Separating fact from fiction

Bee Myths: Don't Believe Everything You Hear!

When it comes to the subject of bees, there is plenty of information that is instantly available with the touch of a few keystrokes – but much of it is unreliable. So, how do you separate fact from fiction?

"For every complex problem there is an answer that is clear, simple, and wrong."

H. L. Mencken, American twentieth-century journalist, satirist and social critic

The health of honey bees and other pollinators and their importance to our food supply has been the subject of countless news articles, television reports and social media blogs over the past few years. Many of these have focused on the use of crop protection products – especially neonicotinoid insecticides – as a driving factor in the alleged reduction of bee populations worldwide. But is it even true that bees are in danger of extinction, or that modern farming practices are a principal cause?

We live in a world of increasing complexity, in which conversations are often conducted in tweets of 280 characters or less, so it's little wonder why people demand simple answers to difficult issues. Predicting how living things, such as bees, react to their environment, does not lend itself to easy answers but that shouldn't stop us from searching.

Everyone knows you shouldn't believe everything you read or hear. Separating fact from fiction is the first step toward increasing our understanding of complex biological systems and is essential if we are to make meaningful decisions that will improve our quality of life, protect our food supply and ensure the preservation of our natural world. Let's take time to fully explore some common beliefs about bees and how knowing the facts can provide greater insights on how we can protect them and protect our food.

Content ////

Bee Myths:

Don't believe everything you hear!

Chapter 1 ////

Myth: *Bees are declining worldwide*

Claim A:

Honey bees are declining and on the verge of extinction

This widely-held view has been a persistent theme in social media and news reports for over a decade. One would think that there ought to be enough information to either confirm or refute it. Guess what? There is plenty of evidence to show that this claim simply isn't true. So why does it persist?

Reality:

There are more managed honey bee colonies today than ever before

While there have been fluctuations in honey bee colony numbers over the past decades and higher annual losses of honey bee colonies in some regions more recently (see Claim C, page 8), honey bees are not in danger of extinction. In Europe and North America, nearly all colonies are managed by beekeepers, as there are few feral colonies to be found anywhere, anymore (see Chapter 3 to find out why). In fact, there are more managed honey bee colonies worldwide today than at any other time in recorded history. According to the Food and Agricultural Organization of the United Nations (FAO) the number of honey bee colonies has increased by 85 % worldwide since 1961.[1]

Records suggest that the number of managed honey bee colonies has declined in certain regions, such as in North America and Europe, but has increased in other areas, such as in Asia, Africa and South America. Within regions, the number of colonies can vary considerably: Researchers found declines in colony numbers in central European countries but increases in Mediterranean countries.[2] Even in the areas that have seen declines over the past 50 years, there is recent evidence showing that colony numbers have either stabilized or are increasing again.

The fluctuations in managed colony numbers can be influenced by many factors, which will be covered later (see Chapter 4, Claim A), but the most important reason is that they are linked to the number of practicing beekeepers.[2]

An increase in beekeepers leads to an increase in colony numbers – and *vice versa*.

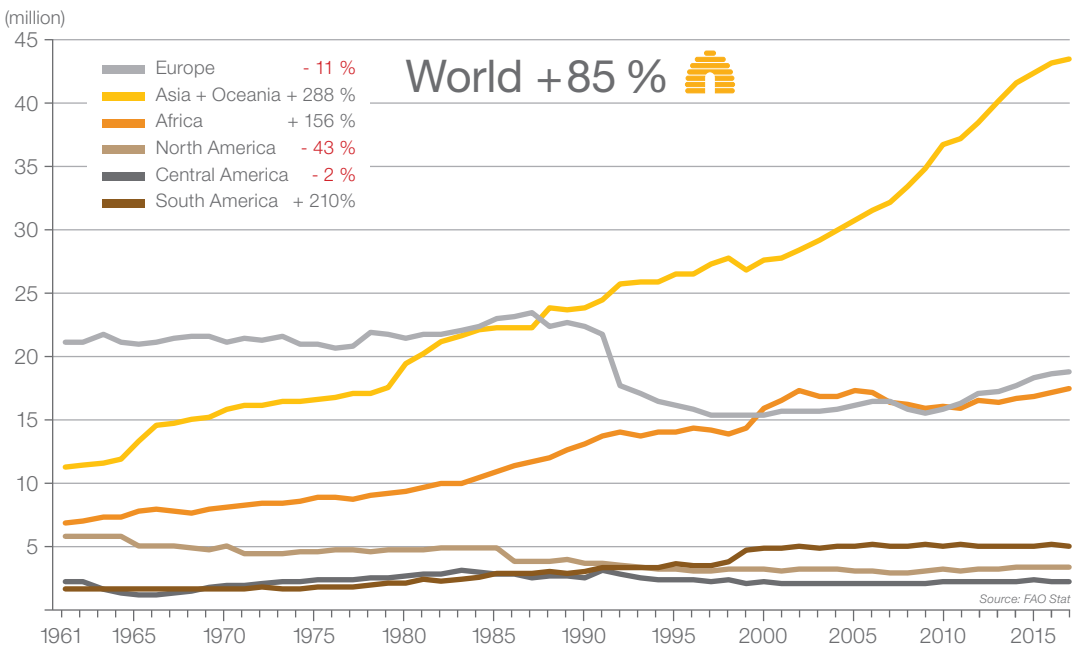
Much like farm livestock, honey bees are managed for honey production and for their value as pollinators of crops. Because of this, the number of bee colonies is determined largely by the number of professional and hobbyist beekeepers who care for them. Declines in the number of beekeepers is affected by many socioeconomic factors, including low honey prices, loss of subsidies, lack of manpower and the high costs of treating diseases, particularly as it relates to the *Varroa* mite.[2]

The evidence is clear: Honey bees are not in decline – they're increasing around the world.

//// Supporting data

Honey bee colonies managed by beekeepers worldwide 1961 - 2017

Source: FAO Stat.



//// The number of honey bee colonies has increased 85 % globally since the 1960s.[1]

//// The number of hives in the European Union (EU) nearly doubled between 2003 and 2016 and increased across Europe during the same time.[4]

//// During the early 90s, the political and economic upheaval following the collapse of the Soviet Union and the Eastern Bloc resulted in beekeeping losing its economic attractiveness and, with it, a dramatic decline of managed colonies – honey bee hive numbers in East Germany alone dropped by 75 % within a year.[5]

//// The only factor with which population development of managed honey bee colony numbers is consistently correlated is the number of beekeepers. This explains, for example, the declines that have been seen for many decades in Europe.

//// Socioeconomic factors such as cuts in government subsidies after the end of the Eastern Block in the 90s are main factors determining population dynamics of managed honey bee colonies. In addition, FAO's reallocation of the former Soviet Republics located in Asia from Europe to Asia in 1990 (see graph above), after they became independent countries, contributes to an apparent drop of European colony numbers.

Chapter 1 ////

Myth: *Bees are declining worldwide*

Claim B:

Wild bees are about to disappear

Wild bee population data are not to be generalized. There is evidence for a decrease of many species in certain regions, but the diversity of bee species makes it impossible to confirm an overall decline in wild bees globally.

Reality:

Many wild bee species are threatened – but there are ways to boost their numbers and diversity

There are more than 20,000 species of bee globally and we don't know enough about their biology, habitats, distribution or abundance to accurately assess any significant changes in the populations of all of these species. Unlike honey bees, many wild bee species are highly tuned to their specific environment and this specialization can hinder their ability to adapt to changes in landscape brought about by urbanization or agriculture. While recent research shows that many species of wild bee have declined in some areas, other native species have either increased or shown no evidence of regional decline. There is no evidence of a general decline among all wild bees in all regions.

A report by a United Nations' scientific panel of experts concluded that many wild bee species are indeed under threat. It noted many reasons for this, including changes in land use, intensive agricultural practices, invasive species and climate change. The good news is there are measures available to reduce factors threatening wild bees, such as the creation and restoration of more diverse habitats and the use of sustainable farming practices.

//// Supporting data

//// The UN IPBES report concluded that 40 % of wild bee species are threatened*.[6]

//// Research shows that adding pollinator strips to farm fields increases wild bee numbers.[7, 8]

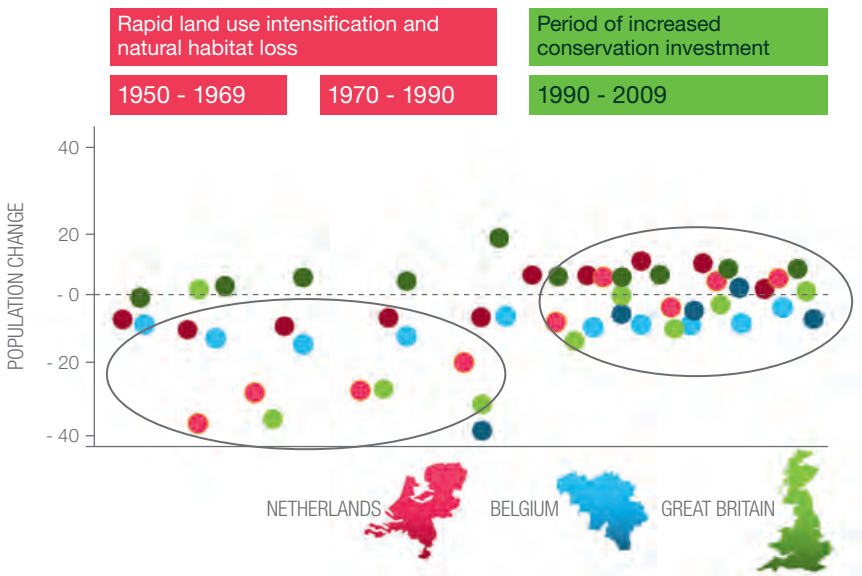
//// A European study compared periods of rapid land-use intensification and natural habitat loss (1930-1990) with a period of increased conservation investment (post-1990) and found extensive species richness loss occurred before 1990, but these negative trends were reduced or partially reversed following conservation measures used in recent decades.[9]

*Note: "Threatened" does not necessarily mean a species is in decline or is even threatened by current human activities. Many species surveyed are rare or have been in decline for many centuries due to long-term changes in climate or landscapes.

//// Supporting data

Conservation measures can positively influence wild bee populations

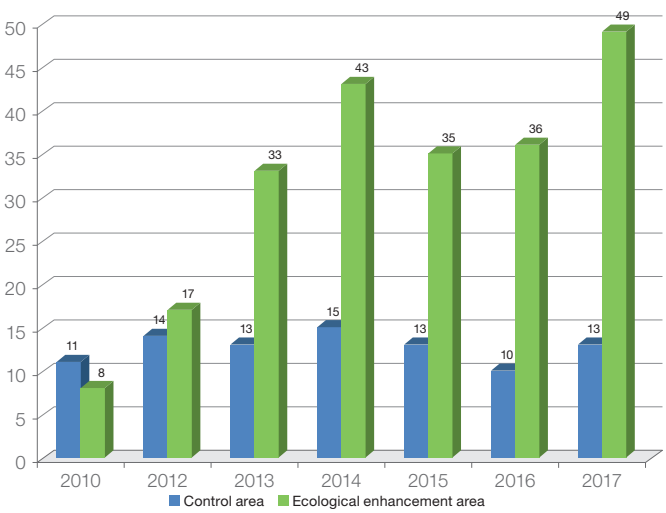
Source : Cavalheiro et al., 2013 Ecology Letters 16, 870 – 878



This study by Cavalheiro et al., 2013 compared three periods of roughly 20 years, that coincided either with rapid land use intensification and natural habitat loss, or with a period of increased conservation investment. Populations of bumble bees and wild bees show a general trend of recovery coinciding with the period of increased conservation investment.

The benefit of ecological enhancement measures for wild bee biodiversity

Source: Buhk et al, BMC Ecol (2018) Flower strip networks offer promising long term effects on pollinator species richness in intensively cultivated agricultural areas.



Since 2010, Bayer has been working with two conservation institutions at two sites in southwest Germany to assess the effects of different biodiversity-enhancing measures, such as flowering strips along maize and cereal fields, on pollinator communities. Results so far (see left) show that creating wildflower areas on arable farmland substantially increases the diversity and abundance of wild bees and butterflies, compared to control areas without ecological enhancement measures.[8]

Chapter 1 ////

Myth: *Bees are declining worldwide*

Claim C:

Honey bee losses are worse than ever

Honey bee colonies routinely suffer some level of losses. Overwintering losses of 5 - 15 % are considered normal in Europe and North America. Today, many beekeepers are seeing losses that are much higher than normal. But are they getting worse?

Reality:

Honey bee colony losses have fluctuated throughout history

Keeping a systematic, accurate track of honey bee colony losses is a relatively new and much-needed practice. There are historical references dating back to the 12th century of periodic and catastrophic losses of honey bee colonies. But in most countries, there have been no systematic measurements of bee losses until the last two decades. Incidents of previous major honey bee colony losses were frequently more confined to a specific geography and certain, shorter periods of time. Today's colony losses in Europe and North America appear to be wider and more persistent, suggesting other factors are preventing honey bee health from fully recovering, as it had done in past years.[10]

Average winter colony losses in Europe between 2007 and 2015 have ranged between 9 and 20 %, with the highest loss occurring in the winter of 2007 and the lowest in 2014. In the USA, winter losses have, on average, been notably higher than in Europe, despite significant yearly fluctuations. While bee losses on these continents are certainly higher than what the scant historical records indicate, they do not appear to be getting worse. Maintaining a high level of losses indefinitely is not sustainable, which is why it is so important that the underlying causes of poor bee health are fully resolved (see Chapter 4 to learn more).

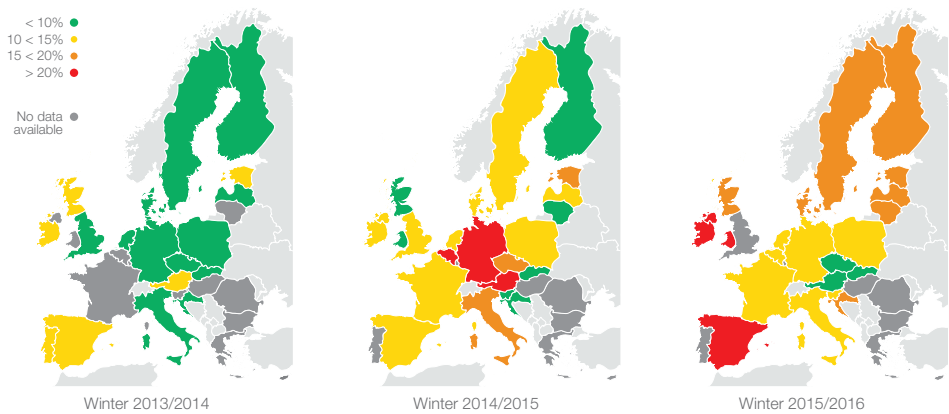
//// **Supporting data**

- //// Major losses of honey bee colonies in Europe have been recorded many times throughout history, beginning as early as 1124 and continuing periodically until the present day.[11]
- //// Significant and unexplained honey bee losses were first recorded in the USA in 1869.[12]
- //// The average winter losses in 29 European countries were 17.9 %, 11.9 % in 2015 and 2016 and just over 16 % in 2017/18.[13]

//// Supporting data

Variations in winter losses of honey bee colonies in Europe between 2013 - 2018

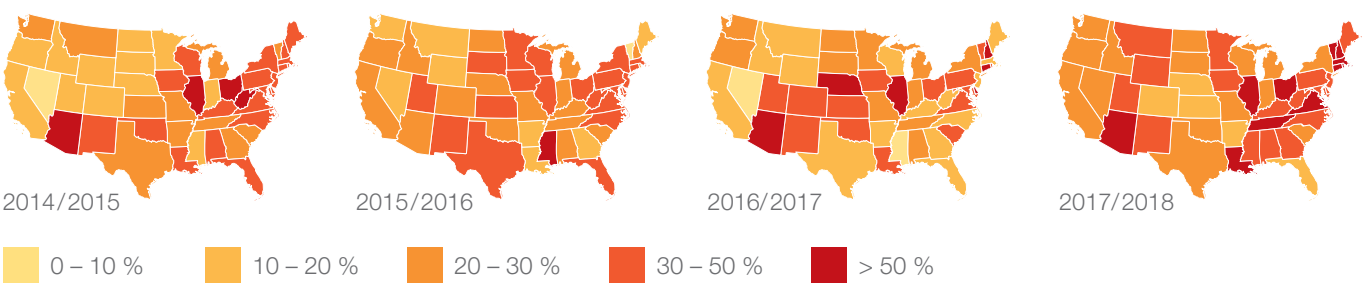
Source: Based on preliminary results of colony losses monitoring data: see www.COLOSS.org



//// Loss rates per country were up to 35 % and more, whereas 5 - 15 % losses are considered normal.
//// Average winter loss rates: 9 % (2013/14), around 18 % (2014/15), almost 12 % (2015/16) and just over 16 % (2017/18).
//// COLOSS results for Europe highlight high spatial and temporal variability, even within countries, but no correlation with agricultural intensity or pesticide exposure.

Losses in the USA

Source: Based on Bee Informed Partnership (BIP; https://bip2.beeinformed.org/loss-map/) annual survey of managed honey bee colony losses in the USA.



//// Loss rates much higher than in Europe, reaching more than 50 % – but are also very variable spatially and temporally.
//// During the 2018 - 2019 winter, surveyed respondent beekeepers, representing 11.9 % of the estimated 2.69 million managed honey-producing colonies in the USA (USDA, 2018), lost an estimated 37.7 % of their honey bee colonies.

Chapter 1 ////

Myth: *Bees are declining worldwide*

Claim D:

The loss of individual honey bees is a serious problem for the colony

The death of individual bees is a normal part of the cycle of life within a colony. Honey bee colonies can sustain a large number of individual losses while continuing to grow and thrive.

Reality:

Individual bee losses are a normal, daily occurrence in the life of a colony

A worker bee's natural lifespan is only three to six weeks during the summer, so a colony of 40-60,000 bees can easily lose hundreds (or thousands) of bees in a single day, naturally. That may seem like a lot, but workers have evolved to be disposable and are easily replenished by the queen, which can lay up to 2,000 eggs per day. Individual workers are part of a "superorganism" and may even willingly sacrifice themselves for the good of the colony, if necessary. That is why honey bee colonies can sustain relatively high losses of workers without significant harm and why the risk assessment for crop protection products is properly focused on the whole colony and not on the individual worker bee.

//// Supporting data

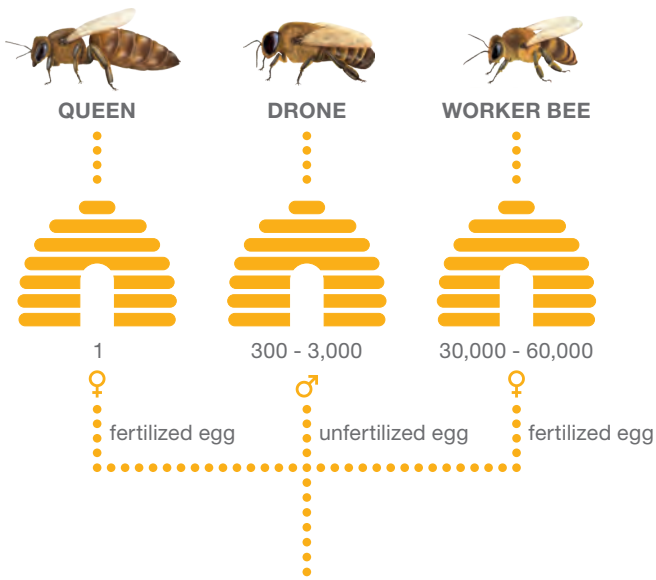
//// Parasitized bees often commit "altruistic suicide" to prevent the spread of disease in a colony.[14]

//// Worker bees within one colony can theoretically be up to 75 % genetically identical to each other, but would only be 50 % identical to their children (assuming they could have them), which is assumed to be one of the reasons why they are driven by evolution to protect the colony (i.e., the queen and their worker bee sisters).[15]

Queen laying eggs in center surrounded by worker bees

//// Supporting data

Lifecycle of a bee



//// A queen may live for up to four years but will typically be replaced by the beekeeper after two years.

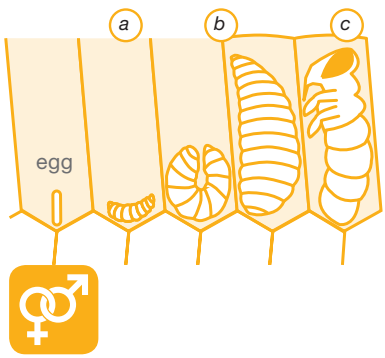
//// Three castes of honey bee (queen, drone and worker bee) make up a colony, each has a characteristic shape and size.

//// A colony normally contains only one queen, a few hundred drones and up to 60,000 worker bees.

//// Worker bees are normally sterile, so reproduction is left to the queen and the drones.

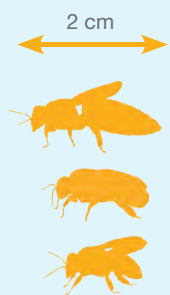
//// A queen can lay as many as 2,000 eggs per day during the height of main egg-laying season.

//// The worker bee progresses through several task-related life stages, from brood care and hive maintenance through to foraging duties.



// a Larva hatches from egg.
// b Larva develops from a coiled into a stretched larva. Worker bees cap, or seal, the comb cell.
// c Larva pupates and emerges as an adult bee.

Relative size of queen versus drone versus worker honey bee.



//// As a result of a different diet with royal jelly, the queen develops into a sexually mature female, unlike the worker bees.

//// Development rates in days:

Queen:	16
Worker bee:	21
Drone:	24

//// A new young queen flies out for her mating flight (nuptial flight) to drone congregation areas. The queen bee will mate with up to 20 drones high in the air, continuing until her sac used to store sperm (spermatheca) is full. This supply will last throughout her entire life to fertilize her eggs.

Chapter 1 ////

Myth: *Bees are declining worldwide*

Claim E:

Pesticide use is forcing farmers to resort to artificial crop pollination

Does the use of pesticides cause a lack of pollinators, which forces farmers in China to artificially pollinate their crops? The evidence says this is not the case.

Reality:

There are plenty of bees to pollinate the vast majority of crops worldwide

A common perception is that an overuse of pesticides has reduced the number of honey bee populations so much in some regions of China that farmers are forced to use artificial methods, namely hand pollination performed by humans. In some areas, nearly 100 % of all fruit trees are hand-pollinated. While irresponsible use of pesticides may indeed play a role in harming bees, hand pollination in China is primarily about economics, not about bees. Realizing that certain fruits could be cash crops, much of land used for subsistence farming was converted to fruit production, which disrupted the habitat for native pollinators. Although farmers could rent bees to do the work, many found it was cheaper to pollinate by hand. Some important fruits require the pollen of another variety, which itself is not productive. Pollinating by hand, which is more targeted than insect pollination, enables Chinese farmers to maximize the number of productive trees and increase their profits.[16]

Apple plantation in Guizhou, Province China

In other areas of the world, there is also little evidence that a lack of bees has forced farmers to use artificial pollination. A few exceptions include crops for which natural pollinators are not known or which are grown in areas where the natural insect pollinators of the crop are not present, such as vanilla.

For various crops, some farmers have tried pollen dusting, hand pollination or even experimented with robotic drones for a variety of reasons, but these uses are relatively rare when compared to insect pollination.

In most cases, the availability of insect pollinators has been sufficient to meet seasonal crop demands. For example, U.S. almond acreage has dramatically increased over the past two decades (now surpassing 1 million acres) and yet, growers still have access to enough honey bee colonies to pollinate this ever-expanding crop. Managed honey bee colonies are the best option for the grower in this case, although the presence of native pollinators together with honey bees has been shown to yield better pollination results.

Pollinating by hand, which is more targeted than insect pollination, enables Chinese farmers to maximize the number of productive trees and increase their profits.[16]

//// Supporting data

Leading natural honey producing countries

Source: Market Publishers Report Database

Rank	Country	Production volume (in 1,000 metric tons), 2016
1.	China	490.84
2.	Turkey	105.53
3.	Iran	80.56
4.	USA	73.43
5.	Russia	69.76
6.	India	61.34
7.	Ukraine	59.29
8.	Mexico	55.36
9.	Argentina	51.36
10.	Ethiopia	47.71

Honey harvesting in Russia

Beekeeper in Turkey

//// Over half of all managed colonies in the USA are used in California to pollinate almonds, and have continued to do so, even as the almond acreage has more than doubled over the past 15 years.[17]

//// 100 % of apple crops in the Maoxian region of China are pollinated by hand because a honey bee hive rental can cost up to 4 times more than using a human pollinator.[16]

//// Despite reports of honey bee scarcity, China is the largest producer of honey, the largest beekeeping country, the largest honey exporter and the largest consumer of honey in the world.[18]

Bee hives near blooming almond orchard, California, USA

Chapter 2 ////

Myth: *Bees are essential for human food security*

Claim A:

Mankind would starve without bees

Bees are important, but we wouldn't be faced with starvation without them.

Reality:

Most of our food is not pollinated by bees

Most of the food we eat comes from crops that do not depend on insect pollinators. Many of the world's most important food crops are wind- or self-pollinated, including potatoes, wheat, rice and corn. On the other hand, bees are very important for a variety of foods we consume, including many fruits, nuts and vegetables. While most of these crops are not entirely dependent on insect pollinators, bees can help increase their fruit-set and -quality, making these foods more abundant and appealing than if these pollinators were not around.

//// Supporting data

//// Of 50,000 edible plants, three – rice, corn and wheat – account for 60 % of the world's food.[19]

//// 10 crops that make up nearly 90 % of the world's food – rice, wheat, corn, sorghums, millets, rye, barley, potatoes, cassavas and bananas do not require pollination by bees.[20]

//// An estimated 5-8 % of global crop production is directly attributable to animal pollination.[21]

Claim B:

One out of every three bites of food we eat comes from bees

This claim significantly overstates the amount of food that is truly dependent on pollinators.

Reality:

Only a relatively small number of bites of food are dependent on bee pollination

60 % of global production come from crops that do not depend on animal pollination.[22] While it's true that about 35 % of our food crops derive some benefit from bees, it's also important to note that even most of these crops are not totally dependent on insect pollinators. According to a global study which examined over 100 crops where insect pollination plays a role, pollinators were essential for 13 crops and significantly important for 30 others, while the remaining 64 crops received a pollinator benefit that is either moderate, minor or unclear.[22] The moderate boost in yield bees can bring to these crops may be economically important, but that's a far cry from saying our food is completely dependent on them.

//// One out of every 12 to 20 bites of food we eat depends on pollination by bees or other pollinating insects.[21]

//// The world's leading food crops like: rice, wheat, corn, sorghums, millets, rye, and barley, and potatoes, sweet potatoes, cassavas or maniocs, bananas and coconuts are, at least facultatively, wind-pollinated, self-pollinated or propagated asexually.[20]

//// Supporting data

The dependence of leading crops on animal pollinators

Source: Data adapted from Klein et al. 2006

The crops fall under the following categories:

ESSENTIAL

atemoya, brazil nut, cantaloupe, cocoa, kiwi, macadamia, passion fruit, pawpaw, rowanberry, sapodilla, squash/pumpkin, vanilla, watermelon

HIGHLY DEPENDENT

almond, apple, apricot, avocado, blueberry, buckwheat, cardamom, cashew, cola nut, coriander, cranberry, cucumber, cumin, durian, feijoa, fennel seed, loquat, mango, naranjillo, nutmeg, peach, pear, pimento, plum, raspberry, rose hip, sour cherry, starfruit, strawberry (cross-pollinated varieties), sweet cherry, tomato (greenhouse)

MODERATELY DEPENDENT

blackcurrant, broad bean, caraway, chestnut, coconut, coffee, eggplant/aubergine, elderberry, fig, guava, hyacinth bean, jack bean, jujube, mammee, mustard seed, okra, pepper (vegetable), pomegranate, prickly pear, rapeseed, seedcotton, sesame, shea nut, soybean, sunflower seeds, tree strawberry

SLIGHTLY DEPENDENT

azarole, bambara bean, citrus (most varieties), cowpea, guar bean, hog plum, kidney bean, linseed, longan, lychee, oil palm, oilseed rape, papaya, peanut, persimmon, pigeon pea, rambutan, safflower, star apple, strawberry (wind-pollinated varieties), tamarind, tomato (field)

UNIMPORTANT

chickpea, garden pea, grape, lentil, olive, pepper (spice), quinoa, cereals, rice, potatoes

UNKNOWN SIGNIFICANCE

anise, breadfruit, grains of paradise, jackfruit, medlar, sapote, star anise, winged bean, velvet bean

Many of the world's most important food crops are wind- or self-pollinated, including potatoes, wheat, rice and corn.

Chapter 2 ////

Myth: *Bees are essential for human food security*

Claim C:

Wild bees are critical for crop pollination and our food supply

Since most of the food we eat is not dependent on insect pollinators, this claim is slightly exaggerated. Moreover, we still have a lot to learn about wild bees and their relative importance to our food supply. Yet, as we learn more about them, their role may be more important than was previously thought.

Reality:

Wild pollinators are important, but most of them are not needed for the food we eat

Of the estimated more than 20,000 species of wild bee, relatively few are significantly involved in the pollination of the world's major crops. Honey bees are the most significant single pollinator species agronomically, but growers are increasingly relying on other bee species that can be managed to economically pollinate their crops. These include bumble bees in greenhouses, mason bees in orchards and leafcutter bees in alfalfa and other crops. There are more than 400 species of wild bee that are agronomically important and this number will undoubtedly increase as we learn more about them.

Some wild species, such as the above-mentioned bumble bees, mason bees and leafcutter bees are economically valuable in many areas of the world while, for instance, carpenter bees and stingless bees are especially important in tropical climates. Because of the rising importance of superior performance hybrid crops, for which wind- or self-pollination is insufficient, wild and managed pollinators play an important role in hybrid seed production. Some hybrid crops that rely on pollinators include carrots, onions, cucurbits, sunflower, canola and alfalfa. As we learn more about how crops are better-pollinated and produce higher yields in the presence of a diverse pollinator community, we can take steps to incorporate wild bee habitats on the farm to increase global food production and security.

//// **Supporting data**

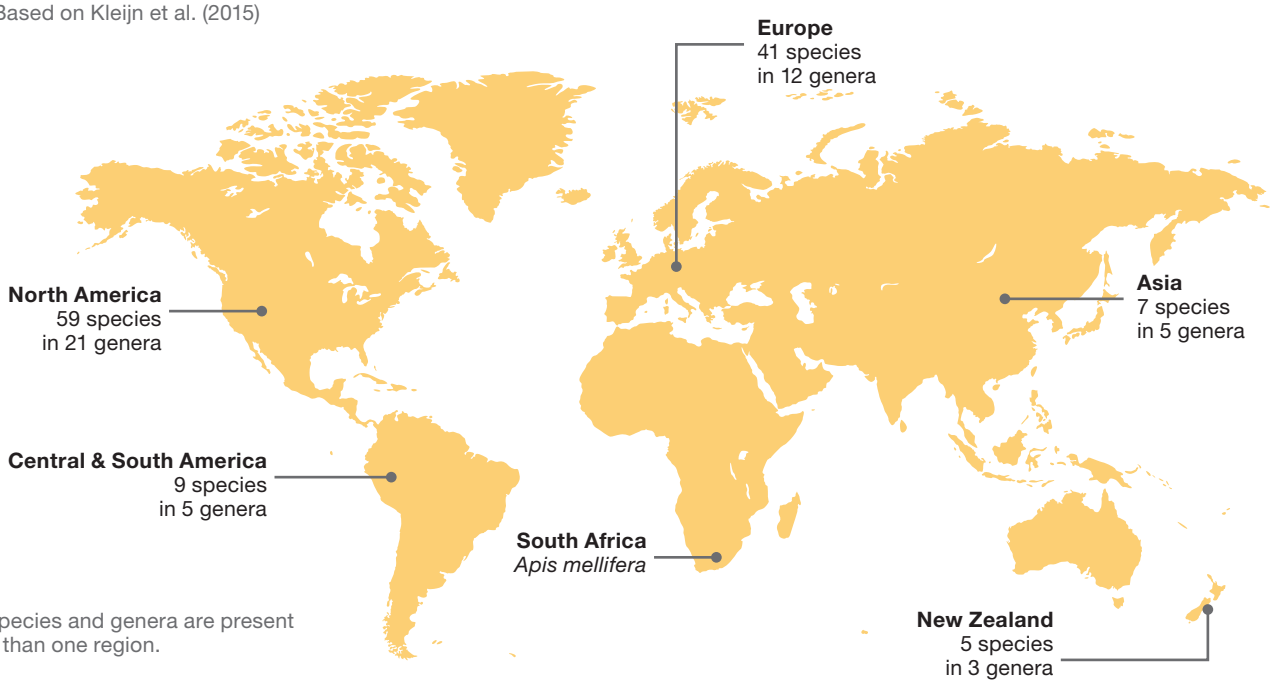
- //// Only 2 % of the known wild bee species are important crop pollinators worldwide.[23]
- //// In more than 40 crops grown globally, researchers found that wild pollinators improved pollination efficiency and increased fruit set by twice that of honey bees.[24] From almond farms and coffee operations to backyard cucumber patches, native pollinators further enhanced yields, even when farmers provided honey bees to their crops.[25]
- //// Stingless bees are known to visit over 90 crops, including coffee, guava, rattan and watermelon and are known pollinators of 17 tropical crops, including macadamia nuts, coconut and mango.[26]

//// **Supporting data**

The bee species identified as dominant crop pollinators in 90 studies

Out of the over 20,000 known wild bee species, proven crop pollinators amount to 121 species in 46 genera*

Source: Based on Kleijn et al. (2015)



* Some species and genera are present in more than one region.

Some global statistics illustrate the scale of pollinator contribution to agriculture and food security:

//// Of the 115 leading global crops consumed by humans, 87 rely on animal pollination, to some degree.
//// 35 % of the crops we eat, in terms of the volume produced globally, depend on animal pollination, to some extent.
//// An estimated five to 8 % of global crop production, with an annual market value of 235-577 billion US dollars, is directly attributable to animal pollination.

Chapter 2 ////

Myth: *Bees are essential for human food security*

Claim D:

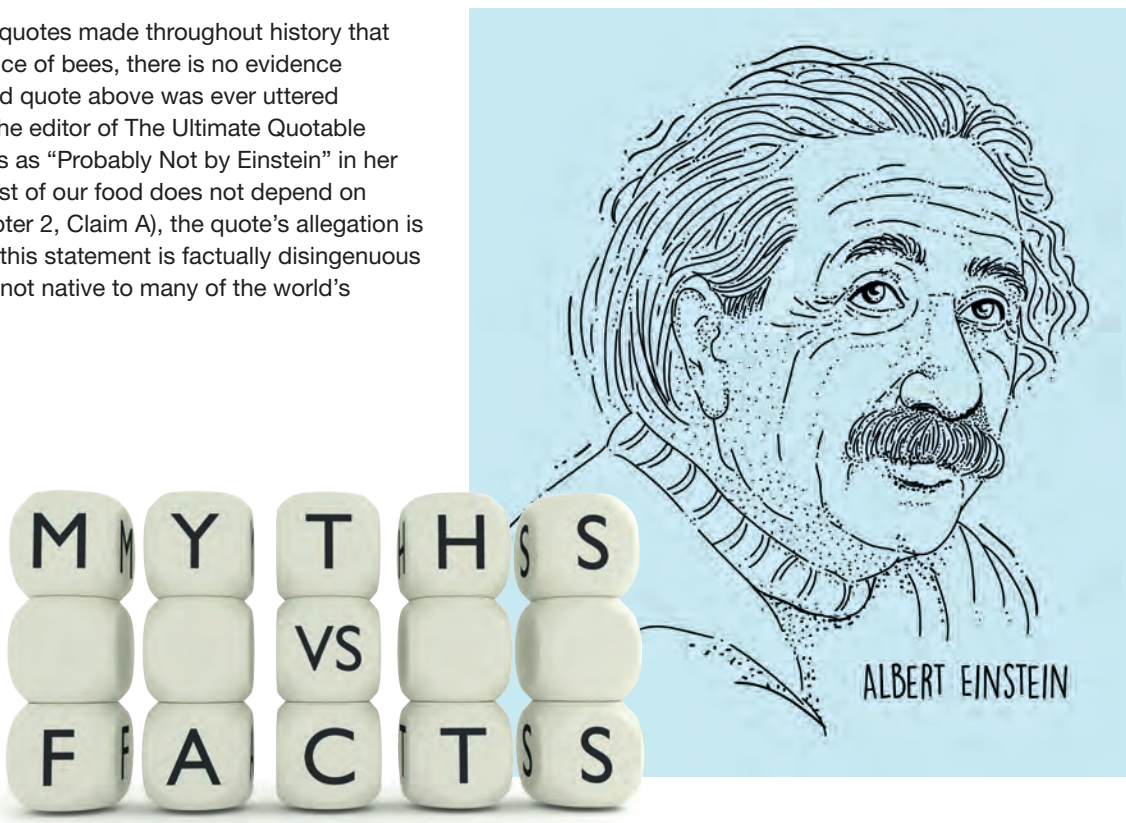
"If the honey bee disappeared off the face of the earth, man would only have four years left to live"

This dramatic quotation is very popular in social media. It is attributed to Albert Einstein and his concerns about the health of honey bees and the important role they play as pollinators. But is it true?

Reality:

There is no evidence that Einstein said this, nor is it true

While there are many quotes made throughout history that speak to the importance of bees, there is no evidence that the often-repeated quote above was ever uttered by Albert Einstein.[27] The editor of The Ultimate Quotable Einstein, classified this as "Probably Not by Einstein" in her collection.[19] Since most of our food does not depend on honey bees (see Chapter 2, Claim A), the quote's allegation is verifiably untrue. And this statement is factually disingenuous since honey bees are not native to many of the world's agricultural regions.



Chapter 3 ////

Myth: *Honey Bees are a sentinel of environmental health*

Claim:

Healthy honey bees reflect the health of our environment

Like the proverbial canary in a coal mine, some suggest that the honey bee may be viewed as a sentinel of the environment. While some species can reflect the health of an ecosystem in specific environments, the honey bee is a poor choice to serve as a sentinel for most situations.

Reality:

Honey bees are a poor choice for an indicator of environmental health

Most people are familiar with the expression "canary in a coal mine" because these birds were once used by miners to serve as an early warning system to detect the presence of odorless carbon monoxide before it reached levels that would be harmful to humans. In fact, many animals have been identified as sentinel species.[28] For example, polar bears are frequently cited as indicators of the dwindling arctic ice associated with climate change and the tiny crustacean, *Daphnia*, can be used to assess the water quality in aquatic systems. So, why shouldn't honey bees be used for similar purposes?

Honey bees are believed to have originated in Africa or Asia and their original distribution range covered Europe, Africa and parts of Asia. They were subsequently spread by humans into other parts of the world.[29] In many regions, their presence is not a natural occurrence but rather an artifact of their importance to human society. In Europe and North America today, honey bees are essentially domesticated livestock and are almost completely dependent on their human caretakers for protection from pests and parasites. As managed insects, honey bee colonies are often moved from one area to another for pollination services or for honey production. Honey bees are, thus, an important species for many reasons, but they are a poor indicator of environmental health.

This is not to say that honey bees don't respond to the natural environment in which they are placed. Just like humans, they are affected by natural events, such as extreme weather and diseases. But the same is true for cattle or other livestock – and no one would consider them to be sentinel animals. Like cattle, bees are placed in a landscape that is created by humans, not nature. So, whether they flourish or flounder in that environment doesn't really matter from an evolutionary perspective. Yet, it is their resilience and adaptability to a wide range of environmental conditions that makes honey bees so valued by beekeepers and farmers, everywhere from Scandinavia to the tropics.

//// Background information

//// The introduction of the *Varroa* mite, an invasive parasite, is a major reason why there are so few feral honey bee colonies in Europe and North America. Without the constant attention of beekeepers, most honey bee colonies could not survive in these regions today.[2, 30]

Chapter 4 ////

Myth: *Pesticides are the main reason for poor pollinator health*

Claim A:

If it weren't for pesticides, honey bees would be doing just fine

With all the negative media attention devoted to pesticides, it's easy to see why many people think they are the main cause of poor bee health. That would imply a simple solution to a complex problem. And it would also be wrong.

Reality:

Honey bee health is affected by many factors (and pesticides are usually low on the list)

Nearly all experts agree that honey bee health is affected by many factors. These include adverse weather, inadequate availability of forage, parasites, diseases, genetic problems and inappropriate hive or crop management practices. Removing one factor – such as pesticides – does not mean that bee health will suddenly improve. For example, restrictions placed on neonicotinoid pesticides in the EU have led to no measurable improvement in honey bee health and colony numbers have continued to rise – just as they were, even before the restrictions were enacted.[31] It's also important to know that beekeepers sometimes use the same active ingredients, as pesticides in veterinary products, to protect bees from pests that attack their colonies. Pesticides are needed for agriculture and so are bees. And bees benefit from healthy crops to forage on; to keep them healthy and thriving, the use of pesticides to protect them is frequently indispensable.

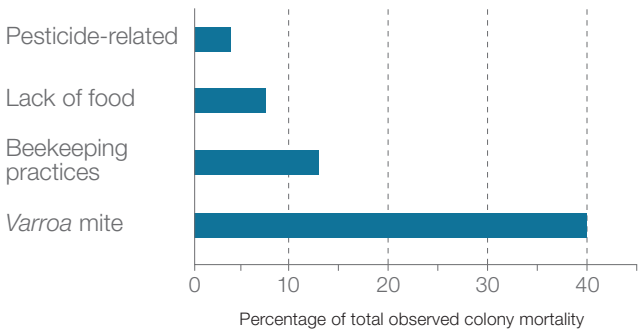
The *Varroa* mite parasitizes adult bees and their brood, transmitting deadly diseases.

Of the many factors affecting honey bee health, none has been as devastating to bee colonies as the *Varroa* mite. Following its introduction in Europe and North America, the damage caused by this invasive parasite has led many scientists and beekeepers to classify *Varroa* as the single biggest threat to honey bee health. Large-scale monitoring data have shown that poor bee health correlates well with the presence of *Varroa* mites and diseases, but not with the use of pesticides.[32a-k] Surveys of colony losses obtained from beekeepers routinely show that pesticides are often ranked far below other causes of bee mortality.[33] Moreover, the number of bee poisoning incidents has significantly declined in most countries where it is systematically monitored (see Chapter 4, Claim E), due to protective pesticide regulations, an improvement in stewardship practices and better awareness and communication.[34] In most cases where bee intoxications by pesticides take place, this is due to incorrect or irresponsible use of the products.

//// **Supporting data**

Key causes of honey bee mortality in France

Source: Direction générale de l'alimentation DGAL (2016).



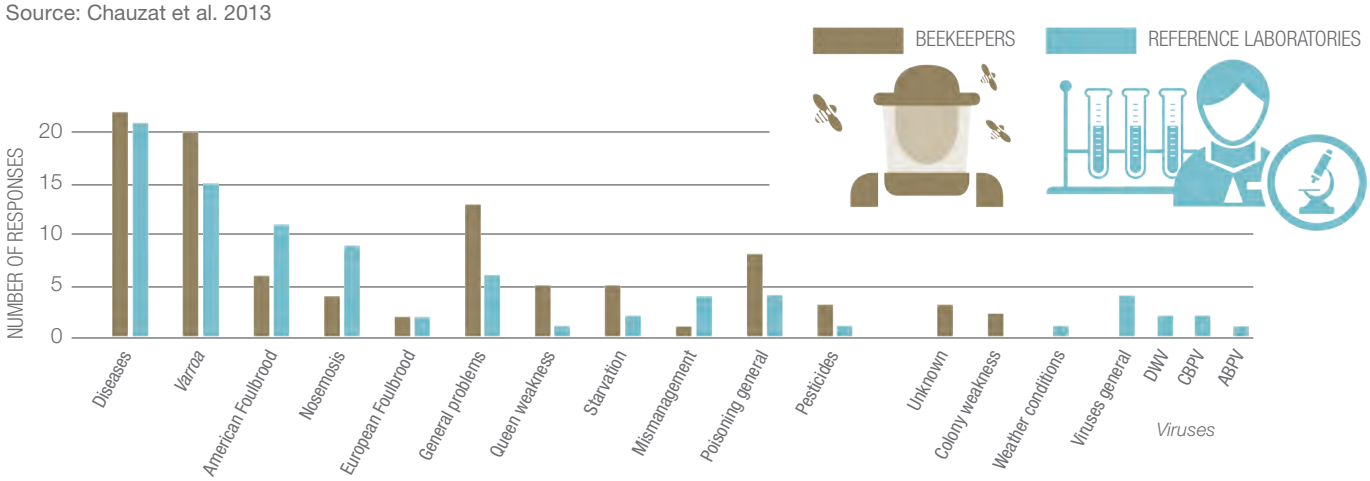
//// U.S. beekeepers list *Varroa* mites and the diseases they spread as the main reason for honey bee colony losses.[35]

//// "If there's a top ten list of what's killing honey bee colonies, I'd put pesticides at number 11." – USDA bee researcher[36]

//// The first pan-European harmonized epidemiological surveillance program on honey bee colony mortality (EPILOBEE) concluded: "Several drivers of honeybee loss have been proposed, but to date, there is little consensus on which driver or combination of drivers are responsible for observed declines in Europe except for the mite *Varroa destructor*, which clearly plays a central role."[37, 38]

Main causes of colony mortality reported by EU beekeepers and Bee Health Reference Laboratories

Source: Chauzat et al. 2013



//// That pesticides are apparently not a key factor in bee mortality in Europe is also confirmed by a survey conducted by the EU Reference Laboratory for Bee Health in numerous European countries. According to this survey, *Varroa* and other disease pathogens are seen as the main cause of colony losses by beekeepers and scientists at reference laboratories for bee health, whereas crop protection products are considered to be of lesser importance (Chauzat et al. 2013).

Chapter 4 ////

Myth: *Pesticides are the main reason for poor pollinator health*

Claim B:

Talking about *Varroa* is just a distraction to shift blame away from pesticides

While it may be hard for some to accept that honey bee health is strongly tied to natural factors, that doesn't change the fact that the *Varroa* mite is one of the most important challenges honey bees face.

Reality:

Varroa is one of the most important factors affecting honey bee health today

Outside of parts of Asia, the *Varroa* mite was relatively unknown until this pest invaded Europe in the 1970s and North America in the 1980s. This parasite not only feeds directly on honey bee adults and their brood, but it also transmits several deadly bee viruses. Today, *Varroa destructor* is considered by nearly all bee experts to be the single most serious threat to honey bee health.

Before the arrival of *Varroa*, beekeepers were accustomed to yearly colony losses of around 10 % or less, but now losses can far exceed that amount. Researchers have noted that the *Varroa* mite has evolved and adapted to honey bee behavior for its own benefit, allowing it to spread widely, even though the mite itself is not very mobile.[39] The close proximity of managed honey bee hives, used in agriculture for pollination services and honey production, make them especially vulnerable to infestation by *Varroa*, so that even hives which are virtually free of *Varroa* mites can quickly become re-infested.

For those who claim that *Varroa* is used as a smokescreen to hide the impact of pesticides, many large-scale monitoring data show that poor bee health correlates well with the presence of *Varroa* (and the diseases it vectors) but not with the use of agrochemicals.[32a-k] Scientists rarely agree on anything, but most bee experts do agree that the *Varroa* mite remains a major culprit of honey bee losses.

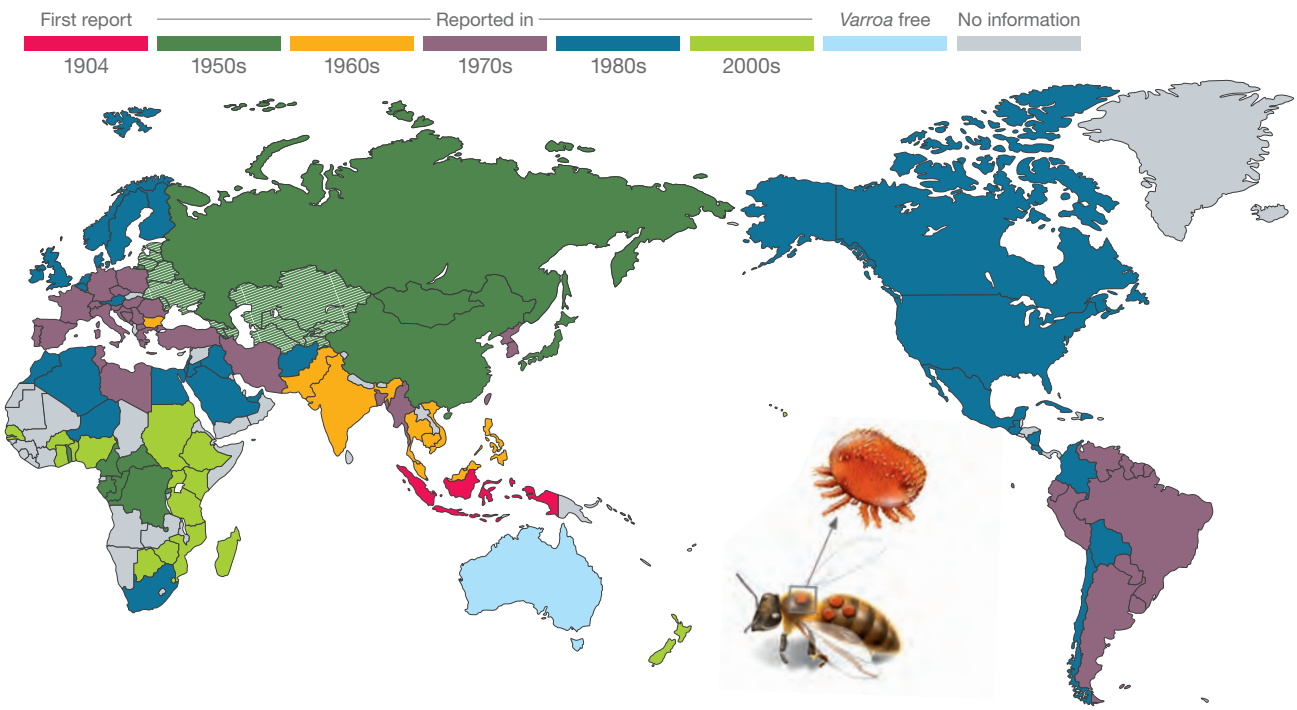
Studies show that poor bee health correlates well with the presence of *Varroa* mites in bee hives.

4

//// Supporting data

Varroa global spread

Source: The *Varroa* Mite – A deadly honey bee parasite*



Varroa destructor originated in Asia but has since spread towards the west and east, and now threatens the Western Honey Bee over almost all of the planet.
*http://beecare.bayer.com/bilder/upload/dynamicContentFull/Publications/The_Varroa_Mitejptfv0ri.pdf

//// *Varroa* mites are estimated to have killed millions of colonies worldwide, resulting in billions of U.S. dollars of economic loss.[40]

//// A European study found that the most significant risk indicators affecting honey bee colony winter survival included the detection of varroosis (parasitism by *Varroa*) and other diseases.[38]

//// Canadian scientists found that *Varroa* mites were the leading cause of colony mortality (associated with up to 85 % of colony deaths).[41]

//// Within a year of the arrival of *Varroa destructor* on Oahu island in Hawaii, 65 % of the colonies were wiped out.[42]

Chapter 4 ////

Myth: *Pesticides are the main reason for poor pollinator health*

Claim C:

Pesticides are sold and marketed without considering their impact on bees

This claim is undeniably wrong. Regardless of what you think about them, pesticides are extensively tested prior to being commercialized, to determine their potential impact on bees.

Reality:

Pesticides are extensively tested to determine their potential impact on bees

Pesticides are among the most highly regulated products in any industry, rivaling the regulatory oversight and processes used in developing medicines for human health. They also require extensive safety testing to ensure they will not cause unreasonable effects on wildlife and the environment. The term "unreasonable" is crucial because pesticides are important contributors to our food security and regulations are designed to find the right balance between food production and protection of the environment. While there is no such thing as zero risk, testing helps ensure the risk is negligible.

All pesticides are thoroughly tested to ensure they can be safely used without harming bees. It might surprise people to learn that most pesticides, including most herbicides and fungicides – and even some insecticides – are not harmful to bees.[43] Ensuring a pesticide's safety to bees starts early in its development and continues throughout the multi-year registration process. The number of studies conducted to evaluate bee safety or to understand the pesticide/bee relationship can be in the hundreds for some products. Laboratory screening tests indicate a product's inherent hazard to bees, which can range from non-toxic to highly toxic. But laboratory tests are not necessarily representative of the real world and frequently (and deliberately) overestimate risk by using high doses applied under highly artificial conditions.

Higher-tiered field and semi-field studies are frequently needed to assess a pesticide's potential risk to bees when used realistically, according to the product label.

Undesirable risks can be reduced or eliminated through use restrictions, which stipulate how and when a pesticide may be used, to avoid harming pollinators. Only after a product's bee safety is clearly demonstrated will it be approved for commercial use.

Today's bee safety testing involves the most sophisticated science available to measure not just the potency of a pesticide, but also its potential impact on bee behavior, reproduction and colony strength. And because science is not static, additional testing is often required as new information becomes available, even long after a product has been commercialized. In many countries, pesticides must be periodically reviewed and re-registered to ensure they comply with the latest standards of safety to protect human health and the environment, including their impact on bees.

Potential side-effects of pesticides to bees are assessed in tunnels under controlled semi-field conditions.

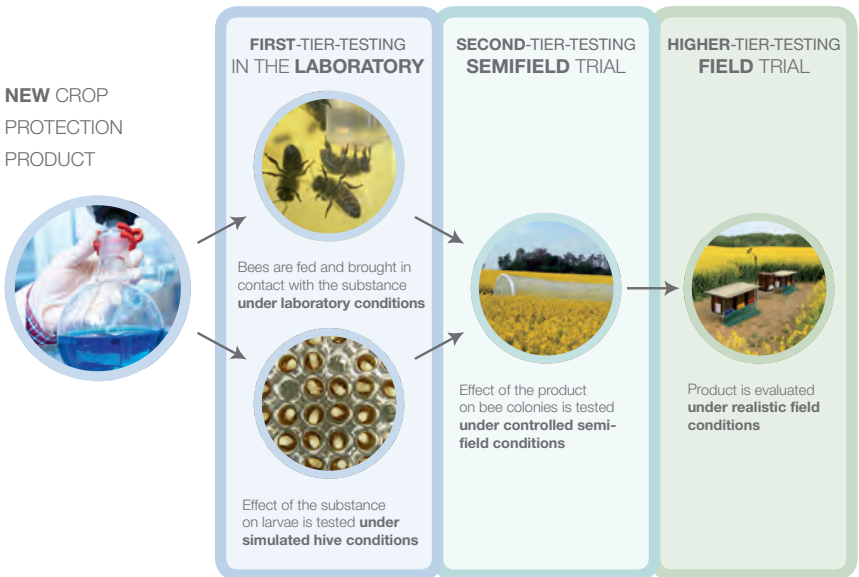
4

//// **Supporting data**

Different tiers of honey bee testing

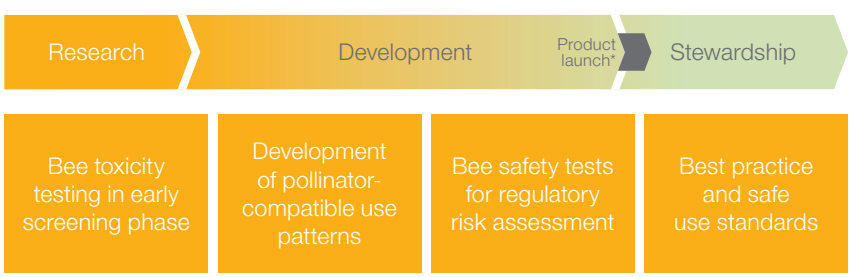
Source: BEENOW. Issue 2., pg. 53

For a crop protection product to receive approval, it must first pass a series of tests for its safety to bees. This simplification of the test pathway for new plant protection products (below) shows the different stages of testing involved. The product can only be declared "safe to bees" after having undergone thorough laboratory and, frequently, also field tests. Products that are found to be intrinsically toxic to bees can only be used under strict conditions – for example, they may not be used on flowering plants.



Focus on pollinator safety along the entire product lifecycle of a crop protection product

Source: BEEINFOrmed # 5, The Science of Bee Testing and Pesticide Risk Assessment.



* On average, only one out of every 160,000 compounds evaluated successfully reaches the market.

//// On average, only about one out of every 160,000 potential pesticides screened is commercialized, and almost all of those that aren't are discontinued for reasons other than bee safety.[44]

//// The development of a new pesticide takes, on average, eleven years before that pesticide is approved for sale.[44]

//// There are pesticides which have undergone hundreds of studies to evaluate their effects on bees.[38]

//// Deducing the effects of a pesticide on bee health from the results of a standard laboratory test would be like judging the effects of fizzy coke on the health of an entire community based on the results of a few people who had drunk nothing else other than coke for five years.

//// In one of the most extensive field studies ever conducted, scientists evaluated the effects of a neonicotinoid used on two crops in four different regions in France over three consecutive years.[39]

//// One of the largest oilseed rape field studies on the impacts of neonicotinoids on bees in Europe covered an area of no less than 130 km^2.[40]

//// Bayer conducts approximately 150-200 honey bee studies each year, to evaluate product safety to bees.

Chapter 4 ////

Myth: *Pesticides are the main reason for poor pollinator health*

Claim D:

Pesticides cause sublethal effects that are surely weakening bee colonies

Studies alleging the sublethal effects of pesticides on bees have become more common, but a closer inspection of the research often provides a very different conclusion than that which makes the headlines.

Reality:

The term 'sublethal' is often misused and does not necessarily imply harm to bees

When used by scientists, the term 'sublethal' describes effects which are not directly fatal, but impair health, behavior or performance and may, indirectly, eventually lead to death or impaired fitness. In recent years, there has been an increasing number of studies investigating the sublethal effects of pesticides on bees. While they add to our body of knowledge, studies which claim sublethal effects often are of questionable design and prone to misinterpretation.

Many claims of sublethal effects are based on studies of individual bees exposed to unrealistically high doses of pesticides under highly artificial conditions. When tested at the colony level under normal exposures and realistic field situations, the effects are frequently found to be either negligible or non-existent.[45] Some studies claim sublethal effects when the observed responses are of uncertain biological significance or pose no appreciable negative health impact whatsoever.[46] And in some study conclusions, only the negative results are emphasized, while neutral or even positive results are essentially ignored or interpreted with a negative bearing.[47]

Assessments at the colony level under realistic field conditions provide insights into all biologically relevant effects.

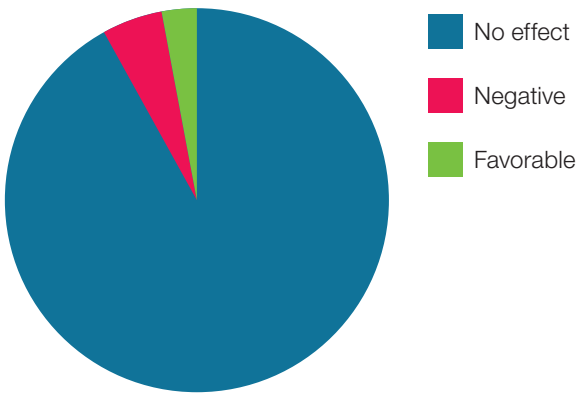
So, why do so many sublethal study conclusions appear eager to emphasize only negative results? In some cases, it is due to confirmation bias, a tendency to overvalue data that supports a scientist's preconceptions. Also, the temptation to publish studies that make alarmist headlines – a form of publication bias – is all too real, even in scientific journals, many of which are reluctant to publish studies which find no significant treatment effects.[48] Scientists who do so are often rewarded with widespread media attention and public recognition, even if the findings are suspect or inconsistent with other work. Unfortunately, the trend to popularize research by using sensational headlines may cause long-term harm to the objective, deliberative process of scientific research.[47]

4

//// **Supporting data**

The impacts of neonicotinoids on honey bees

After completing a large-scale field trial conducted by the Centre for Ecology and Hydrology (CEH), which examined the potential impact on bees from a seed treatment used on oilseed rape, the highly publicized study found no harmful effects in 94 % of the measured endpoints, to assess honey bee colony performance and health (254 different parameters were measured in total), negative effects in 3 % and positive results in 3 %. Yet, the published paper emphasized only the negative results.[47]



Differences between treatment and control groups
Source: BEENOW article; Science versus Sensationalism [47]

//// A three-year sublethal study of honey bees found no adverse effects on colony health following long-term exposure to the neonicotinoid thiacloprid at exposure rates which caused sublethal effects to individual bees.[45]

//// The conclusions of a renowned study on neonicotinoid sublethal effects were later shown to be incorrect because the study inappropriately extrapolated observations from individual bees to entire bee colonies. In a later study, the authors of the original publication confirmed that the sublethal effects they had described had no impact on colony level under realistic field conditions.[49]

Studies demonstrating sublethal effects

Do a check for the relevance to real-life situations.

//// **Is the exposure scenario realistic?**
Studies may be conducted under unrealistic exposure conditions e.g. laboratory with forced feeding, no-choice exposure or exaggerated concentrations.

//// **How relevant are the effects that are seen?**
Every change compared to an untreated control group is considered a sublethal effect. Yet not every sublethal effect is, necessarily, an adverse effect.

//// **Are the effects on individual bees or on the colony?**
Honey bees live in colonies with distinct castes, to fulfill the tasks of reproduction and labor. The caste system assures the common good – colony survival. Strictly seen, single honey bees are not individuals, the colony is the actual individual (a meta-organism).

//// **How specific are the effects?**
Each and every compound, including coffee and water, can cause sublethal effects, if the dose and exposure are high enough.

Chapter 4 ////

Myth: *Pesticides are the main reason for poor pollinator health*

Claim E:

Bee poisoning incidents with pesticides are common occurrences

Pesticide poisoning incidents involving bees usually receive considerable attention, but claims that they are common occurrences are not supported by existing information or records.

Reality:

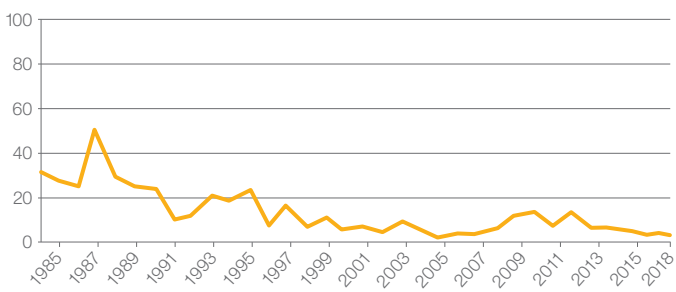
Bee poisoning incidents are rare – and getting rarer

Despite the publicity that follows an incident, bee poisoning events are rare.[33, 34] Even more encouraging is that, based on the data from the few countries where this is systematically investigated, the number of harmful incidents has been declining for years. One reason is that today's farmers are increasingly adopting best management practices, with an emphasis on product stewardship and communication with beekeepers, to reduce potential conflicts and protect bees. The low number of bee incidences, as reported in monitoring programs in Canada, Germany, the UK and the USA, clearly shows that today's responsible farming practices are working to protect bees.

//// Supporting data

Number of bee poisoning incidents in the UK

Source: adapted from Carreck & Ratnieks (2014).



//// Supporting data

//// In the UK, there have only been very few confirmed incidents involving honey bees and the approved use of an agricultural pesticide since 2003.[34]

//// The number of pesticide-related incidents reported in Germany per year affects less than 0.02 % of the more than 800,000 managed hives in that country.[50]

//// Despite millions of acres of crops seed-treated with neonicotinoids, bee poisoning incidents in the USA are very rare. The US Environmental Protection Agency (EPA) received only 21 reports between 2008 and 2016 – some of which were either misapplications or the cause was undetermined and in many of these incidents the number of bees affected was limited and did not put the colony at risk.[51]

Claim F:

Hives contain high levels of pesticide residues, which weakens bee colonies

Finding pesticide residues in honey bee hives does not necessarily mean that bees are in any danger, especially since only trace amounts (levels that are too low to harm bees) are typically detected.

Reality:

The amount of pesticide residues in most bee hives is not harmful

Because honey bees forage in treated agricultural crops, it is not surprising that the pollen and nectar they carry back to the hive may contain small traces of pesticide residues. But the mere detection of residues does not imply that they are harmful. Mostly, the residue exposure is too low to represent a health concern for bees, although some studies suggest they may cause sublethal effects (see Chapter 4, Claim D).

Hardly any studies have found a correlation between the pesticide residues found in hives and colony mortality.[32a-k] A comprehensive study of honey bee colonies in the USA and Canada for pesticides and their metabolites found no direct association with compromised bee health.[32a-k] Interestingly, pesticides applied in the hive by beekeepers to control *Varroa* mites usually represent the largest percentage of the total pesticide residues detected.

//// Supporting data

- //// In a major North American study, 83 % of all residues found in wax and pollen samples were fluvalinate and coumaphos, two common pesticides used by beekeepers to control *Varroa* mites.[52]
- //// In several field studies conducted between 2010 and 2016, researchers found that less than 7 % of pollen samples collected from U.S. colonies contain neonicotinoid residues, making them among the least detected of all pesticide residues found in beehives.[53a-f]
- //// In a long-term German monitoring study involving 1,200 honey bee colonies, no links were found between honey bee colony mortality on one hand, and pesticide residues in bee hives or exposure of bee colonies to neonicotinoid treated crops. The only clear correlation detected with colony mortality was infestation with the *Varroa* mite.[37]

Chapter 5 ////

Myth: *Neonicotinoid pesticides are dangerous and particularly harmful to bees*

Claim A:

Honey bee health issues began with the use of neonicotinoids

This common perception is easily verifiable, and the evidence clearly shows that it is completely wrong. Poor honey bee health is not associated with the use of neonicotinoids.

Reality:

Impaired bee health is an important issue, but neonicotinoids are not a significant factor

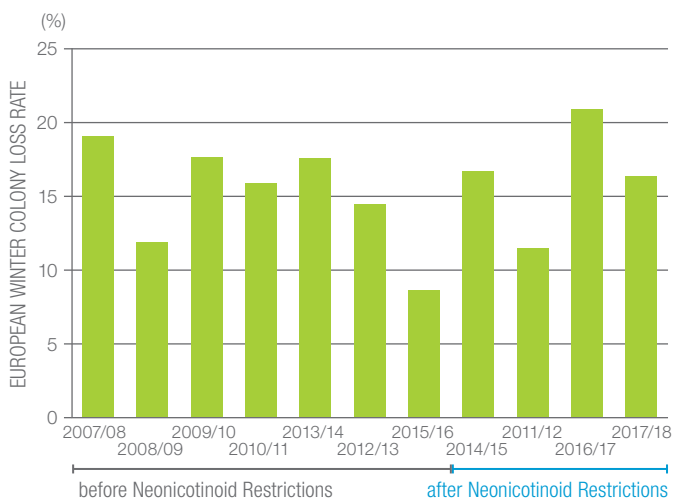
The fact that honey bee colony numbers are increasing – not declining – is indisputable (see Chapter 1, Claim A). However, it is also true that the health of honey bees has been a concern over the past few decades for a multitude of reasons (see Chapter 4, Claim A). Yet, claims that neonicotinoids are responsible for the impaired health of honey bees are not supported by the weight of the scientific evidence – and there's plenty of evidence available.

There are several metrics scientists use to assess honey bee colony health. These include an adequate size, demographic structure and vitality (or survival), an adequate production of bee products and other factors, such as queen performance and fecundity, worker mortality, brood development and the presence of parasites and diseases.[54, 55] A deficiency in any factor can impact colony health and most colonies are faced with multiple factors, which can lead to significant losses – especially during a winter with adverse weather conditions. While neonicotinoids would seem to represent a potential factor, the evidence suggests otherwise. Many field and monitoring studies have examined the impact of neonicotinoids on honey bee health and found these products do not present a risk to honey bee colonies under realistic agricultural conditions when used properly.[32a-k]

The two major areas of concern about honey bee health have been in Europe and North America. How do the numbers of colonies track with the use of neonicotinoids? Let's take the USA as an example: While the number of colonies has declined since the 1950s, most of this occurred many years before neonicotinoids entered the market. And the last major drop in colony numbers correlates with the *Varroa* mite's entry in the late 1980s, well before the first neonicotinoid was registered for use in 1994.[42] In both Europe and the USA, the number of colonies has recently trended upwards, even after neonicotinoids entered the market and became more widely used.

Winter colony losses – Europe

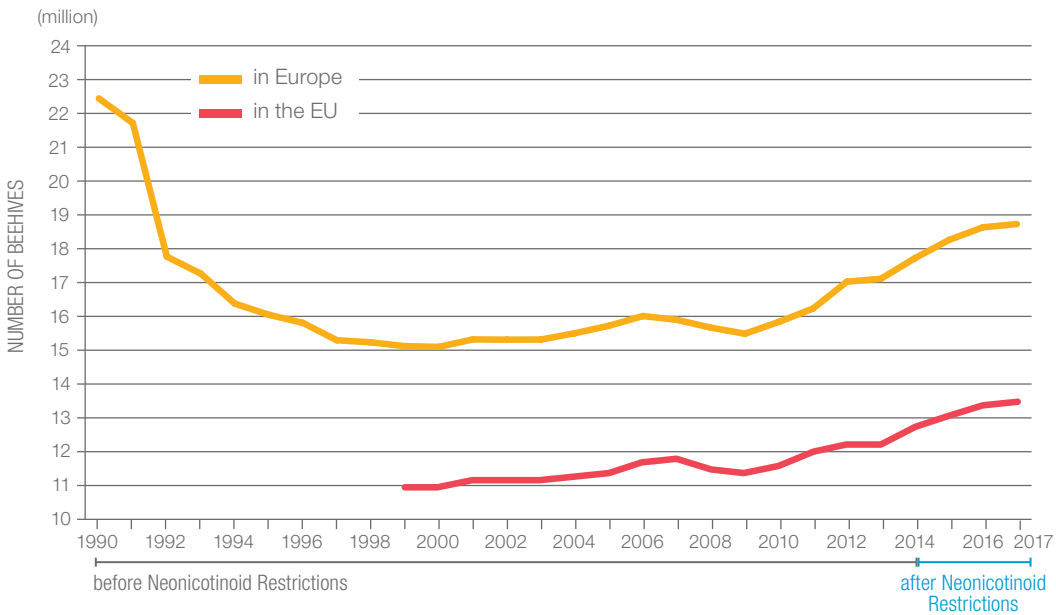
Source: Brodschneider, et al. (2016); COLOSS (2014, 2015, 2017a,b); Neumann (2009)



//// Supporting data

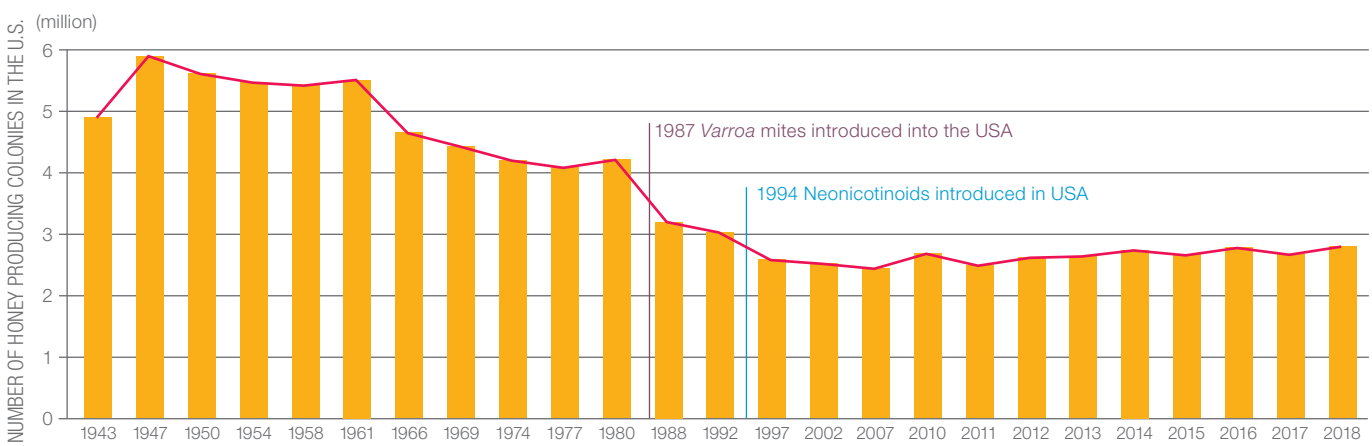
Trend in beehive numbers

Source: FAO STAT (2019) / EU Commission data



Number of honey producing colonies in the U.S.

Source: National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).



Chapter 5 ////

Myth: *Neonicotinoid pesticides are dangerous and particularly harmful to bees*

Claim B:

Neonicotinoids are thousands of times more toxic to bees than DDT

This is what is known as a "red herring" – factually true, but irrelevant. DDT has many reasons to be criticized, but toxicity to honey bees is not one of them.

Reality:

Comparing neonicotinoid bee toxicity to DDT is misleading and meaningless

The point of this claim appears to discredit neonicotinoids by comparing them to a banned and vilified pesticide. The relative toxicities of different pesticides vary greatly among different species. In fact, most insecticides used today are much more toxic to honey bees than DDT, which is relatively non-toxic by comparison.[56] Other bee species also tolerate high concentrations of this chemical without harm.[57] DDT was banned for a host of good reasons, but honey bee toxicity was not one of them.

Considering intrinsic toxicity (hazard) alone is no way to determine a product's risk to honey bees; it only indicates the capability of the product to cause harm, not the likelihood, or risk. **Risk is determined based on both hazard and exposure.** Just like other insecticides, some neonicotinoids are more toxic to honey bees than DDT, but how and when they are used is incredibly important in evaluating their impact on bees, as this is determining the exposure.[58] Fortunately, the evidence shows that when used according to the label directions, neonicotinoids will not impact honey bee colony health.

//// **Supporting data**

//// 500 years ago, the physician Paracelsus gave us the basic principle of toxicology – "The dose makes the poison" – which applies to all substances, including pesticides.

//// The caffeine found in our coffee is not considered particularly harmful and yet, on a weight-by-weight basis, it is more acutely toxic to mammals (including humans) than many pesticides, including neonicotinoids (caffeine LD_{50}*= 200 mg/kg; imidacloprid LD_{50} = 450 mg/kg). If a large group of people were to drink 118 cups of coffee in a single sitting, then half of them would not survive.

*Note: LD_{50} is a term used by scientists to describe the lethal dose that kills 50 % of a test population.

5

//// Supporting data

Insecticide toxicity to honey bees

Source: IUPAC: The Pesticides Properties DataBase (https://herts.ac.uk/aeru/iupac/atoz.htm)

Name	Description	Topical LD_{50} (µg/bee)	
DDT	Chlorinated Hydrocarbon	27.0*	Relatively non-toxic
Imidacloprid	Neonicotionoid	0.02	Highly toxic
Thiamethoxam	Neonicotionoid	0.03	Highly toxic
Clothianidin	Neonicotionoid	0.02	Highly toxic
Acetamiprid	Neonicotionoid	7.0	Moderately toxic
Cypermethrin	Synthetic Pyrethroid	0.02	Highly toxic
Deltamethrin	Synthetic Pyrethroid	0.05	Highly toxic
Bifenthrin	Synthetic Pyrethroid	0.01	Highly toxic
Spinosad	Approved for organic agriculture	0.003	Highly toxic

*Cornell University
http://pmep.cce.cornell.edu/profiles/extoxnet/carbaryl-dicrotophos/ddt-ext.html

Most insecticides are subject to extensive honey bee studies, e.g. a tunnel test with bees foraging on treated canola at the Bayer test station Gut Höfchen in Germany.

Chapter 5 ////

Myth: *Neonicotinoid pesticides are dangerous and particularly harmful to bees*

Claim C:

Neonicotinoids persist in soils for years – like DDT –, threatening ecological systems

Some claim that neonicotinoid persistence in soils and its potential impact on ecological systems is worse than DDT, but nothing could be further from the truth.

Reality:

Neonicotinoids are only moderately persistent in soils and do not bioaccumulate

One of the more grievous claims against neonicotinoids is that they persist in soils and therefore represent an ecological threat to the environment that is worse than DDT.[62, 63] However, such comparisons between DDT and neonicotinoids are unrealistic, inaccurate and wildly irresponsible.

A pesticide's persistence is often measured in terms of its half-life, or the time required for half of the compound to break down in the environment. There is no single half-life for any pesticide, as each will vary based on many factors, including sunlight, temperature, soil microbial activity, moisture and soil type. Laboratory studies tend to produce the longest half-life (worst case) because they provide uniform conditions that slow a pesticide's degradation. Field studies provide a more realistic estimate of a pesticide's half-life, but even these can vary greatly based on the specific location and environmental conditions.

The half-life of imidacloprid typically ranges between 40 and 288 days, as determined by field studies conducted in different areas of Europe,[63] but can vary, dependent on the region and field conditions. Under conditions of extreme cold or dryness, degradation will take longer: One study found a half-life surpassing 1,000 days.[65] These data come from cold, dry climates in Canada and the north-western area of the USA, which are not representative of most agricultural soils.

Critics have used this outlier to justify their comparisons with DDT, which has a half-life that can range from two to fifteen years.[34, 43] But unlike DDT, neonicotinoids do not build up or bioaccumulate in animals or the environment. DDT is well-known to accumulate in the fatty tissues of insects, wildlife and human beings, and for its ability to biomagnify in the food chain over time.[66] Neonicotinoid residues can bind tightly to the soil matrix, over time, so even though they may still be analytically detectible, they are no longer biologically available.

Modern pesticides must strike a balance in being active for long enough to provide effective pest control (and avoid repeat applications) and short enough to avoid accumulation in the environment. Neonicotinoids are widely used by farmers because they achieve the best of both goals.

5

//// Supporting data

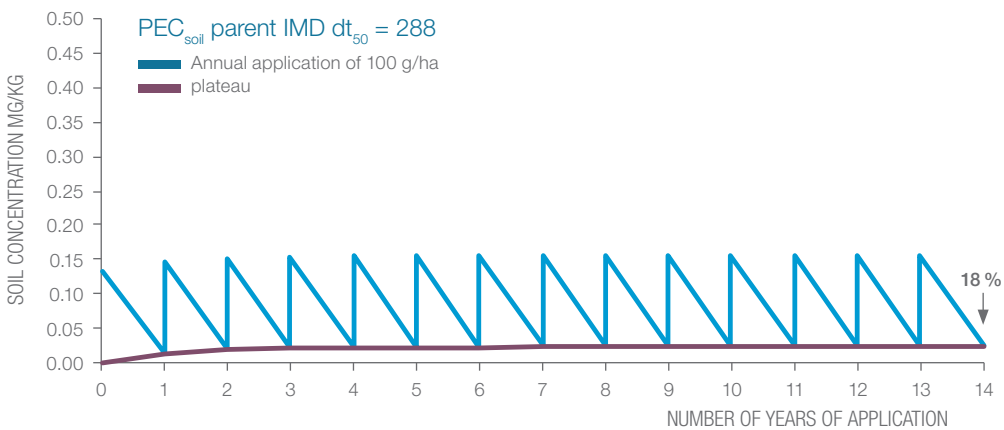
//// The half-life of the organic insecticide pyrethrin is only a few hours. Conversely, the organic fungicide, copper sulfate, can persist indefinitely in soils.[67]

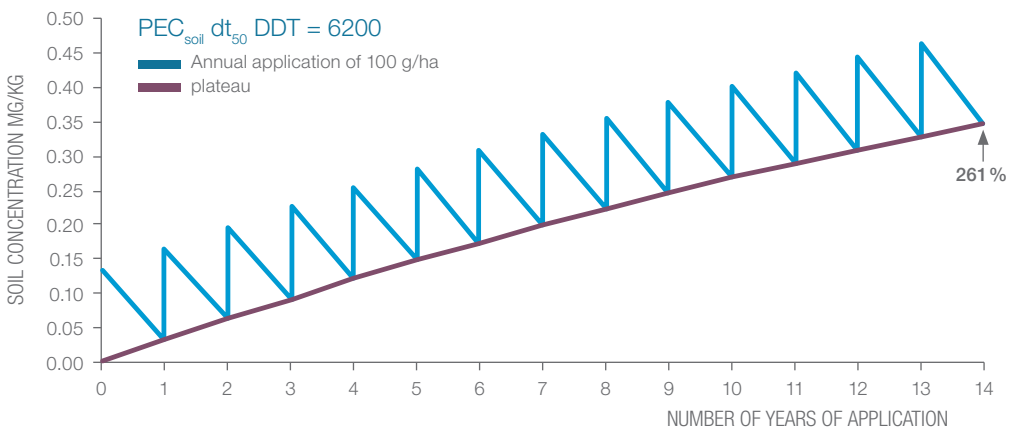
//// Assuming imidacloprid's half-life of 40 and 288 days and an unrealistic 14 years of continuous use, the soil concentration at the start of year 15 would increase only 0.04 % and 18 %, respectively. By contrast, when using the same parameters, the soil concentration of DDT would increase by 261 %.[64]

//// The half-life of DDT in an aquatic environment is about 150 years![66]

Build up of imidacloprid in soil compared to DDT

Source: Imidacloprid data[64]; DDT data from http://www.fao.org/3/X2570E07.htm





Chapter 5 ////

Myth: *Neonicotinoid pesticides are dangerous and particularly harmful to bees*

Claim D:

Neonicotinoids were the cause of Colony Collapse Disorder (CCD)

Scientists do not know what caused the sudden appearance of CCD over a decade ago in the USA. While its occurrence has largely disappeared, the claim that neonicotinoids are the cause of CCD has persisted.

Reality:

Extensive research has found no link between neonicotinoids and CCD

Beginning in 2006, some U.S. beekeepers discovered that most worker bees had rapidly vanished from their colonies, leaving behind only a queen, her brood and a few immature workers, even though the hives contained an ample supply of stored food. This phenomenon was later described as Colony Collapse Disorder or CCD. Nearly all the documented incidences of CCD were found in the USA, but there were occasional reports of its occurrence in other areas of the world.[32a-k, 59]

However, shortly after its discovery, any signs of CCD were largely gone. Researchers have been unable to confirm its existence in recent years and have found no connection with neonicotinoids. The precise cause of CCD remains a mystery, but most scientists believe it was due to a combination of factors that affect colony health.

That honey bees might be mysteriously disappearing was not only of scientific interest, it was also an irresistible news story. For several years, CCD was a headline topic in the media and many claimed it heralded a "bee apocalypse." The lack of a clear explanation for the peculiar symptoms attributed to CCD prompted many new studies to determine its cause, many of which focused on a new insecticide class – the neonicotinoids – the use of which was increasing around the same time.

Even during the height of the concern over CCD, some scientists were urging a cautious approach toward its possible causes and its frequency of occurrence – in fact, CCD was a rather rare phenomenon even at the time when it occurred, and ranked very low among the proven causes of colony mortality.[33] Unfortunately, many in the popular media continue to equate CCD with any type of colony mortality. While new cases of CCD are almost unheard of today, the term is still widely used.

//// Supporting data

//// Scientists evaluated 61 factors and found none that stood out as the primary cause of CCD.[33]

//// Documented incidences of CCD are rare. In 2018, the bee researcher who coined the term "CCD" reported that he had not seen a credible case of its reoccurrence in five years.[60]

//// Mentions of CCD are still seen in print and social media but have been in consistent decline since reaching a peak of more than 8,400 articles in 2013 [source: internal media search].

5

Claim E:

All neonicotinoids are highly toxic to bees

While some neonicotinoids are intrinsically highly toxic to bees, it is wrong to say the same about all the insecticides in this class. Some neonicotinoids have a particularly low toxicity to bees – much lower than most other insecticides.

Reality:

Some neonicotinoids are classified as 'practically non-toxic' to bees

The neonicotinoids are a relatively new class of insecticides when compared to other groups, such as the pyrethroids, organophosphates and carbamates. And like these older classes, individual neonicotinoids vary in their toxicity to bees. Some are categorized as 'highly toxic' while others are only 'moderately toxic' or 'practically non-toxic' according to definitions provided by regulatory agencies, such as the U.S. Environmental Protection Agency (EPA).[61] These differences in pesticide sensitivity result from the way the bees' defense enzymes successfully break down some insecticides into harmless metabolites.

Acetamiprid and thiacloprid are two neonicotinoids that are far less toxic to bees than are many insecticides in other insecticide classes, including many synthetic pyrethroids, organophosphates and carbamates. The same is true in comparing these neonicotinoids with some insecticides that are certified for organic uses, such as spinosad and pyrethrin, which are highly toxic to honey bees. While the toxicity of an insecticide is important in determining its risk to bees, it's not the only factor: Even the most toxic product will do no harm to honey bees or their colonies if it is used in such a way that avoids exposures to harmful doses.

//// Supporting data

//// Thiacloprid can be safely sprayed on flowering crops, even when bees may be actively foraging.[62]

//// Honey bees are a thousand times less sensitive to some neonicotinoids than they are to others.[61]

Some neonicotinoid products can be safely used on flowering crops when bees may be foraging.

Chapter 5 ////

Myth: *Neonicotinoid pesticides are dangerous and particularly harmful to bees*

Claim F:

The systemic properties of neonicotinoids make them especially harmful to bees

Criticisms regarding the systemic nature of neonicotinoid insecticides are based on the false assumption that it increases exposures and risks to bees, when in fact it does the opposite.

Reality:

The systemic nature of neonicotinoids is important in reducing risks to bees

Neonicotinoids have pronounced systemic properties that allow them to be taken up and translocated throughout a treated plant. While neonicotinoids can be sprayed on foliage or applied as soil drenches, in many regions they are predominately used as seed treatments. The benefit of treating seeds is that the product can be applied to only a tiny fraction of the field, and the insecticide moves exactly when and where it is needed to control destructive pests. Critics of neonicotinoids claim their systemic nature makes them especially harmful, creating 'toxic plants', but that description misleadingly paints an alarming picture – one that requires further explanation.

There are three potential routes of exposure to bees when neonicotinoids are used as a seed treatment:

Residues in nectar and pollen. There are two major transportation systems in vascular plants. The xylem handles the one-way movement of water and minerals to leaves, while the phloem is a two-way system that moves sugars and other materials from the leaves to all parts of the plant. Neonicotinoids, applied to the soil or to the seeds via a coating, travel mainly through the xylem to reach developing leaves early in the season. As the plant matures, only a small fraction of neonicotinoid residues is available to reach the later-growing buds and flowers, and this amount is far below the established level of concern to affect honey bee colony health.

Seed treatment dust. Under certain conditions, pesticide-treated seed coatings can be abraded by equipment used during planting or handling. This can result in the release of small amounts of insecticidal dust that could be harmful to bees, if exposed. Fortunately, the use of appropriate seed coatings, planting equipment and flowability agents can significantly reduce or even eliminate this seed dust potential.

Guttation. Plants get rid of excess moisture by actively secreting tiny drops of water from their leaves, a process known as guttation. Guttation fluid of seed-treated crops can contain concentrations of neonicotinoid residues which can be toxic to bees, if consumed. However, guttation fluid is not a relevant source of drinking water for bees and field studies show it has little to no impact on colony health.

Systemic seed treatments give farmers an efficient way to protect their crops without spraying the entire field, which lessens potential exposures in the environment. Extensive long-term field studies show that neonicotinoid residues in plants originating from seed treatments cause no adverse effects on honey bee colony health. Despite millions of hectares of treated seed being planted each year, confirmed bee incidents attributed to dust of neonicotinoids are very rarely seen or reported.

5

//// Supporting data

Neonicotinoid seed treatments are safe when used responsibly

Only rarely, have incidents occurred in which honey bees have been harmed when using neonicotinoid seed treatments. One such incident happened in 2008 in Germany when honey bee colonies were harmed by dust, abraded from treated corn seed during planting.[71] This incident was caused by a faulty seed treatment, which impaired the insecticide's adhesion to the treated seed and was aggravated by windy weather. Although it was a rare occurrence, the incident reinforced the need to always use best practices in applying treated seed.

The agricultural industry has worked to improve seed treatments and planting machines. These efforts have drastically reduced the environmental exposure from dust emissions from treated seeds,[72, 73] making seed treatments among the safest ways to apply these insecticides in the presence of honey bees. Many millions of hectares of neonicotinoid-treated seeds are safely applied each year without incident.

//// Seed treatments reduce soil surface exposures by up to 90 % compared to in-furrow applications and up to 99 % compared to broadcast spray application.[68]

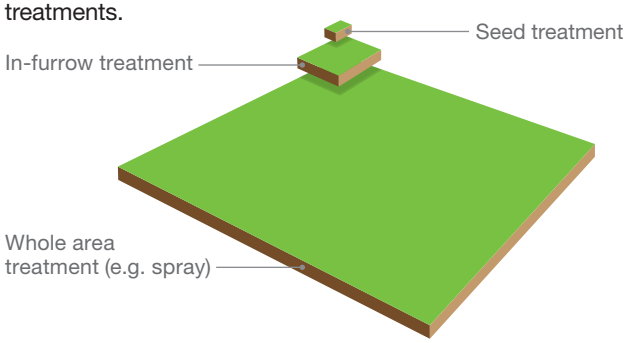
//// Typically, a maximum 1-5 µg/kg of clothianidin residues are found in nectar or pollen of seed-treated crops, well below the accepted concentration that is known to cause no adverse effects to bees (so-called NOAEC) of 20-25 µg/kg.[69]

//// Mitigation measures adopted by farmers, like the use of seed lubricants or deflectors, can reduce airborne dust emissions by over 90 %.[70]

Modern seed treatments allow for targeted application

Source: CropLife Canada

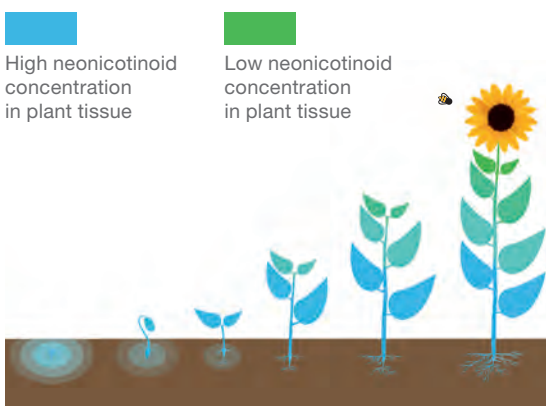
The proportion of the treatment area in direct contact with the active ingredient of the product is significantly and substantially reduced with seed treatments as compared to broadcast sprays or even in-furrow treatments.



Distribution of Neonicotinoids

phases of plant during the growth

Source: based on Sur & Stork 2003



Chapter 5 ////

Myth: *Neonicotinoid pesticides are dangerous and particularly harmful to bees*

Claim G:

A single neonicotinoid-coated seed kernel is enough to kill tens of thousands of bees

Some neonicotinoids are intrinsically highly toxic to bees, but this claim is disingenuous and irrelevant when it comes to assessing the safety of these seed treatments in agriculture.

Reality:

Treated seeds pose little risk to bees because bees are unlikely to encounter them

Analogies are useful in making complex subjects more understandable, but they can also be very misleading when used improperly. In this claim, the use of a simple theoretical mathematical calculation suggests that one kernel of corn treated with clothianidin will kill tens of thousands of bees.[74] However, this completely ignores the reality of modern seed treatments. The truth is that honey bees are unlikely to see a treated seed kernel, much less touch it or eat it.

Risk is determined by hazard and exposure

The example of a treated seed provides a perfect opportunity to talk about risk. Risk is determined by two factors, hazard and exposure. For example, there is enough electricity in a person's home to kill everyone in the family and neighborhood, but this almost never happens. That's because the hazard may be extremely high, but the exposure is extremely low. In the same way, the toxicity (hazard) of a pesticide is only an indicator of its potential risk. If there is little or no exposure, the risk is low or nil.

More discussion on this topic is found in Claim F ("systemic properties"), but to summarize: A kernel of seed treated with clothianidin poses little risk to even a single bee, much less the entire colony.

//// **Supporting data**

- //// Number games: Vitamin D and caffeine are more toxic to humans than imidacloprid.[75]
- //// U.S. farmers plant about 60,000 treated corn seeds per hectare on millions of hectares each year, and yet, reports of bee deaths or colony losses associated with planting are extremely rare.[76]

In the case of neonicotinoid seed treatment, bee exposure is very low because the product is applied to the seed and placed in the ground with the seed.

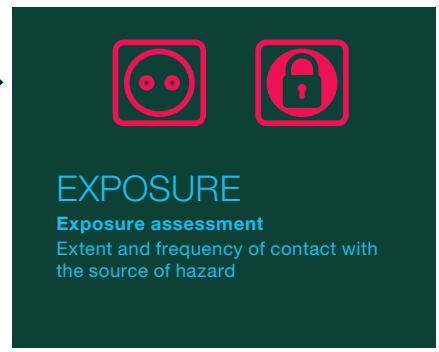
5

//// **Supporting data**

Principles of risk assessment

To understand risk, we need to know what the innate toxicity / potential hazard is and the degree of exposure.

Example: electricity



How does this translate into determining the bee safety of a pesticide?

Chapter 6 ////

Myth: *Genetically modified crops are harmful to bees*

Claim:

GM crops are harmful to bees

Do genetically modified (GM) crops harm bees? Not according to the available evidence.

Reality:

The risk of GM crops to bees is virtually zero

Many growers prefer to use GM (Genetically Modified) crops because they bring significant benefits to farming, including fewer pesticide applications, increased yields, reduced greenhouse gas emissions and improved soil health. Some GM crops include a genetic trait, derived from a common soil bacterium, *Bacillus thuringiensis* (or Bt), that enables them to resist insect pests. Many critics of GM crops have argued that the insecticidal Bt trait is also harmful to bees, but there is almost no evidence to support this claim.

The Bt proteins in insect-protected GM plants have been evaluated for potential toxicity to honey bees in numerous studies and none of them have provided any evidence of harm in either short- or long-term testing with both adult and larval honey bees. One study, in which bees were exposed to extremely high doses of the protein, found that bees fed less, and long-term memory may be impaired. However, when the high concentrations were compared to more realistic field exposures, the same authors concluded that negative effects on honey bee foraging behavior were unlikely to occur under natural conditions[77] (see Chapter 4, Claim D).

Based on the lack of activity of Bt proteins against honey bees and the results of multiple laboratory and field studies evaluating both lethal and sublethal effects, there is a sufficient weight of evidence to conclude that any risk from GM crops to honey bees is negligible.[78]

//// **Supporting data**

//// Over the past 20 years, insect-resistant traits in GM corn and cotton have reduced the total volume of insecticide active ingredient used in these crops by 53 and 29 %, respectively.[79]

//// Sprays of formulated Bt products, widely used by organic farmers to control pests and not considered harmful to honey bees, contain the same active ingredient produced by some GM crops.[80]

//// Supporting data

How do GM crops affect insects?

Source: Brookes & Barfoot. 2018. GM crops*

How GM crops help to preserve natural habitats?

GM crops are one tool that can improve crop yields by allowing fewer acres to produce the same amount of food. This can help **save critical animal and plant ecosystems**:

12 %

IN 2014, genetically modified crops (GM crops) helped preserve the equivalent of 12 % of the arable land in the United States*

That's nearly two thirds of all the land in North American national parks.

*Graham Brookes & Peter Barfoot, GM crops: global socio-economic and environmental impacts 1996-2016, June 2018. https://pgeconomics.co.uk/pdf/globalimpactstudyfinalreportJune2018.pdf

Chapter 7 ////

Myth: *Glyphosate is harmful to honey bees*

Claim A:

Glyphosate is harmful to honey bees

If you think the idea that this common herbicide is harming bees seems a bit strange – you'd be right. While there's almost no evidence to support this claim, there's plenty of evidence to refute it.

Reality:

Extensive studies show that glyphosate does not harm honey bees

Studies to establish the safety of glyphosate to honey bees have already been conducted over three decades ago. Field studies conducted on two continents investigated the potential for harmful effects of glyphosate on honey bee colonies.[81a-d] These and other studies concluded that glyphosate and glyphosate-based products pose little risk to honey bees. Extensive testing has found no acute or chronic adverse effects on honey bee adults, brood development or on colony survival, even when exposed to exaggerated use rates.

Glyphosate inhibits a specific enzyme that plants and some bacteria and fungi use to make amino acids. Plants can only obtain these amino acids by making them directly and this is why glyphosate is effective against a large number of weeds. Humans and animals obtain amino acids from their diet.[82]

Many semi-field studies examining the potential impact of glyphosate were intentionally designed to maximize exposure to honey bees. This has been done for risk assessment purposes but is not typical because glyphosate is often used at times when the exposure to foraging bees is low.

At the time of treatment, crops, such as soybeans or corn, are not flowering and are, therefore, not attractive to bees. Similarly, the elimination of flowering weeds usually occurs earlier in the season and, as such, is unlikely to create potential exposures over an extended timeframe. Glyphosate is non-persistent in soil and water and also dissipates rapidly in plant tissues, which lessens the potential exposure of bees to the substance.[83]

//// Supporting data

//// Much like honey bees, studies conducted using bumble bees and solitary bees demonstrate that glyphosate is practically non-toxic to other bee species.[83]

//// Under worst-case exposure conditions following a treatment in a confined greenhouse, glyphosate residues in nectar and pollen declined by half in just one or two days.[83]

Claim B:

Glyphosate harms pollinators indirectly by destroying their food

This claim gets so many things wrong that it's hard to know where to begin. But we'll try.

Reality:

Glyphosate is used to control problem weeds, not eliminate pollinator habitats

Farmland is managed by humans for the purpose of producing a crop. The fact that glyphosate indirectly alters the vegetative landscape is true, but the impact on pollinators is much more nuanced. The purpose of any herbicide is to create arable fields which are most favorable to the crop and glyphosate certainly removes unwanted weeds within the field. But, depending on the weed species and its stage of growth, it is unlikely that there is an impact on honey bee colonies' forage. Most applications are made when weeds are small and non-flowering because they're easier to manage and can be removed before damage is done to the crop. That also makes them unimportant to foraging bees as an immediate food source.

Full-grown weeds do provide a source of food to many pollinators, but they also compete with the crop itself. Most farmers will not tolerate weeds growing in their fields because unmanaged weeds will severely reduce the crop's productivity. So, whether a farmer uses glyphosate, another herbicide, removes weeds by hand or mechanically, the result is still the same. Despite this commercial reality, some growers are experimenting with ways to improve forage for pollinators by intentionally planting rows of flowering plants interspersed within the field or along the field borders (see Chapter 1, Claim B).[7, 84] Also, as agriculture becomes more efficient, less land is required – which potentially creates spaces for natural habitats and helps to preserve the biodiversity of plants and other wildlife, including pollinators.

Outside of a farm or rural environment, what is a honey bee's natural habitat? As noted in previous chapters, most honey bee colonies in Europe and North America are managed entities and owe their existence to their human handlers. Because of the devastation caused by the *Varroa* mite, there are almost no honey bee colonies left in the wild in these regions. So, one could argue that the habitat for honey bees is wherever their beekeepers decide it ought to be.

//// Supporting data

- //// Benefits of herbicides: Overall, crop losses due to weeds (i.e. competitive plants) produce the highest potential loss (34 %) for farmers, more than the losses caused by animal pests (insects, mites, nematodes, rodents, slugs and snails, birds) and plant pathogens (viruses, bacteria, fungi, chromista) (18 % and 16 %, respectively).[85]
- //// Screening tests to measure the effects of a glyphosate formulation on 18 beneficial predators and parasites found it to be of low concern.[86]
- //// Glyphosate products have been trusted for use in protected habitats such as the Galapagos Islands and the Florida Everglades to protect the native flora and habitats from invasive weed species.[87, 88]

Chapter 7 ////

Myth: *Glyphosate is harmful to honey bees*

Claim C:

Glyphosate weakens honey bees by disrupting the microbes in their gut

A recent study speculates that when honey bees are exposed to glyphosate, it alters the microbial community in the bee's gut and increases its susceptibility to infection and disease, affecting its health and effectiveness as a pollinator. While it may sound ominous, this claim doesn't hold up to further scrutiny.

Reality:

The evidence suggests glyphosate does not affect the health of honey bee colonies

The recent paper by Motta et al. (2018)[89] describes a complicated laboratory study conducted using a small number of individual bees, which shows inconsistent effects that have little relevance in real life.

This paper claims that the glyphosate concentrations to which bees were fed under artificial laboratory conditions were chosen to mimic environmental levels. However, the duration and magnitude of glyphosate exposure in this experiment was unrealistically high and thus not representative of the exposures of bees in typical agricultural situations.[90] Based on a relatively low number of bees evaluated, the study found some changes in composition of bacteria in bees exposed to the low dose but found no changes at the higher exposure. This inconsistency calls into question the biological relevance of the small changes observed. Moreover, the paper does not provide any evidence that the purported effects could have a negative impact on bee health under realistic field conditions. Both these points challenge the credibility of the study's claims.

Microbiomes are complex and variable, and the composition of the honey bee gut microbiome differs with the ages and tasks of bees in the colony.[91] To obtain a better appreciation of the effects that small changes in microbial composition might have (assuming they are biologically relevant), it is vital that field studies be conducted to properly assess the potential impact on the colony as a whole. Colony-level feeding studies have evaluated exposures to glyphosate and no significant negative effects have been observed in honey bee larval development, colony growth and survival.[79, 92]

//// Supporting data

//// If glyphosate makes bees more susceptible to illness, then an impact on mortality and growth rates ought to be seen in studies which have been conducted with entire bee colonies in a more realistic environment, but there is no evidence of this.[93]

//// Glyphosate is typically used early in the crop production cycle to kill emerging weeds, long before they produce flowers. These weeds are, therefore, of no interest as a potential food source for foraging bees and, as such, are not a source of exposure.

//// **Supporting data**

The withdrawal of approval for glyphosate would entail serious consequences for farmers and our environment

1 Every year, as much as 40 % of the world's potential harvests are lost to weeds and other pests.

According to the Food and Agriculture Organization of the United Nations (FAO), these losses could double without crop protection practices, including glyphosate and other herbicides.

2 Herbicides help farmers use water, soil, and other important resources more efficiently.

For example, herbicides control weeds, which compete with crops for water, which reduces crop yields.

3 Analyses from Europe found that the number of weeds resistant to other herbicides and weed control costs would increase if farmers lost access to glyphosate (Cook et al, 2010).

In France alone, losing access to glyphosate is expected to reduce yields by 10 % and require an additional 0.7 million hectares of land to compensate for these losses (Wynn et al., 2012).

Estimated economic losses for Germany alone range from € 79 to 202 million (Steinmann et al., 2012).

4 Glyphosate enables farming practices that have ecological and carbon footprint benefits such as reduced- or no-till farming, a practice that reduces soil erosion, promotes soil health and helps reduce CO_2 emissions.

Without glyphosate, globally, there would be additional carbon emissions arising from increased fuel usage and decreased soil carbon sequestration, equal to the equivalent of adding 11.77 million cars to the roads. (https://www.tandfonline.com/doi/pdf/10.1080/21645698.2017.1390637).

References:

1 FAO. 2009. ProdSTAT Database. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/default.aspx

2 Potts et al. 2010. Declines of managed honey bees and beekeepers in Europe. Journal of Apicultural Research 49: 15- 22. DOI 10.3896/IBRA.1.49.1.02.

3 USDA. March 2017. National Agricultural Statistics Service. Honey (SSN: 1949-1492). https://www.nass.usda.gov/Data_and_Statistics

4 EU Texts Adopted: 1 March 2018. Prospects and challenges for EU apicultural sector. http://www.europarl.europa.eu/doceo/document/TA-8-2018-0057_EN.html
OPERA. Bee health in Europe Facts & figures 2013. http://www.operaresearch.eu/files/repository/20130122162456_BEEHEALTHINEUROPE-Facts&Figures2013.pdf

5 vanEngelsdorp and Meixner. 2010. Chapter 3.8. Socio-political factors affecting managed colony populations. https://www.semanticscholar.org/paper/A-historical-review-of-managed-honey-bee-in-Europe-vanEngelsdorp-Meixner/c888600ac7a120a58db44fd50db338a465e2aa6e

6 IPBES. https://www.ipbes.net/article/press-release-pollinators-vital-our-food-supply-under-threat

7 Ecol Evol. 2015 Aug; 5(16): 3523–3530. Published online 2015 Aug 1. doi: [10.1002/ece3.1444].

8 Bayer. https://beecare.bayer.com/media-center/beenow/detail/bringing-bees-back-to-the-farm

9 Cavalheiro et al. 2013. Ecology Letters 16, 870 – 878. https://onlinelibrary.wiley.com/doi/full/10.1111/ele.12121

10 Neumann, Carreck. 2010. Honey bee colony losses. Journal of Apicultural Research http://www.researchgate.net/journal/0021-8839

11 Fleming. 1871. Animal Plagues: Their History, Nature, and Prevention. Chapman & Hall, London.

12 Underwood and van Engelsdorp. Retrieved 2010-05-02. Colony Collapse Disorder: Have We Seen This Before? The Pennsylvania State University, Department of Entomology.

13 COLOSS. https://coloss.org/core-projects/colony-losses-monitoring (Contains links to surveys for 2015/16 and 2016/17)

14 Social apoptosis in honey bee superorganisms. Scientific Reports. 2016; 6: 27210 DOI: 10.1038/srep27210

15 Forbes. https://www.forbes.com/sites/quora/2015/11/16/how-and-why-honey-bees-make-the-ultimate-sacrifice-when-they-sting-you/#1524ec126346

16 Pearson. 2014. Wired. https://www.wired.com/2014/05/will-we-still-have-fruit-if-bees-die-off

17 USDA-NASS. 2018. https://www.nass.usda.gov/Statistics_by_State/California/Publications/Specialty_and_Other_Releases/Almond/Objective-Measurement/201807almom.pdf

18 Trendrr. 2019. https://www.trendrr.net/6124/top-10-largest-honey-producing-countries-world-famous-best/

19 FAO. Staple Foods: What do people eat? http://www.fao.org/3/u8480e/u8480e07.htm

20 Genetic Literacy Project. 2015. https://geneticliteracyproject.org/2015/08/12/pollinator-myth-bees-responsible-one-third-global-food-heightening-crisis-like-7/

21 IPBES. 2017. Pollinators, pollination and food production. https://www.ipbes.net/sites/default/files/downloads/pdf/ individual_chapters_pollination_20170305.pdf

22 Klein et al. 2007. https://royalsocietypublishing.org/doi/full/10.1098/rspb.2006.3721

23 Kleijn et al. 2015. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nature. https://www.nature.com/articles/ncomms8414

24 Garibaldi et al. 2013. http://science.sciencemag.org/content/339/6127/1608

25 Science News. https://www.sciencenews.org/article/native-pollinators-boost-crop-yields-worldwide

26 Bayer. BEEINFOrmed No. 7. 2018. The importance of insect pollinators for agriculture. http://beecare.bayer.com/bilder/upload/dynamicContentFull/Publications/BEEINFOrmed_7_The-Importance-of-Insect-Pollinatorsjlouz8q1.pdf

27 Quote Investigator. If the bee disappeared off the face of the earth. https://quoteinvestigator.com/2013/08/27/einstein-bees/#note-7108-1

28 C&EN. Meet the Sentinels. 2017. Vol. 95, Issue 46. https://cen.acs.org/articles/95/i46/meet-the-sentinels.html

29 Ecology & Evolution. 2012. Aug; 2(8): 1949–1957. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3433997

30 Pirk et al. 2017. Risks and benefits of the biological interface between managed and wild bee pollinators. Functional Ecology 2017, 31, 47–55 doi: 10.1111/1365-2435.12768.

31 BEEINFOrmed No. 4. 2018. EU misses target. http://beecare.bayer.com/bilder/upload/dynamicContentFull/Publications/Neonicotinoid_restrictions_miss_target_BEEINFOrmed_4-1j85jtix8.pdf

32a vanEngelsdorp et al. 2009. Colony Collapse Disorder: A Descriptive Study. PLoS ONE 4(8): e6481.

32b vanEngelsdorp et al. 2010. Weighing Risk Factors Associated with Bee Colony Collapse Disorder by Classification and Regression Tree Analysis. J Econ Entomology 103(5):1517-1523.

32c Rogers, Kemp. 2004. Assessing Bee Health in the Maritimes: A survey of pesticide residues in honey bee, *Apis mellifera*, colonies. Final Report, Pei Adapt Council Project Number 319.02. October 15, 2004.

32d Nguyen et al. 2009. Does Imidacloprid Seed-Treated Maize Have an Impact on Honey Bee Mortality? J. Econ. Entomol. 102(2): 616-623.

32e Chauzat et al. 2009. Influence of Pesticide Residues on Honey Bee (Hymenoptera: Apidae) Colony Health in France. Environ. Entomol. 38(3): 514-523 (2009)

32f Genersch et al. 2010. The German bee monitoring project: a long term study to understand periodically high winter losses of honey bee colonies. Apidologie 41 (2010) 332–352

32g Solomon, Stephenson. 2017. Quantitative weight of evidence assessment of higher tier studies on the toxicity and risks of neonicotinoid insecticides in honeybees, Publications 1-4: Journal of Toxicology and Environmental Health

32h Pilling et al. 2013. A Four-Year Field Program Investigating Long-Term Effects of Repeated Exposure of Honey Bee Colonies to Flowering Crops Treated with Thiamethoxam. PLoS ONE 8(10): e77193. https://doi:10.1371/journal.pone.0077193

32i Rolke et al. 2016. Large-scale monitoring of effects of clothianidin-dressed oilseed rape seeds. Ecotoxicology (2016) 25: 1691. https://doi.org/10.1007/s10646-016-1723-x

32j Stavely et al. 2013. A Causal Analysis of Observed Declines in Managed Honey Bees. https://doi.org/10.1080/10807039.2013.83 1263

32k Fairbrother et al. 2014. Risks of neonicotinoid insecticides to honeybees. Environ Toxicol Chem. 2014 Apr; 33(4): 719–731.

33 Chauzat et al. 2013. Demographics of the European Apicultural Industry. PLOS ONE. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0079018

34 Jones. 2016. Poisoning of Bees by Agrochemicals: Evidence from Monitoring in England and Wales. Presentation, Chemical Industry Regulations, Nice, September 6th–7th, 2016, 17/ EEC and 91/414/EEC. Official Journal of the European Union 24.11.2009, L 309: 1–50.

35 U.S. Bee Survey. University of Maryland. May 25, 2017. https://phys.org/news/2017-05-survey-honeybee-losses-horrible-bad.html

36 Science 2.0. https://www.science20.com/jon_entine/with_the_science_settled_that_neonicotinoids_dont_cause_honeybee_problems_who_does_europe_need_to_ban_them-232047

37 Chauzat et al. 2013. Demographics of European Apicultural Industry. PLOS ONE. DOI: 10.1371/journal.pone.0079018.

38 Chauzat et al. 2016. Risk indicators affecting honeybee colony survival in Europe. https://link.springer.com/content/pdf/10.1007%2Fs13592-016-0440-z.pdf

39 DeGrandi-Hoffman et al. 2017. Environmental Entomology, Volume 46, Issue 4, August 2017, Pages 737–746. https://academic.oup.com/ee/article-abstract/46/4/737/3745306?redirectedFrom=fulltext

40 University of Florida/IFAS. http://entnemdept.ufl.edu/creatures/misc/bees/varroa_mite.htm

41 Guzman et al. 2010. Apidologie 41. *Varroa destructor* is the main culprit for the death and reduced populations of overwintered honey bee colonies in Ontario, Canada. https://www.apidologie.org/articles/apido/pdf/2010/04/m09037.pdf

42 Martin et al. 2012. DOI: 10.1126/science.1220941. Global Honey Bee Viral Landscape Altered by a Parasitic Mite. (Cited in: The Guardian - Honey Bee Decline Linked to Killer Virus)

43 Pesticide Environmental Stewardship. https://pesticidestewardship.org/pollinator-protection/pesticide-toxicity-to-bees

44 Phillips McDougall. 2016. The Cost of New Agrochemical Product Discovery, Development and Registration in 1995, 2000, 2005-8 and 2010-2014. https://croplife.org/wp-content/uploads/2016/04/Cost-of-CP-report-FINAL.pdf

45 Siede et al. 2017. Performance of honey bee colonies under a long-lasting dietary exposure to sublethal concentrations of the neonicotinoid insecticide thiacloprid. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5485166

46 Crall et al. 2018. Science, Vol. 362, Issue 6415 http://science.sciencemag.org/content/362/6415/683

47 Bayer. 2018. Science versus Sensationalism. https://beecare.bayer.com/media-center/beenow/detail/controversy-over-a-large-scale-field-study-shows-why-good-science-not-sensational-headlines-should-drive-research-conclusions

Project overview: https://www.ceh.ac.uk/our-science/projects/impacts-neonicotinoids-honeybees

48 Enago Academy. 2018. Does academic research suffer from a publication bias? https://www.enago.com/academy/does-academic-research-suffer-publication-bias

49 Henry et al. 2015. Reconciling laboratory and field assessments of neonicotinoid toxicity to honeybees. The Royal Society. https://doi.org/10.1098/rspb.2015.2110

50 German Beekeeping Association (Deutscher Imkerbund e. V.) https://deutscherimkerbund.de/161-Imkerei_in_Deutschland_Zahlen_Daten_Fakten

51 EPA Clothianidin Prelim. Bee Risk Assessment. 2017. Pages 337-339. Bayer Summary Report to EPA on Corn Dust Incidents in 2012. EPA Report No. US0391.

52 Mullin et al. 2010. PLOS One. High Levels of Miticides and Agrochemicals in North American Apiaries. https://doi.org/10.1371/journal.pone.0009754

53a Mullen et al. 2010. High Levels of Miticides and Agrochemicals in North American Apiaries: Implications for Honey Bee Health. PLoS ONE 5(3): e9754.

53b Fischer and Henderson. 2010. Do Pesticide Residues in US Bee Hives Pose a Serious Risk? Poster Presentation to Society of Environmental Toxicology and Chemistry North America Annual Meeting, November 9, 2010 (Portland, OR).

53c Pilling, Campbell, Coulson, Ruddle, Tornier. 2013. A Four-Year Field Program Investigating Long-Term Effects of Repeated Exposure of Honey Bee Colonies to Flowering Crops Treated with Thiamethoxam. PLoS ONE 8(10) 1-14.

53d USDA-APHIS. 2012-2013 National Honey Bee Pests and Diseases Survey Report. 23 pages. http://beeinformed.org/wp-content/uploads/2014/10/2012-13-End-of-year-final-report.pdf

53e Dively et al. 2015. Assessment of Chronic Sublethal Effects of Imidacloprid on Honey Bee Colony Health. PLoS ONE 10(3): e0118748.doi:10.1371/journal.pone.0118748.

53f Lawrence et al. 2016. Survey and Risk Assessment of *Apis mellifera* (Hymenoptera: Apidae) Exposure to Neonicotinoid Pesticides in Urban, Rural, and Agricultural Settings. Journal of Economic Entomology 109(2) · January 2016. Ent. DOI: 10.1093/jee/tov397.

54 Assessing the health status of managed honeybee colonies. 2016. EFSA Journal. https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2016.4578

55 Alaux et al. 2018. Measuring biological age to assess colony demographics in honeybees. https://doi.org/10.1371/journal.pone.0209192

56 Cornell University, Michigan State University, Oregon State University, and University of California at Davis., Pesticide Information Profile DDT (dichlorodiphenyltrichloroethane). http://pmep.cce.cornell.edu/profiles/extoxnet/carbaryl-dicrotophos/ddt-ext.html

57 Ask Nature. August 18, 2016. Bees collect DDT. https://asknature.org/strategy/bees-collect-ddt/#.XBv451xKiUk

58 MN Dept. of Agriculture. Pesticide Toxicity to Bees. https://www.mda.state.mn.us/protecting/bmps/pollinators/beetoxicity

References:

59 Dainat et al. 2012. Environmental Microbiology Reports 4(1), 123–125 doi:10.1111/j.1758-2229.2011.00312. Colony Collapse Disorder in Europe.

60 ScienceNews Magazine. January 17, 2018. The mystery of vanishing honeybees is still not definitively solved. https://www.sciencenews.org/article/mystery-vanishing-honeybees-still-not-definitively-solved

61 EurekAlert! Public Release: 22-Mar-2018. Some neonicotinoid pesticides are more toxic to bees than others; here's why. https://www.eurekalert.org/pub_releases/2018-03/cp-snp031518.php

62 EU Commission. Renewal of Approval. https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en

63 R. Arnason. The Western Producer. Published: October 16, 2014. Comparing neonicotinoids to DDT called irresponsible. https://www.producer.com/

64 EFSA Scientific Report (2008) 148, 1-120, Conclusion regarding the peer review of the pesticide risk assessment of the active substance imidacloprid. https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2008.148r

65 Baskaran et al. Degradation of bifenthrin, chlorpyrifos and imidacloprid in soil and bedding materials at termiticidal application rates. Pesticide Sci. 1999; 55:1222–1228.

66 National Pesticide Information Center. DDT Fact Sheet. http://npic.orst.edu/factsheets/ddtgen.pdf

67 Extoxnet. 1994. Extension Toxicology Network Copper Sulfate. http://pmep.cce.cornell.edu/profiles/extoxnet/carbaryl-dicrotophos/copper-sulfate-ext.html

68 CropLife Foundation. 2013. The Role of Seed Treatment in Modern U.S. Crop Protection – A Review of Benefits. https://static1.squarespace.com/static/59b55b2b37c581fbf88309c2/t/5a2a7f8871c10bf01d01a7aa/1512734670130/The+Role+of+Seed+Treatment+in+Modern+US+Crop+Production.pdf

69 Christian Maus et al. 2003. Safety of imidacloprid seed dressings to honey bees: a comprehensive overview and compilation of the current state of knowledge, Bulletin of Insectology 56, p. 51-57. http://www.bulletinofinsectology.org/pdfarticles/vol56-2003-051-057maus.pdf

70 Bayer data. 2017. Reducing dust drift to protect pollinators, page 4 https://beecare.bayer.com/media-center/beenow/detail/reducing-dust-drift-to-protect-pollinators

71 Pistorius et al. 2009. Bee poisoning incidents in Germany in spring 2008 during sowing of maize. Julius-Kühn-Archiv 423: 118-126.

72 Forster et al. 2012. ICPBR-Working Group Risks posed by dusts: overview of the area and recommendations. Julius-Kühn- Archiv 437: 191-198.

73 Friessleben et al. 2010. An effective risk management approach to prevent bee damage due to the emission of abraded seed treatment particles during sowing of neonicotinoid treated maize seeds. Aspects of Applied Biology 99: 277-282.

74 Hodgson and Krupke. 2012. Iowa State University. Extension and Outreach. Insecticidal Seed Treatments can Harm Honey Bees. https://crops.extension.iastate.edu/cropnews/2012/04/insecticidal-seed-treatments-can-harm-honey-bees

75 Cornell University National Science Teachers Association. Chapter 1 – The Dose Makes the Poison. Assessing Toxic Risk. http://ei.cornell.edu/teacher/pdf/ATR/ATR_Chapter1_X.pdf

76 EPA Clothianidin Prelim. Bee Risk Assessment. 2017. Pages 337-339. Bayer Summary Report to EPA on Corn Dust Incidents in 2012. EPA Report No .US0391

77 GMO Answers. https://gmoanswers.com/ask/gmos-impact-honey-bees

78 Devos et al. 2012. Transgenic Research: Vol. 21, Issue 6, pp 1191–1214. Bt-maize event MON 88017 expressing Cry3Bb1 does not cause harm to non-target organisms.

79 Brookes & Barfoot. 2017. PG Economics Ltd, GM crops: global socio-economic and environmental impacts 1996-2015. https://www.pgeconomics.co.uk/pdf/2017globalimpactstudy.pdf

80 Extoxnet. 1994. Extension Toxicology Network. Bacillus Thuringiensis. http://pmep.cce.cornell.edu/profiles/extoxnet/24d-captan/bt-ext.html

81a Ferguson. 1987. Interim report. Long term effects of systemic pesticides on honey bees. The Australian Beekeeper. Pages: 49-53 (September issue).

81b Ferguson. 1988. Long term effects of systemic pesticides on honey bees. Bee keeping in the year 2000: Second Australian and International Beekeeping Congress, Surfers Paradise, Gold Coast, Queensland, Australia, July 21-26, 1988. Editor: John W. Rhodes. Pages: 137-141.

81c Burgett and Fisher. 1990. A review of the Belizean honey bee industry: Final report prepared at the request of The Belize Honey Producers Federation. Department of Entomology, Oregon State University, Corvallis, Oregon.

81d Thompson et al. 2014. Evaluating exposure and potential effects on honeybee brood (*Apis mellifera*) development using glyphosate as an example. Integr Environ Assess Manag. 10(3):463-70. doi: 10.1002/ieam.1529.

82 Tarpy. 2017. College of Agriculture and Life Science. North Carolina State University. N.C. Agricultural Chemicals Manual, Chapter V, Relative Toxicity of Pesticides to Honey Bees. https://craven.ces.ncsu.edu/wp-content/uploads/2017/08/Relative-Toxicity-of-Pesticides-to-Honey-Bees.docx

83 Thompson et al. 2014. Evaluating exposure and potential effects on honeybee brood (*Apis mellifera*) development using glyphosate as an example. Integr Environ Assess Manag. 10(3):463-70. doi: 10.1002/ieam.1529.

84 Bayer. BEENOW. 2018. Bringing Bees back to the Farm. How ecological enhancement measures boost biodiversity in farming landscapes. https://beecare.bayer.com/media-center/beenow/detail/bringing-bees-back-to-the-farm

85 Oerke. 2006. Journal of Agricultural Science 144, 31–43. Crop losses to pests.

86 Hassan et al. 1988. Journal of Appl. Ent. Results of the fourth joint pesticide testing programme by the IOBC/WPRS-Working Group. https://doi.org/10.1111/j.1439-0418.1988.tb00194.x

87 Buddenhagan. 2006. The successful eradication of two blackberry species Rubus megalococcus and R. adenotrichos (Rosaceae) from Santa Cruz Island, Galapagos, Ecuador. Pacific Conservation Biology Vol. 12: 272-78.

88 Toth. 2007. Establishment of Submerged Aquatic Vegetation in Everglades Stormwater Treatment Areas: Value of Early Control of Torpedograss (Panicum repens). J. Aquat. Plant Manage. 45: 17-20

89 Motta et al. 2018. Glyphosate perturbs the gut microbiota in honey bees. https://www.pnas.org/content/pnas/115/41/10305. full.pdf

90 Taha et al. 2017. Protein content and amino acid composition of bee-pollens from major floral sources in Al-Ahsa, eastern Saudi Arabia. Saudi Journal of Biological Sciences. DOI: 10.1016/j.sjbs.2017.06.003

91 Kaplan. 2018. Agricultural Research Service. Species shifts in the honey bee microbiome differ with age and hive role. https://phys.org/news/2018-07-species-shifts-honey-bee-microbiome.html

92 von Mérey et al. 2016. Glyphosate and AMPA chronic risk assessment for soil biota. Environ Toxicol Chem. 35:2742-2752. doi: 10.1002/etc.3438.

93 Ruishalme. 2018. Genetic Literacy Project. Link between bee death and glyphosate still a 'far-fetched' story. https://geneticliteracyproject.org/2018/10/11/viewpoint-link-between-bee-death-and-glyphosate-still-a-far-fetched-story

Bayer for Biodiversity

go.bayer.com/biodiversity

Bayer Crop Science

bayer.com/en/agriculture

PHOTOS
Bayer AG
shutterstock: pp 1, 2, 3, 10, 12, 13, 18, 22, 52
ageko: p 11 / bee illustrations

climate neutral print
www.klima-druck.de
ID-No. 1983508
bvdm.

FSC
www.fsc.org
MIX
Paper from responsible sources
FSC® C081774