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## Last flight of the honeybee?

A bee-less world wouldn't just mean the end of honey - Einstein said that if the honeybee became extinct, then so would mankind. Alison Benjamin reports on a very real threat

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**Alison Benjamin**

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Dave Hackenberg's bees have been on the road for four days. To reach the almond orchards of California's Central Valley, they pass through the fertile plains of the Mississippi, huge cattle ranches and oilfields in Texas, and the dusty towns of New Mexico on their 2,600-mile journey from Florida. The bees will have seen little of the dramatic landscape, being cooped up in hives stacked four high on the back of trucks. Each truck carries close to 500 hives, tethered with strong harnesses and covered with black netting to prevent the millions of passengers from escaping. When the drivers pull over to sleep, the bees have a break from the constant movement and wind speed, but there's no opportunity to look around and stretch their wings.

Their final destination is some two hours north of Los Angeles. As the sun begins to fade over the vast, flat terrain, the convoy slowly snakes through orchards filled with row upon row of almond trees stretching as far as the eye can see. Every February, the valley plays host to billions of honeybees as trees burst into blossom, blanketing the landscape in a soft, pinkish hue which extends to the horizon.

The sandy loam and Mediterranean climate are perfect for the cultivation of almonds, but that's where any comparisons to picturesque orchards of Spain or Italy end. Here, there are no verdant weeds, wild flowers or grass verges to please the eye, just never-ending trees that form what looks like an outdoor production line.

In the cool hours after sunset and before sunrise, more than one million hives are unloaded at regular intervals between the trees by commercial beekeepers such as Dave Hackenberg, who have travelled from the far corners of the US to take part in the world's largest managed pollination event. The mammoth orchards of Central Valley stretch the distance from London to Aberdeen, and the 60 million almond trees planted with monotonous uniformity along the 400-mile route require half of all the honeybees in the US to pollinate them - a staggering 40 billion.

By February 16, National Almond Day in the US, the trees are usually covered in flowers and humming with the sound of busy bees. Attracted by the sweet nectar that each flower offers, the bees crawl around on the petals to find the perfect sucking position. As they do so, their furry bodies are dusted with beads of pollen. As they fly from blossom to blossom in search of more of the sweet energy drink, they transfer pollen from the male part of the flower to the female part, and so fertilise it. Not long afterwards, the plant's ovaries swell into fruit, which by late August turn into precious, oval-shaped nuts.

Without this army of migrant pollinators paying a visit for three weeks every year, the trees would fail to bear the almonds that are California's most valuable horticultural export. Last year, they earned the state more than \$1.9bn, double the revenue from its Napa Valley vineyards. Moreover, 80% of the world's almonds now come from this pocket of the planet. But the supply of almonds in confectionery, cakes and packets of nuts is now threatened by a mysterious malady that is causing honeybees to disappear.

Hackenberg was the first beekeeper to report that his bees had vanished. On a November day 18 months ago, he checked the hives in his Florida bee yard to find they were empty. "They weren't dead, they were just gone," he recalls.

In Britain, John Chapple was the first to raise the alarm. In January 2007, he lost all of the 14 colonies in his garden in west London. "It's too cold at that time of year to open the hives," he says, "so I always check on the bees by giving the hive a thump and waiting for what sounds like a roaring sound to come back. But there was nothing, just silence." When he opened the hives to see what had happened, he found them practically empty. Examination of a further 26 hives scattered across the capital revealed that two-thirds had perished.

"I was completely shocked," says Chapple, who chairs the London Beekeepers' Association. "I could attribute some losses to a failing queen bee or wax moths, but there were a few I could find no reason for. There was a healthy queen and a few bees, but nothing else." Chapple's inquiries as to whether the parks where he kept some of his hives had sprayed new pesticides also drew a blank.

He was not alone. Beekeepers in north-west London also reported strange losses. Chapple calls the disappearance the "Mary Celeste syndrome". A year later, a survey of hives by government bee inspectors across Britain has found that one in five colonies has perished this winter.

There are some 270,000 honeybee hives in Britain run by 44,000 keepers, more than 90% of them amateurs. According to estimates by the Department for Environment, Food and Rural Affairs (Defra), bees contribute £165m a year to the economy through their pollination of fruit trees, field beans and other crops. In addition, the 5,000 tonnes of British honey sold in UK stores generates a further £12m.

UK farming minister Lord Rooker, however, warned last year that honeybees are in acute danger: "If nothing is done about it, the honeybee population could be wiped out in 10 years," he said. Last month, he launched a consultation on a national strategy to improve and protect honeybee health.

People's initial response to the idea of a bee-less world is often either, "That's a shame, I'll have no honey to spread on my toast" or, "Good - one less insect that can sting me." In fact, honeybees are vital for the pollination of around 90 crops worldwide. In addition to almonds, most fruits, vegetables, nuts and seeds are dependent on honeybees. Crops that are used as cattle and pig feed also rely on honeybee pollination, as does the cotton plant. So if all the honeybees disappeared, we would have to switch our diet to cereals and grain, and give our wardrobes a drastic makeover.

According to Albert Einstein, our very existence is inextricably linked to bees - he is reputed to have said: "If the bee disappears off the surface of the globe, then man would only have four years of life left."

Bees are a barometer of what man is doing to the environment, say beekeepers; the canary in the coalmine. Just as animals behave weirdly before an earthquake or a hurricane, cowering in a corner or howling in the wind, so the silent, empty hives are a harbinger of a looming ecological crisis. But what is causing them to vanish - pesticides, parasites, pests, viruses? No one knows for sure. The more fanciful theories when CCD was first detected included an al-Qaida plot to wreck US agriculture, radiation from mobile phones and even celestial intervention in the form of honeybee rapture.

Scientists around the world are trying to pinpoint the culprit, but it is proving elusive. They have even set up an international network to monitor honeybee losses - a sort of Interpol for bees - which is operating out of Switzerland. Its coordinator, bee pathologist Dr Peter Neumann, blames a bloodsucking mite called varroa. Little bigger than a pinhead, it has preyed on honeybees in Europe and the US since its arrival 30 years ago. Under a microscope, the reddish-brown mite looks like a cross between a jellyfish and a Frisbee. It activates lethal viruses in honeybees and carries them from bee to bee when it feeds on their blood, like a dirty syringe spreading HIV/Aids. "It has to be the backbone of the problem," Neumann says. "But it is probably not acting alone."

In the US, where the genetic code of the honeybee was unravelled by scientists two years ago, they have been employing advanced technology to discover if a new virus is responsible for killing the bees. Genome sequencing techniques

The answer is probably overwork, coupled with various environmental factors that are the flipside of pollination on an industrial scale and intensified food production. After Hackenberg's bees have pollinated the almonds in California, they head north to the apple orchards of Washington State, then east for the cranberries and pumpkins, before reaching Maine in May to pollinate blueberries. In a year, they can cover 11,000 miles. It's a well-worn route that's travelled by many of the 1,000 commercial beekeepers in America who between them own 90% of the country's 2.4 million honeybee colonies. It is pollination, rather than honey production, that keeps US beekeepers in business. In 2007, honey production was worth \$160m to the US economy, compared with pollination services that have been estimated at \$15bn.

Joe Traynor is a California bee broker. From a small office in a quiet side street in downtown Bakersfield, on the southern tip of Central Valley, he runs a lucrative business matching almond growers with beekeepers. I put to him that surely all this moving around of bees, confined to their hives for long periods, must be stressful for them. He admits that too much travel is not good for their health: "When you're trucking bees, they need sleep, just as humans do, and the bumping around in the truck for two to three days keeps them awake, and this lowers their resistance to pests and disease."

Hackenberg, however, disagrees: "I've been doing this 40-odd years. We've done all the same things, but the rules have changed. Something's messing up."

Hackenberg, 59, wears cowboy boots, a checked shirt and blue jeans. He even has a hard hat in the shape of a Stetson, with netting attached that he wears when unloading beehives. He began his own investigations into what killed 2,000 of his honeybees at the end of 2006, by talking to growers and reading up on pesticide use and research into their effects on bees. "It's those new neonicotinoid pesticides that growers are using," he says. "That's what's messing up the bees' navigation system so they can't find their way home."

Honeybees have a sophisticated dance language they use to communicate with each other in the hive. Until Karl von Frisch unlocked the mysteries of this dance - his discovery won him a Nobel prize in 1973 - we didn't fully appreciate that bees returning to the hive laden with nectar and pollen will tell their sisters (all worker bees are female) where they got their supplies by doing a dance that points to the location of the flowers in relation to the sun's position.

Tests have shown that the pesticides Hackenberg refers to can interfere with the bees' communication and orientation skills, and also impair memory.

With innocuous brand names such as Gaucho, Assail and Merit, these pesticides are used worldwide, from sunflower fields to apple orchards, lawns to golf courses. The chemicals they contain are an artificial type of nicotine that acts as a neurotoxin that attacks insects' nervous systems on contact or ingestion. Because it is systemic, the chemical moves throughout a plant, so if it is applied as a seed dressing, it will travel to the shoots, stem, leaves and flowers where bees can come into contact with small doses. Many of these widely used pesticides are classified by the US Environmental Protection Agency as "highly toxic to bees" and come with a warning label intended to help prevent their exposure to the pollinators.

"It's in such small print that the growers don't see it," Hackenberg says. He accuses farmers of "stacking" - or mixing - pesticides, herbicides and fungicides. "No one has ever tested what happens to the toxicity if they do mix, simply because the chemical companies are not required to by law, but this combination could be a thousand times more lethal than if the chemicals are applied separately."

In Britain, beekeeping is very small-scale compared with the US. There are a few hundred professional beekeepers, who run an average of 100 hives each; only around 50 of them transport bees to orchards, usually over distances of 25 or so miles, rather than across a continent. Many orchards provide a year-

In France, beekeepers have for more than a decade waged a war against the chemical giant Bayer CropScience. They hold responsible the company's bestselling pesticide, imidacloprid, trade name Gaucho, for killing a third of the country's 1.5 million colonies. In 1999, the French government banned the use of Gaucho on sunflower crops after thousands took to the streets in protest. Two further pesticides were banned because of their potential link to bee deaths. It appeared to stem the massive bee die-offs for a time, even though the manufacturers' own tests demonstrated there is no correlation, and a long-term study by the French food safety agency revealed no significant differences in death rates before and after pesticides were banned. This winter, bee deaths across France are reported to have shot up again to 60%.

Bayer is also being blamed by German beekeepers for the eerie silence along the Rhine valley, where the buzzing of bees is a common sound at this time of year. They say two-thirds of honeybees have been killed this month by the pesticide clothianidin, sold under the trade name Poncho, which has been widely applied on sweet corn. As a result of the bee deaths, eight pesticides, including clothianidin, have been temporarily suspended in Germany. Anecdotal evidence of pesticide-related bee deaths in Italy and Holland is also piling up.

European beekeepers accuse scientists and government agencies of being in the pocket of the chemical companies. It's a similar story in the US, where scientists maintain that there is no correlation between the bees' disappearance and pesticide use. According to Hackenberg: "Big Ag has control of the USDA [the US Department of Agriculture] from the secretary right down to the lowest guy on the totem pole."

Jeff Pettis is not sure where he comes on the pole. The senior manager at the federal bee laboratory in Maryland, he's the man responsible for coordinating the US government's response to CCD. Pettis advises some beekeepers may do well to forgo the almond pollination and rest their bees. "You are getting them ready for February when the sunlight hours and the temperature are telling them it's too early in the year to be foraging at full strength," he says.

Deceiving bees is an essential part of the business. Beekeepers dupe them into thinking it's already summer by moving them to warm locations in winter and feeding them an array of protein and energy supplements. The more food that comes into the hive, the more eggs the queen lays, to create more of the worker bees to go out and pollinate.

The bee broker Joe Traynor says the deception goes much further than trucking bees south. "We're interfering with their natural cycle because we want strong colonies for almond pollination. We're stimulating hives in August, September and October, and making the queens do a lot more laying. As a result the queens are suffering burnout. It used to be that a beekeeper could pretty much leave his bees alone during winter. That's no longer the case."

Moreover, scientists funded by the Almond Board of California are now experimenting with artificial pheromones that trick bees into thinking there are more larvae in the hive that need feeding, so they forage more, and in the process pollinate more almond blossom.

This is the Almond Board's profit-driven response to a potential shortfall of honeybees: to work even harder those that remain. Bees are being treated as a machine with no consideration for their life cycle and downtimes. And any machine pushed to its limits and not well maintained will break.

Environmentalists argue for conservation measures on land planted with single crops that will both improve honeybee nutrition and attract wild pollinators that could shoulder some of the honeybees' workload. Monoculture, the hallmark of modern agriculture, covers much of the world's 1.5bn hectares of arable land. Single-crop plantations and orchards can stretch for hundreds of kilometres. The advantages for the farmer are manifold: the crop blooms at the same time, can be treated with the same pesticides and can be harvested together for maximum efficiency. But for honeybees, pollen collected from one crop does not provide a balanced, nutritious diet. Scientists agree that malnourished bees are more susceptible to disease and pesticide poisoning.

while the best-fed are the hardiest.

Planting hedgerows of wild flowers would give honeybees a more varied menu. While this has happened in Europe, US almond growers have proved resistant to the idea, concerned that the bees would make fewer visits to the almond blossom if they had a choice. But hedgerows would also provide food and habitat for other pollinators such as butterflies, bumblebees and solitary bees. There are 4,500 wild bee species in North America that are capable of pollinating myriad fruits and vegetables - some more efficiently than honeybees.

Could they prevent a pollination crisis if honeybees become extinct? Only if they have somewhere to make a home in the orchards and fields, and something to eat after the single crop has bloomed. Monoculture deprives them on both counts.

The Xerces Society runs a pollinator conservation project in northern California. Farms in Yolo County receive a mixture of plants that flower throughout the year and nest blocks for wild bees, and they keep large areas of soil untilled for native bees to live on. They say they have seen the return of native bees and benefited from their pollination services. But final details being hammered out in a farm bill on Capitol Hill look like trimming conservation budgets and reducing financial incentives for farmers to manage their land in a more pollinator-friendly way.

So growers will continue to be increasingly reliant on honeybees to do a job once performed by a host of different insects. Their profits now hinge as much on honeybees' availability to pollinate fields as they do on the sun and rain. This is why there is such urgency in solving the mystery of disappearing and dying bees.

This is not the first time that honeybees have disappeared. The first recorded unexplained loss was in the US 150 years ago and ever since large numbers have vanished at intervals throughout North America, Europe and Australia. An epidemic first reported on the Isle of Wight wiped out 90% of honeybee colonies in the UK at the beginning of the 20th century. Then, as now, the main suspects were deficiencies in the bees' diet, pollution in the environment, pests and parasites and mismanagement by beekeepers, but the killer was never identified.

When bees die, beekeepers can restock their hives quickly by buying a new queen who lays 2,000 eggs a day at her peak. Across the world, most have chosen to fill their apiaries with a type of honeybee renowned for its gentle nature and prodigious honey production skills. This race of bee, originally from Italy, now dominates beekeeping. The downside is that the honeybee gene pool has been diminished and with it traits that may have helped bees fend off mites and other parasites, such as a new fungal bacteria, *Nosema ceranae*, that attacks its gut.

There are fears that mites are becoming increasingly resistant to chemicals administered by beekeepers to kill them. Pettis says we are controlling too many bee ailments with drugs and a more organic approach is needed that includes stocking apiaries with locally reared bees better adapted to local climate and environmental conditions.

Meanwhile scientists are hoping to use the mapping of the honeybee genome to engineer in the laboratory a super bee that has the resilience to withstand varroa but retains all the qualities of the Italian bee. Biologists will tell you, however, that it will be only a matter of time before a super bee breeds a super parasite. Geneticists also discovered that honeybees have fewer genes providing resistance to disease than other insects. In particular, the number of genes responsible for detoxification appear to be smaller, making it unusually sensitive to pesticides and poisons. Its large-scale disappearance across the US and high death rates in Europe are signalling that industrialised farming makes demands on honeybees that are not sustainable.

Central Valley has been described as a big brothel where billions of honeybees from all over the US can pick up a contagious illness and take it home. It's spread by mites from infected to healthy colonies. And there are plans to expand Central Valley's almond orchards to the point where, by 2011, they will require 1.6 million honeybee colonies for pollination.

Despite around a third of all US honeybees being wiped out last year, and again

this year after beekeepers had restocked their hives, the almond pollination has yet to suffer. Why?

There are two answers. The shortage of honeybees has pushed up the price of hive rentals for almond pollination to an all-time high of \$140 per hive, so more and more beekeepers are making the trip west, and the Almond Board's requirement of two hives each containing 20,000-30,000 bees per acre to pollinate the almonds is excessive, but provides a buffer should some of the hives be empty.

As the sun rises over the almond orchards after another nocturnal delivery of east coast hives, Hackenberg says it's only the money that brings him and his waning bees to California each year. "I'd rather be back in Florida with my bees. They'd be feeding on the maple and willow. It's paradise down there. Why would anyone come to this godforsaken place? But something's got to pay the bills. I'm here for a \$150,000 cheque."

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