General Introduction

Although bees get most of the press when it comes to pollination, recent research has shown that flies are also extremely important and carry out about one-third of our pollination services. Among the flies, syrphids are usually the most important pollinators. Together, insect pollinators provide over 500 billion dollars' worth of direct benefit to agriculture annually. The actual value when pollination of native plant species is factored in is incalculable.

In addition to the value of pollination services, the importance of immature hover flies must be considered. About one-third of all syrphid larvae (mostly Syrphinae and Pipizinae) are predators of soft-bodied insects like aphids and scales and as such bring huge benefits in natural and biological control of pests. Other syrphid larvae are extremely important in the recycling chain, with species of drone flies (*Eristalis*) and lagoon flies (*Eristalinus*) being the major players in sewage recycling, and jewel flies (*Ornidia*) playing a big role in tropical compost turnover.

Many syrphid larvae in the subfamily Eristalinae are bacterial filter feeders in sap runs or under bark. Many are old-growth forest specialists and are important indicators of overall habitat quality, and some are among the most threatened insects in degraded habitats.

Ant flies (Microdontinae) are among the most ecologically amazing groups of syrphids. Larvae of species with known biologies are found in ant nests, where they feed on ant eggs and larvae while mimicking their host's pheromones to avoid detection. Most known ant flies are predators, but recently the life history of the first parasitoid in the family, *Hypselosyrphus trigonus*, was discovered. This recently discovered Central American species develops externally on ant prepupae, thus avoiding the need to overcome the immune system of the host, as in internal parasitoids.

If you are starting to get the impression that flower flies do almost

Cheilosia covered with pollen. Recent research has shown that nonbees perform 39% of our agricultural pollination services.

Many rat-tailed maggot larvae (*Eristalis* and relatives) are important recyclers in ponds and lagoons, while others live in tree holes, bromeliads, and other standing water. This one was in a tree hole in Backus Woods, Ontario.

Callicera erratica, a presumed old-growth forest specialist.

everything as larvae, you are correct. In addition to the larval life histories mentioned above, there are also plant feeders (including root, stem, and leaf feeders, even leaf miners), fungal feeders, specialized pollen feeders, predators in bee nests, aquatic filter feeders in ponds, puddles, and bromeliads, heartwood borers in old trees, and much more. Few families of insects have such a diverse range of feeding styles, and because of this, syrphids are a model system for the evolution of feeding strategies.


All of our *Microdon* larvae with known biologies are predators in ant nests. At least some mimic the pheromones of their host ants to avoid detection.


Xylota larva under wet bark.


Criorhina nigriventris, a perfect mimic of an eastern *Bombus* (bumblebee).

Syrphids are also a model system for research into mimicry. Most adult syrphids mimic wasps or bees in some way. There are some spectacular cases of "perfect mimicry" where syrphids look and behave almost exactly the same as their models. Have a look through the wasp flies (*Ceriana*), swiftwings (*Volucella*), yellowjacket flies (*Sphecomyia*), and mimics (*Mallota*) to get an appreciation for these remarkable feats of evolution. If you think that the physical resemblance is impressive, wait until you see some syrphids in the field. Some falsehorns (*Temnostoma*), pond flies (*Sericomyia*), and hornet flies (*Spilomyia*) waggle their prolegs to mimic wasp antennae. Their legs are patterned just like their wasp models'. Catch a swiftwing in your hand and you will likely release it on impulse when it buzzes just like a bumblebee. These mimics obtain considerable protection by looking and behaving like stinging wasps and bees. No syrphids bite or sting, but they certainly advertise that they do. While the larger syrphids are often perfect mimics, most of the smaller species (most of the Syrphinae, for example) are known to be "imperfect" mimics. These species have converged on general wasp models (i.e., black and yellow stripes/spots) and are thought to gain protection by looking more or less like bees and wasps and being small enough not to merit a second look by vertebrate predators.

We may be a bit biased, but on top of all of these marvelous natural history traits, we think that syrphids are among the most attractive of all flies. Most are field identifiable and the diversity is comparable to that of other "accessible" animal groups such as birds. There are over 6,300 described species of hover flies in the world, but only 413 species in the area covered by this book. With a bit of time and dedication, it is just as easy to learn to recognize the majority of adult hover flies as it is to learn to identify most birds.

How to Use This Book

Our goal was to make everything in this book as self-evident as possible, but below are some notes to support the field guide pages.

Guide Coverage

This book covers all 413 known syrphid species that occur in or north of Virginia, Kentucky, and Missouri, west to include Iowa, Minnesota, Ontario, and Nunavut, and east to the Atlantic Ocean, including Greenland (the area in green on the map below).

Range Maps

Specimen data were accumulated in the Canadian National Collection of Insects, Arachnids and Nematodes (CNC) database (available from http://www.cnc-ottawa.ca) based largely on specimens in the CNC as well as the American Museum of Natural History (AMNH), the University of Guelph insect collection (DEBU), and the Smithsonian National Museum of Natural History (USNM). BugGuide (http://bugguide.net/) data were incorporated from states not found in collections examined. Dots on the maps represent specimen records. Colored areas on the maps were inferred using these point data in combination with vegetation, elevation, and climate layers (using the program MaxEnt and compiled in QGIS). Darker shading on the maps indicates areas where the species is more likely to occur. The entire Nearctic range of included species is shown.

Illustrations

Field photos were used when available and when we were able to definitively identify species in the photos. Specimen vouchers support many of these field photos and are available in the CNC and DEBU. Museum photos are linked to specimens in the AMNH, CNC, DEBU, and USNM. If there are ever questions about the identity of specimens, we can trace the photos back to these specimen vouchers to check. Lab photos were mostly taken with a Canon EOS 50D

Imperfect mimics like this *Eupeodes* all converge on a similar gestalt, making them very difficult to identify.

All syrphid species known from the green-shaded area are included in the guide.

A drawer of syrphid specimens (*Blera*) from the CNC, showing regional colored labels and a type specimen.

and 100 mm or 65 mm macro lens on a StackShot rail. Multiple photos were usually montaged into single images using Zerene Stacker to provide complete depth of focus. Other specimen photos were taken with a DFC495 five-megapixel camera attached to a Leica M205C stereomicroscope. Image stacks were acquired with the Leica Application Suite software and stacked using Zerene Stacker. Images were processed using Adobe Photoshop.

Toxomerus marginatus, arguably the most abundant syrphid in northeastern North America.

Estimates of Abundance

We apply qualitative terms in the text for each species to give a rough idea of how common the species are in the region of greatest abundance and during their flight periods. Our definitions for these terms are the following: **Abundant** – can be found in large numbers daily, **Common** – found daily without much effort, **Uncommon** – either low density or local and require special effort to be found most days, **Rare** – very low density or very local species, likely to be found annually, **Very Rare** – very low density or very local species unlikely to be found annually, **Vagrant** – presumed not to be able to survive within the region of the guide, occurring only rarely as a migrant.

It's All in a Name

Flower flies are also known as hover flies (and incorrectly as hoverflies). We prefer the name flower fly, as it best captures the true essence of most adult flies in this family. However, there is no dispute that some syrphids are among the best fliers in the animal kingdom, capable of hovering motionless for minutes at a time, backing up out of flowers, and zooming off in an instant. We concede that most people will still connect with the name hover fly and have thus included it here. However, we use flower fly interchangeably with hover fly throughout the text, as we find the former more descriptive.

Although lots of syrphids hover, many more, like this *Temnostoma*, visit flowers; thus our preference for the common name flower flies.


Ant flies, such as this *Microdon*, are in the least-encountered subfamily of syrphids (Microdontinae).


Many of the small black syrphids are in the subfamily Pipizinae.


Eristalinae, the most varied subfamily, includes many bee-like members such as this *Mallota posticata*.


Syrphinae mostly have a generalized wasp-like gestalt, similar to this *Syrphus*.

Subfamilies and Tribes of Flower Flies

There are currently four subfamilies of flower flies recognized: **Microdontinae**, **Eristalinae**, **Pipizinae**, and **Syrphinae**. Each subfamily is color-coded throughout the book. Microdontines (ant flies) are ant associates. Eristalines make up most of the family's diversity, varying widely in morphology and natural history, and possibly not forming a natural group. Pipizines are small black syrphids that specialize on root aphids. Syrphines are mostly imperfect mimics as adults, and predators of soft-bodied arthropods as larvae. The term "tribe" is often used to circumscribe smaller and more manageable groups of species. Phylogenetic evidence suggests that many tribes are not natural groups, and most are of little value in a field guide. We therefore avoid the use of tribal names.

Scientific Names for Species

The best current database of scientific names of syrphids can be found at http://www.cnc-ottawa.ca (adapted from http://www.diptera.dk). Based on these databases and new research, we provide a list of valid Nearctic Syrphidae names at http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm. Flower fly taxonomy is more in flux than taxonomy of vertebrate groups but is among the best available for any group of flies. There are still new flower fly species to be discovered and described (in fact, we have discovered many in the lead-up to publishing this book), and taxonomic hypotheses are typically based only on a combination of adult morphology and DNA. Larvae of very few Nearctic Syrphidae have been described, and behavioral observations are primitive compared to those for vertebrates. Research on interbreeding and knowledge of hybrid zones are still largely lacking! We hope that this field guide will help fill some of these gaps and produce more rigorous species hypotheses as field identification of syrphids becomes attainable.

Common Names for Species

Very few syrphids have been given common names, and many websites are now starting to offer common names for species with no attempt to standardize. We have proposed a set of common names for all Nearctic syrphids (http://www.canacoll.org/Diptera/Staff/Skevington/Syrphidae/Syrphidae_Nearctic_Checklist.htm) and provide them here with the species accounts. Our goal was to provide a single name for each group of species with descriptors added to each. This gives an idea of how species are related, much as generic names do. We tried to create these names with the global fauna in mind and thus hope that syrphidologists in other regions will follow our lead.

This is an undescribed species of *Hammerschmidtia*. Some undescribed species like this have been known for years, while others were discovered while producing this guide.

We created common names that we hope are memorable and descriptive. The sedgesitters (*Platycheirus*) are often found on sedge and grass flowers, where they presumably feed on pollen.

Almost all adult flies have two wings (most insects have four).

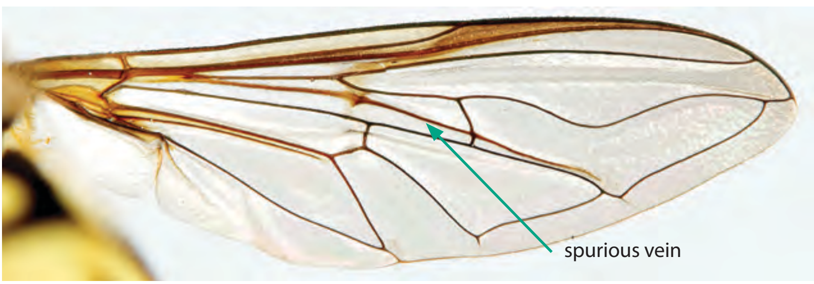
Flower flies are variable in appearance, but most of our species have a spurious vein. Only a few Conopidae share this trait.

Identifying Flower Flies

Is it a fly? Diptera is the scientific name for flies and derives from the Greek words *di* (two) and *ptera* (wings). Whereas most insects have four wings, flies have only two. The hind pair of wings are reduced to small clubs, called halteres, for orientation.

Is It a Flower Fly?

Syrphids usually have large heads, large eyes, and short antennae; many are mimics of wasps or bees. If in doubt, check the wing venation. All of the syrphids in our region except *Psilota* and *Syritta flaviventris* have a spurious vein (a "false" vein, meaning that it is not joined to any others).



The online key to Nearctic syrphid genera will help narrow things down if you can't find your species by flipping pages.


Identifiable without having to catch it if you get a good view


Identification requires careful examination with a hand lens


Identification requires microscopic examination


Indicates species that hilltop (*see* Hilltopping *page 22*)


Shows the middle of the typical size range for each species (*see* Measurements *page 22*)

Icons used in the book.

Parts of a Flower Fly?

As with all groups, you have to learn a specific terminology in order to converse and use the literature. We cover all of the terms used in this book in the illustrations and the morphology sections in the glossary.

Identification to Genus and Species

We have laid out the book so that similar species appear together to facilitate flipping through the images in search of a match. If you cannot match the species you see to photos, figuring out what genus you are dealing with is critical. Learning to recognize the genera of syrphids in the field will help immensely with species identification. A free online illustrated key to Nearctic syrphid genera is available at http://cjai.biologicalsurvey.ca/mylmst_23/mylmst_23.html. Each species in the guide has a symbol associated with it to indicate the detail required for identification. Some species are quite easy to recognize (the eye symbol indicates you should not have to catch it if you get a good view), while others will require careful examination with a hand lens in the field (hand lens symbol) or even a microscope in the lab (microscope symbol). Species that require you to see the microtrichia on the wings require either a high-powered hand lens or microscope. Don't expect to be able to immediately field identify all of the species marked with the eye ( ). You may need to capture and examine many of these "easier" species to first become familiar with them.

Life Cycle

Syrphids are typical of all flies (and in fact all higher insects) in that they go through a complete metamorphosis. Eggs hatch into larvae, larvae transform into pupae, and pupae transform into adults. Syrphid larvae go through three "molts" before forming a pupa within a puparium, which is essentially a cocoon made from the skin of the last larval stage. In contrast, lower flies (including groups like mosquitoes and horse flies) usually have an exposed pupa.

Sexual Dimorphism

Males and females of most syrphids look the same except for their genitalia and the relative size of their eyes. In most species, the eyes of males are larger and touch above

Most males can be distinguished from females by looking at the eyes. In these mating *Toxomerus*, the male's eyes (top) touch in front but the female's (bottom) do not.

Both photos are of *Volucella facialis*. As with their model bumblebees, they have both orange and yellow marked color morphs.

their antennae (holoptic), whereas most females have smaller, completely separated eyes (dichoptic). Males also typically have one extra visible abdominal segment and often appear to have a swollen tip to their abdomen because of their genital capsule. Some syrphid species are sexually dimorphic, with males and females looking quite different. This gives us a bit more to learn and also means that the dimorphic species pages will be more crowded with illustrations of the characters of both sexes (see the sickleleg [*Polydontomyia*] page 84 for an example of this).

Variation within Species

Some flower flies have different color morphs (for example, the bumbleflies [*Criorhina*] often have red and yellow morphs like the bumblebees they are mimicking). Other syrphids look generally the same but vary in more subtle details such as leg color. This type of variation often confounds species hypotheses, and some variable species have been described under many different names. Molecular data are often useful in distinguishing intraspecific variation (variation within a species) from interspecific variation (variation between species).

Measurements

Size variation within syrphid species is often considerable and presumably relates to larval diet. Sometimes, when different generations of larvae feed on different things at different times of the year, size varies seasonally. Measurements of the typical size range of each species are presented in millimeters. A life-size gray silhouette in the middle of the typical size range is provided for each species. Holding a specimen up to these shapes should give a quick idea of whether or not you are in the correct ballpark.

DNA

We have been building a DNA database using several genes. Our most extensive dataset uses part of the mitochondrial cytochrome c oxidase 1 gene (the "DNA barcoding gene" region). Although this is not a panacea for all of our taxonomic problems, it has proven to be useful in delimiting about 80% of Nearctic syrphid taxa at the species level. The most important direct use of this database (accessible at http://www.boldsystems.org/) is in the identification of immature stages. Very few larvae of Nearctic Syrphidae have been studied or are even known. If you find a larva, you have the option of trying to rear it (time consuming but possible) or putting it in 95% alcohol and sending it to someone who can sequence it (Jeff Skevington [JHS] is often available to help with this). It is important to photograph the larva and take good notes on the habitat in which it was found.

Unlike most syrphids, *Platycheirus* species can often be found in cloudy or even rainy weather.

Observing Flower Flies

When to Find Flower Flies

Flower flies are most common in the shoulder seasons (spring and fall), but species vary markedly in time of emergence from the southern to northern ends of their range. Small regional field guides often show flight periods for each species, but given the broad latitudinal range covered by this guide, this is not attempted here and we provide only general estimates of flight periods for most species. In the southern part of the area covered by the guide, some syrphids may be found on warm days in any month of the year. Around the latitude of southern Ontario, the first syrphids start to appear in late March and the peak flight period is from late May to mid-June. Different habitats also see different peak periods, with flower flies in cool environments such as bogs flying up to a month later than those in surrounding habitats. Search the CNC database (http://www.cnc-ottawa.ca/) to find dates of occurrence for particular syrphid species within your area.

Focus your observational efforts from early morning to early afternoon. Flies are morning creatures and although you may find them all day, most flies are not very active from mid- to late afternoon. The best temperature for syrphid activity is typically between about 15 and 25 degrees Celsius. If it is too hot, there is a risk of desiccation, so they are not active. Cool, sunny spring days with low wind encourage activity at lower temperatures. Sun is key for finding most species. Even a passing cloud will radically reduce flower fly activity. Don't entirely give up on overcast or rainy days, though. Some syrphids, including many of the sedgesitters (*Platycheirus*), appear to be most active when it is overcast and even raining lightly.

Flower Fly Habitats

Flower flies can occur in any terrestrial habitat but are least diverse in arid and semiarid environments. They lack water retention systems such as those found in bee flies (Bombyliidae) and many beetles, so most flower flies do poorly in dry environments. The best environments for finding a diversity of syrphids are forest openings, natural meadows, and riparian areas. Flowers can be very productive; flat-topped white compound flowers are particularly attractive to flies. Slowly walking back and forth through a productive area of flowers is a good strategy, and when one plant turns out to be attractive, sitting and watching it can produce a great variety of species. Remember to watch flowers on trees and shrubs as well as herbaceous plants. When not watching flowers, try looking for syrphids around freshly fallen trees or on tree wounds. Other species will be found sitting on low vegetation in sunny patches along forest edges/paths. Patiently watching at these sites will often yield some of the least common species. Some species (typically males) hover over woodland paths, while others hover over shrubs or on hilltops.

Contrast between Europe and North America

Disturbed areas (weedy meadows) in North America can be rich in flowers but almost devoid of syrphids. This is in stark contrast to Europe, where similar-looking meadows are literally teeming with syrphids. Flower flies are often the most abundant, conspicuous, and diverse inhabitants of meadows in Europe. People used to hunting for syrphids in Europe will be shocked at how outwardly similar habitats here contain only a few common flower fly species. We assume that this is because disturbed meadows here are dominated by nonnative plants (in fact, they look so much like European meadows because the floral diversity is so similar). To find a good diversity of syrphids, you thus need to find meadows dominated by native plants. Wet meadows, prairies, and savannas typically fill this role. Unfortunately, the latter two habitats have been decimated in North America and are now among the most endangered ecosystems that we have. For examples of these systems, look at Cook County Forest Preserves (Illinois), Indiana Dunes National Lakeshore, Neal Smith National Wildlife Refuge (Iowa), Oak Openings Preserve Metropark (Ohio), or Pinery Provincial Park (Ontario).

Hilltopping

One of the best ways to find the rarest syrphids is to go to hilltops. Males of rare or unpredictably distributed species cannot easily find a mate and use hilltops as landmark mating sites. Hilltops do not have to be high; they just need to be prominent to attract a hilltopping fauna. In flat areas, a low rise can function as a hilltop, whereas in rolling areas you should look for the most prominent hilltop to start your search. Ridges or escarpments tend to spread out the hilltoppers, so in these situations look for spots that are slightly higher or jut out. Hilltopping is very much a morning phenomenon, starting early and winding down quickly after noon. Ensure you look everywhere, for flies are very specific as to where they occur on hilltops (hovering in the open or under cover, sitting on shrubs, on rocks, on human-made vertical or horizontal structures, on tree trunks, twigs, etc.). Every year we visit the same hilltops and find new syrphids that we overlooked on past visits. In most cases, we can find

Ceriana willistoni is a rare syrphid that can often be found on hilltops. Mount Rigaud, Quebec, 24 May 2015.

the same species again on subsequent visits once we know their tricks.

The spatter marks on this leaf are from artificial honeydew that was sprayed to attract this *Didea fuscipes*.

Honeydew

Another feature highly attractive to syrphids is honeydew. Aphids, scales, and relatives produce sticky, sugar-rich honeydew as a waste product, and syrphids and other insects commonly home in on these secretions to feed. If you find a natural site with honeydew speckling the leaves, watch patiently and you should see a good variety of flower flies in attendance. Of course, you can also simulate natural honeydew by making your own. Mix honey, water, and cola together to make a sweet concoction, put it in a spray bottle, and spray it on broad, exposed leaves in sunny patches in forest habitats. Slowly walk your spray route back and forth and you should encounter a variety of syrphids. Honeydew spraying works best a day or two after heavy rains, before natural honeydew builds up again. It is ineffective if there has been no recent rain and there is a lot of natural honeydew.

Water

Water sources are particularly attractive to syrphids in periods of drought or on very hot days. Small, shaded creeks with lots of moist, exposed rocks can attract a wide variety of flower flies under these conditions.

Field Tools

Binoculars that focus close (within 2 m) are useful. Roof prism binoculars (or related new designs) are the most resistant to bumps and are also typically waterproof. Light transmission may be low in some, and lens coatings may add an undesirable color cast to subjects, so be sure to test new purchases in person rather than buying them sight unseen. Full-size binoculars offer much brighter views than mid-size or compact binoculars.

At the time of writing, Nikon (Monarch 7), and Vortex (Talon) offer some of the best low-end binoculars, while Leica (Ultravid), Swarovski (EL Swarovision), and Zeiss (Victory) dominate the high end. Eight times magnification is likely to work best for most people, as 10× binoculars are harder to hold steady and do not transmit as much light. If you prefer a small binocular, the Pentax Papilio II is popular among entomologists and focuses to 0.5 m. Many review sites are available on the internet for comparing binoculars, but browsing a local store that carries a good variety of binoculars is a good start.

Syrphids can be handled for examination and later release by gently holding their legs between your fingers.

Carrying an insect net may not be for everyone, but if you want to identify all of the flower flies you see, you will need one, even for capture and release. Generally speaking, the smaller the net ring, the faster you can sweep the net and the more control you have over it. Of course, the trade-off is that you have to be very precise and adept with a very small net ring. Some of our colleagues use tiny nets that are only about 7 cm in diameter. We tend to prefer 30–38 cm diameter nets and recommend this size as a starting point. Folding nets are handy if you want to carry one in your pocket and never be caught without it, but the trade-off is that they are more flimsy than nonfolding options. There are many suppliers for entomological supplies, but Bioquip is a good starting point, as they carry a great range of nets and other supplies. Note that pole length is also open to personal preference. Longer poles work well for jumpy flies like robber flies (Asilidae), whereas standard-length 91 cm net poles work well for syrphids. We have found 152 cm net poles work well in some situations but tend to impede you when working around trees. Remarkably, some colleagues use tiny nets with 10 cm handles and rely on stealth to get them close to their targets—insect vision is based largely on movement, so a slow, steady approach may yield results if you opt for this method. Syrphids can be safely caught, handled, examined, and released if you choose not to collect them.

Make sure you have lots of clear vials to put specimens in if you need to keep them for a longer time. A high-quality hand lens is important for examining characters of specimens that you have caught. Ten times magnification should be adequate. Ensure that you evaluate lens quality, as this is the most important feature of this tool. In a pinch, look through your binoculars backward and hold the specimen very close to the ocular lens. This functions as a magnifying glass, albeit an awkward one.

Photography

Options are nearly unlimited, from remarkable lens adapters for phones through to good point-and-shoot cameras with great magnification and macro potential. The problems with these options are typically low depth of field and a time lag when pressing the shutter button. The latter is most aggravating with active subjects. A dedicated DSLR camera system is thus still the best option for serious insect photographers. Canon and Nikon lead the market in this regard, but both have pros and cons. Canon has the best high-magnification insect lens available (the MP-E-65) on the market, but Nikon has more options available in remote flashes and some impressive low-light features for shooting without flash. We used both Nikon and Canon equipment for the field guide. Canon gear included EOS-50D and EOS-1D X bodies paired with either the MP-E 65 mm or the EF 100 mm f/2.8 macro. Kenko extension tubes gave us added magnification range with the latter. With this we used the MT-24EX flash in the field and a variety of flashes and slaves in the lab. Dome lighting proved to be the best for in-lab illumination, and we followed the methods outlined by Kerr *et al.* (2008). Nikon camera bodies used included the D90, D2X, D300, and D800, paired with either a 60 or 105 mm lens.

Collecting and Vouchers

Not everyone reading this will want to collect syrphids, but the only way to identify and voucher some finds will be by using a specimen. Photographs will work as vouchers in many instances, but specimens are still the currency of insect taxonomists and can be preserved for hundreds of years and reexamined by anyone questioning the original identification. This section provides a quick overview of everything required to obtain, preserve, and maintain a voucher collection. For more extensive reading on this, download a free guide written by Martin (1977) at http://esc-sec.ca/aafcmonographs/insects_and_arachnids_part_1_eng.pdf. Note that collecting permits are required for most parks and protected areas.

Syrphidae are best collected by hand and Malaise trap. The latter is a tent-like trap that passively collects insects that fly into the center panel and respond by flying

Malaise traps are an effective way to collect flies, including syrphids. Like all collecting methods, they are not a panacea. Many eristaline syrphids like *Mallota* are undersampled with this method, presumably because they are able to navigate in and out of the trap head as they would a rot hole.

upward, where they then follow the roof line to the trap head. On average, the head of the trap should face the equator to maximize sun exposure to it, as many flying insects, including syrphids, are positively phototaxic and will move into the trap head more readily if it is well lit. Because flies are more active in the morning, angling the trap head to the southeast is optimal. Malaise traps work poorly if placed in shade and best if they intersect a general flight path (road, trail, woodland edge, river edge, etc.). Other options include emergence traps (best used for species that live in wood) and pan traps (yellow pans being the best color for syrphids). Pan traps work well for some groups but are generally not very effective for most syrphids.

If specimens are hand collected, a stainless-steel insect pin (#2 or 3) should be used to pierce the right-hand side of the thorax in larger specimens. Smaller specimens should be glued (glue on right side of thorax) to a point on enamel or stainless-steel pins. Labels should be printed (3.5 to 4 point Arial font) on ~80 gauge acid-free paper and include country, province/state, location, coordinates, collection date, collector, and habitat details. Unique identifiers should be added to labels if you plan to keep a database or refer photographs to individual specimens. These can be in the form of your name plus a number that is never repeated. If specimens are collected into alcohol in traps, they must be properly dehydrated and dried to prevent shriveling. Ethyl acetate (EA) drying is the easiest process for general use. For this, take specimens in 70–80% ethanol (EtOH) and pin them wet (preferably with pins that do not have enamel heads—Asta makes a cheap stainless-steel pin that has a rounded head and works well for this). When pinned, place the still-wet specimens into a 50:50 mixture of EtOH:EA and let them soak for at least four hours. Following this, move them into pure EA with a few drops of glycerin added as a softening agent. Soak for four hours or more and then lay them on a paper towel in a fume hood or well-


Some current collectors. Left: Jeff and Alexander Skevington pinning insects in Arizona. Right: Jim O'Hara and Jeff Cumming preparing the day's catch in Australia.

ventilated area. Position the wings as best you can. Although EA damages DNA, the specimens will be useful for morphological examination for hundreds of years after drying them. Note that ethanol-stored specimens are difficult to identify and degrade rapidly, particularly at room temperature.

Pinned specimens last for centuries but must be kept free of pests. Some beetles (*Anthrenus* species in the family Dermestidae) and book lice (Psocoptera) are the major threats. Keeping the specimens in sealed drawers is the best option but difficult to do without encouraging attack by fungi that can grow in high humidity. Plastic storage containers are particularly problematic for fungi, and you can lose a collection quickly if fungi start to grow. Naphthalene (mothballs) can be used to dissuade pests when nonairtight drawers are used. Freezing specimens to kill pests is a good strategy if an outbreak develops.

The other important thing to consider is the ultimate deposition of your collection. It makes sense to keep a small collection while you are learning, but once it is no longer needed it should be deposited in a permanent insect collection for long-term care, study, and storage. The best syrphid collections in North America are the Canadian National Collection (CNC) and the Smithsonian (USNM). The only other collection to rival these is the Natural History Museum (BMNH) in London, England. Donations of specimens can be made to any of these museums and also to smaller state/provincial, university, and museum collections. If your collection becomes significant, arrangements should be made with your family and a collection representative at the museum of your choice while you are in good health. Virtually everything we know about syrphids comes from these public collections, and citizen scientist donations can be significant. In addition to donations of collections, citizen scientist observations are critically needed to build our knowledge of these fantastic flies. This book aims to facilitate a new generation of research in this way.

Record Keeping and Databases

It is critical to ensure that the data associated with each specimen or photo are accurate. If you cannot be sure of the data for a specimen, it should be disposed of or marked as unknown. A single specimen with erroneous data can undermine confidence in an entire collection, no matter how significant that collection is. Adding unique identifiers to specimens and photos and storing these data in a spreadsheet or database will ensure long-term confidence in your data. A spreadsheet should minimally contain a unique identifier (typically your name or a collection name followed by a unique number—if using a collection identifier, ensure that you are assigned these numbers by the collection manager; for example, CNC12345 would be a unique identifier), collection locality (including country, state/province, specific location, latitude and longitude), collector, date or date range, trap type, habitat, rearing information, identification, and identifier. All data should be on the specimen label as well as in the database. Don't take shortcuts and only put codes on labels. Those who really get serious about this hobby are welcome to contact JHS to arrange access to the CNC database. Users can be set up with access and all data can be directly deposited into the collection database. The CNC database has functions for producing specimen labels from data entered, viewing, mapping and organizing data, and more.

Many databases are available for recording natural history observations. None are yet very robust for entering flower fly records, but two stand out. iNaturalist is growing quickly and may be the best location for entering your records. A free mobile app is available for data entry, and entering single records along with photos is very easy. Entering lists of species from a single location is problematic though, and until this is addressed by developers, entry of more than a single specimen is tedious. Observation.org (http://observation.org/familie/view/15) also has potential but has a less user-friendly interface and is available only on Android at the time of writing. At this time, it seems that iNaturalist is the best bet—at least until we have a syrphid version of eBird or eButterfly.

Rearing Larvae

The most important thing to remember when rearing terrestrial insect larvae is that they desiccate easily, so you will find yourself trying to strike that perfect balance between too dry and too humid. Too much humidity will lead to mold problems. Predacious species are usually easy to rear on the right hosts, while saprophagous species should be maintained in the substrate in which they were collected. The easiest larvae to rear are those collected as mature or prepupal larvae, but bear in mind that the puparia too are subject to desiccation. Some saprophagous species are easily collected as puparia or mature larvae in early spring, and these often emerge soon

It may not look like much from the outside, but the Canadian National Collection of Insects, Arachnids and Nematodes housed in the Neatby Building in Ottawa is one of the largest and most significant collections of insects in the world. Collection repositories like this are critical to our understanding of insect taxonomy and phylogenetics and serve as libraries that we can visit to explore changing patterns in our fauna.

Labels from a typical specimen. The top label contains information on locality (always include country and coordinates), date of collection (use roman numerals for month so there is no confusion), and collector. The second label is a unique specimen identifier (the prefix and number make it unique in the world). The unique identifier is important for databasing and tracking photos and published references to the specimen. Avoid abbreviations. The lower label indicates the species name and who identified the specimen. Never remove a determination label, even if incorrect. Just add another label with your identification. Never put only coded labels on specimens.

Eristalis brousii is one of our most rapidly declining syrphids. It has disappeared throughout most of its range and is now found in only a few places, one of which is Churchill, Manitoba.

after they are warmed up. Placing puparia in containers with moist peat moss usually works for rearing. Ensure that you include toothpicks or sticks that emergent flies can crawl onto to pump up their wings. Without this, the wings often fail to develop properly.

Conservation

Rare Species

Europeans have by far the best knowledge of which syrphid species are at risk and which are not. An annual species account distributed by Martin Speight (Syrph the Net) summarizes all that is known for each European species, including larval behaviors and conservation significance. We have a long way to go to get to this level of knowledge within North America, which means that everyone reading this can contribute a lot. JHS led an Environment Canada initiative to assess the status of all flower fly species found in Canada (Canadian Endangered Species Conservation Council, 2016). This report is based on collection data and as such provides a framework but needs to be followed by rigorous fieldwork. The syrphid that appears to be in the most trouble in North America is the Hourglass Drone Fly (*Eristalis brousii*). This once-abundant species has declined considerably and is now restricted to a few sites in the western mountains and along the northern periphery of its former range. We think that its introduced relative, the European Drone Fly (*Eristalis arbustorum*), has displaced it, possibly through competitive hybridization. Other species to watch closely are extreme specialists (such as ant flies [Microdontinae]) and old-growth forest specialists (such as pine flies [*Callicera*]).

Syritta is an Old World genus with its center of diversity in Africa. Despite this, at least two species have made it to North America. *Syritta pipiens* larvae live in rotting material such as compost and have made their way around the world in association with people.

Introduced Species

A few syrphids from other parts of the world have become established in our area. The European Drone Fly (*Eristalis arbustorum*) mentioned above is one of the most successful and can now be found on flowers throughout most of the field guide area. Other introduced species include all of the bulb flies (*Eumerus funeralis*, *E. narcissi*, *E. strigatus*, and *Merodon equestris*), Common Drone Fly (*Eristalis tenax*), Common Lagoon Fly (*Eristalinus aeneus*), two spikelegs (*Neocnemodon latitarsis* and *N. pubescens*), and Common Compost Fly (*Syritta pipiens*). Among these, the only pests are the bulb flies, which are usually only minor pests of daffodils and other bulbs.

Climate Change

Insects respond quickly to environmental changes and thus serve as excellent indicators of environmental conditions. Bees and butterflies have been used to study climate change, and specimen data now available on flower flies will be a powerful additional dataset for this research. As more and more citizen scientists become interested in syrphids and contribute data to this growing dataset, flower flies will become one of the key groups for studying local and large-scale environmental changes.

Surveying Syrphidae

We suggest that anyone planning to set up long-term or large-scale surveys for syrphids contact one of the authors of this guide for advice. Point counts and transects offer the best potential way to establish such long-term comparative data, but trapping projects can also work, as long as the shortcomings of traps are recognized. Malaise trap results are very hard to quantify unless many traps are run and trap setup is carefully described. Pan traps miss most of the fauna but are useful for comparing the subsets of species attracted. Hilltopping studies may provide some of the best comparative data for surveys but would need to be carefully designed for repeatability.

History of Flower Fly Taxonomic Research in the Nearctic Region

The first recognized Nearctic syrphids were described by Linnaeus in 1758 when he created our current nomenclatural system. Ten widespread species, including the likes of *Eristalis arbustorum*, *Eristalis tenax*, *Melanostoma mellinum*, *Syritta pipiens*, and *Syrphus ribesii*, were named by the great scientist using European specimens. Fabricius conducted the first substantive work using Nearctic specimens between 1775 and 1805 when he named 28 Nearctic species, including distinctive species such as *Ornidia obesa* and *Meromacrus acutus*. The 1800s brought the first significant wave of syrphid discovery with work by Wiedemann, Meigen, Macquart, and Say (the latter introduced us to some of our most abundant species, including *Allograpta obliqua*, *Toxomerus geminatus*, and *T. marginatus*). Only three scientists have described over 100 species in our region. Curran is the clear champion, with 223 species described (724 taxa described worldwide!). Hull is a distant second at 131 species, followed by Williston at 108. Now that most of the species have been described, we are in an era of testing previous species concept hypotheses and

Melanostoma mellinum was described by Linnaeus in 1758. Fortunately, type specimens for most of these early species still exist in museums, as the species definitions often need to be revisited. There are undoubtedly multiple species within what we now refer to as *M. mellinum*, and it may turn out that true *mellinum* occurs only in the Old World. More research is required to solve this puzzle.

List of people who have described more than ten species of Nearctic Syrphidae

Author	Years Active	# Syrphid Taxa Described	Author	Years Active	# Syrphid Taxa Described
Linnaeus	1758	10	Snow	1892–1895	19
Fabricius	1775–1805	28	Coquillett	1894–1910	15
Wiedemann	1818–1830	28	Townsend	1895–1901	22
Say	1823–1829	24	Hunter	1896–1897	21
Meigen	1828–1829	15	Johnson	1898–1929	22
Macquart	1829–1855	57	Jones	1907–1922	21
Harris	1835–1841	25	Shannon	1915–1940	76
Zetterstedt	1838–1849	17	Malloch	1918–1922	11
Loew	1846–1876	95	Lovett	1919–1921	20
Walker	1849–1860	82	Curran	1921–1953	223
Bigot	1867–1885	60	Fluke	1922–1954	96
Osten Sacken	1875–1878	32	Hull	1922–1960	131
Williston	1882–1893	108	Vockeroth	1958–2008	40
Giglio-Tos	1892–1893	12	Thompson	1976–	9*

* 9 species described plus more undescribed species treated in this book.

describing the occasional newly discovered species. Molecular data have been a great addition to our arsenal and provide a significant addition to and major independent test of morphological species concepts. The authors of this book continue in this vein, and undoubtedly many changes will be made to the taxonomy of these flies before hypotheses are stable. A great deal of work is still required in the western and southern parts of the Nearctic Region; this the main reason that this guide focuses on the northeast, where we have the best handle on our diversity. The table to the left lists people who have described more than ten species of Nearctic Syrphidae. Note that this list includes currently valid names and synonyms. Many of these may now be considered synonyms of other species.

Taxonomic Changes Proposed in This Guide

Many of the taxonomic concepts used in this guide are updated and have not been proposed elsewhere in the scientific literature.

New Combinations

Some syrphid genera have been found to be nonnatural through our research. We formally divide the genus *Lejops* into several monophyletic genera here, including *Anasimyia*, *Arctosyrphus*, *Eurimyia*, and *Polydontomyia*. We also elevate *Epistrophella* to genus (from a subgenus of *Epistrophe*), *Hammerschmidtia* to genus (from a subgenus of *Brachyopa*), *Lapposyrphus* to genus (from a subgenus of *Eupeodes*), *Megasyrphus* to genus (from a subgenus of *Eriozona*), and elevate *Meligramma* to

We hypothesize that *Lejops* in the broad sense does not form a natural group. However, the subgenera are monophyletic (natural groups that include all relatives and a single common ancestor) and are elevated to generic status here. *Anasimyia* is shown here.

genus (from a subgenus of *Melangyna*). We have also found that the bizarre species, *Merapioidus villosus*, is simply a divergent species of *Criorhina*.

Resurrected Species

We have re-evaluated species concepts and found that many species formerly treated as synonyms of others are actually valid species. *Anasimyia anausis* is resurrected from synonymy with *A. lunulata* (the latter is now restricted to the Old World). *Baccha cognata* is resurrected from synonymy with *B. elongata* (the latter is now restricted to the Old World, Alaska, and the Yukon). *Cheilosia albitarsis* is resurrected from synonymy with *C. bardus*. *Chrysotoxum plumeum* is resurrected from synonymy with *C. derivatum*. *Eurimyia stipata* is resurrected from synonymy with *E. lineata* (the latter is now restricted to the Old World, Alaska, the Yukon, and the Northwest Territories). *Hammerschmidtia rufa* is resurrected from synonymy with *H. ferruginea* (the latter is now restricted to the Old World). *Leucozona americana* is resurrected from synonymy with *L. lucorum* (the latter is now restricted to the Old World). *Mallota mississippensis*, *M. diversipennis* (restricted to Colorado and Utah), and *M. illinoensis* are resurrected from synonymy with *M. albipilis*. *Myolepta pretiosa* is resurrected from synonymy with *M. varipes*. *Scaeva affinis* is resurrected from synonymy with *S. pyrastri* (now restricted to the Old World). *Temnostoma excentrica* is resurrected from synonymy with *T. vespiforme* (the latter is now restricted to the Old World). *Volucella arctica*, *V. evecta*, and *V. facialis* are resurrected from synonymy with *V. bombylans* (the latter is now restricted to the Old World).

New Synonyms

Anasimyia relicta is a new synonym of *A. chrysostoma*. *Cheilosia browni* and *C. nigroapicata* are new synonyms of *C. lasiophthalma; C. caltha* and *C. sensua* are new synonyms of *C. comosa*; *C. consentiens* is a new synonym of *C. orilliaensis; C. hiawatha* is a new synonym of *C. albitarsis*; *C. nigrofasciata* is a new synonym of *C. hunteri*. *Chrysosyrphus versipellis* is a new synonym of *C. latus*. *Criorhina mystaceae* is a new synonym of *C. nigriventris*. *Chrysotoxum perplexum* is a new synonym of *C. plumeum*. *Eurimyia conostomus* is a new synonym of *E. stipata*. *Ferdinandea dives* and *F. nigripes* are synonymized with *F. buccata*. DNA barcodes are invariant between specimens of these species, and variation within series of specimens encompasses the complete range of these taxa. *Mallota palmerae* is a new synonym of *M. illinoensis*. *Neoascia distincta* is a new synonym of *N. globosa*. *Volucella sanguinea* and *V. americana* are new synonyms of *V. evecta*; *V. lateralis* and *V. rufomaculata* are new synonyms of *V. facialis*.

New Species

Eighteen new species are treated in the guide. They are not given formal names but are given numbers so that future publications can be cross-referenced to them. These names will be validated in a separate scientific publication. New taxa include *Anasimyia* undescribed species 1, *Anasimyia* undescribed species 2, *Brachyopa* undescribed species 17-5, *Brachyopa* undescribed species 78-2, *Cheilosia* undescribed species 17-1, *Cheilosia* undescribed species 17-3, *Cheilosia* undescribed species 76-1, *Hammerschmidtia* undescribed species 1, *Neoascia* undescribed species 1, *Neoascia* undescribed species 17-1, *Orthonevra* undescribed species 1, *Palpada* undescribed species 1, *Psilota* undescribed species 17-1, *Xylota* undescribed species 78-1, *Xylota* undescribed species 78-3, *Microdon* undescribed species 17-1, *Mixogaster* undescribed species 1, and *Trichopsomyia* undescribed species 1.

New species are sometimes genuine new discoveries made in the field, but more often they are sitting under our noses and have previously been overlooked in collections. This new species of *Palpada* was discovered when we noticed that DNA from Nearctic *Palpada furcata* was different from DNA of tropical *P. furcata* specimens. Morphological examination supported the fact that these were two species rather than one.

New research undertaken during the production of this field guide has shown that many preexisting species concepts cannot be supported. For example, molecular data and morphology refute the idea that *Mallota albipilis* is a single widespread species; instead it is four allopatric species. The midwestern species, *Mallota illinoensis,* is shown here. True *M. albipilis* is restricted to Arizona and New Mexico.

Examination of the holotype of *Criorhina mystaceae* showed that it fell within the range of typical variation of *C. nigriventris*. Having a good insect collection with series of specimens of each species allows us to examine variation within a species and refine our species hypotheses.