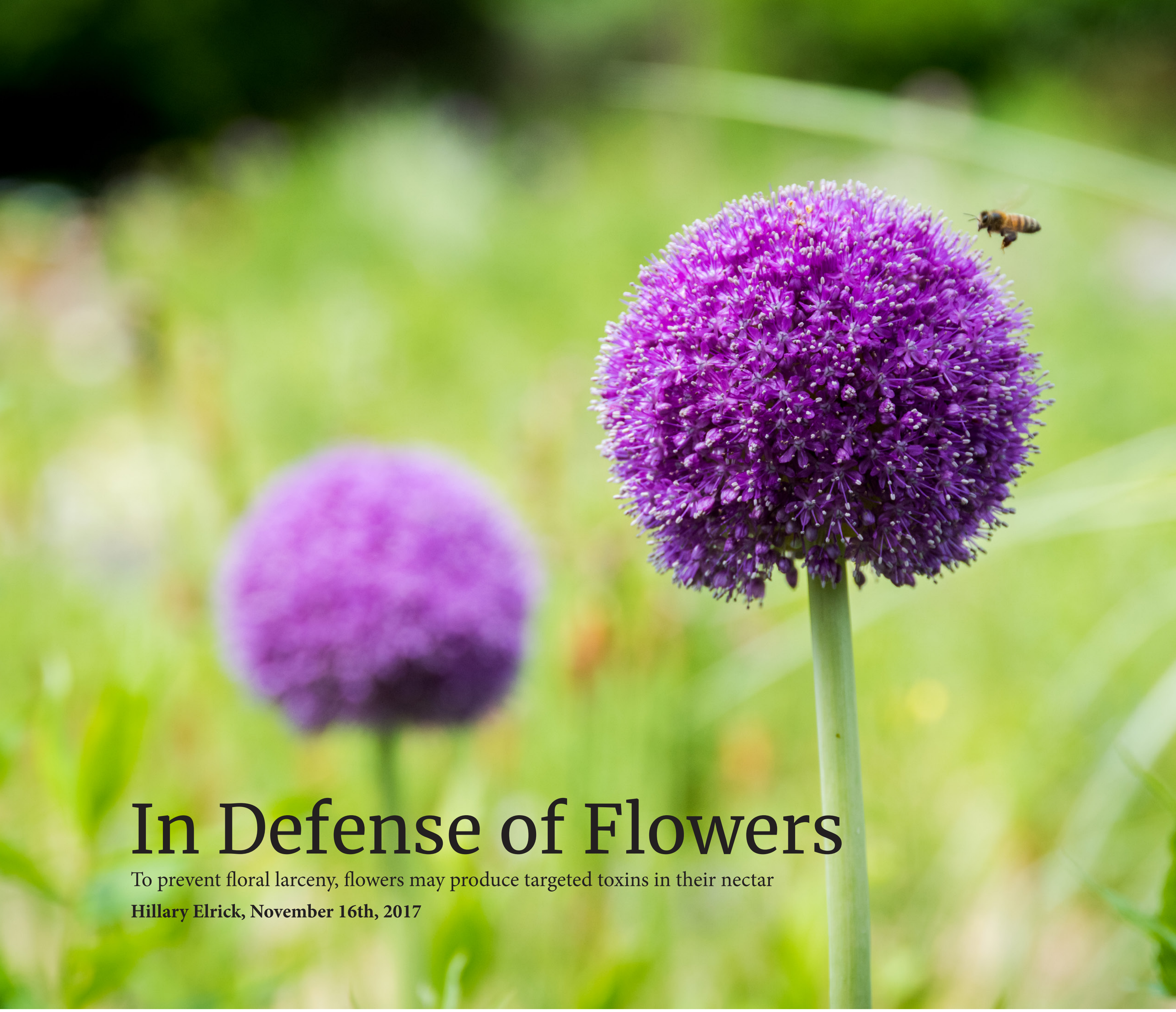


In Defense of Flowers

To prevent floral larceny, flowers may produce targeted toxins in their nectar

Hillary Elrick, November 16th, 2017

Business and store owners may have more in common with flowers than they think. Obviously one of the main priorities when setting up a store is to attract customers, yet deterring thieves from stealing merchandise is another important concern. However one chooses to prevent theft, it comes with a trade-off. While installing an alarm system may be an unobtrusive method, placing items in locked cabinets, and patting down patrons as they leave the store may discourage paying customers from wanting to shop. What's the best balance to strike? Flowers face the same conundrum. How can they prevent pesky 'nectar robbers' from stealing nectar, while still ensuring pollinators want to visit? A recent study has been the first to shown that plants may produce toxic compounds to defend themselves against nectar robbers. Additionally, their study suggests that pollinators may have a higher tolerance to these toxins, which means they won't be significantly deterred from visiting. This evidence for natural plant defense could become important in pesticide development and plant breeding since it could help create plants with natural defense mechanisms, or produce natural pesticides which limit harm to the environment.

Plants have long been known to produce alkaloids which can protect them against herbivores[1], but few studies have investigated the role toxins play in defending against nectar robbers. Nectar robbing, or floral larceny, is when a would-be pollinator accesses a plant's nectar without coming into contact with its pollen. Biologists have been aware of floral larceny since the 18th century, when German naturalist Christian Konrad Sprengel observed bumblebees chewing into flowers and feeding through the holes they had created. Though most studies focus on bees, nectar robbing has been observed in wasps, ants, hummingbirds, bats and even squirrels. Pollinators and plants have a mutualistic relationship; in return for access to nectar, pollinators transport and spread the plant's gametes in the form of pollen. By avoiding their part in the mutualistic contract, nectar thieves are exploiting the flower, so it often develops strategies to counteract this exploitation.

It's an interesting, yet complicated area of research due to the different species and behaviours at play. A study in 2016 showed that nectar quality, volume per flower, and floral morphology are all features that can deter robbery[2], and one found evidence that flowers may modify their nectar to benefit bumblebees that are specialized to extract their nectar[3]. Yet another study concluded that the alkaloids produced by Carolina jessamine flowers reduced both pollination and nectar robbing, but incurred an overall negative cost to the flower[4], though the cost they calculated was a weak one. A recent paper titled 'Distasteful Nectar Deters Floral Robbery' is the first to show that plant compounds in nectar may function in a natural ecological setting as a defense specifically against nectar robbers.

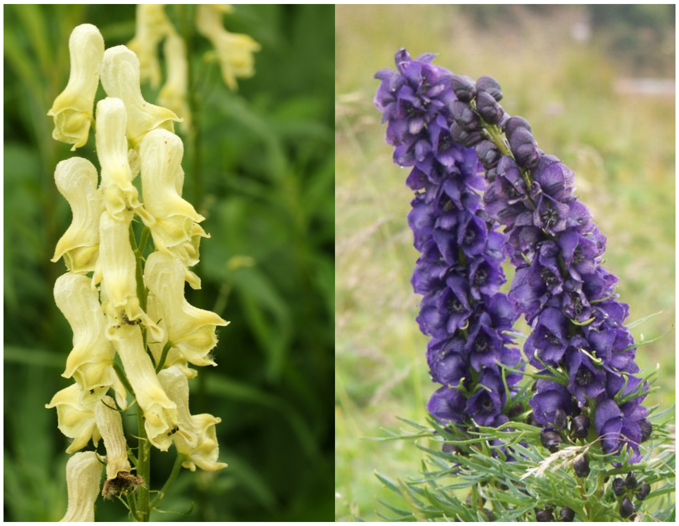
One of the main authors on the paper, Geraldine Wright, PhD, has a varied educational background which includes botany, chemical ecology, neuroscience, and behaviour. She has been studying bees since 2002. Her lab at the Institute of Neuroscience in Newcastle, UK has made several publications in the past few years which link neonicotinoid pesticides to both decreased motor-function[5], and short-term memory loss[6] in adult worker bees. Her research could help determine whether neonicotinoids are a main cause of colony collapse disorder, which has been plaguing bee populations worldwide in recent years. Her recent research on the influence of toxins in nectar on

Dr. Geraldine Wright, Newcastle University

Dr. Sarah Barlow, University of Utah

bee foraging patterns with co-author Sarah Barlow PhD, could have implications in the fields of botany, animal behaviour, and agriculture.

Their study uses 'Rana', a novel system created by UK based company Tumbling Dice, to track visits to flowers. Rana is able to record and monitor footage from a camera, and tracks changing 'frames of motion' to determine the number of pollinator visits to a flower. Since the logger is able to operate using solar panels, it's able to be set up and left for long periods of time in remote field locations. Barlow has previously been involved with studies using the Rana monitoring system to count the number of pollinator visits to flow-



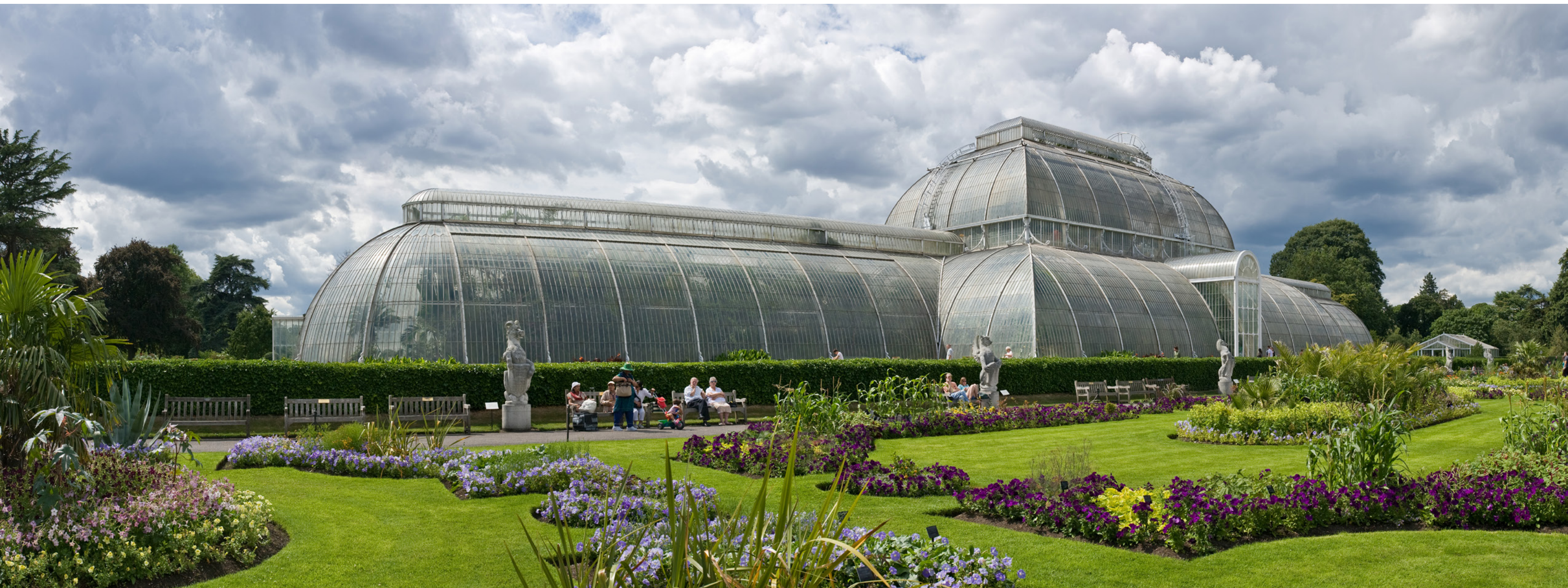
Aconitus lycoctonum (left) and *Aconitus napellus*

ers[7] and the system has also been successful at monitoring hoverfly visits[8]. It saves time and money by reducing frequent and time-consuming field visits. It has been shown to be highly accurate, and could find frequent use in future studies on pollinators.

A Rana system was setup to monitor both *Aconitus lycoctonum* and *Aconitus napellus* plants that were established at the Royal Botanic Gardens in Kew (pictured below), which is located 30 minutes outside of London. Since the Rana system didn't capture footage of a flower being robbed, field visits were required to the gardens as well. Two plants were studied in this experiment, both from the genus Aconitum, commonly known as monkshood, wolf's bane, or devil's helmet. Both are herbaceous, perennial, and extremely poisonous. Though the *A. lycoctonum* plants were robbed more frequently than *A. napellus*, they were visited more frequently by pollinators and robbers alike. Additionally, it was found that the *A. lycoctonum* was more likely to have nectar in each of their flowers, but in flowers that had nectar, A. napellus flowers had a much higher volume of nectar. Upon testing the nectar of each of the species, it was found that the specific concentrations of different alkaloids was different for each of the plant species.

Two bumblebee species accounted for almost all the visits to the flowers under observation. One was *B. hortorum* which is a 'long-tongued' bumblebee, and the other was *B. terrestris*, a 'short-tongued' bumblebee. While the long-tongued bees accessed the nectar properly, by feeding from the nectar spurs, the short-tongued bees never collected nectar in a way that would lead to the flower being pollinated.

Long-tongued bumblebees, who were the true customers, were less likely to visit plants with high concentrations of alkaloids in their nectar. At concentrations of 200 ppm, their visits declined sharply, and flowers with concentrations of 380 ppm and above received no visits from the pollinators. Robbing wasn't observed frequently enough to determine if the short-tongued bumblebees were also deterred by these alkaloid concentrations in the field. However, the researchers employed a novel laboratory method to test the response of short-



tongued bumblebees to nectar with different alkaloid levels. Through this method, they found that short-tongued bees had a very low tolerance for toxins. *B. terrestris* were repelled from nectar with alkaloid concentrations of just 20 ppm, suggesting that the pollinating species, *B. hortorum* may have a higher tolerance for the alkaloids.

Additionally, the bees seemed to find a specific alkaloid toxin called aconitine to be very repulsive. *A. napellus* tends to produce nectar with higher concentrations of aconitine compared to *A. lycoctonum*, and the researchers believe this could be a possible explanation for its lower visitation rate. Knowing which toxins are particularly deterrent to bumblebees could could have important implications in natural pesticide development.

Bees make very complex decisions when deciding whether or not to visit a particular plant. Many studies have determined that the profitability of foraging is the main contributor to bee behaviour[9] so if a bee is uncertain whether a particular flower contains nectar, they may avoid foraging it. The payoff for robbing nectar from either species was almost equal, yet the short-tongued bumblebees were still up to four times more likely to rob from *A. lycoctonum* than *A. napellus*. For pollinator bumblebees, the energetic payoff from foraging *A. lycoctonum* was actually lower than if it foraged on *A. napellus*, yet it still visited the *A. lycoctonum* flowers at a lower rate.

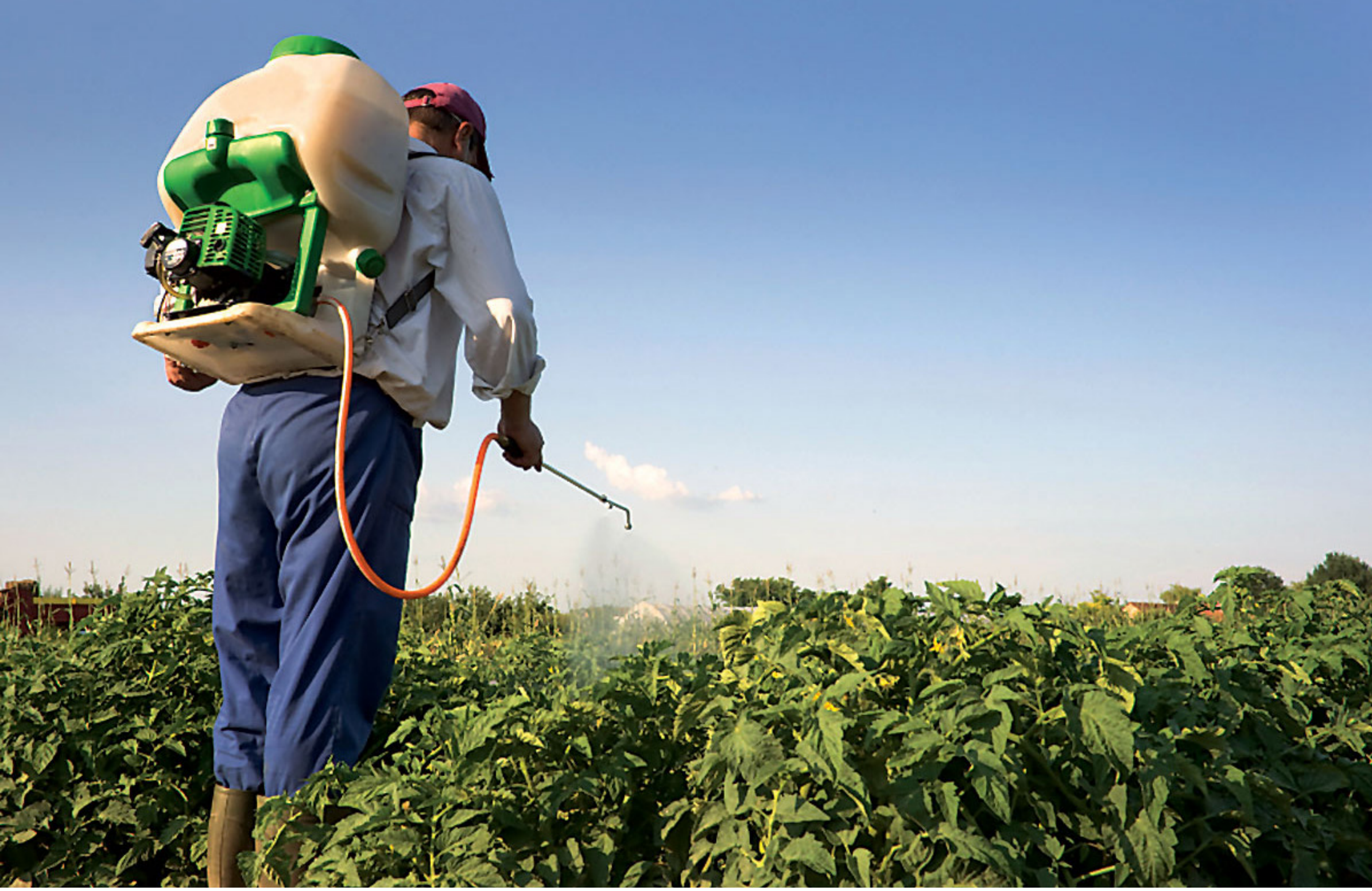
These results give insight to how strong the metabolic costs are for bees to detoxify themselves againsts specific alkaloids. Aconitine was the most prevalent alkaloid in *A. napellus* nectar, so if bees have difficulty detoxifying themselves from it, they may avoid nectar with higher concentrations of aconitine altogether.

B. hortorum, the long-tongued bumblebee

B. terrestris, the short-tongued bumblebee

Barlow et al. have provided important and novel contributions to the relatively unexplored area of nectar robbing in their study. Their observations on how nectar toxicity is factored into bee foraging provide evidence that detoxification costs may modify their foraging behaviour. Further research on the different metabolites that are contained in plant nectar, and how they influence bee behaviour could give important clues into the neural pathways of bees, and how they evaluate their decisions.

Though the study was not able to directly compare how the pollinator and robber bees were deterred by toxic nectar in the field, they show that pollinators visit flowers with higher alkaloid concentrations less frequently in the field. Additionally, in the lab, they discovered that the nectar robbing species had a very low tolerance to nectar alkaloids. Both of the bee species were particularly repelled by aconitine, a finding which was referenced recently in a comprehensive study on the use of natural pesticidal plants in Africa[10]. In the study, researchers



highlight the need for the development of new natural pesticides with lower impacts on the environment and human health.

The novel laboratory technique for testing bumblebee aversion to compounds used by Barlow et. al in thier study could have the potential to determine which compounds repel certain insects the most effectively, and at what concentration the insects begin to be deterred. This could be used to target invasive or particularly damaging insects when developing pesticides.

Finally, successful use and implementation of the Rana system highlighted in the study could encourage it to be adopted by other researchers. This would allow studies to use pollinator data that's been collected over far longer ranges of time than traditional field sampling methods. Having compressed video files as opposed to potentially subjective records from the field could make data collection more robust, and able to be easily shared by several laboratories.

There is a study currently underway at the Red Butte Gardens in Utah, which was set up by their Conservation Department, to study Holmgren's milkvetch, a plant which has been classified as endangered. Ultimately the study hopes to develop a plan to stabilize the plant population. As of now, 3654 plant species, or nearly 17% of listed species, are classified as endangered[11], so if the study is successful its methods could be used to help save other endangered plants.

-Hillary Elrick

The main study referenced in this article was:

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