Mapping and Modelling

The Asian Hornet in the UK

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One of the biggest threats to honey bees across Europe at the moment is undoubtedly the Asian hornet (*Vespa velutina*). Trying to ensure the UK is free from this threat lies partly with the government's National Bee Unit, (NBU) as it is our responsibility (with the help of beekeepers and citizen scientists across the country) to carry out surveillance for Asian hornets and, in the event of a finding, to locate and destroy any nests as rapidly as possible.

Not all of our response happens 'in the field' and, as a Geographic Information Specialist with the Animal and Plant Health Agency, it is my role to provide support to our response in the form of mapping and modelling.

Questions

Much of my role involves trying to understand and communicate where things are, or where they are likely to be, so that we can attempt to understand them and contain any threats and diseases if necessary. In the context of the Asian hornet in the UK, there are several key questions that we are asked regularly. For example, How far can it spread in a year? How many nests are we likely to find in an area if the species is established? And, perhaps most importantly, Do we stand any chance of detecting it early enough and eradicating it?

Specific Challenges

Answering such questions about Asian hornets provides some specific challenges. The species is relatively new to Europe (believed to have arrived in France in 2004) and is still spreading. Although much has been written about the species, and several research groups across Europe have been set up to study it in detail, there are still some big gaps in our understanding of its basic biology.

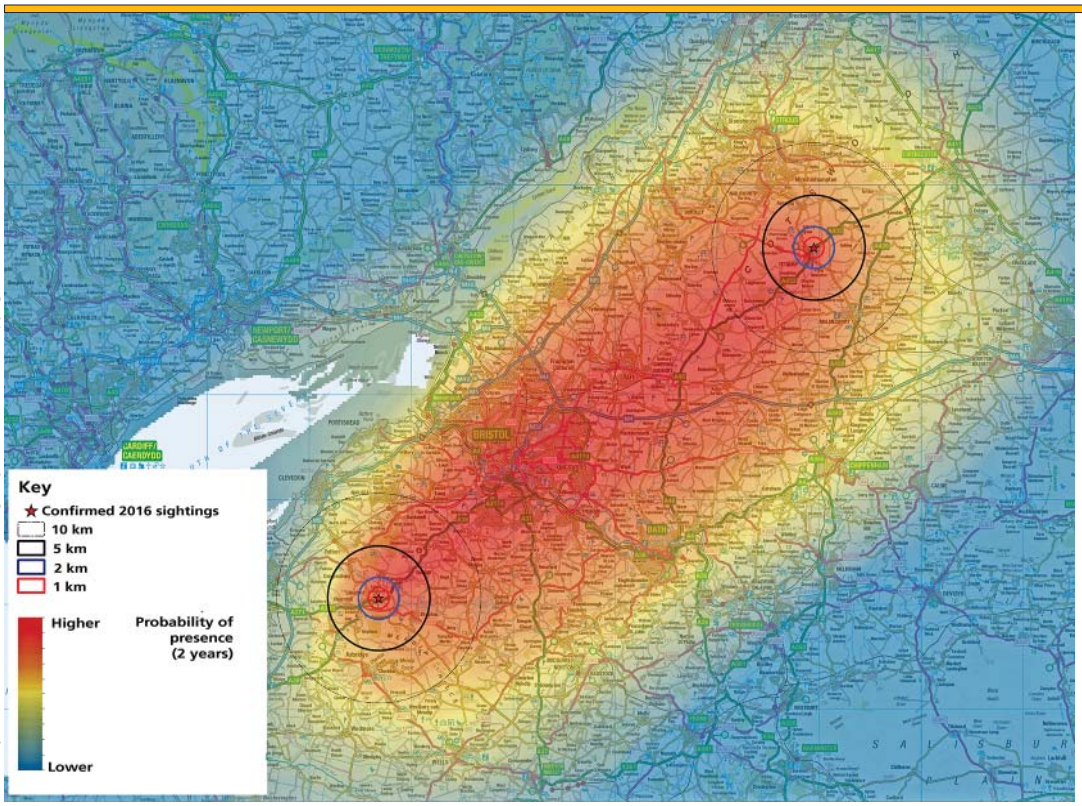
If we can draw one clear conclusion from the research that has been carried out so far, it is that the Asian hornet is highly adaptable and is able to exist and survive in a wide range of landscapes. That aside, over the past few years we have worked to draw together as much evidence as possible and speak to a variety of Asian hornet researchers from across France, Spain and Italy in order to come up with a framework to understand how the species might spread in the UK.

Crucially, we have also developed estimates for how effective our control of the species could be, and combined the two elements in order to come up with a modelling tool that helps us to plan for different invasion scenarios.

Spread

The first component of the model, and one that can be used to address some of the fundamental questions about the Asian hornet, is the spread. This simulates the potential movement of the Asian hornet from one or more locations in the UK. The location(s) used to 'seed' the model are picked prior to running it. In that way we can select a random location, or use the model to run specific scenarios, for example to look at what might have happened had the nests located in Gloucestershire and Devon in 2016 and 2017 managed to reach the point of reproduction.

Within the model, each nest reaches the point of reproduction in September, before dying. Any nests that



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The probability of the existence of an Asian hornet nest in areas after two years, given the scenario that both incursions discovered in 2016 went undetected and produced viable populations. The concentric circles show the focus of our immediate activity following the discovery of a nest.

reproduce successfully can generate up to 20 nests the following year. This figure is intended to represent the fact that Asian hornet nests in France have been estimated to produce up to 500 mated queens (gynes), each capable of establishing a new nest, with around a 95% mortality rate of gynes over winter. Of the surviving gynes, most are likely to establish nests fairly close to their 'mother' nest location (typically within 1–5 km, given enough suitable nest locations are available and that the population of Asian hornets has not reached saturation point in the location).

There is a chance that gynes will disperse further during the autumn and spring (for example, in search of a 'better' location, or simply by being blown or moved a longer distance), with a theoretical maximum annual dispersal distance of 100 km (the invasion 'front' in France advanced around 80–100 km per year).

Using these bits of information, we are able to simulate the dispersal of gynes across the landscape according to some basic preferences. For example, it appears more likely that Asian hornet nests will establish in urban and suburban areas than open agricultural landscapes, as these areas provide a wide range of potential nest locations and plenty of foraging resources.

In France and South Korea (where the Asian hornet is also an invasive species), it has been observed that the Asian hornet has a strong preference for urban environments and can exist in relatively high densities in these areas.

Detection

Queens remain undetectable throughout the hibernation period (estimated to be October to March in the UK), after which they establish a small primary nest. The primary nest allows the queen to develop a small population of workers during the spring and early summer. Once this population is established, a much larger secondary nest is constructed, and the number of hornets in the nest starts to build rapidly. In France, most nests are not detected until they reach this stage (around July), as this is the point at which workers begin to look for proteins and can be found 'hawking' in apiaries. In order to mimic the level of detectability in France, nests in the model have an extremely low probability of being observed until July.

Given that most nests are undetectable for most of the year, we are left with a very small window (two months, from mid-July to mid-September) when we can carry out effective control. Therefore the imperative is to ensure that we detect nests as early as possible.

Based on estimates from France, around 30% of secondary nests are detected and removed prior to the reproductive stage. Applying this level of detection, and ensuring that all areas are regularly and repeatedly checked for nests, means that we can start to have an impact on the population.

Running the Model

Once the model has been seeded, it is run for a specified period of time. A search can be initiated at a pre-defined time too. So, for example, we can run the model through for several years, with no search or control at all, in order to see what might happen if we do nothing (in these scenarios, we see the Asian hornet spread rapidly and become established), or we could initiate the search after just a couple of months to simulate the effect of early detection.

The search component operates by selecting a single nest from the available nests and using this as the start point. The search then radiates outwards from there, mimicking our response on the ground, which is to carry out apiary inspections around the finding, as well as carrying out foot-patrols to search for hornets in forage sites and potential nest locations.

The model simulates the search on a weekly basis; each week the search moves further out from its start point. The distance searched each week depends on the number of inspectors available as well as the landscape we are searching. For example, high density urban areas will take longer to search as they are more complex and likely to have a lot of access issues, as well as presenting a wide range of potential nest locations to check. Open

landscapes should prove faster to search, as there may be fewer potential nest sites and the inspectors can cover the ground more rapidly.

After an area has been searched once, it is repeatedly searched to ensure it is clear. This constant repetition is very important, given that the detection window for nests is so short, and that the probability of actually discovering a nest is only around 30% at each pass.

In addition to the inspector-led searching, we can also include some citizen-science aspects in the model, simulating the actions of beekeepers and members of the public, who may discover and report hornets or nests. This is important, as it potentially allows the detection of nests that are outside of the main search area, allowing us to deal more effectively with long distance dispersals.

Response

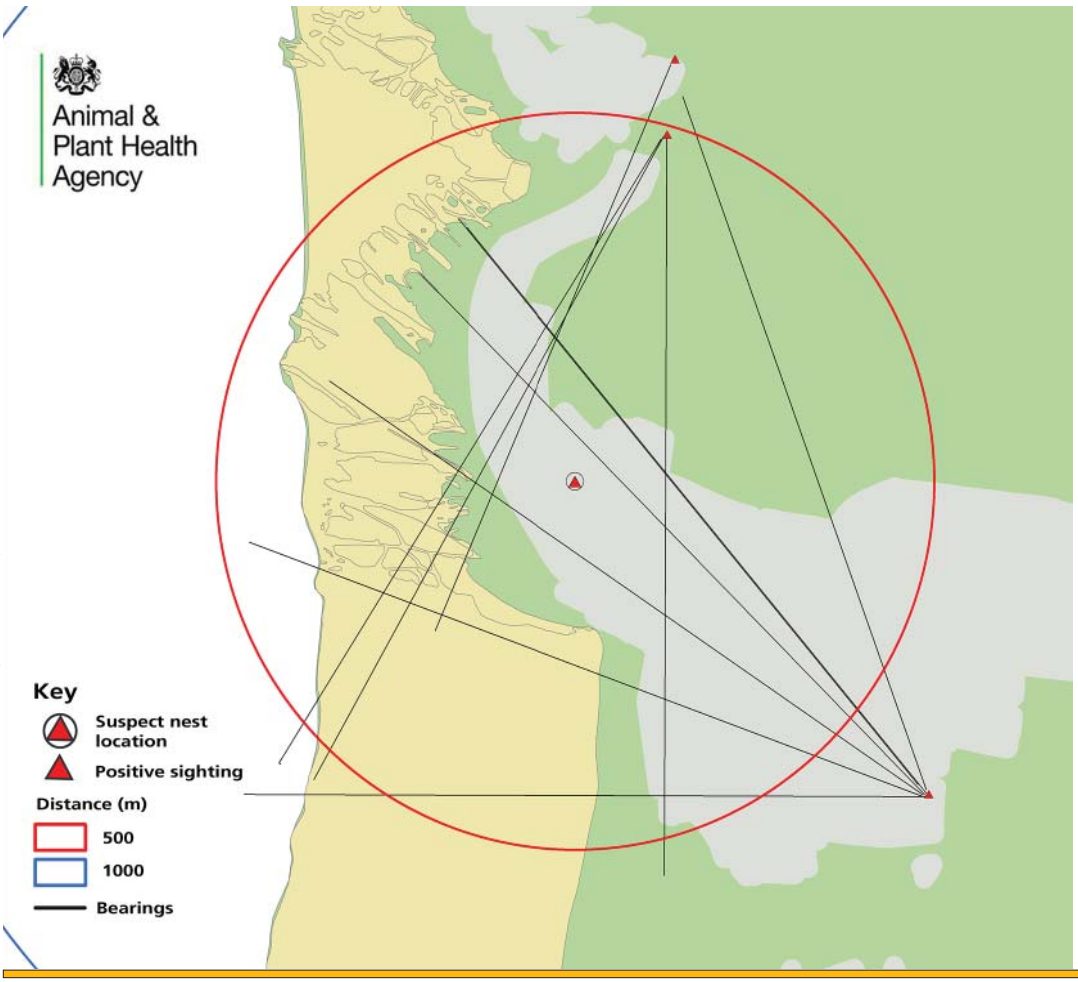
Following the detection and subsequent destruction of an Asian hornet nest in Tetbury, the model output was used to help inform and direct the most effective locations for setting traps the following spring, in order to maximise our chances of detecting any remaining hornet activity. The model also forms part of our response in the event of an outbreak, as we can use the outputs to help communicate key messages about where the largest risks of spread might be. It also helps guide how much effort we might need to achieve successful eradication.

Although a useful tool, modelling only provides part of the response in the event of an outbreak. Another significant part of my role during an outbreak is to help to collate and map the latest information we have from the inspectors out in the field. This helps provide the inspectors with details on where searches and inspections have already taken place. The ability to provide maps quickly is essential in helping understand the unfolding situation as an outbreak develops.

Gilles San martin

Given that most nests are undetectable for most of the year, it is imperative that we detect nests as early as possible

The process of triangulation to identify a potential nest location, based on flight lines observed from foraging hornets. The map shows the general area around Woolacombe, Devon, although actual locations have been adjusted and are for illustrative purposes only.



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Actual locations not shown. Map is for illustratgive purposes only.

Mapping Flight Lines

A key example of this is the mapping of flight lines of hornets, which is one of the methods we use to detect where nest locations might be (using triangulation and intersecting flight paths to identify nest sites).

As well as providing location and field information, the mapping process also allows us to collate information on how much ground we are able to cover over each week. We can feed this back into the model to help us improve our overall detection estimates and search rates.

The tools provided by mapping and modelling are a key part of our response to the Asian hornet in the UK, and help to provide us with essential information on how effective our approach is, as well as delivering a useful set of outputs to help communicate to decision makers some of the threats and risks posed by the Asian hornet.