Laboratory of Apiculture and Social Insects

Annual Report January 2014

University of Sussex
Life Sciences

LASI
LABORATORY OF APICULTURE AND SOCIAL INSECTS

Fig. 1. Members of LASI, Christmas, 2013 (photo: Francis Ratnieks).

Contents

Cover photo: A honey bee collecting maize pollen flowers (Photo: Norman Carreck).

LASI personnel

LASI Director

Prof. Francis L W Ratnieks

Postdoctoral researchers and research technicians

Dr Karin L Alton
Mr Norman L Carreck
Dr Margaret J Couvillon
Mr Luciano Scandian
Dr Martyn J Stenning

Doctoral students

Mr Nick Balfour
Mr Gianluigi Bigio
Mr Tom Butterfield
Mr Sam Jones
Mr Mihail Garbuzov
Mr Kyle Shackleton
Mr Hasan Al Tofailia

Masters students

Mr Alan Gallagher

Undergraduate Summer Bursary students and assistants

Ms Katherine Fensome
Ms Francesca Greetham
Mr Charles Heard
Ms Imogen Ruddock
Ms Elizabeth Samuelson

Volunteers

Ms Ellie Blows
Mr Jérémy Dimora
Ms Chandra Walter

Mission statement and goals

Research

- To carry out basic and applied research on honey bees and social insects.
- To be a world-leading research group and a key component in UK science infrastructure and expertise.

Teaching

- To train the next generation of honey bee and social insect scientists.

Community

- To extend practical knowledge, informed by high quality research, about honey bees and social insects to beekeepers, industry and others.
- To play an active role in the public communication of science.

Contacts

Professor Francis Ratnieks: f.ratnieks@sussex.ac.uk
Dr Karin Alton: karin.alton@sussex.ac.uk
Sue Hepburn: s.j.hepburn@sussex.ac.uk (fundraising)

Website: http://www.sussex.ac.uk/research/researchgroups/lasi

Overview of 2013

The year has been extremely productive with a record number of people working at LASI over the summer months on a variety of projects. Despite the poor winter and spring weather, many new projects were initiated and several existing ones completed. A number of projects in the Sussex Plan for honey bee health and wellbeing have now been reached fruition and are being published as refereed scientific journal papers and popular articles.

Bees and other pollinators have remained in the news, especially with the lively debate about the possible harmful effects of neonicotinoid insecticides, and several LASI members have contributed an objective view to the debate. Lab members have also been involved in the development of the UK Government's new National Pollinator Strategy, to be launched in April 2014.

As usual, members of LASI have been fulfilling our outreach role by giving many talks at local, national and international conferences, to a variety of audiences, running workshops at the university itself, and by working with school children of various ages. Full lists of publications, talks and media appearances are given in the Appendices.

One innovation this year has been the production of a number of short videos which are located on LASI's new You Tube Channel:-

http://www.youtube.com/user/LASIbeeResearch?feature=watch

The films fall into several categories. Some illustrate current research projects. The first was a film production by Eva Riley, and illustrated the work that PhD student Nick Balfour carried out on the pollination of orchard fruit in a project funded by Waitrose:-

http://www.youtube.com/watch?v=hbGRWoqJVQs

Another film describes the completed research project "Quantifying variation among garden plants in attractiveness to bees and other flower-visiting insects" carried out by Mihail Garbuzov and Francis Ratnieks in 2011 and 2012, and now published in the scientific journal *Functional Ecology:-*

http://www.youtube.com/watch?v=4u2LeTPGo9w .

Other videos provide skills for the public. Two Media Studies undergraduate students Imogen Ruddock and Francesca Greetham worked at LASI during the summer funded by under-graduate bursaries and produced several films, such as one to help train the public to identify bees on flowers:-

http://www.youtube.com/watch?v=jhRx6xV3Chw

We intend to develop the site with further films in the future.

Once again we thank our many benefactors whose continuing support makes our work possible.

Research – The Sussex Plan for honey bee health and well being

Breeding disease-resistant hygienic honey bees and providing breeder queens to beekeepers

Norman Carreck, Karin Alton, Gianluigi Bigio, Luciano Scandian, Hasan Al Tofailia and Francis Ratnieks

Background

Honey bees are susceptible to many pests and diseases, in particular bacterial brood diseases such as American foulbrood (AFB) and European foulbrood (EFB), the fungal disease chalkbrood, and the parasitic mite *Varroa destructor* (varroa). These have traditionally been treated with a range of drugs including antibiotics and acaricides, but increasing problems with resistance have been experienced, leading to reduced efficacy. This has led to a search for chemical free alternatives.

So-called “hygienic” worker honey bees remove dead or infected larvae and pupae from their cells, reducing the spread of disease within a colony. Previous research in the USA has shown that hygienic colonies may produce as much honey as other colonies, but are resistant to brood diseases such as AFB, EFB and chalkbrood. Hygienic behaviour can also disrupt the breeding cycle of varroa, thereby slowing down mite population growth, so that beekeepers with hygienic hives will find it easier to control the mite.

Hygienic behaviour is a naturally occurring genetic trait, meaning that it can be selected for using conventional bee breeding methods. Previous studies have shown that about 10% of British hives are hygienic, so a more effective method of breeding for hygienic behaviour via “intracolony selection” has been developed. This involves keeping colonies known to exhibit hygienic behaviour in observation hives to determine which individual workers are the most hygienic. Molecular techniques are then used to determine the patriline (i.e. the identity of the drone father of the worker). Daughter queens are then reared that have the same father as the hygienic workers. In this way breeding for hygienic behaviour is more effective and rapid than breeding on a colony basis (Carreck, 2009a, b, 2011; Carreck *et al,* 2010).

Main aim

To selectively breed and then test under UK field conditions, a strain of hygienic honey bees, and to then make this available to UK beekeepers.

Funding

This project is funded by Rowse Honey Ltd, the Merrydown Trust, and the Somerset Beekeepers Association.

Progress

In parallel with our research activity, 2013 saw significant progress in both our collaboration with local beekeepers and in the breeding programme aimed at producing hygienic honey bees.

Queens belonging to our breeding line were previously given to beekeepers belonging to Worthing Division of the West Sussex Beekeepers Association (WBKA). During Summer 2013, the surviving ones were tested for hygienic behaviour and other traits of practical importance such as aggression. Despite the poor conditions at the start of the season, some queens were able to survive and were tested three times using the freeze-killed brood (FKB) assay. Those colonies did not display high levels of hygienic behaviour, but were very docile, making them ideal to be used in the club apiary where beginner beekeepers will be able to learn the fundamental techniques and build up their knowledge.

Fig. 2. Luciano Scandian (rear, 2nd from left) with Worthing beekeepers taking part in trials of LASI queens.

The last set of FKB trials performed on the colonies belonging to the LASI breeding line showed how a subset of the colonies demonstrated a very high degree of hygienic behaviour. The results obtained will need to be confirmed again in the Spring of 2014, but we are confident that we have established the foundation of a breeding line of hygienic bees. Queens obtained by the best performing colonies will be used in the laboratory for further tests and investigations, as well as being provided to local beekeepers for a long-term evaluation under real-life conditions.

Additionally, to further develop the ongoing relationship between LASI and beekeepers, in August Gianluigi Bigio ran a workshop aimed at showing beekeepers how to rear queens using the grafting / Dolittle method, which allows beekeepers to obtain a up to 50 virgin queens using a single queenless colony. The workshop was hosted by WBKA and was well received, and together with the workshop aimed at carrying out FKB assays, gives the beekeepers the tools required to venture in selecting honey bee colonies that possess increased resistance against brood pathogens.

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Research – The Sussex Plan for honey bee health and well being

Developing new techniques for breeding disease resistant bees

Gianluigi Bigio, Norman Carreck, Luciano Scandian and Francis Ratnieks

Overview and main aim

Gianluigi Bigio started his PhD in April 2010 and is now approaching the end of the programme. He carried out several projects that will provide results to be exploited in the broader context of the Sussex Plan, which aims to selectively breed and then test under UK field conditions a strain of hygienic honey bees. Some of the projects were carried out in conjunction with UK beekeepers, achieving a solid collaboration that hopefully will be expanded even further in the future.

Funding

This PhD project is funded by the British Beekeepers' Association.

Progress

Section 1

During the 2010 field season, we devised an improved methodology to keep virgin queens alive for a week under laboratory conditions. This will allow both beekeepers and scientists studying bees to be able to screen queens prior to mating with a minimal allocation of time and resources. We demonstrated that honey bee queens can be kept in mailing cages under optimum conditions, to be readily available for genotyping and then mating (Bigio, 2011). This work is now completed and resulted in a paper published in the peer-reviewed journal *PLoS ONE* (Bigio *et al,* 2012a).

Section 2

During 2013 we screened the colonies headed by queens that were produced at the end of the previous season, including queens that were given to the Worthing beekeepers (WBKA). In total, nine colonies that overwintered successfully, were tested four times with the freeze-killed brood (FKB) assay to identify the best performing colonies. From those we then obtained more virgin queens for our breeding programme. Colonies led by those selected queens will represent the foundation of our genetic line to be developed according to the feedback provided by WBKA. This will allow us to have an external evaluation of our work, and we will combine their feedback with our data in order to fine tune our selection programme. In the future we plan to also monitor other traits of interest, such as honey production, wintering ability, etc. This is an ongoing project which will support the main breeding programme.

Section 3

Colonies belonging to Luciano Scandian, LASI research facilities manager, have been screened using the FKB assay. We discovered several colonies that were included in our breeding programme, and by continuously monitoring them we were then able to correlate the expression of removal of dead brood as the season progressed. Other traits of interest were also quantified, in order to eventually correlate hygienic behaviour with defensive behaviour and calmness on the comb. This project started in Summer 2011 and ended in October 2012, the data collected were analysed statistically and the results are summarized in a paper that is currently being written.

Section 4

In order to better understand the impact of environmental conditions on the expression of hygienic behaviour, a study was carried out to monitor how hygienic behaviour varies in relation to both the amount of brood present in the colony and food availability. The ability of the colony to detect and remove freeze-killed brood has been monitored in hives that were either being fed with sugar syrup or had frames of brood removed or added. This should

eventually help both beekeepers and researchers to modify the observed behaviour accordingly and also to determine how the behaviour is influenced by other physiological factors. This work is now completed and published in the peer-reviewed *Journal of Economic Entomology* (Bigio *et al.* 2013a) and was presented as an oral communication at the 5th meeting of the European Sections of the IUSSI held in Montecatini Terme (Tuscany, Italy) from 26-30 August 2012 (Bigio *et al*, 2012b).

Section 5
Whilst developing a breeding line of honey bees expressing high levels of hygienic behaviour, and trying to understand how external factors could cause variations, we investigated whether there were fitness costs linked to it; costs that would limit its expression and therefore explain why amongst unselected honey bee colonies, very highly hygienic ones are rare (*c.*10%). Some authors in the literature have suggested that a high ability to detect and remove dead or diseased brood also leads to a high removal rate of healthy brood. During September 2012, we set out to test this hypothesis, running 3 FKB assays on 10 hives, and correlating the hygienic behaviour with the incorrect removal of untreated brood at four different developmental stages (eggs, young larvae, older uncapped larvae, capped brood). The results show that there is no correlation between removal of treated *vs*. untreated brood. This work is now completed and resulted in a paper published in the peer-reviewed *Journal of Evolutionary Biology* (Bigio *et al,* 2013b).

Section 6
Instrumental Insemination is a technique that allows bee breeders to have complete control over honey bee queen mating. Due to its very technical nature, its use in the United Kingdom is very limited. We wanted to assess the importance of instrumental insemination when breeding honey bees capable of high levels of hygienic behaviour. We devised a study comparing the FKB removal between colonies led by queens that belonged to our breeding line. Approximately half of those queens were instrumentally inseminated with semen collected from drones reared in highly hygienic colonies, and half were naturally mated, hence we had no control over the mating process.

Fig. 3. Virgin queens being instrumentally inseminated.

The results show that the colonies led by instrumentally inseminated queens perform more FKB removal than the colonies led by naturally mated queens. Despite this difference being statistically significant, however, most of the colonies led by naturally mated queens displayed high levels of hygienic behaviour, proof that good results in a breeding programme can be

achieved with constant screening, production of selected virgin queens and natural mating. This project is now completed and the results are summarized for a paper that is currently being written and will be submitted to a peer-reviewed journal.

Future developments

We look to the next season with high expectations. As soon as winter is over, we will check our colonies hoping to find that many survived – we already took all necessary measures in order to put our hives in the safest conditions. Then we will evaluate the colonies representing our latest generation, which will tell us how far down the line we are in our genetic improvement plan and again will identify which colonies are most suited to carry on the selection. Similarly, we are looking forward to providing more selected queens to local beekeepers and receiving their feedback. This will be very important, given the long term nature of this project. We value their input in order to provide honey bees that are able to cope with a real beekeeping scenario.

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Research – The Sussex Plan for honey bee health and well being

Honey bee diseases: management, resistance and ecology
Hasan Al-Toufailia, Luciano Scandian and Francis Ratnieks

Overview and main aim
Hasan Al-Toufailia began his PhD degree in April 2012. His research is focusing on the areas of hive management, disease resistance, and disease ecology.

Comparing application methods and doses of oxalic acid to treat varroa mites in honey bee (*Apis mellifera*) colonies
Hasan Al Toufailia, Luciano Scandian, Francis Ratnieks

Oxalic acid is widely used to treat honey bee colonies against the Varroa mite. It can be applied in a number of different ways. Two methods (dribbling and spraying) make use of an oxalic acid and sucrose solution. A third method (sublimation) vaporizes solid oxalic acid crystals. All three methods are used by beekeepers, but which one is the most effective? In addition, which dose is best, both in terms of Varroa mortality and low honey bee mortality? We have aimed to determine the efficacy of oxalic acid applied when hives are broodless and determine the most appropriate dose and method of application.

Fig. 4. Oxalic acid application methods. Clockwise; 1. dribbling; 2. spraying; 3. sublimation, inserting the heater into the hive entrance; 4. sublimation treatment. Photos: Hasan Al Tofailia.

Effect of brood rearing on the efficacy of oxalic acid treatment against Varroa mites, and does sublimation of oxalic acid affect the brood inside the sealed cells.
Hasan Al Toufailia, Luciano Scandian, Francis Ratnieks

Oxalic acid cannot penetrate honey bee brood cells, so mites contained inside cells are unaffected. For this reason it is recommended that treatment occurs during the broodless period in the winter when all mites are phoretic on adult bees and thus easily controlled. But are British colonies really broodless throughout the winter? We have thus monitored brood

levels in UK colonies in autumn and winter to determine the best times to apply oxalic acid solution.

Estimating the number of Varroa mites in hygienic and non hygienic colonies and monitoring how they build up through one year between two periods of oxalic acid treatment.
Hasan Al Toufailia, Luciano Scandian, Francis Ratnieks

Hygienic behaviour is a natural defence against brood diseases in honey bees. Adult bees of two weeks of age perform this behaviour by removing dead, sick or damaged brood from cells thereby reducing the spread of infections. We have been determining the correlation between the number of mites and hygiene over a period of one year, and determine how much mite populations build up. We found that hygienic colonies removed significantly more pupae infested with one mite per cell than the non-hygienic colonies but not all mites were removed.

Genetic and behavioural analysis of patriline differences in aggression and hygienic behaviour in honey bee colonies.
Hasan Al Toufailia, Gianluigi Bigio, Luciano Scandian, William Hughes, Francis Ratnieks

Some colonies headed by queens bred at LASI are very hygienic but can also be aggressive. Honey bee queens mate with 10-20 males, so we have carried out a project to determine whether the hygienic worker bees within such colonies are of different sub-families ("patrilines") to the aggressive worker bees. If we can show this patriline difference in behaviour, it will show that we can breed queens from a hygienic colony that is also aggressive, by rearing daughter queens of hygienic non-aggressive patrilnes.

Determining the efficacy of drone trapping to control Varroa
Hasan Al Toufailia, Roger Schürch, Luciano Scandian, Francis Ratnieks

Drone trapping is a chemical free method used by beekeepers to kill Varroa mites. Varroa mites prefer to breed in drone cells, so a small number of drone brood cells may contain the same number of Varroa mites as a much greater amount of worker brood cells. We have been carrying out studies to determine the efficacy of drone trapping early in the spring, when the first drones are being reared.

Fig. 5. Frame fitted with drone foundation for drone trapping of varroa mites. Photo: Hasan Al Tofailia.

Removal of different sizes of larvae infected by chalkbrood spores in hygienic and non-hygienic bees

Hasan Al Toufailia, Sophie Evison, Luciano Scandian, William Hughes, Francis Ratnieks

Chalkbrood is a common fungal honey bee brood disease that can be controlled via hygienic behaviour. Two week old adult worker bees perform this behaviour by uncapping sealed cells and removing dead larvae which have been infected by chalk brood. We are carrying out a project which will test the hypothesis that hygienic and non-hygienic bees are both able to remove small larvae infected by chalkbrood spores but they differ in their removal of larger larvae.

Research – The Sussex Plan for honey bee health and well being

Neonicotinoid insecticides and bees

Norman Carreck and Francis Ratnieks

Background

From its inception, the Sussex Plan for honey bee health and wellbeing has considered all possible causes of losses of honey bee colonies and practical solutions to improve the wellbeing of honey bees. In recent years, media attention has focussed on just one possible cause of colony loss - pesticides - and in particular, to one specific group of compounds, the neonicotinoids. These compounds are highly toxic to bees in the laboratory, but are normally used as seed dressings, and therefore should in theory be safer for bees than earlier classes of insecticides applied as sprays, which are difficult to target to the pest species. Nonetheless, as soon as they began to be widely used, beekeepers complained of losses, especially in France associated with the use of the neonicotinoid imidacloprid (marketed as Gaucho) on sunflowers. Subsequent field studies failed to find evidence of harm to bees (Carreck, 2008, 2009; Neumann & Carreck, 2010, Ratnieks & Carreck, 2010). In 2012, however, a number of laboratory-based studies showed subtle sub-lethal adverse effects on both honey bees and bumble bees, which prompted wide debate, and has resulted in the EU imposing a two year moratorium on the use of three neonicotinoid compounds (clothianidin, imidacloprid and thiamethoxam) on bee friendly crops from 1 December 2013. LASI has contributed an objective voice to the debate (Carreck & Ratnieks, 2013) and during 2013, two initial field studies were carried out with the aim of supplying some of the information lacking in the debate. Crucial questions remain as to the actual levels of these compounds in nectar and pollen collected from treated crops in the UK, and the proportion of the bees' diets that these represent.

Bee foraging on oilseed rape treated with neonicotinoid insecticides.

Fig. 6. Fields of winter oilseed rape grown from seed treated with neoncotinoid insecticides, May 2013. Photo: Norman Carreck.

Two fields of winter oilseed rape, one treated with clothianidin, the other treated with thiamethoxam to control autumn pests such as the cabbage stem flea beetle, were studied for the five weeks of flowering during May and June 2013. Observations were made of bee

visitation, and samples of whole plants, flowers, nectar and foraging insects, were collected for chemical analysis. The weather throughout flowering was cool, and few bees were seen foraging. Although these weather conditions were unusual, these results are consistent with earlier studies suggesting that winter oilseed rape only forms a minor part of the diet of bees in the UK (Osborne *et al*, 2001; Garbuzov *et al,* 2014). We thank David Taylor, Housedean Farm, East Sussex for providing study sites.

Bee foraging on sweetcorn treated with neonicotinoid insecticides.

Funding
This study was funded by Barfoots of Botley Ltd, and we thank them for providing study sites.

Fig. 7. Clockwise: 1. Field of sweetcorn, Sefter Farm, West Sussex.; 2. Forage strip sown with bee attractive plants; 3. LASI hives on field margin fitted with pollen traps; 4. identifying pollen samples in the lab. Photos: Norman Carreck.

The study
There have been a number of studies in several countries looking at residues of neonicotinoid insecticides in maize crops, but few if any on sweetcorn for human consumption, despite the fact that sweetcorn is frequently treated with clothianidin or thiamethoxam seed dressings. For five weeks during August and September 2013, we monitored three fields of flowering sweetcorn at Sefter Farm, West Sussex. All seed used was treated with a seed dressing of thiamethoxam (Cruiser) to protect against soil pests such as wireworms. Although honey bees are known to visit maize under some circumstances, for example in areas of the US where maize is extensively grown and there is little alternative forage, the extent of insect visitation to maize crops in the UK is largely unknown.

In order to study insect visitation, “standard walks” were made of the sweetcorn crops and for comparison a sown “bee forage strip” and weeds on a field margin. Sweetcorn crop samples, including pollen were collected, and were frozen for analysis of neonicotinoid content. Six

hives of honey bees were also placed in two locations near two of these crops, and were fitted with pollen traps, which were emptied weekly.

At the time of writing, appropriate analytical techniques have been developed and some preliminary results have been produced. Pollen samples are still being sorted and identified. A draft of a paper for publication in a refereed scientific journal is being produced. In summary, the results show that: 1. Very small numbers of honey bees did visit the sweetcorn, but no other insect foragers were seen. In contrast, the sown strips attracted many honey bees, several species of bumble bee, a few solitary bees and some hover flies; 2. The honey bee colonies collected sweetcorn pollen but it was one of a number of sources; 3. All of the sweetcorn samples analysed contained residues of thiamethoxam and its breakdown product clothianidin, but concentrations were lower than in previous published studies of forage maize; 4. Because of these low levels and because sweetcorn forms only part of the diet of the honey bees, it is unlikely that uptake of neonicotinoid insecticide via this route could ever approach the doses used in laboratory-based studies that have shown adverse effects, so it is unlikely to prove harmful to honey bees; and 5. Since no other insects were observed foraging on the sweetcorn it is likewise unlikely that other pollinators would be harmed.

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Research – The Sussex Plan for honey bee health and well being

How good is the British countryside for honey bees? Decoding dances to determine where worker honey bees are foraging

Margaret J. Couvillon and Francis Ratnieks

Who funds our research?

This project is supported by three major donors: Burt's Bees, a company whose ethos supports sustainability and ecological responsibility and which has strong links to bees in its name, in its products and in its founder, US beekeeper Burt Kravitz; Waitrose, a leading supermarket with a strong commitment to social responsibility; and Nineveh Charitable Trust, which is an agricultural charity promoting the preservation of the countryside.

Introduction

Pollinating insects, including honey bees (*Apis mellifera*), continue to decline in Europe and North America, even though the demand for their services is increasing. The number of managed hives in Great Britain has decreased 75% in the past century; in the United States, the 62% decline from 6 million in the 1940s to 2.3 million in 2008 is even more rapid (Neumann and Carreck 2010; Levy 2011). Honey bees face many challenges including pests, pathogens, and pesticides. However, independent of these is another major issue affecting wildlife in general: landscape changes in the last century such as agricultural intensification have reduced flowers and flower-rich habitats that provide nectar and pollen for honey bees and other insects (Fig. 8) (Matson, Parton et al. 1997; Robinson and Sutherland 2002; Carvell, Roy et al. 2006; Westphal, Steffan-Dewenter et al. 2006; Winfree, Bartomeus et al. 2011; Wright and Wimberly 2013). These changes are predicted to continue (Tilman, Fargione et al. 2001).

Fig. 8. Landscape changes in the last century such as agricultural intensification have reduced flowers and flower-rich habitats that provide nectar and pollen for honey bees and other insects. These rolling hills near the lab, while pleasing to our eye, actually provide very little food (nectar and pollen) for honey bees and other insect pollinators. Photo: Margaret Couvillon.

The honey bee possesses a unique and fascinating behaviour in which a successful forager, upon returning to the hive, communicates to unemployed nestmate foragers the location of where she has collected food through the waggle dance (Fig. 9) (von Frisch 1946; von Frisch 1967). During the waggle dance, the forager tells her nestmates the distance and the direction from the hive to the forage. This vector is encoded in two parts of the dance. The direction is encoded in the angle that the bee dances relative to the vertical, which stands for the angle to the forage relative to the sun. The distance is encoded in the duration of the dance.

Fig. 9. A returning forager performs a waggle dance. This communication informs her nestmates of a foraging location, given in distance and angle relative to the sun. This bee was a pollen forager, as we can see yellow pollen in her pollen baskets. Photo: Christoph Grüter.

Distance is particularly interesting because honey bees are economically savvy foragers. With each foraging flight, honey bees weigh the benefit of the forage against the cost of going to get it. Flight distance is one of the biggest costs that a bee must consider. Foragers will not collect at long distances unnecessarily (von Frisch 1967; Seeley 1994). Communicated distance therefore is a simple and powerful proxy for forage availability.

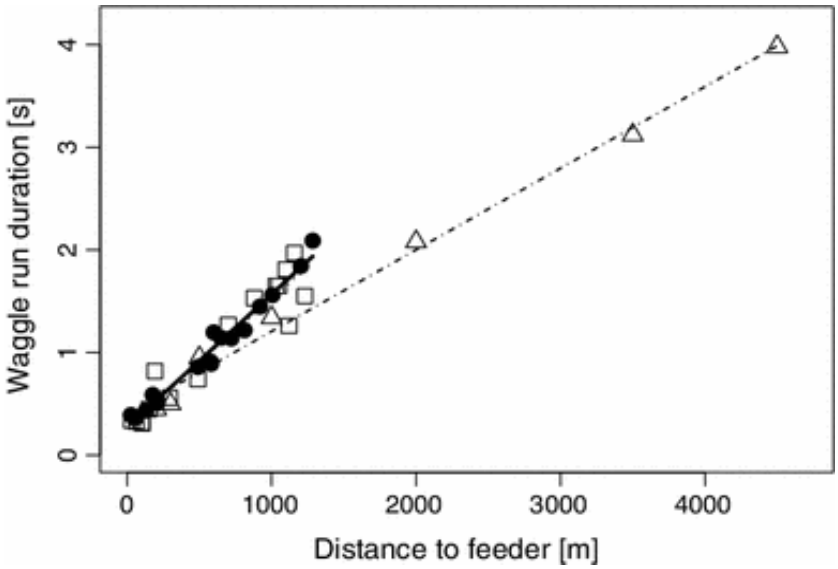

Fig. 10. Data from three calibration experiments. von Frisch (1946; open triangles, dashed line), Wenner (1962; open squares, dotted line), and from this study (closed circles, solid line). In all cases, distance increased linearly with increasing waggle run duration. From Schürch *et al* (2013).

How do we convert waggle duration into flight distance?

Working in collaboration with Roger Schürch at the University of Sussex, we set out to calibrate our “translation” of dance duration into foraging flight distance. We trained individually

marked bees to collect nectar from feeders located at known distances. These bees, upon returning to the hive, would perform waggle dances. By doing this many times, we were able to build up our own calibration curve that is specific to our LASI bees and specific over the landscape (Schürch, Couvillon et al. 2013) (Fig. 10). We learned that the duration of honey bee waggle runs depends linearly on the distance to the food source (Fig. 10). Specifically, we can now estimate with more certainty the distances that our LASI bees fly for given waggle dance durations.

When are the hard months for honey bees to find food? Analysis of foraging distances communicated by the waggle dance

By winter 2013, we had completed all our dance decoding. With a data set of 5097 dances from two full years, we surpassed our original target (4000 dances). Our research represents the most complete data set to date on honey bee foraging in a representative urban-rural landscape. Excitingly, we found that average foraging distance significantly increase from springs (493m) to summers (2156m), before decreasing in autumns (1275m) (Fig. 11).

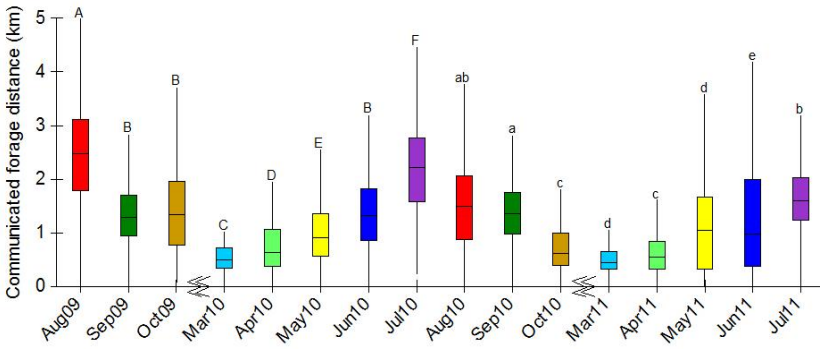

Fig. 11. Seasonal variation in honey bee foraging distance as determined from decoding 5,097 waggle dances. Foraging distance varies significantly with month. The communicated distances were greater in summers (July & August) than springs (March & April) or autumn (September & October). From Couvillon, Schürch, Ratnieks (submitted).

This demonstrates that summer is a harder time for bees to find forage compared to other parts of the foraging year (Couvillon, Schürch et al. submitted). These differences in distances do not depend on type of forage. We divided up the dances by whether they were for nectar or for pollen and then analysed distances per month per forage type. We found that foraging distances were similar for the two types of forage (Data not shown). Therefore, it is not that one type of forage is more rare than the other (Couvillon, Riddell Pearce *et al.* in prep).

Interestingly, we also found that although the bees are roaming further in summers compared to autumns and springs, this is not because they bring back better food. We collected and chilled returning foragers. The immobile bees had gentle pressure applied to their abdomens to cause them to regurgitate some of the nectar in their crop. We tested the nectar for % sugar. Nectar with more sugar content is valued higher by the bees. We saw that sugar content is highest in May, September, and October. It is lowest in spring and summer, although in spring the bees do not have to fly far to collect the nectar (Fig. 12) (Couvillon, Schürch et al. submitted). Therefore, in the summer, bees are flying the furthest and bringing back forage that is not necessarily of better quality.

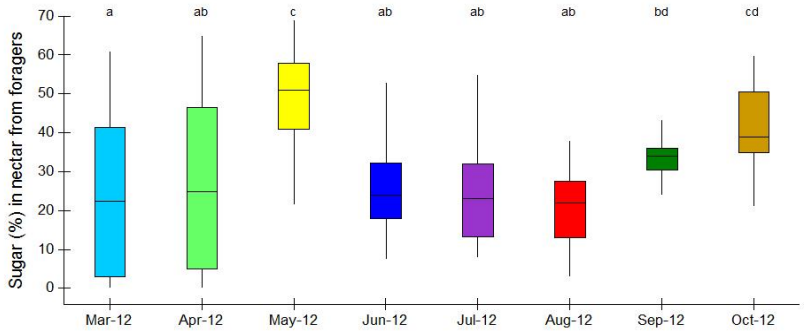

Fig. 12. Sugar content of nectar brought back to the hives by returning foragers. Sugar content is highest in May, September, and October and is lowest in March, April, and June to August. From Couvillon, Schürch, Ratnieks (submitted).

How far the bees fly in the summer is especially striking when we actually map where the bees forage using both (distance and direction) communicated vector components. The mean foraging areas significantly increase from springs (0.8km^2) to summers (15.2km^2) before decreasing in autumns (5.1km^2). In fact, the bees are using a summer area that is 6x greater than what they use in the autumn and 22x greater than what they use in the spring (Fig. 13).

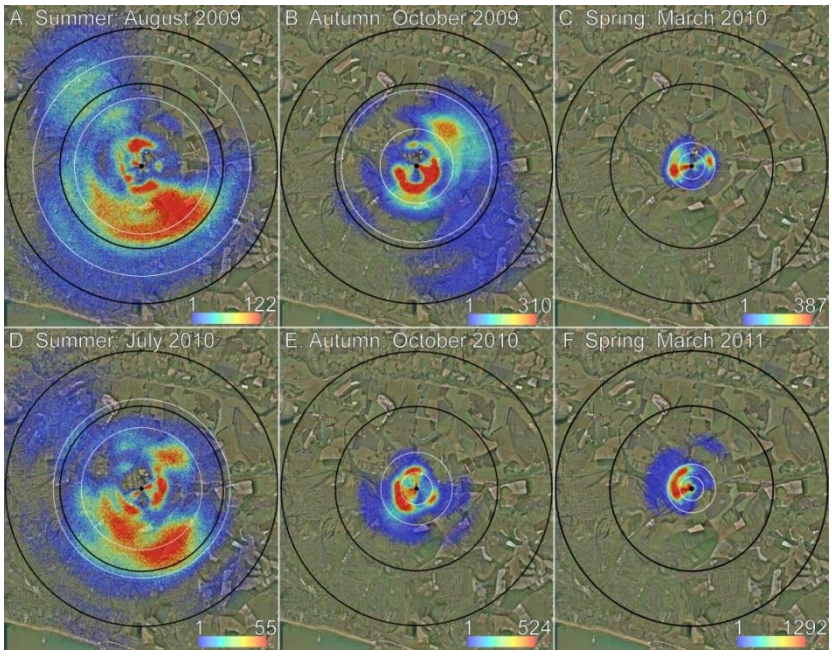

Fig. 13. A novel method of visualising where the bees are foraging in the landscape, devised in Schürch, Couvillon et al. (2013, displays the distribution and density of foraging as determined by waggle dances. Bees forage at the greatest distance in the summer (A, D), less far in autumn (B, E), and most locally (C, F) in early spring, when flowers are available. From Couvillon, Schürch, Ratnieks (submitted).

Where in the landscape are the bees foraging?

Our project ultimately wanted to evaluate the British countryside for honey bees. To answer this question, we had to use all the components that we deciphered over the years. Additionally, we have had to devise important methods of spatial analysis that includes the unique challenges implicit in honey bee foraging. The end result is a rigorous way to ask about

the visits of honey bees to different land-types. For example, we are seeing that the rural countryside, most of which is under some form of stewardship, varies widely in how profitable it is for honey bees. We are currently analysing frequency of visitation to rural areas under different levels of stewardship (Couvillon, Schürch et al. in prep). Overall, we have been able to answer in a novel, exciting, and complete way how good is the landscape for honey bees.

Future directions

At this stage, we have started to move the research ahead into new, exciting directions, both applied and basic in design. We aim to broaden this project to include not just Sussex, but the UK. Our aspiration is that the basic and applied science generated here will become a monitoring scheme that can be applied to other parts of the country. The honey bee is the only animal that tells you where it has been foraging. We are committed to making sure the world listens.

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R Schürch, MJ Couvillon, D Burns, K Tiasman, D Waxman, & FLW Ratnieks (2013). Incorporating variability in honey bee waggle dance decoding improves the mapping of communicated resource locations *Journal of Comparative Physiology A*

R Schürch & MJ Couvillon (2013). Too much noise on the dance floor: intra- and inter-dance angular error in honey bee waggle dances. *Communicative and Integrative Biology* 6 (1)

FC Riddell Pearce, MJ Couvillon, FLW Ratnieks (2013). Hive relocation does not adversely affect honey bee (Hymenoptera: Apidae) foraging. *Psyche* (In press).

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Submitted or publications in preparation

MJ Couvillon, R Schürch & FWL Ratnieks. Dancing bees provide integrated picture of seasonal foraging challenges (In review).

M Garbuzov, MJ Couvillon, R Schürch & FWL Ratnieks. Honey bee dance decoding shows limited foraging on oilseed rape – a potential source of neonicotinoid contamination (In review).

MJ Couvillon, FC Riddell Pearce, C Accelton, K Fensome, SLK Quah, Esme Taylor, and FLW Ratnieks. Honey bee foraging is driven by both nectar and pollen needs (In prep).

MJ Couvillon & FLW Ratnieks. How good are British cities for rural bees? Decoded waggle dances and GIS to identify landscape hot and cold spots for foraging insects (In prep).

MJ Couvillon, R Schürch & FLW Ratnieks. Rural stewardship schemes and honey bee foraging ecology: using waggle dances to evaluate the effectiveness of management strategies (In prep).

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Research – The Sussex Plan for honey bee health and well being

Helping bees and agricultural pollination in farm land
Nick Balfour and Francis Ratnieks

Funding
This project is funded by Waitrose Ltd and The C B Dennis Beekeepers Research Trust.

The movements of honey bees in apple orchards (April-May 2012, 2013)
Apples are the most important crop grown in the United Kingdom that requires bee pollination. This project was carried out in one of the country's main apple-growing regions, West Kent near Tonbridge with the assistance of two apple growers: Adrian Scripps Ltd. and Derbyshire Ltd. The main aim was to determine where honey bees from hives located in apple orchards are actually foraging, and whether this is on apples or not.

Fig. 14. Apple orchard. Photo: Nick Balfour.

Foraging locations will be determined by decoding waggle dances. Pollen samples were also collected, using traps on hive entrances, and will be identified to determine the range of flowers visited and the relative importance of apples. Two aerial surveys of the area were also undertaken in April-May of 2012. This information will be used in conjunction with waggle dance data to construct a map of where bees are foraging over this period. In addition, bee counts were made on apple varieties to provide background information.

The results will help growers use bee hives rented for pollination more effectively. Our results will enable us to address such questions as: are honey bees being drawn into nearby oilseed rape fields?

The fieldwork from April-May 2012 and 2013 has been completed successfully. I am now in the process of decoding waggle dances, analysing pollen and collating bee counts. Preliminary data suggest that honey bees were the most frequent of all apple-flower visitors, accounting for approximately two-thirds of the insects recorded. Waggle dance locations suggest only 10-20% of honey bee foraging was on apples, and a similar amount on oilseed rape.

Fig. 15. Bumble bee *Bombus pascuorum* on apple blossom. Photo: Nick Balfour.

The value of agricultural land as summer forage for bees (July-August, 2012, 2013)
Ongoing LASI research decoding waggle dances as part of the Sussex Plan has shown that during July and August honey bees do much of their foraging in agricultural land, often at long distances (up to *c.* 10km). This shows the importance of farmland as a source of forage. But what are the bees actually foraging on - which habitats, field types and plant species?

The project was carried out with the assistance of Junior Research Associate Bursary Student, Katherine Fensome (2012) and third year Biology student Liz Samuelson (2013) and investigated foraging by honey bees and other pollinating insects in and around the Castle Hill area, *c.* 2-4km SE of the University. This area was surveyed to determine what types of habitat or agricultural land type honey bees are foraging in, and on what species of plants. We also determined which other species of insects (e.g. bumble bees, solitary bees, hover flies, butterflies and moths) were also foraging in these habitats and on these plants. This was achieved by counting flower-visiting insects on transects in these areas. The abundance of flowers was estimated by recording the number of individual flowers in many 1 x 1m areas.

This project will link in well to continuing LASI research. It will also be of great value scientifically and in wildlife conservation by linking together information on honey bee foraging from dance decoding with field work.

Fieldwork from August-September 2013 has been completed successfully. I am now in the process of analysing the data collected. Preliminary results suggest nectivores are far more common in the Nature Reserve, SSSI (Site of Special Scientific Interest) and field margins relative to pastoral fields and areas of set-aside within arable fields.

Blueberry pollination under British field conditions (April-July, 2013, 2014)
Blueberries are a relatively new crop to the United Kingdom. As such there have been few studies investigating blueberry pollination under British field conditions. In this project we will investigate the relative pollination efficacy of honey bees (*Apis mellifera*) and commercially-reared bumble bees (*Bombus terrestris audax*). Furthermore, we will assess the pollination requirements of four commonly British-grown blueberry varieties.

In the spring-summer of 2013 a pilot-project undertaken with the assistance of Hall Hunter Partnership at Tuesley Farm in Surrey. During the blooming period (April-May) pollination cages were erected and bumble bee and honey bee hives were installed in separate cages. We returned in (June-July) to assess the pollination success, yield and berry weight in our cages. Hand pollination was also employed to ascertain the cross-pollination requirements of the four blueberry varieties grown at Tuesley Farm.

The pilot project has been completed successfully. I am currently in the process of analysing the data collected. Preliminary results suggest bumble bees were more efficient blueberry pollinators than honey bees. Furthermore, our findings suggest some varieties respond to cross-pollination better than others. A larger project, in 2014, with more replication will be required to confirm these results.

Research – The Sussex Plan for honey bee health and well being

Helping honey bees and insect pollinators in urban areas

Mihail Garbuzov and Francis Ratnieks

Funding

This research is funded by the Body Shop Foundation

Quantifying variation among garden plants in attractiveness to bees and other flower-visiting insects

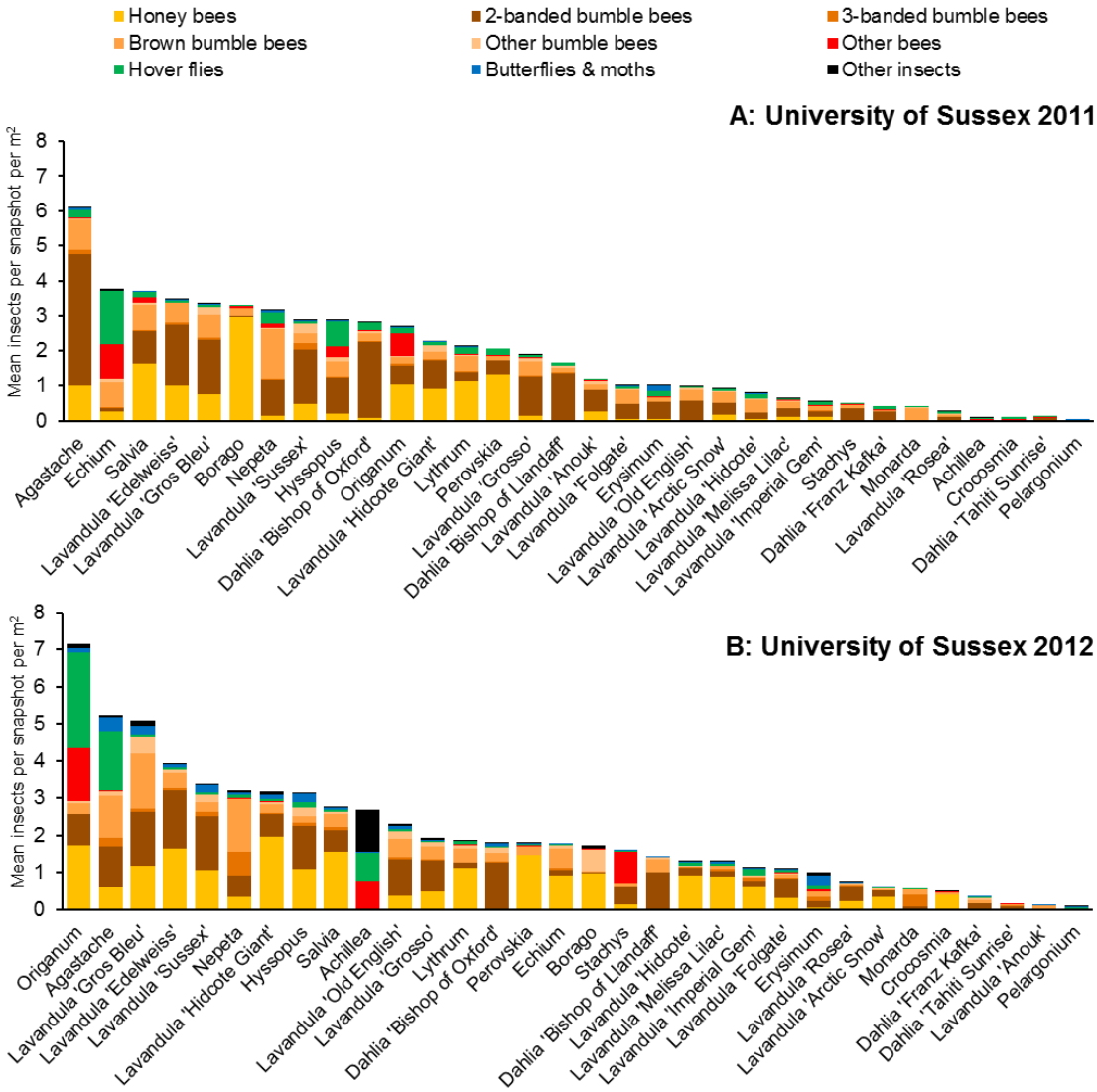


Fig. 16. Main results of comparison of 32 garden plant varieties grown in the experimental flower bed at the University of Sussex campus in 2011 (A) and 2012 (B). Bar heights represent the abundance, and colour represents the type of insect recorded on each plant variety. There is approximately 100-fold difference in attractiveness between the best varieties and the worst.

Pollinating insects are globally declining, with one of the main causes being the loss of flowers. With the value of countryside reducing, urban areas, particularly gardens, are increasingly recognized as of benefit to wildlife, including flower-visiting insects. Many gardeners specifically select plant varieties attractive to wildlife. Given the wide public interest, many lists

of recommended varieties have been produced by both amateurs and professional organizations, but appear not to be well-grounded in empirical data. These lists, however, are not without merit and are an obvious starting point. There is clearly a need to put the process onto a firmer footing based more on data and less on opinion and general experience. We collected data over two summers by counting flower-visiting insects as they foraged on 32 popular summer-flowering garden plant varieties in a specially-planted experimental garden, with two smaller additional gardens set up in year 2 to check the generality of the results. With many thousands of plant varieties available to gardeners in the UK, and other countries or regions, it would have been an impossible task to make a comprehensive survey resulting in a complete and authoritative list. Our results are valuable and encouraging. Garden flowers attractive to the human eye vary enormously, approximately 100-fold, in their attractiveness to insects. Insects, and especially bees and hover flies, can be attracted in large numbers with clear differences in the distribution of types attracted by different varieties. Our results clearly show that there is great scope for making gardens and parks more bee- and insect-friendly by plant selection. Horticulturally-modified plant varieties created by plant breeding, including hybrids, are not necessarily less attractive to insects, and in some cases are more attractive than their wildtype counterparts. Importantly, all the plants we compared were considered highly attractive to humans, given that they are widely sold as ornamental garden plants. Helping insect pollinators in gardens does not involve extra cost or gardening effort, or loss of aesthetic attractiveness. Furthermore, the methods of quantifying insect-friendliness of plant varieties trialled in this study are relatively simple and can form the basis of further research, including 'citizen science'.

This two-year project has finally been completed and the research paper has been accepted for publication in the British Ecological Society journal *Functional Ecology*.
To coincide with the online publication of the research article, we have also made a short video about this project, which is available on the LASI YouTube channel (http://www.youtube.com/watch?v=4u2LeTPGo9w).

Survey of insect visitation of ornamental flowers in Southover Grange garden, Lewes, UK

We have conducted a survey of insect visitation of flowers grown in Southover Grange garden, which is a heritage site of historical significance open to the public and managed by Lewes District Council. It has an area of *c.* 1.5 ha and is managed for non-sport recreation, with lawns, ornamental trees and shrubs, annual and perennial herbaceous flower beds. Our aim was to get a picture of how bee- and insect-friendly, on average, are the garden flowers currently being grown in public gardens and parks.

Ornamental flowers commonly grown in urban gardens and parks can be of value to flower-visiting insects. However, there is huge variation in the number of insects attracted among plant varieties. In this study, we quantified the insect attractiveness of all varieties in full bloom being grown in a public urban garden that is popular due to its beautiful flowers and other attractions. The results showed very clearly that most varieties were either poorly attractive or completely unattractive to insect flower visitors. Several varieties were moderately attractive but very few were highly attractive. Closer examination of *Dahlia* varieties showed that 'open' flowered forms were many times more attractive than 'closed' flower forms. These results strongly suggest that there is a great potential for making urban parks and gardens considerably more bee- and insect- friendly by selecting appropriate varieties.

Fig. 17. Part of Southover Grange garden, Lewes, East Sussex, during the late summer blooming period, August 2012. Photo: Francis Ratnieks.

Measuring the effect of patch size on insect visitation rate per unit area in garden-scale flower patches

This project investigates the effects of flower patch size on the insect visitation. It has importance in making sure that methods used in quantifying attractiveness of different garden plant varieties grown in patches of different size are rigorous. For example, in the two-year project on the University of Sussex campus, the 32 study varieties were grown in patches of equal size (1x1 m^2), so the patch size was not a factor. However, in the survey of a public garden (Southover Grange), varieties were invariably grown in patches of different size. What this study shows is that the patch size can be factored into the analysis of attractiveness in a rigorous manner.

Previous studies investigating the effect of flower patch size on insect flower visitation rate have compared relatively large patches (10-1000s m^2) and have generally found a negative relationship per unit area or per flower. Here, we investigated the effects of patch size on insect visitation in smaller area patches (range c. 0.1-3 m^2) of particular relevance to ornamental flower beds in parks and gardens. We studied two common garden plant varieties in full bloom with 6 patch sizes each: borage (*Borago officinalis*) and lavender (*Lavandula* × *intermedia* 'Grosso'). We counted foraging insects by making multiple counts of the insects foraging at each patch. On borage, all flower-visiting insects were honey bees, *Apis mellifera*, while on lavender insects were bumble bees, *Bombus* sp., (77%), flies (22%), and butterflies (1%). On both plant species we found strong positive effects of patch size on insect numbers; larger patches had more insects. However, there was no effect of patch size on the number of insects per unit area or per flower. These results show that it is possible to make unbiased comparisons of the attractiveness of plant varieties to insects using patches of different sizes within the garden scale range studied and make possible projects aimed at comparing garden plant varieties using existing garden patches of flowers of variable area.

Discussing the strengths and weaknesses of lists of garden plants recommended to help bees, butterflies and other pollinators

In this article we make a critical overview of a selection of 15 plant lists recommended to help bees, butterflies and other pollinators and discuss their strengths and weaknesses, in an attempt to stimulate further debate and research. The paper is currently under review for

publication in a scientific journal.

Pollinators are in global decline. One of the few ways that the general public can help is by cultivating ornamental garden plants that attract pollinators by producing nectar, pollen or both. Advice in the form of lists of recommended plants is available. But how good are these recommendations? Here, we overview a sample of 15 such lists and discuss their strengths and weaknesses. In particular, we find that the range of the number of plant genera per list is large (few tens to few hundreds), and that there is rather little overlap in the recommendations, even among lists addressing the same geographic region (e.g. Britain vs. North America). Furthermore, lists often include poor recommendations, omit many good plants, lack detail, and are almost invariably based on their authors' general expertize rather than empirical data. Nevertheless, some advice given in lists is good, as the recommendations are presumably backed by personal observations and anecdotal data. Lists are also very appealing to public, which makes them an excellent tool in communication from scientists and a useful starting point for further research.

Fig. 18. Some of the lists of bee, butterfly and insect friendly plants analysed in this paper. Top row, lists produced by organizations with standing in plants or pollinators, left to right: UK's Royal Horticultural Society (2011), Natural England (2007), Xerces Society (2011). Bottom row, lists produced by individuals and published as books, left to right: Lavelle and Lavelle (2007); Hooper and Taylor (2006), Baines (2000).

Dance decoding demonstrates that urban honey bees forage mainly in the surrounding urban area

This is the first of the two projects that use waggle dance decoding to investigate honey bee foraging. Both projects commenced in 2011 and took one to two years to collect the data, with up to one year to analyse it and write the reports. By now, both dance decoding projects are finalized and the reports are under review for publication in scientific journals. Below is the summary of the first project investigating honey bee foraging in an urban location throughout the season.

Urbanization is increasing worldwide. From a conservation perspective, urban habitats are highly modified, yet often support considerable biodiversity. Urban parks and gardens are rich in flowers, some of which are a rich source of food for pollinators, including bees. Here, we use waggle dance decoding to investigate foraging by 3 honey bee hives located in the city of Brighton, UK, over most of an entire foraging season, April to October. Foraging was mostly local (within c. 1 km) and mostly within the surrounding urban area, versus the countryside (closest distance c. 2 km) even though this was well within the maximum honey bee foraging range (c. 12-15 km). These distances were lower than those from a previous study for hives located in a rural area 4.5 km away. Honey bees are very sensitive to foraging economics and foragers make waggle dances after visiting only high-quality feeding locations. Low distances

advertised by dances, therefore, indicate sufficient forage nearby and show that urban areas can support honey bees year round. As a corollary, however, urban bees may provide little pollination service to agriculture especially in spring, which had the lowest foraging distances and is when the most economically important UK crops requiring pollination, apple and oilseed rape, are in bloom.

Honey bee dance decoding shows limited foraging on oilseed rape, a potential source of neonicotinoid contamination

The second of the dance decoding projects investigates honey bee foraging on oilseed rape in spring. As oilseed rape is treated with neonicotinoid insecticides, it is a potential source of contamination. However, the effects of these pesticides on bees are controversial and are currently being debated. Our findings contribute to this debate and have potentially important implications to policy.

Recent laboratory and semi-laboratory studies on colony-level effects of neonicotinoids assumed exclusive or near-exclusive levels of colony foraging on a treated crop. But is this a realistic assumption? We monitored six honey bee colonies over two springs (April – May 2011/12) in two neighbouring locations (urban and rural) to quantify foraging on oilseed rape, the most widespread bee-attractive crop in the UK, by decoding waggle dances and trapping pollen. The study area was representative of the UK agricultural landscape in that there were many fields of oilseed rape in bloom (3.3-3.9% of the area around the rural location), close to the national average (3.1%). Foraging on oilseed rape fields was variable, but low: negligible in the urban location and up to c. 26% in for rural. Almost all foraging was to fields within 2 km, even though honey bees can forage at distances of 12-15 km. Pollen trapping in 2012 supported the dance decoding results, with oilseed rape pollen comprising a low proportion of all pollen pellets collected by foragers in both the rural and the urban location. Possible harm to bees has resulted in the EU imposing a two-year moratorium on the use of neonicotinoids on bee-attractive crops from 2013. Our results have important implications for policy as they cast doubt on the relevance of some previous laboratory and semi-laboratory studies estimating colony-level effects of neonicotinoids on social bees. Future attempts to estimate these effects should be based on more realistic proportions of foraging on treated mass-flowering crops, such as oilseed rape.

Honey bee research facilities

Luciano Scandian

Almost two years have passed since the appointment of Luciano Scandian as the Honey Bee Research Facilities Manager, funded by the Esmée Fairbairn Foundation. He is in overall charge of the apiaries and associated facilities, assisting with both basic and applied research projects. He has been working with local beekeepers to help develop “on farm” research and 90% of his time has been allocated to supporting the researchers, for example setting up apiaries, managing hives, maintaining equipment and assisting directly with various research projects. In addition he has participated in the communication of science to the general public as well as training and teaching students for 10% of his time.

Fig. 19. Making new hive stands at the Ridge apiary, University of Sussex. Luciano Scandian with; top left: Hasan Al Tofailia and Nick Balfour; top right: Mihail Garbuzov.

The apiaries

The inclement weather of 2012 adversely affected the wellbeing of our bees, as experienced by most beekeepers in the UK. The colonies went into winter with poorly mated queens and consequently we suffered severe losses the following spring. As the weather improved, however, we were quickly able to increase the number of hives which in turn meant that another apiary had to be found. One was soon located on a farm three miles away from the University. The apiary is situated in a sheltered position, overlooking the Sussex Downs, with easy access by car. The farmer very kindly erected a strong fence all around the apiary to prevent damage to the hives by inquisitive animals. We now have 13 apiaries in different locations in Sussex. At the height of the season there were a total of 190 colonies and 70 mating nuclei. There were also several observation hives at various locations.

With the greater number of hives at our disposal, it was possible to carry out several projects on a much larger scale than ever before. We started January 2003 with oxalic acid research. 110 hives were selected to determine the best method to treat varroa infested colonies with oxalic acid under British conditions; the optimal dosage was also tested. Throughout the year another 70 colonies were used to monitor hygienic behaviour in honey bees. Having identified a number of hygienic queens a breeding programme was devised. 15 daughter queens were open mated and 15 others instrumentally inseminated. The aim was to establish the difference

in the hygienic behaviour of the respective progeny. In September six hives were moved to Chichester in West Sussex to one of the largest sweet corn producing farms in Britain.

Fig. 20. Newly established apiary with LASI hives at Ashcombe Farm, East Sussex. Photo: Luciano Scandian.

LASI used several observation hives for various projects. Four of them are permanently kept in the laboratory; these are used by researchers to decode bee dances and to teach undergraduates, as well as visitors, school parties and members of the public, about various aspects of honey bee behaviour. Three observation hives were also set up at other venues: one in a secondary school for their environmental studies group, another in an agricultural college and the third one in a centre for environmental education for the public. In April and May six observation hives were used for research at an apple farm in Kent.

LASI's new vehicle

With the expansion of the number of apiaries and the distance between them and LASI, it soon became apparent that a suitable vehicle was needed for the department. This was promptly achieved by the purchase of a second-hand Mitsubishi truck in August 2013. It has proved to be a great asset to the department as five people as well as all the material for field experiments and apiary maintenance can be easily moved to and from the many apiaries.

Links with local beekeepers

As part of LASI's outreach programme we carried out a demonstration in July at the out apiary of the Worthing Beekeepers' Association. The aim was to encourage the members to adopt LASI's methodology for the screening of their colonies for hygienic behaviour. This was a successful event and the Association's committee are currently planning the screening programme of their members' colonies from 2014. In December another practical demonstration took place at the apiaries of a semi-commercial beekeeper in West Sussex. This entailed the use of oxalic acid for the treatment of varroa in hives.

Conclusions

After a most exciting and productive year, the winter has arrived and field experiments are coming to a fruitful end. All the colonies and observation hives have been prepared to ensure their best chances of survival during what is considered to be the most difficult period of the year for the bees. The survival of the colonies will enable the research to continue in 2014.

Outreach and public communication

The outreach at LASI this year has been particularly important in terms of connecting with stakeholders. During talks and lectures, mainly given by senior members of the LASI team, to beekeeping groups, horticultural and other organisations, LASI reached an audience of nearly 2,000 people. These talks were given all across the UK from Newcastle to Devon as well as overseas, with topics covering various aspects of research conducted at LASI. A full list of academic and popular talks given in 2013 can be found in Appendices 1 and 2.

Dr Margaret Couvillon continues to be a regular columnist for *Beekeepers Quarterly*, one of Europe's largest hobby beekeeping journals. In her column *Foraging Lines*, Margaret discusses current scientific advances in bee research in a way that is accessible to a lay audience. Topics have included "Do bees know what is best?", "Size matters for male wool-carder bees (*Anthidium* spp.). and "Caffeine boosts bee brains too."

Workshops

Fig. 21. Top left: Francis Ratnieks giving an introductory talk about LASI research and in particular that relating to planting for flower visitors. Top right: Visiting the LASI research experimental planting plot on campus. Bottom left: A typical bedding plant, *Geranium* 'Camden Red' which attracted few flower visitors. Bottom right: Junior Research Assistant, undergraduate Katie Fensome explaining how the snap-shot technique was used in this research.

Our main workshops this year were targeted at stakeholders. Following the two previous years' success, two workshops on "Garden plants for bees" were scheduled for two afternoons in June. However, this year the audience was specifically targeted for their involvement with

the management of green spaces, whether parks, nature reserves, or public gardens or those involved in the horticultural trade. Participants included the staff from the RHS, Kew Gardens, Plumpton College, the National Trust, and Fulham Palace.

The Hygienic Behaviour training workshop took place in September to an audience of members of the UK Bee Farmers Association (BFA), each working from 40 to around 1000 hives. Hygiene is a natural behaviour of honey bee workers that helps confer resistance to brood diseases and to *Varroa*. As with many honey bee behaviours, hygiene is heritable meaning that whether or not a colony is hygienic can be influenced by breeding. Hygiene is found in British honey bees, but only about 10% of British colonies are hygienic. This means that hygiene can be increased by bee breeding. The workshops followed a familiar format, but was focused on methodology for the larger-scale beekeeper. Once again the Department of Life Science's Safety and Technical Officer, Dr Steve Pearce, who as always provides valuable health and safety advice for the lab, taught the bee farmers about the safe handling and storing of liquid nitrogen which is used to test whether honey bees are hygienic. Margaret Ginman, Secretary of the BFA, thanked everyone who made the session such a success, and added that it was great to spend the afternoon looking at current projects being researched at LASI. An article about the workshop appeared in the Bee Farmers Association Bulletin in October 2013.

Fig. 22. Top left: Norman Carreck opening a hive to obtain a frame with sealed brood. Right top: PhD student Gianluigi Bigio explains the freeze-killed brood technique to Margaret Ginman and other bee farmers. Bottom left: Dr Steve Pearce talks about health and safety issues. Bottom right: After all that hard work and knowledge exchanged a little treat of a cream tea was well deserved. All photos (and cakes) Dr Karin Alton.

School and college visits
We continue to host groups of children visiting the laboratory, although these mostly tend to be students from secondary schools, for example, Hailsham Community College and Oathall Community College, Haywards Heath. These visits have proved both popular and successful, Ross Palmer, Assistant Director of Science at Sir Robert Woodard Academy, Lancing, commented:" Please could you pass on our thanks to Francis and his team. We are now much better informed about bees! His session was also excellent."

This year an under-graduate student from Brighton University, Scott Dwyer, joined us for two weeks to learn more about our research. Scott is a beekeeper and has a particular interest in outreach. He also helped make a presentation about different flower visitors (http://www.sussex.ac.uk/lasi/resources/education/flowervisitors).

Younger pupils have been given access to LASI research through workshops with e.g. The Surrey Explorers, a branch of the organisation Potential Plus UK, the children's charity that works with children with high learning potential, visits to local schools and resources on the LASI website.

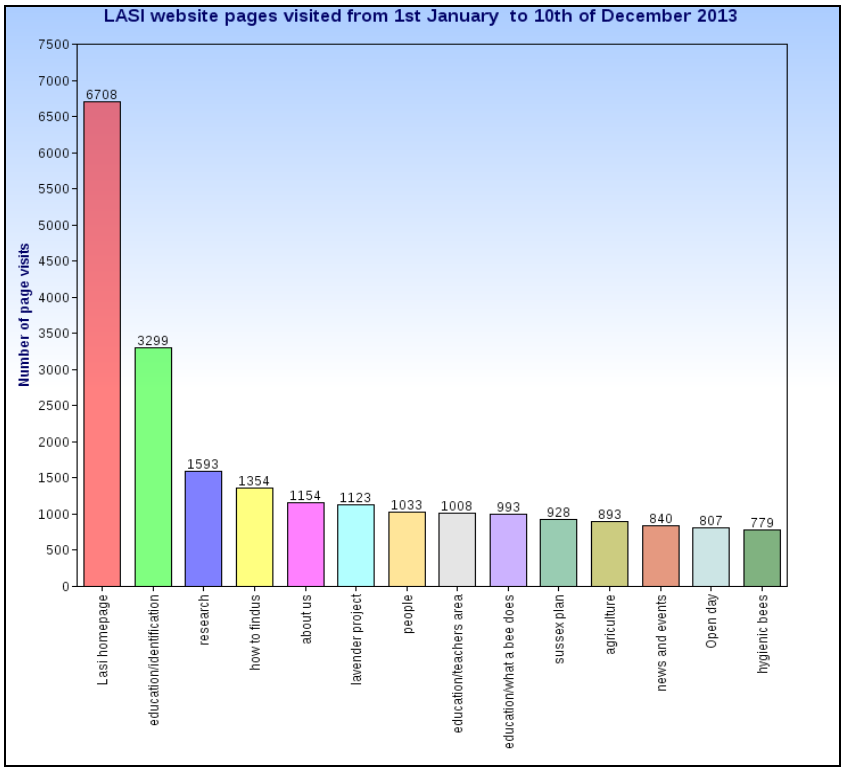
Open Day
Each year LASI receives many requests from beekeepers and others interested in bee and plant research to visit the lab to learn more about our research. However, these visits can be disruptive to our research, so we decided to host an Open Day, where the public would be able to interact with the staff and students at LASI, and see, hear and ask questions about our latest projects.

Fig. 23. Top left: Hasan Al Toufailia and Luciano Scandian showcase the oxalic acid research project. Top left: Nick Balfour shows the intricate differences between bees and other flower visitors. Bottom right: Karin Alton with Gaby Lethbridge and Lisa Anderson who kindly provided home-made cakes and beverages. Bottom left: University of Sussex Head of Donor Relations Sue Hepburn with one of the patches of bee friendly flowers sown on the university campus.

Over a hundred people registered to attend the LASI Open Day on a Saturday in July. All hands were on deck to prepare for this event - with stations set up to demonstrate and explain LASI research. These stations covered gardening for bees, varroa control, hygienic behaviour and queen rearing, and ant communication. Visitors of all generations were represented, and ranged from teachers to gardeners and beekeepers to parents with children. All seemed very enthusiastic, and following an introductory talk from Francis Ratnieks, joined in conversations around the various stations. There were opportunities to ask questions, discuss their own experiences with bees, and listen to what LASI researchers had to say about their work on social insects. As a treat, visitors were welcome to purchase refreshments in the lab garden, which ranged from tea and coffee to a selection of beautiful cakes and muffins, as well as scones with whipped cream and jam. The pop up tea stand was very popular. The afternoon went very quickly and all visitors left with a taste of what LASI is all about.

LASI website and other on-line resources

LASI's website www.sussex.ac.uk/lasi continues to attract many visitors keen to learn more about our research and what resources we offer. Again 40,000 pages were accessed this year, many of these were focused in particular on educational resources for youngsters, our research and our news and events.



Dr Karin Alton also maintains a twitter account and a Facebook page (now nearly 200 members) https://www.facebook.com/groups/366029775708/ where news and information is shared with colleagues from other academic institutions and also interested members of the public.

Media engagement

Media highlights, 2013

JANUARY

Ants are good at crowd control
LASI scientists have discovered how ants respond to heavy traffic to and from the nest.
Earth Times 30/01/13
Press release

Bee-ing kind to struggling bugs
LASI has been awarded £100,000 to continue its work researching honey bees.
The Argus 07/01/13
News story

MARCH

Bees and clothes moths
Norman Carreck guests on an item about bees and clothes moths.
BBC Radio Hereford and Worcester: The Elliot Webb Show 29/03/2013

APRIL

Gardeners urged to let ivy flourish to save bees
Francis Ratnieks and colleagues say that ivy, the scourge of gardeners, is a crucial source of nectar for honey bees during the autumn.
Daily Telegraph 26/04/13
Press release

Pesticide debate (33.35 mins)
Francis Ratnieks airs his views on the likely outcome for bees of banning neonicotinoid pesticides.
BBC Radio 4: The World at One 29/04/13

Beekeepers call on MPs to halt bee decline – video
Francis Ratnieks and LASI are featured for a news item on the neonicotinoid debate.
Channel Four News (website) 26/04/13
As above.
BBC Sussex and Surrey 26/04/13

Tea for two - honey bees
Norman Carreck is guest interviewee for item about bees.
BBC Radio Sussex and Surrey: The Lucy Ambache Show 10/04/2013

Bee deaths: Should the EU ban neonicotinoids?
Norman Carreck reacts to EU banning neonicotinoids.
The Guardian, by Leo Hickman 29/4/13

MAY

Ban on pesticides to save bees may really do them more harm
Norman Carreck quoted on the neonicotinoid debate.
The Times, by Oliver Moody 6/5/13

Bees fight back (19.78 mins)
Francis Ratnieks doubts that neonicotinoids are causing a decline in honey bee populations, and talks about the work of LASI.
BBC Radio 4: Costing the Earth 07/05/13

Take the honey and run
Norman Carreck comments on the theft of beehives.
Modern Farmer, 08/05/2013

How can we revive the honey bee?
Norman Carreck comments in article on honey bee conservation.
Mid Sussex Times, 14/05/2013

Industry reacts to neonicotinoid seed treatment ban
Norman Carreck quoted on the neonicotinoid debate.
Farmers Guardian by Olivia Midgley, 14/5/13

JUNE
Public urged to use smartphone app to aid bee scientists
LASI will be analysing data produced by a new app that encourages people to photograph bees on plants.
The Guardian 20/06/13

Waitrose app points shoppers to bee friendly plants
As above.
The Grocer 20/06/13

Become a 'citizen scientist'
As above.
The Scottish Farmer 19/06/13

Third of all honey bee colonies in England did not survive winter
Francis Ratnieks comments on how cold seasons have contributed to the decline of honey bees.
The Guardian 13/06/13

Versatile ants focus of study by scientists
Tomer Czaczkes is studying the longhorn crazy ant in Brazil.
The Argus 13/06/13
Press release

Poor weather's effect on bee population
Norman Carreck talks about why bees didn't survive several bad seasons of weather.
BBC Radio West Midlands: The Paul Franks Show 13/06/13
As above.
Radio 5 Live 13/06/13

Breeding better bees
Norman Carreck talks about the breeding of bees.
Monocle 24 FM: The Briefing 13/6/13

Neonicotinoids: Europe decides
Norman Carreck quoted on the neonicotinoid debate.
British Beekeepers Association News June 2013

Neonicotinoids banned
As above.
Bee Craft June 2013

Reaction to the EU vote on neonicotinoids
As above.
Beekeepers Quarterly June 2013

JULY
Find out how you can help the honey bee
LASI is holding an Open Day.
West Sussex Gazette 16/07/13
Press release

Open day looks into bee-haviour
Visitors to LASI's Open Day learned more about research into honey bee health and wellbeing.
The Argus 22/07/13
Press release

Flower power
Karin Alton talks about the benefits of having more flowers on campus for pollinating insects.
Meridian Tonight 09/07/13
Press release

To bee or not to bee
Karin Alton discusses the work of LASI and how the public can help bees in their gardens for a special feature.
Sussex Living (magazine) July 2013

AUGUST
Keeping bees in cities could actually be bad for them
Francis Ratnieks and Karin Alton advise that it would be better for people to plant more bee-friendly plants than to keep their own hives.
Mail Online 14/08/13

Urban hives could be bad for bees
As above.
BBC Nature News (online)12/08/2013

Rise in beekeeping a threat to wild bees
Karin Alton is interviewed about the research that reveals domestic beekeeping may harm wild populations.
'The World' (BBC in the US) 13/08/13

As above
Canadian Broadcasting 12/08/13

Urban hives make it worse for bees
As above.
Daily Telegraph 12/08/2013

SEPTEMBER
Honey bee treatment applied in wrong way
Francis Ratnieks is interviewed about his new unpublished study, which shows that a vapour of oxalic acid effectively kills the varroa mite.
The Daily Telegraph 04/09/13

OCTOBER
Love buzz: Bees most attracted to lavender and marjoram

LASI scientists repeatedly counted flower-visiting insects that foraged on 32 popular summer flowering garden plant varieties, in a specially planted experimental garden on the campus.
The Guardian 18/10/13
Press release

Bee friendly plants put to the test
LASI scientists carried out research that showed insect-friendly plants are just as pretty, cheap and easy to grow as less pollinator-friendly varieties.
BBC News (Online) 17/10/13
Press release

As above
BBC Radio Two 17/10/13

NOVEMBER
The taste test: luxury honey
Broadcaster Martha Kearney has revealed she produces 150lbs of honey from her six bee hives every year, and has watched bees doing the waggle dance at LASI.
Financial Times 23/11/13

Herbs are insect havens
Report and photos covering garden flower research by Francis Ratnieks and Mihail Garbuzov.
Garden News, November 2013

DECEMBER
Article on flower research.
The Garden December 2013

Funding

For over five years the Sussex Plan for Honey Bee Health and Well Being has been funded through the vision and generosity of our philanthropic donors. Since 2008, our supporters have recognised the importance of LASI's research in helping to find evidence-based solutions to the problems facing the honey bee and other critical pollinators.

Generous donations have come from a wide variety of sources, including companies, trusts and foundations, beekeepers' associations and individuals. Some of our biggest funders have continued to support LASI research during 2013, for example, Rowse Honey Ltd and the Nineveh Charitable Trust, who have been donating since 2008/9.

Several of our PhD students continue to be funded by the Body Shop Foundation, the British Beekeepers' Association and Waitrose and are now midway through, or nearing completion of their research programmes. Support from the Esmée Fairbairn Foundation for our Honey Bee Research Facilities Manager continues to enhance the research capability and output of LASI.

New donors this year include Brighton and Hove City Council and Barfoots, who have not only provided funding, but also have provided practical assistance to the researchers.

As always we are particularly grateful to all the donors who make a commitment to support LASI over a number of years. Rigorous scientific research is a long term investment and we are grateful that during these uncertain times we have been able to continue this crucial research.

Over the next few years, support of this kind will be essential if the Sussex Plan is to be successful. Everyone at LASI would like to thank our donors, past and present, for their generosity and hope that they might consider supporting our vital work in the future.

Major donors
Barfoots of Botley Ltd.
Body Shop Foundation
Elizabeth Boyling
Brighton and Hove City Council
British Beekeepers' Association
Burt's Bees (UK) Ltd
Michael Chowen
Ernest Cook Trust
C B Dennis British Beekeepers Research Trust
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Dean Forest Beekeepers' Association
Dorchester and Weymouth Beekeepers' Association
Eliot Edmonds, Eleanor Palmer Primary School and 8th Hampstead Scout Group
Elaine Evans
Falling Tree Productions
Shirley Fitch and Fleet Beekeepers' Association in memory of Colin Fitch
Roberta Fourt
Habitat Aid
Jill Hearn
High Wycombe Beekeepers' Association
Hindon and Fonthill Bishop WI
Keith Jones
St Joseph's RC Primary School
Philip King Charitable Trust
John Merrill
Pamela Morton
Dorothy Needham
Newbury and District Beekeepers' Association
Joanne Nickless
Richard Norman
Nutley Women's Institute
Oak Foundation
Isobel Ponsford and Jasmin Bannister and Kingsbridge Primary School
Sarah Potter
Jane Samsworth
Freddie Sowrey
Somerset Beekeepers' Association
South Chilterns Beekeepers' Association
Phyllida Stewart-Roberts
The Tansy Trust
Kathleen Trustrum
University of Sussex Students' Union
Vale and Downland Beekeepers' Association
Nigel Ventham
Jim Vivian-Griffiths
Margaret Whitford
Helen Wilson and Ealing and District Beekeepers' Association in memory of John Wilson MBE
Deborah Winterhalder
Yew Tree WI

Donors in kind
BJ Sherriff
Silver Spoon
Weber Shandwick
Millenium FX

LASI staff biographies

Professor Francis Ratnieks
Francis Ratnieks is Professor of Apiculture and Director of the Laboratory of Apiculture and Social Insects at the University of Sussex. He obtained his PhD at Dyce Laboratory for Honey Bee Studies, Cornell University, USA, and then worked for the New York State Apiary Inspection Service and as a commercial beekeeper with 180 hives in California. He has studied honey bees on all continents, taught honey bee biology at five universities (Cornell, Berkeley, Sheffield, Sussex, São Paulo) and published more than 250 articles on honey bees and social insects.

Dr Karin Alton
Karin Alton is a Research Fellow at LASI. Following a career in commercial and retail finance, she obtained a Zoology degree at Nottingham University, followed by a PhD in Entomology. Karin has worked with hover flies, aphids, tephritid flies, bugs and beetles of various grasslands, and now with honey bees. Her research interests include not only honey bee diseases and pollination but also habitat selection; looking at insect-plant interactions from both an intra-and inter-specific level. Karin is a keen beekeeper with an interest in outreach and education. She teaches beginner courses and helps give hands-on practical experience to novice beekeepers.

Hasan Al-Toufailia
Hasan Al Toufailia studied for his BSc at the University of Damascus, Syria where he had also been working as an entomologist. He came to LASI in June 2010 to carry out a PhD in honey bee biology so that he can return home and become Syria's honey bee expert. His research is investigating how to help honey bees and insect pollinators in urban areas. He has broad interests in ecology and conservation.

Nick Balfour
Nick Balfour read his BSc in *Ecological Science* at Edinburgh University and followed this with an MSc in *Entomology* at Imperial College, London. He began his PhD '*Helping Bees and Agricultural Pollination in Farm Land*' in January 2012. His research will investigate both crop pollination (apples and blueberries) and measures to help nectivores on farmland. This research is being sponsored by Waitrose Plc and the C B Dennis Beekeepers Research Trust.

Gianluigi Bigio
Gianluigi Bigio obtained his BSc in Italy before moving to Ireland to do research in plant genetics. He came to LASI in April 2010 to carry out a PhD in applied honey bee biology. His research is investigating hygienic behaviour in honey bees and improved methods of using queens in a breeding programme.

Tom Butterfield
Ton Butterfield has a 1st Class BSc (Hons) in Biological Sciences (Zoology) from the University of Leicester. He began his PhD at LASI in December 2012 and is studying the chemical ecology and organization of ant colonies, primarily their use of pheromones for intra and inter colony communication. His current study species is the yellow meadow ant, *Lasius flavus*. Initially he will be identifying the constituent compounds in their trail pheromones via

GC/MS and subsequently deducing whether these compounds are modified in response to changes in the foraging environment.

Norman Carreck
Norman Carreck is the senior research technician at LASI and has been keeping bees since the age of 15. He read Agricultural Science at the University of Nottingham and then worked at Rothamsted Research, Hertfordshire, UK, for nearly twenty years as a research scientist studying bee behaviour, pollination ecology and bee pathology. He is the UK member of the Executive Committee of the international bee research network COLOSS, and is also Senior Editor of the *Journal of Apicultural Research* and Science Director of the International Bee Research Association. He holds the National Diploma in Beekeeping and is a Fellow of the Royal Entomological Society and a Fellow of the Society of Biology.

Dr Margaret Couvillon
Margaret Couvillon is a postdoctoral researcher at LASI. She received her BSc from Loyola University, New Orleans, USA in Biology, where she was the highest ranked graduate in 2000. She was awarded a Fellowship from the National Science Foundation to study at the University of Sheffield, from which she obtained her PhD for work on mechanisms of nestmate recognition in honey bees and stingless bees. Afterwards, she won a fellowship to work at the University of Arizona, USA (2007-2009) on honey bees and bumble bees. Her interests include behavioural ecology and evolutionary biology of social insects and science education and outreach.

Mihail Garbuzov
Mihail Garbuzov did his BSc at the University of Sussex, and began his PhD research at LASI in June 2010. His research is investigating how to help honey bees and insect pollinators in urban areas. He has broad interests in ecology and conservation.

Dr Sam Jones
Sam Jones has BSc degrees in both biology and chemistry and an MSc degree in Entomology from Imperial College. He came to LASI in October 2009 to carry out a PhD in the chemical ecology of social insects. His research is investigating foraging behaviour in ants and defence in stingless bees.

Dr Martyn Stenning
Martyn Stenning studied for his PhD at Sussex and is technical supervisor for LASI. He has supervised much of the renovation and ongoing expansion work at the lab. His research interests include the study of organisms (especially birds and dormice) in relation to their environment and he is particularly fascinated by the dependence of species on other species or their own for cues that lead to reproductive regulation. He also has an active interest in investigating effects of climate change on the local ecology and phenology.

Appendix 1.

Publications 2013 (University of Sussex authors in bold).

Papers in refereed journals

Balfour, N.J., Garbuzov, M., Ratnieks, F.L.W. (2013) Longer tongues and swifter handling: why do more bumble bees (*Bombus* spp.) than honey bees (*Apis mellifera*) forage on lavender (*Lavandula* spp.)? *Ecological Entomology*, **38(4)**, 323-329. http://dx.doi.org/10.1111/een.12019

Bigio, G., Al Toufailia, H. Ratnieks, F.L.W. (2014) Honey bee hygienic behaviour does not incur a cost via removal of healthy brood. *Journal of Evolutionary Biology* (In press).

Bigio, G., Schürch, R., Ratnieks, F.W.L. (2013) Hygienic behaviour in honey bees (hymenoptera: *Apidae*): Effects of brood, food and time of the year. *Journal of Economic Entomology* **106**(6): 2280-2285.

Carreck, N.L., Andree, M., Brent, C.S., Cox-Foster, D., Dade, H.A., Ellis, J.D., Hatjina, F., VanEnglesdorp, D. (2013) Standard methods for *Apis mellifera* anatomy and dissection. In *V. Dietemann, J.D. Ellis, P.Neumann (Eds) The COLOSS* BEEBOOK*, Volume I: standard methods for* Apis mellifera research. *Journal of Apicultural Research* **52(4),** http://dx.doi.org/10.3896/IBRA.1.52.4.03

Contrera, F.A.L., **Couvillon, M.J.,** Nieh, J. (2013). Hymenopteran collective foraging and information transfer about resources. *Psyche* **2013**, 1-2.

Couvillon, M.J., Segers, F.H.I.D., Cooper-Bowman, R., **Truslove, G.,** Nascimento, D.L., Nascimento, F.S., **Ratnieks, F.L.W.** (2013) Context affects nestmate recognition errors in honey bees and stingless bees. *Journal of Experimental Biology*, **216(16)**, 3055-3061. http://dx.doi.org/10.1242/jeb.085324

Czaczkes, T.J. Grüter, C., Ellis, L., Wood, E., Ratnieks, F.L.W. (2013) Ant foraging on complex trails: route learning and the role of trail pheromones in *Lasius niger*. Journal of Experimental Biology, 216(2), 188-197. http://dx.doi.org/10.1242/jeb.076570

Czaczkes, T.J., Grüter, C., Ratnieks, F.L.W. (2013) Negative feedback in ants: crowding results in less trail pheromone deposition. *Journal of the Royal Society Interface*, **10(81)**, 1-6. http://dx.doi.org/10.1098/rsif.2012.1009

Czaczkes, T.J., Ratnieks, F.L.W. (2013) Cooperative transport in ants (Hymenoptera: Formicidae) and elsewhere. *Myrmecological News*, **18**, 1-11.

Czaczkes, T.J., Vollet-Neto, A., **Ratnieks, F.L.W.** (2013) Prey escorting behaviour and possible convergent evolution of foraging recruitment mechanisms in an invasive ant. *Behavioural Ecology*, **24(5)**, 1177-1184. http://dx.doi.org/10.1093/beheco/art046

Garbuzov, M., Ratnieks, F.L.W. (2013) Quantifying variation among garden plants in attractiveness to bees and other flower-visiting insects. *Functional Ecology.* http://dx.doi.org/10.1111/1365-2435.12178

Grüter, C., Segers, F.H.I.D., Ratnieks, F.L.W. (2013) Social learning strategies in honey bee foragers: do the costs of using private information affect the use of social information? *Animal Behaviour*, **85(6)**, 1143-1149. http://dx.doi.org/10.1016/j.anbehav.2013.03.041

Kärcher, M.H., Menezes, C., Alves, D.A., Beveridge, O.S., Imperatriz-Fonseca, V-L., **Ratnieks, F.W.W.** (2013) Factors influencing survival duration and choice of virgin queens in the stingless bee *Melipona quadrifasciata. Naturwissenschaften*, **100(6)**, 571-580.

Martin, S.J., Ball, B.V., **Carreck, N.L.** (2013) The role of deformed wing virus in the initial collapse of varroa infested honey bee colonies in the UK. *Journal of Apicultural Research* 52(5), 251-258. http://dx.doi.org/10.3896/IBRA.1.52.5.12

Pinto, M.A., Henriques, D., Chávez-Galarza, J., Kryger, P., Garnery, L., van der Zee, R., Dahle, B., Soland-Reckeweg, G., de la Rúa, P., Dall' Olio, R., **Carreck, N.L.,**

Johnston, J.S. (2014) Genetic integrity of the black honey bee (*Apis mellifera mellifera*) from protected populations: a genome-wide assessment using SNPs and mtDNA sequence data. *Journal of Apicultural Research* (in press).

Riddell Pearce, F.C., Couvillon, M.C., Ratnieks, F.L.W. (2013) Hive relocation does not adversely affect honey bee (Hymenoptera: Apidae) foraging. *Psyche: A Journal of Entomology 2013*.

Schürch, R., Couvillon, M.J. (2013) Too much noise on the dance floor: intra- and inter-dance angular error in honey bee waggle dances. *Communicative and Integrative Biology* **6**(1).

Schurch, R., Couvillon, M.J., Burns, D.D.R., Tasman, K, Waxman, D., Ratnieks, F.L.W. (2013) Incorporating variability in honey bee waggle dance decoding improves the mapping of communicated resource locations. *Journal of comparative physiology. A, Neuroethology, sensory, neural, and behavioral physiology*, **199(12)**, 1143-1152. http://dx.doi.org/10.1007/s00359-013-0860-4

Al Toufailia, H., Couvillon, M.J., Ratnieks, F.L.W., Grüter, C. (2013) Honey bee waggle dance communication: signal meaning and signal noise affect dance follower behaviour. *Behavioral Ecology and Sociobiology*, **67(4)**, 549-556. http://dx.doi.org/10.1007/s00265-012-1474-5

Al-Toufailia, H., Grüter, C., Ratnieks, F.L.W. (2013) Persistence to unrewarding feeding locations by forager honey bees (*Apis mellifera*): the effects of experience, resource profitability, and season. *Ethology*, 119, 1096-1106. http://dx.doi.org/10.1111/eth.12170

Wenseleers, T., **Bacon, J.P.**, Alves, D.A., **Couvillon, M.J., Kärcher, M.H.,** Nascimento, F.S., Nogueira-Neto, P., Ribeiro, M., Robinson, EJ.H., Tofilski, A., **Ratnieks, F.L.W.** (2013) Bourgeois behaviour and freeloading in the colonial orb web spider *Parawixia bistriata* (Araneae, Araneidae). *American Naturalist*, **182(1)**, 120-129. http://dx.doi.org/10.1086/670525

Book chapters, reports, conference proceedings, etc.

Balfour, N., Gandy, S., Ratnieks, F.L.W. (2013) Competition between honey bees (*Apis mellifera*) and bumble bees (*Bombus* spp.) foraging on lavender. In *Abstracts, Entomological Society of America 61st Annual Meeting, Austin, Texas, USA.*

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Appendix 2.

Talks, exhibitions, workshops and public events given in 2013

10/1/13	Talk *"The waggle dance and foraging behaviour"* to Dean Forest Beekeepers Winter Meeting (MC).
11/2/13	Talk at Biology Department Seminar Series, University of Bern, Switzerland (MC).
14/2/13	Talk: *"Breeding hygienic bees"* to Worthing Beekeepers Association (GB).
22/2/13	Talk: *"The changing landscape and planting for pollinators"* to Croydon beekeepers and horticulturists (KA).
23/2/13	Talk: *"LASI research on hygienic behaviour"* to Middlesex Beekeepers Federation Day, London (KA).
23/2/13	Talks *"The waggle dance and foraging behaviour"* (MC) and *"Breeding disease-resistant 'hygienic' honey bees"* (NC) to Holdsworthy Beekeepers Association Spring Convention, Devon.
28/2/13	Talk: *"Why are bees important and why are they declining?"* to the Bankes Natural History Society, Eton College, Berkshire (NC).
3/3/13	Talk *"The waggle dance and foraging behaviour"* to Canterbury Beekeepers Association Spring Convention (MC).
9/3/13	Talk *"The waggle dance and foraging behaviour"* to Somerset Beekeepers Association Spring Convention (MC).
22/3/13	Talk: *"Honey bee nutrition"* to Fareham Beekeepers (NC).
23/3/13	Talk: *"The changing landscape and planting for pollinators"* to North of England Spring Convention, Newcastle (KA).
26/3/13	Talk: *"Why we need to plant for pollinators"* to members of the public, Ardingly, Sussex (KA).
12,14/4/13	Talks: *"Flower - bee interactions"* and *"Foraging patterns"* (FR) and *"Honey bee colony losses: is there something new to say?"* and *"Science for the thinking beekeeper"* (NC) at British Beekeepers Association Spring Convention, Harper Adams University, Shropshire.
30/4/13	Secondary Schools Biology Experience Day, University of Sussex, (FR, MC, KA).
15/5/13	Talk at St Peter's Primary School , Ardingly, Sussex (KA).
26/5/13	Debate about declining bees at London Literature Festival, Southbank (KA).
31/5/13	Talk: *"IBRA relationship, dissemination"* at COLOSS meeting, Athens, Greece (NC).
6/6/13	Talk: *"Britain's changing landscape and the dangers facing bees"* to Crawley Horticultural Society, West Sussex (KA).
11/6/13	Secondary Schools Biology Experience Day, University of Sussex, (FR, MC, KA).
12/6/13	Secondary Schools Biology Experience Day, University of Sussex, (FR, MC, KA).
17/6/13	Secondary Schools Biology Experience Day, University of Sussex, (FR, MC, KA).
12/7/13	Workshop: *"Garden plants for bees"*, LASI (MG, FR, KA).
13/7/13	Workshop: *"Garden plants for bees"*, LASI (MG, FR, KA).
20/7/13	LASI Open Day (all).
28/7/13	Queen rearing workshop to Worthing Beekeepers Association (GB).
31/7/13	Talk *"Summertime and the living is not easy: dancing bees demonstrate seasonal gaps in food availability"* to 50th Annual Conference of Animal Behaviour Society, Boulder, Colorado, USA (MC).
12/8/13	Talk: *"Breeding hygienic bees"* at West Sussex Beekeepers Association,

Pulborough (GB).

2/9/13 Talk: "*Treating bees for varroa using oxalic acid".* Life Sciences Postgraduate research colloquium, University of Sussex (HT).

4/9/13 Talk: *"Bees and bee conservation"* to Pembrokeshire Organic Growers Group, Haverfordwest (NC).

7/9/13 Talk: *"Honey bee colony losses: is there something new to say?"* at Midlands and South West Counties Convention, Hereford (NC).

18/9/13 Workshop: *"Breeding hygienic bees"* for members of the Bee Farmers Association, LASI (NC, FR, GB, KA, HT, LS).

28/9/13 Talk: *"Progress on breeding hygienic bees at the University of Sussex"* at 9th COLOSS Conference, Kiev, Ukraine (NC).

3/10/13 Talk: *"Twenty one years of Varroa in the UK. What have we learned?"* at XXXXIIIrd International Apicultural Congress, Kiev, Ukraine (NC).

8/10/13 Talk: *"Honey bee colony losses - what are the causes?"* to Winchester Beekeepers Association, Itchen Abbas, Hampshire (NC).

10/10/13 Talk: *"Planting for pollinators"* to Fleet Beekeepers Association, Hampshire (KA).

14/10/13 Talk: *"Bees, plants and conservation"* to Horsham Natural History Society, Horsham, West Sussex (NC).

16/10/13 Talk*: "Britain's changing landscape and the importance of gardening for flower visitors"* to Ipswich and East Suffolk Beekeepers Association, Ipswich, Suffolk (KA).

18/10/13 Presented research at Biology Department Seminar Series, Loyola University, New Orleans, USA (MC).

26/10/13 Talk *"Science for the thinking beekeeper"* at National Honey Show, Wadebridge (NC).

7/11/13 Talk *"The waggle dance and foraging behaviour"* to Lincolnshire Beekeepers Association Autumn Meeting (MC).

12/11/13 Talk: *"Competition between honey bees (*Apis mellifera*) and bumble bees (*Bombus *spp.) foraging on lavender"* to Entomological Society of America 61st Annual Meeting, Austin, Texas, USA (NB).

14/11/13 Talk: *"Treating bees for varroa using oxalic acid"* to Worthing Beekeepers Association (HT).

16/11/13 Talk: *"Colony Losses - the reasons behind them"* at Sussex Beekeepers Association Convention, Uckfield (NC).

23/11/13 Talk: *"Treating bees for varroa using oxalic acid"* to East Grinstead Beekeepers Association (HT).

23/11/13 Talk *"Science for the thinking beekeeper"* at Blagdon Beekeepers Association, Avon (NC).

4/12/13 Secondary Schools Biology Experience Day, University of Sussex, (FR, MC, KA).

16/12/13 Talk: *"Breeding for hygienic behaviour in honey bees"* at International Union for the Study of Social Insects North West Europe Section Winter Meeting, Royal Holloway, University of London (GB).