The Insect Pollinators Initiative

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Insects, including bees, hoverflies, butterflies and moths, are essential for the pollination of many wild plants and crops. Unfortunately multiple factors are threatening pollinating insects. Because of the importance of insect pollinators to ecosystems, agriculture and human health the Insect Pollinators Initiative (IPI) was launched in 2010. This exciting initiative, backed by a number of funders, brings together scientists from a range of disciplines to understand the causes and consequences of changes in insect pollinator biodiversity. Their findings will inform new approaches to reduce the pressure on insect pollinators. The nine IPI projects run from early 2011 until 2014 and we would like to take this opportunity to introduce some of the advances in understanding insect pollinators that have been made and the approaches being used in the research. If you want to keep up to date with the research of the IPI please visit us at http://www.insectpollinatorsinitiative.net

Insects that visit flowers are very important to plants. The main groups of insects that visit flowers include honey bees, bumblebees, solitary bees, hoverflies, beetles, butterflies and moths. They are collecting food i.e. nectar and pollen, for themselves, but while moving between flowers they carry pollen from one flower to another. This transfer of pollen is called pollination and it is essential for plant sexual reproduction.

Staple crops, e.g. cereals, that provide the vast majority of human foods, are wind or self pollinated. However, at least one third of the total volume of global agricultural produce relies on insect pollination to some extent. Insect pollinated crops include many fruits, nuts, seeds, beans, coffee and oilseed rape. These provide vital nutrients, e.g. vitamins, and variety to human diets worldwide, and crucial subsistence calories and nutrients to people in some developing countries. Insect pollination is also important to the reproduction and persistence of many wild plants, which underpin a wider and more complex network of animal and plant life. Pollination is therefore an important process in maintaining a healthy and diverse ecosystem.

The Insect Pollinators Initiative (IPI) of the UK funds research into the causes and consequences of changes to insect pollinator populations and communities, and the findings will inform efforts to do something about it. Nine projects were funded running from early 2011 to 2014 and below is more information about some of these.

Honey bees, varroa and viruses

David Evans and colleagues at the University of Warwick1 have analysed the complex interaction between honey bees, varroa and the viruses the mite carries, in particular Deformed Wing Virus (DWV), which is both the most widespread and most important viral pathogen of honey bees. It is known that high levels of DWV are associated with wing deformities and abdominal stunting in individual affected bees and those that do emerge and fly exhibit significantly reduced lifespan, finally resulting in overwintering colony loss.

Rather than using the traditional approach of measuring the average response of a pooled sample of bees to disease this research group analysed responses of individual honey bees exposed to DWV during larval feeding and following mite transmission. By doing this they have gained a unique and highly informative insight into the complex interaction of the bee, mite and virus. Varroa-free bees were exposed to a varroa-infested colony during frame-transfer experiments. Again, in contrast to previous studies, all pupae analysed were age-matched. This has allowed meaningful comparisons to be made of the viral population diversity and levels among individual bee pupae and their associated mites. Strikingly, bee pupae fell into one of three very distinct groups:

- NV: those that had remained varroa-free but had low DWV levels,

Contribution of Funder Project Partners and Research Establishments

1. David Evans and colleagues, the University of Warwick. Analysing the complex interaction between honey bees, varroa and the viruses the mite carries, in particular Deformed Wing Virus.
2. The Rothamsted IPI team, led by Professor Juliet Osborne (now at the University of Exeter), comprises radar engineer; Jason Lim; two post-doctoral researchers specialising in bee behaviour; Stephen Wolf and Beth Nicholls, and a technician, Trish Wells. More information: beth.nicholls@rothamsted.ac.uk
3. IPI Team examining the impact of pesticides on honey bee brain function, led by Dr Chris Connolly at the University of Dundee.
4. Laboratories measuring nutritional quality: Drs Wright & Borland, Newcastle University; Prof Stevenson, Royal Botanic Gardens, Kew; field teams of Prof Jane Memmott (Bristol University) and Prof Kunin (Leeds University).
5. Led by Prof Bill Kunin, Leeds University. Information from: w.kunin@leeds.ac.uk; Dr Mark Gillespie m.gillespie@leeds.ac.uk
6. Claire Carvell, Stephanie Dreier, Seirian Sumner, Jindi Wang, Andrew FG Bourke, John Redhead, Matthew S. Heard; ‘NERC Centre for Ecology and Hydrology; Wallingford; School of Biological Sciences, University of Bristol; Institute of Zoology, Zoological Society of London; School of Biological Sciences, University of East Anglia. For more information: Dr Claire Carvell ccar@ceh.ac.uk
7. Urban Pollinators Research Team: Jane Memmott, Katherine Baldock, Helen Morse, Lynne Ogathorpe (University of Bristol); Mark Goddard and Bill Kunin (University of Leeds); Damien Hicks and Graham Stone (University of Edinburgh); Nadine Mitschunas, Anna Scott and Simon Potts (University of Reading).
VL: those that were varroa-associated but had low DWV levels
VH: those that were varroa-associated and had high DWV levels.

Analysing and comparing these three groups with the control varroa-free colony revealed distinct changes in DWV gene expression in the pupae. The findings suggested that larvae exposed to varroa (or the varroa-transmitted pathogenic viruses that are also circulating in the hive during larval feeding) progress through a series of stages in which DWV levels are initially tightly controlled (groups NV and VL) to a completely deregulated form (VH) associated with overt disease symptoms. Simultaneously, dramatic changes were found to occur in the infecting virus population; initially a high diversity of DWV types was detected, which was replaced in group VH with essentially a single, near-clonal DWV type. These changes resemble those reported by Steve Martin in his population-based studies undertaken in Hawaii over a two-year period, but occur within as little as six days after mite exposure in an individual pupa.

What may this research mean for controlling varroa and DWV?
The scientists’ interpretation of the findings is that pupae in the VL group appear to be able to control DWV replication. This being the case future studies will focus on which honey bee gene or genes confer this trait. Identification of these, only made possible by the analysis of hundreds of individual pupae, should allow selection of honey bees with enhanced resistance to DWV. Alternatively it may be possible to induce resistance now the pathogenic form of DWV has been identified. Despite loss of the 2012 field season due to bad weather, very encouraging progress made in this project and publications describing these studies are currently in peer review. The Evans group greatly appreciate the support they have received from local BBKA beekeeping groups.

Using radar transponders to assess the impacts of disease on honey bee flights
Scientists at Rothamsted Research2 are contributing to part of a project called ‘Impact and mitigation of emergent diseases on major UK pollinators’ led by Prof Robert Paxton. They are using radar technology to study how the bee pathogens Nosema ceranae (a microsporidian fungus) and DWV combine to affect honey bee flight behaviour.

The use of radar technology in entomological research has a history spanning several decades; meteorological radars have been used to study locust swarms and other insect migrations since the 1960s. The harmonic radar system is a newly developed one and is used in this study (figure 1). It is one of only two such systems in existence worldwide and was specifically developed in the 1990s by Rothamsted Research to study the flight of honey bees, bumble bees and butterflies.

Radar systems comprise a radio-wave emitting transmitter, and a receiver antenna, which re-captures these waves once they have been reflected and scattered by the target object. Based on differences between the transmitted and received signal the position of the target can be inferred, although small targets that travel close to the ground, like a foraging bee, mean the reflected signal may be obscured by vegetation or buildings. The harmonic radar system overcomes this problem by using transponders to tag the target. A transponder consists of an antenna, which receives and transmits the radar signal, and a rectifying diode, which converts the signal into multiples (harmonics) of the original frequency making it easy to distinguish from background clutter. The transformation of the signal necessitates the use of a second receiver antenna dish, tuned to the specific harmonic frequency and located above the transmitting antenna (figure 1A). These transponders are extremely lightweight and thus ideal for working with bees. Their length (16 mm) means they must be removed prior to bees entering the hive so as to prevent the bees from getting stuck. Miniaturisation of the transponder is currently part of a five-year research programme at Rothamsted to enable life-long tracking of bees.

Prior to conducting radar-tracking experiments hundreds of recently emerged worker bees are individually marked with unique tags which indicate the treatment a bee has been exposed to e.g. healthy vs. diseased bees. These marked bees are caught at the hive entrance using a marking cage and a transponder is then carefully attached to

Figure 1. (A) Harmonic radar at Rothamsted Research. The larger antenna emits the signal and the smaller antenna picks up the harmonic frequency emitted by the transponder on the bee. Attaching a transponder onto the thorax of a honey bee worker using a sticky foam disk (B) and a tagged honey bee forager (C) prior to her first learning flight. Photos by Stephan Wolf, Rothamsted Research.
the thorax using a small disc of sticky foam (Figure 1B). After quickly checking the transponder is firmly attached, the bee is released (Figure 1C). The transmitting and receiving dishes (Figure 1A) revolve simultaneously at twenty rotations per minute scanning each point in the landscape once every three seconds. The signal emitted from the bee’s transponder can then be viewed in real-time via a monitor connected to the radar unit. The tracking range is approximately one kilometre, although if a bee flies close to dense vegetation or outside of this range then the signal may be temporarily lost (Figure 2).

Once a bee returns to the hive, she is recaptured, and the transponder is removed. The disease load of each bee is then measured by laboratory analysis. Meteorological data are also recorded, since weather conditions can affect flight behaviour. Flight paths are then manually digitised to allow flight characteristics of diseased and healthy bees to be analysed and compared (see Figure 2).

The effects of pesticides on honey bee brain function

All animal nervous systems work through the rapid transmission of information between cells (neurons) within the brain. Certain pesticides target insect pests by disrupting information flow within the brain by affecting the crucial brain mechanism of cholinergic neurotransmission. This is highly effective pest control, but the use of such pesticides has been implicated as a threat to insect pollinator populations. An IPI team, led by Dr Chris Connolly at the University of Dundee, is examining the impact of such pesticides on honey bee brain function. Honey bees can be exposed to two widely used classes of cholinergic pesticide: neonicotinoids (nicotinic receptor agonists) and organophosphate pesticides and miticides (acetylcholinesterase inhibitors). Although sub-lethal levels of neonicotinoids are known to disrupt honey bee learning and behaviour, the neurophysiological basis of these effects was unknown.

The Dundee team used recordings from a specialised region (the mushroom body Kenyon cells) of the honey bee brain, isolated in the laboratory, to show that the neonicotinoids imidacloprid and clothianidin, and the organophosphate, coumaphos oxon, (e.g. CheckMite) disrupted the normal signalling functions of cholinergic nerve cells. These effects were observed at pesticide concentrations that could be encountered by foraging honey bees and within the hive. Researchers found that exposure to different pesticides in combination resulted in an ‘adding together’ of their negative effects to worsen the overall impact on the bee brain. These findings reveal a neuronal mechanism that may explain the observed impairment of bee learning caused by neonicotinoids (below), and predict that exposure to multiple pesticides that target cholinergic function. However, the mechanisms underpinning this will become clearer as the analysis proceeds, but there are a couple of hypotheses that might explain this observation. Firstly, the energy reserves of bees fighting infections are more limited than healthy bees, meaning foragers simply run out of fuel on their return journey. Secondly, diseases, particularly those which bees are exposed to as larvae/pupae, e.g. DWV, may affect brain development and impair the ability of foragers to learn about the location of the hive. If disease leads to increased loss of foragers less food will enter the hive and this could be a major factor contributing to slow colony growth and ultimately to greater winter losses. Thus, through studying the impact of disease infection on the flight behaviour of individual bees we hope to further scientific understanding of colony dynamics under stress from diseases, with the ultimate goal of mitigating these effects.

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Diagrammatic sketch of the main components involved in cholinergic transmission in the brain and the sites at which neonicotinoids (n) and organophosphate pesticides (op) act. The cholinergic neuron synthesises and releases onto its target neuron a chemical called acetylcholine (ACh). ACh binds to specialised proteins or nicotinic receptors ( ) on the target neurons, which ultimately produce an effect within the target neuron. An enzyme, acetylcholinesterase (AChE), which is found within the gap between the two neurons, breaks ACh down, thereby stopping its action. Neonicotinoids, like ACh, bind to and activate the nicotinic receptors. Organophosphates act on AChE and prevent it from breaking down ACh.
signalling pathways in the insect brain will enhance impacts on pollinators.

Pesticide effects on honey bee learning and behaviour
Dr Jeri Wright has led studies at Newcastle University on how exposure to pesticides affects the ability of honey bees to learn odours associated with food rewards. By exposing bees to sub-lethal doses of pesticides in their food for four days they showed that prolonged exposure to a neonicotinoid pesticide (imidacloprid) and a mite treatment (coumaphos) impaired learning and memory in adult forager honey bees, with the reduction in learning compounded when these chemicals were combined. A striking finding was that although bees exposed to pesticides appeared to learn the odour-sugar association, they could not select the correct odour during memory testing 24 hours later using the familiar odour and a novel odour.

Later experiments examined the influence of prolonged exposure to each of four neonicotinoid insecticides (imidacloprid, dinotefuran, clothianidin, thiamethoxam) on learning and memory using a more complicated task called ‘differential learning’. Here, individual bees are taught to associate one odour with a sugar reward, and a second odour with bitter-tasting quinine. Forager honey bees treated with imidacloprid, dinotefuran or clothianidin learned to avoid the quinine-associated odour, although their performance was slower than the control group with no pesticide exposure. Strikingly, the bees fed thiamethoxam were unable to perform differential learning or differentiate the odours in the memory test, implying that of the four compounds tested thiamethoxam had the greatest toxicity. These studies imply that foraging worker honey bees subjected to very low doses for longer than 24 hours — doses that they could experience in nectar in the field while foraging — are likely to be most affected by crops treated with thiamethoxam.

If bees cannot discriminate among scents associated with rewarding and unrewarding flowers they are unlikely to forage efficiently. If they cannot remember floral cues associated with profitable floral food sources they are also less likely to be efficient foragers.

Impact of a neonicotinoid on bumblebee behaviour and colony dynamics
Collaborative work between two of the IPI projects, ‘Emergent bee diseases’ and ‘Pesticide impacts on bees’, at Royal Holloway University of London, has shown that extended periods of stress can lead to bumblebee colony failure. Using a combination of laboratory experiments and computer modelling this team showed how stress from low-level pesticide (imidacloprid) exposure can affect bumblebee behaviour. The publication of their findings is free to download from the Ecology Letters website (see reference opposite). The researchers found that stress can lead to colony failure without directly killing individual bees. Even slight changes in behaviour can be enough to stop colonies from growing normally if enough bees in the colony are affected. Although the researchers used low-level exposure to imidacloprid as a stressor in this study, their findings are also likely to apply more generally to the impacts of other stressors such as disease and poor diet. This discovery confirms what many beekeepers know, which is that colonies are vulnerable to various types of stress. Nevertheless, it is an important breakthrough because it provides evidence linking the effects of stress, caused by many factors, to bee declines. As the effects of these stress-causing factors could accumulate or interact, this may explain why the causes of bee declines have been so hard to establish. The question of how bees respond to stress is complicated. To get to the root of the problem of bee declines, scientists will need to study the combined effects of pesticides, diseases and other factors on bees and their colonies.

Honey bee nutrition
Poor nutrition has been highlighted as a factor that could increase honey bees’ vulnerability to stressors, such as pesticides and disease, and so contribute to their
widespread and ongoing population declines. However, it is not known how nutrition affects stress resistance in social insects such as honey bees. Collaboration between the research groups of Dr Jeri Wright at Newcastle University, Prof Sue Nicolson at the University of Pretoria, South Africa and Prof Shafir at the Hebrew University of Jerusalem is addressing this.

Prof Nicolson’s team examined how exposure to a neurotoxin, nicotine, and to low temperatures affect nutrient regulation in honey bees. Groups of queenless, newly-emerged workers were given diets containing specific ratios of protein and carbohydrate to determine, firstly, how toxin exposure and environmental temperature affected their nutrient intake and, secondly, how nutrition affected survival under stress.

The researchers found that low temperatures and nicotine exposure interacted to reduce survival in honey bees that ate low protein, high carbohydrate diets, whereas bees reared on a high protein diet were better able to survive the impact of these interacting stressors. Although protein conferred a survival benefit in honey bees exposed to nicotine and low temperature, caged workers did not shift their intake towards a higher protein diet to improve their survival under these stressful conditions. Taken together, these results show that nutrition affected survival in stressed honey bees, but that strategies of nutrient regulation by bees did not change to improve survival under stress.

Dr Wright’s group found that diets composed of ten essential amino acids and carbohydrates affected the survival of nurse and forager honey bees. Cohorts of workers of defined castes/ages (newly-closed nurses or foragers) were confined to diets containing specific ratios of amino acids and carbohydrates (AA:C). These experiments revealed that nurse honey bees in the first eight days require a diet high in essential amino acids (1:50, AA:C). As these same bees aged, their nutritional needs shifted towards a ratio that was higher in carbohydrates. Bees aged eight and fourteen days required a ratio of 1:75 (AA:C), whereas bees that were foraging, (fourteen plus days old) required a ratio of 1:250 (AA:C).

Critically, however, foragers had low survival when confined to feeding on diets that were high in essential amino acids. These data and other published studies from the Pretoria group, show that adult worker honey bees do not survive well on diets high in protein or essential amino acids, except during the first week after they have emerged from pupal cells. Foraging worker honey bees not only require a diet high in carbohydrates, they also die rapidly if their diet has too much protein or essential amino acids. These data have important implications for the survival of colonies that have been provisioned with artificial food supplements.

Prof Shafir has tested whether honey bee foragers are able to select foods to balance their colony’s nutritional deficit, and the consequences of malnutrition. Initially his group focused on amino acids. In choice tests where nectar was enriched by single amino acids, nectar foragers from nutritionally balanced colonies preferred certain amino acids, with a slight preference for essential over non-essential amino acids, and were repelled by others. To test whether pollen foragers preferentially collect food that balances their colony’s nutritional state, test colonies were allowed to collect an artificial diet poor in a particular essential amino acid i.e. a deficit diet. The foragers’ choice between the original deficit diet and other artificial diets, either poor or rich in that particular amino acid, was then tested. Foragers preferentially chose the diet rich in the amino acid that was lacking in their original diet, thereby appearing to try and balance the colony’s nutritional requirement. This was also shown in similar experiments with fatty acids. The link between nutrition and honey bee behaviour is also being explored by testing worker performance in homing flights. So far, results suggest that performance seems unaffected by whether bees were fed sucrose solutions with either a preferred or a repellent amino acid.

Carbohydrate concentrations remain to be tested.

A large collaborative undertaking across the IPI is seeking to measure the nutritional quality of pollen and nectar of plants across the British landscape. Samples of nectar and pollen of over three hundred plant species including wild/native, cultivated or alien-invasive species have been taken from a range of managed and unmanaged UK habitats. The analysis of pollen samples for amino acids and fatty acids is ongoing, and the database containing this information should be published in late 2014. As found in other studies, the main difference among plant species in the carbohydrate composition of nectar is whether the dominant sugar is sucrose or a combination of fructose and glucose.

Considerable variety in the distribution of essential and non-essential amino acids in floral nectar has also been found, with amino acids ranging widely in concentration from nanomolar to micromolar. The significance of these findings will be more apparent when...
the final analyses of these data are completed in 2014. In addition, honey samples donated by beekeepers from around the UK, and bee bread samples will be analysed for their nutritional content. This information will be publicly available in an online database hosted by Newcastle University from late 2014.

**Effects of agriculture and land use on pollinators**

The 'AgriLand' project, led by Prof Bill Kunin at Leeds University, is a large-scale assessment of the role of historic and current land use in agricultural landscapes in affecting pollinator diversity and abundance. The field surveys are now complete and the team is busily sorting and analysing the data. Already, however, some key results are beginning to emerge.

In one aspect of the project, field teams conducted re-surveys of bees at 24 sites where good historical wild bee records were available from the first half of the 20th century, accumulating enough data for analysis in twenty of these. Bee diversity was found to have decreased significantly in 80% of sites examined, which provides strong corroboration of trends inferred in the past from biodiversity records. Work is still ongoing to test whether these diversity losses could be predicted by differences in land use history between sites.

This IPI project has also worked alongside the EU STEP (Status and Trends of European Pollinators) project to examine changes in wild pollinator (bees, hoverflies and butterflies) diversity over recent decades. This work used records of plant and pollinator occurrence collected in national databases in the UK, Belgium and the Netherlands. The results (see Carvalheiro reference opposite) confirmed previous evidence of declines in wild bee diversity during the mid 20th century but also detected that the declines have apparently slowed for bumblebees and even partially reversed for solitary bees in the last twenty years. One possible interpretation is that the substantial public investment in conservation in recent decades may be paying off.

It is difficult to know for certain what has been driving shifts in wild bee diversity and abundance. Most of the processes probably act on landscape scales (multiple square km), far too big to allow controlled laboratory testing. To understand why bees are faring better in some areas than in others, the project selected a set of 96 field sites across Britain, chosen to differ substantially in habitat diversity, the abundance of flowers, the amount of pesticides applied and the density of commercial beekeeping. Field teams have surveyed floral resources in these sites, as well as sampling local bee and hoverfly communities, and assessing the quality of the ‘pollination services’ provided by pollinators by testing the seed production of potted flowers set in each landscape. They also set out small honey bee hives in each landscape, to see if the floral resources recorded by human observers can predict how well honey bees can gather resources in each site. It is too early to report the results, but the findings may be as valuable to beekeepers as they will be to those responsible for wild pollinator conservation. Ultimately, this project aims to understand the features of the British rural landscape that are most vital to maintaining and improving stocks of bees and other pollinators.

**Impact of habitat structure on queen and worker bumblebees**

Dr Claire Carvell is leading a collaborative project that is using a novel combination of genetics, field studies and landscape modelling to better understand the effects of land management and habitat structure on bumblebee behaviour and colony dynamics. Although bumblebees have been well studied in some respects, fundamental aspects of their ecology, such as how far queens disperse in the spring and how far workers fly to forage in different environments, remain unknown. This is largely due to the difficulty of finding bumblebee nests in the wild.

As in honey bees, bumblebee workers are daughters of a single queen, but, unlike honey bees, bumblebee queens mate with only one male. So, in genetic terms, workers within a bumblebee colony are highly related i.e. as full sisters. The research team have explored this aspect of bumblebee biology to produce a detailed picture of how bumblebees use space in an agricultural landscape.

The team worked in a large area of mixed farmland in which selected field margins were sown with nectar-rich flower mixtures as part of an agri-environment scheme. DNA was sampled non-lethally from live wild bumblebees (2,577 workers and 537 queens of five different species) captured across the landscape.

DNA sampling was achieved using a validated method that involves clipping the tip of a mid-leg, which has been shown not to impact on the bees’ survival or foraging efficiency. Samples were then genotyped in the laboratory, allowing estimates of relatedness between individuals and colony membership to be made. The resulting
sisters, mothers and daughters were grouped into more than 2,000 colonies.

The mapped locations of all bees were then overlaid onto highly detailed maps of the study landscape obtained using high resolution radar scans taken from aircraft. Based on the distribution of related workers, the team was able to estimate the location of each colony and calculate the average foraging distance of its workers, as shown in figure 3. Worker foraging distances varied between species, with averages ranging from 268m to 553m. Importantly, foraging distances also varied within species depending on where in the landscape a colony was located. For colonies in parts of the landscape with fewer flowers, foraging distances were much greater; up to and exceeding two kilometres.

The final stage of the research aims to develop models to give us a ‘bees’ eye view’ of the study landscape. This involves looking at the proportions of different habitats, their interconnections in space and time, and how these affect the distances travelled both by workers, when they are foraging, and by queens, when they are dispersing across the landscape or searching for nest sites.

Using these genetic approaches we can start to understand how bumblebee queens and their workers use the landscape around them. Most importantly, we can assess whether agri-environment schemes designed to improve the countryside for bees, like those involving the planting of extra flowers along field margins, are having a positive effect. For example, reducing the distance that bumblebees have to fly to find food might increase their chances of survival into the next generation because they can devote more energy to reproduction. Under the current Environmental Stewardship scheme, the area targeted for bees and other pollinators is less than 0.1% of the total managed area. The results of this project will help policy-makers and land managers improve schemes both to conserve bumblebee populations in agricultural and urban areas, and to enhance pollination services for crops and biodiversity.

**Urbanisation and pollinators**

On one hand, urbanisation is considered to be one of the major causes of insect decline, in particular through the alteration of food and nesting sites important to pollinators. On the other hand, some urban habitats are remarkably good for pollinators: half of all German bee species have been found in urban Berlin and 35% of British hoverfly species have been recorded in a garden in Leicester.

**The Urban Pollinators Project** led by Prof Jane Memmott, coordinated by Dr Katherine Baldock at the University of Bristol and involving many project partners, has been investigating insect pollinators in urban areas across the UK by studying whole communities of flower-visiting insects and the plant species they visit. This project is investigating three questions:

- How do insect pollinator communities in urban areas compare to those in nature reserves and farmland?
- Where are the hot-spots of insect pollinator biodiversity in urban areas?

![Figure 3. Map showing the locations of nineteen worker bumblebees (red dots) across a farm from a colony of the nationally rare species, Bombus ruderatus. DNA samples from the bees were used to identify them as sisters from the same colony. This information allows the location of their nest (red star), and the average foraging distance of the bees (dotted red line) to be estimated. Image credit: John Redhead, CEH, Acquisition of airborne remote sensing data to produce the underlying landscape. Funded by Syngenta PLC.](image)
How can we improve insect pollinator diversity and abundance in urban areas?

The researchers walk transects which are a two metre wide strip of a fixed length, through the target sites sampling all bumblebees, solitary bees, honey bees, hoverflies, butterflies and moths observed visiting flowers. All insects are subsequently identified by taxonomists at the National Museum of Wales. These data are visualised as flower-visitation networks (Figure 4) which show the plant species used by each insect species to collect food in the form of pollen or nectar, and the insect species which are potential pollinators for each plant species. By studying the architecture of these networks and which species most frequently interact, it is possible to predict how resilient communities of plants and their pollinators are likely to be to environmental change.

To examine how the pollinator communities in urban habitats compare to other habitats, the project team collected data at three different sites: farmland, nature reserves and urban areas, in and around twelve towns and cities across the UK, ranging from Dundee in the north to Southampton on the south coast. These data are currently being analysed and the findings prepared for publication. To identify the hot spots for insect pollinators in urban environments a range of urban habitats have been sampled more intensively in Bristol, Reading, Leeds and Edinburgh over two years: 2012 and 2013. Habitats sampled include allotments, gardens, parks, cemeteries and churchyards, man-made surfaces, e.g. car parks and pavements, urban nature reserves and road verges. Flower-visitor interactions were sampled along transects totalling one kilometre per habitat in each city, split between ten separate sites per city. As most gardens are too small to accommodate a sampling transect of 100 metres, sampling took place in ten gardens close to one another in ten regions per city. Thus 400 householders gave permission to sample the insect pollinators in their gardens and researchers sampled over 700 separate sites during the two years of the study. The data from this stage of the project will be scaled up by the area of each urban habitat per city to construct city-scale flower-visitor interaction networks. It can then be incorporated into models to simulate the potential effects of habitat loss on pollinators at the city scale.

To investigate how urban areas can be improved for pollinators, sixty large flower meadows have been sown in parks, playing fields and on road verges in collaboration with local councils and schools. Planting meadows containing flowers rich in nectar and pollen provide additional and sustained pollen and nectar foods for urban pollinators. Fifteen sites in each of Bristol, Reading, Leeds and Edinburgh were sown with either an annual flower mix or perennial flower mix to create meadows of 300 m² and these were sampled for pollinators throughout 2013.

Researchers and representatives from Wildlife Trust partners have also been visiting schools during 2013 to deliver educational sessions on the importance and diversity of insect pollinators. The final stage of the project will be a conference for conservation practitioners in 2014 where the project team will share findings so the research results can be used to inform better management of urban habitats for pollinators.

While the Insect Pollinators Initiative will draw to a close by the end of 2014/early 2015, the process of data analysis and publication in scientific journals will continue for some time thereafter. At the BBKA Spring Convention in 2014 there will be a series of IPI talks and posters where BBKA members can hear first-hand about the latest findings and pose questions to the assembled researchers. Summaries of these talks will also be published in June BBKA News. Visit the IPI website, http://www.insectpollinators initiative.net to find out more and check out the publications page. This will soon provide a list of the IPI outputs with links to journal websites with open access, or contact details for lead authors who will be able to supply copies of the paper.