole area of neonicotinoids and bees is controversial. Studies have shown that under experimental conditions bumblebee colonies can be harmed or individual honey bees can become disoriented. However, it is probable that some of these studies

Extracting varroa from a sample of worker bees to determine the number of mites per 100 bees. Samples were collected immediately before and ten days after oxalic acid treatment



used unrealistic amounts of insecticide. One much-reported study carried out in France that showed disorientation, had fed individual worker bees an amount of neonicotinoid at one time that would have taken one week to collect when foraging.

By contrast, another study that was not reported in the media showed that there was no correlation between trends in honey bee populations and the use of neonicotinoids. Declines in the numbers of honey bee colonies, for example, predate the introduction of neonicotinoids approximately 20 years ago. Better data are needed on the amounts of insecticide present in the nectar and pollen of the treated crops, the extent to which bees forage on these crops and the effects on colony performance. This is what the Sussex Plan is studying.

In one project we are using dance decoding and pollen analysis to investigate honey bee foraging on oilseed rape (OSR) in the Brighton/Sussex University area, where it is abundant. OSR is by far the most widely grown UK crop whose seeds have been treated with neonicotinoids and whose flowers are visited by bees. OSR fields now cover approximately 3% of Britain. What we found was that when bee hives were more than 1.5–2 km from the nearest OSR fields they did not forage on OSR. In hives located 0.8 km from the nearest field, dance decoding showed foraging in OSR fields of around 23% (that is 77% of the foraging was in other locations) and pollen analysis showed that only 13% was from OSR. This indicates that laboratory studies that assume that all foraging is on a treated crop are unrealistic. Under natural foraging conditions bees have a choice. Although a field of OSR in bloom would appear to be a magnet for bees and pull in all the foragers, this is not the case. OSR flowers in the spring when there are many other flowers in bloom.

At the time of writing (April 2014), we are carrying out a large project using 72 honey bee colonies. Half have been placed in three apiaries in or beside a field of OSR, to maximise their exposure. The other half are placed in three nearby apiaries 1.2 km or more from the nearest OSR fields. From the previous study we expect these colonies to forage little on the OSR. Each hive is also fitted with a pollen trap so that we can monitor them individually. We are also monitoring colony performance in terms of brood amount, weight gain and queen and colony survival. This project should tell us whether the hives suffer any detriment from being close to the OSR fields. OSR may both help colonies, by providing pollen and nectar, and harm colonies, by the effects of neonicotinoids in the pollen and nectar. What matters is the overall effect.

The final neonicotinoid project concerns foraging on sweetcorn and was carried out at a Sussex farm that is the UK's largest sweetcorn grower. The aim was to monitor foraging on sweetcorn and other plants in bloom and also to collect samples of pollen for analysis of neonicotinoid residues. We moved six bee hives to the farm in two apiaries, each hive being fitted with a pollen trap. Pollen analysis showed that there was substantial honey bee foraging on corn pollen, amounting to about half the total. (Note: corn produces pollen but not nectar.) Counts of insects on corn and other flowers in bloom showed that only honey bees foraged on corn. Bumblebees, other bees and hoverflies visited other plants.

Will honey bees be harmed? Two reasons they probably will not be are that the level of neonicotinoid we detected in the pollen was low and because corn only produces pollen. A honey bee colony collects about six times as much weight of nectar as pollen per year meaning that nectar can potentially deliver much more neonicotinoid.

Summary

I will let the British beekeepers judge for themselves what they think of these projects and the results. In the area of honey bee pests and diseases, I feel that we have made substantial contributions to honey bee health by showing the value of hygienic behaviour, by breeding a line of hygienic bees and by determining the best method and dose for treating hives with oxalic acid. In the area of foraging, we have obtained a range of results that will help focus efforts on making flowers more available. These include showing that summer is the challenging season for foraging, that higher level stewardship schemes seem to benefit bees and showing how gardens and parks can be made more bee friendly, at no cost, simply by better plant selection or by allowing existing wild flowers in grassland to grow. In the area of neonicotonoids, our research will help fill important gaps in the data used by policy makers who make decisions about the use of agricultural chemicals.

Future Prospects

If funding can be obtained, the Sussex Plan will continue doing research of value to bees and beekeepers. Outreach is also important to get the results out to beekeepers, land managers, farmers and gardeners and supplying hygienic queens.

People

The Sussex Plan was carried out by a large number of people at LASI including: Postdoctoral researchers: Dr Karin Alton, Dr Margaret Couvillon, Dr Roger Schürch; Research technicians: Norman Carreck, Luciano Scandian; PhD and MSc students: Nick Balfour, Gianluigi Bigio, Mihail Garbuzov, Fiona Riddell, Hasan al Toufailia; undergraduate summer bursary students: Chris Accleton, Jodie Baker, Lee Cooper, Katie Fensome, Charles Heard, Shaun Kit Lung Quah, Liz Samuelson, Kiah Tasman, Esme Taylor; volunteers: Ellie Blows, Dominic Burns, Sarah Hudson, Matt Silk, Suzie Johanson; visitors: Héloise Blanchard, Aurelie Croizelle; final year project students: Buffy Harris-Jones, Vicky Howard, Amanda Kuepfer, Samantha McKenzie, Hunter Phillipps, Laura Rozario, Sydney Tillings.

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Further Information

Please see the LASI YouTube channel 'LASI Bee Research & Outreach': https://www.youtube.com/user/LASIbeeResearch and the LASI website: www.sussex.ac.uk/lasi Research articles will be listed on Francis Ratnieks's Google Scholar web page as they are published: http://scholar.google.co.uk/citations?user=mF4l2Z0AAAAJ&hl=en