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Research Article

Syrphidae of Southern Illinois: Diversity, floral associations, and preliminary assessment of their efficacy as pollinators

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Abstract

Syrphid flies (Diptera: Syrphidae) are a cosmopolitan group of flower-visiting insects, though their diversity and importance as pollinators is understudied and often unappreciated. Data on 1,477 Syrphid occurrences and floral associations from three years of pollinator collection (2017-2019) in the Southern Illinois region of Illinois, United States, are here compiled and analyzed. We collected 69 species in 36 genera off of the flowers of 157 plant species. While a richness of 69 species is greater than most other families of flower-visiting insects in our region, a species accumulation curve and regional species pool estimators suggest that at least 33 species are yet uncollected. In order to further the understanding of Syrphidae as pollinators in the Southern Illinois region, we produced a NMDS ordination of floral associations for the most common syrphid species. The NMDS did not sort syrphid species into discrete ecological guilds, and syrphid floral associations generally fit those predicted by traditional pollination syndromes. We also conducted a preliminary analysis of the pollen-carrying capacity of different syrphid taxa, which found several *Eristalis* species to carry pollen loads comparable to the European Honey Bee, *Apis mellifera*, and showed significant differences in the pollen-carrying capacity of various syrphid species. Notably, the extremely common genus *Toxomerus* and other small Syrphinae species carried very little pollen, while large and pilose Eristalinae species carried large pollen loads.

Keywords

Syrphidae, hover flies, flower flies, syrphid richness, Southern Illinois, pollinators, pollen load, species accumulation curve, *Toxomerus*

Introduction

Syrphidae, known as syrphids, hover flies, or flower flies, is one of the largest families of flies (Diptera), represented by almost 6,000 described species worldwide and 812 in the United States and Canada (Miranda et al. 2013). Syrphids are common flower visitors, though their role in pollinator communities is understudied and often unappreciated (Inouye et al. 2015, Klecka et al. 2018, Rader et al. 2015). Syrphids are pollinators of many wild plants (Ssymank et al. 2008), in some cases as important as bees (Forup et al. 2007, Levesque and Burger 1982, Ornduff 1975, Scribailo and Posluszny 1984). Compared to bees, syrphids as a group tend to exhibit higher degrees of generalization (Klecka et al. 2018, Lucas et al. 2018), a propensity to visit flowers considered anemophilous (Ssymank and Gilbert 1993, Inouye et al. 2015, Holloway 1976), and a capacity for temporary floral constancy similar to that of bees (Inouye et al. 2015, Raguso 2020). Syrphid adults feed almost exclusively on pollen, nectar, or honeydew (Rotheray and Gilbert 2011), and at least one species is known to possess branched palynophilic hairs and pollen combing behavior similar to that of bees (Holloway 1976). Because syrphids do not provision their offspring in a nest as do bees, syrphids are able to range over more of the landscape and may carry pollen longer distances than bees (Lysenkov 2009, Rader et al. 2011). However, the wide diversity in ecology and morphology makes generalizations about the efficacy of Syrphidae as pollinators difficult (Raguso 2020).

Evaluating the efficacy of flower-visiting taxa as pollinators can be difficult and labor-intensive. Often, visitation data alone is used as an indicator of pollinator efficacy, but this assumption may lead to overestimation of the importance of abundant species that do not actually transport, or transport little, pollen between conspecific flowers (King et al. 2013). As such, some measure of pollinator 'quality' is necessary in order to evaluate the importance of different pollinators to plant reproduction (Herrera 1987). Factors influencing pollinator quality include visitation rate, floral constancy, and the amount of pollen carried on a visitor's body (Herrera 1987, Herrera 1989, Tepedino et al. 2011, Erhardt 2008). A species' mean pollen load size has been found to correlate positively with pollen deposition on stigma (Howlett et al. 2011). In general, flies carry less pollen than bees (Orford et al. 2015, Inouye et al. 2015). While some authors have suggested that the abundance of flies as flower visitors may make up for their inefficiency as pollinators, this may not be true, as visitors that consume floral resources with little or no pollination services may negatively impact plant pollination. Because pollinator efficacy is variable within Syrphidae (Raguso 2020), measures of pollinator quality should be conducted on a per-species basis.

Comprising six level IV US EPA Ecoregions (Woods et al. 2006), Southern Illinois is an area of high biodiversity within the Midwestern US (Stein et al. 2000). Syrphids, however, have historically been little sampled in the Southern Illinois region, with just 8 museum records compiled on GBIF for the 16 southernmost counties of Illinois as of May 2020 (GBIF.org 2020a). The objectives of this paper are 1) to report on Syrphidae diversity in Southern Illinois using data of floral visitors from a region-wide pollinator inventory, and 2) to develop a baseline of understanding of the efficacy of Syrphidae as pollinators of wild plants in Southern Illinois by establishing measures of both the abundance and potential pollinator quality of syrphid species in the region. To our knowledge, this is the first study to provide a regional inventory of syrphid species in Southern Illinois.

Material and methods

Collection methods

Collection methodology was consistent for each of the three studies contributing data, and followed standardized procedures for bee sampling (Droege et al. 2016), with slight modifications made to accommodate the objectives of the studies. Collection events all consisted of targeted hand-netting of floral visitors plus pan trapping. These events were supplemented with additional opportunistic hand-netting. The use of both pan trap and hand-net methods has been shown to be complementary and offset the taxonomic biases of each method alone (Baum and Wallen 2011). Hand-netting was conducted for 80 person-minutes per collection event. Flower-visiting hymenopterans, dipterans, coleopterans, and lepidopterans were collected with aerial insect nets and euthanized in cyanide kill jars. Insects were kept separate by floral associations. Netting was conducted primarily during clear, sunny days. All netting was carried out between 7:00 and 17:00. Plants from which floral visitors were collected were identified to species using published keys of Mohlenbrock (2014).

Pan traps were 7 cm diameter polypropylene bowls (DART manufacturer, stock number 325PC) painted fluorescent blue, yellow, or white and filled with a dilute detergent solution (Dawn Blue dish soap). Traps were set out in sets of three along a transect at a spacing of 10 m. Each set consisted of a blue, a yellow, and a white bowl placed along a line perpendicular to the transect and spaced 5 m apart. Pan trap sets were set along two 50 m transects. Pan traps were left from 4-6 hours during daylight hours, all between 7:15 and 18:00.

Study sites & dates

All specimens reported here were collected during surveys of all flower-visiting taxa. We sampled throughout the southernmost eleven counties of Illinois as well as Randolph county. Sampling focused on federally managed lands (Shawnee National Forest and Crab

Orchard Wildlife Refuge) but also included state and private lands. Sites were stratified with respect to land use and major habitat types, and included upland and bottomland hardwood forests, open areas, roadsides, agricultural fields, reclaimed strip mines, limestone glades, and wetlands. The majority of the specimens were collected during three studies: a 2017-2019 regional inventory of flower-visiting insects of Southern Illinois focused on the USFS Shawnee National Forest and USFWS Crab Orchard Wildlife Refuge (Figs 1, 2), a 2017 study of pollinators on agricultural weeds and clover cover crops in agrosystems within Crab Orchard Wildlife Refuge in Williamson County (Fig. 4), and a 2019 inventory of the Illinois National Guard Sparta Training Area in Randolph County, IL (Fig. 3). Taxa other than Syrphidae collected during these studies will be reported elsewhere.

Figure 1. doi

Bass Ponds, a wet habitat typical of Crab Orchard National Wildlife Refuge. Photo credits Daniel Presley.

Floral visitors were collected from April-September of 2017, February-September of 2018, and March-July of 2019. Over the three years of collection, 292 sites were visited and 756 collection events conducted, with 55% of these events conducted for the regional inventory, 40% for the agricultural study, and 5% for the Sparta Training Area inventory. Syrphids were collected at 222 of the sites and 445 collection events (Figs 5, 6; Suppl. material 1). The 70 sites and 311 collection events that did not yield any syrphids are not included in these analyses.

Figure 2. doi

Rocky Bluff (Crab Orchard National Wildlife Refuge) in early spring, a typical forested habitat of Southern Illinois. *Collinsia verna* (Scrophulariaceae) in bloom. Photo credits LK.

Species identification

Specimens were identified to species by JLC and GFGM using published keys of Skevington et al. (2019) and Miranda et al. (2013). Two percent of specimens were identified only to genus level (female *Sphaerophoria* and *Paragus*), and 6% were unidentified due to damage. Species-level circumscriptions follow Skevington et al. (2019). All collected specimens are deposited at the Southern Illinois University Carbondale.

Species accumulation and species pool estimators

To determine if syrphids were sufficiently surveyed to capture the species richness of Southern Illinois, a species accumulation curve was generated based on individuals sampled using the rarefaction method (rationale in Gotelli and Colwell (2001). Specimens unidentified to species were not included in this analysis. The regional species pool was estimated by first-order jackknife and bootstrap estimators. Jackknife estimators have been shown to perform better than other estimators where a small proportion of the total species richness has been sampled (Fattorini 2013), as is suggested by the species accumulation curve for this study. These analyses were conducted in the package "vegan" version 2.5-4 in R version 3.5.1 (Oksanen et al. 2019).

Figure 3. doi

Typical grassland-forest habitat matrix of Sparta Training Area. *Lotus corniculatus* (Fabaceae) in bloom. JLC and Daniel Crosby pictured hand-netting floral visitors. Photo credits Carmen Burkett.

Pollen load estimation

To survey the potential efficacy of syrphids as pollinators, we assessed pollen carried on specimens using a modification of the methods of Tepedino et al. (2011). Syrphid pollen coverage was estimated for eight regions of the body: dorsal head, anterior head, ventral head, dorsal thorax, legs, ventral thorax, dorsal abdomen, and ventral abdomen. Syrphids were examined under a dissecting microscope and the pollen coverage for each region was scored either 0 (no pollen grains present on region), 1 (1-several pollen grains on region), 2 (pollen grains separated by >1mm), 3 (pollen grains separated by <1mm), 4 (near complete pollen coverage of region) or 5 (multiple layers of pollen covering region). For the two most abundant species, *Toxomerus marginatus* and *T. geminatus*, a subsample of 39 and 25 undamaged specimens were selected for examination, respectively. For all other species, all specimens collected off flowers were examined (386 specimens total). A selection of 30 specimens of *Apis mellifera* (European Honey Bee) were also examined for comparison to the syrphids. Scopal pollen was ignored in *A. mellifera* pollen scoring.

Figure 4. doi

A field sampled for floral visitors during the cover crop study. The field is planted with *Trifolium incarnatum* (flowering at time of photo), *T. repens*, and *T. pratense* (Fabaceae). Photo credits SIUC photographer Russell Bailey.

Figure 5. doi

Map of US showing the study region outlined in red.

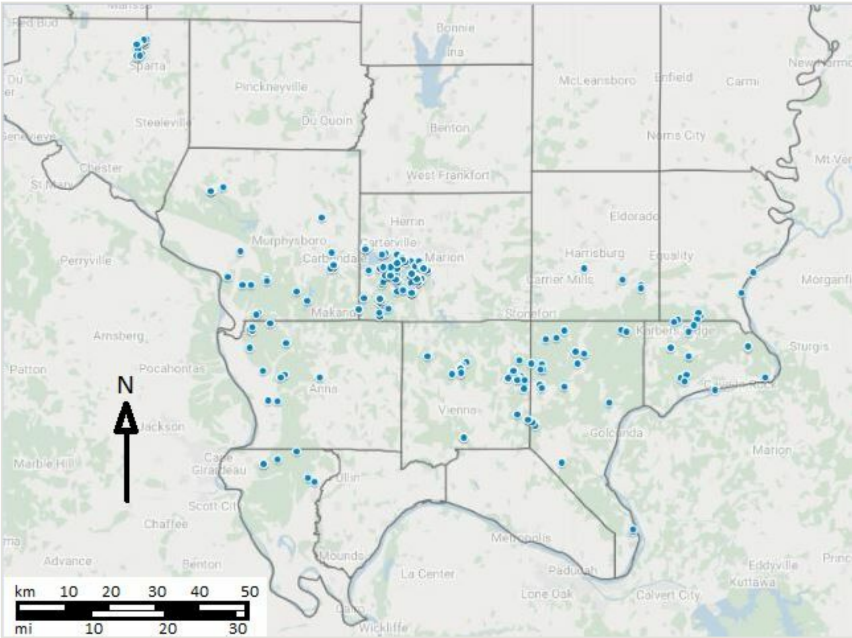

Figure 6. doi

Location of sites in Southern Illinois, United States, from which syrphids were collected. Many sites were revisited several times. Map created in Google My Maps.

To test for significant differences in pollen load size between species, a weighted mean score for each specimen was calculated by downweighting the scores for the three head regions by 1/3, and then averaging all 8 scores. Downweighting the head regions corrected the bias of having three head regions versus two abdominal and thoracic regions. These weighted mean scores were used to run a Kruskal-Wallis non-parametric test and post-hoc Bonferroni corrected pairwise Wilcoxon Rank Sum Tests in R (alpha=.05). Only those species with >6 specimens examined were included in the analysis (18 species and 338 specimens). *Apis mellifera* was not included in statistical analyses.

Floral association ordination

A non-metric multidimensional scaling (NMDS) ordination of syrphid species by floral association genera was produced to identify guilds of floral visitors (Bray-Curtis distance). The 18 most abundant floral visiting syrphid species were included, excepting *Toxomerus jussiaeae*, a specialist that was collected only off of *Ludwigia peploides*.

Data resources

A table of coordinates for collection sites is given in Suppl. material 1. A spreadsheet of syrphid occurrence data reported here is in Suppl. material 2. Raw values for the syrphid pollen analysis are reported in Suppl. material 3.

Results

Faunal composition

The floral visitor surveys used in this study yielded a total of 33,563 insect specimens, of which 1,477 were Syrphidae (4.40% of the total collection). The rest of the collection was comprised of 60.21% bees, 5.66% non-bee Hymenopterans, 12.92% non-syrphid Diptera, 5.07% Coleoptera, and 11.74% Lepidoptera; these will be reported on elsewhere.

The 1477 syrphids represent 69 species belonging to 36 genera (Table 1). Sixty-four of these species were identified as valid described species, 1 identified as a currently-undescribed species ('*Palpada* undescribed species 1' according to Skevington et al. 2019), and 4 taxa identified to species groups or affinities. The most abundant species in the collection were *Toxomerus marginatus* (45.63% of all collections), *Toxomerus geminatus* (13.61%), *Paragus haemorrhous* (3.05%), *Toxomerus politus* (2.91%), *Milesia virginiensis* (2.17%), *Toxomerus boscii* (2.03%), and *Eristalis transversa* (1.96%).

Table 1.

List of syrphid species collected in Randolph county and the southernmost 11 counties of Illinois, United States, from 2017-2019 with number and date range of specimens collected. Floral associations are reported for each species and correspond to family and species codes given in Table 2. Taxa with no floral associations listed were collected only from pan traps and/or free flying. Full occurrence records are provided in Suppl. material 2.

†This species not previously documented from Illinois. Compared to occurrence records in Skevington et al. (2019), GBIF.org (2020d)[1]This species previously known only from Virginia, US-New Brunswick, Canada (Skevington et al. 2019). [2]Introduced species from Palearctic. [3]This species previously known only from US States Oklahoma-North Carolina, south to Argentina (GBIF.org 2020b). [4]Undescribed species closely related to *P. furcata* (Skevington et al. 2019). [5]This species previously only known from <10 records from US States Ohio-Georgia-Pennsylvania (GBIF.org 2020c, Skevington et al. 2019). [6]*E. americanus* or *pomus*.

Taxonomic name (Author, Year)	# of Specimens	Months Collected	Floral Associations
Family Syrphidae	**1477**	Feb-Sep	
Subfamily Eristalinae	**257**	Feb-Sep	
Chalcosyrphus (*Xylotomima*) *libo* (Walker, 1849) †	1	Apr	
Chalcosyrphus (*Xylotomima*) *metallicus* (Wiedemann, 1830)	5	Jun-Aug	**Adox**: *Samnig* **Aste**: *Eristr* **Rubi**: *Cepocc*
Chalcosyrphus (*Xylotomima*) *nemorum* (Fabricius, 1805)	1	Apr	
Cheilosia aff. *florella*	1	Apr	**Ranu**: *Ran*
Cheilosia aff. *platycera*	1	Apr	

Taxonomic name (Author, Year)	**# of Specimens**	**Months Collected**	**Floral Associations**
Cheilosia primoveris (Shannon, 1915) †,1	6	Mar	**Port**: *Clavir*
Cheilosia wisconsinensis (Fluke & Hull, 1947) †	3	Mar-Jul	**Anac**: *Rhucop* **Aste**: *Vervir*
Copestylum (*Phalacromya*) *vesicularium* (Curran, 1947)	3	May-Aug	**Aste**: *Acthel* **Ranu**: *Anevir*
Eristalis (*Eoseristalis*) *arbustorum* (Linnaeus, 1758) [2]	1	Jun	**Apia**: *Daucar*
Eristalis (*Eoseristalis*) *dimidiata* (Wiedemann, 1830)	12	Feb-Sep	**Aste**: *Bolast, Eri, Sengla* **Bras**: *Barvul* **Hama**: *Hamvir* **Rosa**: *Pyrcal*
Eristalis (*Eoseristalis*) *flavipes* (Walker, 1849)	3	May-Jul	**Apia**: *Daucar* **Faba**: *Tripra*
Eristalis (*Eoseristalis*) *stipator* (Osten Sacken, 1877)	18	May-Aug	**Aste**: *Cirvul, Cor, Eristr, Helhel, Leuvul, Rudhir, Vermis* **Lami**: *Menpip* **Ranu**: *Ranabo* **Verb**: *Phylan, Verhas*
Eristalis (*Eoseristalis*) *transversa* (Wiedemann, 1830)	29	Apr-Sep	**Apia**: *Daucar* **Aste**: *Acthel, Bid, Cor, Eriann, Hel, Helhel, Leuvul, Rudhir, Rudsul, Sengla* **Eric**: *Vacarb*
Eristalis (*Eristalis*) *tenax* (Linnaeus, 1758) [2]	3	Feb-Jun	**Aste**: *Eri* **Eric**: *Vacarb* **Hama**: *Hamvir*
Helophilus (*Helophilus*) *fasciatus* (Walker, 1849)	25	Apr-May	**Apia**: *Chatai, Daucar* **Aste**: *Eriphi, Kri, Sengla* **Bora** : *Phapur* **Bras**: *Barvul* **Cary**: *Stemed* **Corn**: *Corfoe* **Faba**: *Trirep* **Lami**: *Blehir* **Papa**: *Stydip*
Mallota (*Mallota*) *bautias* (Walker, 1849)	8	Apr-Jun	**Adox**: *Samnig* **Aste**: *Eriphi, Eristr* **Bras**: *Brarap* **Hydr**: *Hydarb*
Mallota (*Mallota*) *posticata* (Fabricius, 1805)	1	Jun	**Ranu**: *Anevir*
Milesia virginiensis (Drury, 1773)	32	Jun-Sep	**Anac**: *Rhugla* **Aste**: *Ech, Eri, Hel, Liapyc, Rudhir, Symeri* **Faba**: *Trirep* **Hype**: *Hyppro* **Oxal**: *Oxastr* **Rubi**: *Cepocc*
Myolepta (*Myolepta*) *pretiosa* (Hull, 1923) †	1	Apr	**Corn**: *Corflo*
Myolepta (*Myolepta*) *strigilata* (Loew, 1872)	2	Apr	**Rosa**: *Prupad*
Orthonevra nitida (Wiedemann, 1830)	17	Apr-Jul	**Adox**: *Samnig* **Apia**: *Daucar, Eryyuc* **Aste**: *Achmil, Eristr, Leuvul* **Bras**: *Barvul* **Faba**: *Melalb* **Lami**: *Pycten*

Taxonomic name (Author, Year)	# of Specimens	Months Collected	Floral Associations
Palpada agrorum (Fabricius, 1787) †,3	6	Jun-Jul	**Apia**: *Daucar* **Aste**: *Cirvul*, *Eristr* **Faba**: *Trirep*
Palpada undescribed species 1 †,4	1	Jul	**Apia**: *Daucar*
Palpada vinetorum (Fabricius, 1799)	27	Jun-Sep	**Anac**: *Rhu* **Apia**: *Daucar, Eryyuc, Torarv* **Aste**: *Elecar, Eristr, Eupser, Heldiv, Rudhir, Solalt, Soljun* **Capr**: *Symorb* **Dips**: *Dipful* **Faba**: *Melalb* **Lami**: *Pruvul*, *Pycten* **Poly**: *Per* **Verb**: *Verhas, Verurt*
Parhelophilus integer (Loew, 1863) †	1	Apr-Apr	**Papa**: *Stydip*
Parhelophilus laetus (Loew, 1863)	1	May	**Corn**: *Corfoe*
Pterallastes thoracicus (Loew, 1863)	3	Jun-Jul	**Adox**: *Samnig* **Camp**: *Camame*
Sphecomyia vittata (Wiedemann, 1830)	1	Apr	**Bora**: *Mervir*
Sphegina (*Asiosphegina*) *petiolata* (Coquillett, 1910) †	1	May	**Corn**: *Corfoe*
Spilomyia alcimus (Walker, 1849)	2	Jun-Jun	**Adox**: *Samnig*
Spilomyia longicornis (Loew, 1872)	3	Jul-Sep	**Aste**: *Bolast*, *Eup*, *Soljun*
Syritta flaviventris (Macquart, 1842) †,2	1	Jul	**Verb**: *Verurt*
Syritta pipiens (Linnaeus, 1758) 2	23	May-Aug	**Apia**: *Daucar*, *Torarv* **Aste**: *Cicint*, *Eristr*, *Olirig*
Temnostoma balyras (Walker, 1849) †	2	Apr-May	**Faba**: *Medlup*
Temnostoma daochus (Walker, 1849)	1	Apr	**Corn**: *Corflo*
Teuchocnemis bacuntius (Walker, 1849)	1	Apr	
Teuchocnemis lituratus (Loew, 1863)	1	Apr	
Tropidia (*Tropidia*) *albistylum* (Macquart, 1847)	8	May-Jul	**Apia**: *Chapro* **Aste**: *Eriphi*, *Eristr* **Gera**: *Gercar* **Poly** : *Per* **Rubi**: *Diovir*
Xylota (*Xylota*) *ejuncida* (Say, 1824) †	1	Sep	
Subfamily Microdontinae	**4**	May-Jun	

Taxonomic name (Author, Year)	**# of Specimens**	**Months Collected**	**Floral Associations**
Microdon (*Dimeraspis*) *abditus* (Thompson, 1981)	1	May	
Microdon (*Dimeraspis*) *globosus* (Fabricius, 1805) †	1	Jun	**Faba**: *Medlup*
Microdon (*Microdon*) *aurulentus* (Fabricius, 1805) †,5	1	May	
Microdon (*Microdon*) *manitobensis* (Curran, 1924) †	1	May	
Subfamily Pipizinae	**9**	Apr-Aug	
Heringia (*Heringia*) *salax* (Loew, 1866)	3	May-Aug	**Camp**: *Camame* **Oxal**: *Oxastr*
Pipiza femoralis (Loew, 1866)	5	Apr-Apr	**Port**: *Clavir* **Scro**: *Colver* **Viol**: *Viosor*
Trichopsomyia apisaon (Walker, 1849)	1	Apr	
Subfamily Syrphinae	**1122**	Feb-Sep	
Allograpta (*Allograpta*) *exotica* (Wiedemann, 1830) †	1	May	**Faba**: *Medlup*
Allograpta (*Allograpta*) *obliqua* (Say, 1823)	18	Apr-Jul	**Apia**: *Conmac*, *Daucar*, *Torarv* **Aste**: *Eri*, *Sengla* **Faba**: *Cercan* **Hypo**: *Hyphir* **Oxal**: *Oxastr* **Ranu**: *Ran*
Epistrophella emarginata (Say, 1823)	2	Jun-Aug	**Aste**: *Vermis* **Lami**: *Monfis*
Eupeodes cf. *americanus* 6	24	Feb-Sep	**Aste**: *Bidpol*, *Heldiv, Kri, Sengla, Solcan* **Bora**: *Bugarv* **Bras**: *Barvul* **Capr**: *Valloc* **Hama**: *Hamvir* **Hype**: *Hyp* **Poly**: *Per* **Rubi**: *Diovir*
Eupeodes latifasciatus (Macquart, 1829) †	1	Apr	**Bras**: *Lepvir*
Ocyptamus fascipennis (Wiedemann, 1830)	1	Jun	**Bras**: *Lepvir*
Ocyptamus fuscipennis (Say, 1823)	10	Jun-Jul	**Anac**: *Rhugla* **Aste**: *Acthel* **Comm**: *Trad* **Gent**: *Sabang* **Hype**: *Hyp* **Lami**: *Monfis* **Oxal**: *Oxastr*
Paragus (*Pandasyopthalmus*) *haemorrhous* (Meigen, 1822)	45	Apr-Sep	**Apia**: *Daucar* **Aste**: *Ant, Eriann, Eristr, Eup, Helpau* **Bras**: *Bra* **Euph**: *Eupcor* **Lami**: *Teucan* **Plan**: *Plalan* **Rubi**: *Hou*

Taxonomic name (Author, Year)	# of Specimens	Months Collected	Floral Associations
Paragus (*Paragus*) *angustifrons* (Loew, 1863)	1	Aug	**Aste**: *Elecar*
Pelecinobaccha costata (Say, 1829)	2	Jun	**Anac**: *Rhugla* **Faba**: *Medlup*
Platycheirus cf. *albimanus*	1	May	
Pseudodoros clavatus (Fabricius, 1794)	4	Jul-Aug	**Verb**: *Verhas*, *Verurt*
Sphaerophoria contigua (Macquart, 1847)	23	Apr-Jun	**Apoc**: *Apocan* **Aste**: *Eristr, Leuvul, Sengla* **Bras**: *Lepvir* **Capr**: *Valloc* **Oxal**: *Oxastr* **Ranu**: *Ranbul*
Syrphus knabi (Shannon, 1916)	1	May	
Syrphus rectus (Osten Sacken, 1875)	1	May	
Syrphus ribesii (Linnaeus, 1758)	1	Mar	**Lami**: *Pyc*
Syrphus torvus (Osten Sacken, 1875)	1	Feb	**Hama**: *Hamvir*
Toxomerus boscii (Macquart, 1842) †	30	Apr-Sep	**Alis**: *Alisub* **Aste**: *Eriann, Eristr, Leuvul* **Cary**: Cerglo **Faba**: *Medlup, Trirep* **Hype**: *Hypdru* **Oxal**: *Oxastr* **Ranu**: *Ranabo, Ranbul, Ranpus* **Verb**: *Phylan*
Toxomerus geminatus (Say, 1823)	201	Mar-Sep	**Apia**: *Daucar, Osmcla, Torarv* **Aste**: *Acthel, Cicint, Eriann, Eriphi, Eristr, Eup, Heldiv, Hiegro, Kri, Leuvul, Rudser, Sengla, Silint, Taroff, Vervir* **Bora**: *Mervir* **Bras**: *Carcon* **Camp**: *Camame*, *Trilep* **Capr**: *Valloc* **Cary**: *Cerglo, Stemed* **Comm**: *Comcom, Tradvir* **Corn**: *Corfoe* **Cras**: *Sedpul* **Euph**: *Eupcor* **Faba**: *Medlup, Melalb, Secvar, Trirep* **Gent**: *Sabang* **Hydr**: *Hydarb* **Lami**: *Blehir, Lampur, Pruvul, Pyc* **Lyth**: *Ludalt* **Oxal**: *Oxastr* **Phry**: *Mimala* **Plan**: *Penhir* **Pole**: *Phlpil, Polrep* **Port**: *Clavir* **Rosa**: *Geucan* **Rubi**: *Galapa* **Verb**: *Phrlep*
Toxomerus jussiaeae (Vige, 1939)	9	Jul-Aug	**Lyth**: *Ludpep*

Taxonomic name (Author, Year)	# of Specimens	Months Collected	Floral Associations
Toxomerus marginatus (Say, 1823)	674	Apr-Sep	**Adox**: *Samnig* **Alis**: *Alisub* **Apia**: *Conmac, Daucar, Osmcla, Taeint, Torarv* **Aste**: *Achmil, Acthel, Cirvul, Concan, Cor, Eriann, Eriphi, Eristr, Eup, Kri, Kribif, Leuvul, Parint, Rudhir, Rudtri, Sengla, Sympil, Taroff* **Bora**: *Phapur* **Bras**: *Barvul, Bra, Lepvir, Rorten* **Camp**: *Trilep, Triper* **Capr**: *Valloc* **Cary**: *Cerglo, Cervul, Diaarm, Stemed* **Euph**: *Cromon* **Faba**: *Lotcor, Medlup, Medsat, Melalb, Meloff, Secvar, Triinc, Tripra, Trirep, Vicvil* **Gera**: *Gercar* **Hypo**: *Hyphir* **Irid**: *Sisang* **Lami**: *Pruvul* **Oxal**: *Oxastr* **Plan**: *Pendea, Pendig, Plalan, Verarv, Verper* **Poly**: *Per* **Port**: *Clavir* **Ranu**: *Deltri, Ranabo, Ranbul, Ransar* **Rosa**: *Amecan, Pot, Pyrcal* **Rubi**: *Cepocc, Diovir, Houlon* **Sola**: *Solcar* **Verb**: *Phylan*
Toxomerus politus (Say, 1823)	43	Jul-Aug	**Acan**: *Ruehum* **Apia**: *Daucar* **Aste**: *Eri, Eutfis, Hel, Rud, Sol* **Camp**: *Camame* **Conv**: *Ipolac* **Faba**: *Tripra* **Hydr**: *Hydarb* **Lami**: *Pruvul*, *Sta* **Malv**: *Hiblae, Sidspi* **Phry**: *Mimala* **Poac**: *Zeamay* **Poly**: *Per* **Verb**: *Verhas*
Xanthogramma flavipes (Loew, 1863)	1	Jun	**Amar**: *Allcan*
Unidentified to species	**85**	-	

To our knowledge, only one species historically observed in Southern Illinois was not collected during our inventory: *Temnostoma trifasciatum* (Robertson, 1901), known from one 1951 Union County specimen held at the Smithsonian National Museum of Natural History (NMNH, catalog number USNMENT 1541967). All other syrphid records from Southern Illinois at the NMNH, Illinois Natural History Survey, and iNaturalist Research-grade Observations represent species collected in this study.

Collections of note include *Microdon aurulentus Fig. 7*, which is known only from <10 records from US States Ohio-Georgia-Pennsylvania (GBIF.org 2020c, Skevington et al. 2019). *Palpada agrorum Fig. 8*, represented by 6 records in this collection, is a common species along the Gulf Coast and into Oklahoma but had previously not been collected as far north along the Mississippi river as Illinois. Introduced species comprised 1.9% of the total collection and include *Eristalis arbustorum* (n=1), *Eristalis tenax* (n=3), *Syritta flaviventris* (n=1), and *Syritta pipiens* (n=23).

Species pool estimate

The species accumulation curve (Fig. 9) does not approach asymptotic, suggesting that surveying was not adequate to capture the full syrphid species richness of Southern Illinois. First-order jackknife estimates the total species pool to be 101.93 (standard error 6.07). Bootstrap estimate predicted a lower number, 82.47 species (standard error 3.12). These values may underestimate the real regiona richness, as discussed below.

Figure 7. doi

Collected specimen of *Microdon aurulentus*, with scale.

Floral associations

Of the 1477 syrphid specimens collected, 1047 (70.89%) were collected by hand-netting off of flowers and 107 (7.24%) were collected by hand-netting while flying. Syrphids were collected from the flowers of 157 plant species representing 47 plant families in Table 2. Collections from flowers yielded 62 syrphid species, 41 of which were never collected in pan traps. Of syrphids collected off flowers, Asteraceae comprised 50.78% of collections, followed by Fabaceae (7.39%), Apiaceae (6.23%), Oxalidaceae (3.79%), Brassicaceae (3.70%), Ranunculaceae (2.82%), and 41 other plant families (the remaining 25.29%). Pan trapping collected 323 (21.87%) syrphids, constituting 28 species. Seven species were collected in pan traps but never collected in nets: *Chalcosyrphus libo, Chalcosyrphus nemorum, Microdon manitobensis, Teuchocnemis bacuntius, Teuchocnemis lituratus, Trichopsomyia apisaon*, and *Xylota ejuncida.* Each of these species was represented by just one individual.

Figure 8. doi

Collected specimen of *Palpada agrorum*, with scale.

Table 2.

List of all floral taxa from which syrphids were collected. Plant species codes (as reported in Table 1) are comprised of the first three letters of the genus and specific epithet, and family codes are comprised of the first four letters of the family name. Floral associations were occasionally identified only to genus level, and these are reported in Table 1 as the first three letters of the genus name (except *Tradescantia* and *Tragopogon*, for which the first four letters are used).

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Pan Trap		323	28
Acanthaceae	**Acan**	**1**	**1**
Ruellia humilis	*Ruehum*	1	1
Adoxaceae	**Adox**	**11**	**6**
Sambucus nigra	*Samnig*	11	6
Alismataceae	**Alis**	**9**	**2**
Alisma subcordatum	*Alisub*	9	2
Amaryllidaceae	**Amar**	**1**	**1**
Allium canadense	*Allcan*	1	1
Anacardiaceae	**Anac**	**5**	**5**

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Rhus copallinum	*Rhucop*	1	1
Rhus glabra	*Rhugla*	3	3
Rhus spp	*Rhu*	1	1
Apiaceae	**Apia**	**61**	**15**
Chaerophyllum procumbens	*Chapro*	1	1
Chaerophyllum tainturieri	*Chatai*	1	1
Conium maculatum	*Conmac*	3	2
Daucus carota	*Daucar*	41	15
Eryngium yuccifolium	*Eryyuc*	3	2
Osmorhiza claytonii	*Osmcla*	4	2
Taenidia integerrima	*Taeint*	1	1
Torilis arvensis	*Torarv*	7	5
Apocynaceae	**Apoc**	**1**	**1**
Apocynum cannabinum	*Apocan*	1	1
Asteraceae	**Aste**	**521**	**28**
Achillea millefolium	*Achmil*	4	2
Actinomeris helianthoides	*Acthel*	5	5
Antennaria spp.	*Ant*	1	1
Bidens polylepis	*Bidpol*	1	1
Bidens spp.	*Bid*	2	1
Boltonia asteroides	*Bolast*	2	2
Cichorium intybus	*Cicint*	2	2
Cirsium vulgare	*Cirvul*	3	3
Conyza canadensis	*Concan*	1	1
Coreopsis spp.	*Cor*	4	3
Echinacea spp.	*Ech*	1	1
Elephantopus carolinianus	*Elecar*	2	2
Erigeron annuus	*Eriann*	27	5
Erigeron philadelphicus	*Eriphi*	26	5
Erigeron spp.	*Eri*	139	15

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Erigeron strigosus	*Eristr*	95	14
Eupatorium serotinum	*Eupser*	1	1
Eupatorium spp.	*Eup*	4	4
Eutrochium fistulosum	*Eutfis*	1	1
Helianthus divaricatus	*Heldiv*	5	3
Helianthus pauciflorus	*Helpau*	1	1
Helianthus spp.	*Hel*	10	4
Heliopsis helianthoides	*Helhel*	3	2
Hieracium gronovii	*Hiegro*	1	1
Krigia biflora	*Kribif*	1	1
Krigia spp.	*Kri*	44	5
Leucanthemum vulgare	*Leuvul*	28	8
Liatris pycnostachya	*Liapyc*	1	1
Oligoneuron rigidum	*Olirig*	1	1
Parthenium integrifolium	*Parint*	1	1
Rudbeckia hirta	*Rudhir*	17	5
Rudbeckia serotina	*Rudser*	1	1
Rudbeckia spp.	*Rud*	16	5
Rudbeckia sullivantii	*Rudsul*	1	1
Rudbeckia triloba	*Rudtri*	1	1
Senecio glabellus	*Sengla*	51	9
Silphium integrifolium	*Silint*	2	1
Solidago altissima	*Solalt*	1	1
Solidago canadensis	*Solcan*	1	1
Solidago juncea	*Soljun*	2	2
Solidago spp.	*Sol*	2	2
Symphyotrichum ericoides	*Symeri*	1	1
Symphyotrichum pilosum	*Sympil*	1	1
Taraxacum officinale	*Taroff*	2	2
Tragopogon spp.	*Trag*	1	1

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Verbesina virginica	*Vervir*	2	2
Vernonia missurica	*Vermis*	2	2
Boraginaceae	**Bora**	**5**	**5**
Buglossoides arvensis	*Bugarv*	1	1
Mertensia virginica	*Mervir*	2	2
Phacelia purshii	*Phapur*	2	2
Brassicaceae	**Bras**	**38**	**11**
Barbarea vulgaris	*Barvul*	13	5
Brassica rapa	*Brarap*	1	1
Brassica spp.	*Bra*	4	2
Cardamine concatenata	*Carcon*	1	1
Lepidium virginicum	*Lepvir*	18	5
Rorippa tenerrima	*Rorten*	1	1
Campanulaceae	**Camp**	**12**	**5**
Campanulastrum americanum	*Camame*	6	4
Triodanis leptocarpa	*Trilep*	3	2
Triodanis perfoliata	*Triper*	3	1
Caprifoliaceae	**Capr**	**17**	**5**
Symphoricarpos orbiculatus	*Symorb*	1	1
Valerianella locusta	*Valloc*	16	5
Caryophyllaceae	**Cary**	**9**	**4**
Cerastium glomeratum	*Cerglo*	3	3
Cerastium vulgatum	*Cervul*	1	1
Dianthus armeria	*Diaarm*	2	1
Stellaria media	*Stemed*	3	3
Commelinaceae	**Comm**	**3**	**2**
Commelina communis	*Comcom*	1	1
Tradescantia spp.	*Trad*	1	1
Tradescantia virginiana	*Tradvir*	1	1
Convolvulaceae	**Conv**	**1**	**1**

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Ipomea lacunosa	*Ipolac*	1	1
Cornaceae	**Corn**	**7**	**6**
Cornus florida	*Corflo*	2	2
Cornus foemina	*Corfoe*	5	4
Crassulaceae	**Cras**	**1**	**1**
Sedum pulchellum	*Sedpul*	1	1
Dipsacaceae	**Dips**	**2**	**1**
Dipsacus fullonum	*Dipful*	2	1
Ericaceae	**Eric**	**2**	**2**
Vaccinium arboreum	*Vacarb*	2	2
Euphorbiaceae	**Euph**	**9**	**3**
Croton monanthogynus	*Cromon*	1	1
Euphorbia corollata	*Eupcor*	8	2
Fabaceae	**Faba**	**75**	**15**
Cercis canadensis	*Cercan*	2	1
Lotus corniculatus	*Lotcor*	2	1
Medicago lupulina	*Medlup*	16	7
Medicago sativa	*Medsat*	1	1
Melilotus albus	*Melalb*	7	4
Melilotus officinalis	*Meloff*	1	1
Securigera varia	*Secvar*	2	2
Trifolium incarnatum	*Triinc*	1	1
Trifolium pratense	*Tripra*	10	3
Trifolium repens	*Trirep*	31	6
Vicia villosa	*Vicvil*	2	1
Gentianaceae	**Gent**	**3**	**2**
Sabatia angularis	*Sabang*	3	2
Geraniaceae	**Gera**	**5**	**2**
Geranium carolinianum	*Gercar*	5	2
Hamamelidaceae	**Hama**	**13**	**4**

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Hamamelis virginiana	*Hamvir*	13	4
Hydrangeaceae	**Hydr**	**4**	**3**
Hydrangea arborescens	*Hydarb*	4	3
Hypericaceae	**Hype**	**11**	**4**
Hypericum drummondii	*Hypdru*	1	1
Hypericum prolificum	*Hyppro*	1	1
Hypericum spp.	*Hyp*	9	4
Hypoxidaceae	**Hypo**	**2**	**2**
Hypoxis hirsuta	*Hyphir*	2	2
Iridaceae	**Irid**	**5**	**1**
Sisyrinchium angustifolium	*Sisang*	5	1
Lamiaceae	**Lami**	**21**	**11**
Blephilia hirsuta	*Blehir*	2	2
Lamium purpureum	*Lampur*	1	1
Mentha piperita	*Menpip*	2	1
Monarda fistulosa	*Monfis*	2	2
Prunella vulgaris	*Pruvul*	4	4
Pycnanthemum spp.	*Pyc*	2	2
Pycnanthemum tenuifolium	*Pycten*	6	2
Stachys spp.	*Sta*	1	1
Teucrium canadense	*Teucan*	1	1
Lythraceae	**Lyth**	**10**	**2**
Ludwigia alternifolia	*Ludalt*	1	1
Ludwigia peploides	*Ludpep*	9	1
Malvaceae	**Malv**	**2**	**1**
Hibiscus laevis	*Hiblae*	1	1
Sida spinosa	*Sidspi*	1	1
Oxalidaceae	**Oxal**	**39**	**8**
Oxalis stricta	*Oxastr*	39	9
Papaveraceae	**Papa**	**3**	**2**

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Stylophorum diphyllum	*Stydip*	3	2
Phrymaceae	**Phry**	**2**	**2**
Mimulus alatus	*Mimala*	2	2
Plantaginaceae	**Plan**	**17**	**3**
Penstemon deamii	*Pendea*	1	1
Penstemon digitalis	*Pendig*	3	1
Penstemon hirsuta	*Penhir*	1	1
Plantago lanceolata	*Plalan*	9	2
Veronica arvensis	*Verarv*	2	1
Veronica peregrina	*Verper*	1	1
Poaceae	**Poac**	**1**	**1**
Zea mays	*Zeamay*	1	1
Polemoniaceae	**Pole**	**2**	**1**
Phlox pilosa	*Phlpil*	1	1
Polemonium reptans	*Polrep*	1	1
Polygonaceae	**Poly**	**5**	**5**
Persicaria spp.	*Per*	5	5
Portulacaceae	**Port**	**7**	**4**
Claytonia virginica	*Clavir*	7	4
Ranunculaceae	**Ranu**	**29**	**8**
Anemone virginiana	*Anevir*	2	2
Delphinium tricorne	*Deltri*	1	1
Ranunculus abortivus	*Ranabo*	9	3
Ranunculus bulbosus	*Ranbul*	5	3
Ranunculus pusillus	*Ranpus*	1	1
Ranunculus sardous	*Ransar*	2	1
Ranunculus spp.	*Ran*	9	3
Rosaceae	**Rosa**	**9**	**4**
Amelanchier canadensis	*Amecan*	1	1
Geum canadense	*Geucan*	1	1

Taxon	Taxon Code	# syrphid specimens collected from	# syrphid species collected from
Potentilla spp.	*Pot*	2	1
Prunus padus	*Prupad*	2	1
Pyrus calleryana	*Pyrcal*	3	2
Rubiaceae	**Rubi**	**19**	**7**
Cephalanthus occidentalis	*Cepocc*	6	3
Diodia virginiana	*Diovir*	7	3
Galium aparine	*Galapa*	1	1
Houstonia longifolia	*Houlon*	3	1
Houstonia spp.	*Hou*	2	2
Scrophulariaceae	**Scro**	**1**	**1**
Collinsia verna	*Colver*	1	1
Solanaceae	**Sola**	**1**	**1**
Solanum carolinense	*Solcar*	1	1
Verbenaceae	**Verb**	**17**	**8**
Phryma leptostachya	*Phrlep*	1	1
Phyla lanceolata	*Phylan*	7	3
Verbena hastata	*Verhas*	6	4
Verbena urticifolia	*Verurt*	3	3
Violaceae	**Viol**	**1**	**1**
Viola sororia	*Viosor*	1	1

Floral association NMDS

The NMDS of floral associations is given in Fig. 10.

Pollen load comparison

Pollen scores for each of the 18 species analyzed are summarized in Fig. 11. Species ranged from mean scores of 2.33 (*Eristalis stipator*) to 0.15 (*Toxomerus politus*).

Discussion

The results of this inventory have provided a baseline of Syrphidae species richness and relative abundance in the Southern Illinois region. The genus *Toxomerus* represents the majority of the flower-visiting syrphids, comprising 69% of all syrphid individuals collected.

Our collections near agricultural areas (Crab Orchard National Wildlife Refuge, Sparta National Guard Training Area) likely contribute to the abundance of the three most commonly collected species (*Toxomerus marginatus*, *T. geminatus*, and *Paragus haemorrhous*), as larvae of these species are common predators of crop pests (Eckberg et al. 2014), especially aphids. While the subfamily Syrphinae outnumbered Eristalinae in abundance by a factor of 4.4, species richness in the Syrphinae (23 species) was only 59% that of the Eristalinae (39 species).

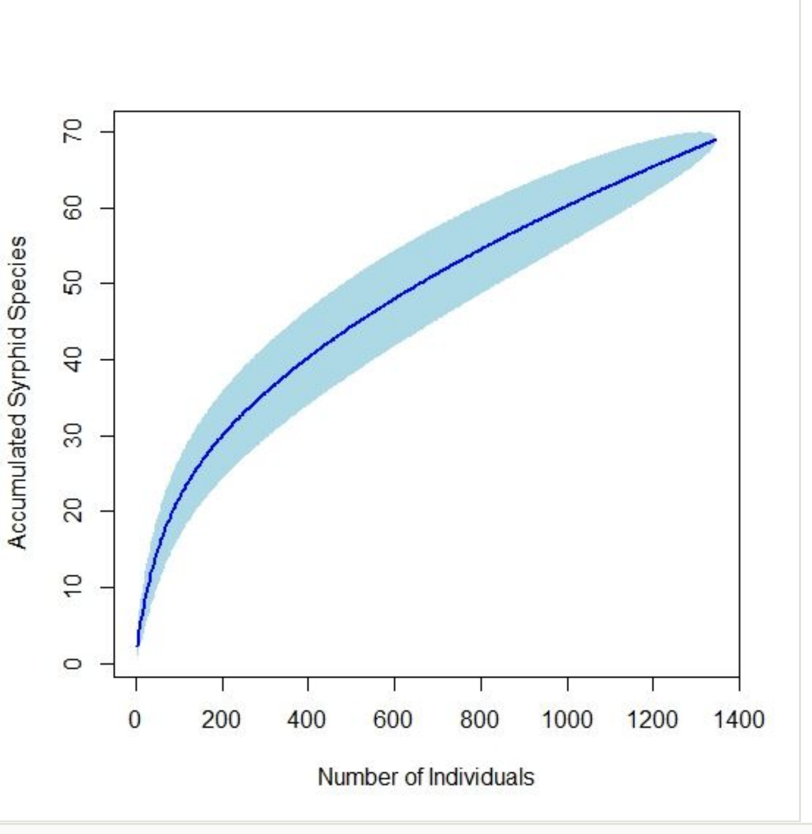

Figure 9. doi

Species accumulation curve for syrphid individuals collected from 2017-2019. Light blue confidence intervals show standard deviation.

Though sampling for this inventory was thorough (756 collection events), the species accumulation curve (Fig. 9) suggests that sampling failed to capture much of the regional syrphid diversity; the curve rises at a nearly constant slope after the 400th individual, rather than leveling off as expected if the full regional richness was captured. The first-order jackknife estimate (102 species) suggests that as little as 68% of the regional species pool may be known. This is, however, very likely an underestimation, as the jackknife estimates the species pool of the sites, rather than the region as a whole. Additionally, some habitats may have been undersampled, wetlands, which generally contain high syrphid diversity.

The first-order jackknife estimation of 102 species may be used as a lower limit for the regional species pool, though more sampling will be required to fully document the syrphid richness of the Southern Illinois region. While collections for this study encompassed a broad range of floral visitors, collection targeting syrphids would be more productive; malaise traps should be employed, which have been shown to be efficient in capturing syrphid diversity (Burgio and Sommaggio 2007). One group likely to be undersampled by our methodology is the genus *Microdon*, a group of ant nest predators which do not regularly associate with flowers (Duffield 1981). The single record of *Microdon globosus* visiting *Medicago lupulina* is of note, as there are very few observations of Microdontinae visiting flowers (M. Reemer, personal communication). Just four *Microdon* specimens were collected (3 in pan traps), constituting four different species. As *Microdon* are not typically flower visitors, however, they are unlikely to be pollinators of any import in our region.

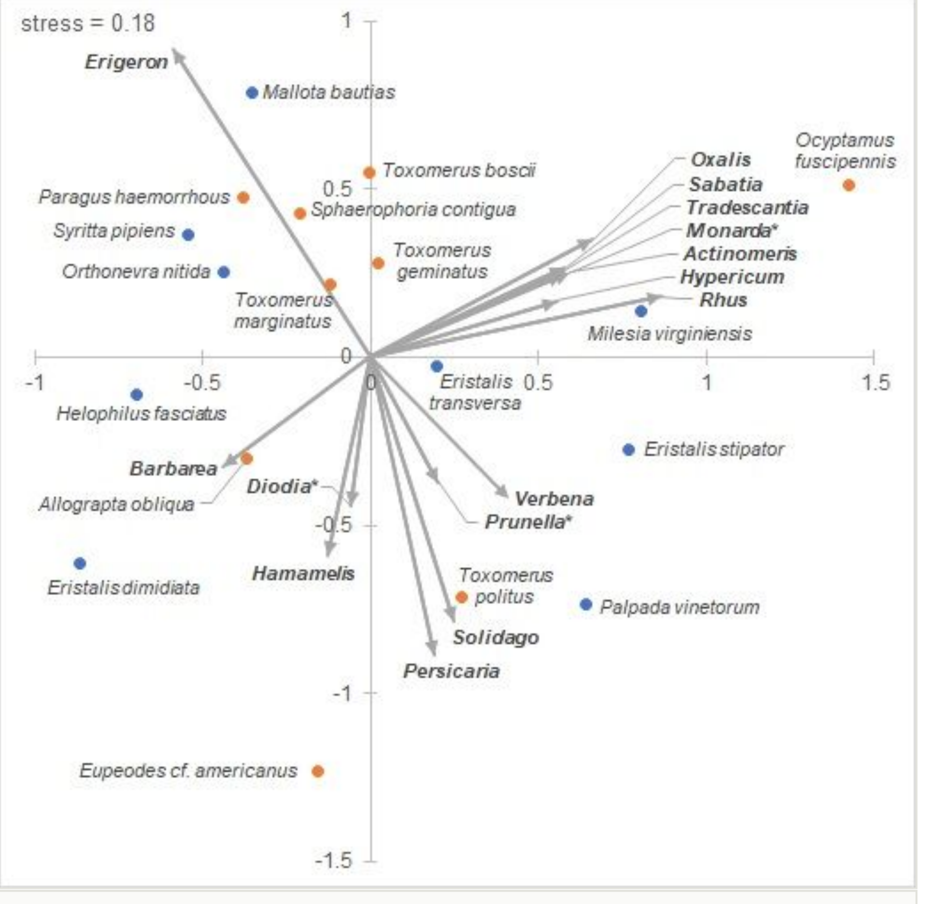

Figure 10. doi

NMDS ordination of 18 syrphid species by floral association genera. Blue points represent species in subfamily Eristalinae, orange points Syrphinae. Significant (alpha=0.1) plant vectors are shown. Plant genera names followed by an asterisk have $p<0.1$; all others have $p<0.05$.

At 69 species, Syrphidae is one of the most diverse groups of floral visitors collected in our 2017-2019 surveys. Bee families yielded from 19 (Colletidae) to 67 (Apidae) species, and butterflies including skippers (Lepidoptera: Rhopalocera) yielded 72 species. One reason for the high syrphid richness documented may be that Southern Illinois is predominantly rural; syrphid abundance and richness have both been shown to decline with increasing urbanization (Udy et al. 2020). Seventeen species (25% of total) reported in this study have not been recorded in Illinois before (Table 1), according to records in Skevington et al. (2019) and 10 datasets in GBIF.org (2020d). This demonstrates the large gap in our knowledge of syrphid distribution in the Eastern US, stressing the need for further studies of this diverse group of pollinators.

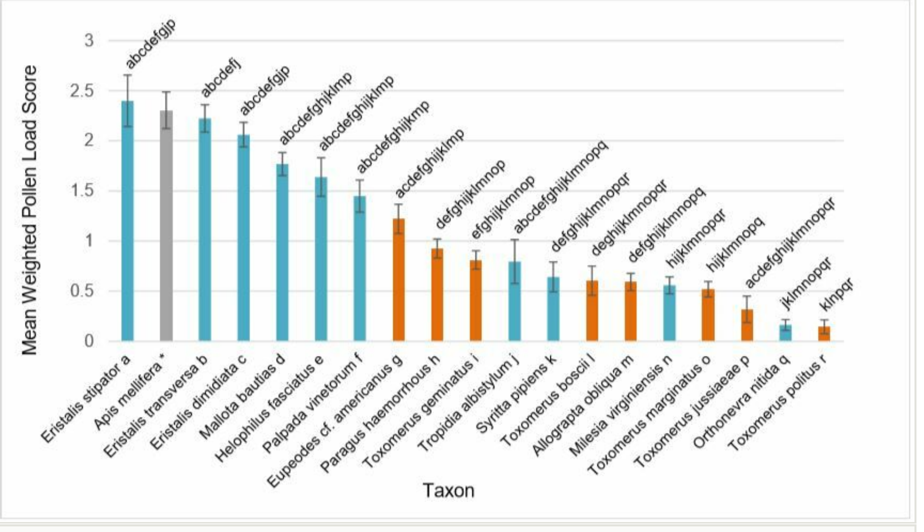

Figure 11. doi

Mean weighted pollen scores for each species analyzed, with standard error bars. Blue bars represent species in subfamily Eristalinae, orange bars Syrphinae, and grey bar *Apis mellifera*. Shared letters above bars denote no significant pairwise difference (pairwise Wilcoxon Rank Sum Test, alpha=0.05 with Bonferroni correction). *Apis mellifera* is included for comparison to syrphids but was not included in pairwise tests.

Syrphids were collected from a wide range of flowers (157 species). Floral associations generally followed the predicted pattern for non-carrion fly pollination syndromes: white, yellow, green, or brown flowers in color, radial symmetry, exposed pollen and nectar (Faegri and Pijl 1979). Over half of flower visits observed were to Asteraceae (40 floral species, 28 syrphid species collected from). The 25 most common floral associations (all those with more than 7 syrphids collected) have either white perianths, yellow perianths, or both (as in the bicolored capitula of *Erigeron* and *Leucanthemum*) except for *Trifolium pratense* (pink flowers) and *Plantago lanceolata* (anemophilous without showy flowers, though anthers are large and white). However, the pink flowers of *T. pratense* may not differ visually from white flowers to syrphids, as flies exhibit low sensitivity to red light (Lunau 2014). The frequency of Fabaceous flowers as floral associations (7.39% of the total; second most commonly visited plant family) is of note as the Fabaceous flowers collected off of (mostly *Trifolium*) possess tubular rather than open corollae, contrasting with the classical fly pollination syndrome. However, pollination syndromes have been shown to be poor predictors of floral visitation (Ollerton et al. 2009), and syrphids have been documented to forage on *Trifolium* species (Larson et al. 2014) and are likely pollinators.

The NMDS of floral associations failed to sort syrphid species into discrete guilds (Fig. 10), though some clustering is apparent. Syrphinae species are all (except for *Ocyptamus fuscipennis*) within ±0.5 of axis 1, whereas Eristalinae is far more evenly distributed in the ordination space. Eristalinae does cluster into two long groups on either side of axis 1, though this grouping is loose and does not reflect strong similarity in floral association within the Eristalinae. Five small predatory Syrphines (*Paragus haemorrhous*, *Sphaerophoria contigua*, *Toxomerus boscii*, *T. geminatus*, *T. marginatus*) and two small Eristalines (*Orthonevra nittida*, *Syritta pipiens*) are grouped around the *Erigeron* vector, the strongest vector in the ordination ($p<0.001$). Each of these species are common and exhibit low (below 1 mean pollen load score) pollen-carrying ability (Fig. 11). This group may act as abundant but low-quality pollinators of *Erigeron* and other weedy plant species. *Toxomerus* species except for *T. politus* are grouped in ordination space, showing high similarity in floral visitation within the genus. Larvae of *T. politus* feed on pollen of corn (*Zea mays*) (Reemer and Rotheray 2009), whereas other *Toxomerus* species in our area are predatory (*T. marginatus*, *T. geminatus*, *T. boscii*) or unknown (*T. jussiaeae*) Skevington et al. 2019; this difference in life history may play a role in the different floral visitation patterns exhibited by *T. politus* and its congenerics. *T. politus* also carries less pollen than other *Toxomerus* species (Fig. 11), which does not support grouping the whole genus as an ecologically similar guild. The grouping of *Toxomerus* (except for *T. politus*) in ordination space is in contrast to *Eristalis*, the three species of which are widely separated in the NMDS. *Milesia virginiensis* and *Ocyptamus fuscipennis* are at the most positive values of axis 1; both species inhabit forests (Skevington et al. 2019), which is reflected by the vectors in their quadrant of the ordination (forest plants such as *Tradescantia* and *Actinomeris*).

Examination of pollen loads showed significant differences in pollen carrying capacity of syrphid species (Fig. 11). Of note, the pollen analysis scored pollen <u>coverage</u> rather than <u>number</u> of pollen grains. Pollen coverage may be more important than pollen count in successful pollination, though we are aware of no studies assessing this. Many pairwise comparisons were not significant likely due to low sample sizes. Even so, some trends are clear. The six syrphids with the highest pollen scores were all in the tribe Eristalini of the Eristalinae, large bodied, and pilose: *Eristalis stipator*, *E. transversa*, *E. dimidiata*, *Mallota bautias*, *Helophilus fasciatus*, and *Palpada vinetorum*. This is expected, as pilosity and size are positively correlated with pollen load in flies (Inouye et al. 2015). This generalization is not a rule, however; *Milesia virginiensis* is large and pilose yet scored in the bottom five of the 18 species analyzed. The three *Eristalis* species analyzed all scored within ±0.25 of *Apis mellifera*, with *Eristalis dimidiata* even scoring slightly above. The high pollen load scores of these Eristalines has definite implications for the quality of the species as pollinators. Still, other factors such as floral constancy and pollen deposition on stigmas need be considered in order to further quantify their efficacy (Herrera 1987).

Several syrphids were collected in February, extremely early for floral visitors in the region: *Eupeodes* cf. *americanus*, *Eristalis dimidiata*, and *Syrphus torvus*. These specimens were collected off of a cultivated *Hamamelis virginiana* (American witch-hazel) on the SIUC campus. Considering the high pollen scores of *Eristalis dimidiata* and *Eupeodes*, these species may be important pollinators in the very early spring, before bees and most other floral visitors are flying.

The high pollen scores of the tribe Eristalini contrast greatly with many of the Syrphinae and less pilose Eristalinae. *Orthonevra nitida* and *Toxomerus politus* carried almost no pollen, and are thus unlikely to pollinate with any consistency. *Toxomerus marginatus* and *T. boscii* each scored ~0.5 on average, frequently carrying no pollen at all. *T. geminatus* scored slightly higher, though pairwise tests between the *Toxomerus* species were not significant. This is of note because *Toxomerus* was the most abundant genus of syrphids by far (69% of total). The similarity in pollen load size and floral association (Fig. 10) suggests that *Toxomerus marginatus*, *T. geminatus*, and *T. boscii* may be treated as a guild of similar pollinators. While their abundance may compensate for their low quality, consumption of floral resources by *Toxomerus* without pollen deposition on stigmas may harm plant reproduction. In contrast, *Eristalis spp* and other large pilose Eristalini syrphids are likely to be important pollinators where they occur, though their relatively low abundance means that these species are not ubiquitous across the Southern Illinois landscape and their importance as pollinators will be localized to where they are abundant.

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Author contributions

JLC: Identified syrphids, analyzed data, and wrote manuscript draft. NMS, LK, CJB: Designed and led field collection and reviewed manuscript. GFGM: Identified difficult syrphid specimens and reviewed. KLG, SDS: Obtained funding for the project, provided technical expertise, and reviewed manuscript.

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Supplementary materials

Suppl. material 1: Table of localities doi

Authors: Jacob Chisausky
Data type: Coordinates
Brief description: Matrix of coordinates of all sites from which syrphids were collected
Download file (21.64 kb)

Suppl. material 2: Collection occurrence data doi

Authors: Jacob Chisausky
Data type: Occurrence
Brief description: Data matrix of 1477 syrphids collected in Southern Illinois from 2017-2019, including species determinations, locality data, and floral associations.
Download file (249.62 kb)

Suppl. material 3: Syrphid pollen analysis data doi

Authors: Jacob Chisausky
Data type: Pollen load scores
Brief description: Data matrix from analysis of pollen load size of 416 syrphid specimens. Pollen coverage for eight regions of the body was assigned a score of 0-5 for each specimen.
Download file (39.02 kb)