Raising awareness among Canadians about plant pollinators and the importance of monitoring and conserving them
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Pollen on the back of this carpenter bee gets a ride to the next wild pea flower. In exchange for this pollination service, the bee gets food for itself and its larvae.

Preface

Floral ecology and pollinator conservation are relatively new concerns within the environmental community. Pollination by insects, however, is such a fundamentally critical function to all terrestrial ecosystems that full attention to it is long overdue. The main purpose of this paper is to provide an information base about this function. Both monitoring and conservation issues are discussed as well. The intent here is to be comprehensive without relying on language that only the scientists specializing in this topic can read.

The floral ecosystem is complex and varied. Whether or not one chooses to be proactive in conserving insect pollinators, a better understanding and appreciation of the pollination ecosystem is still a rewarding experience. One concept that is followed in this document addresses the co-evolution of flowers with pollinating insects which resulted in the wide assortment of flower colours, sizes and shapes that humans find so pleasing. The most remarkable diversity, however, is encountered on the insect side of this system. What is even more remarkable, and sobering, is how heavily dependant both global ecosystems and the human food chain are to insect pollination. The process which takes place on a patch of flowers in bloom has all the attributes one would expect in a typical ecosystem, including forage, foragers and predators. Within this system many complex societies thrive. Like our own social structures, these societies support workers, ruling classes, lone wanderers and a criminal element - the cleptoparasites, predators and assorted other parasites. But the biggest threats that these communities face are from humans. In order to ensure that a diverse and healthy set of pollinator ecosystems survives, the first step is a better public understanding and an effective use of citizen science in monitoring these pollinating insects.

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PART I - THE CONCERN ABOUT POLLINATORS

In 1962, Rachel Carson grabbed the world's attention with "Silent Spring," launching the modern environmental movement. Another 30 years would pass before a similar, high-profile public out-reach would target the true value of flower visitors in "The Forgotten Pollinators."[11] Recognizing this milestone should not over-shadow the efforts of those scientists who have been studying this issue for several decades, nor the gardeners, field naturalists and other volunteers who have stepped forward to champion pollinator conservation. Up to 200,000 animals help pollinate the 250,000 kinds of flowers. Animals pollinate three-quarters of the world's staple crops, 80% of all flowering plants in temperate climates[57] and 90% globally.[5,32] One mouthful in three requires insect pollination.[26] Since 25% of all birds eat seeds or fruit, they are also dependent on pollinators.[5] Quite simply, without pollinators, the entire terrestrial globe would look entirely different and would not be able support the number of people that it currently does. There is a wide-spread lack of appreciation and knowledge about native bee species and other pollinators.[40] For example, most Canadians are unaware that about 1,000 wild bees live in Canada.[69] To understand the insect-flower relationship is to appreciate a special chapter in the story of evolution.[29]

Decision VI/5 of the *Convention on Biological Diversity* (CBD) adopted the *International Pollinators Initiative*, a plan of action for the conservation and sustainable use of plant pollinators. The initiative identifies the need to monitor changes in the diversity and abundance of pollinators, promote awareness about the value of pollinator diversity and build capacity to carry out pollinator inventories through training of both taxonomists and parataxonomists. The recruitment of parataxonomists begins with better public awareness and cooperation. Hence, there is a real need to inform the public, particularly gardeners, about plant-pollinator relationships, the threats that face pollinators and the need to conserve them.[64] The response to this initiative in Canada was to begin development of a volunteer-based pollinator monitoring program.

Several new organizations have recently taken up the pollinator conservation challenge and represent contact sources for those delving further into this issue. The Xerces Society, an international organization dedicated to preserving invertebrates, has prioritized the provision of homes for bees. This involves building bee nests in parks, golf courses and other potentially bee-friendly public places. The North American Pollinator Protection Campaign (NAPPC) is an alliance of researchers, conservation and environmental groups, private industry and government. NAPPC's goal is to improve public awareness and policy. Their emphasis on the great interconnectedness of life in general is an important message. The American Museum of Natural History and the Illinois Natural History Survey run an annual International Bee Course at its field station in Arizona where people interested in learning how to identify bees are taught by a team of North American experts.[62] Seeds of Diversity Canada (SoDC) is an organization dedicated to preserving open-pollinated heritage crop varieties. SoDC has recognized the importance of pollinators to heritage seeds and has accepted a partnership role in organizing a volunteer pollinator monitoring program.

The Role of the Amateur Observer

In the context of pollination, a parataxonomist is an amateur observer capable of making and recording scientifically valid sightings of flower-visiting insects. This observer must recognize the differences among the most common groups of insects that frequent flowers. Some knowledge of floral and insect anatomy and morphology (shapes), at least in lay terms, are useful. An appreciation of the purpose of the visitors, if not for pollination, is also beneficial. Pollinators are threatened as much by lack of awareness about their importance to plants as by pesticides, invasive species and habitat destruction.[39,51] Pollinators are keystone species, meaning that most other species in their respective ecosystems depend on them, either directly or indirectly.[64] Pollination ecology is still too weak a discipline to deal with the threats that face floral ecosystems.[11] Poor spatial resolution in pollinator observations is a major weakness and a gap that can be partly filled by volunteers. While reliable taxonomic identification of all pollinating species is too much to expect of most volunteers, they can still collectively shed considerable light on insect diversity and the conditions in which these pollinators do their work.

The following text is intended to both raise awareness of pollinators and provide background for those volunteer observers of insect pollinators who are motivated to delve into the pollination issue in more depth. The intent here is to inform, rather than preach, because if you have read this far, motivation is not the issue. It is unlikely to be any more than a refresher for most graduate biologists, particularly those with training in entomology. Parataxonomy is treated as an instrument that must strengthen ecological monitoring as much as taxonomy. Instead of using destructive sampling of insects for study, the alternative of observing and recording insects as they forage and pollinate[1,7] is the basis of the monitoring program described here.

Terminology will be kept as simple as possible and explained where necessary, and common names will be given preference over scientific labels. To begin with, the standard scheme used by biologists to identify organisms can be simplified to a six-level taxonomic classification system, including phylum, class, order, family, genus and species. But suborder, superfamily, and subfamily distinctions will also be made in the following descriptions. Insects make up most of the class Hexapoda of the phylum Arthropoda. Bees, the main pollinators, make up most of the insects in the superfamily Apoidea.[56] Honeybees are one genus (*Apis*) among the bees and the domesticated honeybee, *Apis mellifera*, is one of the less than a dozen species in this genus.

The proposed volunteer pollinator monitoring program was inspired by the parataxonomy concept. Ideally, parataxonomy should serve research by monitoring changes in the pollinator community (which pollinators and their numbers) at particular spots, surveyed during the same periods (season, date or time of day) and in different rural and urban landscapes. There are some easily identified bees that have recently invaded Canada and tracking their increase in distribution will be of interest. There are a few native bees that can be easily identified as well.

However, it was also recognized during conception of a pollinator monitoring program that such scientific monitoring would require a higher degree of recognition skills than can be expected of most amateur observers. In the following text an effort was made to present in relatively plain language the basic features of the pollinator community, how it interacts with the plants that supply the floral forage products, and an introduction to some of the key members of that community. Once this background setting has been established, the basic expectations of volunteers, along with some observer guidance, will be laid out in Part IV. In trying to raise public awareness about insect pollinators, the threats they face and the conservation measures under consideration, it is hoped that some readers will try to embrace the challenge of the proposed volunteer pollinator monitoring program, if they haven't already.

PART II – UNDERSTANDING THE POLLINATOR ECOSYSTEM

Flowers as Seen by Insects

Flowering plants, or angiosperms, make up 80% of the world's vegetation and almost all food crops.[29] Since pollinator diversity is a new concern for the public, a quick review of the descriptive terms of flowers will facilitate a common level of understanding of the interdependence of flowers and insects. While scientific discussions must rely on their own technical terms, they are used here only to encapsulate each concept. So committing them to memory is not a prerequisite to becoming a successful observer.

Flower tissue includes sepals (taken collectively they form the calyx), petals (taken collectively they form the corolla), the pistil (the flower's female organ) and the stamen (the male organ). These four tissue groups are attached at the flower receptacle by the bract (green tissue) to a special stem called the peduncle (or pedicel if the flower is part of a cluster). When they are all present the flower is complete.

The filament and anther at its tip together make up the stamen. Each anther contains two pollen sacs. The pistil consists of the stigma and the ovary, which are connected by the style. The stigma is intended to catch pollen, the male reproductive cells. The ovary houses ovules, the plant-equivalent of unfertilized eggs. A flower can have one or more stamens or pistils, or compound pistils bound together. In a compound pistil, each ovary-housing is called a carpel.[10] The nectary, the plant tissue of high interest to most pollinators, is inside and below the petals and sepals. Illustration 1 provides diagrams of a flower and a generic insect with these parts labeled.

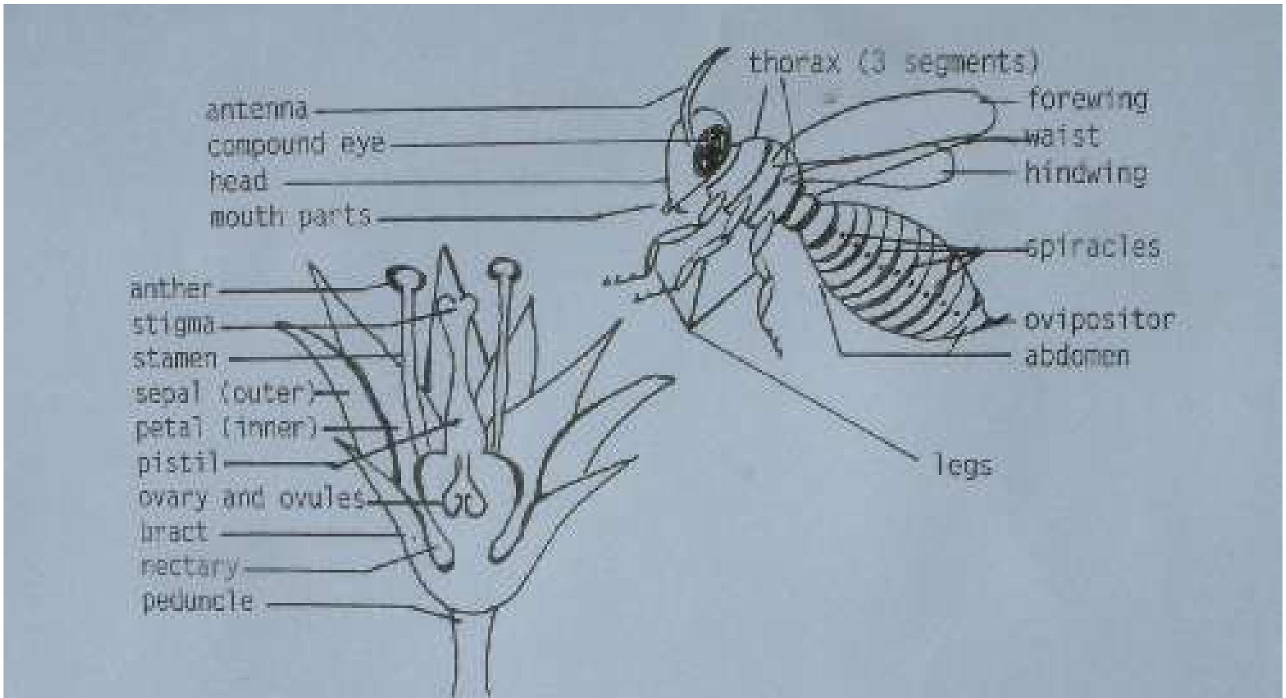

Illustration 1. Recognizable features of a generic cutaway flower and external features of a pollinating insect (in this case a bee, although all insect pollinators have much the same body plan). Hair is not shown.

A complete flower is hermaphroditic and produces both male and female gametes, or sex cells.[29] Flowers missing either stamens or pistils are incomplete, and are called either staminate (male) or pistilate (female).[10] If the same plant has both staminate and pistilate and no hermaphroditic flowers, it is monoecious. If staminate and pistilate flowers are on separate plants, they are dioecious. But most flowers are complete, or at least hermaphroditic. Flowers may also be asepalous (missing sepals) or apetalous (missing petals), or gamosepalous if the calyx is fused, or gamopetalous if the corolla is fused. An irregular flower (not radially symmetrical) can have two petals fused together to form a keel. When multiple flowers on the same plant are grouped together into a single floral presentation, they form an inflorescence.[10] A pseudoanthia, or false flower, occurs when an inflorescence can imitate a solitary flower.[45]

Pollination is the transfer of pollen from an anther to a stigma[14,38] where it can fertilize the ovule by growing a tube down through the stigma.[10] Flowering plants produce fruit or seeds only after pollination.[10,14,37] The flowers of wind-pollinated plants, including grasses, sedges, rushes, stinging nettles and many trees, do not have elaborate insect-attracting structures. While cereals (descended from wild annual grasses) are wind-pollinated, most orchard fruits, market vegetables, some field crops, clovers and legumes are insect-pollinated.[6] Apples and other tree fruit depend on pollination to produce a viable crop.[26] In self-pollination, pollen is transferred to a stigma within the same flower before it opens, which is a process known as cleistogamy.[37] Flowers can be self-pollinating and self-compatible, but still be pollinated after they open, which is known as chasmogamy. Often, self-pollinating crops, such as canola and sunflower, are more productive when they receive pollen from another plant. Self-fertile plants set fruit or seed with their own pollen.[23] Self-infertile plants need cross-pollination - pollen from other plants - to produce fertile seeds. Cross-pollination of self-compatible species usually increases the size, quality and quantity of their seed or fruit.[23,50]

In order to utilize pollinators, flowers must attract the insect, stick pollen to the visitor, and usually reward the visitor.[20,57] In exchange for offering nectar and pollen to pollinators, most flowers can succeed with far less pollen than wind-pollinated plants.[57] Occasionally, extra-floral nectaries have an indirect use for self-defense. They achieve this by attracting omnivorous insects that still need nectar, but are also predators that will attack the nearest insect herbivores.[26] Males of both ambush bugs and crab spiders (two floral-based predators) will take nectar to sustain their search for females.[58,74] Nectar is derived from phloem sap and emitted by floral glands called nectaries[10,38] located below the anthers so that insect tongues or heads will pick up pollen while feeding.[57] Nectar is mostly water and sugar, plus a wide array of organic compounds and minerals in trace amounts.[24,57] Sugar is more concentrated in flowers that use more specialized pollinators. Nectar with the highest amino acids is taken by insects that don't take pollen. All 20 protein amino acids are in nectar.[38] Since nectar production is costly to the plant, some genera, such as *Cucurbita* and *Linaria*, recover the energy invested in nectar by resorption if pollinator visits are down or during inclement weather or if the nectar is not too concentrated. Under arid climate conditions, water evaporation from nectar can be reduced by closure of the corolla.[53]

Floral energy balance pits what sap the flower can afford to give up as nectar against what the insect needs to survive and continue visiting.[38] It reflects the degree of insect-plant co-evolution. Insects consume much energy in flight. Bees typically metabolize 10-11 mg of sugar per hour. For every two hours of continuous activity, a honey bee consumes its own weight in sugar.[20] A pound of white clover honey is the result of nine million flowers visited by honeybees.[38] For cross-pollination, some flowers on each plant must be visited, but the right nectar flow is needed so that pollinators do not stay too long at any one flower. Plants never invest more than 5% of their total productivity in nectar.[9]

Figure 1. Although most bees, particularly honeybees (Apis mellifera), rake most of the pollen they gather into their pollen baskets, the only viable pollen is that which sticks to their back where it can't be reached. The honeybee is what most people think of when bees are mentioned, even though it is not native to North America.

Obligatory flower feeders, such as adult bees and butterflies, derive all of their nutrients from flowers.[9] Nectar is the ideal food for such insects, providing easily digested, high energy sugars, namely sucrose, fructose and glucose. A dilemma that plants must deal with is that their floral products can be attractive to visitors that are ineffective pollinators.[57] Complex, even exotic, flower appearance is usually an effort to restrict their rewards to effective pollinators. Decoy nectaries, often external to the flower, also serve this purpose.[10,38] Because many flowers require loyalty from their insect partners, insects with memory (such as bees and some flies), or those that have evolved innate preferences, often make better partners.[9]

Pollen is secondary to nectar as a floral feed reward for most insects. Because it is rich in protein, between seven and 35%,[57] and starch, it is a vital food to the minor or primitive pollinators, as well as to bee larvae, which are totally dependent on pollen, nectar and in some instances floral oils.[26,56,71] In plants that don't offer nectar, pollen can be rich in lipids, including sterols that are building blocks of hormones and pheromones. Pollen can also contain vitamins, enzymes and pigments. Special food bodies called staminodes (non-pollen-producing stamen) satiate floral-destructive insects.[38] Some plants that need pollination, such as wild roses or kiwi fruit, don't even produce nectar.[19,37] Plants must ensure that any one visiting insect does not take so much pollen in one visit that pollination success is jeopardized by that insect either returning directly to its nest satiated or not leaving any floral rewards for the next visitor. Many complex flowers force bees to forage in a restricted position so that some pollen becomes attached to a part of their body that cannot be easily groomed into their pollen baskets,[71] thereby ensuring pollen transfer.

Climate affects pollinator roles.[35] Butterflies and flies often replace bees at high altitudes on temperate mountains. Flies also dominate arctic areas. Simple pollinators thrive when specialty pollinators are not present. Pollinators are essential to ensure gene flow within plant populations. Climate change may push the range of many pollinators northward, but will have the biggest impact on alpine species that cannot gradually move north.[64] British experience has shown that micro-climate disruptions created by land use changes can have a damaging effect on pollinators.[11] Pristine climax forests are not as productive of floral forage as open canopy or coppiced woodlots, because the ecological succession is arrested. The same effect is seen in sites with thin soil.

People often associate flowers with their odour because flowers employ a wide range of aromas. Butterfly-pollinated flowers are the weakest scented, whereas flowers pollinated by nocturnal moths have a heavy sweet scent. Alpine flowers can be sweet and attractive to bumblebees, or skunky (like carrion or dung) and attract flies[9,38] since most flies are attracted to carrion odours.[55]

Floral Evolution and Morphology

Flower morphology reflects the means of pollination.[38,39] Present-day flowers that rely on pollinators can be classified by their morphology (shape and structure), or features that are a response to selective activity and sensory abilities of their pollinators.[45] Flowering plants and insects have co-evolved for over 200 million years.[10,38] Entomophilous (insect-attracting) plants reflect six distinct floral evolution stages, including amorphic, haplomorphic, actinomorphic, pleomorphic, stereomorphic and zygomorphic.[45] These levels sometimes demonstrate convergence across taxonomically unrelated plant groups, although most types tend to typify specific plant orders. For example, most legumes are zygomorphic.

Haplomorphic flowers are generally hemispheric and actinomorphic flowers are radial and flat. Distinct radial spokes composed of petals and/or sepals make their appearance in pleomorphic flowers. Stereomorphic and zygomorphic flowers are considered complex. Tubular corollas characterize the three dimensional stereomorphic flowers. Zygomorphic flowers, sometimes referred to as irregular, are bilateral as well as three dimensional. No amorphic floral types have survived, but many haplomorphic flowers such as dandelions still exist.[45] Although these terms are useful to the plant physiologists who study floral evolution and morphology, an understanding in less technical language can still provide useful insight into the diversity that plants bring to pollinator ecology.

The floral shapes described are better identified by their common names including: (1) dome, (2) cup, (3) radial, (4), numeric radial (5), tubular, and (6) bilateral. This set of floral shape classes has been modified here from their original form[45] by adding the cup-shaped flowers and expanding the tubular flowers to include trumpet shapes. Regardless of which of these two floral morphology descriptions is cited, it is important to remember that they are conceptual guidelines, rather than rigid classification schemes. The following list illustrates how the descriptive classes correspond.

- haplomorphic (1) dome (dandelions) and (2) cup (buttercups) shaped,

- actinomorphic (3) flat radial with many spokes (daisies),
- pleomorphic (4) radial spokes of petals or sepals in numeric patterns (chickweed),
- stereomorphic (5) tubular corollas & three dimensional (morning glory),
- zygomorphic (6) irregular & bilateral (snap dragons),
- amorphic (no flowers of this type have survived).

Floral evolution was driven by the increasing ability of insects to recognize and memorize floral characteristics as the more skilled insects responded to more sophisticated signals. Haplomorphic flowers evolved into the two-coloured concentric rings of the actinomorphic flowers.[45] The radial patterns of pleomorphic flowers convey numeral signals which honeybees, wild bees, bumblebees, butterflies and some flies can distinguish.[45] The iconic numerals recognized by these insects represent numbers 1 to 12, missing seven and eleven, although three, four and five are the most common. Three or six "spokes" of a pleomorphic flower typify monocots such as grasses, lilies and sedges, whereas four, five and eight "spokes" are typical of dicots, including the most common vegetables.[28] Iconic numerals for six and eight are produced by three petals and three alternating sepals, or by four of each. Iconic numerals have disappeared in the bilateral, zygomorphic flowers.[45] Development of protected nectaries began with the pleomorphic flowers developing cup nectaries. The next level was spur nectaries in stereomorphic flowers, followed by coiled nectaries in the zygomorphic flowers. To reward the more specialized visitors, more complex flowers offer more nectar, but they make it more difficult to obtain.

Unrelated plants often form similar floral patterns from different plant tissues, such as petals, sepals, bracts or even leaves. Haplomorphic and actinomorphic flowers are visited by beetles, flies and occasionally by ants. Bumblebees, butterflies and some of the other large wild bees mainly prefer pleomorphic, stereomorphic and zygomorphic flowers.[45] Zygomorphic flowers, which are specialized bee flowers, diverged from stereomorphic flowers.[29] In the alfalfa or lucerne (*Medicago sativa*) flower (which is zygomorphic), the staminal column is kept under pressure within the keel. When penetrated, it snaps forward, or trips, to distribute the pollen so that some will stick to the bee, usually its back where the bee cannot rake it down to the pollen basket. The flowers that remain un-tripped do not seed.[54]

How flowers on the same stem organize themselves affects the ease by which they are navigated by foraging insects. Large flowers are often actually tight clusters of small incomplete flowers attached in an inflorescence to a ball or disk of plant tissue, such as asters and sunflowers, instead of a solitary flower, such as a rose.[10] Floral displays also often appear as floral clusters, such as lilacs. Both solitary flowers and floret clusters on the same plant can array themselves as a spike, a raceme, an umbel, or compounded forms of these arrays. The result is another five categories for describing flower structure:

- spike: floral array alternating top to bottom on one stem each very close to the stem.
- raceme: floral array alternating on one stem but each flower (or floret) has its own stem.
- compound raceme: raceme stems branch off a main stem in a raceme pattern (panicle).
- umbel: each flower (or floret) has its own stem but all stems radiate from one point.
- compound umbel: array of umbels all radiate from one point.

The separate stems of racemes or umbels, or their compound forms, are sometimes extended to form a flat plain of flowers or florets (floral plains) across which large pollinators can walk as they forage (for example, Queen Ann's Lace). These plains accommodate butterflies that need a landing platform to feed, but also provide perfect cover for stationary predators like the elaborately camouflaged ambush bugs[7] and crab spiders[1].

Other than these general morphological principles, no specific guidance is given here on plant identification because there are so many good field guide books available on wild flowers and weeds. As well, flowers can be handled and examined closely, and unlike insects, are sessile. However, an appreciation of the diversity among floral shapes and display helps one understand how interconnected plant-insect co-evolution has been.[9,45]

Insect Pollinators

There are between 25 and 30 insect orders, depending on which classification scheme is quoted, which are grouped into three subclasses based on wing morphology.[6,66,73] In common language, these groups are the wingless insects, including silverfish, firebrats and jumping bristletails (Apterygpota), old-winged insects, including mayflies, dragonflies and damselflies (Palaeoptera) and the new-winged insects, including all of the remaining insects (Neopterygota). Unlike mayflies and dragonflies, the "new-winged" insects can rotate their wings over their bodies, so they can crawl into small spaces.

Most living insects are in the third subclass. The Neopterygota contains all of the insect pollinators and is further sub-divided as to whether the transition from egg to adult is an incomplete or a complete metamorphosis.[6] When insect development entails a caterpillar, grub or maggot-like larva that must pupate before becoming a breeding adult, it is complete; it is incomplete when the insect grows through a series of nymphal stages, called instars, resembling small adults (except in aquatic families) with immature wings. The pollinating insect orders that occur in Canada are Coleoptera (beetles), Diptera (flies), Hymenoptera (bees), and Lepidoptera (butterflies).

To fully appreciate pollinator diversity, some understanding of insect anatomy will be an asset. Insect bodies are separated into the head, thorax and abdomen.[65,66,73] The insect head bears the eyes, mouth parts and antennae. For all insects, the thorax bears the three pairs of legs, one on each segment, and the two pairs of wings, on the last two segments.[1,6] The three segments of the thorax are labeled 'pro-' (nearest to the head), 'meso-' and 'meta-' (furthest from the head). The top of the first segment, the pronotum, on beetles is the top, and only visible, part of the prothorax.

Wings are a very useful means of distinguishing major groups of pollinators. For example, flies have one pair and bees have two pairs of wings. The hind pair of wings in true flies has been modified into small gyroscopic balancing organs that can be seen, upon close inspection, just behind the base of the first pair. Bee wings are very effectively hooked together during flight, so it often looks as if they only have one pair. In beetles and true bugs the front pair of wings is hardened and leathery. The wings are one way to tell these two fairly common flower visitors apart. Beetles have a straight margin down the middle of their back where the forewings meet, rather than having one wing overlapped across the other which is the situation in true bugs and their relatives, aphids and cicadas.

Pollinating insects have evolved specialized mouth parts.[56] Butterflies and moths have a long narrow tubular proboscis through which nectar, and other liquids, can be sucked (see Figure 12). Most beetles have mouth parts primarily adapted for chewing with laterally moving mandibles. The chewing mouth parts provide another way of identifying beetles versus true bugs which have sucking, tubular mouth parts. Bees, wasps and flies have a more complex set of mouth parts that involve lapping and sucking structures but the flies no longer possess distinct mandibles, and so cannot bite or chew. Some bees use their mandibles to loosen pollen on anthers, most bees and wasps use their mandibles to help them construct their nests. As well, bees have evolved a tongue which allows them to sip nectar, and tongue-length is also a useful basis for grouping bee families (see Figure 4).

Figure 2. One family of bees, Megachilidae, stands out as using abdominal, rather than leg, hair as their pollen baskets. The highly valuable alfalfa leafcutter bee is in this family. The example in this illustration is in the Megachile genus.

Legs vary considerably among insects and are important in distinguishing most bees because of the pollen-collecting apparatus which is usually (but not always) on the hind legs.[7] While the abdomen has no appendages (except for the ovipositor or "stinger" at the tip), its shape is often helpful in identification, particularly for separating wasps and bees, and in distinguishing some bees. Body hair, a character of most bees, is a major adaptation to floral foraging and is usually one criteria of a good pollinator. Besides bees, two fly families, Syrphidae and Bombyliidae, have hairy bodies, as well as long proboscises.[36,66]

The lensless, compound eye of the insect is as well adapted to floral identification as it is to avoiding predation.[9] It does not focus an image as the vertebrate eye does, but transmits numerous cones of light to individual photoreceptors.[6,9] Visual acuity, the minimum angle subtended between distinguishable objects, is one sixteenth of a degree for humans and only two degrees for most insects. Flicker fusion, the frequency at which light pulses appear continuous, is 50 per second for humans and 300 for insects, giving insects much greater sensitivity to motion. As well as predator avoidance, it can allow rapid identification as the insect approaches a flower.[9,38]

Insects see ultraviolet, but most do not see red colour. Some insects, such as beetles, have only tonal vision and therefore do not see colours.[9,38] For insects, however, ultra-violet (UV) radiation is just another colour. Most insects, as well as humans, use trichromatic colour vision. Flower colours are more diverse and discrete to insects than to us due to vision in the UV range. Some butterflies see red, but floral red is intended mainly for bird pollinators (such as hummingbirds in Canada). Typical are multi-coloured, bull's-eye patterns (concentric rings) which draw the pollinator to the centre of the flower. Blue attracts bees, yellow attracts a wide variety of insects and pale flowers are often associated with nocturnal insects. Gardeners will be aware that many flowers change colour as they age. This seems to be a mechanism to ensure that pollinators only visit flowers that can provide or receive pollen for pollination. Older flowers that have already been pollinated change to colours that are less attractive to the pollinators.

Insect vision has another advantage over ours: a wide angle of coverage. Hence, some large-eyed insects, such as most flies, are very difficult to surprise. The compound eye has great forward-looking acuity because there are many densely packed ommatidia (eye cells) pointing forward.[73] The differentiation of various parts of the compound eye can be found in predatory insects but also in males that have to visually locate potential mates. Bees see polarized light and can recognize the orientation of that light.[49,54] They use this ability to navigate by the angle of the sun even when the sun is behind a cloud, as long as there is some blue sky.[49] On a day of full cloud cover, bees likely navigate by landmarks,[20] but their activity is sharply reduced.

Insects have become so successful and diverse largely because of the internal structures that are ideal for their small size. Insect blood and circulation are much simpler than vertebrate blood and circulation.[57] Their blood is composed of plasma and hemocytes that clean the blood by encapsulating invading bodies. Hormones, nutrients and waste are circulated in the plasma. Few insects have any blood pigments, so oxygen is also dissolved in the plasma, rather than having a specific transport mechanism like hemoglobin. The insect digestive system, compared to higher animals, is a rather simple, linear tube system through the body length. Blood cleansing is carried out by the malpighian tubules, the equivalent of the mammalian kidney, which empty into the hindgut.[65] The crop is the first storage cavity immediately behind a complex set of mouth parts. It can also provide temporary storage for nectar.[49] Insects breathe through spiracles, or openings along the thorax and abdomen (see Illustration 1), that lead to a network of interconnected tracheae (airways) throughout the body. With an exoskeleton, insect growth requires periodic molting.[6] The crop, hindgut and tracheal linings must all be shed with each molt.

Insect Behaviour and Adaptation

The range of floral forms means that there is a correspondingly wide range of insects that feed at, if not on, flowers.[38] Anthophile diversity is in the millions of species.[39] The major insect orders that pollinate include bees (Hymenoptera), several families of flies (Diptera), moths and butterflies

(Lepidoptera), and some beetle families (Coleoptera).[11,38,72] All four orders undergo complete metamorphosis.[6,63] A few insects that are not from these orders have a minor role in pollinating plants.[38] For example, thrips (Thysanoptera) often are more damaging than they are beneficial during pollination.[20,38] Other insects that are commonly found sitting on flowers include the true bugs (Hemiptera). Rather than pollinating flowers themselves, ambush and assassin bugs are usually waiting for pollinators so that they can eat them. Other floral-based predators include crab spiders and candy striped spiders.

Figure 3. Ambush bugs (Phymatidae) are neither beetles nor pollinators, but sucking bugs (Hemiptera) that may look hideous, but are well-suited to their stationary predatory lifestyle on wild flowers such as goldenrods and asters. Their big shoulders and arms (forelegs) help them to achieve an astounding 95% success rate in attacks on floral-foraging insects.

Not all anthophiles are effective pollinators, or pollinators at all. Some are floral larcenists or merely innocuous visitors. For example, concave petals of haplomorphic flowers (see above discussion of floral morphologies) offer protection to insects seeking shelter.[45] But most insects have important roles in the plant ecosystem, and are predators of insect pests in agriculture.[37] Many flies may feed on floral products for the adult part of their life-cycle, or use flowers to hide in or as a mating site, and as larvae are often important predators.[36,43] Flower-based predators usually pick flowers with the most nectar and pollen.[37,66] Although they often prey on pollinators, they are a minor threat:[37,38] their significance is that they illustrate the complexity of the floral ecosystem.

The co-evolution of insects and flowers is reflected in the diversity among pollinators.[38] To pollinate a flower, pollinators must visit and forage in such a way, within a specific period, that viable pollen is transferred to other flowers.[14] Individual flowers must reward, but not satiate, visitors so that they carry pollen to other flowers of the same species. The correct insect anatomical and behavioural fit and floral advertisement and rewards are required. Many flowers are effectively pollinated by a diversity of animals. Very few plants are pollinated by a single species.[37] An insect must be a frequent floral visitor in order to be effective. Because a plant only requires its pollinators for short periods of the year, these insects must either forage at other plants or shorten their adult life and schedule it to that particular flowering period.[57]

Figure 4. A close-up front view of this squash bee (Peponapis pruinosa) provides a good view of how bees have adapted their mouth parts for sipping nectar from nectaries below the flower's stamens and pistils. As a member of the Apidae, this bee illustrates the long-tongue bee.

Bees rank high as pollinators because they are obligatory flower feeders.[38] The entire bee life cycle is fed by floral products. With few exceptions, in one foraging run a bee will visit many flowers, promoting cross-pollination if the flowers are on different individual plants.[9] Foraging preferences are as diverse as insect anatomy.[38] For example, some species forage early in the day,[42] such as on sundrops, which open early in the morning and are visited by bees sometimes even before sunrise.[56] Evening primrose flowers open around sunset and are visited by crepuscular bees that are rarely, if ever, seen flying during the day. Some bees are truly nocturnal, often being more active on moonlit nights, but there are no strictly nocturnal bees in Canada.

Flowers that co-evolved with long-tongue bees (see Figure 4) are often large and bilaterally symmetrical, and have nectaries protected within a spur or tube (see Figure 7).[14] Shorter-tongue bees visit more flowers at a faster rate, while long-tongue bees go to specialized deep flowers. Foraging paths zig-zag, but on average, go straight across floral patches. Bees turn sharper and more often in richer patches. On tall stems with vertical distributions of flowers, bees visit the bottom flowers first and the top flowers last, and then move to the next plant. Since ripe female flowers are the lowermost, this ensures that pollen is transported to the next plant for cross-pollination. Nectar theft is usually done by small insects, but when larger insects turn to nectar robbing, the flower is usually damaged as the insect has to bite a hole near the base of a petal to steal the nectar.[38]

Hymenoptera

The Hymenoptera order is defined on the basis of its membranous wings, complete metamorphosis and males produced from unfertilized eggs.[56] Wing construction entails a moderate number of cells (polygons outlined by wing veins) which are important identification features. There are two major subdivisions of the Hymenoptera. 1) The sawflies, which are herbivorous as larvae (some are pests of garden plants such as redcurrants), with caterpillars that look somewhat like those of butterflies. As adults, sawflies can be separated from the remaining Hymenoptera by their cylindrical bodies and lack of a narrowed waist.[21,56] 2) The remaining Hymenoptera, which have narrow waists, include mainly ichneumon wasps and chalcids that are mostly parasites of other insects. Some chalcids are tiny enough to lay their eggs inside the eggs of other insects and a single host egg may end up producing a dozen tiny adult parasitic wasps. Chalcids and ichneumonids are commonly used as biological control agents and some species can be purchased from garden supply companies.

The most important contribution of Hymenoptera to floral ecology was through evolution of the suborder Apocrita, since it gave rise to bees within the Aculeata.[56] The Aculeata are defined on the basis of their sting. Only female bees and wasps can sting because the sting is a modified ovipositor (an egg laying structure), which the males do not have. Yellow jackets (and other social wasps), some ants, digger wasps and most bees have a functional sting. Some bees have secondarily lost the ability to sting. Although many aculeate wasp species are important predators of the insects that eat plants, they normally play only a minor role as pollinators.[37]

Wasps are most active during summer and fall and neglect most spring flowers.[55] As well, they do not penetrate any flowers deeply. Like many predators, wasps often visit flowers to sustain themselves on nectar.[21,57] The most commonly observed wasps in Canada are the social yellow jackets, bald faced hornets and paper wasps.[48] All of these live in colonies started by over-wintered mated females, which then produce one or more broods of worker females. The colonies increase in size during the summer and this is partly why they are most likely to be a nuisance at the picnic table during August. These wasps have solitary relatives which are also carnivorous, feeding other insects to their young caterpillars. Among the solitary Vespid wasps, one subfamily (Masarinae) has adapted to a bee-like lifestyle.[21] Unlike other Vespid wasps, they collect flower products for their offspring. Although masarids have far fewer species than do bees (and in Canada they are very rare and only found in the West),[56] they illustrate that 'beeness' is both an ecological niche and a taxonomic unit.[49]

Figure 5. This Yellow Jacket Hornet (Vespidae, Polistes dominulus) is looking through these senescent flowers for small insects that it will chew up to take back to its hive as food for the larvae, but it will also take nectar, particularly in late summer. They role their wings when not in flight, rather than fold them back over their bodies the way bees do. Their social structure is much like the honeybee, with the bulk of the population made up of sterile females.

Another group of wasps that is important in the garden is the group from which the bees arose.[56] The apoid wasps (referred to in the past as Spheciformes or sphecid wasps), are solitary and mostly nest in the ground, although some nest in plant stems or holes in wood. The habit of digging nests in the ground gives them their common name of digger or sand wasps. They construct a simple nest and collect animal matter, usually other insects, for their offspring to eat. The prey is paralysed, rather than chewed up, in this way staying fresh until it is eaten by the wasp larva.

In an evolutionarily sense, bees are sand or digger wasps that have relinquished the predatory lifestyle of their ancestors and take pollen as their major source of protein.[56] Differentiating wild bees simply as short- and long-tongue families may be necessary since there are no taxonomic terms between families and super-families that would describe this basis of grouping. Short-tongue bees in Canada include Colletidae, Halictidae and Andrenidae bee families, while long-tongue bees include the Megachilidae and Apidae families.[49] Although short-tongue bees are considered as a group of older families distinct from the long-tongue bees,[49] most experts put colletid bees at the base of the evolutionary tree for bees. Long-tongue bees would occupy one branch in the tree.[50] Interestingly, andrenid bees seem to have evolved their short-tongues independently from the other short-tongue families.

Figure 6. A member of the most primitive family of bees, this Colletidae (Hylaeus sp.) has no pollen baskets and looks the most like a wasp of any bee family, with white or yellow markings, most apparent on the male. Bees in this genus are quite small and the females can be mistaken for sweat bees or small carpenter bees when observed on the wing.

Evolution of the Social Bee

Sociality comes in several different forms in the insect world. The most common one is technically termed eusociality.[49,56] The mandatory conditions for eusociality are: cooperative parental care; overlapping generations; and division of labour, in the form of castes.[6,49] Eusocial insects include termites, ants, some bees and some wasps.[6] The other type of society found among a few Canadian bees is referred to as communal. In a communal colony all individuals construct brood cells, collect food and lay their own eggs. Basically, they act as solitary insects but they share a nest entrance and the upper part of the burrow. The advantage of communal nesting seems to be that because there is constant traffic at the nest entrance, it is difficult for the numerous natural enemies of bee nests to gain entrance. The advantage of eusocial nesting is more complex to explain because the workers are generally sterile (or at least lay few eggs in comparison to those of solitary bees). Depending on how it is defined, sociality has evolved at least five times among insects but only once outside the Hymenoptera.[61] Understanding why will explain much about this order.

The role of male insects often seems functionally unimportant because most insect females can store sperm in their spermatheca, making them less dependant on repetitive matings.[6,73] Among Hymenoptera, male societal contributions are further diminished since unfertilized eggs produce haploid males through parthenogenesis.[11,66,73] Their life-cycle is always the same, to find a breeding female (preferably unrelated), if successful, mate, then die, but never function as a worker. So why should some female members of these societies be effectively sterile? Because males are haploid, all of the sperm that they contribute to produce daughters are identical.[57] Hence, daughters of a fertilized queen are more closely related than sisters would be from a diploid father, and more closely to each other than to the queen. Since one of the sisters will eventually become a queen, it is a genetic advantage for the others to sacrifice their own eggs (becoming worker bees) toward the much higher probability of survival for eggs from their breeding sister than for their own eggs. The evolution of the cooperative sisterhood society was also advantageous among Hymenoptera because, with complete metamorphosis, larvae must be fed and protected by adults.[11,54,66]

Figure 7. Bees in the Dialictus *subgenus of the genus Lasioglossum (Halictidae) are small and can be green, brown or blackish, with even some orange in a few species. Most species nest in the ground, but a few nest in rotten wood. Some species in Canada are social with up to several dozen individuals in a nest.*

The most highly eusocial bees are all in the family Apidae, including the honey and bumble bees and tropical stingless bees.[49] Two genera in the sweat bee family (Halictidae) have evolved sociality, although there are solitary and social species in the same genus.[56] For example, both *Halictus* and *Lasioglossum* contain eusocial species.[49,64,66] The spring queen's first generation of daughters can lay eggs, but because they were not mated, their offspring are all males. This sequence provides males for spring queen's second generation of daughters, from which mated queens come for the next spring. In this form of eusociality, each female creates her own nest, but from a common tunnel.

Honeybees

Although not native to North America, the common honeybee is the most important insect pollinator. They collect both nectar and pollen to supply their complex social system.[15,39] They are easily handled by beekeepers[68] and are much more valuable as pollinators than as honey producers.[11,23,37] They have long tongues, hairy pollen-collecting coats, the ability to warm themselves, and a high frequency of floral visits during their lives.[15] Honeybees live year-round, so they must use whatever plants are in flower (polylectic) and cannot afford to specialize. However, individuals or entire colonies may concentrate upon particularly rewarding flower species for short periods of time.[39,72] A honeybee colony has one queen, several hundred drones (males) and around 80,000 workers. The queen can lay 2,000 eggs a day.[39,68]

There are nine species of honeybees, although only one is commercially viable.[20] The honeybee that Canadians know is *Apis mellifera.* It was domesticated for honey and wax in medieval Europe.[54,68] Our ancesters started collecting wild honey at least four to five thousand years ago and bee-keeping may have started as early as 3,500 years ago.[11] Domesticated honeybees arrived in North America with the earliest European settlers around 1638.[66] The eastern honeybee (*Apis cerana*) is indigenous to India, China and Japan and is domesticated in some parts of the world. Attempts to domesticate two other honeybee species, including the giant (*Apis dorsata*) and the dwarf (*Apis florea*), have failed.[68] Several races of the European honeybee have been cultivated, including Italian (the most domesticated and commonly used), Caucasian and Carniolan. Several Ontario plants have been identified as ideal honey plants. Clover, including white, sweet, occasionally red, alsike and alfalfa are good field crops for honey. Weeds, including fireweed and blueweed, dandelion, goldenrod and aster, provide good forage. Good conditions for honey production are sunshine during bloom and good rainfall for plant growth.[68]

Honeybees are in decline as a result of two parasitic mites: the tracheal mite originally from South America and the varroa mite originally from Asia.[6,39,72] The varroa mite seems to be eliminating feral European honeybee colonies and recent media reports indicate similar losses in eastern Canada. They attach themselves externally to the bee and suck the blood, while the tracheal mite invades the bee's spiracles and tracheae (windpipes) and eventually suffocates its victim. There is hope that bees can become resistant to the varroa mite by developing better bee-hygiene inside the hive.[70] Moving varroa-infested honeybees from areas where the Asian honeybee (*A. cerana*), a natural carrier of varroa, is indigenous to un-infested areas during the 1970's was a factor in mite transfer. Wasps are suspected of carrying varroa into beehives, since these mite pests are also found in wasp broods. Tracheal mites may feed on small rodents that are attracted to beehives.[13] In addition to parasitic mites, honeybees are also in decline because of Africanization. This refers to native honeybees interbreeding with an aggressive African strain following their importation to Brazil in 1956.[38] The honeybee industry has declined in regions affected by Africanization because of fear among producers for their own safety and legal liability.[26] Feral colonies and managed beehive operations are both in decline. The latter has been due partly to depressed honey prices.[38,39,40] The effect of tracheal and varroa mites on honeybees as well as the spread of Africanized honeybees have shown how vulnerable agriculture is in depending on a single pollinator species.

As pollinators, honeybees are not suitable for all crops and do not 'buzz-pollinate,[6,38,47,54] or sonicate (vibrate) anthers to dislodge pollen.[50] Although honeybees are more effective pollinators when they gather pollen than nectar, they are primarily nectar gatherers. Examples of crops that require this method of pollination include tomatoes and blueberries, but these are better pollinated by bumblebees and an assortment of wild solitary species. Honeybees are also not very good at pollinating some complex flowers such as alfalfa. Honeybees tend to pack pollen into their pollen baskets in a wet mix with nectar so less is available for pollinating the next visited flower.[8] Even though apple blossoms are open flowers, honeybees are not as effective at pollinating them as are blue orchard bees.[37]

Since flowers such as dandelions out-compete apple blossoms in nectar production, honeybees are easily distracted from the latter. Honeybees avoid inclement weather and will not fly if the windspeed is greater than about 19 km/h.[3,12] In spite of the superior pollination performance of many wild bees in orchards,[52] honeybees are still relied upon because wild bee populations tend to fluctuate unless managed.[14] Also, because the number of individuals per hive is so large, honeybees can be used to pollinate crops quite successfully even if their pollination success rate is low per flower visited. But the honeybee industry dropped from 5.9 million colonies in the 1940's to 4.3 million in 1985 to 2.7 million in 1995.[32] This means that strong honeybee colonies for crop pollination have been steadily decreasing[29] and alternative pollinator species must be fostered.

Bumblebees

Besides the imported honeybee, the bumblebee is the dominant group of social bees in the northern latitudes.[66] Bumblebees have a fat furry look, and are large-bodied bees. They require sustenance throughout the spring, summer and fall.[39] A large bumblebee colony will have, at its peak in late summer, 150-200 bees.[23,29] A typical underground nest will be 15-23 cm in diameter with a 30 cm, sloping, 2.5 cm wide, tunnel.[23] Some bumblebees are attracted to deserted mouse nests. Poor drainage can affect bumblebee nests.[23,39,44] Males and queens are born at the end of the season. Bumblebee queens mate in late summer and store fat since they are the only colony members that over-winter.[23,29] The queen lays her eggs in the spring and forages to feed the larvae herself until the first workers mature.[29] Males, produced from unfertilized eggs, leave the nest to forage on their own.[23] Many bilaterally symmetrical flowers (zygomorphic) and flowers with deep corolla tubes (stereomorphic) rely on bumblebees for successful pollination.

Figure 8. The workhorse of the garden, the first bumblebee (Apinae, Bombini sp.) in spring is a welcome sight to those starting crops of beans, tomatoes and other vegetables. They are generally bigger and hairier than most other bees and will forage through a wide range of flower types. While there are several species in central Canada, they are all easily recognized as bumblebees.

There are about 250 species of bumblebees, which live primarily in temperate regions,[20,49] and about two dozen species reside in Canada.[56] The North American bumblebee species have a wide range of forage preferences. Although all are in the long-tongue group, varying tongue-lengths partition them among flower types with different shapes and corolla tube lengths.[38] Short-tongued bumblebees will bite holes in a corolla and become robber bees if there is no other source of nectar. Longer-tongued bumblebees are important pollinators of many legumes such as field beans (*Vicia faba*)[14,66] and red clover (*Trifolium pratense*).[44] Red clover seed production is below potential in much of Canada because of bumblebee shortages.[38] The need for red clover flowers and many field crops to be tripped by heavy insects makes the bumblebee the pollinator of choice, rather than honeybees. Field beans are long-flowered with nectar reserved for long-tongued bumblebees. Short-tongued bumblebees only pollinate field beans if they enter from the front to collect pollen.[23] Bumblebees are usually too few in numbers to pollinate large cultivated areas.

Managed bumblebees are better pollinators of greenhouse tomatoes than are honeybees largely because honeybees cannot be easily confined; the latter will abandon tomatoes in preference for other flowers outside the greenhouse.[14] Tomato greenhouses used to hire people with sonication devices to induce self-pollination, but these devices have been replaced by managed bumblebees.[11] Nectar is supplied to bumblebees as an artificial mix because tomatoes only supply pollen. Capturing some wild bumblebee queens in spring for stocking greenhouses may be possible without serious impact on wild populations. Since in nature queens are hatched in excess, they must compete for nesting sites, so those captured would not threaten the existing wild population.[17] Although parasitic mites do not affect bumblebees like they do to honeybees,[5] threats to their populations include a closely-related look-alike cuckoo bee that invades nests, as well as parasitic flies.[66]

Cuckoo Bees

The cuckoo-bumblebees just mentioned are just one example of a lifestyle that has evolved repeatedly among the bees – the habit of entering the nest of another bee species and laying eggs on the food found there.[23,56] Technically, this lifestyle is referred to as cleptoparasitism. Most common genera of "honest, hard-working" bees have a genus of these cleptoparasites. For example, most *Nomada* species attack solitary mining bees of the genus *Andrena*; most *Sphecodes* species attack sweat bees of the family Halictidae; most species of *Epeolus* attack *Colletes* sp., the cellophane bees; and *Coelioxys* species attack leaf cutter bees of the genus *Megachile*.

Cleptoparasitic bees lack pollen-collecting and nest-constructing structures and are normally quite hairless compared to other bees.[23,56] They are often more brightly coloured than are nest constructing bees. Because of this, they will often be confused with wasps, especially since some cuckoo bees seem to mimic wasps. Under normal circumstances it is very difficult to tell cleptoparasitic bees from wasps without very close examination, at least until one has become acquainted with the appearance of the various forms.

Cuckoo bees can most easily be seen flying around slowly looking for nests of their hosts.[56] Those that invade ground nests can be seen flying low over the ground, often entering holes or cracks in the soil. Those that attack species that nest in stems or holes in walls or wood, can be seen flying around those materials, often in regular patterns, and inspecting anything that looks similar to a host nest entrance. Cleptoparasitic bees feed on nectar to sustain their parasitic forays, and can often be seen on flowers late in the day when their hosts have stopped foraging and have returned to their nests for the night.

Different species of cleptoparasitic bees use different strategies to obtain entry into the nests of their hosts.[23,56] Some wait until the nesting female is out foraging and enter the nest, open a brood cell, remove the egg that is there and replace it with one of their own. Others simply lay their egg in an already occupied host brood cell and the cleptoparasitic larva develops very quickly and kills the host's egg or newly hatched grub.

Figure 9. The nomada bees (Nomadinae), such as this one, are all cuckoo bees (cleptoparasites), though not all cuckoo bees belong to the Nomadinae. While cuckoo bees are frequently seen foraging for nectar, they are not considered to be good pollinators. They are wasp-like with very little hair, and often have bright, sharply contrasting colours.

Solitary Bees

All of the remaining bees are loosely referred to as solitary bees. There are, however, dozens of species – primarily in the family Halictidae - that have small colonies with at most a few dozen individuals. In North America, approximately three quarters of bees are solitary. Ground nesting bees account for 70% of wild bees,[8,64] but hollow stems of plants and abandoned beetle burrows in wood are also exploited.[54,66] Solitary bees lay an egg on a loaf of pollen and nectar.[39] Many of these bees are only active during a short season. With the decline of feral honeybees by varroa and tracheal mites, wild bees are becoming a more recognized resource as pollinators.[50] The polylectic, social bees must forage throughout the season, whereas solitary bees can more easily afford to be monolectic, and specialize.[23] Parasitic mites in honeybees do not affect solitary bees.[5] Native bees such as squash and orchard bees, will forage through more inclement weather than will honeybees.[12,14]

In spite of honeybee services, many crops have difficulty growing in new areas where their natural pollinators are absent.[23] For example, native bees in British Columbia are not abundant enough near blueberry, cranberry and raspberry patches to supply adequate pollination on those crops.[46] Although these fruit crops are not native to BC, the bio-geography and rainfall there do not explain low pollinator populations. Spraying with malathion and diazinon is common in the Fraser River Valley of BC, and it is probable that small, solitary bees have a greater susceptibility to pesticides. Spraying for spruce budworm infestations has had a similar impact on blueberries in Atlantic Canada.[41] In BC, nest habitat destruction, growth of residential areas in the valley near the berry patches and, possibly, competition from honeybees also account for the lack of native bees (Honeybees will often compete with wild bees for floral rewards.[23]). Annual fluctuations of native bees make them unreliable pollinators as well.[23,46] Specific wild bee pollinators can be exploited if peak crop flowering is timed with the bee life span. Keeping fields small, not planting competing crops near to each other, providing rough terrain for nest sites and allowing other early flowering plants to grow, will attract an assemblage of wild bees.

Figure 10. The carpenter bee (Xylocopinae, Xylocopa virginiensis) looks very much like

a bumblebee but is less hairy and usually flies faster. It is the only bee that digs its own nest in wood, but seldom does significant damage to buildings since it is a solitary bee and does not eat wood.

There are several solitary bees that are noteworthy. One species of the Megachilidae deserves special mention partly because it is the best known representative of that family.[26] The alfalfa leafcutter bee (a close relative of the bee shown in Figure 2) represents a commercial success story, the details of which are discussed below. These bees are distinct because they have pollen baskets that are on their abdomens, rather than on their hind legs.[56] The carpenter and little carpenter bees are two additional frequently seen solitary bees. Older classifications placed them in the Anthophoridae family,[49] but they are now grouped in the Apidae family and Xylocopinae sub-family.[7,27] Although the little carpenter bee resembles many of the smaller sweat bees,[56] it is a stem borer, whereas the latter is a ground nester. The large carpenter bee is often mistaken for a bumblebee.

Another solitary bee that has recently attracted attention is the blue orchard bee (*Osmia lignaria*) (see Figure 14). This bee has the potential of replacing honeybees as the most important fruit tree pollinator.[52] Orchard mason bees are hard working and adapted to a cool climate and can fly in chilly, even drizzly weather. Thus, they are often busy pollinating when honeybees remain inside the hive. They are called mason bees because they partition off and close up their nests with mud. Although primarily western, they are seen throughout northern USA and southern Canada. Because they nest above ground in nest sites that can be managed, there is growing interest in exploiting them for pollination in commercial orchards. Their solid cobalt blue appearance probably contributes to their popularity.

Non-bee Flower-visiting Insects

Flies (Order Diptera) are the fourth largest insect order[66] and are more important as pollinators than commonly realized, largely because there are so many of them.[64] All true flies have only one pair of wings, a soft body and short bristly antennae, and they have no stinger.[51] The two-winged fly is an advancement in flight over all of the four-winged body types, and experiments with fruit flies have demonstrated that two-winged flight evolved from four-winged flight.[73] The most important fly pollinators represent the Syrphidae, Bombyliidae, Tachinidae, Calliphoridae and Empididae families, particularly the first two.[38,43] Although their larvae feed on insect pests, the adults of most beneficial fly species need pollen and nectar to sustain them and enable them to lay the maximum number of eggs.[25] Flies started feeding at flowers early in the floral evolution process.[38] Long-tongue flies are attracted to both nectar and pollen whereas short-tongue flies are attracted only to easily accessible nectar.[20]

Bee flies (Family Bombyliidae) feed on nectar as adults and lay eggs on the ground near the nests of a wide range of insects, including bees and wasps.[64,66] The tachina fly (Family Tachinidae) is another nectar feeder in its adult stage, and can probe deep tubular flowers with its long proboscis.[31,44,66] The larvae of all 1,400 species are important parasites of aphids, cutworms, tent caterpillars, cornborers and stinkbugs.[25,43,44] They are seen at flowers less often than hover or bee flies are since they prefer dung, or carrion, to nectar.[38] They are more important as bio-controls than as pollinators, although they do some feeding on nectar and are considered quite good pollinators.[43,64,66]

Blue bottle and green bottle flies (Family Calliphoridae) are frequently seen around plants and occasionally on some flowers. They are also typically seen, however, around garbage or decaying carcasses where they lay eggs. They are best known for their parasitic larvae and as carrion feeders and disease vectors.[64] They are not significant pollinators and are not beneficial otherwise.[43] The feeding habits of flesh flies (Family Sarcophagidae) are much like blow flies and they also are not important as pollinators. Empid (or Dance) flies (Family Empididae) are known for their swarming and courtship dance.[43,48] Although less effective pollinators than bee flies or syrphids, they are common floral visitors and nectar feeders. They are also wide-spread and predatory.

Figure 11. Hover Flies (Syrphidae) are very commonly seen hovering and darting among wild flowers throughout the summer, but seldom caught at rest like this one. A fair variety of syrphid flies can be seen in North America, but they almost all share the black and yellow or black and orange colouring that mimics bees and wasps.

Syrphid flies (Family Syrphidae) are flower specialists that are second only to bees as effective pollinators.[38,43,55,64,73] They are also considered to be the best fliers of all insects.[73] Hover flies visit flowers for both pollen and nectar[51] and they tend to visit many flowers of one type in succession.[24] They choose composite, as well as umbelliferous and rosaceous flowers with small florets that face up, rather than hanging bell shapes. Being fast fliers, they require acute vision, and so have large eyes, and choose mostly yellow and white flowers. They are best known as mimics of bees and wasps,[30,73] particularly the drone fly (species - not male flies) which mimics bumblebees.[66] After a bad infestation of aphids, apparent increases in wasps are often reported. This is actually a successful crop of syrphid flies from the larva that had exploited the aphids.[43]

Although small, syrphid flies often have long tongues and will enter long corolla flowers[55] and they can push aside petals to get at deep nectaries.[43] They are most active beginning in July.[24] They feed on pollen first for the protein to mature their reproductive organs and shift toward nectar as they become more active. The males become particularly dependent on nectar for the energy to chase females and defend territory. Females need abundant pollen to develop their eggs.[24] Depending on the species, larva can be either predators of aphids or live in muddy water. The aphid predators are extremely important bio-controls.[73] Egg-laying females are attracted to aphid colonies by the smell of honeydew[24] where their small larvae devour 200-800 aphids in a 7-10 day life-cycle phase.[38] With several generations per year, they are very effective aphid predators.[30] Like bees, female syrphids can store live sperm in their spermathecae.[24] Syrphid larva and pupa are heavily parasitized by a group of very small wasps (Family Diplazotinae) so that only a small percentage reaches adulthood.

Moths and butterflies (Order Lepidoptera) are the second largest insect order.[66] This group can be divided into two suborders, butterflies (Rhopalocera) and moths (Herterocera). Butterflies can be sub-divided again as one super-family (Papilionoidea) of the commonly seen butterflies, while skippers are separated as another super-family (Hesperioidea). Lepidoptera are not major pollinators in spite of being frequent floral visitors, because their long slender proboscis can reach into nectaries without their head contacting the pollen. Their role as pollinators is most significant in alpine flowers. They feed on nectar and sap as adults, but not pollen,[22,38] and take less viscous nectar and use saliva to dilute and digest it. Some adults do not feed at all, or only on rotting fruit.[63]

Figure 12. The appearance of butterflies is always popular with gardeners, but the most revered of the butterflies in North America is the monarch butterfly (Danuus plexippus). As both a long-distance migratory flier and a pollinator, they demonstrate the interconnectedness between floral ecology and other ecosystems. Unfortunately, butterflies are more decorative than effective as pollinators, particularly in comparison to bees.

Flowers pollinated by diurnal butterflies and moths are colourful, usually blue or violet, while those pollinated by nocturnal moths are pale or white, and strongly scented.[20,55] Most moths are nocturnal while most butterflies are diurnal. Butterflies thrive in open meadows with a diversity of plants. Skippers thrive in the temperate grasslands in both North America and Asia and their larvae are grass feeders.[22]

Butterflies prefer flat-faced[38] long-corolla, nectar-rich flowers, and they avoid small flowers.[63] Some flowers provide landing platforms, since butterflies must land to feed, while other flowers are adapted for moths which can hover while feeding.[44,55,63] Both butterflies and moths have a coiled sucking mouth or proboscis that is as long as their own bodies and probes so deeply that their heads seldom enter even a long corolla.[9,55,63] Although butterflies get more attention from gardeners than moths do,[64] a few moths probe several deep-throated flowers and are effective pollinators of the species they visit.[9,55]

Figure 13. The goldenrod soldier beetle is the most commonly seen beetle on flowers in mid-to-late summer in southern Ontario and is seen in large numbers actively breeding and mating. They are frequently seen on both goldenrod and queen ann's lace. Not having hair, they are not considered to be very good pollinators.

Butterflies tend to fly at a constant height (typically 4 feet or less),[63] but like sunny, sheltered gardens.[55] Male butterflies can sometimes be seen drinking from mud or manure in order to get minerals to make pheromones.[22,26] Most butterflies will find their specific host plant on which to lay their eggs.[22] In evolutionary terms, the Lepidoptera made quite a recent appearance. In spite of this, butterflies and moths are diverse. But moths outnumber butterflies about nine to one and are about 100 million years older (140 and 40 million years, respectively).

Beetles (Order Coleoptera) are the earliest, most primitive of the major insect pollinator groups[9,38,64] and are the largest insect order.[57,66] There are over 30 families of beetles,[7,66] many of which can be seen on flowers, but the majority of them are not floral foragers. The flowers that they visit are heavily constructed and cup or bowl-shaped (haplomorphic) with well concealed ovaries.[55] Beetles often severely damage flowers since they tend to feed on flower parts[20,38,45] as well as pollen. They are attracted to fruity flowers with wide openings to accommodate their clumsy flight.[38] Beetles are attracted by odours from dull coloured flowers without nectar,[20] but most are only effective pollinators of flowers with sticky pollen.[56] Some beetles, on the other hand, are quite hairy and may be good pollinators as a result. They may have been pollinating plants older than Angiosperms, since some Gymnosperms are insect-pollinated.[9,20]

PART III – THE CONSERVATION ISSUES

Commercial Value of Pollinators

Management of non-honeybee pollinators is creating a pollinator technology to buffer the honeybee decline.[38] The annual value of crop pollination in Canada is at least $1.2 billion and $19 billion in the USA.[39,40] If the ecosystem services that rely upon pollination were to be added, such as soil improvement through growth of legumes that add nitrogen to the soil but which require pollination for growth, then the economic benefits of pollination would be astronomical. Although the world's staple grain crops (such as millet, corn, wheat and barley) are wind pollinated, most fruits, vegetables and legumes require insect pollination.[20] Some annual crops that depend on insects include flax, safflower, sunflower, some cole crops, some canola varieties, mustard and oilseed radish.[37]

Fruit crops, such as tomatoes, peppers, some strawberry varieties and cucurbits (melons, pumpkins, squash, and cucumbers) need cross-fertilization by pollinators for top quality production.[38] Other fruit-producing garden plants are primarily self-pollinated.[2] For hybrid seed production, insects are needed to transfer pollen between different genetic lines (hybrid sunflower or oilseed rape).[14] For many crops (such as faba beans), an abundance of pollinators means a greater proportion of early flowers, and an earlier, more uniform crop yield.[23]

The cucurbits provide numerous commercial crop varieties that will cross easily, several of them able to produce parthenocarpic fruit.[23] Since cucurbits are monoecious, with male and female organs on separate, yellow flowers,[2,29] pollen transfer between flowers is essential for fruit development. Although the cucurbit flowers are visited by many bees, flies and beetles,[23] squash bees specialize in the foraging of this plant.[12]

Blueberries grow wild in Canada and lowbush blueberries (*Vaccinium angustifolium*) are cultivated commercially in forest clearings in the Maritime Provinces.[23] Cross-pollination by insects is needed for good yields.[39] Blueberry flowers in Atlantic Canada are visited by four genera of solitary bees (up to 190 species) and three genera of flies, as well as honeybees and nine species of bumblebees.[23,47] Small fields are adequately pollinated by wild bees, but the largest fields require managed pollinators. This is because such monocultures provide food sources for bees for only the brief period in spring when the blueberries are in bloom. Bee populations can persist if there are additional sources of food nearby, but this is only true for small fields or around the edges of large ones.

Bumblebees are grown at a commercial hatchery at Leamington, Ontario and are shipped to greenhouses across North America.[29] Both the eastern *Bombus impatiens* and the western *Bombus occidentalis* species are grown there. Similarly, honeybees and alfalfa leaf-cutter bees are being raised for commercial pollination services. Honeybee colonies for pollination are needed at approximately two or three per ha,[57] and they can be rented for this purpose. Until 1980, greenhouse tomatoes were a minor commodity due to poor pollination. Since the western North American species, *Bombus occidentalis*, was domesticated, British Columbia growers have been producing large, beautifully shaped tomatoes. The commercially-raised bumblebees are worth an estimated $5 to $6 million to the BC hothouse tomato growers.[29] Similarly, there are enormous greenhouses in Quebec that are pollinated by managed bumblebees. One type of syrphid fly (*Eristalis tenax*) is being studied as a suitable greenhouse pollinator of sweet pepper.[33]

Honeybee hives are hired for pollinator service to apples, cherries and raspberries.[29] Inter-planting different cultivars of fruit trees to facilitate cross-pollination is an associated practice.[14] Hybrid-seed production is increasing the bee-dependent crops that rely on first generation hybrid vigour with both parent plants grown in the same field.[29] As a result of declining honeybee operations, the price of hiring beehives for pollination services has increased dramatically.

The alfalfa leafcutter bee (*Megachile rotundata*) got its name by pollinating alfalfa, but earned its fame by saving the Canadian alfalfa seed industry.[23,29,60] Several native leafcutter bees and bumblebees will pollinate alfalfa, but their populations fluctuate, so alfalfa seed production is also highly variable.[60] Honeybees are ineffective alfalfa pollinators because they can steal nectar without tripping the flower.[14] The leafcutter bee is both gentler and less likely to wander than honeybees.[59] In the first half of the twentieth century alfalfa seed production decreased because expanding agriculture and land clearing destroyed nesting sites of native bees. By 1950 Canada was importing alfalfa seed to meet 95% of its domestic needs.

After the new leafcutter bee was introduced to Canada in 1961,[23] scientists and seed growers worked out a management system that soon raised alfalfa yields six times over.[59] Thirty years later, due largely to research work by Agriculture and Agri-Food Canada,[47,60] Canada was meeting or exceeding its demand for alfalfa seed due to the alfalfa leafcutter bee.[29,66] These little solitary bees are now being used in Eastern Canada by the lowbush blueberry producers[38,47,59] and are also now used for buckwheat and hybrid canola.[29] Leafcutter bees have created a new kind of beekeeper: one who sells bee larvae to other growers in need of pollination services.

Management techniques for leafcutter bees involve building large arrays of nests with layers of grooved laminated materials. With temperature-controlled incubation, bee emergence can be synchronized with alfalfa bloom. Nesting blocks are stored at 4ºC until about three weeks before the expected crop bloom, when the temperature is turned up to 29ºC to trigger final development of leaf-cutter bee adults.[29] This system has made Canada the leading producer of alfalfa leafcutter bees. Pests include chalcid wasps, the dried fruit moth whose larvae eat the pollen-nectar provisions meant for the leafcutter bee egg, the chalk brood and other viral, bacterial and fungal diseases.[60]

Figure 14. Until recently, the blue orchard bee (Megachidae, Megachile osmia) has been an unsung hero in terms of the contribution it makes as a pollinator in tree fruit and berries. There is, however, growing interest in raising and exploiting these bees for managed pollination services. They are most likely to be seen in the tops of flowering trees in the spring.

Conservation and Future Needs

The plant-insect relationship is now in peril because of the many threats facing pollinators with the most specialized relationships being the most vulnerable to disruption.[38,56,75] Threats to pollinators include habitat loss, land degradation, fragmentation, pesticide use and non-native invasive species.[64] Habitat destruction, including loss of nesting sites, food sources and mating sites, is the main issue in the decline of wild pollinators.[39,40] By plowing, digging, cutting, paving and spraying unwanted vegetation (particularly wild flowers) we devastate the sites where wild bees make their homes.[6,50,69] Flood irrigation saturates nests. Soil tillage, particularly in meadows, destroys nests and larvae.[11,29] When tillage is required it should not go deeper than six inches.[6] The demise of native leafcutter bees in Manitoba (and the collapse of alfalfa seed production) was due to habitat destruction in the 1930's and 1950's. Wild pollinator populations have trouble establishing in areas of widespread monocultures[29] because there is one kind of flower designed to bloom in a very narrow time window. Many annual crops do not depend on biotic pollination and provide little bee forage since they only bloom a few days each year.[29,37] Many vegetable crops also do not require pollination, since the roots, stems or leaves are harvested, rather than the fruit.[37]

Because alien species pose a threat to all biological diversity, introducing non-native pollinators requires careful assessment and quarantine.[37] Introduced plants displace native forage flowers and introduced insects prey on or compete with native pollinators.[64] However, some importations, such as the alfalfa leafcutter bee, have been very successful and some weeds have been shown to be good bee forage. Unfortunately, introduced weeds and introduced pollinators often combine to produce a population boom that can force populations of native species into a decline.[56] Monolectic bees are particularly prone to extinction when their specialty flowers are lost. Importing bees that have closely related native bees has the added risk of disease transfer to those native species. The impact of imported European bumblebees on Japanese species is a good example of this risk.[37,56] There are now well documented declines of bumblebees in the western USA, probably resulting from the same cause. The sale and transport of east coast bumblebee species to the west coast greenhouse industry could have the same impact on native bumblebees in that region.

No matter what values are attributed to honeybees as pollinators, it should be kept in mind that they are a non-native species. Honeybees can out-compete native bees because of their concentration of numbers and will extract most of the pollen and nectar from high-productivity sites, leaving only the less rich dispersed sites for other pollinators.[11] Large-scale production of cross-pollinated crops has led to commercial honeybee pollination services. These services are only marginally cost-effective and have increased the spread of parasitic mites.[29,67] Honeybees also create competition for their floral forage.[50] Bumblebees have declined as a direct function of nectar and pollen reductions, as a direct result of competition from the honeybee. Other wild bees suffer in much the same way, though perhaps more seriously, since unlike the two social bees, they do not store forage.[11] Because they arrived so long ago, the total impact of honeybee importation to North America cannot now be determined.[64] Introduced bumblebees are a more recent phenomenon which are having impacts on continents worldwide,[56] particularly in areas where there are native bumblebee species (such as in North America, Israel and Chile) as well as areas which have never had these large species (Australia and New Zealand).

Pesticides have a direct impact on native pollinators.[29,39,50] Pesticide use has doubled in North America since 1960.[32] Broad spectrum insecticides are more effective at killing predators than the pests that they are made to target.[31] Even at sub-lethal levels pesticides affect longevity, memory, navigation and foraging abilities of pollinating insects.[37,38] Not only do insecticides kill foraging adult bees, they can contaminate larval food and destroy the next generation.[8,64] Mosquito control caused major die-offs of honeybees, and while impacts on native pollinators are unknown, they are certainly severe.[56] The control of spruce budworm with fenitrothion in Atlantic Canada, where spraying was near commercial blueberry fields, has affected essential pollinators for that crop. In New Brunswick, blueberry crop value dropped about 70% in one county, likely due to the start of fenitrothion spraying.[41] Herbicides eliminate the natural forage that wild pollinators need before and after the crops are in bloom.[8,29,64] Since Canadian farmers apply much more of it than insecticides, herbicides are a bigger threat. But in fairness to farmers, some urban watersheds have higher concentrations than do many rural farmland drainage systems.[64]

Recent work has shown that bee and wasp populations are up to ten times as likely to become extinct as are populations of most other organisms.[56,75] The reason for this lies in the unusual sex determination system found in most Hymenoptera, including bees. As described above, males are generally produced from unfertilized (haploid) eggs and females from fertilized (diploid) eggs. But it is not really whether an egg is diploid or haploid that determines the bee's sex. Bee gender is determined by a sex gene. This sex gene is a point on one specific chromosome (locus) in the egg cell nucleus. During fertilization, this chromosome comes together with a matching chromosome from the sperm cell (the normal diploidal arrangement) so that the two sex-determining gene forms (also known as alleles; male or female) are matched up (at the same locus). The normal result is a female because usually there is a necessary degree of variability in the genetic material of these two sex genes which will combine for femaleness. However, when two sex genes are matched up that are too much alike, the result is the same as when there is only one sex gene. And since only one such gene is also the haploidal case, which produces a male, then this diploid egg is like an egg that has only one of these sex genes. The result is a diploid male, and such males are usually sterile or at least non-viable.

In large bee populations the sex determining allele is sufficiently variable to avoid this problem. As a population decreases, for environmental reasons, the variability of the sex alleles will decrease. This means that the proportion of male diploid eggs that are produced will increase with the result that there are even fewer reproductively capable individuals in the next generation. This is a vicious cycle and it can result in an accelerating decrease in a population, leading to extinction. Evidence from long term bee surveys suggests that such extinctions may be occurring quite often. This is best known for bumblebees, partly because they are such obvious insects, but also because they live in colonies that need lots of resources and support a very small number of breeding individuals for their population size. It might look as though there are lots of them around, but most are sterile workers.

Fragmentation is an urban problem. Small isolated patches of wild habitat may look natural and healthy, but they often lack essential pollinators.[32] Fragmentation of plant communities leads to declines in pollinators, among other wildlife. Parks or protected areas should be set aside as pollinator habitat.[39] Small wildlife reserves need to be connected with undeveloped corridors for pollinators to follow so that they can remain in safe zones while moving from place to place.[14] Hedges should be planted along fence rows and rights of way. Crownvetch and birds foot trefoil are good roadside ground cover and forage for natives bees. Plants such as thistles, milkweed, and chicory, should not be viewed as weeds, but as bee forage.[39] Without corridors and continuous areas of dense plant cover, pollinating insects are at risk from lack of forage, genetic isolation and predators.

In Prairie grasslands, many flowering wild plants which support native pollinators, mainly bumblebees, are in danger from over-grazing.[38] If not too heavily grazed, natural pasture offers floral resources to a variety of native pollinators.[37] This entire habitat is destroyed, however, if the land is brought into annual crop production. Early cutting of leguminous hay (clovers and alfalfa) before it blooms also deprives native pollinators of their feed. Native pollinators are as essential to most wild flowering plants as they are to cultivated crops.[14,32] Inadequate seed set on crops is usually easily recognized. However, symptoms of inadequate pollination for wild flowers may go unnoticed for years or decades since many are perennials and individuals may survive for many years without successfully reproducing. In the long term this dooms the population to extinction when those individuals complete their life span.[14,64]

Creating Habitat and Attracting Pollinators

A diverse floral habitat provides the most abundant forage.[47] Flower-rich field borders, where non-crop forage plants are not treated as weeds, encourage beneficial insects to visit them.[37] Plants with small flowers rich in nectar attract beneficial predators to the garden, in addition to the regularly expected pollinating insects.[25] Field borders, fence lines and hedge rows provide habitat and eliminate the need for alternative food sources.[29,38] Agroforestry, including windbreaks, riparian forests and nectar-producing trees, holds promise for pollinator preservation.[29] While modern agriculture has moved towards more sustainable practices, there is still no habitat management program for wild pollinators. The same holds true for urban environments. Although fragmentation can be a factor within city limits, some surprisingly vibrant pollinator communities can be observed.

Figure 15. The andrenid bee (Andrenidae) is another of the typical bees that can be seen in spring in Ontario foraging in the tops of flowering fruit trees. Preserving these trees provides greater variety of habitat and forage, and promotes bee diversity. Although they are grouped with the other short tongue bee families, their hairiness and habits make them effective pollinators.

Open perennial herbaceous vegetation with high floral diversity provides a seasonal sequence of forage for a range of pollinator species.[15] Since native bees come in a wide range of sizes and habits, there is usually a good chance that a pollinator suited to a single flower type, weather conditions and time of year will be available to fulfill a specific pollination requirement.[6] Dependence on honeybees means that one is not truly gardening naturally, whereas small solitary bees are usually better for small gardens than are honeybees.[26] Sites for ground nesting bees require bare patches in well-drained areas with alternate plant heights.[6,26,64] The open ground can be horizontal stretches, slopes or vertical faces (cliffs, river banks, rock walls) with different species preferring different habitats.[26] There are even some species of ground-nesting bees that will have their burrows in dense grass cover. The wider the range of nesting conditions, the greater will be the diversity of species.[6] A range of slopes and soil textures, created by adding sand piles, with sun-exposure or rockeries, can give variety. For the 30% of wild bees that do not nest in the ground, bundles of hollow twigs and a range of hole sizes drilled into wood blocks will create nest sites.[5,26,64].

A few cautionary guidelines for human-made nesting sites should be noted.[56] Any artificial housing should have morning sun exposure. It is best to have hollow stems scattered around the habitat so that parasites and other enemies of the bees do not have a singular, clear site to congregate around. Drinking straws and other thin-walled tubes are easy for some bee parasites to penetrate and can often serve as a sink for a population (lots of bees will nest there, but their brood will be parasitised).

Bumblebees have special needs.[64] The queens use mulch, compost, trash, leaf litter and even piles of coal dust or ashes from wood stoves as over-winter shelter, but come spring they construct their nests in cavities such as abandoned mouse dens.[26] As well, too tidy a garden deprives bees of nest sites.[64] Larvae of soldier and soft-wing beetles also hunt in soil leaf litter. By tunneling into weakened trees, long horn beetle larvae create holes for bee nests. Only the big carpenter bees can make their own holes.[64]

Good pollinator habitat must provide a succession of blooms throughout the summer season with several flowers in bloom at once, with a variety of annuals and perennials of various colours and no pesticide usage.[6,64] Although some weeds are good forage, those whose flowers are not frequented by insects should be removed to allow room for native wild flowers.[6] Ground cover in orchards should be good forage with a mix of native wild flowers and perennials, rather than monoculture hay fields. For butterflies, their host plants should be left in the ground over the winter.[64]

Habitat corridors that include permanent vegetation strips will promote re-colonization and genetic exchange among bees.[6] Hobby gardeners can provide the best shelter for native wild pollinators[11] and corridors or way-stations across landscape gradients from urban to suburban to rural areas.[26] Modern ornamental flowers are usually poor forage because they are hybridized and rather sterile in terms of nectar or pollen or they are of such exotic and extravagant form that native bees cannot obtain what resources might be there.[26,64] Old heirloom varieties are usually good forage.[64] Heritage seed growers gain directly from pollinating insects because they depend on seed from the plants they grow themselves.[11,26]

The more types of insects there are in a garden, the better, because diversity means both stability and manageability, since any given population is not likely to explode.[26] When insect diversity is low, the most likely insects to appear are the obnoxious ones. The crucial interdependence of biological control organisms and floral resources is often not considered in agriculture.[38] Similarly, to attract and maintain predators, prey is needed throughout the summer, particularly when the target pest is not active.[26] These predators are those that can sustain themselves on nectar when their prey are not available (such as social wasps), or are floral foragers as adults and predators as larvae (such as the syrphids described above). It is impossible to separate pollinators from other insects that come with chemical-free gardening and good cover. It reflects balance through diversity.

The Road Ahead

For managing wild or natural pollinators, agro-ecosystems and other landscapes, not just individual species, must be protected.[15] In their natural settings, and in well integrated farming systems, pollinator guilds that include several unrelated species, provide reliable pollination. The movement toward low-input farming, organic methods and reduced tillage over the last decade is good news for pollinators.[38] Home owners can reduce lawn areas which are barren with respect to pollinator forage, plant native flowers or at least allow them to grow along lawn boundaries, and reduce or eliminate pesticide use since homeowners use more pesticides than agriculture (on a per capita basis?).[64] Gardeners should get to know the microcosm of insects and other invertebrates in their backyard and garden. Learning the insects that visit plants outside of their garden will demonstrate what can be attracted. The insect roles beyond being pests should be appreciated since the same conditions that attract beneficial predators will also attract a diversity of pollinators. Public officials should be asked to set aside park borders, strips along fence rows and rights of way as protected areas for pollinator habitat.[39] Hedges of natural and diverse vegetation should be planted in these areas.

Unlike private dwellings and public parks, farms are the source of food and livelihood for farm families. Few farmers can afford major adjustments solely to protect wild pollinators. Farmers should, however, appreciate the implications of this conservation issue for their sector. Farmers should start by noticing non-honeybee species (and not just bumblebees), then by looking for ways to create habitat.[6] While for many farmers, monoculture may be a fact of life, the hedge rows and fence lines that border these fields should be devoted to bee forage. Integrated Pest Management (IPM), the scheduling of pesticide applications with respect to wind and the lifecycle of target pests, is an agri-environmental success story. But this scheduling must also avoid mortality of beneficial insects such as pollinators. Not spraying when crops are in bloom would greatly reduce this risk to pollinators.[38] Herbicides should be targeted against invader weeds, not native flowers.[64] Non-crop plants along fence rows and field borders should be treated as floral forage, rather than just as weeds. By setting aside habitat such as herbicide-free meadows, farmers can support the great interconnectedness of all wild life, large or small. Encouraging native bee habitat enhances a farmer’s wild life-friendly image.[6] Finally, the return of native bees to a hedge or garden is just as valuable as seeing a hawk flying over the back woodlot.

PART IV – DESCRIBING AND MONITORING POLLINATORS

Monitoring Pollinators at Work

Because pollinators and landscape ecology are so inter-related, pollinator assemblages are good bio-indicators of land use.[37,56] Furthermore, because damage to the pollinators would cause the decline of entire ecosystems, pollinators should be monitored, not just as indicators, but as a keystone resource.[56] An understanding of both the diversity of species and abundance of insects are needed to indicate stress on ecosystems.[41] Since not all species are affected to the same degree, niches open up for lesser species as others decline. The sudden abundance of a species can mask loss of diversity. Because of the wide range of nest conditions for bees and larval functions for non-bee pollinators, single species are usually poor indicators of environmental stress.

Except for the legitimate needs of taxonomic classification and study at the species level, as much can be learned by observing pollinators at work in the field as by killing them for lab scrutiny.[1,7]

Most insects can be observed up close with a magnifying glass, close focusing binoculars, or a high resolution digital camera accompanied by a close focusing telephoto lens. In some cases it may be possible to capture insects temporarily in a net. Collecting, taking, killing and mounting specimens are not likely a significant threat to most insect species, given their death rates, for example on car windshields, and their short life spans. But this is not advisable as a part of on-going monitoring. A large enough group of collectors, as has been popular with butterflies,[64] can cause extinctions in local areas and may destroy populations that are rare or isolated. Certainly private collections for their own sake should be discouraged and are not scientifically ethical.

Typically, biological scientists have interacted with volunteer observers by suggesting that they bring in a sample specimen of the animal in question for proper lab examination and identification. There have been citizen science programs created based on volunteers collecting and mailing in samples to scientists. Although killing and collecting is a far more reliable means of identification than recorded observations, the identification of specimens being regularly mailed in by potentially a thousand volunteer observers would overwhelm the limited number of professional entomologists available. For most gardeners, the thought of killing a bumblebee as a reward for having just pollinated their flowers should be less appealing than just observing how it lives and functions. Therefore, the approach proposed here will be to ask volunteer observers to record the diversity of insect types they see without taking samples and without necessarily achieving specific identification of any one species.[18]

Figure 16. A close look at this very shiny and dark blue bee with the rather square appearing back-end and a small ivory marking on the face will distinguish this small carpenter bee from the small sweat bees. In reality though, when seen on the wing, it is very difficult to tell this small bee from the small blackish bees that have evolved in four other bee families.

Along with safe-guarding pollinators, there are some precautions for observers. These will not be discussed in detail here, but one danger must be noted. A sting from one yellow jacket or bald faced hornet can be very painful, but an attack from a swarm can be life-threatening. For those with a severe allergy, even one sting can be fatal. But with a little caution, observing pollinators should be no more dangerous than any ordinary summer picnic.

The proposed volunteer pollinator monitoring program is expected to be on three distinct technical levels: 1) those whose role is primarily appreciation; 2) those capable of distinguishing among pollinators without making precise or reliable identifications; and 3) those with the inclination to identify what they observe, or at least its family. Frequently (with the right tools), successful identification could be expected at the genus level and, in some cases, even the species. Sometimes the timing and flower visited will reveal a pollinator identity. It is hoped that the three participation levels (appreciators, counters and identifiers) will accommodate the widest range of volunteers possible and this text will help them to improve their monitoring skills and become more effective observers. For those whose schedule limits their involvement to no more than appreciating the issue, spreading the word is still a valuable contribution.

Since it promises to be the heart of the volunteer pollinator monitoring procedure, the notion of a counter needs some clarification. The observations of a volunteer, untrained in formal entomology, will not have scientific credibility when the identification of a specific insect is under scrutiny, particularly given that this monitoring program will not rely on destructive sampling. Volunteers are not expected to become entomologists overnight.[18] When volunteer observations consist of counts, however, specific identification is sacrificed for recording the number of different insects observed. A typical observer may have recorded ten different bees at a specific site. If, for example, only four different bees were recorded at that site last year (or last month) then these ten sightings would indicate a change in pollinator diversity. So with a monitoring program based on counts, failing to identify them did not make these data valueless.

Preparation for count-based observing will emphasize a systematic recording of a range of features that can be observed without destructive sampling (see Illustration 1), but can define these differences. At the same time, some participants will acquire the skills to attempt specific identifications, driven by either natural curiosity about what they are looking at or prior training in biology. To facilitate this higher recognition level, a reference set of visual pollinator images is organized into an electronic album that can be viewed on the internet.

Since nobody will be expected to identify each and every species, parataxonomy does not really describe what the amateur naturalist who will join the pollinator monitoring program is being asked to undertake (at least as a counter). The mission is to describe the diversity among members of the communities that surround flowers.[18] By simply recording the numbers of each different insect, volunteers can also document changing densities. Volunteer observers can establish a baseline against which trends stemming from environmental change can be identified and tracked. This effort to understand relationships between flowers and insects, why they exist and how they can change is an ecological approach.[4,23]

Providing Useful Data from the Pollinator Monitoring Program

Information is only useful to ecologists if it is accompanied by complete records, including date, location coordinates, site and habitat descriptions, the flowers visited, weather conditions, and the number of pollinators seen.[24] Typical observing sites would include backyards and gardens, school yards, business campuses, urban green spaces, parks, golf courses, highway and railway embankments, utility easements, farms, and wild areas.[64] Good records and sightings are most likely if the observer has spent time prior to the recorded event just getting to know and recognize the target pollinator and its habits. Monitoring usually involves gathering comparative data over the season at one site, plant and time of day and is the most useful data for analyzing trends. Visiting a site or specific plant at regular intervals throughout the growing season can reveal the development of insect populations and the succession of members of the insect communities.[7]

The variability in size, shape and colour results in uncertainty of species recognition within families, although a suite of these features and functions such as flight and foraging habits facilitate standardized insect descriptions.[7] The album of pollinator images should help to make volunteers more confident about these distinctions. Taxonomic differences based on early life-cycle stages would not be needed for the pollinator monitoring program since only adults pollinate. Hence, only flying insects that are actually seen in or on flowers need to be recorded.

Pollinator Names, Identifying Features and Classifications

Although common names are used here as much as possible, some caution is needed in the use of these. In different regions the same common names can apply to different creatures, or the same creature can have different names. Common names generally describe large groups, including a whole order in the case of beetles or groups of families, such as bees. A common name is usually only species-specific if it involves an economically important species, such as the honeybee.[7] For bees, common names other than honey, bumble, sweat or cuckoo bees, reflect nesting habits, such as plasterer, mining, leafcutter, mason, carder, carpenter, and cellophane.[64]

For those with a gardening or naturalist background, distinguishing among the four insect orders that contribute the most important pollinators[20,57] should be common knowledge. To fully assess their potential as crop pollinators, recognizing insects at the family level or below – genus or species - is preferable.[50] But in a general public introduction to insects it is usually impractical to attempt taxonomic description much below the family level.[48] As a general introduction to pollinating insects, the same principle was applied to this document.

Although identifying the species or even the genus is not usually realistic when observing live animals, a few exceptions are easily recognized, including the bumblebee genus and the commonly known honeybee. Without careful observation however, even the honeybee can be confused with similar sized wild bees. For butterflies and beetles, the family level is less critical, whereas for the pollinating flies, the family level is a reasonable expectation. Moths only need to be identified as moths rather than butterflies (or skippers), given their nocturnal habits and rather minor role as pollinators. However, with large wings, wing beats much slower than flies, bees or wasps and a guidebook, family or lower identification levels are possible for those interested. One should never be surprised to see any other insects, including crickets, grasshoppers, wasps and thrips on flowers, but these are only occasional visitors and are neither efficient nor significant as pollinators.[57]

Observable Differences among Pollinator Orders

The following descriptions give some details on a few more common flower-visiting insects in central Canada.[1,7,9,20,34,38,44,48,49,50,64,66,73] The intent is only to illustrate the diversity that can be encountered, rather than describe all of the pollinating insects in Canada. Since the significance and habits of the major pollinators were discussed above, these descriptions will focus on the visible physical features.

Many insect identification guides rely on question and answer keys or charts.[7,16,48] For the task of identifying the four pollinating orders from the other insect orders and from each other, such a key is probably not practical or necessary. But an objective set of descriptive features is needed to make these distinctions and yield reliable variety counts. The key feature for distinguishing orders is wing patterns. Beetles, butterflies, moths, flies, bees and wasps can be separated by wing types. Wings that are membranous and not covered by hardened forewings (elytra) indicate wasps, bees or flies. The most easily observed feature of most Vespid wasps, as compared to bees, is that they curl their wings longitudinally when at rest. Large scaly wings indicate butterflies or moths, and hard shiny or waxy wing covers that fold forward and do not operate in flight suggest beetles.

Flies are distinct from bees and wasps because they only have one pair of membranous flying wings. The hooked fore-and-aft wings of bees and wasps make them appear much like a single pair. Thus, this feature is usually not a good diagnostic without destructive sampling (Instead, the thicker waist, very skinny legs, larger eyes that dominate the face, and the short feathered, rather than long and slender, antennae are better than wings for distinguishing flies from bees.). Beetles can be distinguished from sucking bugs, such as stink bugs, by wings that meet in a straight margin down the centre of their backs, rather cross over their backs. Butterfly wings usually fold up at rest and moth wings usually lie flat or fold down and back.

Figure 17. As adults, bee flies (Bombyliidae) are frequent floral visitors and are moderately good pollinators. Their larvae are parasites of bees and wasps. They are hairy and typically quite large for flies, and their wings are wide-spread at rest. In this case the lack of hindwings is quite evident and is a feature that distinguishes them from bees and wasps.

The four main orders of pollinators also exhibit distinctive flight patterns. Flies are the master fliers, with their speed, agility and ability to hover, apparently motionless with wings moving far too fast to observe. Bees and wasps are also efficient and fast fliers, with wings too fast to observe as well. Most are not capable of hovering motionless like many flies, however. Instead, they sometimes weave left to right over one spot. Unless stationary hovering is obvious, confusion arises between flies and bees or flies and wasps during flight. At the other end of the scale, butterflies and moths display a fluttering flight with observable wing beats. Beetles display a clumsy style of flight, with their fore wings quite visibly folded up and forward to expose the operating hind wings.

Drone, flower or hover flies (Syrphidae), the most important family of flower-visiting flies, mimic bees and wasps. Size and shape must be observed in order to distinguish them as flies. The key elements of shape include tip of the abdomen (ovipositor), size and shape of the eyes, antennae, neck (head to thorax), waist (thorax to abdomen), and in some cases mouth parts and hairiness. The most reliable features when flies are not collected are short feathered down-turned antennae, large eyes that dominate their faces and thicker waists.[7,64,66] Flies are also typically smaller and softer-bodied than the bees and wasps they usually try to mimic.

Bees (Apoidea or Apiformes)

Except for the commonly known bumblebees and honeybees, recognizing bee families is quite difficult without destructive sampling. They are in a separate order from flies and a separate super-family from most wasps (except the spheciformes), but can resemble some of both. Bees are distinguished from vespid wasps (yellow jackets or bald faced hornets) or sphecid (hunting) wasps by hairiness, more robust bodies and pollen baskets either on the hind legs or on the under side of the abdomen.[21,50,56] Many bee families are difficult to distinguish from each other, particularly when the bees are small and the same size. But their diversity and specific features are well worth getting acquainted with since bees are the most important pollinators.[56] The major bee families are organized into two groups based on length of mouth parts (tongues), with long-tongue bees having evolved from short-tongue bees.[50,56]

Short-tongue bees:

1. Colletidae: this family has no pollen-carrying scopa (pollen baskets) and must carry floral products in their crops. They have a short bi-lobed tongue (glossa). There two main types in central and eastern Canada. 1)Yellow-faced bees (*Hylaeinae* spp.) are slender black bees with white or yellow marks on their faces. The leg and face marks are more distinct among males. 2) Plasterer or cellophane bees (*Colletinae* spp.) line their nests with a cellophane-like material. Colletid bees can be difficult to separate from wasps. But except for vespids, few solitary wasps visit flowers, and the social vespid wasps will usually not be seen alone.

2. Halictidae: sweat bees are the best known members of this family. Their colours run from black to brown to metallic green, some with abdominal stripes and yellow legs. Compared to little carpenter bees, their abdomens are wider and pointed. They are a quarter to half inch (6-12 mm) long. They are distinctly bee-ish in having thick tarsi (hind leg pollen baskets) and relatively short antennae. Sweat bees are small to medium sized and have white or grey abdominal bands

and yellow legs, and sometimes a green thorax. Their heads viewed from the side are wedge-shaped.

3. Andrenidae: most bees in this family are mining bees. They are most commonly seen in spring at mid-latitudes. Some are small with yellow or white marks, without much hair. Andrenid bees, the most common genus, are brownish black, moderately hairy with a flattened tip of the abdomen. They are a quarter to three quarters of an inch (6-16 mm) long and live among and pollinate both low bush blueberries and apples. Andrenid bees are typically smaller than honeybees, have a proportionately shorter abdomen, flattened abdominal tips and lack the soft black-yellow abdominal bands.

Long-tongue bees:

1. Megachilidae: this family includes leaf-cutter, mason, osmia and wool carder bees (the latter is not native). They are medium sized with bands of abdominal hair. They must carry pollen on the abdomen, not the rear legs, because they carry nest-building material with their legs. Hence, they are most easily identified by their abdominal pollen baskets. Alfalfa leafcutter bees are black with pale yellow to white stripes on the abdomen and pale yellow stripes on the face, and are about one third inch (8-9 mm) long from face to abdominal tip.

2. Apidae: bumblebees and honeybees are the best known and the most social bees. Bumblebees (*Bombus* spp.) are mostly black with yellow and brownish red areas, and large thick bodies. Their noisy flight is distinctive. Queens can be a half to one inch (6-12 mm) long and workers are about half to three quarters as big. Honeybees (*Apis mellifera*) are golden to yellow with brown-yellow bands on the abdomen giving them soft black tones. They have dense fine hairs on their thorax and abdomen and distinctive pollen baskets and combs on hind legs. Workers are a half inch (12 mm) long and queens, seldom seen, have slightly longer abdomens. In Apidae, the bumblebee is easily recognized by its size, extreme hairiness and distinctive blends of yellow and black. These well-known social bees must not overshadow the fact that Canada has a few solitary bees in this family, such as the squash bee (*Peponapis pruinosa*) or Melissodes.

3. Xylocopinae (sub-family of Apidae): Large carpenter bees (*Xylocopa* sp.) look like bumblebees but are bare and shiny on the top (dorsal) of the abdomen. The little carpenter bee (*Ceratina* sp.) is another common small bee in Canada that resembles sweat bees. They are slender shiny or oily, nearly hairless, dark metallic blue (which can appear as black), with a narrow abdomen that is not so pointed as the Halictids. They sometimes have white or yellow on their faces. They are a quarter inch (6.5 mm) long, found only in Quebec and Ontario. They nest inside Sumac or other pithy plant stems.

Wasps and Hornets (non-bee Hymenoptera)

Ichneumons (Family Ichneumonidae) are small slender wasps, typically a quarter inch or less (3.5-7 mm) in length, but some can be as large as one and a half inches (40 mm). They have long ovipositors and legs. Braconids (Family Braconidae) are generally smaller than Ichneumons and lack the pointed abdomen (ovipositor). Chalcids (Family Chalcidoidea) are a large group of very small wasps, usually a tenth of an inch (2.5 mm) long. They come in a variety of colours and have compact bodies with fringed wings. Vespid wasps (Family Vespidae) are large, black and yellow or black and white wasps, commonly known as hornets (bald face hornets in Canada) and yellow jackets. Most are social and feed chewed-up insects to their larva. Other than their colour, they are easily distinguished from bees by slender hairless bodies. They are typically one half to two thirds of an inch (12-16 mm) long. Mud daubers and sand wasps make up a large family (Sphecidae), or Superfamily (Sphecoidae), of solitary wasps that attach their eggs to insects and spiders and put them into nests with their eggs. They are easily distinguished from bees by their long slender black and yellow bodies and long legs.

Sawflies and horntails are easy to distinguish from other Hymenoptera by the lack of the typical narrow wasp waist (although unlikely to visit flowers). Wasps shorter than 8 mm are likely chalcid, pteromalid, eulophid or gall wasps. Wasps longer than 8 mm could be braconid or ichneumon wasps. If longer than 8 mm, and more robust and hairy but still with a slender waist, then it is likely a bee, particularly if it is visiting flowers.

Flies

Fly wings (a single pair) are typically swept back in a wedge at rest, rather than folded over their back like bees or curled like vespid wasps. The hind wings, or 'haltares,' are only vibrating knobs for stability. Other features include an enlarged mesothorax, slender movable neck, short, branched antennae and large compound eyes.[1,20,35,43,48,66] Nevertheless, some flies are easy to confuse with bees and wasps in flight because both orders have membranous wings and the hooked wings of wasps and bees can make it hard to tell if one or two pairs are in operation. The usually thicker waist, very skinny legs, larger eyes that dominate the face, and the short feathered, rather than long and slender, antennae are better than wings for distinguishing flies from bees.

Hover, flower and drone flies:

Flies of this family (Syrphidae) range in length from a third to half inch (8-12 mm). The largest is the drone fly which can be mistaken for a honeybee. Some syrphids have orange, rather than yellow, patches. Almost all syrphids have distinct black and yellow stripes and bands that likely mimic yellow jackets. With their bee-like buzz and colours, some hairy syrphids mimic bumblebees so well that they can be very deceptive to the human eye. As well as being generally smaller, syrphid flies can be distinguished from bees or wasps by the large red or brown eyes, thicker waist and, mostly, by the short, branched antennae. Also, their abdomens are typically flattened whereas wasp abdomens are tubular. Male eyes are larger than female eyes and meet at the top of the head. More importantly, it is usually only the male syrphids that actually hover in search of mates and appear to occupy a point in space to which they return.

Less important flies:

Bee flies (Family Bombyliidae) are medium to large flies with a prominent proboscis. They hover close to flowers while sipping nectar and fly fast and in straight lines between flowers.[66] They are large for flies, a third to half inch (8-12 mm) long, and are stout and quite hairy, but have long thin legs. They are bright velvety black or fuzzy brown, with partly blackish, or grey wings. Tachinid flies (Family Tachinidae) resemble large house flies. They are hairy, with more hair on their legs than syrphids. They are usually drab black, grey or brown, but can be a variety of brighter colours. Some have yellow-brown on the thorax. Some species are quite big for flies, at a quarter to half inch (6-12 mm). Blow flies (Family Calliphoridae), have a bright metallic green thorax and abdomen and are the size and shape of house flies, at a quarter inch (6 mm), with little or no hair. Flesh flies (Family Sarcophagidae) are also seen on flowers. They are slightly bigger than house or blow flies, but can resemble house flies. They are grey-black with lighter grey stripes on top of the thorax, but are not at all metallic. Empid (or dance) flies (Family Empididae) are grey, with a silver-to-black head, red-brown antennae, yellow proboscis, hump-backed thorax, narrow abdomen, and are a quarter inch (6 mm) long at the most.

Beetles

Beetles are easily recognized by their hard wing covers (elytra) and clumsy flight. Their wing covers make them distinct from most other orders except for the sucking bugs (Order Hemiptera) or some leaf hoppers (Order Homoptera). The best means of differentiating beetles from these groups is by the size of the scutellum, the triangle above the thorax defined by the two hardened fore wings and the pronotum, the hardened top of the first segment of the thorax.[7] In beetles, the pronotum is always very small and there is a very straight margin separating the fore wings. In comparison, in sucking bugs the scutellum is proportionally large and the wings angle back and may cross. At a careless glance, beetles can also be confused with earwigs (Order Dermaptera) which are distinctive with pincers at their tail ends, very short wing covers and more elongated bodies than most beetles. In addition to the soldier beetles, longhorn beetles, various flower beetles and ladybird beetles commonly seen on flowers, a wide range of other beetles from the Scarabaeidae, Nitidulidae, Curculionidae and other families are also encountered occasionally.[1,7,48,44,64,66]

Soldier beetles (Family Cantharidea), specifically the goldenrod soldier beetle, is a very common species seen on flowers in Ontario. They are long-bodied with straight sides and have flexible gold and black tone (but not spotted) wing covers. The longhorn beetles (Family Cerambycidae) most commonly seen on flowers are a subfamily (Lepturinae) in the very large family of longhorn beetles. Longhorn beetles have long cylindrical bodies and are characterized by antennae at least half as long as their bodies. They are typically ‘big-shouldered’ with elytra that narrow towards the back end. A member of this family seen on goldenrod in late summer is the locust borer (*Megacyllene robiniae*), a beetle that mimics the yellow jacket wasps, being about the same length (12 mm) with striking yellow and black colouring.[7]

Tumbling flower beetles (Family Mordellidae) are small, one eighth to quarter inch (3-7 mm) long, silky blackish with white marks on the elytra, humpbacked and wedge-shaped, with a pointed abdomen just visible beyond their elytra.[66] Their heads are bent down underneath and their antennae are short and thread-like. They jump and tumble when disturbed. Shining flower beetles (Family Phalacridae) are small, eighth-inch (3 mm) or less in length, blackish, humpbacked and differ from tumbling flower beetles by short clubbed antennae and an abdomen tip that does not show. Ladybird (ladybug) beetles (Family Coccinellidae) are typically red with varying black spot patterns, depending on the species, nearly spherical and small, typically a quarter inch (6 mm) or less in length. Oil beetles (*Meloe* spp.) are a genus of the blister beetle family (Meloidae - named for the blister-causing defensive secretions from their abdomens).[7] They are black or bluish and oily with elytra shorter than their abdomens. They are about a half inch or less (10-13 mm) in length. Snout beetles or weevils (Family Curculionidae), recognizable by their long snouts and pear-shaped bodies, are also seen occasionally on flowers.

Butterflies, Skippers and Moths

This order is characterized by two pairs of scaly, large wings that are almost always coloured.[44] Moths (Suborder Herterocera) can be distinguished from butterflies (Suborder Rhopalocera) by wings that either don't fold, or fold down and back; butterfly wings fold up. More definitively, moths have shorter antennae that are usually feathered or branched, whereas butterfly antennae are long, single-stranded and usually clubbed at the end.[6]

Although just identifying a floral visitor as a butterfly would be sufficient, their varied and colourful wings will often permit identification at the family level.[22] Only those families with members likely to be seen in Canada are described here.[66] The family (Papilionidae) includes both swallowtails and parnassians. The swallowtails have distinct back-pointing projections from the hind wing that parnassians do not have. The parnassians are mainly western alpine insects and are not likely to be seen around urban parks or gardens. Sulphurs and whites (Family Pieridae) are characteristically white or yellow (occasionally brownish), and are nearly always almost a uniform colour. This family includes the well-known pest, the white cabbage worm. Milkweed butterflies (Family Danaidae) include the well-known migrating monarch butterfly. They are typically light brown to orange, with black borders and white dots. Satyrs and wood nymphs (Family Satyridae) are usually brown with conspicuous eye spots.

Brush-footed butterflies (Family Nymphalidae) have antennae as long as their bodies, orange to brown background with checkerspot markings. Wings have fan-like veins. This family includes the fritillary and checkerspot butterflies. It includes the viceroy that mimics the monarch. It is a large family with some members that could be confused with swallowtails due to the irregular posterior edge of the hind wing. Snout butterflies (Family Libytheidae) are characterized by the elongated mouth parts that form the snout. The wings of gossamer winged butterflies (Family Lycaenidae), including hairstreaks, harvesters, coppers and blues, are iridescent purple, blue, brown copper-green. Most are small. Skippers (Family Hesperiidae) are all in one family, but are distinctly different than butterflies in appearance and flight. They have more stout bodies with smaller wings and they fly faster in a more darting fashion. They come as dark to light, yellow and brown, and have no gaudy colours or patterns.

Because there are over 20 families of moths that are mostly nocturnal, they are very difficult to identify by family. Being nocturnal, most will not be observed when other pollinators are active. Given their relatively minor role as pollinators, it was decided early not to expect observers to attempt any further identification than to distinguish them from other Lepidoptera. Hence no descriptions of family differences are provided here.

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