National Park Service
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Natural Resource Stewardship and Science

Catch the Buzz – Pollinator Diversity, Distribution, and Phenology in Shenandoah National Park

Natural Resource Report NPS/SHEN/NRR—2017/1441

ON THIS PAGE
Top: Citizen scientists (Peg Clifton, Mary O'Meara, Carolyn Smith) running pollinator traps on Skyline Drive in August 2015, Shenandoah NP. **Bottom:** Bee bowl trap and informational sign. Photographs courtesy of J. Rykken.

ON THE COVER
Bumble bee (*Bombus* sp.) on nodding onion (*Allium cernum*) in Big Meadows, Shenandoah NP. Photograph courtesy of J. Rykken.

Catch the Buzz – Pollinator Diversity, Distribution, and Phenology in Shenandoah National Park

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May 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Rykken, J. J. 2017. Catch the buzz – pollinator diversity, distribution, and phenology in Shenandoah National Park. Natural Resource Report NPS/SHEN/NRR—2017/1441. National Park Service, Fort Collins, Colorado.

NPS 134/138251, May 2017

Contents

Contents (continued)

Figures

Tables

Page

Appendices

Page

Abstract

Insect pollinators, specifically bees (Hymenoptera: Anthophila) and flower flies (Diptera: Syrphidae), are critical to maintaining functioning ecosystems in Shenandoah National Park. Despite their ecological importance and potential vulnerability to environmental threats such as climate change, the diversity of these pollinators has remained largely unknown. In an effort to establish a baseline pollinator database for the park, we conducted a survey with three main objectives: (1) to document the diversity, distribution, and phenology of bees and flower flies in selected habitats of the park; (2) to establish a series of citizen scientist-run sampling sites and develop protocols for continued monitoring of pollinators; and (3) to educate park staff and visitors about pollinators and threats to pollinator health. Between May and October, 2015, we used nets and bee bowls to collect bees and flower flies at 100 different sites in the park (including seven monitoring sites run by nine citizen scientists). Sites ranged in elevation from 336 to 1225 m, and stretched north to south from MP 2 to MP 101 along Skyline Drive. We targeted areas of high or unusual floral diversity, including: forest roads, meadows, roadsides, and rock outcrops. In all, we collected 3,387 bees and 377 syrphid flies, comprising 145 and 40 separate taxa, respectively. Among bees, this represented half the genera known from Virginia, and approximately one quarter of the bee species known from the mid-Atlantic region.

Notable bee finds included 16 oligolectic (specialist) species, dominated by spring-active bees in the genus *Andrena.* A group of high elevation Appalachian species which are also found in more northern regions included several *Andrena*; the two bumble bees, *Bombus sandersoni* and *B. vagans*; the masked bee *Hylaeus annulatus*; and a rarely collected cellophane bee, *Colletes aestivalis*. Interesting syrphid flies included the rarely collected ant predator, *Microdon ruficrus*, and a single female in the genus *Chalcosyrphus* that is one of two very rare species in North America. The most abundant pollinator group was the social, ground-nesting bees, including *Lasioglossum* species and *Augochlorella aurata*. However, the most abundant species overall (13% of all bees) was the wood-nesting solitary bee, *Augochlora pura*. The syrphid catch was dominated by two species in the genus *Toxomerus* (57% of the total syrphid catch). Sampling effort across habitats was uneven (primarily meadows), but when this was accounted for by rarefaction curves, meadows still had the highest species richness among bees, while syrphids were most diverse in forest habitats. Standardized monthly sampling at the seven monitoring sites allowed us to track the seasonal activity of various pollinator genera, and also highlighted the need to begin sampling earlier in the season (i.e., April or May).

Park visitors and staff learned more about Shenandoah's pollinators through hands-on microscope sessions at Byrd and Dickey Ridge visitor centers, as well as one evening presentation at the Skyland amphitheater. Citizen scientists were invaluable to this inventory effort, and the development and documentation of detailed sampling protocols will allow Shenandoah to continue sampling at the established monitoring sites with the help of citizen scientists in the future if funding allows.

Figure 1. Examples of syrphid fly diversity in Shenandoah NP. **Row 1** (left to right*): Epistrophella emarginata, Brachypalpus oarus, Sericomyia chrysotoxoides*; **Row 2**: *Eristalis tenax, Allograpta obliqua, Spilomyia longicornis*; **Row 3**: *Rhingia nasica, Microdon* sp., *Xanthogramma flavipes*; **Row 4**: *Paragus haemorrhous, Temnostoma balyras, Melanostoma mellinum*; **Row 5**: *Cheilosia* sp., *Chalcosyrphus libo, Toxomerus marginatus*. Note that photos were not taken in Shenandoah NP, and photographs identified only to genus represent different species than those collected in the study. All photographs courtesy of Tom Murray.

Figure 2. Examples of bee diversity in Shenandoah NP. **Left column** (top to bottom): *Agapostemon virescens, Andrena alicieae, Nomada maculata,Osmia georgica, Melissodes desponsa*; **Middle column**: *Halictus ligatus* (covered in pollen), *Ceratina mikmaqi* (mating pair), *Stelis lateralis, Coelioxys sayi, Panurginus potentillae*; **Right column:** *Bombus impatiens, Hylaeus modestus, Anthophora bomboides, Lasioglossum platyparium, Augochlora pura, Megachile xylocopoides*. Note that bees in photos were not collected in Shenandoah NP. All photographs courtesy of USGS Bee Inventory and Monitoring Lab, except for mating *Ceratina*: Sandra Rehan.

Acknowledgments

Many thanks go to all the NPS staff at Shenandoah who enthusiastically supported the pollinator project, and helped make my time in the park productive, efficient, and comfortable. Wendy Cass and Jim Schaberl were especially helpful and welcoming.

I am very grateful to have had the help of retired entomologist Ken Kingsley, transplanted for several damp months to Shenandoah from the arid west. Ken sampled pollinators in and around Big Meadows for much of the summer, served as a contact and resource for the other citizen scientists, and also accompanied me in the field several times.

A remarkable contribution to this project was made by the efforts of a dedicated team of Virginia Master Naturalists: Peg Clifton, Mary Lee Epps, Grace Cangialosi, Becky Minor, Alex Newhart, Nora Rice, Carolyn Smith. This enthusiastic and reliable team of volunteers far exceeded my expectations, and proved to be an integral part of the overall pollinator survey. Peg Clifton went the extra mile and learned to wash, blow-dry, pin, and label bees to perfection!

Several taxonomists donated their valuable time and expertise to help with species identifications. Thanks go to Joan Milam, Michael Veit, and Sam Droege (USGS Bee Inventory and Monitoring Lab) for help with bees, and Andrew Young for taking on all of the syrphid fly identifications.

This project was funded with a generous research grant from the Shenandoah National Park Trust. Thanks to Susan Sherman and Rose Ann Smythe, especially, for supporting my efforts.

Introduction

The vast majority of flowering plants rely on insect pollinators for successful reproduction (Ollerton et al. 2011). Among the most efficient and diverse pollinators are native bees (Hymenoptera: Anthophila), with 4,000 species known in North America (Mader et al. 2011). Adult bees rely on pollen and nectar for their own nourishment, and bring both resources back to the nest to provision their developing young. Another conspicuous group of pollinators that mimic bees and wasps are syrphid flies (Diptera: Syrphidae; also known as flower flies or hover flies), represented by approximately 870 Nearctic species (Vockeroth and Thompson 1987). Most adult syrphid flies also feed on pollen and nectar, but their larvae are active feeders on a variety of resources such as aphids, ant larvae, plant stems and leaves, fungi, dung, and microbes associated with decaying wood and vegetation. Despite the ecological importance of these two groups of pollinators and their potential vulnerability to a variety of environmental threats, their diversity, distribution, and natural history has remained largely unknown to scientists, resource managers, and visitors in most national parks.

Pollinators are known to be at risk from various human-mediated threats such as habitat loss and alteration, invasive species, parasites, pesticides, and climate change (Potts et al. 2010). Dramatic declines have been well-documented and publicized for honey bees (Natural Research Council 2006), and have also been observed among native bumble bees (Cameron et al. 2011), and solitary bees (Burkle et al. 2013). Comparatively scant literature exists on the status of syrphid flies, although changes in species richness and composition pre-and post-1980 have been documented in Europe (Biesmeijer et al. 2006).

A recent U.S. Presidential Memorandum recognized the profound implications of pollinator losses, and called on a number of federal agencies and offices to develop a National Pollinator Health Strategy (Obama 2014). The assessment of native pollinators is a focal point in the Strategy's research action plan (Pollinator Health Task Force 2015). National parks, because they protect a broad diversity of both wild and cultural landscapes, provide an ideal natural laboratory in which to measure patterns of native pollinator diversity and to measure change in these patterns over time (Rykken et al. 2014, Rykken 2015, Rykken and Farrell 2015).

As in many parks, climate change may pose a significant threat to pollinator communities in Shenandoah, with potential consequences including range shifts, phenological decoupling of plant-pollinator networks, and population declines (Bartomeus et al. 2011, Franzén and Öckinger 2012, Iler et al. 2013). At particular risk are pollinator communities associated with habitats most vulnerable to effects from warming temperatures and altered climates. In Shenandoah, these include rock outcrop habitats, which harbor globally rare plant communities (Fleming and Patterson 2013). In addition, the park has a wide range of natural and managed habitats that are likely to provide forage and/or nesting substrate for a diversity of pollinators, including: meadows, deciduous woodlands, roadsides, overlooks, and wetlands. Skyline Drive, running for 169 km north-south through the park, provides an obvious sampling transect that includes elevational gradients (162-1,235 m), as well as transitions in geologic substrate and forest types.

The variety of accessible pollinator habitats in Shenandoah provides an ideal opportunity to establish baseline information on bee and syrphid fly species diversity, distribution, and phenology in the Blue Ridge Mountains of Virginia. These baseline surveys may also serve as the foundation for future monitoring efforts to measure population declines and shifts in range and phenology in response to human-mediated disturbances such as climate change.

Specifically, our primary objectives were to:

(1) Document and database the diversity, distribution, phenology, and host plant associations of bees and syrphid flies in selected habitats across Shenandoah National Park.

(2) Establish sites and develop protocols for citizen scientists to sample throughout the growing season, and to allow for continued monitoring of pollinators by park staff, citizen scientists, or other researchers.

(3) Educate park rangers, resource managers, visitors, and volunteers about the importance of pollinators and their potential role as indicators of climate change.

Methods

Study area

Shenandoah National Park comprises nearly 80,000 ha of primarily forested land, straddling the Blue Ridge Mountains in Virginia. The park is bisected by Skyline Drive, a paved road that runs 105 miles (169 km) north to south through the park. Elevations in the park range from 171 m at the northern end to 1,225 m on Hawksbill Peak. The park receives an average of 100-127 cm of rain annually, and air temperatures range from -23°C in winter to 38° C in hot, humid summers. The park is rich in plant diversity with more than 60 rare plant species, including 8 species ranked as globally rare (Shenandoah Fact Sheet April 2013). Many of these plants are associated with rock outcrop and cliff habitats, which make up approximately 2% of the park's total area (Wood et al. 2006).

Site selection and timing of collections

We selected a total of 100 sampling sites along the north-south axis of the park (20 sites in both North and South Districts, 60 sites in the Central District, including Old Rag; Fig. 3a, 3b, and 3c). These were distributed among several habitat types, including 24 forested sites (including roads and trails), 35 meadow sites (including lawns), 24 roadside sites, 15 rock outcrop sites, and 2 swamp sites (Table 1). Six citizen-scientist monitoring sites were spaced 24-40 km apart along Skyline Drive, two per ranger district, with the northernmost site at Dickey Ridge Visitor Center, and the southernmost site at Beagle Gap. All monitoring sites were located in meadow, lawn, or roadside habitats, and ranged in elevation from 623 m (Dickey Ridge) to 1031 m (Old Rag Overlook). Elevations of all sites ranged from 336 m at MP 1 at the north end of Skyline Drive, to 1,225 m on Hawksbill Peak.

Intensive collections by the principal investigator (JR) were timed to coincide with major flowering events throughout the growing season. The first collecting trip was May 11-20, 2015, when spring flowering plants such as *Viola*, *Senecio*, *Barbarea*, *Geranium*, *Fragaria*, *Vaccinium*, and *Zizia* were in bloom. The second intensive collection was mid-summer, July 31-August 06, 2015, targeting plants such as *Hylotelephium*, *Monarda*, *Achillea*, *Daucus*, *Centaurea*, *Helianthus*, and *Allium*. The final collection was made by JR during September 17-20, 2015, timed to coincide with flowering of plants such as *Eupatorium, Solidago, Cirsium, and Symphyotrichum*. Additionally, volunteer Ken Kingsley made weekly or biweekly collections (as weather permitted) primarily in Big Meadows and near Byrd Visitor Center from early June until early October, 2015. Citizen-scientist monitoring sites were sampled once at the beginning of each month from June 1 to October 1, 2015.

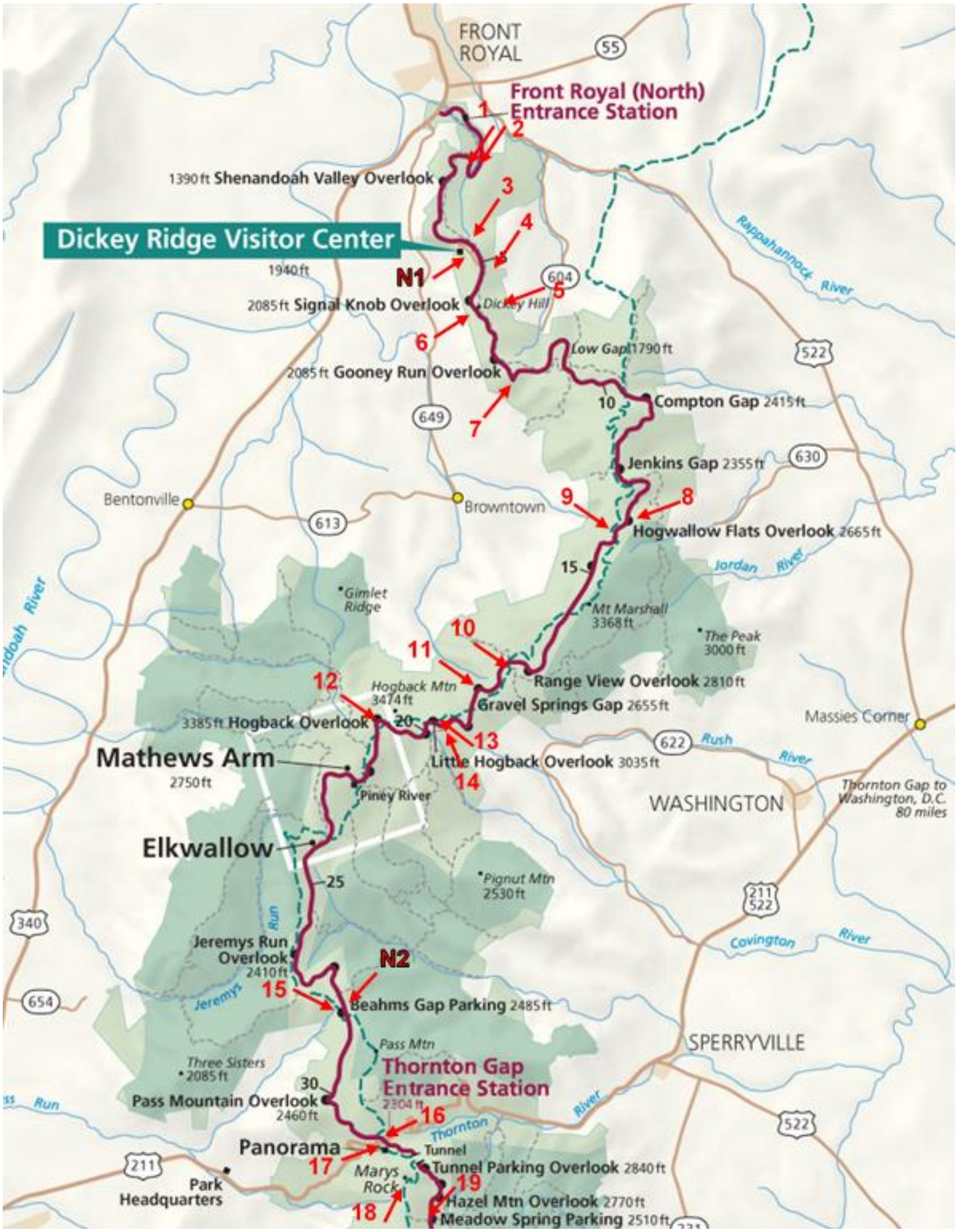

Figure 3a. Approximate locations for sampling sites 1-19 plus two monitoring sites (N1, N2) located in the North District of Shenandoah NP (maps accessed on 5/15/2016 from www.nps.gov/shen/planyourvisit/maps).

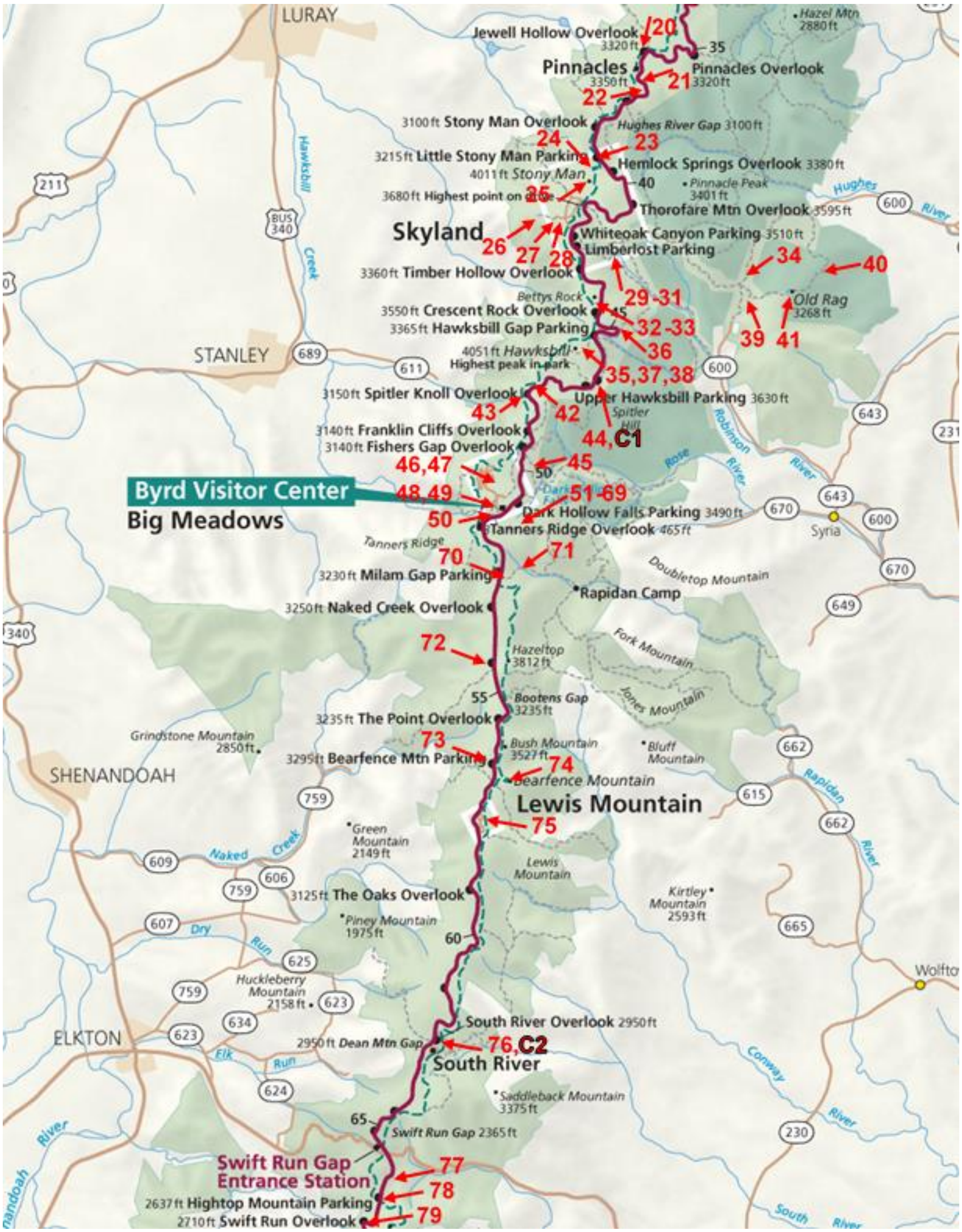

Figure 3b. Approximate locations for sampling sites 20-79 plus two monitoring sites (C1, C2) located in the Central District of Shenandoah NP (maps accessed on 5/15/2016 from www.nps.gov/shen/planyourvisit/maps).

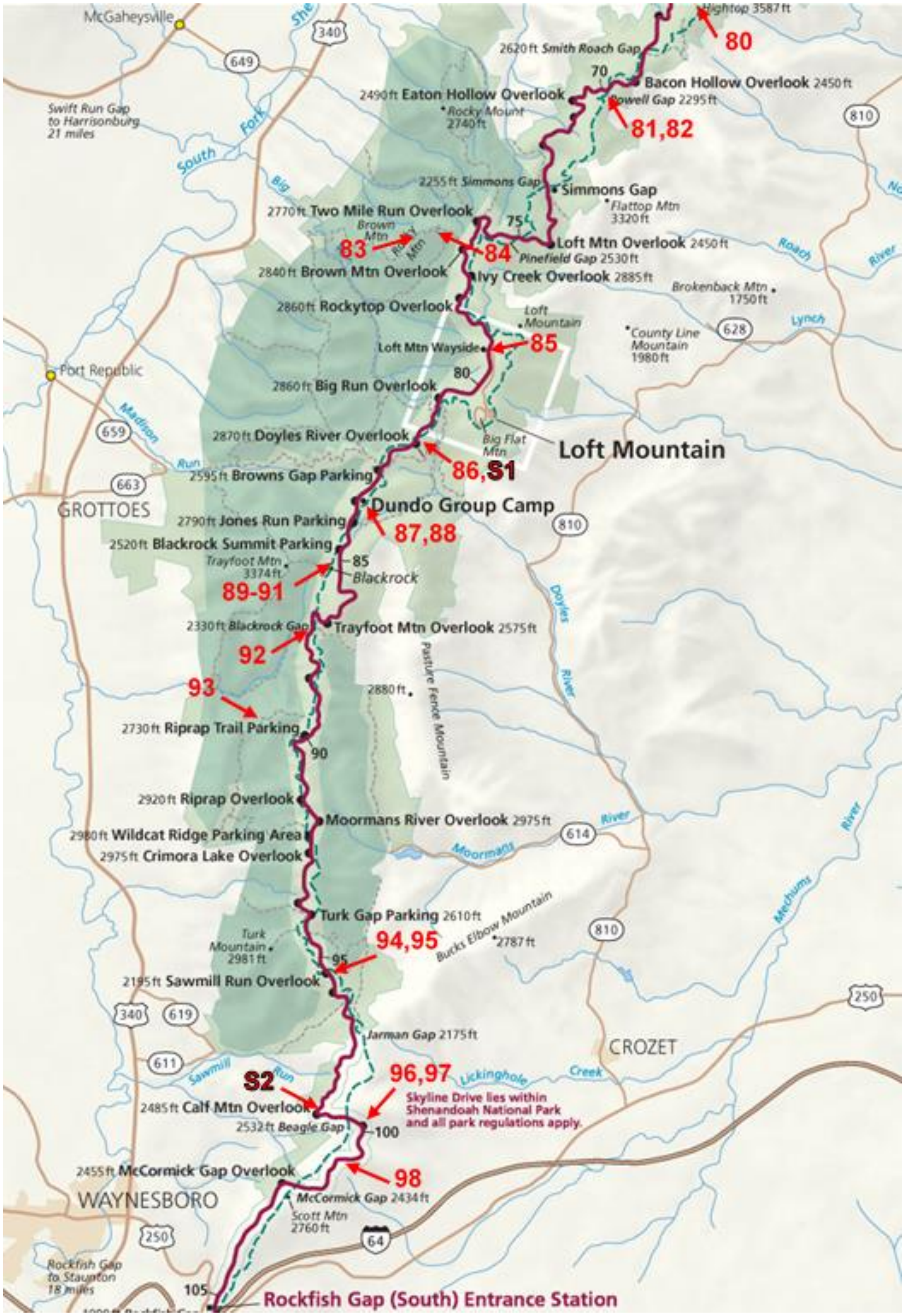

Figure 3c. Approximate locations for sampling sites 80-98 plus two monitoring sites (S1, S2) located in the South District of Shenandoah NP (maps accessed on 5/15/2016 from www.nps.gov/shen/planyourvisit/maps).

Table 1. Location, habitat type, and collecting dates and methods used at each pollinator sampling site in Shenandoah National Park in 2015.

Site #	Locality	Latitude (N)	Longitude (W)	Elevation (m)	Habitat	Bowl	Net
1	Skyline Dr. ~MP 2	38.8917	-78.1952	384	roadside		19-May
2	Skyline Dr. ~MP 1	38.8916	-78.1922	336	roadside		19-May
3	Fox Hollow Tr.	38.8721	-78.2033	580	meadow		14-May, 20-Sep
N1	Dickey Ridge VC	38.8711	-78.2041	623	meadow	19-May, 7-Jun, 7-Jul, 8-Aug, 6-Sep, 8-Oct	
4	Snead Farm Fire Rd.	38.8622	-78.2009	589	forest road		14-May, 1-Aug
5	Dickey Ridge Tr.	38.8538	-78.2066	745	rock outcrop		1-Aug
6	Signal Hill Overlook, south	38.8491	-78.2051	670	roadside		10-May
7	Gooney Manor Overlook	38.8361	-78.2044	554	rock outcrop		14-May, 19-May, 2-Aug, 20-Sep
8	Hogwallow Flats Overlook	38.7958	-78.1811	813	roadside		20-Sep
9	Skyline Dr. ~MP 14	38.7906	-78.1890	814	forest		14-May
10	Gravel Springs Fire Rd.	38.7667	-78.2335	737	forest road	14-May	14-May
11	Gimlet Ridge Overlook	38.7635	-78.2448	914	roadside		19-May
12	Hogback Overlook	38.7614	-78.2822	961	forest		14-May
13	Little Hogback Overlook	38.7589	-78.2623	928	roadside	1-Aug	1-Aug
14	Keyser Run Fire Rd.	38.7573	-78.2569	896	forest road		6-Aug
15	Beahms Gap Overlook	38.6954	-78.3195	672	meadow	20-Sep	1-Aug, 20-Sep
N2	Beahms Gap Overlook	38.6954	-78.3195	672	meadow	14-May, 7-Jun, 1-Jul, 1-Aug, 1-Sep, 6-Oct	
16	Thornton Gap	38.6616	-78.3212	715	roadside	20-Sep	
17	Panorama	38.6599	-78.3203	702	roadside	20-Sep	
18	Marys Rock	38.6503	-78.3174	1039	rock outcrop		2-Aug
19	Meadow Spring Tr.	38.6383	-78.3136	843	roadside		2-Aug
20	Jewell Hollow Overlook	38.6276	-78.3375	1029	meadow	15-May, 31-Jul, 17-Sep	15-May
21	Sklyine Dr. ~ MP 37	38.6205	-78.3439	970	roadside		2-Aug
22	Pinnacles Research Stn.	38.6133	-78.3433	913	meadow	31-Jul, 17-Sep	
23	Little Stony Man Tr.	38.6057	-78.3664	1004	forest trail		19-May
24	Little Stony Man Tr.	38.6029	-78.3685	1060	forest trail		3-Aug
25	Stony Man	38.5966	-78.3718	1209	rock outcrop		19-May

Table 1 (continued). Location, habitat type, and collecting dates and methods used at each pollinator sampling site in Shenandoah National Park in 2015.

Site #	Locality	Latitude (N)	Longitude (W)	Elevation (m)	Habitat	Bowl	Net
26	Millers Head	38.5933	-78.3942	1099	rock outcrop	4-Aug, 17-Sep	5-Jun, 4-Aug
27	Millers Head Tr.	38.5914	-78.3863	1167	forest trail		12-May, 4-Aug
28	Skyland amphitheater	38.5905	-78.3838	1106	meadow		5-Aug, 17-Sep
29	Old Rag Fire Rd.	38.5791	-78.3693	1026	forest road		11-May
30	Old Rag Fire Rd.	38.5791	-78.3722	983	forest road	15-May	15-May
31	White Oak Cabin, behind	38.5783	-78.3652	1041	forest	11-May	
32	Bettys Rock	38.5676	-78.3821	1123	rock outcrop	15-May, 19-Sep	31-Jul, 17-Sep
33	Bettys Rock Tr.	38.5641	-78.3821	1096	forest trail	15-May, 19-Sep	17-Sep
34	Weakley Fire Rd.	38.5583	-78.3310	582	forest road		4-Aug
35	Lower Hawksbill, AT	38.5571	-78.3954	1101	rock outcrop		5-Aug
36	Skyline Dr. MP 45, Fire Rd.	38.5570	-78.3789	1049	forest road	16-May	
37	Lower Hawksbill Tr.	38.5562	-78.3870	1028	forest trail		16-May
38	Hawksbill Peak	38.5551	-78.3958	1225	rock outcrop		23-Jun
39	Old Rag Shelter	38.5535	-78.3298	640	forest trail		4-Aug
40	Old Rag-Ridge Tr.	38.5529	-78.3059	822	rock outcrop		4-Aug
41	Old Rag summit	38.5518	-78.3152	972	rock outcrop		4-Aug
42	Rock Spring Cabin	38.5481	-78.4132	1024	roadside		3-Aug
43	Spitler Knoll Overlook	38.5476	-78.4148	1007	meadow		11-May
44	Old Rag Overlook	38.5455	-78.3902	1031	meadow		11-May, 18-Sep
C1	Old Rag Overlook	38.5455	-78.3902	1031	meadow	13-May, 1-Jun, 1-Jul, 2-Aug, 11-Sep, 8-Oct	
45	Rose River Fire Rd.	38.5288	-78.4251	975	forest road		29-Jun
46	Big Meadows, campg.	38.5259	-78.4356	1004	swamp	13-May	
47	Big Meadows, campg.	38.5255	-78.4343	1072	swamp		12-May
48	Byrd VC	38.5178	-78.4370	1075	roadside		9-Jun, 23-Jun, 28-Jun, 19-Jul, 23-Jul
49	Byrd VC	38.5178	-78.4365	1064	meadow	18-May	
50	Big Meadows	38.5172	-78.4397	1052	roadside		20-May
51	Big Meadows	38.5165	-78.4358	1064	meadow	8-Sep	
52	Big Meadows	38.5161	-78.4348	1062	meadow	14-Aug	

Table 1 (continued). Location, habitat type, and collecting dates and methods used at each pollinator sampling site in Shenandoah National Park in 2015.

Site #	Locality	Latitude (N)	Longitude (W)	Elevation (m)	Habitat	Bowl	Net
53	Big Meadows	38.5157	-78.4386	1026	meadow		12-May
54	Big Meadows	38.5157	-78.4359	1052	meadow	24-Aug	
55	Big Meadows	38.5154	-78.4386	1039	meadow		31-Jul, 17-Sep
56	Big Meadows	38.5154	-78.4359	1057	meadow	12-Jul	
57	Big Meadows	38.5153	-78.4403	1073	meadow		15-May
58	Big Meadows	38.5151	-78.4396	1068	meadow	16-Jun	
59	Big Meadows	38.5148	-78.4353	1005	meadow		31-Jul
60	Big Meadows	38.5148	-78.4383	1065	meadow	24-Aug, 8-Sep	
61	Big Meadows	38.5146	-78.4376	1058	meadow	12-Jul	
62	Big Meadows	38.5142	-78.4313	1042	meadow		15-May
63	Big Meadows	38.5138	-78.4396	1037	meadow	20-May	
64	Big Meadows	38.5138	-78.4367	1064	meadow	14-Aug	
65	Big Meadows	38.5133	-78.4341	1059	meadow	22-Jun	
66	Big Meadows	38.5131	-78.4348	1063	meadow	9-Oct	
67	Big Meadows	38.5129	-78.4361	1028	meadow	20-May, 22-Jun, 9-Oct	
68	Big meadows	38.5127	-78.4366	1073	meadow		15-May
69	Big Meadows	38.5126	-78.4372	1075	meadow		16-Jun, 30-Jun, 12-Jul, 14-Jul, 25-Jul
70	Mill Prong Tr.	38.5004	-78.4456	986	forest trail		15-May
71	Mill Prong Tr.	38.4998	-78.4410	960	forest trail		20-May
72	Hazeltop Ridge Overlook	38.4783	-78.4566	954	meadow		17-Sep
73	Bearfence Mountain Tr.	38.4527	-78.4670	1022	roadside		3-Aug
74	Bearfence Mountain	38.4497	-78.4656	1088	rock outcrop		3-Aug
75	Lewis Mountain picnic area	38.4387	-78.4771	1051	meadow		16-May
76	South River Overlook	38.3837	-78.5173	915	meadow		16-May, 17-Sep
C2	South River Overlook	38.3837	-78.5173	915	meadow	1-Jun, 1-Jul, 4-Aug, 2-Sep, 6-Oct	
77	Skyline Dr. MP 66	38.3512	-78.5460	788	roadside		17-Sep
78	Hightop Tr.	38.3454	-78.5527	825	roadside		3-Aug, 17-Sep

Table 1 (continued). Location, habitat type, and collecting dates and methods used at each pollinator sampling site in Shenandoah National Park in 2015.

Site #	Locality	Latitude (N)	Longitude (W)	Elevation (m)	Habitat	Bowl	Net
79	Swift Run Overlook	38.3403	-78.5589	832	roadside	18-Sep	5-Aug
80	Hightop Mountain	38.3373	-78.5528	1081	rock outcrop		3-Aug
81	Powell Gap	38.3223	-78.5905	703	roadside	18-Sep	
82	Powell Gap	38.3213	-78.5914	727	meadow	18-Sep	
83	Rocky Mountain	38.2995	-78.6722	873	rock outcrop		18-Sep
84	Rocky Mountain Tr.	38.2984	-78.6615	755	forest trail		18-Sep
85	Loft Mountain Wayside	38.2624	-78.6610	848	roadside		18-Jul
86	Doyles River Overlook	38.2466	-78.6944	808	roadside		13-May
S1	Doyles River Overlook	38.2466	-78.6944	808	roadside	13-May, 11-Jun, 9-Jul, 1-Aug, 3-Sep, 7-Oct	
87	Dundo picnic area	38.2351	-78.7178	850	roadside		9-Jun
88	Dundo picnic area	38.2346	-78.7182	869	roadside		18-May
89	Blackrock, AT	38.2231	-78.7334	892	forest trail		5-Aug
90	Blackrock summit	38.2221	-78.7350	943	rock outcrop		18-May
91	Blackrock summit	38.2208	-78.7407	920	rock outcrop		5-Aug
92	Blackrock Gap	38.2067	-78.7494	746	forest road		13-May
93	Rip Rap Tr.	38.1856	-78.7744	857	forest trail		5-Aug
94	Sawmill Run Overlook	38.1136	-78.7836	685	roadside		5-Aug
95	Sawmill Run Overlook	38.1131	-78.7818	667	forest trail		13-May
S2	Calf Mountain Overlook	38.0777	-78.8026	773	meadow	11-Jun, 1-Aug, 3-Sep, 7-Oct	
96	Beagle Gap	38.0731	-78.7954	730	meadow		13-May
97	Beagle Gap	38.0729	-78.7945	773	meadow		6-Aug, 18-Sep
S2	Beagle Gap	38.0729	-78.7945	773	meadow	9-Jul	
98	Sklyine Dr. ~ MP 101	38.0702	-78.7899	770	roadside		18-Sep

Sampling techniques for pollinators

The survey employed two methods for collecting insect pollinators: aerial insect nets and bee bowls. Nets allow active sampling of insects while they are in flight, feeding at flowers, or landed elsewhere. Netted specimens were killed with ethyl acetate in collecting jars. When possible, floral hosts were noted for net-collected specimens.

Bee bowls are passive traps that attract pollinators with color (mimicking floral blooms). Bee bowl transects were comprised of 30 plastic cups (Solo® 3.25 oz.) spaced 5 m apart. The cups were laid out in alternating colors: 10 blue, 10 yellow, and 10 white, and were filled approximately 3/4 full with a solution of 2 L water mixed with a few drops of non-scented dish-washing detergent to break the surface tension of the water. Bee bowl transects were generally set out by 10 am and kept open for six or more hours, ensuring that they were open during the warmest part of the day, when bees are most actively foraging. Small signs were placed at either end of each transect, explaining the purpose of the bowls to help avoid disturbance by human visitors (see photo inside cover). At the end of the day, contents (i.e., drowned insects in soapy water) of all 30 bowls from a transect were poured into an 80 mm diameter tight-mesh kitchen strainer. The pooled insect catch from all bowls was then transferred from the strainer into a 4 oz. Whirl-Pak® via a wide-necked plastic funnel. Ethanol (70%) and a locality label were added to the contents before sealing shut the Whirl-Pak®.

With each sampling event (net or bowl), I recorded location and elevation with GPS (Garmin® Oregon 600; datum WGS 84); general weather conditions; habitat description; and dominant plants in bloom. I also took photos of the site. For bee bowls, I recorded the time bowls were set out and picked up, and if there were any disturbances to the bowls (e.g., cups tipped over, missing, or otherwise disturbed).

Each of the six monitoring sites was sampled with bee bowls by one or more citizen scientists at the beginning of each month. We held a training at Big Meadows in mid-May to enroll volunteers and train them in bee bowl sampling techniques. Each volunteer or team of volunteers were provided with NPS VIP safety gear, printed bee bowl sampling protocols and data sheets (Appendices A and B), as well as sampling equipment. As part of the monthly protocol, volunteers were asked to record the presence of plants in bloom on either side of the sampling transect, using visual 1 m x 5 m quadrats between successive bowls—for a total of 58 quadrats in all (Appendix B, page 43). Volunteers mailed completed data sheets and specimens to the principal investigator at the end of the season.

Sample processing and specimen identification

Specimens collected dry in nets were pinned or point-mounted during the field season at park facilities. Wet specimens from bee bowls were stored in ethanol in Whirl-Paks® as explained above and brought back to the lab for further processing. Bees were washed in soapy water and then blow-dried with a hand-held hairdryer according to methods described in The Very Handy Manual, compiled by Droege (2015). One of the citizen scientists (Peg Clifton) was trained to prepare bees, and assisted with this task at her home. Once pinned and labeled with locality information, all syrphid flies were sent to Andrew Young in the Skevington Lab at the Canadian National Collection of Insects, Arachnids and Nematodes. Prepared and labeled bees were primarily determined by J.

Rykken, with some assistance from Michael Veit and Joan Milam. Sam Droege at the USGS Native Bee Inventory and Monitoring Lab, Patuxent Wildlife Research Center, provided substantial help with more difficult bee determinations and also confirmed most of J. Rykken's identifications. All bee and syrphid fly specimens were assigned SHEN accession (SHEN-02375) and catalog numbers (SHEN 60616 to SHEN 64383), and were deposited in the collections at the Smithsonian Institution National Museum of Natural History.

Data analysis

All specimen, sample, and associated data were entered into an MS Access relational database and graphs were created with MS Excel. To estimate absolute (versus observed) species richness for syrphid flies and bees in Shenandoah NP I used EstimateS version 9.1.0 (Colwell 2013) to calculate the Chao 1 species richness estimator with log-linear 95% confidence intervals (Chao et al. 2005). The estimate is calculated as: $S_{Chao\ 1} = S_{obs} + F_1^2/2F_2$ where S_{obs} is the total number of species observed in all the samples pooled; F_1 is the number of observed species represented by one individual; and F_2 is the number of observed species represented by two individuals. Therefore, as the number of singletons and doubletons increases, the estimate increases. I also used EstimateS to generate rarefaction curves for comparing expected numbers of pollinator species collected in each habitat as sample number increases (based on the total that were actually collected in each habitat). The slopes of these rarefaction curves also indicate how much more sampling is required to capture the full diversity of each habitat.

Techniques for outreach and education

I used a variety of methods to educate park staff, visitors, and citizen scientists about native pollinator diversity, ecology, and health in the parks. These included:

(1) Engaging with people in the field while conducting fieldwork, explaining the focus and importance of the research and talking about pollinators.

(2) Displaying informational signs near transects of bee bowls to explain their purpose, and the purpose of the study (see inside front cover).

(3) Hosting "show and tell" sessions inside Byrd and Dickey Ridge visitor centers with a microscope and pinned specimens to engage visitors with a magnified view of the diversity of color, texture, structure, and life histories of bees and syrphid flies.

(4) Presenting an evening program for NPS staff and visitors about pollinator diversity, natural history, conservation concerns, monitoring strategies, and the importance of pollinator research in national parks.

(5) Training eight citizen scientists to assist in pollinator collection throughout the summer and fall; including one volunteer who was also trained to prepare specimens.

Results

Bee and syrphid fly diversity

We (myself plus eight volunteers) collected a total of 3,387 bees and 377 syrphid flies between May11 and October 9, 2015 (Appendix C). These comprised 145 bee taxa (including 26 genera and 136 species-level identifications) and 40 syrphid taxa (including 29 genera and 36 species-level identifications). Among the bees, 144 specimens could be identified only to genus, primarily members of the taxonomically challenging parasitic genus *Nomada*, and many males in the sweat bee genus *Lasioglossum*. A few other specimens were identified down to an indistinguishable species pair. Among syrphid flies, 58 specimens were identified only to genus (in the genera *Chalcosyrphus, Heringia, Neocnemodon, Paragus*). There are some species for which only one sex is described. For ease of reporting, all identified taxa will be referred to as "species" in the remainder of the report.

Five bee families were represented: Andrenidae, Apidae, Colletidae, Halictidae, and Megachilidae. The two most diverse bee genera were *Lasioglossum* (38 species) in the family Halictidae, and the mining bee genus, *Andrena* (34 species), in the family Andrenidae (Fig. 4). *Lasioglossum*, primarily comprised of eusocial species, was also by far the most abundant genus, represented by almost 1,000 specimens (Fig. 4). The parasitic genus *Nomada* (family Apidae) was fairly diverse at 13 species, but this is likely a gross underestimate of the actual observed species richness, as 97 specimens could not be identified below genus level. Most *Nomada* species are parasitic on bees in the genus *Andrena*. The second most abundant genus was the green sweat bee, *Augochlora* (434 specimens), but this was represented by just one species, *Augochlora pura*. Thirteen additional genera had just one species, but most of these had few specimens (with the exception of another green sweat bee genus, *Augochlorella*, with 257 specimens).

Although syrphid fly catches were very low compared to bees (10% of total pollinator catch), generic diversity was slightly higher. The genus *Toxomerus* was vastly more abundant than any other syrphid genus (223 specimens), and with four species, was also the most diverse genus (Fig. 5). Twenty-one syrphid genera were represented by just one species.

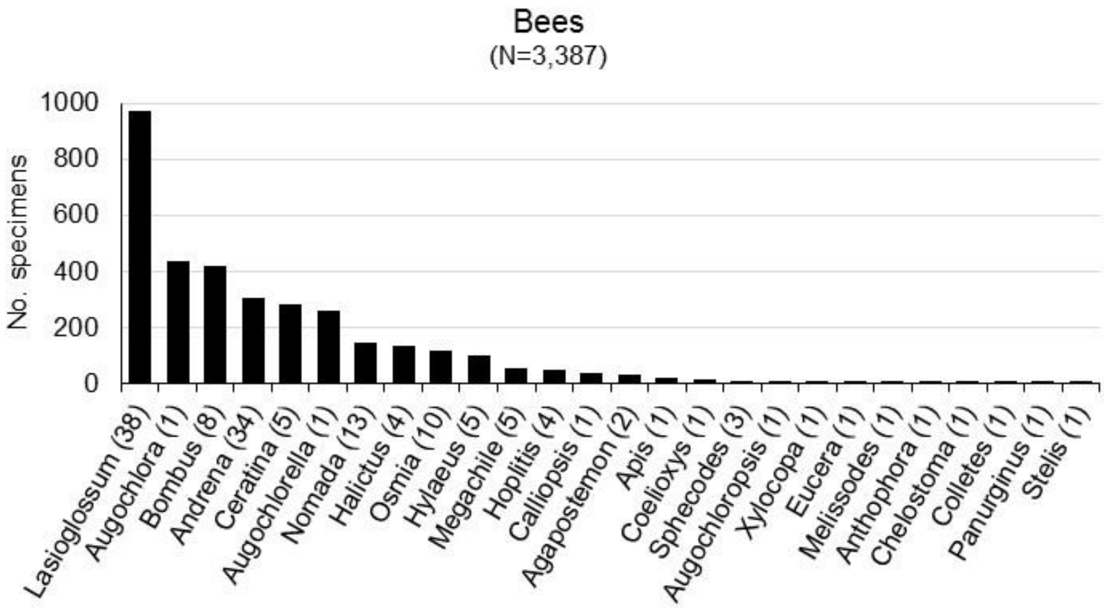

Figure 4. Twenty-six genera of bees collected in Shenandoah NP in decreasing order of abundance. Numbers in parentheses represent the species richness for each genus.

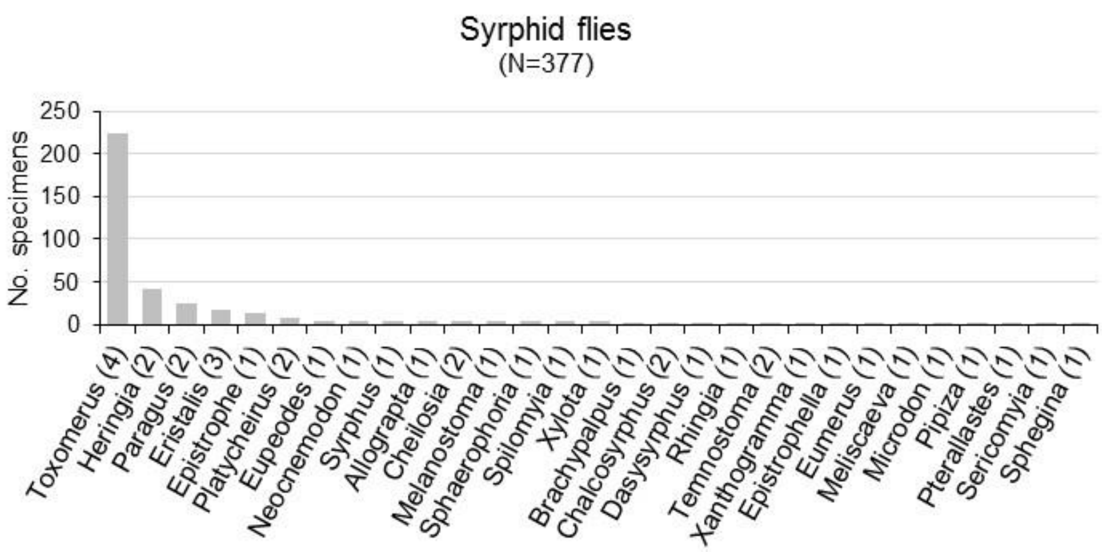

Figure 5. Twenty-nine genera of syrphid flies collected in Shenandoah NP in decreasing order of abundance. Numbers in parentheses represent the species richness for each genus.

At the species level, the six most abundant bees (more than 100 specimens each) made up almost half (46%) of the total number of bees. These included four species of sweat bees (*Augochlora pura*, *Augochlorella aurata*, *Lasioglossum versatum*, *Lasioglossum coriaceum*), the common eastern bumble bee (*Bombus impatiens*), and a small carpenter bee (*Ceratina calcarata*). Among syprhid flies, the catch was dominated by just two species, *Toxomerus marginatus* and *T. geminatus*, which together made up 57% of the total (150 and 64 specimens, respectively). Not surprisingly, the most abundant bee and syrphid fly species were also among the most widespread across sites.

Many more species were rarely collected. Fully half of the syrphid fly species (20 species) were represented by only one or two individuals, while almost one third of the bee species (46 species) were similarly uncommon.

Our observed species richness for bees (140 species, including four distinct morphospecies) and for syrphid flies (36 species) was lower than the 95% confidence interval for the estimate of absolute species richness for both groups (Fig. 6).

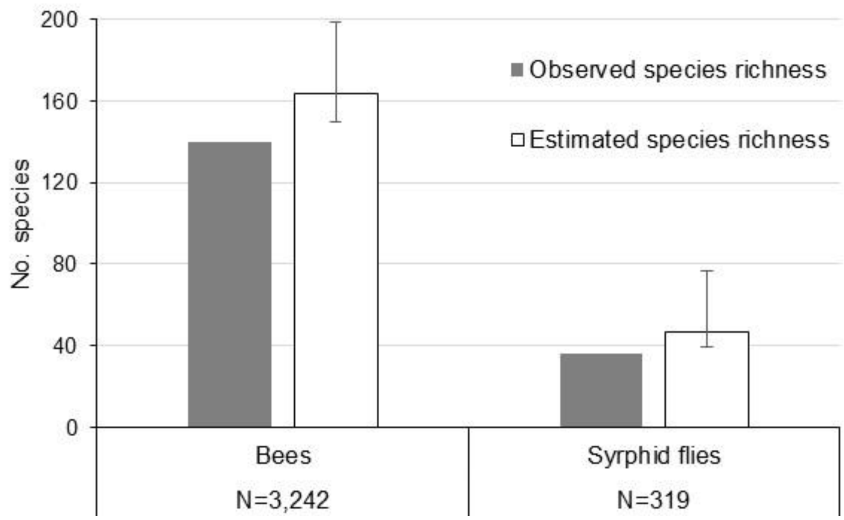

Figure 6. Comparison of observed and estimated absolute species richness for bees and syrphid flies, using Chao 1 species richness estimator (with log-linear 95% confidence intervals).

The bees showed a diversity of life history traits (Table 2; Appendix C). We collected five non-native species: Andrena wilkella, Apis mellifera (honey bee), Lasioglossum leucozonium, *Osmia cornifrons*, and *Osmia taurus*; their total abundance was relatively low (Table 2; Appendix C). Approximately one half of the species were solitary bees, but eusocial bees were more abundant overall (Table 2). Soil-nesting bees dominated the catch in both richness and abundance. Because many of the parasitic bees could not be identified to species, their proportion of the total species richness (0.13) is an underestimate.

Table 2. Summary of taxonomic affiliation and life history traits among bee taxa collected in Shenandoah NP. Note that parasitic bees do not build their own nests or provide pollen to their young, so they have their own category under "nesting" and "pollen specialization".

	Prop. species (N = 141)	**Prop. specimens** (N = 3,337)
Family		
Andrenidae	0.25	0.10
Apidae	0.21	0.26
Colletidae	0.04	0.03
Halictidae	0.35	0.54
Megachilidae	0.16	0.07
Origin		
Native	0.97	0.98
Non-native	0.03	0.02
Social behavior		
Eusocial	0.31	0.47
Subsocial	0.04	0.09
Solitary	0.51	0.39
Parasitic	0.13	0.05
Nesting		
Soil	0.57	0.49
Cavity	0.16	0.08
Wood/stem	0.07	0.24
Hive	0.06	0.13
Parasitic	0.13	0.05
Pollen specialization		
Oligolectic	0.11	0.05
Polylectic	0.75	0.90
Parasitic	0.13	0.05

Eleven percent of the bee species we collected are known to be pollen specialists; they made up only five percent of the total catch (Table 2, 3). Also known as oligolectic bees, they are defined here as specializing on pollen from a single plant family, and often only one genus within that family. The majority of these specialist bees were in the genus *Andrena*, with host plants that bloom early in the year. Four of the oligoleges are considered to be rare bees; others listed as “uncommon” may be locally rare (Table 3).

Table 3. Bee species collected in Shenandoah NP that are known to be specialists on the pollen of particular host plants. Information taken from Fowler and Droege (2016).

Species	Known host plants	Rarity	Season
Andrenidae			
Andrena aliciae	*Helianthus*	rare	summer
Andrena carolina	*Vaccinium*	uncommon	spring
Andrena distans	*Geranium*	uncommon	spring
Andrena erigeniae	*Claytonia*	common	spring
Andrena geranii	*Hydrophyllum*	uncommon	spring
Andrena nubecula	*Solidago, Symphyotrichum*	uncommon	autumn
Andrena phaceliae	*Phacelia*	rare	spring
Andrena uvulariae	*Uvularia*	rare	spring
Andrena violae	*Viola*	common	spring
Andrena ziziae	*Zizia*	uncommon	spring
Andrena ziziaeformis	*Potentilla, Waldsteinia*	uncommon	spring
Panurginus potentillae	*Potentilla*	uncommon	spring
Apidae			
Melissodes desponsa	*Cirsium*	common	autumn
Colletidae			
Colletes aestivalis	*Heuchera*	rare	summer
Megachilidae			
Megachile xylocopoides	Asteraceae	uncommon	summer
Osmia distincta	*Penstemon*	uncommon	spring

Syrphid flies were represented by three subfamilies: the commonly collected Eristalinae and Syrphinae, as well as a single specimen from the rarely-collected Microdontinae (Table 4). While species within Syrphinae made up a little more than half the total diversity, their abundance dominated the catch (90% of all specimens collected). Larval forms of syrphids vary in their natural history, especially diet (Table 4). We collected two non-native syrphid flies: Eristalis tenax and Eumerus funeralis, represented by 11 and 1 specimen(s) respectively.

Table 4. Summary of taxonomic affiliation and larval diet of syrphid fly taxa collected in Shenandoah NP. Note that many larval Eristalinae feed on microbes associated with decaying vegetation, plant sap, etc.

Genus	Larval diet/habitat
Subfamily Eristalinae (prop. species = 0.43; prop. specimens = 0.10)	
Brachypalpus	tree holes/sap/under bark
Chalcosyrphus	under bark/decayed wood
Cheilosia	fungi; living stems/leaves/roots; under bark
Eristalis	decaying organic matter in stagnant water
Eumerus	bulbs
Pterallastes	unknown
Rhingia	dung
Sericomyia	decaying organic matter in stagnant water
Sphegina	sap/under bark
Spilomyia	decayed wood/tree holes
Temnostoma	decayed wood
Xylota	decayed wood/sap/tree holes
Subfamily Microdontinae (prop. species = 0.03; prop. specimens = 0.003)	
Microdon	immature ants
Subfamily Syrphinae (prop. species = 0.55; prop. specimens = 0.90)	
Allograpta	aphids
Dasysyrphus	aphids
Epistrophe	aphids
Epistrophella	aphids
Eupeodes	aphids
Heringia	aphids
Melanostoma	aphids
Meliscaeva	aphids
Neocnemodon	aphids
Paragus	aphids
Pipiza	aphids
Platycheirus	aphids
Sphaerophoria	aphids
Syrphus	aphids
Toxomerus	aphids; pollen
Xanthogramma	aphids

Comparison between sampling methods and habitats

The two collecting methods complemented each other and varied in their yield of pollinators (Fig. 7; Appendix C). More bees were collected in bowls than by active net collecting, but a high proportion of species were shared between the two techniques (more than half the total species). In contrast, more syrphid fly species were collected by netting, and only a small proportion of the total species were shared between the two techniques (15%).

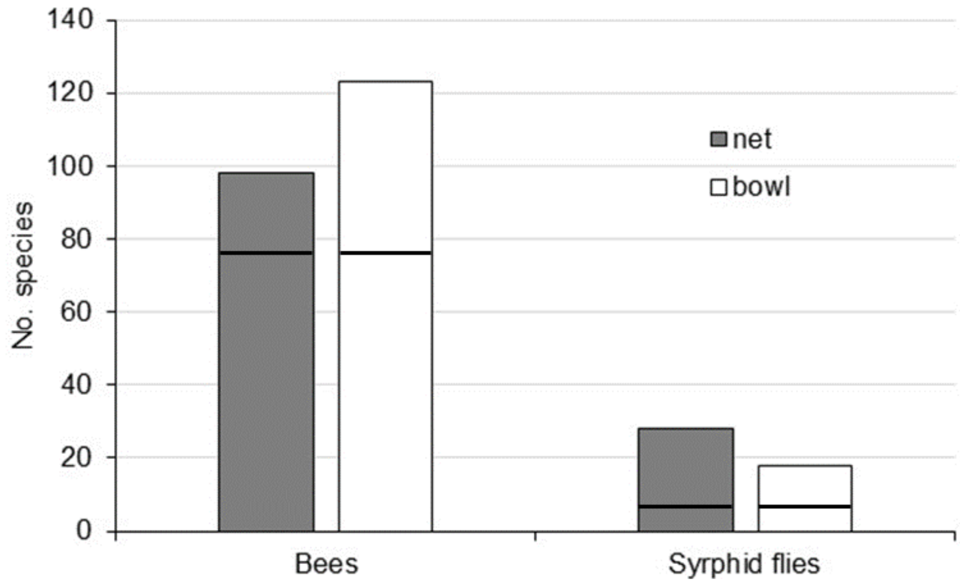

Figure 7. Comparison of trapping methods for bees and syrphid flies in Shenandoah NP. Area below line in adjacent columns indicates proportion of species shared between trapping methods.

In all, we collected a total of 73 bee bowl samples and 101 net samples across 100 sites. These included 30 forest samples, 85 meadow samples, 24 rocky outcrop samples, 33 roadside samples, and just 2 swamp samples (the last habitat had few specimens/species and is not shown in Figs. 8 and 9). The high sampling intensity in meadows was due in large part to repeated sampling (5 replicates) at the citizen scientist monitoring sites, most of which were classified as meadows.

The number of bee and sryphid fly specimens collected in the meadow habitat was more than four times higher than in any other habitat, but while bee species richness was also by far the highest in meadow samples, for syrphid flies, the number of species collected in meadow and forest habitats was comparable (Fig. 8; Appendix C). Abundance and species richness for both bees and flies was lowest in the rock outcrop habitats (Fig. 8). Rarefaction curves showed that for bees, species richness was highest in meadows even if uneven sampling intensity among habitats was accounted for (e.g., estimates at 22 samples: meadow = 69 species; forest = 63 species; roadside = 55 species; rocky = 50 species; Fig. 9). For syrphid flies, however, species richness was estimated to be much higher in forest habitats if uneven sampling intensity was accounted for (e.g., estimates at 11 samples: meadow, roadside, rock outcrops are all 7-8 species; forest = 16 species; Fig. 9). The strong upward trajectories of all rarefaction curves except for bees in the meadow habitat suggest that with additional sampling, many more species could be collected in all of these habitats (Fig. 9).

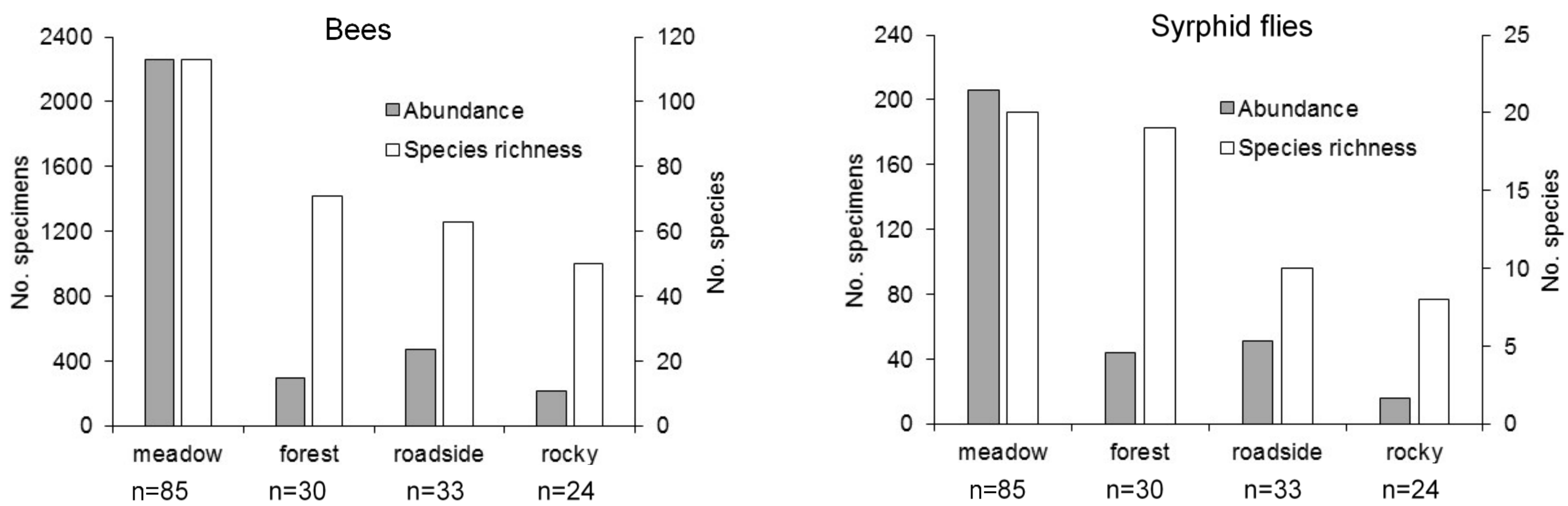

Figure 8. Comparison of total abundance and species richness across four habitats in Shenandoah NP for bees and syrphid flies. Number of samples taken in each habitat (n) is noted below habitat label. Note different scales on left and right axes in each plot.

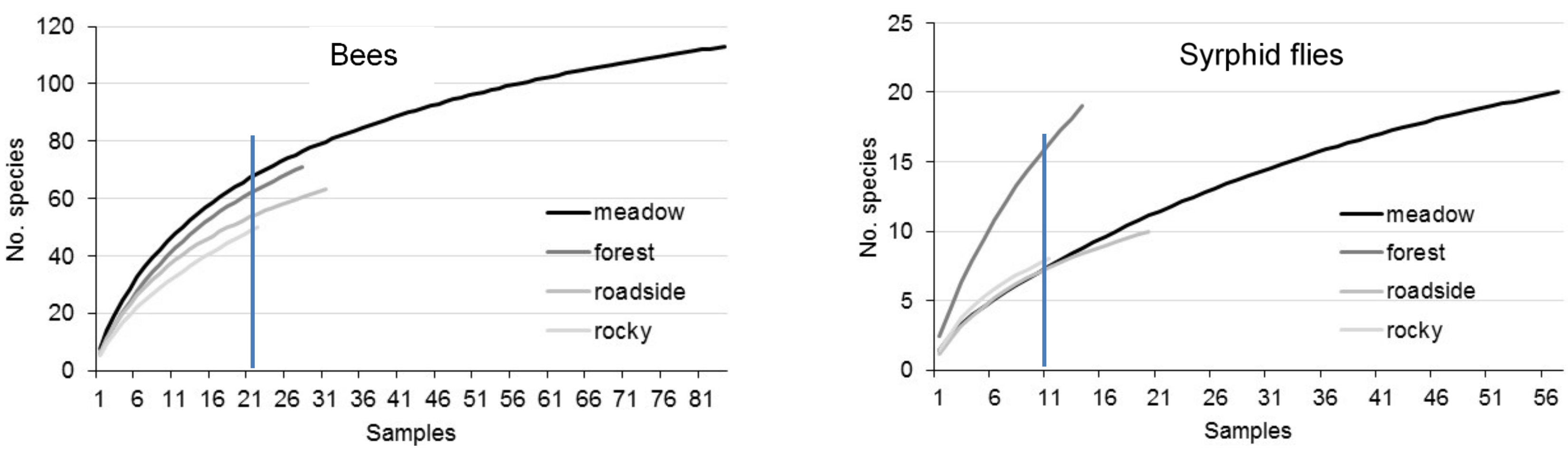

Figure 9. Rarefaction curves for total numbers of bee or syrphid fly species collected in each habitat in Shenandoah NP. The number of samples on the x-axis represent only the samples in which that taxon (bees or flies) were collected. The vertical line at 22 samples for bees and 11 samples for flies indicates a standardized minimum sample size for which species richness can be compared across all habitats (see text).

Pollinator floral associations

Pollinators were net-collected on a variety of plants. While it was not possible to ascertain whether a particular bee or syrphid fly was resting, foraging on nectar or pollen, or actively pollinating the plant on which it was found, we kept track of "visitation" to plants by some of the pollinators we collected (Table 5). Within our limited dataset, the generalist bees *Apis mellifera* (honey bee) and *Bombus impatiens* (common eastern bumble bee), were found on the highest diversity of plant genera (8-10).

Table 5. Pollinators net-collected from various plant genera in Shenandoah NP. Associations represent "visitations" on flowers, not necessarily pollen-collecting/transferring events. These represent a relatively small subset of net-collected pollinators, we were not able to keep track of host plants for all net-collected individuals.

Pollinator species	Plant genus
Syrphid flies (Syrphidae)	
Epistrophe grossulariae	*Helianthus*
Eristalis dimidiata	*Eupatorium*
Eristalis tenax	*Achillea, Daucus, Packera*
Eristalis transversa	*Eupatorium, Helianthus*
Paragus haemorrhous	*Hylotelephium*
Pipiza puella	*Eupatorium*
Temnostoma excentrica	*Helianthus*
Toxomerus marginatus	*Fragaria, Packera, Zizia*
Toxomerus politus	*Asclepias*
Pollinator species	Plant genus
Bees (Anthophila)	
Agapostemon virescens	*Aster*
Andrena carlini	*Vaccinium*
Andrena geranii	*Geranium*
Andrena nuda	*Heracleum*
Andrena pruni	*Vaccinium*
Andrena spiraeana	*Asclepias*
Andrena thaspii	*Vaccinium*
Andrena vicina	*Vaccinium*
Andrena wilkella	*Melilotus, Zizia*
Andrena ziziae	*Zizia*
Anthophora bomboides	*Penstemon*
Apis mellifera	*Actaea, Allium, Asclepias, Hylotelephium, Melilotus, Rubus, Solidago, Spiraea*
Augochlora pura	*Aster, Daucus, Erigeron, Helianthus, Melilotus, Solidago*
Augochlorella aurata	*Solidago*
Augochloropsis metallica	*Aster, Solidago*
Bombus bimaculatus	*Asclepias, Trifolium*
Bombus fervidus	*Trifolium*
Bombus griseocollis	*Asclepias, Baptisia, Trifolium*
Bombus impatiens	*Allium, Asclepias, Hylotelephium, Kalmia, Melilotus, Scrophularia, Solidago, Spiraea, Taraxacum, Trifolium*
Bombus perplexus	*Asclepias, Pycantheum, Rubus*
Bombus sandersoni	*Kalmia, Prunus, Rubus*

Table 5 (continued). Pollinators net-collected from various plant genera in Shenandoah NP. Associations represent "visitations" on flowers, not necessarily pollen-collecting/transferring events. These represent a relatively small subset of net-collected pollinators, we were not able to keep track of host plants for all net-collected individuals.

Pollinator species	Plant genus
Bees (Anthophila)	
Bombus vagans	*Penstemon, Trifolium*
Ceratina calcarata	*Daucus, Eupatorium, Helianthus*
Coelioxys sayi	*Helianthus, Solidago*
Halictus confusus	*Melilotus, Solidago*
Halictus ligatus/poeyi	*Leucanthemum*
Halictus rubicundus	*Achillea*
Hylaeus affinis/modestus	*Solidago*
Hylaeus annulatus	*Hylotelephium*
Hylaeus modestus	*Asclepias, Daucus, Solidago*
Hylaeus sparsus	*Zizia*
Lasioglossum anomalum	*Hylotelephium*
Lasioglossum apocyni	*Centaurea*
Lasioglossum cattellae	*Daucus, Melilotus, Solidago*
Lasioglossum coriaceum	*Melilotus, Solidago*
Lasioglossum cressonii	*Asclepias, Solidago*
Lasioglossum fuscipenne	*Scrophularia*
Lasioglossum imitatum	*Solidago*
Lasioglossum laevissimum	*Daucus, Hylotelephium, Solidago*
Lasioglossum leucocomum	*Barbarea*
Lasioglossum lineatulum	*Penstemon*
Lasioglossum quebecense	*Helianthus, Hylotelephium, Solidago*
Lasioglossum tegulare	*Solidago*
Lasioglossum trigeminum	*Scrophularia*
Lasioglossum versans	*Asclepias*
Megachile mendica	*Centaurea, Helianthus, Hylotelephium, Solidago*
Megachile petulans	*Helianthus*
Megachile relativa	*Helianthus, Solidago*
Megachile xylocopoides	*Solidago*
Nomada luteola	*Zizia*
Osmia bucephala	*Pedicularis*
Osmia cornifrons	*Lonicera*
Xylocopa virginica	*Asclepias, Barbarea, Robinia, Solidago, Spiraea, Vaccinium*

Monitoring sites and pollinator phenology

With the exception of one "mowing casualty" in July at Beagle Gap Overlook (site S2), volunteers successfully collected monthly bee bowl samples at six established sites along Skyline Drive as well as a seventh site in Big Meadows. A total of 11 syrphid fly species comprising 90 individuals were collected, and 81 bee species represented by 1,660 individuals. Species richness and overall abundance varied considerably between the sites in any one month (see 95% confidence intervals in Fig. 10), with the exception of the September sample which was consistently low among all sites.

Mean species richness was similar in all months except September (Fig. 10). Mean abundance was similar in June to August but was higher in October (Fig. 10). This was due mainly to high numbers of the sweat bee, *Augochlora pura*, as well as an abundance of small carpenter bees (*Ceratina*) and common eastern bumble bees, *Bombus impatiens*, at several of the sites. Flower density along transects was also quite variable among sites in any given month, although there was a trend of decreasing mean density from July to October (Fig. 11).

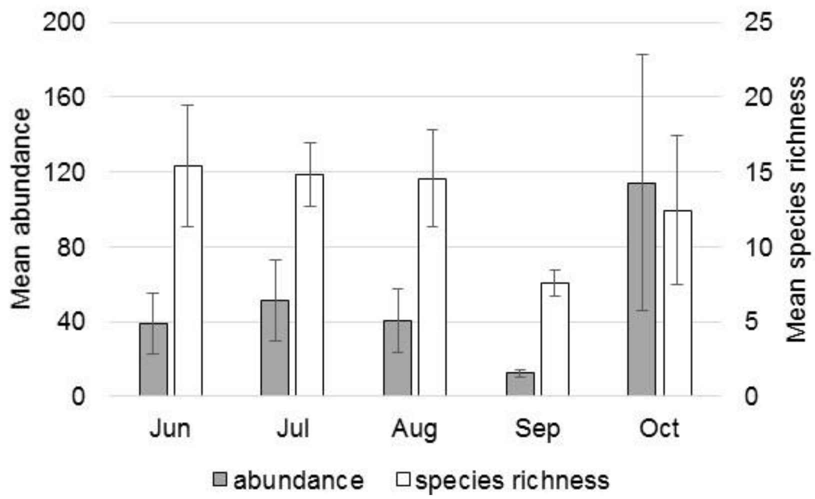

Figure 10. Comparison across months of bee and syrphid fly mean species richness (no. species) and mean abundance (no. specimens) with 95% confidence intervals. Note that left and right axes are on different scales. N = 7 sites for each month except July, where N = 6 sites (one site destroyed).

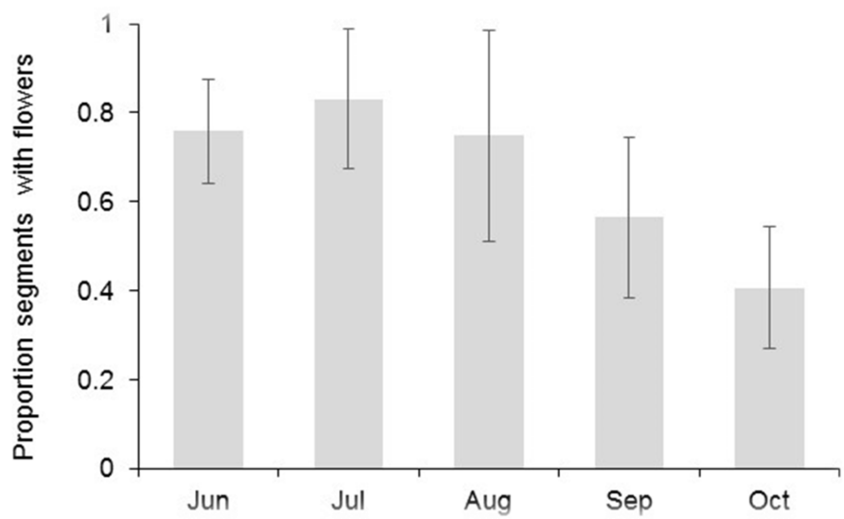

Figure 11. Comparison across months of the mean density of flowers along bee bowl transects, measured as the proportion of 58 quadrats with flowers present along a 150 m transect. N = 7 sites.

Phenology

Seasonal patterns of species richness and abundance varied among various bee and syrphid fly genera collected at the seven monitoring sites (Fig. 12). Genera that were diverse and abundant earlier in the summer (June and July) and absent the rest of the summer/fall included *Andrena* (mining bees, including many pollen specialists) and the mason bee genera *Hoplitis* and *Osmia*. Bumble bees (*Bombus*) increased in diversity and abundance from June to August, but only one species (*B. impatiens*, the common eastern bumble bee) was active in September and October, with very high numbers in October. Three to five species of small carpenter bees, *Ceratina*, were collected all summer/fall but *C. calcarata* abundance spiked in October. Many syrphid and bee genera had only one species with five or fewer specimens (not shown in Fig. 12), but two metallic green sweat bee genera each with a single species (*Augochlora pura*, *Augochlorella aurata*) had very high abundances in October (Fig. 12).

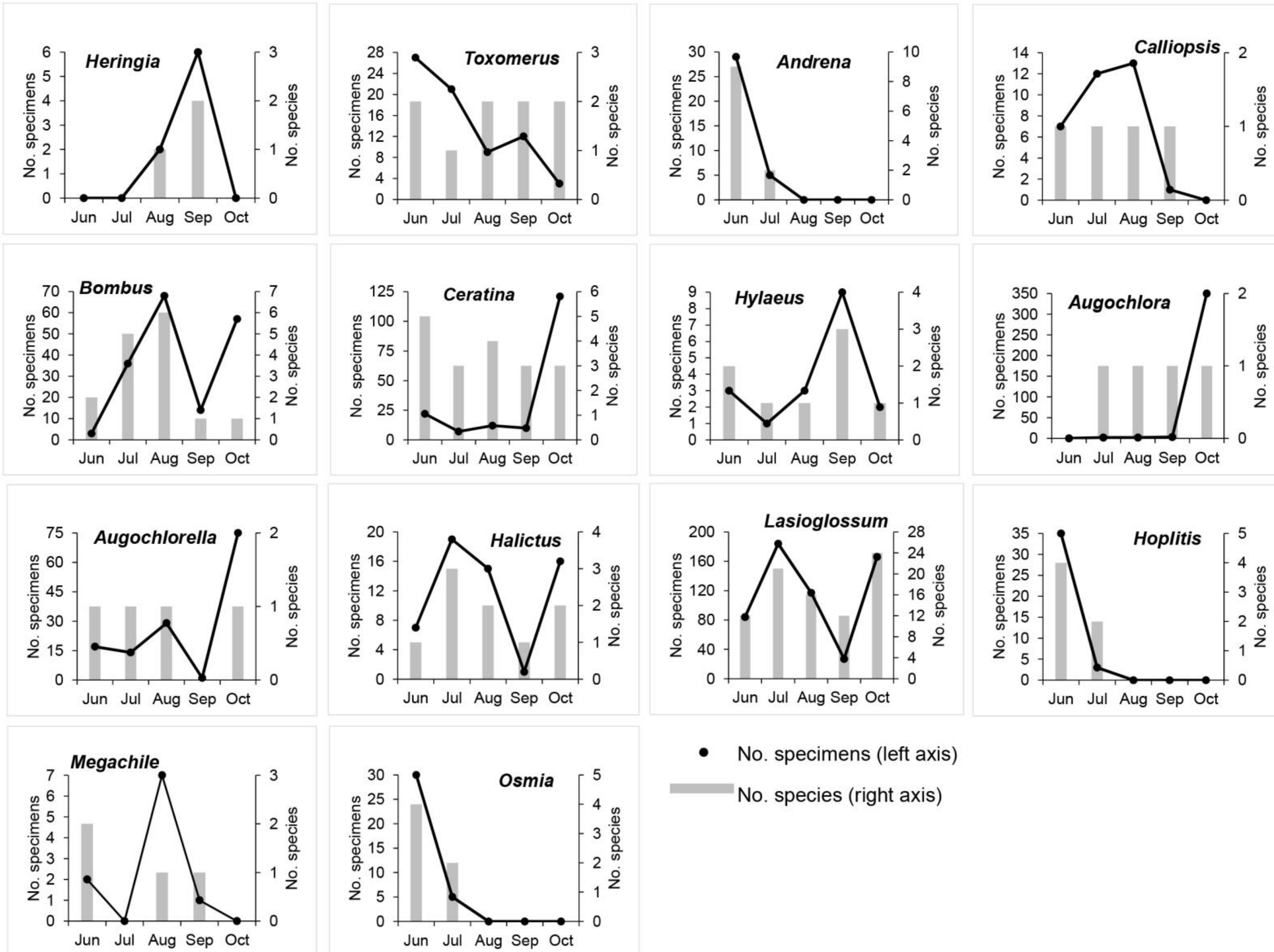

Figure 12. Change in total abundance and total species richness of syrphid fly and bee genera from seven monitoring sites over five months in 2015. Only genera with more than five collected specimens (across all months) are included.

Discussion

Shenandoah's pollinator diversity

More than 3,700 pollinator specimens were collected and identified during our 2015 survey, far exceeding expectations for a preliminary inventory of Shenandoah pollinators. Because Shenandoah is primarily a forested mountain park, we concentrated our collecting efforts where flower diversity was highest—meadows, roadsides, open forest roads (especially in spring), and rocky outcrops—with the expectation that pollinator diversity would also be high. In all, we collected half the known bee genera from Virginia, and almost one quarter of the known bee species from the mid-Atlantic region (Adamson et al. 2012, Droege et al. 2016). Regional syrphid fly species lists are not readily available, so it is impossible to assess what proportion we captured. Even though syrphid flies made up only 10% of the total pollinator catch and less than 25% of the total species richness, their generic diversity was higher than for bees, with most genera represented by one or two species. The observed species richness for both bees and syrphids fell short of the estimated absolute richness, suggesting that continued sampling would likely document more species.

Bees

Among bees, the genus *Andrena* rivaled *Lasioglossum* for the most species (34 versus 38). Many *Andrena* are pollen specialists on flowers that bloom early in spring (e.g., *Salix, Vaccinium*) or later in the fall (e.g., *Solidago, Symphyotrichum*). We collected 11 pollen specialist species, most were active in spring, and several are quite uncommon or rare. Sampling earlier in April and May would likely have picked up even more *Andrena*, there are approximately 99 species known or suspected to occur in Virginia (Droege et al. 2016), almost half of which are pollen specialists (Fowler and Droege 2016). *Andrena* are mining bees that nest in the soil, often in aggregations, and several species were conspicuous on the dirt foot paths crossing Big Meadows in mid-May (Fig. 13). This type of bare or sparsely, vegetated open ground provides ideal nesting habitat for many soil-nesting bee species. Cleptoparasites in the genus *Nomada,* which parasitize *Andrena* nests, were also abundant and diverse. All but one of the 145 *Nomada* specimens were collected in May, prior to the first sample collected by the monitoring sites.

The leafcutter bee genus, *Megachile*, was noticeably under-represented, with just five species (there are approximately 36 known from Virginia; Droege et al. 2016). Most *Megachile* are cavity nesters, using pre-existing cavities like plant stalks, gaps between rocks, or insect holes in wood; a few species excavate their own nests in soil (Eickwort et al. 1981). The cosmopolitan species *Megachile mendica* occurred at 18 sampling sites; this is a generalist forager and soil-nesting species that occurs across the U.S. In contrast, the cavity-nesting *M. xylocopoides* was collected at only one site, and it is a specialist on plants in Asteraceae. We collected only one cleptoparasite of *Megachile*, the cuckoo bee *Coelioxys sayi*.

Cleptoparasites made up a sizeable proportion of bee species (13%) and genera (15%); they represented three families (Megachilidae, Apidae, Halictidae). Cleptoparasitic (or cuckoo) females typically enter the nest of a host species, and lay their egg in a cell with the host egg which has been provisioned with nectar and pollen. The developing cuckoo larva kills the host egg or larva, and eats all its nectar and pollen provisions. *Nomada* (parasites on *Andrena*) were by far the most abundant and diverse cleptoparasites collected in Shenandoah, and likely represented many more species than we could identify. The other cleptoparasitic genera—*Sphecodes*, *Stelis*, and *Coelioxys*—were much scarcer. We also collected one social parasite, *Lasioglossum platyparium*. The host of this species is unknown, but it is likely a social species of *Lasioglossum* (Gibbs 2011). This type of parasite invades the colony of a social host species, kills the host queen, and usurps the workers into raising her young.

Figure 13. Foot path through Big Meadows in mid-May with aggregations of *Andrena* nests (left). Note small mounds in middle photo (center), and female near nest entrance with pollen-loaded hind legs (right).

Not surprisingly, generalist (polylectic), social, ground-nesting bee species dominated the bee fauna. The sweat bee genus *Lasioglossum* was by far the most diverse and abundant genus. Species in the large and taxonomically challenging subgenus, *Dialictus*, are almost all presumed to be social. Another social sweat bee, *Augochlorella aurata*, had a spike in abundance late in the season. The similar-looking green metallic sweat bee *Augochlora pura* was also extremely abundant in October, but this species is solitary and nests in decayed wood. Another abundant polylectic genus that nests in pithy stems and twigs and is considered sub-social was the small carpenter bee *Ceratina*.

A subset of the bees we collected in Shenandoah are species that are shared with more northern latitudes, but are found in Virginia at higher elevations, these included: the mining bees, *Andrena commoda*, *A. geranii* (a specialist on waterleaf, *Hydrophyllum*), *A. milwaukeensis*, *A. thaspii*, *A. wheeleri*; the bumble bees, *Bombus sandersoni* and *B. vagans*; the bumble bee mimic, *Anthophora bomboides*; the cellophane bee, *Colletes aestivalis* (a rarely collected bee in general); the masked bee, *Hylaeus annulatus* (I have collected it in Gates of the Arctic NPP, Alaska); and the sweat bees, *Lasioglossum anomalum*, *L. apocyni*, *L. lineatulum*, and *L. tenax.*

Other uncommonly and rarely collected bees included: a *Helianthus* specialist, *Andrena aliciae*; a bellwort (*Uvularia*) specialist, *Andrena uvulariae*; a *Phacelia* specialist, *Andrena phaceliae*; a masked bee, *Hylaeus sparsus*; and sweat bees, *Lasioglossum albipenne* and *L. pruinosum*. An uncommon genus we hoped to find in Shenandoah was *Macropis*, in the family Melittidae. Three species of *Macropis* are known from Virginia, all are specialists on *Lysimachia*, and all are uncommon or rare (Fowler and Droege 2016). This genus collects oils from flowers rather than nectar, and feeds the oils to their young. We did not collect any *Macropis*, but targeted searches on *Lysimachia* when it is in flower should discover one or more of these rare species in the park. Whorled loosestrife (*L. quadrifolia*) is abundant in Big Meadows in summer.

Another rare species *not* seen in the park survey was the rusty-patched bumble bee (*Bombus affinis*). This once-common and widespread eastern species has all but disappeared from most of its range, but was found just northeast of Shenandoah NP in Sky Meadows State Park, Delaplane, VA in 2014 (by one of our volunteers!). In January, 2017, the U.S. Fish and Wildlife Service listed *B. affinis* as an endangered species under the Endangered Species Act. Eric Rayfield, a graduate student at Appalachian State University, conducted an intensive bumble bee survey along the Blue Ridge Mountains from Front Royal, south through Shenandoah NP, and ending in Great Smoky Mountain National Park in 2015. No *Bombus affinis* were found among the many thousands of specimens collected, however they did find two additional *Bombus* species in Shenandoah NP: *B. auricomus* and the social parasite, *B. citrinus* (E. Rayfield, pers. comm.).

The five non-native bee species we collected included honey bees (*Apis mellifera*), and two mason bees, *Osmia cornifrons* and *O. taurus*. *Osmia cornifrons* was introduced to the U.S. from Japan in the 1970's to pollinate fruit trees; of all the non-native bee species we collected, this was the most abundant (25 individuals) and widespread (12 sites).

Syrphid flies

While charismatic syrphid flies have long been appreciated (Rotheray 1993, Ball and Morris 2015) and even used as indicator species in ecological studies in Great Britain and the rest of Europe (Speight 2011, Sommaggio and Burgio 2014), it is difficult to find useful taxonomic or natural history information on the North American fauna, with a few notable exceptions (Vockeroth and Thompson 1987, Vockeroth 1992, Miranda et al. 2013). Thus, compared to bees, species-level ecological information (e.g., adult and larval hosts) or distribution ranges are difficult to come by, as are estimates for regional diversity.

Most adult flower flies visit flowers to feed on pollen and/or nectar, and thus effect pollination while moving between plants. They are far less efficient pollinators than bees, however (Bischoff et al. 2013), in part, because they do not have anatomical adaptations to carry pollen and nectar back to the nest to provision their young, a unique characteristic of bees. Adults of a few genera (e.g., *Xylota, Chalcosyrphus*) do not feed on flowers, but feed on aphid honeydew and pollen stuck to leaves instead (Ball and Morris 2015). Others, like *Melanostoma* and *Platycheirus*, feed on pollen from wind-pollinated plants such as grasses and sedges (Ball and Morris 2015). Flower flies are generally quite conspicuous while feeding, and their mimicry of stinging bees and wasps is believed to be a defensive strategy against predators (Vockeroth and Thompson 1987).

Syrphid larvae lead very active lives compared to bees, and must feed themselves. Larvae of the subfamily Syrphinae are predators, feeding mainly on aphids and other homopterans, and some have been used for biocontrol of aphid pests in agriculture. Nine of the ten most abundant syrphid genera we collected were aphid predators. Different genera of predatory larvae feed on aphids found on different kinds of plants or plant parts. For instance, *Dasysyrphus* feed on tree-dwelling aphids, while some *Heringia* larvae feed on gall-dwelling aphids (Ball and Morris 2015). Larval *Xanthogramma* are known to feed on aphids tended by ants and have been found in ant nests (Vockeroth 1992).

Larval Eristalinae are quite varied in their feeding habits. Plant feeders include *Cheilosia* and *Eumerus*. We collected *Eumerus funeralis*, the lesser bulb fly, a non-native (European) pest on bulbs. Some *Cheilosia* feed on fungi. Most other Eristaline larvae feed on the microbes associated with decomposing organic matter, and live in wet places where they can filter feed. Several genera are associated with rotting wood, including tree holes (e.g., *Xylota*, *Brachypalpus*) and under bark (*Sphegina*, *Chalcosyrphus*). So-called “rat-tailed maggots” (genus *Eristalis*) feed on decomposing organic matter in stagnant water (as do *Sericomyia*) and use their “tail” as a breathing snorkel. *Eristalis tenax*, an introduced drone fly, closely resembles the honey bee. *Rhingia* larvae live in dung!

There were two very noteworthy finds among the syrphid flies. The much rarer subfamily Microdontinae was represented by *Microdon ruficrus*, whose larvae live in ant nests where they feed on ant larvae and pupae. *Microdon ruficrus* is associated with the ant genus *Lasius* (Duffield 1981). The larvae are odd-looking, resembling tiny slugs or sowbugs more than grubs. Adults are usually captured near the ant nest, and not on flowers, thus the genus is uncommonly collected. The other syrphid fly of note was an eristaline in the genus *Chalcosyrphus* (subgenus *Chalcosyrphus*) but could not be identified to species because it was female. The specimen is either *C. aristatus* or *depressus*, both of which are extremely rare in North America (Andrew Young, pers. comm.).

Efficacy of sampling methods

All insect collecting methods have benefits and biases, and inventories are best accomplished using a combination of active and passive (i.e., trapping) approaches (Grundel and Frohnapple 2011). Net-collecting is the simplest method, and in this survey was used in all habitats. It allowed us to make records of flower visitations for individual species (see Table 5). The drawbacks of netting include that it provides only a snapshot of what is active at the time of sampling, it is not easily repeatable, and, depending on the skill of the sampler, there may be a bias towards more obvious, larger, and/or slower insects. Trapping with bee bowls is a relatively simple passive collecting technique, and complements net-collecting by allowing a longer window of sampling. Bee bowl collecting represents a more standardized effort, and is also easily repeatable by anyone, regardless of skill. This makes it especially suitable for monitoring by citizen scientists. On the down-side, bee bowls also have biases in their catch (generally towards smaller bees), they can collect huge numbers of a single species (like *Augochlora pura* and the eastern common bumble bee, *Bombus impatiens*, in October monitoring traps), and because they are left out all day, they are vulnerable to disturbance from curious wildlife or park visitors. This last limitation was especially problematic in rock outcrop sites as these tended to be destination areas for visitors, and the open area was typically quite small so traps were liable to get trampled or disturbed.

Grundel and Frohnapple (2011) found that the most common species in their bee surveys were collected by both nets and bee bowls, but less common species were often preferentially collected with one method or the other, and thus concluded that both netting and pan-trapping were necessary for a complete survey of diversity at their sites. In Shenandoah, a relatively high proportion of bee species were shared between net and bowl samples, though more were collected by bowls. The 47 bee species collected only in bowls included seven oligolectic species, several of the uncommon and rare species mentioned above, and all the cleptoparasitic *Stelis* and *Sphecodes* species. The 22 species collected only by net also included five oligolectic species, several uncommon species, and our largest species, the eastern carpenter bee, *Xylocopa virginica*. Thus, it appears that using both collecting techniques was more productive in documenting diversity than either would be alone.

Total catches of syrphid flies were low compared to bees. In contrast to bees, more syrphid flies were collected with nets, and a much smaller proportion of species were collected by both techniques. However, bowls captured both the ant nest-associated *Microdon ruficrus*, and the rare C*halcosyrphus*, neither of which are typically found on flowers as adults. Additional active collecting with sweep nets (sturdy nets which are swung down low through the vegetation) may have been effective for syrphid flies that spend more time in grasses or on leaves. Another passive collecting method often used for syrphids is the malaise trap (Sommaggio and Burgio 2014), a large mesh tent-sized flight-intercept trap. Malaise traps are relatively expensive, large and conspicuous, and can generate overwhelming quantities of non-target insect by-catch, and for these reasons they were not deployed in our study.

Habitat and floral associations

Habitat needs for bees and flower flies include: host plants with nectar and pollen for adults and bee larvae to feed upon; various other food resources for syrphid fly larvae (e.g., aphids, plant stems, roots, leaves, decomposing wood and sap, fungus, dung, organic stagnant water); and nesting substrate for bees (e.g., bare ground, pithy stems and twigs, cavities in wood, abandoned rodent nests). In Shenandoah, spring ephemeral plants provide food for a diversity of pollinators before leaf-out in forests, but after the tree canopy fills in, most of the floral diversity is found in open areas such as meadows and roadsides. Our sampling began too late in May to capture much of the spring woodland bee diversity, and after May, we concentrated our sampling efforts in open areas where floral diversity was higher. This strategy may have compromised our collection of syrphid flies, many of which are tied to forests for larval food (e.g., decomposing wood, or tree-dwelling aphids), and adults are often found nearby.

It was clear that the high numbers of bees and syrphid flies caught in meadows were dominated by just a few species. For bees this included the generalist sweat bees *Augochlorella aurata*, *Augochlora pura*, and *Lasioglossum versatum*, and the eastern common bumble bee *Bombus impatiens*. All but the *Lasioglossum* were most abundant in the autumn. Interestingly, *Augochlora pura* nests in wood, and was among the most abundant bees in every habitat. Syrphid flies collected in meadows were dominated by one species, *Toxomerus marginatus*, whose larvae are aphid predators. All of these super-abundant species in meadows were also habitat generalists, each was collected in at least four of the five habitats, and at between 22 and 37 separate sites.

Other relatively abundant species (at least 10 individuals) that were found exclusively in meadows, included: *Andrena ziziaeformis* (a specialist on *Potentilla* and *Waldsteinia*); *Agapostemon texanus* (solitary generalist); *Lasioglossum albipenne, L. nymphaearum, L. pilosum* (all social generalists); and *L. platyparium* (a social parasite on other *Lasioglossum*). No other abundant species were tied to particular habitats. A more intensive sampling effort in forests, rock outcrops, or swamps may reveal stronger habitat associations.

Rock outcrops comprise only two percent of Shenandoah's total area, but are habitats of great regional ecological significance (Wood et al. 2006). They are home to nine globally rare plant communities (two are endemic to the park) and 21 state rare plant species (Shenandoah National Park 2008). Many of these rare plants are typically boreal in distribution, and are disjunct from their northern populations (similar to some bees). While we were interested in sampling pollinators from these unique communities, it proved challenging. Many of the sites that are accessible from Skyline Drive are popular destinations for park visitors (Wood et al. 2006). Not only has heavy foot traffic impacted plant communities, but it poses problems for leaving out bee bowls in plain view on exposed rocks. Many of the outcrops are also fairly small in size and/or steep, and in these it was impossible to lay out transects of 30 bowls, spaced 5 m apart. Timing of sampling on rock outcrops was also challenging, because flowering plants may bloom for a short time only. We used nets to associate pollinators with host plants, but our net-collecting opportunities were limited to three relatively short windows when the PI was in the park. That said, we collected 61 bee and syrphid fly taxa from rock outcrops, and six of these were species of "northern" regions, including *Colletes aestivalis*, one or our rarest finds. We decided not to set up our monitoring sites (with bee bowls) in rock outcrops for the reasons outlined above, but certainly these unique and vulnerable habitats warrant more focused investigation.

Pollinator phenology

Monthly bee bowl sampling at seven monitoring sites in meadow and roadside habitats allowed us to track pollinator phenology in a standardized manner. As expected, several genera were most abundant and active in the late spring (June), including most of the oligolectic *Andrena*, and mason bees in the genus *Osmia*, many of which are very efficient spring pollinators in orchards. Beginning sampling earlier in April and May would likely have yielded even more specialist *Andrena* species, as well as their cleptoparasites in the genus *Nomada*. At other non-monitoring sites in the park, we collected 145 *Nomada* specimens in May.

Within individual genera, abundance and species richness did not always track each other. For example, bumble bees were most abundant and diverse in mid-summer (July-August), as is often the case for generalist foragers, but abundance was also high in October and represented by just one species, the common eastern bumble bee, *Bombus impatiens*, whose colony cycle lasts longer into the autumn. Bumble bee colonies go through an annual cycle, the timing of which varies between species. Typically, towards the end of the season, males and new queens are produced and they leave the nest to find a mate. Once mated, the new queens will find a place to hibernate but the rest of the colony will perish. Our October sample included almost one third males, indicating that the end of the season was near for *B. impatiens* (and perhaps was over for most of the other *Bombus* species).

Two other species that peaked in October were the generalist sweat bees, *Augochlora pura* and *Augochlorella aurata*. *Augochlora pura* is a solitary wood-nesting species, but may have two generations per year (Stockhammer 1966). Although a few *A. pura* were found between May and August at the non-monitoring sites, the high activity in October may have been comprised of females who had already mated but had not yet established their winter hibernacula (Stockhammer 1966).

Catches across all sites and all genera were consistently low in September. Data sheets indicate that sites had favorable weather on the days they were sampled in September, but it is possible that extremely dry weather in the last weeks of August had some effect on pollinator activity. This presumed anomaly emphasizes the need to sample consecutive months throughout the growing season.

Threats to pollinators and the need for monitoring

Insect pollinators are intimately linked to their host plants and larval habitats in complex ecological networks, and thus they can serve as effective indicators of habitat quality and ecosystem integrity (Proctor et al. 2012, Sommaggio and Burgio 2014). Human-induced threats to pollinators include habitat loss and fragmentation, pesticides and pathogens, invasive species (both insects and plants), and climate change. Of these, a protected national park like Shenandoah will be most vulnerable to negative effects from invasive species and climate change, although conditions outside park boundaries may also have consequences for park ecosystems. Invasive plants can displace native floral resources for specialist bees, or compete with native plants for generalist pollinators and thus affect the reproductive success of natives, however some positive effects on native plants have also been observed (Stubbs et al. 2007, Bartomeus et al. 2008). It is worth noting that over-browsing of native plants associated with high deer populations can have also have negative effects on pollinator populations (Sakata and Yamasaki 2015).

Climate change is also a threat that transcends park boundaries. One danger is that host plants and their pollinators will respond to climate change at different rates, so that the timing of flowering will no longer coincide with pollinator emergence, particularly detrimental in climates with shorter growing seasons, or for bees with a narrower range of host plants (Bartomeus et al. 2011, Iler et al. 2013). Climate change may also drive shifts in geographical ranges of pollinators, especially northwards in latitude or upwards in elevation. For instance, Kerr et al. (2015) showed that southern range limits for many northern bumble bee species in Europe and North America have shifted northwards (compressing the overall range), and southern species have moved upward in elevation over the last century. As the body of research looking at effects of climate change on pollinator distribution and diversity grows, one common conclusion is that structured pollinator survey and monitoring on both local and global scales is imperative (LeBuhn et al. 2012, Pollinator Health Task Force 2015).

One of the objectives for this project was to establish a network of permanent sites for future pollinator monitoring and to develop a set of detailed sampling protocols. We selected six sites with diverse floral resources that were easily accessible from Skyline Drive, plus a seventh site in Big Meadows that was tended by our in-park volunteer and received additional sampling. All of these sites were classified as either meadow or roadside habitats. The easy access from Skyline Drive made the sites convenient for volunteers, but sites were also vulnerable to mowing. Only one transect of bowls was physically destroyed by a mower, but mowing may also negatively affect bee bowl catches by depleting nearby floral resources. Alternatively, mowing could be beneficial by making bowls more visible to pollinators. The timing of sampling relative to the last mowing was likely different for each site, and may have been responsible for some of the variability in pollinator abundance/richness between sites in a given month (except for September, when catches were consistently low). Another factor that may have influenced bee abundance or diversity was elevation; the difference in elevation between the lowest and highest sites was about 400 m, but this variable was not investigated.

Monthly collections at the sites tracked seasonal variation in the composition of the pollinator community. In order to capture species turnover, it was important to collect over the entire growing season, and extending the sampling earlier to April and May would undoubtedly have added more species to the total richness, including more early spring specialist bees. Another important reason to sample in early spring is because warmer temperatures associated with climate change are expected to trigger earlier plant emergence, and thus spring-active bees may be at the highest risk of mismatch with their host plants (Forrest and Thomson 2011). However, warmer overwintering temperatures are also predicted to affect bee phenology, and research suggests that bees overwintering as adults may be more likely to emerge earlier in the spring with increasing winter temperatures (Fründ et al. 2013).

Our volunteer network, comprised mainly of Virginia Master Naturalists, proved to be enthusiastic, skilled, and dedicated. Several volunteers had prior experience collecting bees for the Virginia Working Landscapes program coordinated by the Smithsonian Conservation Biology Institute. Although the park has no current plans (or funding) for continued monitoring at these sites, this project has established a baseline pollinator database and documented detailed sampling protocols that will enable consistent, replicated pollinator sampling by park staff, citizen scientists, or other researchers in the future.

Educating park staff and visitors about Shenandoah's pollinators

Another important goal of the survey was to foster awareness and appreciation of insect pollinators to park staff and visitors. Shenandoah boasts an impressive diversity of plants and vertebrate fauna which visitors come to view and learn about, but, as in most national parks, the far vaster diversity of the "microwilderness" has thus far received little attention (Rykken and Farrell 2013). In large part, this is because invertebrate wildlife is tiny and challenging to view, and also because accessible information is scarce.

Engaging with the public at the visitor center and providing access to a microscope so that people could see the bizarre and beautiful attributes of pollinators up close, proved to be a successful way to generate curiosity and enthusiasm about Shenandoah's insect pollinators among both staff and visitors. An image-rich (including 3-D) pollinator presentation to park staff and general public at the Skyland amphitheater was also well-received.

Conclusions and Recommendations

This preliminary survey of Shenandoah pollinators, although constrained by time and spatial coverage, established a baseline database for the diversity, distribution, and phenology of two key pollinator groups: bees and syrphid flies. Bees were much more abundant and diverse than syrphid flies, and this was likely, in part, an artefact of sampling methods and habitat bias. Interesting finds included oligolectic bee species, disjunct "northern" species, and several rare species of bees and syrphid flies. As in most insect surveys, a few very abundant species dominated the catch, and for bees these species were primarily generalists and social or sub-social, although the most abundant bee, *Augochlorella aurata*, is a solitary wood-nesting species. Syrphid flies had a higher generic diversity than bees, and the subfamily Syrphinae, comprised of aphid predators (as larvae), composed 90% of the catch. Bees were most diverse in meadows, while syrphid flies had higher species richness in forests. A standardized monthly sampling effort at six monitoring sites along Skyline Drive and one site at Big Meadows allowed us to track the phenology of pollinator activity over the growing season, which varied greatly between genera. Citizen scientists from the Virginia Master Naturalists program excelled at running these sites.

Management guidelines and future priorities for pollinator work in Shenandoah:

- Continue with pollinator inventory work in the park. In particular, focus on rock outcrops, and pay attention to rare plant phenology so that net and bowl collecting can be timed to coincide with bloom times of insect-pollinated plants. Also focus on rare plants found in Big Meadows. Begin sampling in April or early May on the earliest blooms which may have specialist pollinators. Search for *Macropis* bees on *Lysimachia*. Search for more *Chalcosyrphus* (and other syrphids) in forest habitats.
- Consider developing a long-term pollinator monitoring program, using the sites and protocols established in 2015. For each sampling year, begin sampling in April, and continue until October. Coordinate with the park mowing crew to avoid mishaps.
- Management strategies for enhancing native forb diversity, such as controlling invasive plants, limiting over-browsing by deer, maintaining early successional habitats, and moderating the frequency and intensity of mowing regimes will also benefit pollinator diversity.
- In May, when the dirt paths criss-crossing Big Meadows are active with nesting *Halictus* and *Andrena* bees, rangers could take advantage of this "outdoor classroom" to educate visitors about Shenandoah's pollinator diversity. Informational signs could be installed on the trails to explain the natural history of solitary ground-nesting bees, and/or rangers could lead walks to the nesting sites to show and tell.
- Another effective outreach tool would be to create a pollinator page on the park's website that features close-up photos (see Figs. 1 and 2) of bees and syrphid flies and provides natural history information for some of the more commonly observed taxa. Denali National Park's digital pollinator exhibit (https://www.nps.gov/rlc/murie/virtual-tours.htm) may provide some ideas for such a product.

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Appendix A. Instruction sheet for citizen scientists collecting monthly bee bowl samples.

Shenandoah National Park Pollinator Survey 2015

Setting out bee bowls
(Try to set out before 10am)

Equipment (per transect):

30 x painted bee bowls (10 each color)
One half gallon water plus a few drops of blue Dawn soap mixed together
5 x orange flags
2 x bee monitoring signs
Camera/phone
Data sheet
Pencil

1. Mark one end of transect with orange flag and/or sign (so that it's visible to passers-by).
2. Fill out first two sections of data sheet, including weather and a general description of the transect location.
3. Fill each bee bowl with soapy water to about ¾ mark (not too full or insects may crawl out, try to avoid excessive suds). Place bowl on level ground. Avoid tall vegetation. If you can't see the bowl, chances are pollinators can't either.
4. Walk five paces (about 5 m) and fill the next bowl, repeat process above. Colors should alternate along transect.
5. At every 5th bowl, or if the bowl is in an odd or hidden place, mark with orange flag (also if transect bends).
6. Transect does not have to be straight, can bend or make a loop. You can also set up two parallel shorter transects (transects should be at least 10 m/paces apart)
7. When you reach the far end of the transect, put in another sign and/or flag
8. Fill in the time (Time set out) on data sheet, and the number of bowls set out (30).
9. Take a couple of photos of the transect if possible, record this on data sheet (in second section).
10. Walk back along transect (or have other people do this while you are setting bowls) and record flowering plants to left and right of transect **between** bowls on data sheet. Look close to the transect, just a meter or two, not off in the distance.

Bringing in bee bowls
(Try to leave out until 4pm or later)

<u>Equipment (per transect):</u>
Whirl-Pak
Plastic funnel
Strainer
Ethanol
Data sheet
Pencil (NOT PEN!)
Ziploc bag for collecting bowls

1. Swirl contents of each bowl to get insects in suspension and then swiftly pour contents into strainer. If any insects remain in bowl, you can pick out with forceps if necessary (or just rap bowl on side of strainer to dislodge). Combine contents of ALL 30 bowls into the strainer.
2. Once all bowls are emptied (count them to make sure you didn't miss any), mark down time on data sheet (Time brought in).
3. Note down on data sheet any bowls that were empty either because they were tipped over or trampled/eaten/missing etc.
4. Tear top off of Whirl-Pak and pull tabs to open the mouth of the bag; either blow or put your fingers inside the bag to open it up. Place the plastic funnel tip inside the bag (you can hold the Whirl-Pak and the bag securely in one hand) and then, with your other hand, rap the strainer upside down on the funnel a few times to dislodge all insects into the funnel. If there are a lot of bugs, the hole of the funnel will get clogged, but you can gently shake the funnel and they should start to move down. Rinsing the sides of the funnel with ethanol will get the last specimens down into the Whirl-Pak.
5. Once you have all the insects in the Whirl-Pak, wash down any that are stuck to the sides of the bag so that they go down to the bottom with the rest. Make sure there is enough ethanol to cover the insects, but no excess.
6. **Tear off and ADD LABEL. Label instructions are on data sheet. Label goes INSIDE THE BAG with the insects. Use pencil.**
7. Get all the air out of the Whirl-Pak, then fold down the wire top several times, until you have folded down to where the insects are. Bend the two ends of the wire until you can twist them together.
8. Pick up flags and signs.
9. Check over data sheet to make sure everything is complete.

Appendix B. Data sheet for citizen scientists collecting monthly bee bowl samples

Date: **Samplers:**

SITE LOCATION **District:** **South** **Central** **North** **(circle one)** **Number:** **1** **2** **(circle one)**
(Site 1 should be the one furthest north)

Name of site (nearest overlook, trailhead, and/or milepost):

Weather (cloud cover, wind, humidity etc.):

Air temp. (high projected for day):

Describe condition of transect location: (dominant plant species in bloom (if known), grass mowed, etc.)

Photos taken?

Number of bowls set out: **Time set out:** **Time brought in:**

Condition of bowls at pick-up: "all okay" (circle if true)

 # tipped over, destroyed, or dry:

 # bowls disappeared:

Explain disturbances if you can: humans, birds, other animals, wind??

Label for Sample (WRITE IN PENCIL, LABEL GOES INSIDE WHIRL-PAK)

Write the sample code (choose one from below) + sampling date(s) + initials of samplers

SHEN-BB-N1 **(north district, site 1)**

SHEN-BB-N2 **(north district, site 2)**

SHEN-BB-C1 **(central district, site 1)**

SHEN-BB-C2 **(central district, site 2)**

SHEN-BB-S1 **(south district, site 1)**

SHEN-BB-S2 **(south district, site 2)**

Example:

SHEN-BB-N1
June 3, 2015
JR, LL

Your label:
(identical to label below)

More on back side….

Label for Whirl-pak (tear off):

Bloom density next to transect:

Walk down transect from Start to End, and look an arm's length (~1m) left and right of transect.

Record presence (√) or absence (0) of blooming flowers in interval between one cup and the next.

Count up total # of segments with blooming flowers (x/58):

Cup interval	Left side	Right side
1-2		
2-3		
3-4		
4-5		
5-6		
6-7		
7-8		
8-9		
9-10		
10-11		
11-12		
12-13		
13-14		
14-15		
15-16		
16-17		
17-18		
18-19		
19-20		
20-21		
21-22		
22-23		
23-24		
24-25		
25-26		
26-27		
27-28		
28-29		
29-30		

Appendix C. Bee and syrphid fly taxa collected during 2015 pollinator survey in Shenandoah NP.

Information for each species includes: the number that were collected by net (**#net**), bee bowl (**#bowl**), and in total (**# total**); the number of sites (out of 100) where species was collected (**# sites**); habitat totals where species was collected (forest (**For**), meadow (**Mea**), roadside (**Roa**), rock outcrop (**Roc**), swamp (**Swa**)). For bees only: **SOB** = social behavior (social (soc), solitary (sol), sub-social (sub), cleptoparasite (clp), social parasite (sop)); **NES** = nesting substrate (soil, hive, pithy stem (pith), wood, cavity (cav)); and **SPES** = pollen specialization (oligolectic (oligo), polylectic (poly), or unknown (unk).

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Order Diptera													
Family Syrphidae: Subfamily Eristalinae													
Brachypalpus oarus (Walker)	Eastern catkin fly	2		2	2	2							
Chalcosyrphus libo (Walker)	Long-haired forest fly	1		1	1	1							
Chalcosyrphus sp.	Forest fly		1	1	1	1							
Cheilosia caltha (Shannon)	Marsh marigold pollen fly	2		2	2	1	1						
Cheilosia prima (Hunter)	Swarthy pollen fly		1	1	1	1							
Eristalis dimidiata Wiedemann	Black-shouldered drone fly	3		3	2		2	1					
Eristalis tenax (Linnaeus)	Drone fly	10	1	11	7	1	6	4					
Eristalis transversa Wiedemann	Transverse-banded drone fly	3		3	3		1	1	1				
Eumerus funeralis Meigen	Lesser bulb fly		1	1	1	1							
Pterrallastes thoracicus Loew	Goldenback		1	1	1		1						
Rhingia nasica Say	American Heineken fly	2		2	1	2							
Sericomyia chrysotoxoides Macquart	Oblique-banded pond fly		1	1	1		1						
Sphegina petiolata Coquillett	Striped spatulate fly	1		1	1	1							
Spilomyia longicornis Loew	Eastern hornet fly	3		3	2		3						
Temnostoma balyras (Walker)	Yellow-haired falsehorn	1		1	1	1							
Temnostoma excentrica (Harris)	Black-spotted falsehorn	1		1	1	1							
Xylota ejuncida Say	Polished forest fly		3	3	3		3						
Family Syrphidae: Subfamily Microdontinae													
Microdon ruficrus Williston	Spiny-shield ant fly		1	1	1		1						
Family Syrphidae: Subfamily Syrphinae													
Allograpta obliqua (Say)	Oblique stripetail	3		3	3	2			1				
Dasysyrphus venustus (Meigen)	Transverse conifer fly	2		2	1			2					
Epistrophe grossulariae (Meigen)	Black-horned smoothtail	14		14	7	5	1	5	3				

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Epistrophella emarginata (Say)	Slender smoothtail	1		1	1			1					
Eupeodes americanus (Wiedeman)	American aphideater	1	3	4	3		4						
Order Diptera													
Family Syrphidae: Subfamily Syrphinae													
Heringia salax (Loew)	Eastern woolly fly		4	4	3		4						
Heringia sp.	Woolly fly		37	37	9		28	9					
Melanostoma mellinum (Linnaeus)	Western roundtail	3		3	3	3							
Meliscaeva cinctella (Zetterstedt)	American thintail	1		1	1	1							
Neocnemodon sp.	Spikeleg		4	4	2			1	3				
Paragus haemorrhous Meigen	Black-nosed grass skimmer	4	4	8	7	1	3		4				
Paragus sp.	Grass skimmer		16	16	11		13	3					
Pipiza puella Williston	Dim Pipiza	1		1	1			1					
Platycheirus hyperboreus (Staeger)	Silvery sedgesitter	1		1	1		1						
Platycheirus obscurus (Say)	Eastern forest sedgesitter	7		7	6	5			1	1			
Sphaerophoria contigua Macquart	Tufted globetail	1	2	3	2		2		1				
Syrphus ribesii (Linnaeus)	Common flower fly	4		4	2		4						
Toxomerus boscii Macquart	Thin-lined calligrapher		2	2	2		2						
Toxomerus geminatus (Say)	Eastern calligrapher	12	52	64	23	8	40	16					
Toxomerus marginatus (Say)	Margined calligrapher	16	134	150	31	5	125	17	2	1			
Toxomerus politus (Say)	Maize calligrapher	7		7	7		1	3	3				
Xanthogramma flavipes (Loew)	American painted fly	2		2	1	2							
Order Hymenoptera													
Family Andrenidae													
Andrena (Trachandrena)	Mining bee	2		2	2	2					sol	soil	unk
Andrena aliciae Robertson	Mining bee	2		2	1		2				sol	soil	olig
Andrena alleghaniensis/atlantica	Mining bee	1		1	1	1					sol	soil	poly
Andrena carlini Cockerell	Mining bee	7	5	12	7	1	11				sol	soil	poly
Andrena carolina Viereck	Mining bee	2		2	1	2					sol	soil	olig
Andrena commoda Smith	Mining bee		1	1	1		1				sol	soil	poly
Andrena cressonii Robertson	Mining bee		1	1	1		1				sol	soil	poly
Andrena distans Provancher	Mining bee		2	2	2	1	1				sol	soil	olig
Andrena erigeniae Robertson	Mining bee		3	3	3	2		1			sol	soil	olig
Andrena forbesii Robertson	Mining bee	4	2	6	3		6				sol	soil	poly
Andrena geranii Robertson	Mining bee	19	2	21	5	18	2		1		sol	soil	olig

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Andrena imitatrix/morrisonella	Mining bee	2	3	5	5	2	2	1			sol	soil	poly
Andrena macra Mitchell	Mining bee		2	2	2	1	1				sol	soil	poly
Andrena mandibularis Robertson	Mining bee		1	1	1	1					sol	soil	poly
Andrena milwaukeensis Graenicher	Mining bee	1		1	1	1					sol	soil	poly
Andrena miserabilis Cresson	Mining bee	1	2	3	3		3				sol	soil	poly
Order Hymenoptera													
Family Andrenidae													
Andrena nasonii Robertson	Mining bee	5	28	33	9	10	17	6			sol	soil	poly
Andrena nivalis Smith	Mining bee	3	10	13	8	7	5			1	sol	soil	poly
Andrena nubecula Smith	Mining bee	2	1	3	2			1	2		sol	soil	olig
Andrena nuda Robertson	Mining bee	1		1	1		1				sol	soil	poly
Andrena perplexa Smith	Mining bee		4	4	2	3	1				sol	soil	poly
Andrena phaceliae Mitchell	Mining bee		6	6	3		5	1			sol	soil	olig
Andrena pruni Robertson	Mining bee	2		2	2	1	1				sol	soil	poly
Andrena robertsonii Dalla	Mining bee	2	3	5	3	4	1				sol	soil	poly
Andrena rugosa Robertson	Mining bee	1		1	1	1					sol	soil	poly
Andrena spiraeana Robertson	Mining bee	3	1	4	4	2	1		1		sol	soil	poly
Andrena thaspii Graenicher	Mining bee	1	1	2	2		2				sol	soil	poly
Andrena uvulariae Mitchell	Mining bee		2	2	1			2			sol	soil	olig
Andrena vicina Smith	Mining bee	6	2	8	5	4	3		1		sol	soil	poly
Andrena violae Robertson	Mining bee		26	26	9	12	12	2			sol	soil	olig
Andrena wheeleri Graenicher	Mining bee	11	14	25	12	18	5			2	sol	soil	poly
Andrena wilkella (Kirby)	Mining bee	7	7	14	6	1	7	6			sol	soil	poly
Andrena ziziae Robertson	Mining bee	9	13	22	8	10	10	2			sol	soil	olig
Andrena ziziaeformis Cockerell	Mining bee	3	64	67	9		66			1	sol	soil	olig
Calliopsis andreniformis Smith	Mining bee		38	38	8		33	4	1		sol	soil	poly
Panurginus potentillae (Crawford)	Mining bee	1		1	1	1					sol	soil	olig
Family Apidae													
Anthophora bomboides Kirby	Bumble bee mimic Anthophora	1		1	1	1					sol	soil	poly
Apis mellifera Linnaeus	Honey bee	12	5	17	10		9	7	1		soc	hive	poly
Bombus bimaculatus Cresson	Two-spotted bumble bee	3	21	24	11		14	9	1		soc	hive	poly
Bombus fervidus (Fabricius)	Yellow bumble bee	5	1	6	5	1	2	3			soc	hive	poly
Bombus griseocollis (DeGeer)	Brown-belted bumble bee	19	21	40	15		36	3	1		soc	hive	poly
Bombus impatiens Cresson	Common eastern bumble bee	28	290	318	37	2	214	89	13		soc	hive	poly

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Bombus perplexus Cresson	Perplexing bumble bee	4	2	6	6		2	4			soc	hive	poly
Bombus sandersoni Franklin	Sanderson bumble bee	10	5	15	11	3	6	3	3		soc	hive	poly
Bombus sp.	Bumble bee		1	1	1		1				soc	hive	poly
Bombus vagans Smith	Half-black bumble bee	2	4	6	6	1	4	1			soc	hive	poly
Ceratina calcarata Robertson	Small carpenter bee	32	141	173	26	9	119	29	16		sub	pith	poly
Ceratina dupla Say	Small carpenter bee	3	45	48	10		9	37	2		sub	pith	poly
Ceratina floridana Mitchell	Small carpenter bee		3	3	2		2	1			sub	pith	poly
Ceratina mikmaqi Rehan & Sheffield	Small carpenter bee	3	15	18	10		16	1	1		sub	pith	poly
Ceratina strenua Smith	Small carpenter bee	8	32	40	12	3	11	11	14	1	sub	pith	poly
Order Hymenoptera													
Family Apidae													
Eucera hamata (Bradley)	Long-horned bee		3	3	2		3				sol	soil	poly
Melissodes desponsa Smith	Long-horned bee		2	2	2		2				sol	soil	olig
Nomada articulata Smith	Cuckoo bee		3	3	3		2	1			clp	clp	clp
Nomada bethunei Cockerell	Cuckoo bee		1	1	1		1				clp	clp	clp
Nomada bidentate sp.	Cuckoo bee	15	63	78	15	63	12	1	2		clp	clp	clp
Nomada composita Mitchell	Cuckoo bee		1	1	1		1				clp	clp	clp
Nomada denticulata Robertson	Cuckoo bee		2	2	1	2					clp	clp	clp
Nomada imbricata Smith	Cuckoo bee	2	3	5	3	4	1				clp	clp	clp
Nomada luteola Olivier	Cuckoo bee	1		1	1			1			clp	clp	clp
Nomada luteoloides Robertson	Cuckoo bee		2	2	2	2					clp	clp	clp
Nomada maculata Cresson	Cuckoo bee	6	15	21	12	16	2	1	2		clp	clp	clp
Nomada nr. *armatella* Cockerell	Cuckoo bee	2		2	2	2					clp	clp	clp
Nomada parva Robertson	Cuckoo bee	1	5	6	4	5	1				clp	clp	clp
Nomada pygmaea Cresson	Cuckoo bee	2	2	4	4	1	2			1	clp	clp	clp
Nomada sp.	Cuckoo bee	4	15	19	8	15	2	2			clp	clp	clp
Xylocopa virginica (Linnaeus)	Eastern carpenter bee	5		5	4		4		1		sub	wood	poly
Family Colletidae													
Colletes aestivalis Patton	Cellophane bee	1		1	1				1		sol	soil	olig
Hylaeus affinis (Smith)	Masked bee	2	37	39	12	1	31	7			sol	cav	poly
Hylaeus affinis/modestus	Masked bee	1		1	1			1			sol	cav	poly
Hylaeus annulatus (Linnaeus)	Masked bee	1	3	4	4		3		1		sol	cav	poly
Hylaeus modestus Say	Masked bee	36	12	48	16	5	26	12	5		sol	cav	poly
Hylaeus sparsus (Cresson)	Masked bee	5		5	4	1		3	1		sol	cav	poly

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Family Halictidae													
Agapostemon texanus Cresson	Sweat bee		23	23	8		23				sol	soil	poly
Agapostemon virescens (Fabricius)	Sweat bee	1	6	7	6		5	2			sol	soil	poly
Augochlora pura (Say)	Sweat bee	71	363	434	35	24	345	45	20		sol	wood	poly
Augochlorella aurata (Smith)	Sweat bee	22	235	257	27	2	187	39	29		soc	soil	poly
Augochloropsis metallica (Fabricius)	Sweat bee	3	2	5	4	1	3	1			sol	soil	poly
Halictus confusus Smith	Sweat bee	9	79	88	21		75	9	4		soc	soil	poly
Halictus ligatus/poeyi	Sweat bee	3	34	37	13		34	2	1		soc	soil	poly
Halictus parallelus Say	Sweat bee		1	1	1		1				soc	soil	poly
Halictus rubicundus (Christ)	Sweat bee	3	3	6	6	1	4		1		soc	soil	poly
Lasioglossum abanci (Crawford)	Sweat bee	2	5	7	7	2	2	2	1		soc	soil	poly
Lasioglossum admirandum (Sandhouse)	Sweat bee		21	21	12		20	1			soc	soil	poly
Lasioglossum albipenne (Robertson)	Sweat bee		14	14	5		14				soc	soil	poly
Order Hymenoptera													
Family Halictidae													
Lasioglossum anomalum (Robertson)	Sweat bee	1	38	39	8		36	2	1		soc	soil	poly
Lasioglossum apocyni (Mitchell)	Sweat bee	3		3	2	1		2			soc	soil	poly
Lasioglossum callidum (Sandhouse)	Sweat bee		8	8	7		8				soc	soil	poly
Lasioglossum cattellae (Ellis)	Sweat bee	7	9	16	10	7	3	2	4		soc	soil	poly
Lasioglossum coeruleum (Robertson)	Sweat bee		1	1	1		1				soc	wood	poly
Lasioglossum coreopsis (Robertson)	Sweat bee		6	6	4		5			1	soc	soil	poly
Lasioglossum coriaceum (Smith)	Sweat bee	8	141	149	16	3	124	19	3		sol	soil	poly
Lasioglossum cressonii (Robertson)	Sweat bee	8	63	71	20	7	49	6	9		soc	wood	poly
Lasioglossum ephialtum Gibbs	Sweat bee	1	2	3	2		2		1		soc	soil	poly
Lasioglossum fuscipenne (Smith)	Sweat bee	1		1	1				1		sol	soil	poly
Lasioglossum gotham Gibbs	Sweat bee		1	1	1				1		soc	soil	poly
Lasioglossum hitchensi Gibbs	Sweat bee	1	64	65	10		59	3	3		soc	soil	poly
Lasioglossum illinoense (Robertson)	Sweat bee		1	1	1		1				soc	soil	poly
Lasioglossum imitatum (Smith)	Sweat bee	3	26	29	8		15	2	12		soc	soil	poly
Lasioglossum laevissimum (Smith)	Sweat bee	23	33	56	21	10	20	6	20		soc	soil	poly
Lasioglossum leucocomum (Lovell)	Sweat bee	2	3	5	5		5				soc	soil	poly
Lasioglossum leucozonium (Schrank)	Sweat bee		3	3	3		3				sol	soil	poly
Lasioglossum lineatulum (Crawford)	Sweat bee	1	3	4	4	1	3				soc	soil	poly
Lasioglossum nymphaearum (Cockerell)	Sweat bee		10	10	6		10				soc	soil	poly

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Lasioglossum obscurum (Robertson)	Sweat bee	1		1	1	1					soc	soil	poly
Lasioglossum paradmirandum (Knerer & Atwood)	Sweat bee	1	8	9	4		4	4	1		soc	soil	poly
Lasioglossum pectorale (Smith)	Sweat bee		1	1	1		1				sol	soil	poly
Lasioglossum pilosum (Smith)	Sweat bee		21	21	4		21				soc	soil	poly
Lasioglossum platyparium (Robertson)	Sweat bee		10	10	6		10				sop	sop	clp
Lasioglossum pruinosum (Robertson)	Sweat bee		2	2	2		2				soc	soil	poly
Lasioglossum quebecense (Crawford)	Sweat bee	11	9	20	12	7	3	5	5		sol	soil	poly
Lasioglossum sp.	Sweat bee	23	23	46	20	4	20	3	19		soc	soil	poly
Lasioglossum subviridatum (Cockerell)	Sweat bee	2	8	10	5	1	3	6			soc	wood	poly
Lasioglossum tegulare (Robertson)	Sweat bee	2	76	78	16		72	4	2		soc	soil	poly
Lasioglossum tenax (Sandhouse)	Sweat bee	1	3	4	3	1	1		2		soc	soil	poly
Lasioglossum trigeminum Gibbs	Sweat bee	1	14	15	8		14		1		soc	soil	poly
Lasioglossum versans (Lovell)	Sweat bee	1	6	7	5	4	2		1		soc	soil	poly
Lasioglossum versatum (Robertson)	Sweat bee	3	218	221	22	1	214	4	2		soc	soil	poly
Lasioglossum weemsi (Mitchell)	Sweat bee	1	13	14	8	1	9	3	1		soc	soil	poly
Lasioglossum zephyrum (Smith)	Sweat bee		1	1	1		1				soc	soil	poly
Order Hymenoptera													
Family Halictidae													
Sphecodes coronus Mitchell	Cuckoo bee		1	1	1	1					clp	clp	clp
Sphecodes galerus Lovell & Cockerell	Cuckoo bee		3	3	2	1	2				clp	clp	clp
Sphecodes levis Lovell & Cockerell	Cuckoo bee		2	2	1	2					clp	clp	clp
Family Megachilidae													
Chelostoma philadelphi (Robertson)		1		1	1			1			sol	cav	poly
Coelioxys sayi Robertson	Cuckoo bee	12	3	15	8		2	13			clp	clp	clp
Hoplitis pilosifrons (Cresson)	Mason bee		4	4	3		4				sol	cav	poly
Hoplitis producta (Cresson)	Mason bee	1	31	32	9	3	28		1		sol	cav	poly
Hoplitis spoliata (Provancher)	Mason bee	1	8	9	6		7	1	1		sol	cav	poly
Hoplitis truncata (Cresson)	Mason bee		2	2	2		2				sol	cav	poly
Megachile brevis Say	Leafcutter bee		1	1	1		1				sol	cav	poly
Megachile mendica Cresson	Leafcutter bee	20	16	36	18		16	13	7		sol	soil	poly
Megachile petulans Cresson	Leafcutter bee	1		1	1			1			sol	cav	poly
Megachile relativa Cresson	Leafcutter bee	5	12	17	7		8	9			sol	cav	poly
Megachile xylocopoides Smith	Carpenter-mimic leafcutter bee	1		1	1			1			sol	cav	olig
Osmia atriventris Cresson	Mason bee	1	12	13	5	5	4	3	1		sol	cav	poly

SPECIES	COMMON NAME	# net	# bowl	# total	# sites	For	Mea	Roa	Roc	Swa	SOB	NES	SPES
Osmia bucephala Cresson	Bufflehead mason bee	3	9	12	7	6	6				sol	cav	poly
Osmia collinsiae Robertson	Mason bee		7	7	5	3	2	1		1	sol	cav	poly
Osmia cornifrons (Radoszkowski)	Hornfaced bee	17	8	25	12	18	5	1	1		sol	cav	poly
Osmia distincta Cresson	Mason bee		1	1	1		1				sol	cav	olig
Osmia georgica Cresson	Mason bee	3	10	13	6	8	4	1			sol	cav	poly
Osmia lignaria Say	Blue orchard bee		4	4	3	4					sol	cav	poly
Osmia pumila Cresson	Mason bee	5	34	39	13	5	28	4	2		sol	cav	poly
Osmia subfasciata Cresson	Mason bee		1	1	1		1				sol	cav	poly
Osmia taurus Smith	Mason bee	3	1	4	3	3	1				sol	cav	poly
Stelis lateralis Cresson	Cuckoo bee		1	1	1		1				clp	clp	clp

NPS 134/138251, May 2017

National Park Service
U.S. Department of the Interior

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