This case study was the winning entry to BBSRC's Impact Writing Competition 2019. The competition invited PhD and early-career researchers to submit a case study showcasing social or economic impact arising from BBSRC investments, providing experience of writing about science for a policy audience. This case study was written by Luke Woodford, a PhD student at the University of St Andrews.

Using Coordinated Varroa Treatments to Improve Honey Bee Health *by Luke Woodford.*

Varroa destructor is a parasitic mite that lives on the bodies of honey bees, feeding on their fat and haemolymph (a blood-like substance in invertebrates). The mite was originally a parasite of the Asian honey bee, *Apis cerana*, before jumping host to the European honey bee, *Apis mellifera*. As humans have moved colonies of European honey bees around the world, they have facilitated the spread of the mite, which is now found on every large landmass in the world, except Australia. But it isn't only the mite itself that presents a challenge for beekeepers worldwide: Varroa acts as a vector for several highly pathogenic viruses, most notably Deformed Wing Virus (DWV). Together, the mite and the virus are responsible for over 25 % of colony losses every year and represent one of the biggest threats to honey bee survival on a global scale.

Our EastBIO BBSRC-funded project measures changes in honey bee colony health by examining the DWV populations of the colonies. Previous research from our group (Ryabov *et al.* 2014) has indicated that DWV levels change dramatically in the presence of Varroa: in healthy, mite-free colonies, virus levels are very low and cause no symptomatic infections, but in the presence of Varroa the virus levels become dramatically elevated and often lead to symptomatic infections, increased mortality and a high risk of colony loss. The Varroa mites can be removed from colonies with the use of readily available miticide treatments. However, there are currently no regulations in place in the UK to enforce correct or timely treatment, and awareness of the problem among amateur beekeepers remains relatively poor.

A key goal of this project is to produce a body of evidence for Scottish Government policymakers to show that regulating both the type and the timing of miticide treatments would be highly beneficial to Scottish honey bee health. One of the largest economic benefits of this work will be the significant positive impact on Scottish crop pollination, as an improvement to pollinator health would directly benefit crop production in the UK.

To explore the possible effects of regulation on a larger scale, our project involves running a coordinated treatment regime within a geographically isolated environment – the island of Arran, on the west coast of Scotland. Our aim is to use coordinated treatments to remove Varroa mites from the honey bee colonies on the island and show an improvement in overall colony health. By working on an island, we can control for 'drifting' of bees between colonies (honey bees are known to not fly over large bodies of water), as well as regulating any bees brought into the area during the course of the study.

This project is being carried out in collaboration with the Arran Bee Group, an affiliate of the Scottish Beekeepers' Association, which comprises around 20 amateur beekeepers with varied experience in beekeeping. The group has experienced problems with high Varroa levels in the past and lost all its honey bee colonies in 2013 due to an infestation of the parasite and suspected associated DWV infections. Unfortunately, after the members had replaced their colonies, a further infestation followed. As a result, the group was highly motivated to take part in the study and learn more about ways to improve colony health and reduce or even remove Varroa from the island.

The researchers aim to use coordinated treatments to remove Varroa mites from honey bee colonies, ultimately informing regulation of miticide treatments and contributing to improved Scottish crop pollination.

This is an ongoing three-year study, begun in the summer of 2017 and concluding in the summer of 2020. The whole project is funded by the BBSRC through an EastBIO PhD studentship and the funding is also used to cover lab consumables, fieldwork costs and treatments for all the colonies on the island of Arran. We are providing the beekeepers with two treatments per year. The first is a 6-week late-summer treatment of Apivar: the beekeepers place chemical strips in the hives and collect the mites which drop out of the bottom of the hives in envelopes for us to count and analyse. This is the easiest and most effective treatment for Varroa and is best applied in late summer, once beekeepers have removed any honey crop from the hives.

We have also introduced a second annual treatment in midwinter, using an Apibioxal 'dribble method'. The rationale behind treating in midwinter is to treat the colony when the queen isn't laying eggs and therefore there are no sealed cells containing brood in the comb. This is because around 90% of Varroa in a hive reside in the sealed brood cells with the developing pupae. Treating with the correct dose of Apibioxal dribble has no negative effect on the bees but kills the mites. BBSRC funding allows us to provide the beekeepers with the chemicals, the plasticware and, crucially, extensive guidance on how to administer this treatment.

We communicate regularly with the Arran Bee Group and have presented at several of their beekeeping meetings – an excellent way to ensure that the aims and principles of the study can be clearly and accessibly communicated to the non-virologist. We have presented evidence from past work and other ongoing experiments as justification for the methods we are applying on Arran, and have also shared interim data with the group as a way to maintain their enthusiasm and commitment to the project.

The project is already contributing in a tangible way to the health of honey bee colonies on Arran, as the BBSRC funding allows us to bring expert beekeepers to the island to meet with the group and share practical advice about colony management, including checking for signs of diseases and applying the correct treatments if an issue is found. We have introduced the beekeepers to mite management techniques such as the 'shook-swarm', a method which removes all sealed brood and a large proportion of the mites from a colony prior to treatment, and introduced them to the midwinter miticide treatment, something the group had not previously attempted. We believe this shows the societal impact of this project because we are improving the overall understanding of bee health amongst the beekeeping community of Arran and engaging them in important scientific research.

The project is connected to the Scottish Government through Fiona Highet, Senior Entomologist at Science and Advice for Scottish Agriculture (SASA), and one of the co-supervisors of the PhD project. Fiona is hugely knowledgeable on honey bee health and has proven key in establishing initial communications with the beekeepers. This link to government creates a very real possibility that this project will be used as a pilot study for Scottish beekeeping, showing that a) coordinated treatments over large geographical areas are both possible and effective, and b) beekeepers will engage with the science of disease management and pest control. We hope that evidence from this study will influence future policy decisions in Scotland, perhaps ultimately leading to the implementation of regulations for a coordinated Varroa treatment regime across the country.

We believe the outcomes of this study will be of significant benefit to Scottish honey bee health, at a time when improving the health of pollinating insects is of critical importance for both agriculture and the wider environment.

Varroa mites and the Deformed Wing Virus they transmit are responsible for over 25% of honey bee colony losses every year. Image credit: Amy, Flickr