The complex causes of worldwide bee declines

January 12 2016, by Nicole Miller-Struttmann

B. frigidus pollinating C. scopulorum. Credit: N. Miller-Struttmann

Over the past two decades, bee declines worldwide have drawn international attention. Managed honey bee (Apis mellifera) colonies decreased by 25% over 20 years in Europe and 59% over 58 years in North America, and many bumble bee populations in Europe and North America have gone locally extinct, resulting in dramatic range contractions. It is important to note that not all bees in all places are declining. Some populations are actually growing, and there are many more for which data are insufficient or nonexistent.

However, given the potential agricultural and ecological consequences, several governmental agencies, including the Obama administration, have issued initiatives to combat dwindling bee populations. As we attempt to pinpoint why bees are declining and how we can help them, a common trope is emerging: it's complicated. For example, in a recent review in *Science* magazine, Goulson et al. (2015) point to several, interacting factors: availability of food and nest resources, exposure to agrochemicals, incidence of antagonists (i.e., disease, parasites and invasive species), and climate change. While these co-occurring factors may not point to a simple story, or an easy solution, the vast majority of recent research suggests that the reality is indeed complex.

Bees rely exclusively on the plants they visit for their nutritional needs. Adults collect pollen to feed their brood and nectar for their own energetic requirements. Inturn, they act as pollen vectors, transporting pollen as they fly from one flower to the next.

This mutualistic relationship is responsible for over $200 billion dollars worth of food products and the reproductive success of more than 85% of flowering plants.

Declines in bees, the primary pollinators in both agricultural and natural settings, threaten these pollination services.

Loss of flowers/food

One of the most important factors restricting bee populations is food availability, particularly in urbanized and agricultural settings. Land conversion to housing, roads, and other human infrastructure restricts and isolates patches of flowering plants. Intensively farmed regions with mass-flowering crops provide insufficient resources for bees which require nectar and pollen throughout the foraging season. Wild habitats are exhibiting similar deficits due to climate change.

Miller-Struttmann et al. (2015) recorded flower declines of 60% with 40 years of warming in alpine meadows that are largely protected from land use changes.

To compensate for this deficit, alpine bumble bees (Bombus balteatus and B. sylvicola) diversified their foraging portfolio to include a greater variety of plants. This type of behavioral plasticity allows bees to respond quickly to fluctuating resources and adapt to their new environments. Bees in regions experiencing both landuse and climate change-induced flower deficits may be particularly reliant on this plasticity.

Four species of bees visiting the same flower sequentially

Disease

However, behavioral plasticity may also enhance the transmission of parasites, another key perpetrator of bee declines. Flowers are the watering holes of the pollinator world, offering a place for individuals (and their parasites) to come into contact with each other. By experimentally manipulating the foraging sequence of two bee species (A. mellifera and B. terrestris),

Graystock and colleagues (2015) illustrated that flowers act as reservoirs for parasites, facilitating transmission between and within bee species.

When flowers are abundant, pollinators select their 'favorite' (most energetically efficient) flowers and therefore are less likely to share flowers with other species. As flower abundances decline due to habitat loss and/or climate change, pollinators (regardless of how specialized they are initially) forage from a greater diversity of plants, potentially coming into contact with many more individuals and increasing parasite transfer.

If this is the case, a more generalized world may be a more disease-prone world.

Oilseed rape field (common target for neonicotinoids) in West Lothian (UK) by Agriculture, Food, and Rural Communities (creative commons license).

Climate Change

Climate change poses an increasing threat to bees as global warming and its impacts accelerate. Unlike many other organisms, many bees are not tracking these changes. For instance, bumble bees, the group of bees for which we have the most complete biogeographical data, appear to be in a climate change vice. A recent study by Kerr et al. (2015) indicates that distributions of bumble bees in North America and Europe are constricting. While their trailing range limits (those at the lower altitudes and latitudes) are advancing, the cooler, leading edges of their ranges are not. The warm-edge advancement makes sense, since bumble bees have relatively low heat tolerance. However, it is unclear why they are not migrating into habitats with cooler climates.

Neonicotinoids

Finally, neonicotinoids, which are commonly used agricultural pesticides, pose significant threats to managed and wild bees.

Neonicotinoids are slow-release, agricultural pesticides that attack the central nervous systems of insects.

Since they break down slowly, they provide protection as the plant develops, reducing pesticide treatments. However as systemic chemicals, they pass readily into reproductive tissues and interfere with mutualist, as well as antagonist, insects. At this point it is clear, that honeybees, our most prominent agricultural pollinators, exhibit neonicotinoid-induced declines in foraging success and navigation. Honeybees seem to prefer neonicotinoid-laced nectar, become inebriated and have difficulty finding their way home. Wild (non-cultivated) bees are expected to follow suit. However, honey bees are highly social and exhibit unique behaviors that may make them poor surrogates for the diverse suite of wild bee species found around the world. Rundlöf et al. (2015) suggest that honeybee susceptibility may actually underestimate that of other bees. The authors monitored wild bee (solitary and bumble bee) and honey bee populations in 14 fields paired by land-use history and neonicotinoid treatment. Wild bee densities and colony success declined in neonicotinoid-treated oilseed rape fields, providing support for the previously controversial claim that neonicotinoids may contribute to bee population declines. Honeybee colonies, on the other hand, were surprisingly unaffected.

Greater neonicotinoid susceptibility of non-honey bee species is particularly disturbing as we attempt to diversify our agricultural pollinators. Declines in managed honey bees highlight our dependence on a single species of pollinator for all our agricultural needs, prompting many to call for a more stable, diverse suite of pollinators. Diverse pollinator communities are more robust to disturbances, such as population fluctuations of a given species, because there is redundancy within the system. They also provide greater pollination services. Recent work in PLoS One highlights this response: Zhang et al. (2015) show that bumble bees (Bombus patagiatus) are more effective pollinators of peaches (Prunus persica) than honeybees. Not only are more fruits produced, but they develop faster, reducing risk of damage. By expanding our agricultural pollinators to include a more diverse suite of bees, threats to any given species will be less detrimental to crop yield and farmers' bottom line.

The complex nature of bee declines poses a significant conservation challenge. In order to save the 'disappearing' bees, we must determine which taxa are threatened, which threats are most imminent, and how to address them. When the solutions to conservation issues are relatively simple, such as in the cases of ozone-depletion and eggshell-thinning chemicals, concerted efforts can quickly rally public and political support to protect important natural resources. While there are certainly actions we can take to conserve bee populations, they will need to be both concerted and multifaceted.

Public support has escalated with increased awareness of bee declines; however, the efforts that have emerged to address them may be misplaced or oversimplified.

Our next challenge is to direct this energy, not just to the most notorious culprits, but to the most effective strategies for combating all of them.

More information: Simon Potts et al. Declines of managed honey bees and beekeepers in Europe., *Journal of Apicultural Research* (2010).

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