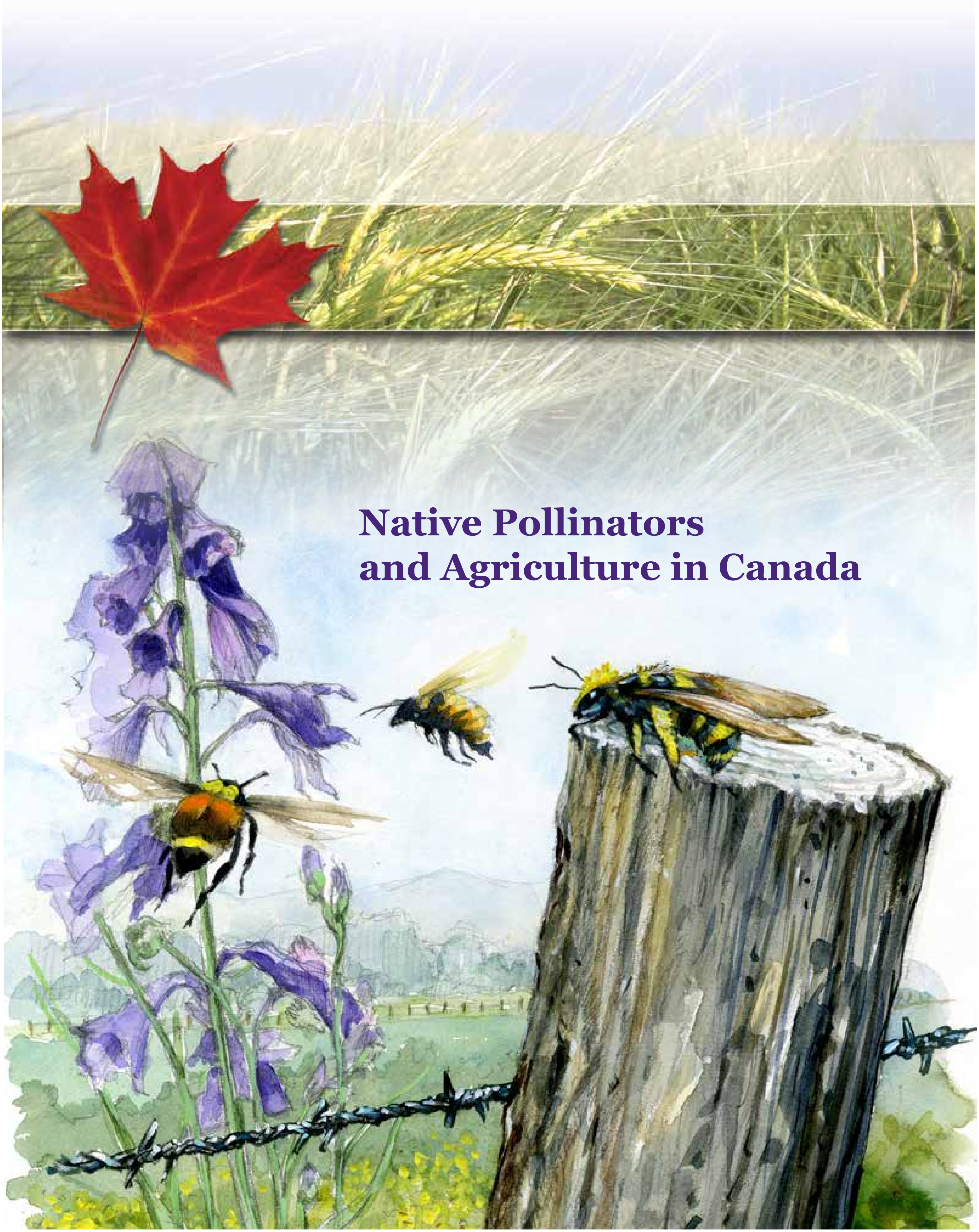
Agriculture and
Agri-Food Canada

Agriculture et
Agroalimentaire Canada

Canada



Native Pollinators and Agriculture in Canada

Native Pollinators and Agriculture in Canada

Electronic version available at www.agr.gc.ca

Catalogue No. A59-12/2014E

ISBN - PDF format: 978-1-100-23303-1

AAFC No. 12192E

Paru également en français sous le titre *Les insectes pollinisateurs indigènes et l'agriculture au Canada*

For more information, reach us at **www.agr.gc.ca** or call us toll-free at **1-855-773-0241**.

Table of Contents

List of Figures

Tables

Cover illustration and Figures 2, 11 and 21 created by Metrographics Design & Advertising, Calgary, AB.

Introduction

We live in an inter-connected and inter-dependent world – children to parents to grandparents, aunts and uncles, cousins and second cousins, and on and on. A job stocking shelves in the supermarket puts money into someone's pocket who buys a shirt that was made in a factory somewhere by someone who used cloth made from cotton that was grown on a farm someplace else. A seed planted into soil, watered by rain and last winter's snow and warmed by sunshine grows into a plant that produces many more seeds that are processed into spaghetti and baked into bread, which we eat, allowing us to work and volunteer and play. The connections are nearly endless and together, whether we are aware of them or not, they weave into the fabric of our lives and

Figure 1: Lasioglossum bee on smooth fleabane (*Erigeron glabelus*) – M. Wonneck

experiences. This booklet tells the story of one of these threads, a surprisingly important one – pollinators and their connection to agriculture.

Pollinators are animals, mostly insects, and primarily bees, but also birds and bats and a few other animals that help plants produce fruit and seed. Pollinators transfer pollen between the male and female parts of flowers more or less

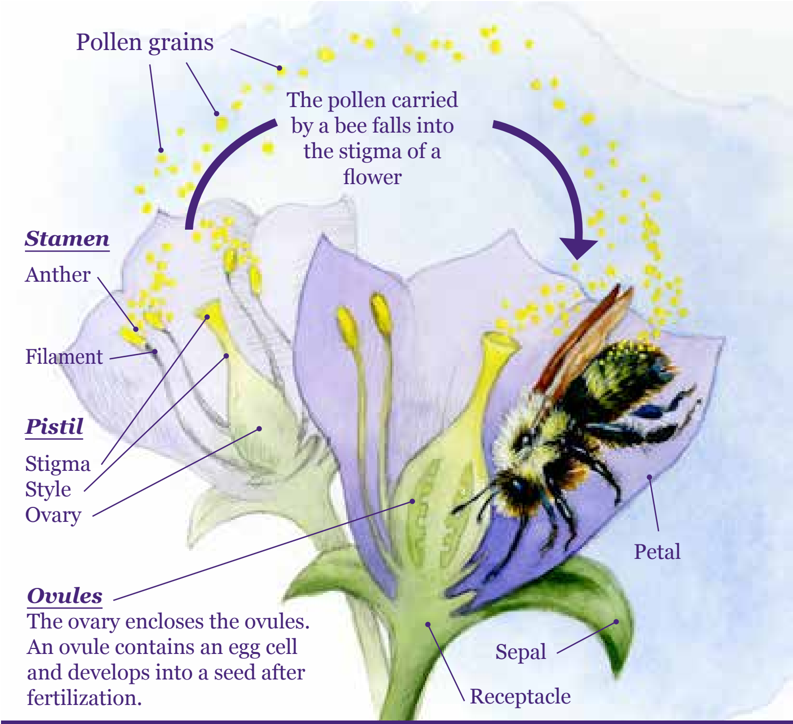


Figure 2: The role of animal pollinators in plant pollination

accidentally while they are collecting food in the form of pollen and nectar. We say "more or less accidentally" because it turns out that in the long run, doing so is beneficial to both the pollinators and the plants.

Almost three-quarters of all the flowering plants in the world rely, at least to some degree, on pollinators to play this role (CSPNA 2007). In fact, we can call it a "service" because from both the plant's perspective and ours, that is what it is. And because of this, entire terrestrial ecosystems, within which these flowering plants grow and interact, depend on this service – from Amazon forests (most tropical tree species are insect pollinated (Michener 2007)) to the native grasslands in the North American Great Plains, to the vegetated "green" zones along prairie streams in western Canada. And if that wasn't enough, pollinators are vital to agriculture (Table 1). Most fruit, vegetable and seed crops (about 70 percent) are pollinated by animals (Klein 2007) as are some fibre crops (e.g., flax and cotton) and major forage-seed crops like alfalfa and clover (Michener 2007). Some crops are entirely dependent on insect pollination for seed and fruit production while others benefit from higher yields, better quality produce, or more uniform maturation (Corbet 1991; Delaplane 2000). In fact, roughly 35 percent of global crop production depends on pollinators (Klein 2007), and even more, these plants tend to be nutritionally very important to our diet – they provide about 90 percent of our vitamin C, all of our lycopene, almost all of the antioxidants b-cryptoxanthin and b-tocopherol, most of the lipid, vitamin A and related carotenoids, calcium and fluoride, and a large amount of the folic acid intake (Eilers 2011). In the case of honey bees, which provide the majority of agricultural pollination done by bees, they also produce useful and economically important products: wax and honey.

Pollinators are Important to Important Crops.

Canada ranks first and second in the world in terms of canola and blueberry production, respectively. Both of these crops are dependent on insect pollinators, especially hybrid canola seed production.

There are approximately 706,000 honey bee colonies in Canada. The estimated value of honey bee pollination in Canada is about $2 billion. In addition, there are about 41 million kg of honey produced annually in Canada, with about 44 percent of it exported.

(Agriculture and Agri-Food Canada 2013)

Table 1: Major crops grown in Canada that depend on or benefit from insect pollination.

Legumes and relatives	Bean, Lima Bean, Soybean
Vegetables	Cucumber, Peppers, Pumpkin, Squash, Tomato
Vegetables (seed)	Asparagus, Beet, Broccoli, Brussels Sprouts, Carrot, Cauliflower, Celery, Lettuce, Onion, Parsnip, Radish, Rutabaga, Turnip
Fruits, berries and nuts	Apple, Apricot, Blueberry, Cherry, Cranberry, Melons, Peach, Pear, Plum/Prune, Raspberry, Strawberry, Watermelon
Oils, seeds and grains	Alfalfa, Buckwheat, Canola, Flaxseed, Mustard Seed, Sunflower
Clover and relatives (seed)	Alsike Clover, Red Clover, White Clover, Yellow Sweet Clover, White Sweet Clover

(based on data derived from (Statistics Canada 2011a), and adapted from (NRCS 2006))

The number of honey bee colonies in Canada has been increasing over the last five years from about 570,000 in 2008 to more than 706,000 in 2012 (Agriculture and Agri-Food Canada 2013) as beekeepers import more and more bees to fulfill increasing demands for pollination services as requested by farmers. For wild bees, there are indications that their abundance and diversity is declining and that some species are already at risk (COSEWIC 2010; CSPNA 2007). For the domesticated and agriculturally-important European honey bee, annual losses in the range of 15-30 percent of colonies in North America, primarily due to over-winter kill, appear to be typical (van der Zee 2012; vanEngelsdorp 2012). However, since 2006, a phenomenon termed **Colony Collapse Disorder** has been reported in the United States where entire colonies are lost because of what appears to be a combination of factors that are difficult to gauge, thereby adding to the vulnerability of pollination services to agriculture (Dainat 2012).

While the causes of all of these declines (wild and managed bees) can be hard to pin down, the following are among the culprits:

- declines in the diversity of flowering plants (Di Pasquale 2013);
- loss, fragmentation and degradation of habitat due largely to agriculture and urban development (Grixtia 2009; Kremen 2002; Larsen 2005; Richards 2001);
- the introduction of invasive non-native plant species (Potts 2010);
- the toxicity and widespread use of pesticides (Desneux 2007; Kevan 1975; Pettis 2013);
- air pollution (Girling 2013);
- climate change (Potts 2010); and
- diseases and parasites (Potts 2010).

The honey bee, while amazing, is not typical of most bees.

Most of us think that bees make honey, live in wax-covered hexagonal-celled honeycombs as perennial colonies consisting of a queen and her numerous daughter workers (Michener 2007; O'Toole 1991). Indeed, this describes the life of honey bees. Among honey bees, the queen and workers look quite different, the queen depends on the workers for her sustenance and workers cannot form viable colonies without the queen to produce female offspring (Michener 2007). Honey bees are not native to North America, but have been long domesticated and were introduced by early European settlers to produce honey and wax. More recently, they have become an integral part of our agricultural system. Their value as crop pollinators has been estimated to be more than $17 billion dollars in additional yields in North America alone. While honey bees are not always the most efficient pollinator, on a per-bee basis compared to some of the native bee species, they are easy to keep in large numbers, easy to transport and the beekeeper has the added benefit of harvesting honey products in addition to the revenue from renting the colonies for their pollination services.

Fortunately, beekeepers have been able to increase the number of honey bees that they import from other countries, not only to compensate for over-winter kill and colony collapse disorder, but to respond to the increase in demand from farmers for pollinators for their crops and from the demand for more honey. Honey production increased from ~29,500,000 kg to over 41,000,000 kg between 2008 and 2012 (Agriculture and Agri-Food Canada 2013).

It is also true, however, that for the majority of species, we don't know very much about the habitats they depend on, their interdependencies with other species, the trends in their populations, or how changes in the environment affect them.

This booklet is the story of the pollinators *as we know it,* what we know about why they are important to agriculture in Canada and some ideas on how we think they can be protected.

The Lives of Important Pollinators

Notwithstanding the contributions of as many as 300,000 flower-visiting species worldwide, insects and particularly bees are the most important animal pollinators globally as well as the chief pollinators of Canadian agricultural crops (Nabhan and Buchmann 1997 as cited in Kearns *et al*. 1998; Klein 2007; Richards 2002). In addition to bees, wasps and flies do a significant amount of pollination in Canada, and butterflies, beetles, ants and birds (notably hummingbirds) also contribute. With the exception of a few species of wasps, bees are the only animal that deliberately collects pollen to feed their young (Mader 2011). In contrast, butterflies, most wasps, flies, moths, and beetles visit flowers to feed on nectar or (in the case of some beetles) the flower petals themselves (Mader 2011). Bees also exhibit something called **flower constancy** – which refers to their tendency to forage only on one flower species during a foraging trip. So given their importance, let's start with the "empress" of animal pollinators, the bees.

Give a thought to the lives lived and be sure to lick the spoon!

What's in a spoonful of honey? It has been estimated (O'Toole 1991) that it takes a honey bee worker 20 million foraging trips to gather enough nectar to make 1 kg of honey. So when you have a 5 mg teaspoon of honey in your tea or on your toast, it represents about 100,000 foraging trips. And if the bee works say 10 hours (or 36,000 seconds) a day and each foraging trip is approximately 185 seconds (Collins 1997) – let's assume, as some researchers have found (Collins 1997), that she'll visit an average of 22 flowers, spending about 4.4 seconds on each flower – she'll make at most about 195 trips per day. That translates into at least 512 workdays for each teaspoon of honey! But it turns out that at the height of nectar gathering season, honey bee workers live on average a mere 42 days (O'Toole 1991). So that means that about 12 worker daughters commit their entire lives to providing you with that one teaspoon of honey!

Figure 3: Photograph by A. Lee

Bees

Almost everyone is familiar with bees. And it's no surprise. Our association with them is long and close. It stems from the honey and wax that honey bees make and the pollination services they provide to our crops. But our relationship is deeper than that, extending into mythology and

Figure 4: *Bombus ternarius* on gooseberry *(Ribes oxyacanthoides)* – M. Wonneck

folk medicine. Their murmuring buzz completes our imagined picture of a perfect warm summer afternoon. Their legendary work ethic humbles us. In the case of the colonial honey bees, their sacrifice for the group is awe-inspiring. Songs and poems have been written, and even movies have been made about them. But despite all of this, most of us know very little about most of the bees, and our conceptions of them are skewed by what we know about European honey bees, which is possibly the most studied insect in the world, but which is also quite different from other non-honey bees.

For the purpose of this booklet, our focus is exclusively on native wild bees, as the needs of honey bees, an introduced species to North America, and other managed bees are largely taken care of by their keepers.

Types of Bees

There are over 970 different bee species native to Canada alone (if it helps you to remember, that's about the same number of months as the average human life in Canada – which is something to think about in its own right …) and most of these (about 90 percent) are solitary (i.e., do not live in colonies). Solitary bees live for only one year and are only active for a short period of time throughout the summer. Mated females spend this time creating nests, gathering food and laying eggs, which develop into larva and pupa in the nest, and eventually emerge as adults the following year. Solitary bees, in particular the sweat bees (yes, as in perspiration) and mining bees are the most abundant bees in Canada.

Figure 5: Sweat bee *(Halictus* spp.) – M. Wonneck

Of the social native bees (e.g., bumble bees and some sweat bees), none are even close to the degree of sociality of the honey bees. For example, a bumble bee colony typically consists of between 100 to 400 individuals (O'Toole 1991), depending on the type of bumble bee, whereas honey bee hives are commonly 40,000 to 80,000 workers in size (Michener 2007). Like honey bees, bumble bee workers collect food, while the queen remains in the nest laying eggs. Towards the end of the summer, the bumble bee queen produces males and new queens who leave the nest and mate. In Canada, the newly-mated queens burrow into the soil to hibernate for the winter and all other bees die off. Honey bee hives in North America, on the other hand, are perennial – they need special care during the winter months to stay alive (just like the rest of us …).

Foraging

Bees are highly effective pollinators for many reasons: their hairy bodies allow for the transport of large amounts of pollen; their consistent foraging focus on flowering plants (almost all are strictly vegetarians (Michener 2007)); and their behaviour around flowers, such as "buzzing" in the case of bumble bees, which is extremely effective in shaking free and distributing pollen (Osborne 2003).

When foraging for food, most bees search for two things: nectar for energy and pollen to feed their brood or provision their eggs. The range of flowers from which bees can gather nectar depends on the length of their tongue – short-tongued bees can drink only from open flowers like asters; long-tongued bees can reach the nectar offered by deep or complex flowers such as beardtongues *(Penstemon* spp.), lobelias and lupines *(Lupinus* spp.) (Mader 2011).

Social bees are generalist foragers, a fancy term meaning that they will collect pollen from a wide range of different flowering plants. This not only reduces their risk of famine should any one flowering species have a bad year, but also allows them to be active over a longer period as they can switch flowers as they come into bloom. Solitary bees, on the other hand, play the survival game differently – they tend to specialize on one or only a few species of plants – those flowering during the relatively short period of time they are foraging during the summer.

Flight Period

Solitary bees usually live for about a year, but their flight period (i.e., the amount of time during the year that they are active and visible) is only three to six weeks. A few solitary bees, like some sweat bees in the genera *Halictus* and *Lasioglossum*, have two or three generations each year and so are present over a longer period of time (Mader 2011). Social bees, like bumble bees, have a much longer flight period. They are often the first bees active in the spring and the last bees active in the fall. Accordingly, early-blooming plants such as willows and late-blooming plants such as goldenrod are especially important to their survival. Their ability to regulate body temperature by shivering or basking in the sun enables bumble bees to forage during wetter, cooler conditions than honey bees and many other native bees.

Figure 6:
Canada goldenrod
(*Solidago canadensis*)

– M. Wonneck

Figure 7:
Smooth aster
(*Symphyotrichum laeve*)

– M. Wonneck

Figure 8:
Harebell
(*Campanula rotundifolia*)

– M. Wonneck

Figure 9:
Smooth blue beardtongue
(*Penstemon nitidus*)

– M. Wonneck

Deep and Shallow Flowers

Shallow, open flowers like goldenrod and aster tend to be visited by bees with shorter tongues.

Long-tongued bees are able to reach the nectar offered by deep and complex flowers like harebell and beardtongue.

Flight Distance

For a bee to successfully construct and provision a nest there must be adequate forage within the flight range of the bee. It seems that size matters when it comes to the distance a bee can efficiently fly from the nest to collect nectar and pollen. Large bees like bumble bees can forage at distances of 1.5 km or more from the nest. Medium-sized bees such as mining bees (*Andrena* spp.) or leafcutter bees (*Megachile* spp.) can fly 350-450 m from the nest. Small bees, such as sweat bees (*Halictus* spp.) and small carpenter bees (*Ceratina* spp.) generally fly no more than 200 m from their nest.

Figure 10: Leaf-cutting bee (*Megachile inermis*) on thistle – S. Javorek

Perdita spp., the tiniest bees of all, may be limited to 75 m or so. But it is important to remember that the shorter the distance a bee has to fly to find flowers, the more efficiently it can forage and provide for more offspring (Mader 2011). In other words, no matter what the size of the bee, bee populations thrive best when abundant forage resources are available close to their nests.

Nesting Resources

Nest location and construction varies greatly by species of bee. About 70 percent of solitary native bees nest underground. All ground-nesting bees burrow narrow tunnels ending in small chambers from 15 cm to 1 m in depth. Unfortunately, the best soil type and texture, degree of compaction and moisture-holding capacity needed by most ground-nesting bees is not well understood. The other 30 percent of solitary bees build their nests above-ground in hollow tunnels in the soft pithy centers of twigs or canes of some plants (e.g., box elder (*Acer negundo*), red elderberry (*Sambucus racemosa*) and raspberry (*Rubus ideaeus*)), in abandoned wood-boring beetle tunnels, or in tunnels that some species excavate themselves into wood, especially dead or decaying stumps and snags.

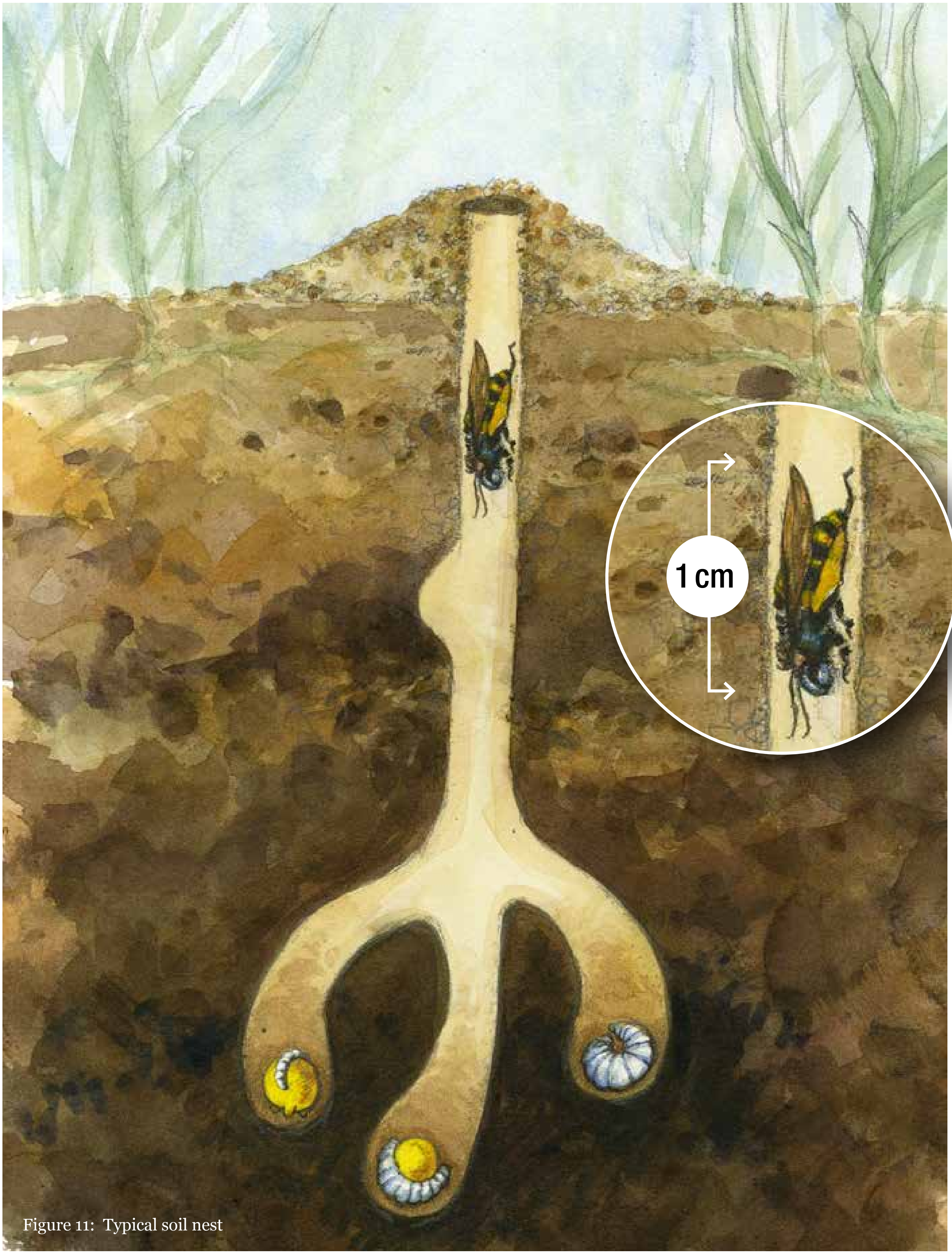


Figure 11: Typical soil nest

Figure 12: Tunnel excavation (*Anthophora* sp.) – M. Wonneck

Bumble bees, which make up about 20-30 species in any one region in the agricultural landscapes of Canada and are among the most important native pollinators of agriculture crops, construct nests underground in existing cavities like rodent burrows, or in natural cavities under rocks, tree roots and grass tussocks. Occasionally some species will construct their nests above ground in bird nests or tree cavities.

Figure 13: Bumble bee (*Bombus ternarius*) – M. Evans

For solitary species, each egg is laid in a separate nest cell, the composition of which also varies by species. The common names of many bees are derived from their choice of nesting sites and materials:

- leafcutters (*Megachile* spp.) create nest cells with leaves;
- mason bees (*Osmia* spp.) use mud;
- mining bees (*Andrena* spp.) dig in soil;
- plasterer bees (*Colletes* spp.) secrete a waterproofing substance that they use to coat the inside of the cell;

Figure 14: Bumble bee colony – L. Zink

- carpenter bees (*Xylocopa* spp.) nest in wood and are able to excavate their own tunnels (Roulston 2011).

Both ground-nesting and cavity-nesting bees must collect water for use in nest construction (Kearns 1997).

Figure 15: Halictid bee emerging from soil nest – M. Wonneck

For all species, there seems to be a preference for nest openings oriented towards the morning sun, so east and south facing slopes may be preferred. Preferred nest entrances are sloped or well-drained. Ground-nesting solitary bees have a preference for bare soil that allows them easy access for digging. Ground-nesting bumble bees, on the other hand, prefer a thick vegetation cover that hides the nest entrance. In all cases, tilled land is not preferred – remember, some species spend up to eleven months of the year underground.

Overwintering solitary bees pass through the stages of egg, larva and pupa during the winter in the cells constructed by their mothers the previous summer. However, in the case of the bumble bees, females mated in late summer and early fall burrow into soil or leaf litter, preferably in a shady location on a north-facing bank or forest edge, and hibernate.

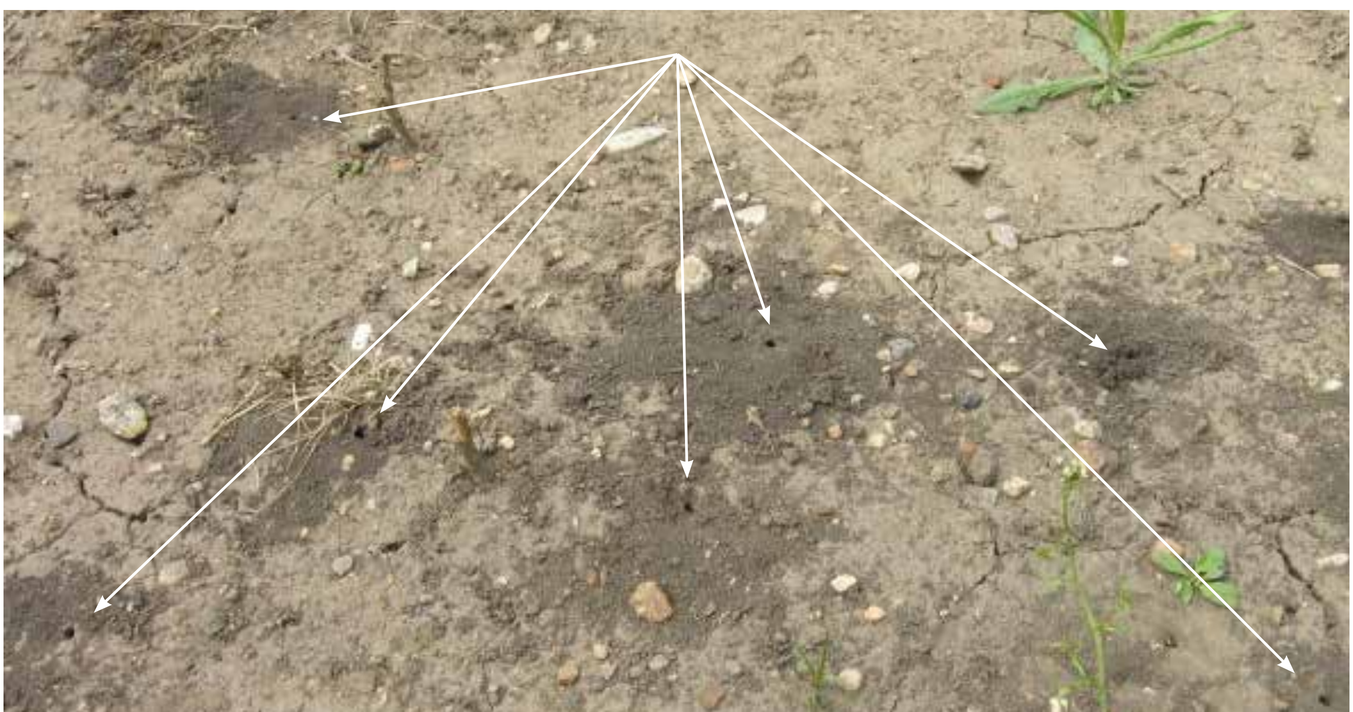


Figure 16: Small "village" of solitary Halictid bee nests – M. Wonneck

Wasps

Wasps are bees' closest relatives. As larvae, wasps are typically carnivorous, feeding on insect bits provided by their mothers. As adults, wasps switch to a vegetarian diet fueled by nectar and other sugar sources, such as rotting fruit. Adult wasps have short tongues and so tend to be attracted to shallow flowers, like goldenrod and asters. They are not nearly as "hairy" as most bees and what "hair" they do have is not branched, as is the case in bees, and so they tend not to move a lot of pollen around. Still in some locales they can be abundant and can offer significant pollination services due to their high numbers.

Flies

Although they only have two wings, some species of flies can be mistaken for bees and wasps (which both have four). Two groups of flies called "hover flies" (or "flower flies") and "bee flies" are striking examples of bee mimicry, presumably to discourage birds and other predators. However, they have the large eyes characteristic of flies, and hover flies, in particular, fly in a jerky manner that readily distinguishes them from bees.

Flies are among the most frequent visitors to flowers. However, because they don't provision nests, they do not collect pollen and do not need large quantities of nectar. Further, they are relatively sparsely haired and thus tend not to transfer much pollen. One estimate for canola pollination suggests that it takes five times more hover flies to pollinate to the same degree as mason bees (*Osmia rufa*) (Jauker 2012). Still, because they can often be important pollinators of specific plants where other pollinators are not, and because they are thought to contribute significantly to the pollination of many flowering plants in North America (Kearns 2001), they are worthy of attention.

Of the agricultural crops, flies can be important pollinators of strawberries, onions and especially carrots. In fact, because carrots are not favoured by managed bees, some carrot-seed producers use commercially-reared flies inside cages to provide pollination.

Butterflies and Moths

Butterflies are beautiful, extravagantly so, well known and conspicuously associated with flowers. Like wasps and flies, they feed on nectar only as adults. They do not provision nests nor do they have branched hairs like bees to trap pollen, although sometimes they are a bit "fuzzy" and accidently trap small amounts of pollen.
As a result, they are generally thought not to contribute significantly to pollination.

Moths, on the other hand, are often overlooked and sometimes even maligned. Perhaps it is because they tend to be drab in appearance compared to their movie-star cousins the butterflies. Perhaps it is because they are largely nocturnal. Or perhaps it is because a few species are known to be pests. It's a shame because

Figure 17: Greenish blue (*Plebejus saepiolus)* on strawberry – J. Hannes

there are more than 10,000 species of moths in North America and many of these are important pollinators of native plants. An example is the yucca plant (*Yucca* spp.), the range of which now extends into southern Canada. It depends entirely on the yucca moth (Family Prodoxidae) to pollinate its flowers. As well, nocturnal moths are the most important group of pollinators for night-blooming plants like the common evening primrose *(Oenothera biennis*).

Beetles

With over 30,000 species in North America, beetles contain the greatest species diversity of all pollinators. Because of their body shape and behaviour, they tend to contribute to the pollination of a relatively limited group of flowering plants that have bowl-shaped flowers with many stamens and pistils. Because of their sheer numbers and the fact that for many species adults emerge in synchrony with specific flowers, they can play an important pollinating role for some flower species. In addition, many beetles lay eggs on or within weakened or dying trees. Their grub-like larvae burrow beneath the bark or even into the wood, which when abandoned create nest sites for wood-nesting bees such as leafcutters and mason bees. Thus, these species of beetles are indirectly critical to the pollination services provided by wood-nesting bees.

Figure 18: Beetle on Woods' rose (*Rosa woodsii*) – J. Hannes

How to Protect Wild Pollinators

While the "lives of pollinators" sections above hopefully make for interesting reading, it is really just background to the main intention of this booklet, which is to provide some guidance for you to take what action you can to conserve and protect wild pollinators. That's the focus of this section.

It turns out there are a great number of things you can do to protect or create the conditions that support wild pollinator populations on your farm or ranch, but generally they involve providing:

- forage (in the form of a diverse and abundant array of flowering plants rich in nectar and pollen, preferably native and with varied and overlapping blooming times);
- nesting sites and materials (such as untilled, pesticide free and partially bare ground, trees and shrubs, hollow-stemmed plants, suitable leaves, mud and water);
- hibernation and over-wintering sites (untilled areas with perennial vegetation cover); and
- a landscape free of substances such as pesticides, insecticides, introduced diseases, viruses and bacteria (Gathmann 2002; Kearns 1998).

Not surprisingly, given no farm or ranch is the same, how best to provide for pollinators depends on your local conditions. Important considerations are soil and climate conditions, topography (and particularly the orientation of sloped land), drainage, history of cultivation, and the distribution and "connectedness" of non-cropped areas. Still, there are some general guidelines that can be adapted by anyone.

1. **Save what you've got.** In most instances, this is the most important thing you can do to conserve pollinators and pollination services, the one that costs the least and requires the least change. The trick is to be able to identify existing pollinator habitat.
2. **Create new habitat.** Chances are that there are things you can do to develop more habitat to enhance pollinator populations. Creating habitat requires more planning and effort, but it also affords the opportunity to find synergies between the creation of favourable habitat for pollinators and other benefits to your operation, such as groundwater recharge, snow trapping, pest suppression, and wind erosion protection.
3. **Manage to benefit pollinators**. Many pesticides are toxic to insects, so whether and how they are used can make a great difference to pollinators. As well, other activities can disturb pollinators at different times of the year and so there are opportunities to make adjustments to minimize impacts.

The following sections describe in some detail how to go about saving, creating and managing pollinator habitat, but a handy point-form summary is also included as an appendix to this booklet.

Figure 19: Potential pollinator habitat: ditch, fenceline, in-field willow-ring wetland, wooded area – M. Wonneck

Save What You've Got

The first step in saving existing habitat is to recognize it. You can start by watching which flowers in the non-cropped areas on your farm are visited by pollinators. Places like field margins (shelterbelts, remnant treed areas, and even grassed ditches), roadsides, areas around buildings and corrals, hay and pasture lands, forested areas, habitat along streams and around wetlands, unused inaccessible areas and even flower gardens may already be important habitat to pollinators on your land. You are probably familiar with bumble bees, honey bees, and butterflies, so start by looking for these. Take a look at some of the photographs of the less familiar pollinators in this guide or a field guide to insects and develop an eye for the less familiar bees, wasps, hover flies and beetles.

Take special note of the time during which plants are flowering. If you are lucky enough to have many different types of flowering plants covering the spring and summer periods, then you can focus on getting more late-season flowering plants into your good habitat areas. Goldenrod (*Solidago* spp.) and some of the asters are important late-season flowering plants in many of the agricultural regions of Canada, so watch for these.

In addition to flowering plants, look for nest sites. What you are looking for is untilled land with some bare soil. Standing dead and decaying trees, deadfall and hollow-stemmed plants (like raspberry canes, and elderberry, sumac (*Rhus* spp.) and box elder stems) are also good nesting options for tunnel nesters like leafcutter and mason bees (Vaughan 2004). These sites may be found in pastures, field margins, hedgerows, and roadways, but rarely within cultivated areas. These kinds of sites are even more valuable to pollinators if they are well drained, sunny and sloped to the south, associated with abundant and diverse flowering plants, and near a water source. Many bumble bees nest in old rodent burrows, under tussocks of bunch grasses, in old compost piles and even in bird houses, so these are other valuable habitats to look for.

Figure 20: Potential pollinator habitat – shelterbelt along canola field – M. Wonneck

Once you have identified existing pollinator habitat on your farm, protect it. This will be both the least expensive and least disruptive action you can take to encourage pollinators. Thoughtful neglect (a confusing term, but you get the idea) can be a very effective way of protecting pollinator habitat! In some cases (e.g., where weedy undesirable species are invading a habitat area), management to maintain optimal conditions may be required. However, care should be taken to avoid introducing toxic substances and pathogens.

Create New Habitat

If you don't believe you have enough existing habitat or would simply like to do more, then the next step is to consider developing pollinator-friendly environments on your farm/ranch. In creating habitat for pollinators, there are three main considerations:

- Site(s) Selection
- Habitat Design
- Planting and Establishment

Site Selection

The best sites to create habitat for pollinators are near to the fields where pollinator-dependent crops are planted. The next thing to look for are areas already being used by bees or with existing resources that bees depend on such as a diversity of flowering plants, nesting sites (well-drained sites with bare soil, south-facing slopes, decaying logs and snags, hollow-stemmed plants) and resources (a diversity of plants for leaf-material and resins for nest-building), and over-wintering areas (shaded areas of exposed soil or thick leaf litter). Because

Figure 21: When choosing where to develop habitat, look for areas as close as possible to pollinator-benefitting crops and opportunities to connect to existing habitat on the farm.

some species have a tendency to initiate nests close to the place where they were born, habitats developed in and adjacent to areas where nesting already occurs are likely to be particularly effective in supporting additional pollinators.

As a rule of thumb, try to locate habitats such that the maximum distance bees would have to travel to reach the most distant crop flowers is no more than about 150 m. In other words, try to keep field sizes where you grow pollinator-dependent crops no more than 300 m wide and provide pollinator habitat along the margins of these fields. Further, to increase the effective area of pollinator habitat and provide access to a wider diversity of species, wherever possible, habitats should be sited such that they have the potential to connect existing habitat.

Care should be taken when planting habitats adjacent to perennial forage fields containing invasive plants, such as brome and alfalfa. These sites can be used, but you should expect they will require extra maintenance to manage the encroachment of forage crops into the habitat until the flowering plants capture the site.

Habitat Design

One of the most effective ways to increase local pollinator numbers is to increase the flowers available to them. Consider removing grassy, weedy, or invasive vegetation in non-cropped areas and planting them to native flowering plants (trees, shrubs and forbs) and/or a pollen- and nectar-rich mix of agricultural legumes (Goulson 2008). This approach is based on the strong relationship that has been found between flower abundance and diversity and pollinator abundance and diversity (Potts 2003). Indeed, studies show that replanting sites with a diverse group of native flowering plants has a positive effect on pollinator populations (Carvell 2004; Goulson 2008; Hopwood 2008).

To attract a diverse array of native bees, plant a diversity of flower species that:

- have flowers ranging from open and shallow to deep and complex;
- have different colours, heights and growth habits;
- provide good pollen and/or nectar resources, or are known to be used by bees; and
- exhibit overlapping bloom periods from April to October.

How much diversity is enough? Studies suggest that as few as 10 carefully chosen plant species will provide excellent habitat, but that pollinator diversity can continue to rise with increasing plant diversity, leveling only after 20 or more species are present at a site (Mader 2011). To the extent possible, plant species endemic to your area as native bees will have been adapted to visit these. As well, to speed the "capturing of the site", thought should be given to planting desirable species that sucker and readily spread so that the need for post-planting weed control is reduced.

Figure 22: Demonstration "eco-buffer" planting approximately 5 years old, featuring suckering pin cherry (*Prunus pensylvanica*), choke cherry (*Prunus virginiana*), saskatoon (*Amelanchier alnifolia*) – L. Poppy

Figure 23: Canola (*Brassica napus*) in bloom – M. Wonneck

For pollinator-benefitting crops (e.g., canola, sunflower) that are used in rotations with crops that do not benefit from pollinators (e.g., wheat, barley), it is important that surrounding non-crop habitats contain a sufficient diversity of flowering plant species that "collectively" bloom throughout the spring-summer-fall so that native bee populations (and pollination services) are available when needed. That is, plantings should contain species that flower in the early spring (April and early May), species that flower from spring to early summer (May to mid-June), during summer (late June to August) and into the fall (late August to October).

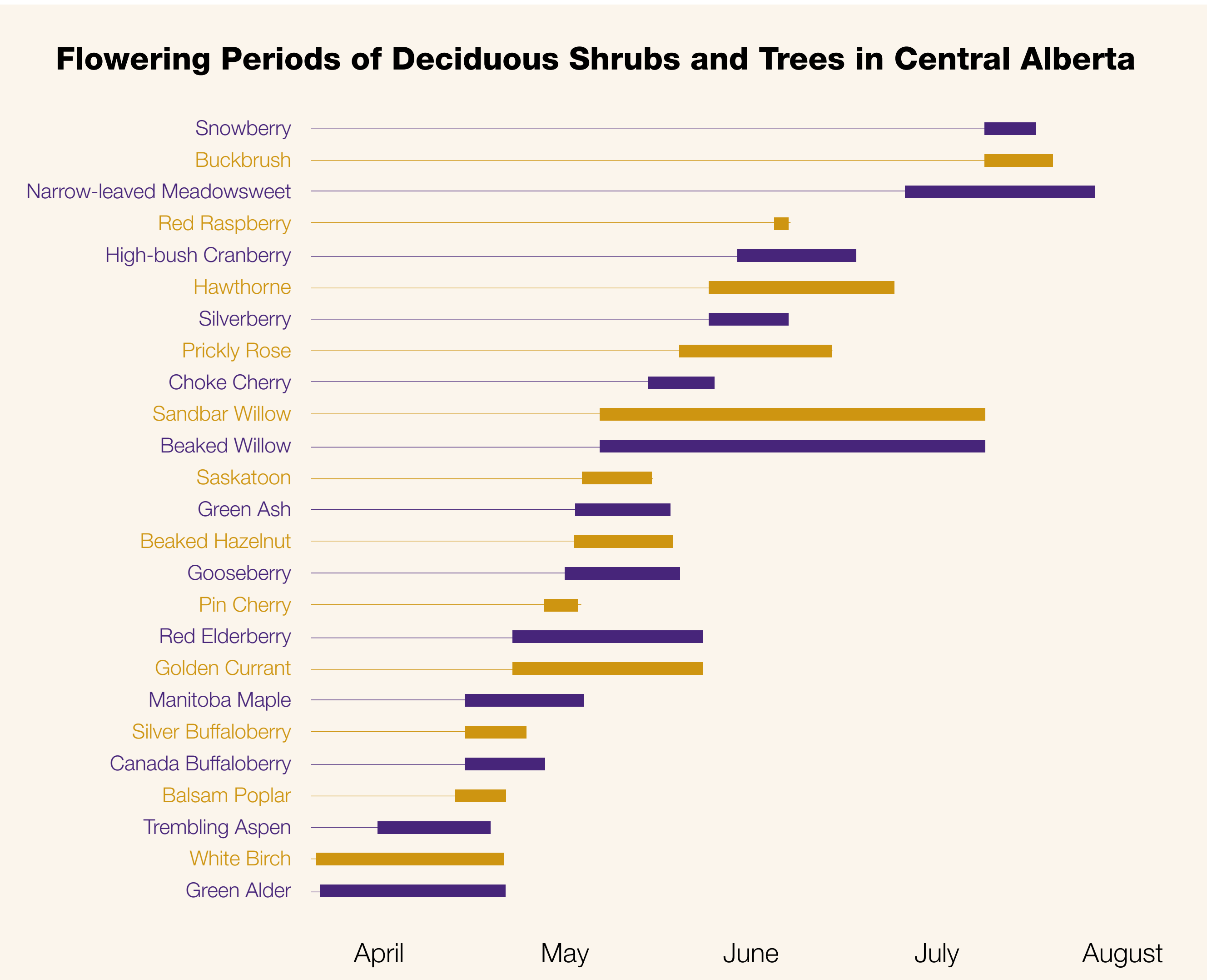


Figure 24: Flowering periods of selected deciduous shrubs and trees in central Alberta

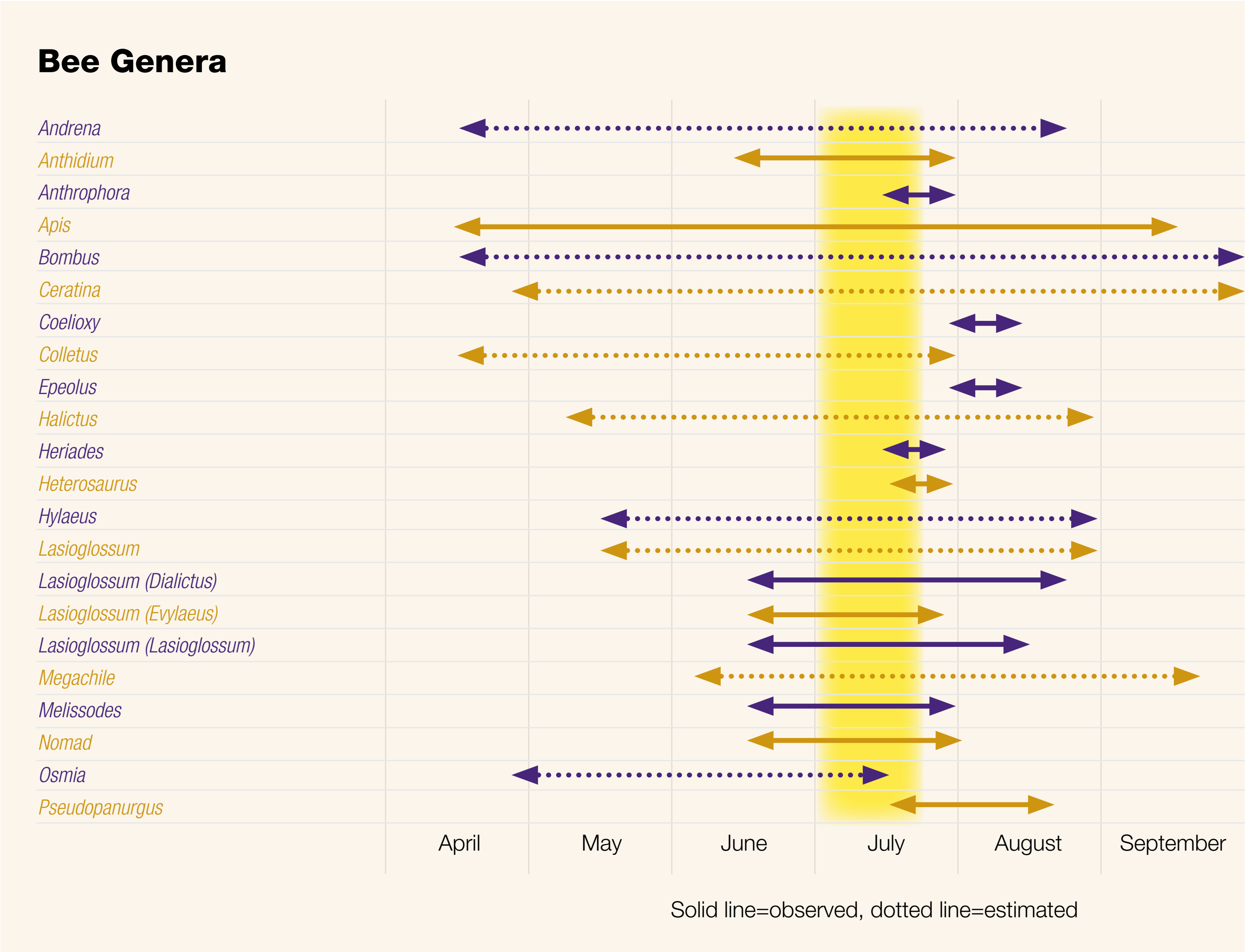


Figure 25: Canola bloom period (yellow bar) and flight periods for wild bees in central Alberta, Canada

As a general rule, habitat patches that are bigger and closer to other habitat patches are better than smaller and more isolated patches, although even small patches of native flowers within large fields can provide some benefit to pollinators (Carvalheiro 2012). Because of their lower edge-to-area ratio, rounder patches tend to experience less weed encroachment than squared-off patches, while at the same time offering more microhabitat diversity at their edges. Where new habitats are sited along linear field margins, they should be as wide as possible to allow for as much plant microhabitat diversity as possible. Broad curves along the long axis of the field-margin habitats can be incorporated to increase the diversity of microhabitats along the length of the habitat.

Table 2: Relative nectar and pollen resources for selected trees, shrubs and forbs

Species	Common Name	Nectar	Pollen
Alnus spp.	Alder species	0.125	0.500
Amelanchier spp.	Serviceberry species	0.500	0.400
Aster puniceus	Purple-stemmed aster	0.625	0.500
Betula papyrifera	Paper birch	0.000	0.500
Epilobium angustifolium	Fireweed	0.625	0.500
Fragaria virginiana	Strawberry	0.500	0.500
Melilotus alba	White sweetclover	0.700	0.700
Mentha arvensis	Wild mint	0.835	0.500
Pinus spp.	Pine species	0.000	0.500
Populus spp.	Poplar species	0.000	0.625
Prunus pensylvanica	Pin cherry	0.750	0.750
Quercus macrocarpa	Bur oak	0.000	0.700
Rubus spp.	Rubus species	0.700	0.600
Salix spp.	Willow species	0.800	0.900
Sambucus pubens	Red elderberry	0.335	0.665
Solidago spp.	Goldenrod species	0.750	0.750
Spiraea latifolia	Meadowsweet	0.500	0.500
Taraxacum spp.	Dandelion species	0.900	0.800
Trifolium repens	White clover	0.900	0.800
Vaccinium spp.	Vaccinium species	0.500	0.500
Viburnum spp.	Viburnum species	0.500	0.500
Vicia spp.	Vetch species	0.625	0.500

Adapted from (Loose 2005)
0=no pollen/nectar, 1=major pollen/nectar source

Figure 26: Curved field margin eco-buffer design – M. Wonneck

The best pollinator habitat sites have areas with good sun exposure during the growing season along with other areas with more shade and protection for over-wintering insects. For linear plantings, an east-west orientation provides lots of south exposure for soil nesting sites and flowering plants, as well as protection and shade on the north exposure. However, very sunny sites may be particularly dry and thus may also require the use of drought-tolerant plant species. For north-south oriented buffers, the east side of the planting should offer good sun exposure for nesting sites where bees can warm themselves in the morning before they can fly. In these situations, it may be appropriate to consider planting fewer trees to allow for more sunlight over a longer period of the day.

Research suggests that pollinators are better able to take advantage of flower resources if plants are clumped in groups of at least 1 m in diameter (Mader 2011). However, for very large plantings and in other cases where the extra planting effort required to create clumped plantings is a significant barrier, the disadvantage of not clumping can be overcome by increasing the density of flowering plants in the habitat (i.e., plant more flowers!).

To provide nesting resources for a diverse community of native bees, consider incorporating the following elements into the design of the habitats:

- logs and stumps left to decay in sunny areas of the planting to create nesting habitat for tunnel-nesting bees;
- at least one species of a warm-season native bunch grass;
- well-drained areas of bare soil to provide nesting habitat for ground-nesting bees and over-wintering sites for bumble bees;
- rock and brush piles to provide over-wintering sites for bumble bees;
- a diversity of plants to provide resin and other nest-building materials are readily available; and
- poorly-drained or otherwise wet areas to provide clay and moisture for nest-building.

Figure 27: 18x18x18 cm bumble bee box with 15 cm plastic tube entrance prior to burial in south-facing ditch bank – M. Wonneck

To augment natural nesting habitat elements, human-made structures can also be used. For wood or tunnel nesting bees these include wooden bee boxes, or bundles of hollow stems or straws, and for ground nesting bees, patches of bare ground or piles of sand or sandy loam are beneficial (Vaughan 2004). You can find lots of information on the internet on different designs and how to construct them (refer to the List of Useful Resources in Appendix B).

Figure 28: Newly installed tunnel-nesting bee box installed in poplar (*Populus* spp.) shelterbelt – G. Bank

Once you know which plants you would like to include in your new habitat, you need to plot out your design based on the pollinator habitat considerations described above (or refer to the summary table in Appendix A). Each plant will have a mature size for your area (an estimate of its maximum height and diameter when it is fully grown). Generally, this can be used to space plantings in the habitat. However, you will also want to consider whether a plant tends to sucker and the degree to which it will tolerate shaded conditions. Suckering plants can capture a site relatively quickly, but may also compete with less aggressive plants, so you will need fewer of these and will want them widely spaced. As well, slower growing plants (e.g., oak (*Quercus* spp.)) may benefit from "nurse" plants (poplar *(Populus* spp.)) to shelter them during the early growth stages, so it is also important to consider the succession of plants in your habitat design. You may find it really helpful to use landscaping software to help you design your buffer and visualize the buffer once it's mature. Your local agricultural extension agency may be able to provide some assistance as well.

Planting and Establishment

Once you have sited and designed your pollinator habitat, the next step is acquiring plant material, and then considering how you will plant the habitat and encourage its establishment. Native plant material can be sourced from local nurseries that specialize in propagation of native plants. Ideally, you want plants sourced from stock within 100 km of your location. Often you can identify these kinds of nurseries through an internet search, by asking your local agricultural extension agency, watershed stewardship groups and other environmental organizations in your area, or local plant nurseries. Native plant nurseries often supply reclamation projects along roadways, so calling your local or provincial department of transportation can also be effective. Generally, you will need seedlings (bare root stock or small plugs) as these will establish readily and are relatively low cost. Although native seed can also be used, it can be variable in germination, and thus less reliable. Once you have your plant material sourced, set your planting day (or days) based on plant availability and the recommendation of the nursery.

A key step in habitat establishment is preparing the site for the new plants. You want to create a weed-free planting bed that will facilitate quick establishment and thereby "capture the site" quickly to reduce weed infestation problems. How you prepare the site will depend on local conditions. In some areas, deep tillage is recommended as a first step. In others, shallow disking is sufficient. Check with your local agricultural agency for advice if you are unsure about how to approach this. If you plan on using herbicide, such as glyphosate, to loosen roots to make sod breaking and cultivation easier, consult with local regulations to determine what, if any, prohibitions there are with respect to use near sensitive areas like rivers, streams, wetlands, water wells and residential areas. After herbicide application, the habitat site should then be prepared for planting by disking or cultivating. To minimize future weed problems, the site should ideally be disked in fall the year prior to planting and then again in the spring just before planting. Generally, the soil should be worked until it is loose and black to at least 15 or 20 cm. When you are done, your soil should be residue free, with no sod, soil clumps, weeds or large stones present.

Figure 29: Plastic mulch in newly prepared seedbed for eco-buffer planting – M. Wonneck

In recent years, the use of plastic mulch for linear shelterbelt (windbreak) plantings has been found to be extremely effective for both weed suppression and soil moisture retention. It can also be used for habitat plantings where plants are planted in long arcing rows. While there has been some concern that plastic mulch may impede suckering, early experimentation with diverse shelterbelt plantings in the prairies suggests that it can work well for more complex, multi-row, multi-species plantings. Other mulch materials can also be used, such as sprayed-in wood mulch. Instead of or in addition to mulch, in some regions cover crops can be planted during site preparation to suppress weeds during establishment of the habitat (Miles 2003). Again, consult with local experts for recommendations for your area.

Planting

Once you have the seedlings, plant them as soon as possible. If planting is delayed, the bare root stock packages should be left sealed and stored in a cool, dark location. Properly stored packages of trees can be kept for up to five days with limited

Figure 30: Planting bare-root seedlings into plastic mulch – G. Bank

impact on survival. Cooler days with below-freezing evening temperatures allow seedlings to be kept in storage for a longer period of time. After a few days of storage, you may want to make a small cut in the packages to ensure the seedlings are moist. If planting is delayed beyond five days, and the seedlings in the packages are starting to show signs of mold or bud break, then you need to get the seedlings planted in their permanent location or in a temporary site (called heeling in). The heeling-in method involves planting the seedlings close together in soil trenches in a shaded field or garden plot. You will want to ensure the roots do not dry out and are well covered with moist soil. Heeling in involves a significant amount of extra work, and you will need to replant the seedlings in their permanent location at a later date. These seedlings should only be moved again when they are dormant (before bud break that spring, later in the fall, or the following spring). During planting, protect the roots of seedlings from wind and sun by covering them with moist soil or peat moss to prevent drying. If possible, plant the trees on a cool, cloudy day or in the early morning or evening rather than on hot, windy days.

Plugs can be stored more easily and for longer than root stock because they come with their own soil. They can be stored upright in their containers in partial sun locations. The plugs dry out quickly, so you will need to take care to water them regularly to keep them moist. Planting plugs is a relatively simple process – make a hole just larger than the plug, pop the plug out of its container and into place, and press the surrounding soil around the plug.

Figure 31: Plug of white prairie aster (*Aster ericoides*) ready for planting – G. Bank

Establishment

Native plants are by definition well-adapted to the local environment on your farm. The key is to get them established, and in this regard the first few years are critical. Because of the widespread persistence of non-native weed species in agricultural landscapes, weed suppression is critical in these first years. Planting them into a weed-free seedbed and using a mulch goes a long way to giving them a good start. Further, native plants do not require any fertilization – in fact, fertilization will tend to encourage weeds that compete and interfere with their establishment. In some regions, wood or straw mulch applications after planting are the most effective way of suppressing weeds, but can be impractical for very large plantings. Otherwise, well-timed (i.e., before they set seed) mowing of weedy plants every 4 to 6 weeks for 1 to 2 years after planting will help speed along site capture. Shallow disking of weedy areas several times during the growing season has also been an effective weed management tool during establishment. Not only does disking control weeds but it also stimulates development of rhizomes which aid in the capture of the site by desirable plants.

Figure 32: Mat-forming grasses used for weed control between rows – G. Bank

Normal rainfall conditions should ensure adequate soil moisture and good establishment. However, if the seedbed is very dry or if drought conditions occur, particularly immediately following planting and during that first year, supplementary irrigation may be required. Once established, supplementary irrigation will normally not be required.

Manage to Benefit Pollinators

It is one thing to conserve and create pollinator habitat, but without careful management its benefit to pollinators may amount to very little. If you have existing habitat or have created new habitat, you will want to maintain the flower and nesting resources it contains. At the same time, you will want to continue to control crop pests and invasive species on your farm, but without harming pollinators. Here are some ideas:

Use of Pesticides

To the extent possible, minimize the use of pesticides, whether on field crops or within habitat plantings, to control invasive and noxious weeds and to protect pollinators and other beneficial insects. Herbicides that drift from nearby cultivated fields can kill desirable plants in pollinator habitat. Deciduous plants can be particularly susceptible to drift of broad-spectrum herbicides. As well, herbicides, insecticides and fungicides can be toxic to the bees you are trying to encourage. Depending on the orientation of the habitat, it may be possible to mitigate the impact of accidental pesticide drift by planting coniferous trees on the field-side edge of the habitat – coniferous trees are less susceptible to damage by herbicides specifically designed to control broad-leaf weeds. Further, as a general rule, if pesticides are used in fields, their use should be limited to early in the morning and after sunset to avoid direct contact with foraging bees, and, if at all possible, avoid using them during crop flowering.

Herbicides can be a valuable tool to control invasive weed species within new and existing pollinator habitat. Because of the potential of herbicides to indirectly harm pollinators, it is important to minimize their use and the area sprayed. Where possible, use wicks or handheld sprayers and take care to only spray target plants. In general, don't use herbicides around native flowering plants, especially when they are in flower, or around butterfly larval host plants when caterpillars are present.

Grazing

This section focuses largely on pastured grazing operations on native and modified grasslands typically found on the prairies, in south-central British Columbia and in Ontario.

The relationship between grassland management strategies and pollination populations is complex. To start with, the type of livestock used for grazing appears to be important, with sheep and goat grazing being more forb-focused than cattle grazing and thus more profoundly reducing pollinator forage, abundance and diversity (Carvell 2002, 2004; Hatfield 2007; Yoshihara 2008). Decreased grazing intensity has generally been found to be associated with increases in bee and butterfly diversity, as well as the abundance of butterflies, solitary bees and wasps (Carvell 2002; Hatfield 2007; Kruess 2002; Yoshihara 2008). However, different insect pollinator groups (e.g., bees, butterflies, hover flies and beetles) and individual species may react differently to grazing intensity and resulting habitat characteristics, suggesting that the best strategy for the conservation of pollinators may be a variety of grazing levels within and between pastures (Carvell 2002; Sjodin 2008). As well, while it seems obvious, grazing management should be such that invasive plant species are controlled and flowering native plants thrive.

The End of This Story

This is where this booklet ends. In the appendices you'll find a summary of all the ideas given in the publication to protect, create and manage pollinator habitat on your land. You'll also find a list of the many useful pollinator conservation resources that you can look up on the internet. There are many organizations working on pollinator conservation and putting together some incredible information about pollinators, pollination services, conservation and its relationship to agriculture. We hope the list gives you a sense not only that it is an important subject, but also that you are not alone! We encourage you to explore and use these resources, as well as tap into the groups and agencies that exist in so many of the agricultural regions across Canada that can help you with your pollination conservation efforts.

If you've read this far, we're grateful. But more importantly, it also means that you are well on your way. Build on the momentum you've created for yourself. There is a deceptively simple saying that stems from ecological thinking that goes "You Cannot Do Only One Thing". By taking up the task of pollinator conservation, you will do much more than conserve pollinators and pollination services. We'll leave it to you to find out what.

Appendix A: Summary of What You Can Do to Protect, Create and Manage Pollinator Habitat on your Farm/Ranch

Conservation Strategy	Component	Element	Description
Save What You've Got	Habitat	Identify land types with good potential to support pollinators (forage, nesting and over-wintering habitats)	Any untilled land; field margins (shelterbelts, remnant treed areas, and even grassed ditches); roadsides; areas around buildings and corrals; hay and pasture lands; forested areas (standing dead/decaying trees, deadfall and hollow-stemmed plants (e.g., raspberry, elderberry, sumac, box elder); riparian habitat along streams and around wetlands; unused inaccessible areas (e.g., rocky areas); flower gardens; well-drained, sunny, south-facing slopes; areas with bare soil; muddy or poorly-drained areas; old rodent burrows; tussocks of bunch grasses; old compost piles; boulders; bird houses; shaded areas of exposed soil or thick leaf litter
	Pollinators	Look for pollinators on flowers	Bees, wasps, flies, butterflies, moths, beetles
	Flowers	Look for nectar- and pollen-rich flower species	Native flowering trees, shrubs and forbs, different flower species that bloom at different times, a range of flower colours, a range of flower types from deep and narrow to shallow and wide, a range of flower heights

Conservation Strategy	Component	Element	Description
Create New Habitat	Site Selection	Crops that benefit from pollinators	Site habitat as near as possible to benefitting crop
		Presence of bees	Site habitat in areas where native bees are already present (see Save What You've Got section above)
		Presence of bee habitat	Site habitat in areas offering what bees need (see Save What You've Got section above)
		Maximum distance to crop	Site habitat such that the maximum distance bees would have to travel to pollinate the crop is no more than 150 m
		Connecting habitat across the landscape	To the extent possible, site the habitat such that it has potential to connect to existing vegetated non-cropped areas (e.g., other field margins, riparian areas, forested blocks)
	Habitat Design	Size and shape	Habitats should be designed to be as large as possible
			Broad curves can be used on linear buffers to create more habitat "edge"
		Orientation	Site habitat to maximize sun exposure
			For linear field margin habitats, large trees should be limited to north edges of east-west oriented habitats to conserve south exposures for flowering plants and nesting sites
			For linear field margin habitats, large trees should be limited in north-south oriented habitats to increase sunlight within the habitat

Create New Habitat	Habitat Design	Plant grouping	To the extent possible, clump flowering plants to cover an area of at least 1 m^2
			Where clumping is impractical, increase the number of flowering plants in the buffer
		Plant species selection	Strive to include 20 species of flowering plants with overlapping flowering periods such that some flowers are always available from April to October
			Select plant species that offer good pollen and/or nectar resources (or are known to be used by bees)
			Select plant species that have flowers that range from open and shallow to deep and complex
			Select plant species that grow to different heights, have different growth habits and whose flowers are of a range of colours
			Wherever possible, use plant species endemic to the local area
		Nesting resources	Leave logs and stumps to decay in sunny areas of the habitat to create nesting habitat for tunnel-nesting bees
			Include at least one warm-season (C4) bunch grass in the habitat
			Use south-sloping or well-drained areas of bare soil for nesting habitat
			Leave or provide rock and/or brush piles to provide over-wintering sites for bumble bees
			Plant a diversity of plant species to provide resin and other nest-building materials
			Leave poorly drained or otherwise wet areas to provide clay and moisture for nest-building

Create New Habitat	Establishment and Maintenance	Irrigation	In drought-prone regions, plan for irrigation for the first two years after planting
		Weed suppression	Use tillage or herbicide with low toxicity and persistence to prepare the site, ideally one year ahead of planting
			Install mulch (wood or plastic) to suppress weeds to facilitate establishment
		Pesticide use	Plan to minimize pesticide use in proximity to the habitat
			Where it doesn't conflict with habitat design, plant coniferous trees along inside edge of habitat to mitigate pesticide drift
			Plan on avoiding use of pesticides when bees are most active and when the crop is flowering

Conservation Strategy	Component	Element	Description
Manage to Benefit Pollinators	Use of Pesticides	General use	To the extent possible, minimize the use of pesticides, whether on field crops or within habitat plantings to control invasive and noxious weeds, to protect pollinators and other beneficial insects
		Timing	Limit the use of pesticides in fields to early in the morning and after sunset to avoid direct contact with foraging bees, and avoid using them during crop flowering
		Within pollinator habitat	In general, don't use herbicides around native flowering plants, especially when they are in flower, or around butterfly larval host plants when caterpillars are present
			Where pesticides must be used (to control invasive alien species or noxious weeds) use wicks or handheld sprayers and take care to only spray target plants
		Create diversity	Employ a variety of grazing levels within and between pastures
	Grazing	Control weeds	To the extent possible, use grazing management strategies to control invasive plants

Appendix B: Useful Resources and Contacts

Biorationals: Ecological Pest Management Database

www.attra.ncat.org
Click on "Databases" and then "Biorationals: Ecological Pest Management Database"

Bumble Bee Pages

www.bumblebee.org

Communicating Ecosystem Services

Ecological Society of America
www.esa.org/ecoservices
"Pollination Tool Kit"

Discover Life

www.discoverlife.org
Resources to help study wildlife, including keys to identify bees, wasps, flies, moths, butterflies and beetles

Great Pollinator Project

http://greatpollinatorproject.org/
Although focused on the pollinators of New York City, this site has all kinds of great information about the lives of pollinators and attracting them

Native Plant Network

www.nativeplantnetwork.org
Information on growing plants from seed

NatureServe

www.natureserve.org
An online encyclopedia of information on more than 70,000 plants, animals and ecosystems of the United States and Canada

Pollination Canada

www.pollinationcanada.ca

Pollinator Partnership

www.pollinator.org
Founder of the North American Pollinator Protection Campaign, which is a consortium of conservation groups, government agencies, universities and private industries from the United States, Mexico and Canada that share information and work together for the good of pollinators

The Pollination Home Page

www.pollinator.com
A website of information on bees, beekeeping and crop pollination

The Xerces Society for Invertebrate Conservation

http://www.xerces.org/
Bee biology, conservation advice, butterfly gardening and links

USDA, Natural Resources Conservation Service Documents for Pollinator Conservation and Enhancement

http://plants.usda.gov/pollinators/NRCSdocuments.html

References

Agriculture and Agri-Food Canada (2013) Statistical Overview of the Canadian Honey Industry 2012. Agriculture and Agri-Food Canada, Ottawa, ON, pp.

Carvalheiro LG, C.L. Seymour, S.W. Nicolson, and R. Veldtman (2012) Creating patches of native flowers facilitates crop pollination in large agricultural fields: mango as a case study. J Appl Ecol 49: 1373-1383.

Carvell C (2002) Habitat use and conservation of bumblebees (Bombus spp.) under different grassland management regimes. Biological Conservation 103: 33-49.

Carvell C, W.R. Meek, R.F. Pywell and M. Nowakowski (2004) The response of foraging bumblebees to successional change in newly created arable field margins. Biological Conservation 118: 327-339.

Collins SA, J.K. Connor, and G.E. Robinson (1997) Foraging behaviour of honey bees (Hymenoptera: Apidae) on Brassica nigra and B. rapa grown under simulated ambient and enhanced UV-B radiation. Behaviour 90: 102-106.

Corbet SA, I.H. Williams, and J.L. Osborne (1991) Bees and the pollination of crops and wild flowers in the European Community. Bee World 72: 47-59.

COSEWIC (2010) COSEWIC Assessment and Status Report on the Rusty-patched Bumble Bee Bombus affinis in Canada. In: CotSoEWi Canada (ed). Her Majesty the Queen in Right of Canada, Ottawa, ON, pp. 34

CSPNA (2007) Status of Pollinators in North America. The National Academies Press

Dainat B, D. vanEngelsdorp and P. Neumann (2012) Colony collapse disorder in Europe. Environmental Microbiology Reports 4: 123-125. DOI: 10.1111/j.1758-2229.2011.00312.x

Delaplane KS, and D.F. Mayer (2000) Crop Pollination By Bees. CABI Publishing, Wallingford, UK and New York, USA

Desneux N, A. Decourtye, and J.M. Delpuech (2007) The sublethal effects of pesticides on beneficial arthropods. Annu Rev Entomol 52: 81-106.

Di Pasquale G, M. Salignon, Y. Le Conte, Luc P. Belzunces, A. Decourtye, A. Kretzschmar, S. Suchail, J-L. Brunet and C. Alaux (2013) Influence of Pollen Nutrition on Honey Bee Health: Do Pollen Quality and Diversity Matter? PLoS ONE 8: e72016. DOI: 10.1371/journal.pone.0072016

Eilers EJ, C. Kremen, S. Smith Greenleaf, A.K. Garber, and A-M. Klein (2011) Contribution of Pollinator-Mediated Crops to Nutrients in the Human Food Supply. PLoS ONE 6: e21363. DOI: 10.1371/journal.pone.0021363

Gathmann A, and T. Tscharntke (2002) Foraging ranges of solitary bees. Journal of Animal Ecology 71: 757-764.

Girling RD, I. Lusebrink, E. Farthing, T.A. Newman and G.M. Poppy (2013) Diesel exhaust rapidly degrades floral odours used by honeybees. Sci Rep 3. DOI: 10.1038/srep02779 http://www.nature.com/srep/2013/131003/srep02779/abs/srep02779.html#supplementary-information

Goulson D, G.C. Lye and B. Darvill (2008) Decline and Conservation of Bumble Bees. Annual Review of Entomology 53: 191-208. DOI: doi:10.1146/annurev.ento.53.103106.093454

Grixtia JC, L.T. Wong, S.A. Cameron and C. Favreta (2009) Decline of bumble bees (Bombus) in the North American Midwest. Biol Conserv 142: 75-84.

Hatfield RG, and G. LeBuhn (2007) Patch and landscape factors shape community assemblage of bumble bees, Bombus spp. (Hymenoptera: Apidae), in montane meadows. Biological Conservation 139: 150-158.

Hopwood JL (2008) The contribution of roadside grassland restorations to native bee conservation. Biological Conservation 141: 2632-2640.

Jauker F, B. Bondarenko, H.C. Becker and I. Steffan-Dewenter (2012) Pollination efficiency of wild bees and hoverflies provided to oilseed rape. Agricultural and Forest Entomology 14: 81-87. DOI: 10.1111/j.1461-9563.2011.00541.x

Kearns CA (2001) North American Dipteran Pollinators: Assessing Their Value and Conservation Status. Ecology and Society 5.

Kearns CA, and D.W. Inouye (1997) Pollinators, flowering plants, and conservation biology. BioScience 47: 297-307.

Kearns CA, D.W. Inouye, N.W. Waser (1998) Endangered mutualisms: the conservation of plant-pollinator interactions. Annual Review of Ecology, Evolution, and Systematics 29: 83-112.

Kevan PG (1975) Forest application of the insecticide Fenitrothion and its effect on wild bee pollinators (Hymenoptera: Apoidea) of lowbush blueberries (Vaccinium spp.) in Southern New Brunswick, Canada. Biol Conserv 7: 301–309.

Klein A-M, B.E. Vaissiere, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen and T. Tscharantke (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B 274: 303-313.

Kremen C, N.M. Williams and R.W. Thorp (2002) Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences of the United States of America 99: 16812-16816.

Kruess A, and T. Tscharantke (2002) Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. Conservation Biology 16: 1570-1580.

Larsen TH, N. Williams, C. Kremen (2005) Extinction order and altered community structure rapidly disrupt ecosystem functioning. Ecol Lett 8: 538–547.

Loose JL, F.A. Drummond, F. A., C. Stubbs, S. Woods and S. Hoffman (2005) Conservation and management of native bees in cranberry Technical Bulletin 191. Maine Agricultural and Forest Experiment Station, University of Maine, Orono, ME, pp. 27

Mader E, M. Shepherd, M. Vaughan, S. Hoffman Black, G. LeBuhn (2011) Attracting native pollinators -- protecting North America's bees and butterflies. Storey Publishing, North Adams, Maryland

Michener CD (2007) The bees of the world, second edition. Second edn. The Johns Hopkins University Press, Baltimore, Maryland, U.S.A.

Miles CA, and M. Nicholson (2003) Can Cover Crops Control Weeds? Two-year Study Tests Efficacy in Vegetable Production Systems. Agrichemical and Environmental News: 1-7.

O'Toole C, and A. Raw (1991) Bees of the world. Blandford Publishing, London, UK

Osborne JL, and J.B. Free (2003) Flowering and Reproduction: Pollination. In: B Thomas, DJ Murphy, BG Murray (eds) Encyclopedia of Applied Plant Sciences. Elsevier, UK, pp. 315-325

Pettis JS, E.M. Lichtenberg, M. Andree, J. Stitzinger, R. Rose and D. vanEngelsdorp (2013) Crop Pollination Exposes Honey Bees to Pesticides Which Alters Their Susceptibility to the Gut Pathogen *Nosema ceranae*. PLoS ONE 8: e70182. DOI: 10.1371/journal.pone.0070182

Potts SG, B. Vulliamy, A.Dafni, G. Ne'eman, and P. Willmer (2003) Linking bees and flowers: how do floral communities structure pollinator communities? Ecology 84: 2628-2642. DOI: doi:10.1890/02-0136

Potts SG, J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger and W.E. Kunin (2010) Global pollinator declines: trends, impacts and drivers. Trends in Ecology & Evolution In Press, Corrected Proof. DOI: DOI: 10.1016/j.tree.2010.01.007

Richards AJ (2001) Does Low Biodiversity Resulting from Modern Agricultural Practice Affect Crop Pollination and Yield? Ann Bot 88: 165-172. DOI: 10.1006/anbo.2001.1463

Richards KW, and P.G. Kevan (2002) Aspects of bee biodiversity, crop pollination, and conservation in Canada. Ministry of Environment Brasilia

Roulston TH, and K. Goodell (2011) The role of resources and risks in regulating wild bee populations. Ann Rev Entomol 56: 293-312.

Sjodin NE, J. Bengtsson and B. Ekbom (2008) The influence of grazing intensity and landscape composition on the diversity and abundance of flower-visiting insects. Journal of Applied Ecology 45: 763-772.

Statistics Canada (2011a) Farm cash receipts. In: S Canada (ed). Minister of Industry, Ottawa, ON, pp. 45

Statistics Canada (2011b) Production and value of honey and maple products. In: S Canada (ed), Ottawa, pp. 6

van der Zee R, L. Pisa, S. Andonov, R. Brodschneider, J.-D. Charrière, R. Chlebo, M. F. Coffey, K. Crailsheim, B. Dahle, A. Gajda, A. Gray, M.M. Drazic, M. Higes, L. Kauko, A. Kence, M. Kence, N. Kezic, H. Kiprijanovska, J. Kralj, P. Kristiansen, R. M. Hernandez, F. Mutinelli, B.K. Nguyen, C. Otten, A. Özkırım, S.F. Pernal, M. Peterson, G. Ramsay, V. Santrac, V. Soroker, G. Topolska, A. Uzunov, F. Vejsnæs, S. Wei, S. Wilkins (2012) Managed honey bee colony losses in Canada, China, Europe, Israel and Turkey, for the winters of 2008-9 and 2009-10. J Apic Res 51: 100-114.

vanEngelsdorp D, D. Caron, J. Hayes, R. Underwood, M. Henson, K. Rennich, A. Spleen, M. Andree, R. Snyder, K. Lee, K. Roccasecca, M. Wilson, J. Wilkes, E. Lengerich, and J. Pettis (2012) A national survey of managed honey bee 2010-11 winter colony losses in the USA: results from the Bee Informed Partnership. J Apic Res 51: 115-124.

Vaughan M, M. Shepherd, C. Kremen and S.H. Black (2004) Farming for bees: guidelines for providing native bee habitat on farms. The Xerces Society, Portland, OR

Yoshihara Y, B. Chimeddorj, B. Buuveibaatar, B. Lhagvasuren and S. Takatsuki (2008) Effects of livestock grazing on pollination on a steppe in eastern Mongolia. Biological Conservation 141: 2376-2386.