Understanding Epidemics in Crowded Apiaries

Dr Lewis Bartlett, Center for the Ecology of Infectious Diseases, University of Georgia, discusses a recent quantitative study

New horizons, new challenges, new tools – critical components of scientific momentum. One marvel of the modern era is how the range of applications for quantitative scientific studies (those resting on heavy use of mathematics) have increased with the availability of modern, high-power, low-cost computer technology.

Combining mathematics and computer simulations is often one of the first and fastest scientific responses to a new threat. Climate projections are a popular example, used to provide global information for the long term. Weather predictions – like hurricane or flood forecasts – are a similar, more immediate advisory branch of quantitative science, brought to bear to help mitigate disaster.

In my own field of infectious diseases, we apply the same principle of simulating mathematical approximations of the real world to disease outbreaks, often to look at all the likely outcomes of a new disease arriving, or of circulating diseases gaining in severity.

I grew up seeing this technique most famously used in the context of the foot-and-mouth outbreak in the United Kingdom (UK). More recently, I have used this approach in the southern United States of America (USA) to help inform projections of pandemics, like the spread of Zika virus, in 2016.

Dr Lewis Bartlett

Supplied by Lewis Bartlett

Application to Bee Diseases

Bees are my longstanding passion and another focus for my scientific research. Diseases (old and new) are a problem for our bees. Bringing to bear the tools used in other facets of disease biology – especially those used in agriculture and public health – is what drives my current honey bee research agenda and was the motive for my recently published paper, *Industrial bees: The impact of apicultural intensification on local disease prevalence*.

We are all familiar with the blights our honey bees face, much more so now than in the past. While pesticides get most of the media limelight, diseases are arguably even more important (certainly in relation to extinctions of native bees). However, disentangling all the different aspects of what drives the spread of damaging bee diseases has remained a challenging scientific topic, even for large cooperative international confederations of scientists. Overall, these efforts are often framed in understanding just how different beekeeping has become in certain parts of the world.

Impact of Scale

In my experience of beekeeping in the UK and beekeeping in the USA, there is certainly a difference in meaning for the term 'big operation'. This is not just in terms of number of colonies, but also of geographical spread.

Up to three-quarters of all colonies in the USA are trucked to California in early spring to pollinate almond orchards. Many of these colonies are overwintered in Florida, where temperatures are mild and the citrus blossom season starts as early as January. Where they head after the almonds is less predictable – whether it is up to North Dakota or down to South Texas.

But, if you are going to buy a lorry to move your bees, you best have enough bees to make that lorry a worthwhile investment; and if there are thousands of hectares of one crop flowering all at once, it takes a lot of bees for optimum pollination and to take maximum advantage of the nectar flow. However, after that crop is done, there are a huge number of honey bee mouths to feed and precious little else left to flower.

Everything is bigger in America and the impact of monocrop farming on a huge scale now means that the old saying 'go big or go home' is true of beekeeping as well. A hundred years ago, apiaries might have been counted in tens of hives and moved maybe a few hundred miles within a state during the season; beekeepers here now count them in hundreds, if not thousands, and transport them thousands upon thousands of miles across landscapes of monocrops.

Just like elsewhere with other livestock and, indeed, in our own cities, crowding often raises one concern above everything else: disease.

We have all struggled with disease afflicting our bees. Here in the USA, especially, things can get out of hand quickly. Alongside poor-quality nutrition, pesticides and a startling lack of genetic diversity, how much is the crowding of hives onto moving trucks, through packed holding yards and in colossal apiaries contributing to the spread of disease? This was the rationale for the work we set out to do.

We know bees drift and when they drift, they carry pests and pathogens with them. We know they drift more when they are hit with pesticides and when there are too many lookalike hives all packed together in a regular grid. We know industrial beekeepers equalise colonies by moving brood, and we know they don't always have the person-power to manage robbing when it occurs. Fortunately, from the perspective of scientists distilling down to core processes, a lot of this comes down to one main thing: infectious agents spreading between colonies much more easily. So, how much does this matter? Ultimately, we wanted to ask the question: 'If I crowd far more colonies into this yard, can I expect a larger proportion of my bees to have diseases?'.

Methodology

To answer the question, we used the sort of mathematics and computer simulations I talked about at the start of this article. I will spare the gory scientific details, but the more curious amongst you are invited to read the full open-access scientific paper[1].

In brief, we combined two approaches. We used some advanced biological mathematics, developed by my colleague, Carly Rozins, who completed her doctorate in Canada working on the mathematics of livestock diseases. We compared the calculations to computer simulations, which I developed. These work off basic rules programmed into software to mimic the sort of things which happen in a beehive as far as diseases are concerned. We can run the same simulations hundreds of thousands of times, to see how likely certain outcomes are, based on all the probabilities of different things happening.

These two different approaches have been used to do great work on bees in a single colony, but we were the first to try and do this with whole apiaries.

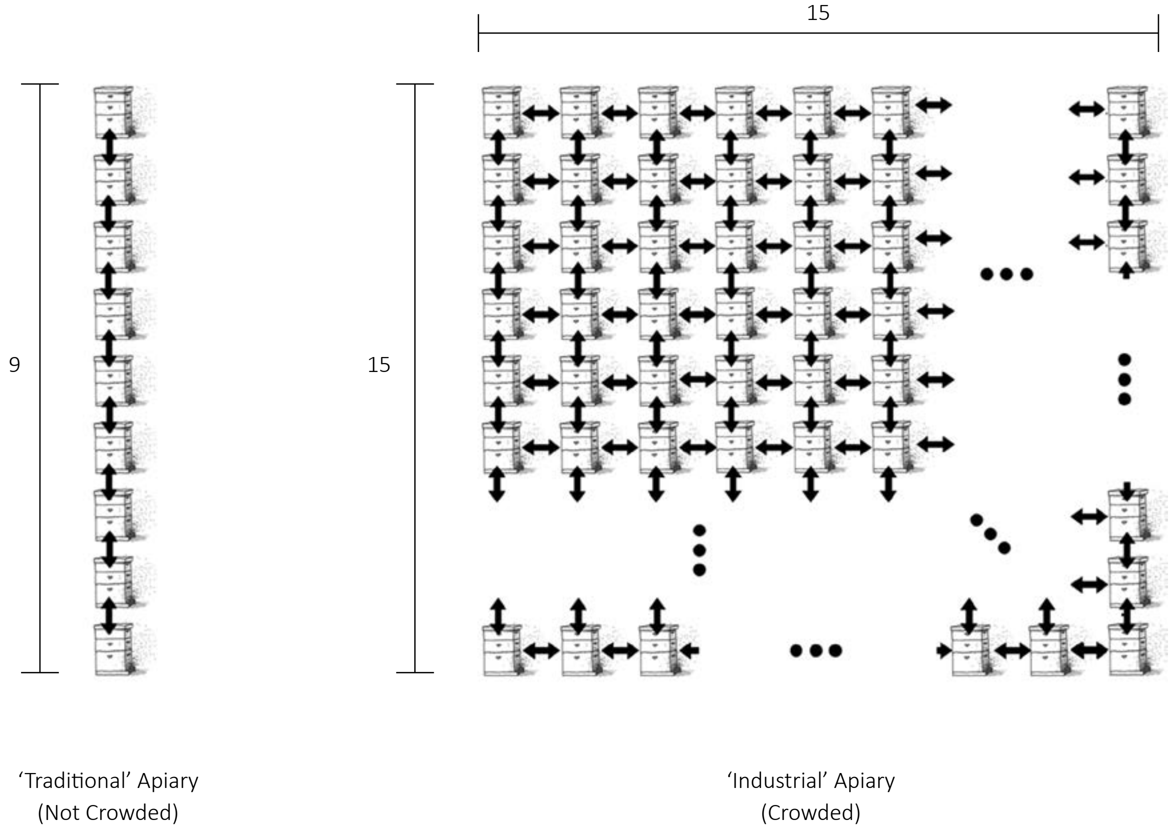
Once we confirmed our two approaches agreed, we drew our main conclusion from comparing two extreme cases of beekeeping, shown in Figure 1. One where a small, single-row apiary of nine colonies had very low likelihoods of things like bee drift, and a much bigger apiary of 225 colonies in a tightly packed grid, where there was approximately ten times higher likelihood of events like a single forager returning to the wrong colony. By looking at these extreme cases of what are 'traditional, not crowded' and 'industrial, crowded' beekeeping styles (as far as apiaries are concerned), we can look at the worst-case scenario.

Contagiousness

It is worth saying here that all diseases differ in how contagious they are – some spread very easily and some are very difficult to spread. This has two components: environment (crowding) and the biology of the disease (here, I will talk about 'contagiousness').

We looked at a big range of contagiousness values to see if there were certain diseases which were more likely to benefit from crowding than others. Further, we know enough about one disease and its casuative organism, *Nosema ceranae*, thanks to work done in the UK at the University of Leeds and Queen's University Belfast, to calculate its lowest and highest likely contagiousness values. So, for a whole range of possible contagiousness values, including our best estimates for nosema, we can look

Figure 1. Diagram showing the two apiary types modelled



Figures supplied by Lewis Bartlett (adapted); hive illustration by Keith Delaplane

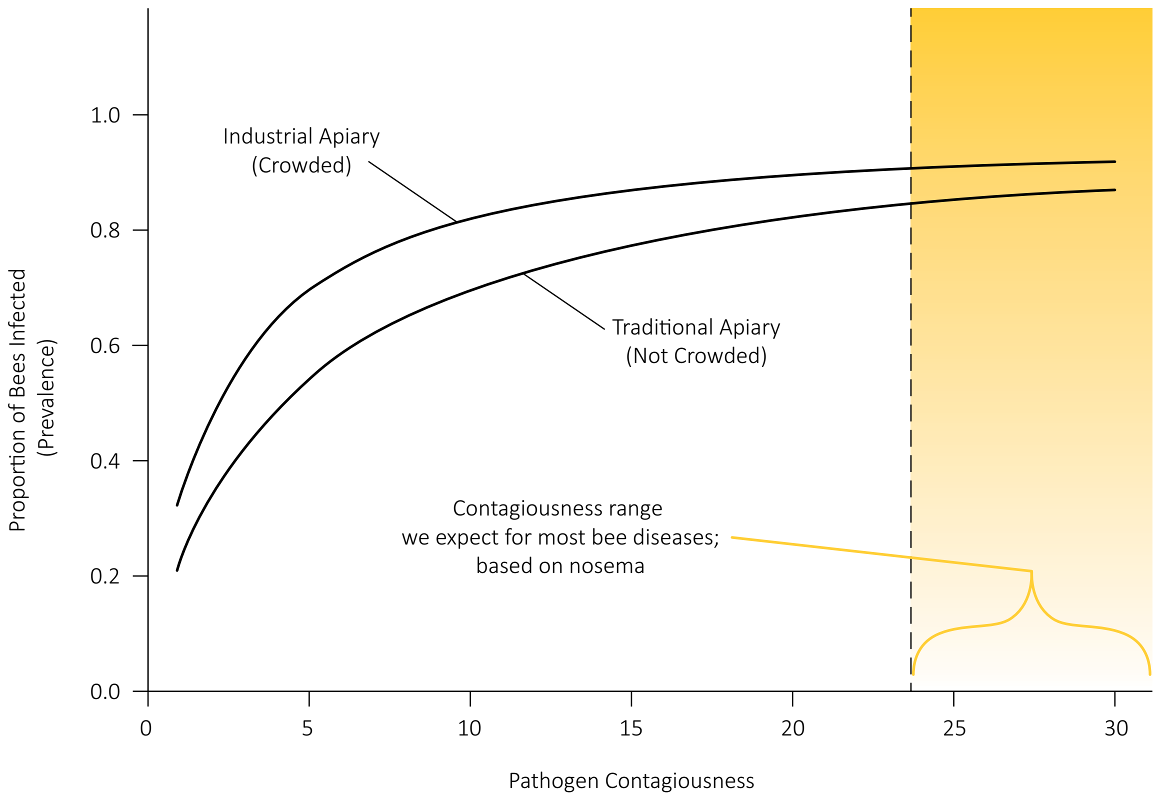


Figure 2. Graph showing the proportion of bees infected against pathogen contagiousness for crowded and not crowded apiaries

at what proportion of bees we expect to be infected in a non-crowded apiary compared to the proportion expected to be infected in a crowded apiary. This gives us an idea of whether crowding (on its own) helps diseases spread enough to meaningfully contribute to the declines in honey bee health we have seen, especially in places like North America.

The Result

The graph, Figure 2, shows the main result of what is described above. The critical lesson we learnt (that we were not at all expecting – scientists' best guesses can be wrong!) was that, even in not-at-all crowded apiaries, most bees are likely to be infected with most diseases, even if those diseases aren't all that contagious. Partly because of this, there was not all that much difference between the extremely crowded 'industrial' apiary and the 'traditional' case. Pathogens (infectious agents) which were already quite contagious spread to most bees, regardless of the level of colony crowding.

In real terms, this occurs because, unlike in other livestock and examples involving people, honey bees live in such huge numbers – even in a single colony – that one sick bee is going to expose huge numbers of other bees to the disease. Also, because we have tens of thousands of bees in a single colony, even if drifting rates are really low, there are so many bees that it never takes long for a sick bee to drift over to another colony and expose thousands of others.

We looked at some of the most recent real-world studies (including my own work after this study began) and, using the most sensitive methods, we do indeed see that when we look at numbers of adult bees infected, most bees and certainly almost all colonies test positive for most, if not all, diseases. Simply put, bees are so social that they are already so crowded as to spread most diseases quickly. Crowding them further does not have much further impact, because most bees are being exposed to most diseases already.

Practical Implications

What does this mean for us as beekeepers? Well, one thing is: do not worry about crowding your colonies, so long as you can stay on top of robbing and the bees have enough nutrition.

What the result really shows, I think, is that whether our bees encounter a disease is not too meaningful in itself – it is all about how strong they are to be able to fight that disease. Most of our bees have viruses, bacteria and other nasties infecting them, but so long as they are strong and healthy, they can control those infection levels, keeping severity low so that impact is negligible.

Making sure our bees have access to good nutrition, are not hit with too many pesticides, are not suffering from rampant varroa parasitism or small hive beetle (SHB) infestations, and have a variety of plants from which they can gather propolis which they can use to self-medicate is really where we need to look to address honey bee health.

We need not worry about crowding bees from a pure disease perspective, so that is one less thing to think about and one extra reason to concentrate on a holistic approach to keeping healthy bees.

While to some of you this is likely just scientists catching up with what you have suspected all along, having the maths to prove that apiary size and density is not something to worry about has been a lesson for us and, hopefully, some other people as well. ◻

Reference

Bartlett, LJ, Rozins, C, Brosi, BJ, Delaplane, KS, de Roode, JC, White, A, Wilfert, L, Boots, M (2019). Industrial bees: The impact of apicultural intensification on local disease prevalence. *Journal of Applied Ecology* **56**(9), 2195–2205.
doi: 10.1111/1365-2664.13461

Dr Lewis Bartlett is an infectious disease biologist and entomologist at the Center for the Ecology of Infectious Diseases, University of Georgia. He started beekeeping as a teenager in the United Kingdom (UK), in his home county of West Yorkshire and undertook his scientific training at the University of Cambridge and the University of Exeter, before moving to the United States of America (USA), in 2016.