Wild and Managed Pollinators: Current status and strategies to increase diversity

Julie Wray and Elizabeth Elle
Simon Fraser University

Executive summary. Global declines in wild and managed pollinators are illuminating the importance of the services they provide and highlighting the need for conservation efforts. In this report, we discuss what is happening to pollinator populations and where opportunities exist to help increase the diversity and size of regional pollinator populations. This discussion specifically describes the benefits pollinators provide to humans and wildlife, evaluates the current state of pollinator populations and main drivers behind pollinator decline, compares contributions of and interactions among managed (honey bees) and wild pollinators, and provides strategies to mitigate the negative impacts threatening pollinator populations.

Findings:

- Wild and managed pollinators provide vital ecosystem services for agricultural food production and for animals in natural ecosystems, and also stabilize native plant community dynamics
- Habitat loss and invasive plants reduce food and nesting resources for pollinators while pesticides cause direct deaths and impair pollinator foraging
- Wild bees are more effective pollinators of many crops than managed honey bees and diverse pollinator communities provide insurance for continued pollination services in the face of environmental changes
- When honey bees are introduced, wild bees suffer from competition for resources
- Urban and agricultural landscapes can support wild and managed pollinators

Recommendations:

- Plant pollinator-friendly gardens that produce pollen and nectar throughout the growing season, provide nesting habitat, such as wood cavities and compact soil, and maintain existing natural areas that have diverse assemblages of plants and nesting sites
- Avoid pesticide-treated plants in pollinator gardens
- Avoid honey bee keeping in areas with rare or endangered pollinators or plants
- Consider risks of beekeeping to other animals, such as bears seeking honey, and for invasive species management.

Table of contents

WHY DO POLLINATORS MATTER?

Ecosystem services benefit human welfare by providing clean air, water, and nutrients (Daily, 1997). The ecosystem service of pollination is vital for plant reproduction and the human food supply (Kearns et al., 1998). Almost 90% of the world's flowering plants rely on animals to produce fruits and seeds (Ollerton et al., 2011), including 87 of 128 global food crops (Klein et al., 2007). Worldwide, pollination of crops is valued at over 153 billion euros annually (=243 billion CAD, Gallai et al., 2009), and fruits/vegetables pollinated by bees tend to have a disproportionate contribution to human nutrition (Eilers et al., 2011). However, it is not only humans that benefit from the products of pollination; wild fruit- and seed-bearing plants also provide food for wildlife. In British Columbia, we have estimated that the majority of the diet of 180 out of 458 species of bird, and 59 out of 160 species of mammal, comes directly from the seeds and berries that result from animal pollination of wild plants (McKinley and Elle, *unpublished data*). Pollinators are clearly important to sustain both natural ecosystems and agricultural productivity.

What is a pollinator?

Any animal that visits a flower to eat pollen or nectar has the potential to be a pollinator (defined as moving pollen from one flower to the next). Bees, flies, wasps, butterflies, and hummingbirds are the main pollinators in our region. However, animals vary in their effectiveness as pollinators, due to differences in their basic natural history. As adults, hummingbirds and butterflies drink nectar, while hover flies, wasps, beetles, and other flower visitors often use a combination of nectar and pollen. In contrast, female bees not only eat pollen and nectar, but also actively collect pollen and nectar to feed their young. This means that bees visit more flowers, transfer more pollen, and generally tend to be more important for pollination globally than other visitors. Therefore, we largely focus on bees in this report.

> **Wild pollinators** exist in natural environments and provide the ecosystem service of pollination free of charge.
>
> **Managed pollinators**, like honey bees, have been domesticated by humans for agricultural pollination and/or honey production.

The needs of pollinators, in terms of food and lodging, are similar to our needs in many ways. Different flowers provide different kinds of food, and diverse diets improve pollinator health (Alaux et al., 2010) just as they improve our own. Like humans without transportation, bees prefer to live and nest in close proximity to a grocery store (a patch of flowers). The distance bees can fly to forage for food depends on how large they are. Some small bees can only fly up to 100-200 metres to reach their food source (though bumble bees can travel 1-2 kilometres). So, it's important to keep food (flowering plants) and lodging (potential nesting sites) close to each other, in order to maintain diverse pollinator communities. Timing is also important; the vast majority of our wild bee species are solitary nesters, and individual bees live only for 4-6 weeks, during which they need all food and lodging requirements to produce the next generation. Other bees (like bumble bees) are social, and although individuals still live just a few weeks, the colony persists from early spring through early fall—and needs food for that entire period.

Perhaps different from humans, however, is the absence of readily available housing developments for lodging; wild bees and other pollinators construct their homes in a myriad of fascinating ways (Box 1, next page). Some, like mining bees and sweat bees, excavate tunnels in the ground. Others, like mason and leafcutter bees, lodge in pre-existing holes in woody material (beetle holes in dead trees, or hollow stems of shrubs). The bumble bees, which are the largest bees in our region, require large empty spaces or cavities, such as abandoned rodent holes. Some bumble bees will nest in old bird nests in human-provided bird houses, and others will even nest in air pockets in compost bins, in loose insulation in walls or roofs, or any other available cavity!

Like bees, hummingbird and wasp nests also vary in location and building supplies, and tend to be close to their food supply (nectar and insects). “Lodging” for other pollinators is more complicated. Butterflies lay their eggs on plants, and so the host plant used by caterpillars can be important for butterfly conservation. Flies also lay their eggs on plants, as well as in soil, on decomposing vegetation, and on other substrates. Although perhaps not as effective pollinators as bees, the larvae of flies and wasps provide natural pest control by feeding on pest insects like aphids, so these insects make multiple contributions to ecosystem services.

How many pollinators do we need?

Biodiversity strengthens ecosystem services by providing multiple back-up plans in changing environmental conditions (Brittain et al., 2013; Rader et al., 2013). Different species respond differently to changes in temperature, wind, and precipitation. When environmental changes result in the decreased activity of one species, the presence of a diversity of other species ensures that ecosystem services like pollination will still be provided. For example, if a plant begins blooming earlier as a result of warmer spring temperatures, it may no longer be synchronized with the flight period of its usual pollinator. In a species-rich community, it may be pollinated by a different, early-flying pollinator, but may not get pollinated at all in a community with low pollinator diversity.

In natural ecosystems, diverse pollinator communities contribute to stable, functioning plant communities. For instance, seed production of native plants is higher with abundant, diverse bee communities (Slagle and Hendrix, 2009; Williams and Winfree, 2013). The managed introduced honey bee has been proposed as providing pollination services for both natural and agricultural communities when wild pollinators are declining. However, relying on any single bee species is a risky strategy in changing environments (Winfree, 2008), especially at a time when honey bees are facing numerous threats (Potts et al., 2010). Instead, promoting diverse pollinator communities provides insurance for ecosystem services that humans rely upon in both natural areas and agroecosystems.

Box 1. Social structure, foraging periods, and nesting habits of common pollinators in Metro Vancouver.

Honey bee (*Apis mellifera*)

Introduced from Europe, honey bees are highly social managed pollinators. Colonies are perennial, lasting many years, and can number tens of thousands of bees. Queen and worker bees live through winter and are active foragers from early spring to late fall.

Bumble bee (*Bombus* spp.)

Bumble bees are also social, but colonies are smaller (about 200-300 workers) and annual (lasting just one year). In early spring, mated queens emerge and start a nest. Worker bees are active through summer. Males and new queens are produced in late summer to early fall, mate, and then mated queens hibernate over winter while the rest of the colony dies. Bumble bees require large cavities for nests, and forage spring to fall.

Mason bee (*Osmia* spp.)

These are highly diverse solitary spring bees, with 20-30 species in Metro Vancouver. Individual female bees (not colonies) forage and construct nests. Typical lifespan is 6 weeks. Eggs are laid on top of a ball of pollen and nectar in nests within cavities in wood or in hollow stems. Different species use mud, plant resins, and other materials to line the nest. Larvae develop over the summer, and the next generation of adults emerges the following spring.

Box 1 continued

Leafcutter bee (*Megachile* sp.)

Related to mason bees, leafcutters also nest in cavities in wood or the ground, but line nests with pieces of leaves. These solitary bees are active in early and late summer but otherwise have a similar life cycle to mason bees.

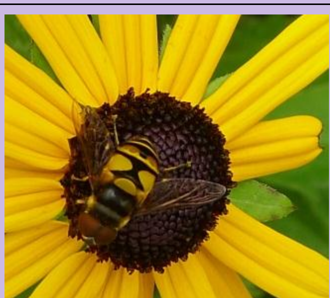
Mining bee (*Andrena* spp.)

Solitary spring bees, mining bees are aptly named for "mining" holes in the ground for nesting. These bees are active early in the year. There are 30-40 species in Metro Vancouver, some of which specialize on just one or a few plant species when foraging for pollen.

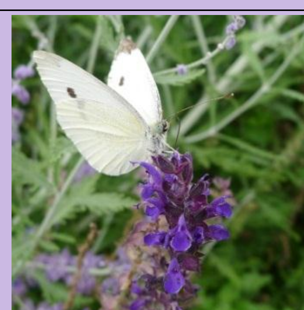
Sweat bee (*Halictus* and *Lasioglossum* spp.)

Diverse in sociality, colour, and size, sweat bees are named for their attraction to the salt in some soils and in human sweat. Semi-social species nest in aggregations, but the life cycle is the same as in solitary species. Sweat bees excavate nests in the ground and are active in spring and summer. Common in urban environments.

Other pollinators



In Metro Vancouver parks, almost 90% of the visits to flowers were from bees. Still, hover flies, butterflies, hummingbirds, wasps, and beetles also contribute to pollinator diversity. This group forages throughout the season, with diverse requirements for larvae and nests.



CURRENT STATE OF POLLINATOR POPULATIONS

With the exception of some butterflies, there is currently little data on BC's pollinators, including approximately 450 species of bee. Without historical information, it is difficult to determine how different species or even genera have responded to changes in land use, available plant communities, and climate in western Canada. In order to evaluate the state of regional pollinator populations without an extensive body of research, we reviewed both the limited local research and outcomes from work done elsewhere to infer regional status.

Research shows that some bumble bees have experienced drastic declines both in North America and Europe (Cameron et al., 2011; Colla et al., 2012). As a local example, the western bumble bee, *Bombus occidentalis,* used to be one of the most common pollinators in the lower mainland. In the 1980's, 25-30% of the bumble bees collected on berry farms in the lower mainland were this species (Winston and Graf, 1982; Mackenzie and Winston, 1984). In contrast, Claudia Ratti collected just 27 *B. occidentalis* in 2003 and 2004 in blueberry fields in the same general area as the earlier Winston studies, just 0.7% of all bumble bees collected (Ratti et al., 2008). In an urban bee study in the Metro Vancouver region, Tommasi et al. (2004) also found that *B. occidentalis* was present but uncommon. Since 2010, the Elle lab at SFU has been working in farms and parks of the region and has collected thousands of bumble bees. We have documented *Bombus occidentalis* in the lower mainland only once, at Boundary Bay in 2013. *Bombus occidentalis* was also found in 2012 at 8 sites in the greater Victoria region of Vancouver Island (after 7 unsuccessful years of searching for it). Clearly this particular species is one of conservation concern although it has not yet been listed under the Species at Risk Act. In contrast, other bumble bees like the yellow-faced bumble bee, *Bombus vosnesenskii*, may be becoming more abundant in the region (Fraser et al., 2012).

Generally, most of what scientists infer about pollinators is on the level of family or genus, rather than individual species. There are 20,000 species of bee in the world, and so being able to generalize is useful. Species within a family or genus usually exhibit similar nesting characteristics and floral resource needs, and so are expected to respond in similar ways to threats from the surrounding environment. Although approaching the problem in this way is logical, it can mask individual species' responses. For example, the blue orchard mason bee (*Osmia lignaria*) readily uses commercially available "bee condos" for nesting and thrives in urban habitats. Other mason bees may be more specialised and require natural nesting materials or native flowering plants (Neame et al., 2013). Determining the state of pollinator populations, therefore, is an ongoing effort and requires considering how different threats contribute to pollinator declines, and how the response to those threats might differ among species.

In the following section, we review the main threats to pollinator populations from numerous studies aimed at pollinator conservation.

Habitat loss *reduces floral and nesting resources bees require, but agricultural and residential development can be managed to promote pollinator populations*

The main threat to wild pollinator populations is habitat loss. When natural areas are repurposed for agricultural or residential use, natural nesting materials and floral resources become less available across the landscape. Bees are then forced to spend more time and energy on foraging (think of it as a longer commute to work!) and less time on producing and feeding offspring (Zurbuchen et al., 2010). However, when human development is moderate and patches of natural habitat are maintained in the landscape, pollinators are able to persist.

Urban gardens, agricultural habitat enhancements, and parks can act as surrogates for natural habitat, supporting diverse and abundant pollinator communities (Fetridge et al., 2008; Morandin and Kremen, 2013; Wray and Elle, 2015). As might be expected, the pollinators in human landscapes tend to be “urban adapters”, the equivalent of crows and squirrels. These species can feed on any floral resource available and/or are more flexible in nest requirements (Hinners et al., 2012; Wray et al., 2014). In contrast, some “urban avoiders” are found only in natural areas where specific host plants or nesting sites are available (Wray et al., 2014; Wray and Elle, 2015). This means that conserving both natural lands, and enhancing gardens and parks, will be needed to sustain pollinator diversity in urban and agricultural landscapes.

Pesticides *kill pollinators and can impair foraging ability*

Pesticides have been shown to negatively impact many different types of pollinators. For example, neonicotinoids are now known to have short- and long-term effects on bee foraging, reproduction, and resistance to diseases and parasites (Brown et al., 2014). Neonicotinoids are systemic pesticides applied to protect against sucking and chewing insects like aphids and weevils, and their toxic elements make their way into the pollen and nectar of treated plants. When bees are exposed, their foraging ability is impaired, which can lead to reductions in the number of offspring produced and so reduced population sizes (Gill et al., 2012; Gill and Raine, 2014). A 2014 survey by Friends of the Earth Canada found that 50% of plants sold in retail stores tested positive for neonicotinoids, so gardeners and landscape managers should use caution when purchasing so-called “bee-friendly” plants for pollinator-friendly gardens. Concern about these pesticides led to a recent ban on neonicotinoid-treated bedding plants by the Vancouver Park Board, as well as a plan by the Province of Ontario to reduce the planting of agricultural corn and soybean seeds treated with neonicotinoids by 80% by 2017. Pesticide use should be restricted outside of agriculture to eliminate the possibility of killing beneficial insects like pollinators, and to reduce the potential for other negative effects.

Diseases *can be transferred from managed to wild pollinators*

In combination with pesticides, collapses in managed honey bee populations are attributed in part to the interacting effects of pathogens (*Varroa* mites, *Nosema* fungus) and viruses (deformed wing virus). *Varroa* mites suck out body fluids (for comparison picture a Frisbee-sized parasite on a human body) and can transmit deformed wing virus, which as its name suggests, inhibits wing development. *Nosema* are tiny fungal parasites; spores develop and feed on cells in the gut of the bee, weakening their host such that infected worker bees leaving the nest to forage generally do not return. Unfortunately, it is not only honey bees that suffer from these diseases. Honey bees forage and coexist with wild pollinators, and recent evidence indicates that diseases can spread from honey bees to wild bumble bees (Fürst et al., 2014). In North America, declining bumble bees, like the western bumble bee, tended to have higher incidences of *Nosema* parasites compared to stable bumble bee species (Cameron et al. 2011). Limiting the interaction between managed bees and wild pollinator populations could help limit the transmission of diseases.

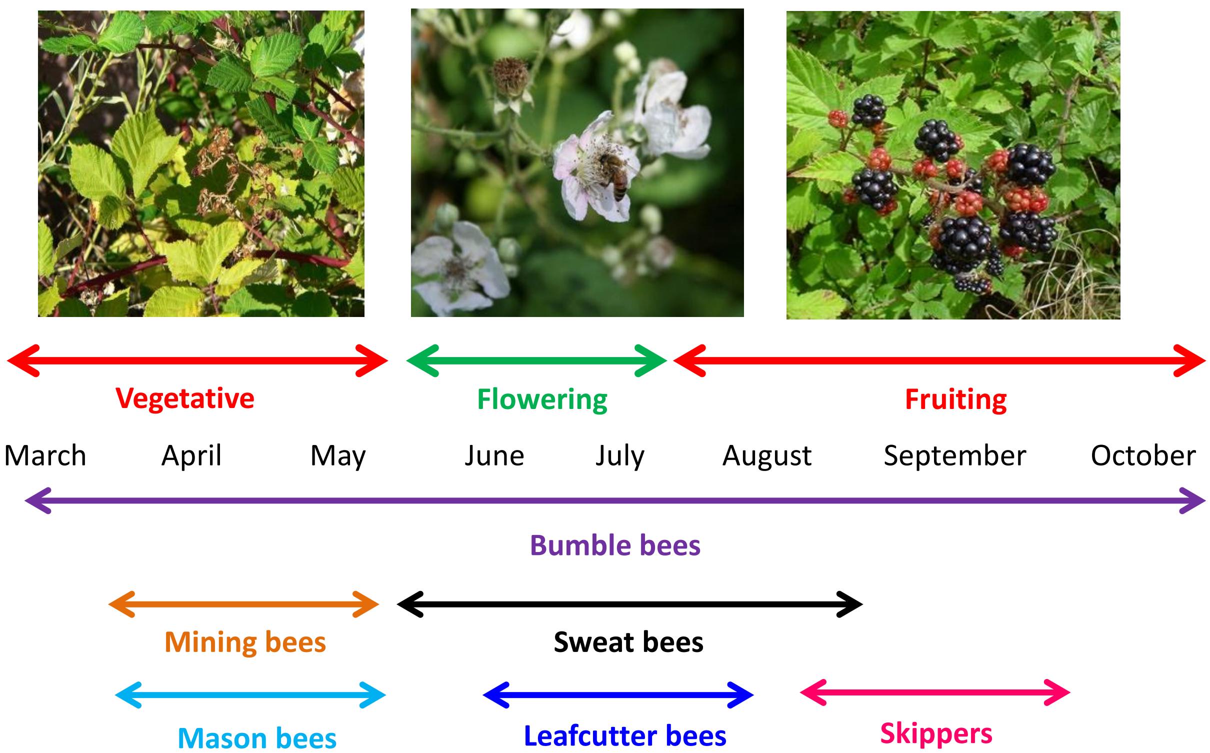
Climate change *shifts the blooming period of floral resources*

Changing climatic conditions result in dramatic weather events and gradual temperature and precipitation changes, impacting pollinator habitat. Some spring wildflowers are blooming earlier due to warmer temperatures, creating mismatches between their bloom times and the flight periods of pollinators. In the American Midwest, some pollinators have been lost due to these mismatches (Burkle et al., 2013), because the pollinators no longer have a reliable food source. European bumble bees with narrow climate tolerances have experienced greater declines, especially near the edges of their geographic ranges (Williams et al., 2007), than those with broader tolerance. Given that diverse bee communities are essential for sustaining crop and wildflower pollination in changing environmental conditions (Brittain et al. 2013, Rader et al. 2013), combating and adapting to the effects of climate change is increasingly important for pollinator conservation.

Invasive species *reduce wild flowers that would support bees all year*

Invasive plants are those that are novel to an ecosystem and out-compete wild plants. When invasive plants dominate a community, the resulting monoculture can negatively impact pollinators by eliminating sources of food (wild flowering plants). For example, Himalayan blackberry (*Rubus discolor*) is increasingly dominating disturbed areas and parks in and around Metro Vancouver. Though it provides nectar and pollen to bees, the bloom doesn’t overlap with the foraging periods of all pollinators (Box 2, next page). We found that restored areas in Metro Vancouver Regional Parks had 26% more pollinator species, and pollinators were 30% more abundant, compared to non-restored areas mostly dominated by Himalayan blackberry (Gehrels and Elle, *in prep*.).

Box 2. Invasive species do not provide forage throughout the flight period of diverse pollinator communities. This graphic shows the timing of Himalayan blackberry (*Rubus discolor*) life cycle, and foraging times of some pollinators that are common in Metro Vancouver.



Although invasive species can be problematic, restoration efforts need to consider the availability of all floral resources before commencing removal programs (Elle et al., 2012). Invasive plants may actually support pollinators when wild plants are scarce (Kleijn and Raemakers, 2008; Schweiger et al., 2010). In cases where wild plant abundance is low, removing an invasive species may eliminate the only resource available in the landscape, with negative effects on bee populations. Establishing plants that bloom throughout the growing season, combined with slow removal of invasive species, may be essential to ensure pollinators have a food supply throughout their life cycle.

Strategies for supporting pollinator populations

Considering the nesting and foraging needs of wild bees and other pollinators is essential to maintaining diverse, functioning communities. Although some pollinators may rely on resources available only in natural habitat, others can adapt to living in residential or agricultural environments. In agriculture numerous studies have shown that maintaining natural or semi-natural habitat near farms can boost pollinator diversity and contribute to higher crop yield (Ricketts, 2004; Ricketts et al., 2008; Kennedy et al., 2013). In urban areas, gardens and parks can support a high diversity, abundance, and richness of pollinators (Tommasi et al., 2004; McFrederick and LeBuhn, 2006; Wray and Elle, 2015; Gehrels and Elle, *in prep*.). Establishing pollinator-friendly, pesticide-free plants in community gardens, parks, and wildlife-friendly corridors, and encouraging farmers and homeowners to grow bee-happy plants on their property, may be the most effective avenue for conservation in increasingly urban landscapes. In some cases, this strategy can actually support higher richness and abundance of bees than in purely natural environments (Winfree et al., 2007). Although it is mostly common species of pollinator that will be conserved in this way, rare species can also sometimes be supported. Our work on Vancouver Island has shown that late-blooming flowers in urban residential gardens support a diversity of bees, including the endangered western bumble bee, *Bombus occidentalis* (Box 3, Wray and Elle, 2015).

Box 3. Pollinator-friendly gardens

Because pollinators vary in size, shape, flight period, and nesting requirements, it's important to provide them with flowers that also vary in size, shape, colour, and blooming period (see photos, next page). We recommend using native plants where available, but non-invasive garden plants can also help to support pollinators if they contribute to a long period of bloom. In our work in Metro Vancouver regional parks, we found that easily accessible, open flowers supported the highest diversity of pollinators (Gehrels and Elle, *in prep*). In urban gardens in Victoria, BC, horticultural varieties of lavender even attracted the endangered western bumble bee, *Bombus occidentalis*. Based on our work in these and other environments, we recommend the following pollinator-friendly plants for restorations and pollinator gardens, and also note that there are some beautiful garden plants that are not pollinator-attractive (worth planting for your enjoyment, just not to feed the bees!).

*Note that planting native plants with berries will also support wild birds and mammals of BC!

Native plants for pollinators

- Yarrow, *Achillea millefolium*
- Pearly everlasting, *Anaphalis margaritacea*
- Fireweed, *Chamerion angustifolium*
- Red-osier dogwood, *Cornus stolonifera*
- Beach strawberry, *Fragaria chiloensis**
- Salal, *Gaultheria shallon**
- Common avens, *Geum aleppicum*
- Black twinberry, *Lonicera involucrata**
- Arctic lupine, *Lupinus arcticus*
- Tall Oregon-grape, *Mahonia aquifolium**
- Red-flowering currant, *Ribes sanguineum**
- Baldhip rose, *Rosa gymnocarpa*
- Nootka rose, *Rosa nutkana*
- Thimbleberry, *Rubus parviflorus**
- Salmonberry, *Rubus spectabilis**
- Trailing blackberry, *Rubus ursinus**
- Canada goldenrod, *Solidago canadensis*
- Snowberry, *Symphoricarpos albus*
- American cranberrybush, *Viburnum trilobum*

Garden plants to consider

- California lilac, *Ceanothus*
- Pot marigold, *Calendula*
- Bellflower, *Campanula*
- Heather, *Erica*
- Cranesbill, *Geranium*
- Lily of the valley bush, *Pieris*
- Rhododendrons, *Rhododendron*
- Lavender, *Lavandula*
- Shrubby veronica, *Hebe*
- Asters, sunflowers, and relatives

Popular garden plants that are unattractive to pollinators

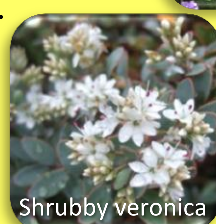
- Geranium, *Pelargonium*
- French marigold, *Tagetes*
- Begonias, impatiens, petunias, pansies
- Gladiolus, iris, lilies, most peonies
- Forsythia, witch hazel (*Hamamelis*)

Additionally, pollinators would appreciate flowering non-invasive "weeds" such as dandelions (*Taraxacum officinale*), lawn daisies (*Bellis perennis*), and white clover (*Trifolium repens*) much more than perfectly manicured lawns.

Many native shrubs have open, easy-access flowers for a diversity of large and small pollinators.

Flowers with long tubes exclude many pollinators, but hummingbirds, butterflies, and bumble bees have long tongues to reach nectar.

Plant non-invasive garden plants with flowers in a diversity of sizes, shapes, and colours.



Food for bees = food for people …and wildlife!

MANAGED OR WILD POLLINATORS?

The right bee in the right place

In most cases the general public is unaware that wild pollinators, in all their diverse shapes and sizes, even exist. It is a common misconception that honey bees are the sole organism responsible for pollination. In fact there are over 800 species of bee in Canada and over 20,000 recorded species across the globe, with more being discovered regularly. Understanding the differences between honey bees and wild pollinators is clearly an important avenue of outreach and education.

Wild bees are the dominant pollinators in natural habitats and essential to the maintenance of local biodiversity (Michener, 2000). Disruptions in plant-pollinator relationships in natural ecosystems can lead to lower viability of plant populations. Honey bees, native to Africa, Western Asia, and Europe (Butz Huryn, 1997), have been introduced to countries across the globe for agricultural crop pollination and, as a by-product, honey production. ***Managed honey bees are best thought of as contributing to large-scale commercial agriculture, and not to the overall ecosystem service of pollination.*** In fact, recent research shows that honey bees are not always the most efficient pollinators even in conventional agriculture, and instead a combination of wild and managed pollinators provides the highest quality of ecosystem services (Button and Elle, 2014; Garibaldi et al., 2014, Box 4 next page).

Competition *between managed and wild pollinators*

Both honey bees and wild bees forage for pollen and nectar, and if floral resources are limiting in an ecosystem the potential for competition exists between them. To evaluate competitive interactions, we examined studies that quantified changes in overall abundance, reproductive success, resource use, and richness/diversity of wild bees in both the presence and absence of managed honey bees. We found 42 published studies, most with multiple tests for competition. Overall, where honey bees are non-native, such as in North America, competitive effects on wild bees were overwhelmingly negative (Fig. 1 to right). In areas where honey bees are native, negative and neutral impacts were equally common.

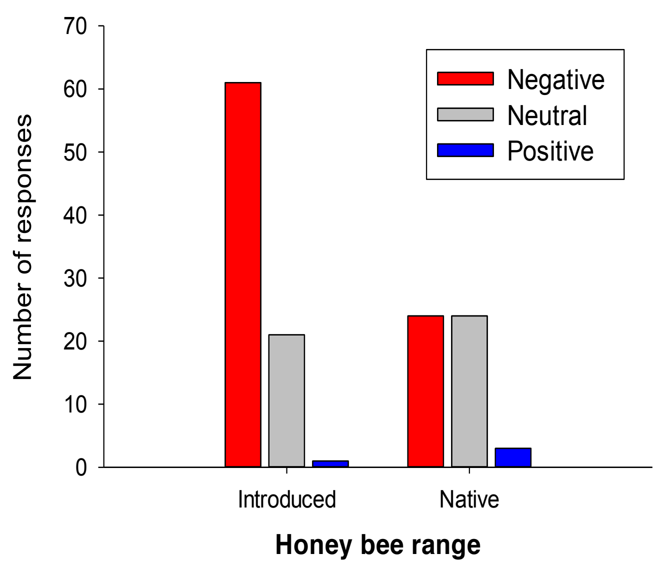


Figure 1. Native bees suffer from competition with honey bees, especially in their introduced range.

Box 4: A local example of the differences in services provided by honey bees and wild bees

In addition to coming in a variety of shapes and sizes, different pollinator species also behave differently when pollinating a flower, and in some cases the differences are very important. For example, some flowers are pollinated by “sonication”, where the bee must vibrate the flower to release pollen. Crops that require this kind of “buzz pollination” include tomatoes, blueberries, and cranberries. Honey bees are not effective buzz pollinators, and actually “cheat”, stealing nectar from blueberry flowers rather than properly pollinating, because their short tongues can’t reach the nectar reward (Courcelles et al., 2013). In contrast, wild bumble bees easily buzz pollinate flowers and blueberry yield in the lower mainland of British Columbia is higher when there are more bumble bees on farms (Button and Elle, 2014).

The conversion of natural lands to agriculture, combined with other threats to pollinators, has reduced wild bumble bee populations. Although once common (Winston and Graf, 1982; MacKenzie and Winston, 1984), Western bumble bees are no longer observed in blueberry fields (Button, 2014). The good news is that Button and Elle (*submitted*) found that other species of wild bumble bee increase when there is more semi-natural land cover surrounding blueberry fields—mostly pastures and hay meadows. This means that farmers can consider landscape management and habitat enhancement for wild bumble bees as a strategy to improve pollination services on their farms.

Reducing negative effects *of honey bees on natural ecosystems*

Our results, based on reviewing published studies, indicate that wild bees suffer from competition with honey bees (Fig. 1), and disease transfer is also possible (Fürst et al., 2014). Honey bees can have other unexpected negative effects in natural areas, such as compromising invasive plant removal or impacting other forms of wildlife. We therefore recommend that land managers take into account the following when considering permission for and placement of honey bee colonies.

1. Are populations of endangered or threatened pollinators present?
    - Rare or endangered wild bees are more susceptible to the negative effects of competition, and even low population numbers are vital for species' persistence.

2. Are there invasive plant populations, or ongoing efforts to eradicate invasive plant species, that would be affected by the inclusion of honey bees?
    - Removal of invasive species can be compromised if pollinators facilitate seed production. If honey bees use the invasive plant as a primary food source, managers may want to exclude honey bees during bloom to aid in eradication efforts.

3. What are the potential impacts to other wildlife?
    - Honey bee swarms may compete with cavity nesting birds such as woodpeckers for nest cavities, and so managers should consider whether rare cavity nesters are present.
    - Bears can be attracted to the apiary as a food source. Land managers should work with beekeepers to determine if the presence of honey bees will increase the potential for human–bear conflicts. Electric fencing and its maintenance may be required.

Finally, we recommend allowing honey bee keeping only in more disturbed areas where wild pollinator-plant relationships have already been disrupted. Implementing a capping system to limit the number of bee hives within a given area may help to alleviate the effects of resource competition between honey bees and wild pollinators.

CONCLUSIONS AND RECOMMENDATIONS

Conservation within neighborhoods, cities, and in agriculture can play a significant role in minimizing the negative effects of habitat loss, invasive species, and other factors limiting the distributions of wild organisms (Goddard et al., 2010). Pollinators can be supported by planting a diversity of flowering plants and protecting nesting resources, which may help stabilize essential ecosystem services they provide. Considering the needs of plants, pollinators, and other wildlife will take a concerted human effort, but may serve to increase overall pollination services, aesthetic enjoyment, awareness, and understanding of the ecosystems we live in.

Acknowledgements

We thank M. Hunter for reviewing literature on honey bee/wild bee competition, D. McKinley for her review of pollinator-dependent birds and mammals in BC, and M. Vaughan of the Xerces Society of Invertebrate Conservation for sharing his thoughts on the precautionary principle regarding honey bees in public areas. Metro Vancouver provided funding and encouragement.

We additionally thank providers of images used, identified by page number below.
Cover: L. Button
Pages 5-6: Honey bee: L. Button, Hives: T. Haapalainen; Bumble bee: J. Wray, nest: K. Bobiwash; Mason bee: E. Elle, nest box: J. Wray; Leafcutter bee: J. Wray, nest box: B. Plank Wikimedia; Mining bee: E. Elle, Ground nest: J. Wray; Sweat bee: J. Wray, Ground nest: J. Wray; Hoverfly: J. Wray, Butterfly: J. Wray
Page 9: all Wikimedia. Left to right: S. Shebs, S. Phillips, G. King
Page 12: Thimbleberry: Allan Carson UNBC, Ocean spray: E. Elle, Snowberry: E. Elle, Nootka rose: J. Wray, Oregon grape: E. Elle, Western bumble bee on snowberry: L. Button, Red-flowering currant: J. Wray, Black twinberry: H. Gehrels, Columbine: T. Haapalainen, Blanket flower: E. Elle, Lily of the valley bush: E. Elle, Rhododendron: T. Haapalainen, Lavender: E. Elle, Bellflower: J. Wray, Pot marigold: J. Wray, Western bumble bee on lavender: T. Haapalainen, Salal: Wouter Hagens Wikimedia, Salmonberry: David McMaster Wikimedia, Evergreen huckleberry: J. Wray, Raspberry: J. Wray
Page 14: Berries L. Button, Bee E. Elle

Works cited

Alaux, C., Ducloz, F.,Cruaser, D. et al., 2010. Diet effects on honeybee immunocompetence. Biol. Letters 6, 562-565

Brittain, C., Kremen, C., Klein, A.-M., 2013. Biodiversity buffers pollination from changes in environmental conditions. Glob. Change Biol. 19, 540-547.

Brown, T., Kegley, S., Archer, L., et al., 2014. GardenersBeware2014: Bee-toxic pesticdes found in “bee-friendly” plants sold at garden centers across the U. S. and Canada. Friends of the Earth-U.S. and Canada.

Burkle, L.A., Marlin, J.C., Knight, T.M., 2013. Plant-pollinator interactions over 120 years: loss of species, co-occurrence and function. Science 339, 1611–1615.

Button, L., 2014. Pollination in highbush blueberry (*Vaccinium corymbosum* L.) and the effects of surrounding landscape on wild bee abundance. M.Sc. Thesis, Simon Fraser University.

Button, L., Elle, E., 2014. Wild bumble bees reduce pollination deficits in a crop mostly visited by managed honey bees. Agr. Ecosyst. Environ. 197, 255–263

Button, L., Elle, E., *submitted*. The importance of local management practices and surrounding landscape composition for bumble bee abundance in blueberry fields. Basic Appl. Ecol.

Butz Huryn, V.M., 1997. Ecological impacts of introduced honey bees. Q. Rev. Biol. 72, 275–297.

Cameron, S.A., Lozier, J.D., Strange, J.P., et al., 2011. Patterns of widespread decline in North American bumble bees. P. Natl. Acad. Sci. USA 108, 662–667.

Colla, S.R., Gadallah, F., Richardson, et al., 2012. Assessing declines of North American bumble bees (*Bombus* spp.) using museum specimens. Biodivers. Conserv. 21, 3585-3595.

Courcelles, D.M.M., Button, L., Elle, E., 2013. Bee visit rates vary with floral morphology among highbush blueberry cultivars (*Vaccinium corymbosum* L.). J. Appl. Entomol. 137, 693–701.

Daily, G.C., 1997. Nature’s Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D. C.

Eilers, E.J., Kremen, C., Greenleaf, S.S., et al., 2011. Contribution of pollinator-mediated crops to nutrients in the human food supply. PloS one 6, e21363.

Elle, E., Elwell, S.L., Gielens, G.A., 2012. The use of pollination networks in conservation. Botany 534, 525–534.

Fetridge, E.D., Ascher, J.S., Langellotto, G.A., 2008. The bee fauna of residential gardens in a suburb of New York City (Hymenoptera: Apoidea). Ann. Entomol. Soc. Am. 101, 1067–1077.

Fraser, D.F., Copley, C.R., Elle, E., et al., 2012. Changes in the status and distribution of the Yellow-faced bumble bee (*Bombus vosnesenskii*) in British Columbia. J. Entomol. Soc. B. C. 109, 31–37.

Fürst, M. A., McMahon, D.P., Osborne, J.L., et al., 2014. Disease associations between honeybees and bumblebees as a threat to wild pollinators. Nature 506, 364–366.

Gallai, N., Salles, J.-M., Settele, J., et al., 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econ 68, 810–821.

Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., et al., 2014. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science 339, 1608–1611.
Gill, R.J., Raine, N.E., 2014. Chronic impairment of bumblebee natural foraging behaviour induced by sublethal pesticide exposure. Funct. Ecol. 28, 1459–1471.
Gill, R.J., Ramos-Rodriguez, O., Raine, N.E., 2012. Combined pesticide exposure severely affects individual- and colony-level traits in bees. Nature 491, 105–108.
Goddard, M. A, Dougill, A.J., Benton, T.G., 2010. Scaling up from gardens: biodiversity conservation in urban environments. Trends Ecol. Evol. 25, 90–98.
Hinners, S.J., Kearns, C.A., Wessman, C.A., 2012. Roles of scale, matrix, and native habitat in supporting a diverse suburban pollinator assemblage. Ecol. Appl. 22, 1923–1935.
Kearns, C.A., Inouye, D.W., Waser, N.M., 1998. Endangered mutualisms: The conservation of plant-pollinator interactions. Annu. Rev. Ecol. Syst. 29, 83–112.
Kennedy, C.M., Lonsdorf, E., Neel, M.C., et al., 2013. A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems. Ecol. Lett. 16, 584–599.
Kleijn, D., Raemakers, I., 2008. A retrospective analysis of pollen host plant use by stable and declining bumble bee species. Ecology 89, 1811–1823.
Klein, A.-M., Vaissière, B.E., Cane, J.H., et al., 2007. Importance of pollinators in changing landscapes for world crops. Proc. Roy. Soc. Lond. B. Bio. 274, 303–13.
Mackenzie, E., Winston, L., 1984. Diversity and abundance of native bee pollinators on berry crops and natural vegetation in the Lower Fraser Valley, British Columbia. Can. Entomol. 116, 965–974.
McFrederick, Q.S., LeBuhn, G., 2006. Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera: Apidae)? Biol. Conserv. 129, 372–382.
Michener, C. D., 2000. The Bees of the World. John Hopkins Press, Baltimore.
Morandin, L.A., Kremen, C., 2013. Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields. Ecol. Appl. 23, 829–839.
Neame, L.A., Griswold, T., Elle, E., 2013. Pollinator nesting guilds respond differently to urban habitat fragmentation in an oak-savannah ecosystem. Insect Conserv. Diver. 6, 57–66.
Ollerton, J., Winfree, R., Tarrant, S., 2011. How many flowering plants are pollinated by animals? Oikos 120,321–326.
Potts, S.G., Biesmeijer, J.C., Kremen, et al., 2010. Global pollinator declines: trends, impacts and drivers. Trends Ecol. Evol. 25, 345–353.
Rader, R., Reilly, J., Bartomeus, I., et al., 2013. Native bees buffer the negative impact of climate warming on honey bee pollination of watermelon crops. Glob. Change Biol. 19, 3103–10.
Ratti C. M., H. A. Higo, T. L. Griswold, and M. L. Winston. 2008. Bumble bees influence berry size in commercial *Vaccinium* spp. cultivation in British Columbia. Canadian Entomologist 140: 348-363.
Ricketts, T.H., 2004. Tropical forest fragments enhance pollinator activity in nearby coffee crops. Conserv. Biol. 18, 1262–1271.
Ricketts, T.H., Regetz, J., Steffan-Dewenter, I., et al., 2008. Landscape effects on crop pollination services: are there general patterns? Ecol. Lett. 11, 499–515.
Schweiger, O., Biesmeijer, J.C., Bommarco, R., et al., 2010. Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination. Biol. Rev. Camb. Philos. 85, 777–795.
Slagle, M.W., Hendrix, S.D., 2009. Reproduction of *Amorpha canescens* (Fabaceae) and diversity of its bee community in a fragmented landscape. Oecologia 161, 813–823.
Tommasi, D., Miro, A., Higo, H.A., et al., 2004. Bee diversity and abundance in an urban setting. Can. Entomol. 136, 851–869.
Williams, N.M., Winfree, R., 2013. Local habitat characteristics but not landscape urbanization drive pollinator visitation and native plant pollination in forest remnants. Biol. Conserv. 160, 10–18.
Williams, P.H., Araújo, M.B., Rasmont, P., 2007. Can vulnerability among British bumblebee (*Bombus*) species be explained by niche position and breadth? Biol. Conserv. 138, 493–505.
Winfree, R., 2008. Pollinator-dependent crops: an increasingly risky business. Curr. Biol 18, R968–9.
Winfree, R., Griswold, T., Kremen, C., 2007. Effect of human disturbance on bee communities in a forested ecosystem. Conserv. Biol. 21, 213–223.
Winston, M.L., Graf, L.H., 1982. Native bee pollinators of berry crops in the Fraser Valley of British Columbia. J. Entomol. Soc. B. C. 79, 14–20.
Wray, J.C., Elle, E., 2015. Flowering phenology and nesting resources influence pollinator community composition in a fragmented ecosystem. Landscape Ecol. 30, 261-272.
Wray, J.C., Neame, L.A., Elle, E., 2014. Floral resources, body size, and surrounding landscape influence bee community assemblages in oak-savannah. Ecol. Entomol. 39, 83–93.
Zurbuchen, A., Cheesman, S., Klaiber, et al., 2010. Long foraging distances impose high costs on offspring production in solitary bees. J. Anim. Ecol. 79, 674–681.