The Importance of Restoring Insect Pollinators

By

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Background Information

Fruitless Fall by Rowan Jacobsen focuses on the many possible reasons behind the global decline of one of our most prolific pollinators, the European honey bee (*Apis mellifera).* The honeybee is not native to North America but serves an important role in the pollination of many of our major agricultural crops (Jacobsen 2008). Bee keepers transport bees nationwide and deliver their hives (e.g., apiaries) to farmers who rent them (Jacobsen 2008). Some time ago, farmers began to recognize that crop yields were substantially higher when a hive of bees was present in the area; however, natural hives were rare and thus, a business was born (Jacobsen 2008). In fact, it is widely recognized that "apiaries and fruit culture must go together" (Jacobsen 2008).

Jacobsen (2008) effectively notes that our diets might be rather bland without the benefit of bee pollinators. A variety of fruits, including cherries, apples, cranberries, and melons all rely on bees to reproduce (Jacobsen 2008, Losey and Vaughan 2006). Perhaps even more importantly, bees serve a major role in coffee bean proliferation (Jacobsen 2008). I for one would be pretty unhappy without my daily cup of Joe. Pumpkins and squash also depend on honeybees for pollination (Jacobsen 2008). Even livestock that graze on clover and alfalfa rely on bees. It may not be as apparent of a connection but a decrease in the primary production of pasture forage could negatively affect dairy and meat production (Losey and Vaughan 2006). The extent to which we depend on plant pollination is most assuredly taken for granted (Jacobsen 2008).

Many of our major food crops and native flora and fauna depend on delicate plant-pollinator relationships that are being threatened by disease, habitat fragmentation, overuse of chemical toxins, and a changing global climate (Jacobsen 2008). Rachel Carson even warned of the potential for a "Fruitless Fall" in her book *Silent Spring.* Carson (1962) laments that "man is more dependent on these wild pollinators than he usually realizes…Without insect pollination, most of the soil holding and soil enriching plants of uncultivated areas would die out, with far reaching consequences to the ecology of the whole region. Many herbs, shrubs, and trees of

forests and range depend on native insects for reproduction; without these plants many wild animals and range stock would find little food".

This paper aims to explore the many threats to honeybees and the farther reaching consequences of those threats to native pollinators. In doing so, it is first important to note what services non domesticated pollinators and other insects provide.

Ecological Services Provided by Insects

Ecological services are those services that are deemed valuable to humanity (Ricketts 2004). Insects provide no lack of such services; however, their often unappealing nature tends to devalue their purpose in the ecosystem (Losey and Vaughan 2006). Insects not only act as pollinators but also serve important functions in waste removal (especially for the livestock industry), pest management (e.g., biological control), and wildlife sustenance (Losey and Vaughan 2006). Given the multitude of services insects provide, pollination likely remains one of the most vital (Losey and Vaughan 2006). The economic value of crops pollinated by native and domestic honeybees is estimated to be somewhere between 8.3 and 14.6 billion dollars (Losey and Vaughan 2006). From that estimate, approximately three billion dollars makes up the financial contribution by native pollinators (Losey and Vaughan 2006).

It is also interesting to note that the combination of domestic honeybees and native bees on the landscape may provide the highest crop yields (Losey and Vaughan 2006). Bumble bees are able to provide pollination services to plants such as the tomato that honeybees have no interest in (e.g., there is no pollen reward)(Losey and Vaughan 2006, Evans et al. 2008). In fact, the presence of bumblebees may increase tomato harvest by as much as 45% and increase fruit weight by nearly 200% (Losey and Vaughan 2006). Additionally, competition between native bees and honeybees is known to double the amount of pollen delivered by honeybees on sunflower crops (Losey and Vaughan 2006). Native bees chase honeybees from flower to flower, increasing the rate of pollen delivery by 50% (Losey and Vaughan 2006). Native bumblebees are also able to fly in lower light levels and temperatures, extending the amount of time that pollination can occur (Evans et al. 2008).

Insects don't only benefit the agricultural industry. Wildlife recreationists would find fewer animals (e.g., game birds) available to hunt, fewer migratory birds to view, and fewer fish to catch if their primary insect food source wasn't available (Losey and Vaughan 2006). Overall, the value placed on insects for the few services outlined here is estimated to be around 60 billion dollars annually (Losey and Vaughan 2006). Many insect populations are undergoing slow, rather than drastic declines in numbers (Losey and Vaughan 2006, Ricketts 2004). If these declines continue, a general loss in biodiversity can be expected and a veritable domino effect could ensue in which every other aspect of the ecosystem gradually begins to decline in the wake of the insects' disappearance (Losey and Vaughan 2006, Ricketts 2004). Furthermore, maintaining a highly diverse group of pollinators in an ecosystem will help to ensure future plant and crop pollination by compensating for the natural boom and bust cycles that these species undergo (Ricketts 2004). Because of their value to the agriculture industry, pollinators have been given more conservation attention than other invertebrates but, research into why pollinators are declining is still lacking.

Threats to Pollinators

The importance of pollinators (and insects in general) has been well established so, what threats are our native and domestic pollinators contending with? The primary offenders are habitat fragmentation, changing climates, pesticide and insecticide usage, disease, and human encroachment/development.

Habitat fragmentation is a common problem related to agricultural and urban development. The farther the distance between native habitat fragments the sharper the decline in the species that inhabit those fragments (Ricketts 2004). Bees and other pollinators have restricted ranges making pollination of crops less likely as native habitat is continually reduced (Ricketts 2004). A study conducted by Ricketts (2004) demonstrated that coffee crops located close to forest fragments experienced greater pollination efforts by a wider diversity of native bee species than crops located farther away from forest fragments. Forest fragments also helped to maintain native bee biodiversity and thus stabilized pollination of crops close to the forested habitats over several years (Ricketts 2004). Similar findings were evident in

California, where watermelon crops located near natural habitats produced higher yields (Ricketts 2004). Fragmentation also destroys nesting sites leaving many insects homeless during the critical winter months (Evans et al. 2007). Bumblebees are especially sensitive to habitat fragmentation because they rely on ample blooming vegetation from spring to autumn (Evans et al. 2007). Infrequent and small patches of native land are simply unable to support diverse and abundant populations of bumblebee (Evans et al. 2007).

Additionally, disease and parasite infestation are also leading to pollinator declines, particularly for the domesticated honeybee. Varroa mites (*Varroa destructor)* are an especially destructive parasite. Varroa mites have decimated millions of honeybee colonies since their introduction from Europe (Jacobsen 2008). Mites weaken hives by feeding on developing larva, generally without directly killing the bees (Jacobsen 2008). Open wounds left by the fangs of the mites act as vessels for infection, leaving adult bees deformed and malnourished (Fig 1) (Jacobsen 2008).

Figure 1. Varroa mite attached to a developing honeybee. Photo courtesy of Debbie Roos with the North Carolina Cooperative Extension.

Varroa mites also inhibit royal jelly production which nourishes developing larva and is delivered by nurse bees whose glands have been damaged by mite infestation (Jacobsen 2008). Use of insecticides had proven somewhat successful but recent research suggests that

prevalent use of toxic chemicals has only helped to create “super” mites and weaker bees (Jacobsen 2008). Furthermore, escaped domestic and commercially raised bees often infect native bee populations with introduced diseases and parasites (Evans et al. 2008). Native bumblebees are believed to be suffering mass casualties because of infection by the parasites *Nosema bombi* and *Crithidia bombi,* both of which are believed to have arrived with shipments of European honeybees (Figure 2 and Figure 3)(Evans et al. 2008).

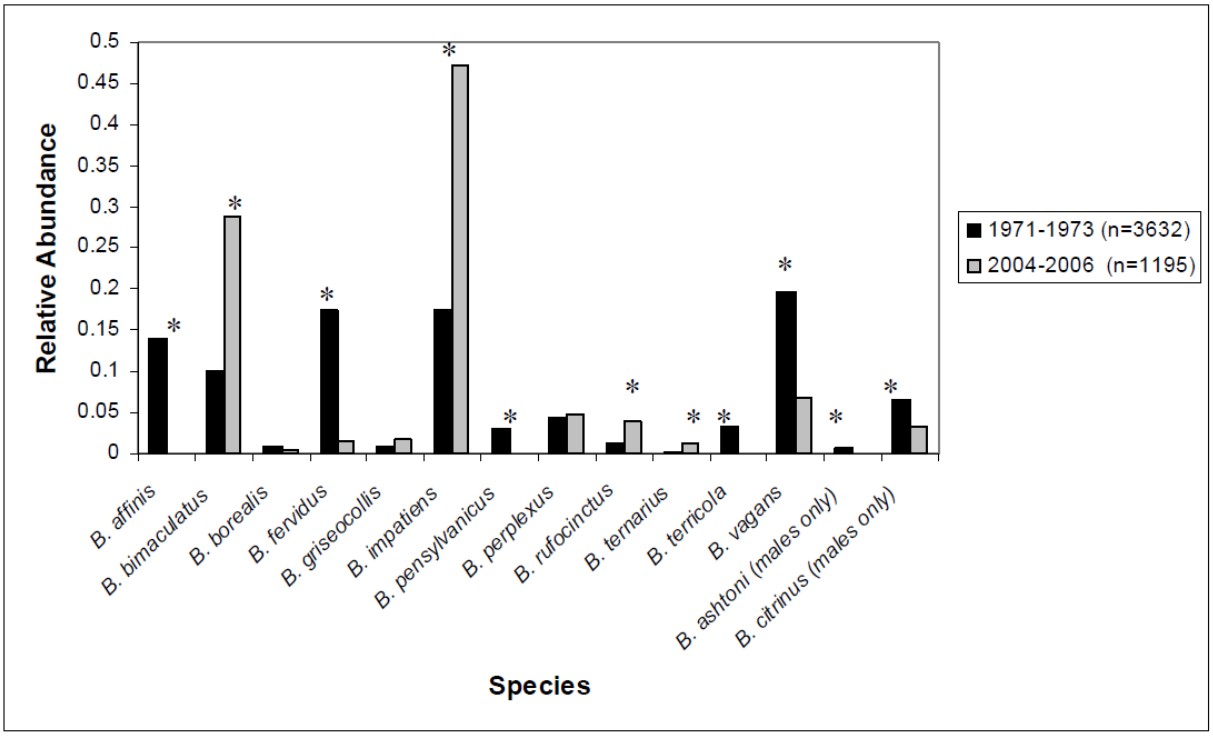

Figure 2. Relative differences in the abundance of native bumblebee species taken from 1971-1973 and 2004-2006. The * indicates a significant difference in abundance of that species. It is apparent from the graph that many species have continued to decline. (Evans et al. 2008).

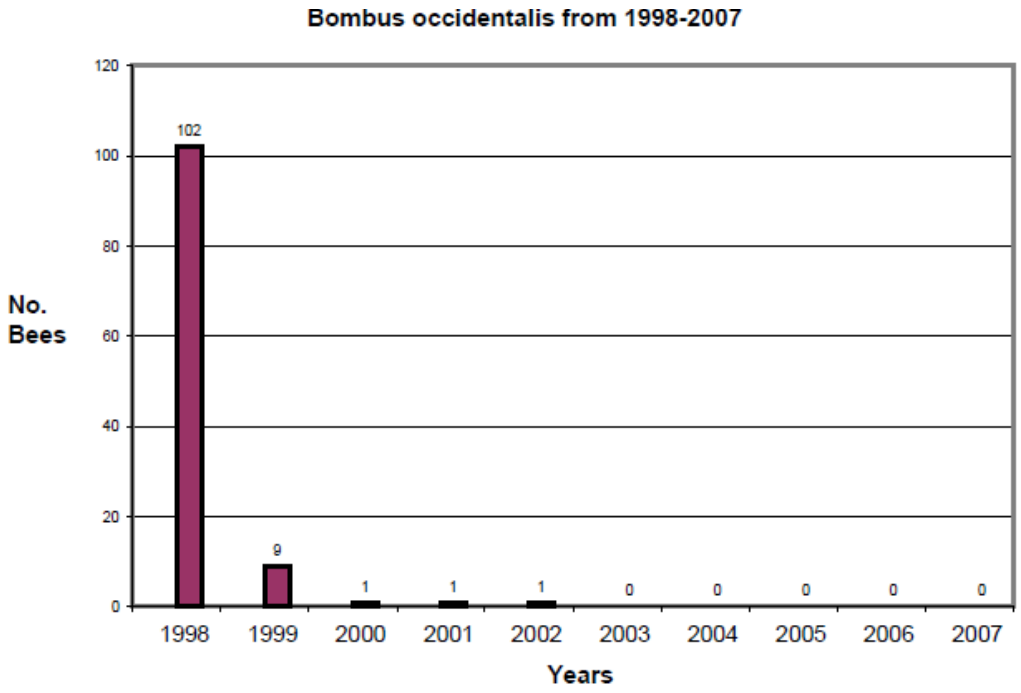

Figure 3. Shows the sharp decline of *B. occidentalis* from 1998 to 2007. Bees were sampled in Oregon. (Evans et al. 2008).

Young males and queens infected with *N. bombi* and *C. bombi* spores experience a complete loss of fitness leading to an eventual collapse of the entire colony (Otti and Schmid-Hempel 2007). In such cases, the commercial rearing of honeybees is clearly effecting the survival of native pollinators.

Domestication itself has probably also done a disservice to the honeybee (Jacobsen 2008). Natural hives may eventually collapse if infected by mites but in doing so they rid themselves of the infestation, leaving the varroa mite without a host (Jacobsen 2008). Feral bee communities have the benefit of not having had their natural defense mechanisms selectively bred out of them (Jacobsen 2008). For instance, wild bees are generally smaller, and thus produce smaller cells for larva to develop in (Jacobsen 2008). These smaller cells are too tight for the varroa mite to infiltrate so invaders are noticed and promptly removed from the hive (Jacobsen 2008). Domestic honeybees are bred to be larger since bigger bees make more honey, however, bigger bees also make bigger (mite friendly) cells (Jacobsen 2008). Such selective breeding has made domestic bees unable to fend for themselves in the natural world without the help of toxic chemicals and other types of human intervention.

Pesticide and insecticide use may prove especially harmful to native insect species (e.g., the bumblebee) that often nest on the ground. Soils become saturated with chemicals and entire populations are wiped out (Evans et al. 2007). Certain chemicals have also been shown to disrupt bee navigation abilities and cause "drunken" behavior (Jacobsen 2008). "Drunk" bees that are unable to find their way back to the hive will be left stranded out in the elements and will perish (Jacobsen 2008). Our general dependence on chemicals is altering the natural cycles of insect species and will in turn impact pollination of native plants and crop plants.

Additionally, human development presents a threat to native and domestic pollinators. Jacobsen (2008) writes that bees are suffering from "suburbia disease" – resulting from more roads, more fragmentation, more super malls, and fewer flowers (Jacobsen 2006). Vast monocrops of cultivated lands are also contributing to a decrease in species diversity (Evans et al. 2007). Diverse habitats beget diverse genes beget diverse plants and animals (Jacobsen 2008). One interesting example given was that of the moth swirling around a porch light (Jacobsen 2008). Does that moth ever get around to pollinating anything before it eventually dies? Pollutants stemming from developed areas have also been shown to decrease pollination potential (Evans et al. 2007). Researchers at the University of Virginia found that pollutants were able to bind with flowers' scent molecules and destroy them (Jacobsen 2008). The range that a flower's scent might travel was significantly reduced making pollination far less likely (Jacobsen 2008).

Lastly, climate change has also been shown to reduce pollinator range (Fleishman 2009). In Uruguay, warming climates have been blamed for their honeybee population collapse (Jacobsen 2008). The warmer weather is not thought to be the problem; however, the drought that has accompanied the change could be to blame (Jacobsen 2008). Bees evolved in warm climates but no organism can survive without the benefit of water (Jacobsen 2008).

There are likely many more threats that pollinators face but, the above examples are fairly well documented and are perhaps the most detrimental to pollinator health and biodiversity. The general reduction in pollinator numbers has led to the disruption of some very specific plant-pollinator relationships. In most cases, a permanent disruption of the

relationship will spell the downfall of the pollinator, the plant, and the other wildlife species that depend on that plant for survival (Evans et al. 2009). In other cases, humans have had to replace pollinators, making the need for laborious crop management techniques necessary (Jacobsen 2008).

Life Without Pollinators – A Few Real World Examples

Jacobsen's book provided a few poignant examples of what life without pollinators looks like. For example, farmers in Mexico must hand pollinate their vanilla plants (Jacobsen 2008). Vanilla plants open for only one day and have evolved a specialized flap that protects their pollen grains (Jacobsen 2008). Deforestation has eradicated the native melipona bee, the sole pollinator capable of manipulating the vanilla's pollen protecting flap (Jacobsen 2008). The plant and the bee each co-evolved a design that was meant for the other. Since the demise of the melipona bee, vanilla plants rely on hand pollination by humans using toothpicks (Jacobsen 2008). Such efforts increase production costs that are eventually passed on to the consumer and also make the vanilla plant completely reliant on humans to survive (Jacobsen 2008).

In the rainforests of South America, the strangler fig (*Ficus spp.*) is considered a keystone species (Jacobsen 2008). The fig helps to maintain forest biodiversity, providing shelter and food for a variety of wildlife (Jacobsen 2008). The fig relies on a very specific relationship with the fig wasp to achieve cross pollination (Jacobsen 2008). The female wasp lays her eggs inside of the fig fruit and as she enters the pollen from the fig tree from which she originally emerged is deposited (Figure 4) (Jacobsen 2008). These two species completely depend on one another for their reproduction. Without the wasp, the fig would eventually decline as would the species that rely on it for survival.

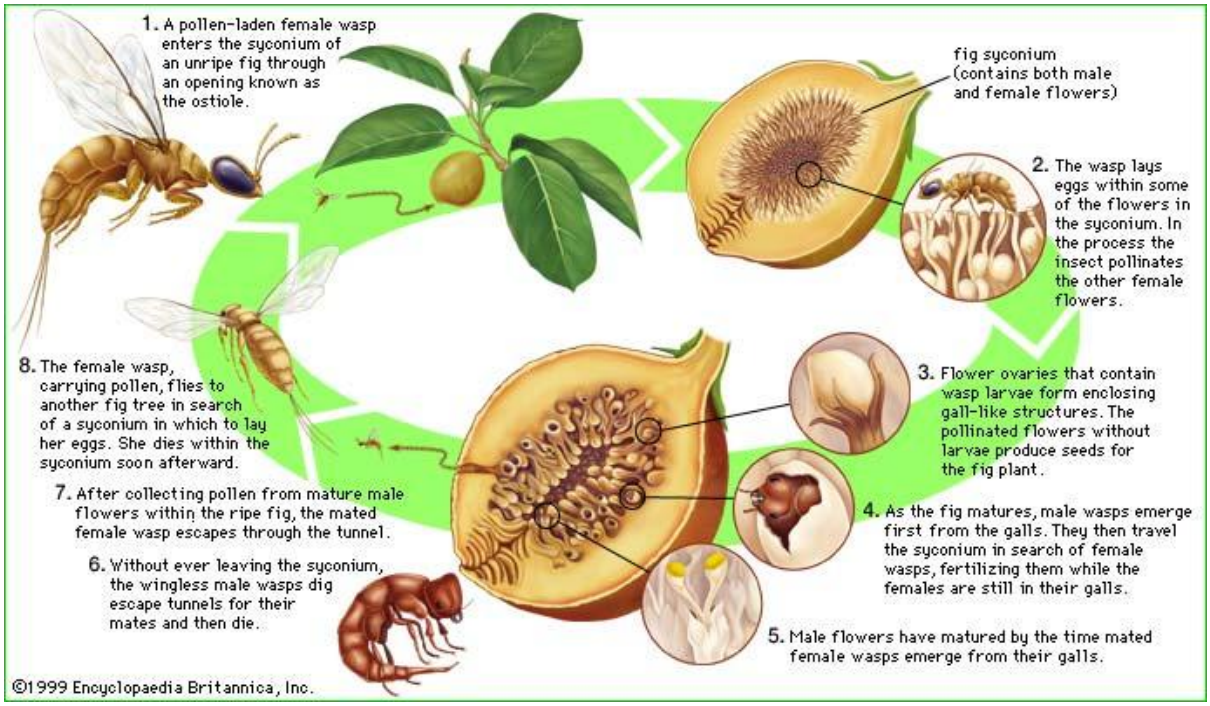

Figure 4. Pollination of the strangler fig by the female fig wasp. Image courtesy of encyclopedia Brittanica.

Butterflies and wasps also serve important roles in the pollination of plants that humans may not be able to take direct agricultural advantage of (Jacobsen 2008). Butterflies and wasps produce caterpillars which are essential to the diets of birds and thus contribute to bird survival (Jacobsen 2008). So, birds need the caterpillars and caterpillars need the plants. Every piece of the ecosystem puzzle has an important function. Unfortunately, people want to be able to enjoy the beauty of the butterfly without enduring the destruction of the caterpillar (Jacobsen 2008). In our efforts to make our yards and parks look prettier we may very well be destroying the bigger picture, contributing to a landscape free from butterflies, plants, and birds. If we want to avoid living in a world where we have to hand pollinate crops to help maintain balanced ecosystems then things are going to need to change.

What Can We Do?

Restoring habitats to a healthy state and species to sustainable numbers is easier said than done (Waltz and Covington 2004). The good news is that many invertebrates (including butterflies) respond quickly when habitat improvements are made and can often be used as effective monitoring devices to indicate ecosystem health (Waltz and Covington 2004). In fact,

studies have shown that restored areas had greater butterfly species richness and abundance (Waltz and Covington 2004). If butterflies can demonstrate such marked improvements in their populations then it is probably reasonable to assume that other pollinators would follow suit. Ultimately, pollination is a key ecosystem service that must be considered when making restoration efforts (Forup et al. 2008). Pollinators are responsible for the reproductive success of nearly 70% of all flowering plants species, however, these interactions are not automatic (Forup et al. 2008). Bee pollinators will require habitats that include hiding cover and nesting materials before long term, successful pollination of the plant communities can take place (Forup et al. 2008).

Many of these restoration efforts can begin in one's own backyard. Landscaping with native plants will tend to attract more pollinators and creating nesting sites from wood blocks affixed to trees will provide protection from the elements (Jacobsen 2008). It is also important not to over develop an area. Keeping a mixture of bare ground, tall grasses, and brush will enhance wildlife diversity since monocultures tend to favor a lack of diversity and low population numbers (Jacobsen 2008).

On a larger scale, organic or eco farming may offer a partial solution to the pollinator problem (Harder 2004). Researchers suggest that farmers who restore lands surrounding their agricultural crops to a native condition will have better yields, healthier soils, and will reduce their dependence on imported/cultivated honeybees (Harder 2004). Such measures would aim to increase native bee populations and thus create a sustainable and diverse annual pollination period (Harder 2004, Ricketts 2004). The double threat comes in the form of the organic farm that practices natural cultivation methods and is also located near native/restored habitats. These farms contained 50% more native bees and species than did their non organic counterparts (Harder 2004). Additionally, researchers discovered that "native bees delivered an average of nearly 1,800 pollen grains per day to each flower on organic farms near natural lands, but only about 600 and 300 grains per flower per day, respectively, to [other] farm types. About 1,000 pollen grains per flower per day are required for successful fertilization". As with backyard restoration, the key to attracting diverse groups of native pollinators lies in

maintaining diverse crops (e.g., no monocultures), avoiding/eliminating the use of toxic chemicals, and allowing native plant communities (even weeds) to thrive in certain areas (Harder 2004). Convincing farmers that employ traditional methods to switch to organic cultivation may be a far reaching concept. Crop yields may be lower at the outset but dependence on chemicals and bee "rentals" would no longer be necessary and farmers may eventually break even.

Additionally, decreasing developments and linking fractured habitats is essential to pollinator survival. The presence of roads and paved areas increases the distance between plant communities and reduces the distance that pollinators are able to travel (Evans et al. 2007). This can be partially accomplished by planting native vegetation and closing non essential access roads. Furthermore, decreased development would hopefully be followed by a decrease in pollutants that inhibit scent production by flowers, disrupting pollination efforts (Evans et al. 2007).

Fire suppression in undeveloped areas may also be harming native bumblebee communities (Evans et al. 2007). Bumblebees nest and feed in meadows, however, fire suppression has allowed forested areas to invade these native feeding and nesting grounds, further contributing to the bees decline in numbers (Evans et al. 2007). Considering natural fire cycles in a given ecosystem should help to maintain a native and diverse group of plants and animals.

Not unexpectedly, curtailing the use of domestic/imported honeybees in the pollination of North American crops would likely boost native bee numbers (Evans et al. 2007). Imported bees introduce diseases and parasites that native bees are unable to combat and also out-compete native wildlife for limited resources (Evans et al. 2007, Jacobsen 2008). Researchers have documented greater harvest and reproduction rates in imported bees (Evans et al. 2007). This may prove economically favorable for farmers but is detrimental to the survival of native bees. As native colonies dwindle so too will their genetic viability (Evans et al. 2007). Such genetic bottlenecks will create malnourished/defective bees and eventually lead to total colony collapse (Evans et al. 2007).

Global climate change may present the most daunting challenge of all. Species ranges will shift as cold adapted species move farther north and species that thrive in warmer temperatures begin to invade new areas (Evans et al. 2007). Plant-pollinator relationships rely heavily on seasonal cues (which are altered as temperatures rise and/or fall) and when those begin to change, the relationship falls apart (Evans et al. 2007). Plant communities will die off and new invaders will overtake the landscape.

Global climate change is not easily dealt with on the landscape level but will require a national/global effort if CO2 levels are to be brought back down to manageable levels. Until then, restoration efforts will need to include the aforementioned techniques. Hope is certainly not lost for these creatures. Pollinators are a resilient group and demonstrate positive responses when ecosystems are enhanced. It is important not to take these seemingly insignificant invertebrates for granted. Humans, plants, and wildlife rely on them for sustenance and in many cases for survival. In fact, the next time I spot a bumblebee, I might just take a second to feel lucky about it instead of feeling nothing at all.

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