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Natural Resource Stewardship and Science

What's the Buzz? Pollinator Diversity and Distribution Along the Chilkoot Trail

Natural Resource Report NPS/KLGO/NRR—2020/2136

ON THIS PAGE
Park warden Christine Hedgecock took these photos of a large congregation of *Bombus sylvicola* workers, loaded with pollen, on June 14, 2019, after an unseasonal snowstorm up in the high country. It appears the bees were suddenly grounded because of the cold temperatures, or perhaps the entrance to their nest was blocked? (CHRISTINE HEDGECOCK)

ON THE COVER
Left to right, **TOP ROW:** Pollinator crew at Canyon City; Langton's forester moth (*Alypia langtoni*) **MIDDLE ROW:** Black tail bumble bee (*Bombus melanopygus*) on fireweed (*Chamerion*); Mary Hake collecting pollinators between Crater Lake and Happy Camp. **BOTTOM ROW:** Mary Hake collecting pollinators above Lindeman Lake; black tail bumble bee on harebell (*Campanula*) (NPS/JESSICA RYKKEN)

What's the Buzz? Pollinator Diversity and Distribution Along the Chilkoot Trail

Natural Resource Report NPS/KLGO/NRR—2020/2136

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Contents

Page

Figures v

Tables v

Abstract vi

Acknowledgments vii

Introduction 1

Methods 3

Study Area 3

Coastal Forest 3

Alpine Tundra 3

Boreal Forest 3

Collecting Pollinators 6

Sample Processing and Identification 6

Specimen Deposition 8

Results 9

Community Patterns 10

Elevation 12

Host Plant Associations 12

Discussion 16

Pollinator Diversity and Distribution 16

Natural History of Focal Pollinator Taxa 18

Bumble Bees 18

Solitary Bees 18

Flower Flies (Syrphidae) 18

Educating Park Staff and Visitors About Pollinators 19

Threats to Pollinators and the Need for Monitoring 19

Conclusions and Recommendations 21

Contents (continued)

Page

Literature Cited 22

Appendix A. List of Bee and Flower Fly Species Collected, July 9-14, 2019 25

Figures

Page

Figure 1. Route of the Chilkoot Trail through Klondike Gold Rush National Historical Park and Chilkoot National Historic Site, including names associated with sampling sites 4

Figure 2. Elevation and ecozones of the Chilkoot Trail through Klondike Gold Rush National Historical Park and Chilkoot National Historic Site, including names associated with sampling sites 5

Figure 3. Abundance of males and females (workers and queens for bumble bees) of 16 bee species and 10 flower fly taxa collected along the Chilkoot Trail, July 9-14, 2019. 9

Figure 4. Proportional representation of pollinator species collected in each ecozone along the Chilkoot Trail, July 9-14, 2019. 11

Figure 5. Range in elevation where each pollinator species was collected 12

Tables

Page

Table 1. Location, general habitat description, and sampling dates for 13 sites along the Chilkoot Trail. 7

Table 2. Ecozones where host plant genera were sampled (x). 13

Table 3. Number of pollinator specimens (for each bee species) collected from each host plant genus. 13

Table 4. Number of pollinator specimens (for each flower fly species) collected from each host plant genus. 15

Abstract

Insect pollinators, specifically bees (Hymenoptera: Anthophila) and flower flies (Diptera: Syrphidae), are critical to maintaining healthy plant communities and functioning ecosystems. Despite their ecological importance and potential vulnerability to environmental threats such as climate change, the diversity of these pollinators has remained largely unknown to park staff and visitors in Klondike Gold Rush National Historical Park and Chilkoot Trail National Historic Site.

We conducted surveys of bees and flower flies along the length of the Chilkoot Trail to document the diversity and distribution of pollinators along an elevational gradient of more than 1000 m, passing through three distinct ecozones. Field work was conducted from July 9-14, 2019.

Between two and four people used insect nets to collect bees and flower flies at 13 sites in three ecozones along flower-rich sections of the trail, beginning in coastal forest at Dyea, climbing steeply to alpine tundra at higher elevations, and descending gradually to boreal forest in the headwaters of the Yukon River at Lindeman and Bennett Lakes. Elevations ranged from a few meters above sea level at Dyea to 1,067 m at Chilkoot Pass. In all, we collected 348 bees and 19 flower flies, representing 16 bee species and 10 flower fly taxa. Bumble bees dominated the catch (94% of the total), but we also collected a few solitary bees in addition to flower flies.

Among the three ecozones, tundra stood out as the least diverse, however it yielded several bumble bee species that were strongly associated with high elevation/Arctic habitats. Coastal and boreal forests were somewhat more similar in their sampled fauna, both yielded several flower flies and shared most of their bumble bee species, although relative abundances differed. Coastal forest had one strongly associated bumble bee *Bombus sitkensis* and was the only ecozone where we collected solitary bees. Boreal forest was distinct for having a very large number of male parasitic bumble bees, and the highest richness of sampled host plants.

This survey provided a quick snapshot of pollinator diversity along the Chilkoot Trail, it was not intended to be a comprehensive survey. We recommend continued sampling to further explore patterns of pollinator diversity and distribution across these very pronounced ecological gradients. We also recommend establishing monitoring protocols for documenting long-term changes in pollinator populations, ranges, and phenology in the face of warming temperatures and other environmental changes.

Acknowledgments

Many thanks to the pollinator wrangling crew, including staff at Klondike Gold Rush National Historical Park (KLGO): Katlyn Fuentes, Mosaics in Science intern; Mary Hake, Acting Natural Resource Management Program Manager; and Morgan Wooderson, Archeological Technician. Morgan was an excellent guide along the first half of the trail, bringing to life some cultural sites and enabling us to enjoy deluxe accommodations. Special thanks to Ashley Mocorro Powell, Geoscientists in the Parks intern at Denali National Park and Preserve (DENA). Even though we didn't all get across the border, I so appreciated everyone's dedication to the project and to ensuring its success with good grace and humor.

Thanks to Dave Schirokauer, Science and Resources Team Leader at DENA, who conceived of the idea of doing a pollinator survey along the Chilkoot Trail, and Annie Matsov, Chief of Resources at KLGO, who provided the encouragement and support that allowed us to pull it off. Many staff at KLGO helped in various ways with logistics. Tyler Ross, Research Coordinator at Chilkoot Trail National Historic Site assisted with permitting for our collections in Canada.

Along the trail, we met many skilled and knowledgeable rangers, but Christine Hedgecock, the park warden who patrols from Chilkoot Pass to Bennett Lake, stands out as a passionate and stalwart steward of the Chilkoot Trail. During our few days along this section of the trail, we encountered Christine several times as she seemed to be everywhere at once, and just ten minutes of conversation made it clear how much she knows and cares about the natural history of plants and animals in this landscape, including the pollinators.

I'm extremely grateful to Kevin Moran, doctoral student at the Canadian National Collection of Insects, Arachnids, and Nematodes in Ottawa for identifying the syrphid flies. Ashley Mocorro Powell labeled and databased all the pollinator specimens, no small task.

This report benefitted greatly from helpful suggestions and comments provided by reviewers, Mary Hake, Wildlife Biologist, NPS, AKRO and Dave Payer, Alaska Regional Wildlife Biologist.

Introduction

The vast majority of flowering plants rely on animal pollinators for successful reproduction (Ollerton et al. 2011). Native bees (Hymenoptera: Anthophila) are among the most efficient and diverse insect pollinators, with approximately 4,000 species known in North America (Mader et al. 2011). Another important pollinator group, which includes many bee mimics, is the flower fly family (Diptera: Syrphidae), represented in the Nearctic by approximately 870 species (Vockeroth and Thompson 1987). Though comparatively inconspicuous and understudied in Alaska national parks, insect pollinators are critical to ensuring the reproductive success of many of the plants that vertebrate herbivores and omnivores depend upon for survival, and thus are essential for maintaining healthy, functioning wild ecosystems in Alaska.

Pollinators are known to be at risk from various environmental threats such as habitat loss and alteration, parasites and pathogens, pesticides, and climate change (Potts et al. 2010, Goulson et al. 2015, Soroye et al. 2020). Dramatic declines have been well-documented and publicized for honey bees (Natural Research Council 2007), but have also been seen among native bumble bees (Cameron et al. 2011), and solitary bees (Burkle et al. 2013). Comparatively scant literature exists on the status of flower flies, although changes in species richness and composition pre- and post-1980 have been documented in Europe (Biesmeijer et al. 2006).

In Alaska and neighboring northern regions, changing climate is likely the prevailing threat to pollinator communities, with potential consequences including range shifts, decoupling of plant-pollinator networks, and population declines (Bartomeus et al. 2011, Iler et al. 2013, Kerr et al. 2015). We know that the northern latitudes are warming more rapidly than any other region on Earth (Serreze et al. 2000) and alarming ecological and physical changes are being seen in Alaska (Chapin et al. 2014). In the face of such unprecedented threats, establishing a database of pollinator diversity in northern ecozones, especially those that are most vulnerable to effects from climate change, is essential to better understand current species composition and distribution, and to develop baselines for monitoring future changes.

The Chilkoot Trail was established in the late 1800's. It originally served as a route for gold prospectors to travel between the settlement of Dyea, Alaska on Taiya Inlet, over the infamous Chilkoot Pass, to the headwaters of the Yukon River at Lindeman and Bennett Lakes in British Columbia. Today the trail is known primarily for its historical and cultural significance and is managed jointly between the National Park Service and Parks Canada. The 53-km trail also has great ecological significance as it provides relatively easy access to an elevational gradient of more than 1,000 meters passing through three distinct ecozones: coastal forest, alpine tundra, and boreal forest. Such an accessible and diverse ecological transect presents an ideal opportunity for documenting pollinator diversity.

The main goal of our project was to document insect pollinator diversity along the Chilkoot Trail and raise awareness of pollinators among KLGO staff and visitors. Our specific objectives were to:

1. Document the diversity and distribution of bees and flower flies along the length of the Chilkoot Trail in coastal forest, alpine tundra, and boreal forest ecozones.

2. Describe patterns in species composition and turnover with changes in habitat, elevation, host plants, or other ecological parameters.

3. Engage with trail staff and other trail hikers to educate them about the diversity and ecological importance of pollinators in wild landscapes and create a display of pollinator specimens for the KLGO visitor center in Skagway.

Methods

Study Area

The Chilkoot Trail stretches 53 km (33 miles) from Dyea, an abandoned settlement at the mouth of the Taiya River in KLGO, Alaska to Bennett Lake, in Chilkoot Trail National Historical Site (CHTR), British Columbia (Figure 1). This historic Gold Rush trail rises from sea level at its southern end to more than 1,000 m in elevation at Chilkoot Pass, passing through three distinct ecozones before ending at Bennett Lake in the Yukon River headwaters (Figure 2).

Coastal Forest

At its southern terminus, the trail starts just a few meters above sea level and travels through dense coastal forest of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*). The trail generally follows the Taiya River and passes through a deciduous riparian canopy including black cottonwood (*Populus balsamifera*), paper birch (*Betula papyrifera*), and red alder (*Alnus rubra*), with a dense understory of devil's club (*Oplopanax horridus*), ferns, and a diversity of other herbaceous plants. The trail passes through a complex of beaver ponds at about 4.3 km which provide open habitat. At historic Canyon City Town Site (13.5 km; 70 m a.s.l.), the vegetation is a mix of deciduous and coniferous regrowth, with overgrown meadows of fireweed (*Chamerion angustifolium*), common yarrow (*Achillea millefolium*), and other herbs. North of Sheep Camp (300 m a.s.l.), the trail rises steeply up Long Hill and the Golden Staircase to Chilkoot Pass (26.6 km; 1,067 m a.s.l.), leaving the coastal forest, emerging into talus and boulder fields, and transitioning into the alpine tundra ecozone.

Alpine Tundra

Descending on the north side of Chilkoot Pass, the trail passes through alpine tundra and travels along the edge of sprawling Crater Lake. The terrain is open with a high diversity of alpine plants, including ericaceous plants such as sidebells (*Orthilia secunda*) and Alaska bellheather (*Harrimanella stelleriana*), as well as more cosmopolitan species such as dwarf fireweed (*Chamerion latifolium*). The trail follows an outlet stream to Happy Camp campground (33.0 km; 900 m a.s.l.), passing through areas of bare rock, patchy willows (*Salix* spp.), and krummholz conifers. The trail beyond Happy Camp rises above Long Lake, and then descends to Deep Lake (37.0 km; 883 m a.s.l.).

Boreal Forest

Beyond Deep Lake, the trail descends into subalpine boreal forest. The forest on the east side of the Coast Mountains is much drier and more open than the coastal forest and is dominated by lodgepole pine (*Pinus contorta*), subalpine fir (*Abies lasiocarpa*), willow (*Salix* spp.) and alder (*Alnus* spp.). The trail descends to Lindeman City (41.8 km; 670 m) on Lindeman Lake and then rises to Bare Loon Lake (46.7 km; 747 m a.s.l.); the trees are taller at these lakes, but the canopy is still quite open. Bennett City (53.1 km; 670 m a.s.l.) on Bennett Lake, marks the end of the trail. The "weedy" area around the train station has a high diversity of flowering herbs that are attractive to pollinators. Some of these herbs are non-native, e.g., white clover (*Trifolium repens*).

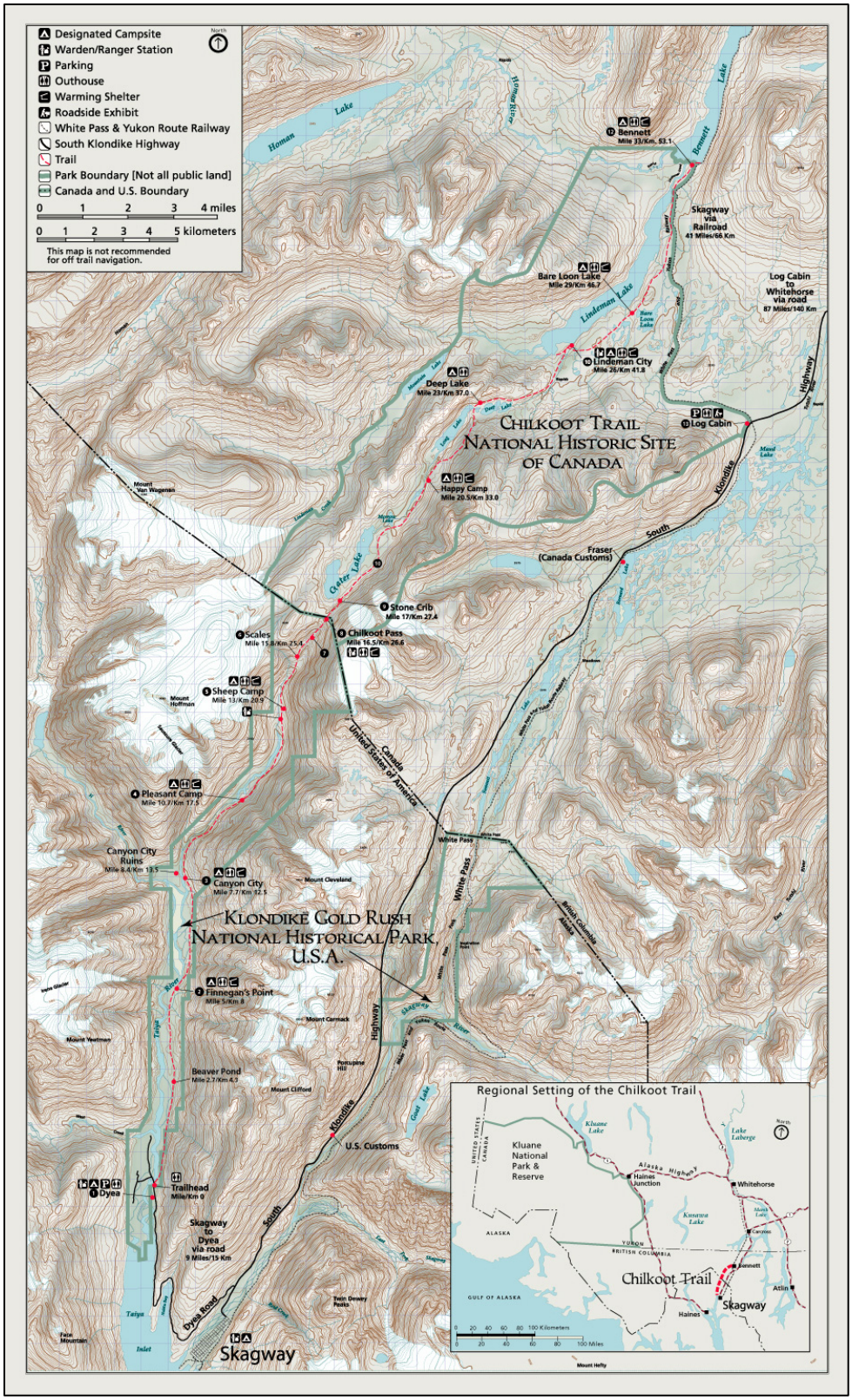

Figure 1. Route of the Chilkoot Trail through Klondike Gold Rush National Historical Park and Chilkoot National Historic Site, including names associated with sampling sites (see Table 1). (Map accessed from https://www.pc.gc.ca/en/lhn-nhs/yt/chilkoot/activ/hiking-randonee)

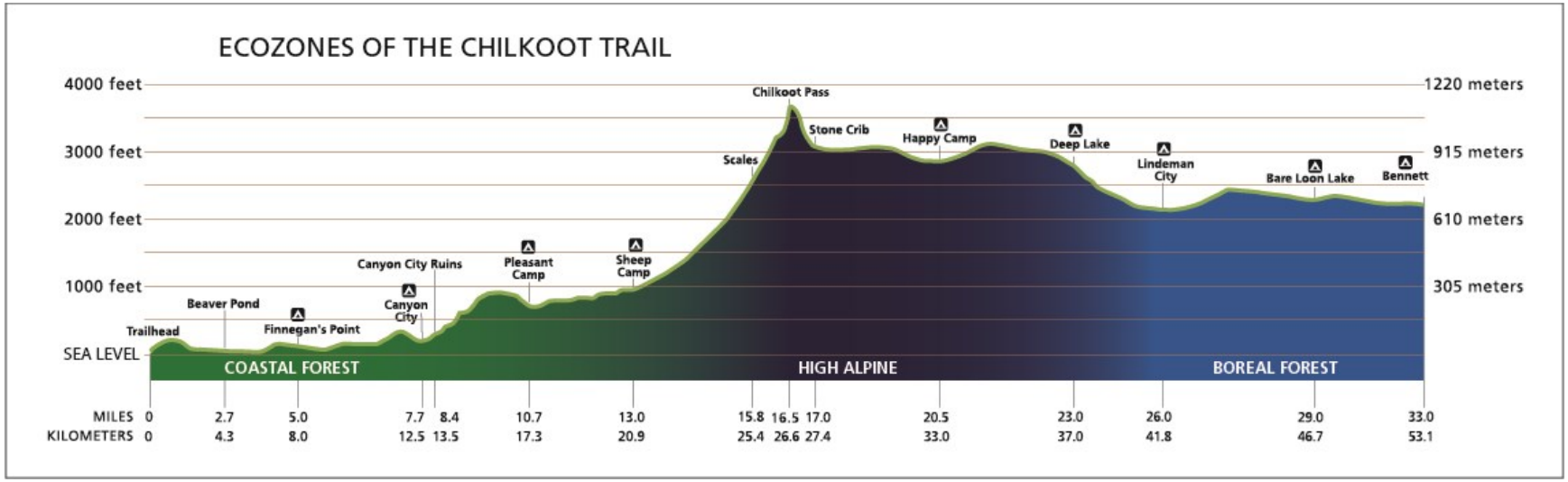

Figure 2. Elevation and ecozones of the Chilkoot Trail through Klondike Gold Rush National Historical Park and Chilkoot National Historic Site, including names associated with sampling sites (see Table 1). (NPS image/M. LEMKE)

Collecting Pollinators

Field work was conducted from July 9-14, 2019. Because almost all species of insects need to be examined with a microscope to determine their identity, it was necessary to collect voucher specimens. Four people collected with standard aerial insect nets between the trailhead at Dyea and Chilkoot Pass in the United States, and two people collected between Chilkoot Pass and Bennett Lake in Canada.

Sampling was nonrandom and opportunistic. Sampling effort varied by day and site, depending on weather, terrain, number of people collecting, and distance to the next camp. Sampling was focused on insect-pollinated plants in flower. In forested terrain, we stopped in areas that were more open and had flowers, including at the edge of beaver ponds, in the historic Canyon City town site, and along edges of the trail. In the alpine tundra, flower abundance and diversity were much higher, however, the weather was cooler and rainy much of the time. This likely inhibited pollinator activity in this ecozone.

Pollinators were actively collected with standard insect nets. Specimens were transferred from the net to a kill jar charged with ethyl acetate, and dead specimens were then transferred to plastic vials according to which host plant they were collected from (if any).

We recorded the plant species or genus from which we collected individual pollinators. Insect pollinators used flowers both for foraging and as shelter during cool, wet, and windy weather. Some bees and flower flies were collected in flight or when landed away from flowers.

Sampling sites (Table 1) represent specific locations or sections of the trail where we sampled. For example, the two Crater Lake sites represent west versus east ends of Crater Lake, and the Happy Camp site represents the entire section of trail between Happy Camp and the eastern end of Crater Lake. Because we were keeping track of host plants for each specimen (at times up to 11 separate vials for different plant species), we could not establish more than three or four sites per day, depending on the host plant diversity. If the sampling habitat remained the same along a stretch of trail, we recorded it as one site. As an example of the variability in sampling effort between sites: the Happy Camp sample represents 5.5 hours of collecting (two people) along a flower-rich 2.5 km section of trail in poor weather (88 specimens total), while the Beaver Ponds sample represents 0.5 hours of collecting (two people) off one species of flowering plant in one or two isolated patches in good weather (11 specimens total).

Sample Processing and Identification

At the end of each day, specimens were transferred from plastic collecting vials to squares of paper towel and then placed in wax paper envelopes, which were stored in plastic tubs. This prevented damage to the specimens from mold and compaction. Specimens were pinned at the end of the trip, on arrival in Skagway. Once back at the lab in DENA, pinned specimens were labeled with locality information and Interior Management Collection System (ICMS) catalog numbers (Figure 3), then entered into a database. All flower flies were submitted to Kevin Moran at the Canadian National Collection of Insects, Arachnids, and Nematodes in Ottawa, Canada, for identification. Prepared and labeled bees were identified to species by J. Rykken.

Table 1. Location, general habitat description, and sampling dates for 13 sites along the Chilkoot Trail.

Country	State/ Province	Park	Latitude	Longitude	Elevation (m)	Locality	Habitat	Ecozone	Sample date
USA	AK	Klondike Gold Rush NHP	59.5119	-135.3463	18	Dyea Trailhead	disturbed opening	coastal forest	7/13/2019
USA	AK	Klondike Gold Rush NHP	59.5528	-135.3350	18	Beaver Ponds	forest/pond edge	coastal forest	7/9/2019
USA	AK	Klondike Gold Rush NHP	59.6090	-135.3297	70	Canyon City	shrub/meadow	coastal forest	7/9-10/2019
USA	AK	Klondike Gold Rush NHP	59.6567	-135.2676	221	Sheep Camp	disturbed meadow	coastal forest	7/10,12/2019
USA	AK	Klondike Gold Rush NHP	59.6724	-135.2660	449	Long Hill	shrub	coastal forest	7/11/2019
Canada	BC	Chilkoot Trail NHS	59.7095	-135.2160	982	Crater Lake	alpine tundra	alpine tundra	7/11/2019
Canada	BC	Chilkoot Trail NHS	59.7242	-135.1949	947	Crater Lake	alpine tundra	alpine tundra	7/11/2019
Canada	BC	Chilkoot Trail NHS	59.7375	-135.1779	898	Happy Camp	alpine tundra	alpine tundra	7/12/2019
Canada	BC	Chilkoot Trail NHS	59.7654	-135.1399	880	Deep Lake	shrub/dry forest	boreal forest	7/13/2019
Canada	BC	Chilkoot Trail NHS	59.7663	-135.1117	836	Deep Lake Gorge	dry forest	boreal forest	7/13/2019
Canada	BC	Chilkoot Trail NHS	59.7839	-135.0880	829	Lindeman City	dry forest	boreal forest	7/13/2019
Canada	BC	Chilkoot Trail NHS	59.7961	-135.0362	784	Bare Loon Lake	dry forest	boreal forest	7/13/2019
Canada	BC	Chilkoot Trail NHS	59.8456	-134.9987	643	Bennett Lake	disturbed meadow	boreal forest	7/14/2109

Specimen Deposition

KLGO specimens were assigned individual ICMS catalog numbers and an accession number (KLGO-00661). All KLGO and CHTR (Canadian) specimens will be deposited at the University of Alaska Museum at the University of Alaska Fairbanks.

Ashley Mocorro Powell labeling and cataloging a box of insect pollinator specimens.

Results

We collected a total of 348 bees and 19 flower flies along the Chilkoot Trail from July 9-14, 2019, including 81 bees and 16 flower flies in KLGO and 267 bees and three flower flies in CHTR. Pollinators from both national historical parks were combined in results for all analyses below.

Pollinators comprised 13 bumble bee species, including two social parasites (*Bombus insularis* and *B. flavidus*), two leafcutter bees (*Megachile* species), one digger bee (*Anthophora terminalis*), and 10 flower fly taxa (Figure 3, Appendix A). Some of the flower flies could be identified to genus only (*Eupeodes*, *Platycheirus*, *Sphaerophoria*), and one species, *Sphaerophoria philanthus*, is a tentative identification. For simplification, we refer to all flower fly taxa as "species" in the remainder of this report. The most abundant bee was *Bombus sylvicola* (109 specimens), however, *Bombus insularis* was more widespread across sampling sites (collected in 9 sites; Figure 3, Appendix A). Almost half of the bee species and all but one of the flower fly species were represented by three or fewer specimens (Figure 3). Many of the more abundant bee species were dominated by males (Figure 3). Both the parasitic bumble bee species (*B. insularis* and *B. flavidus*) were represented by all males.

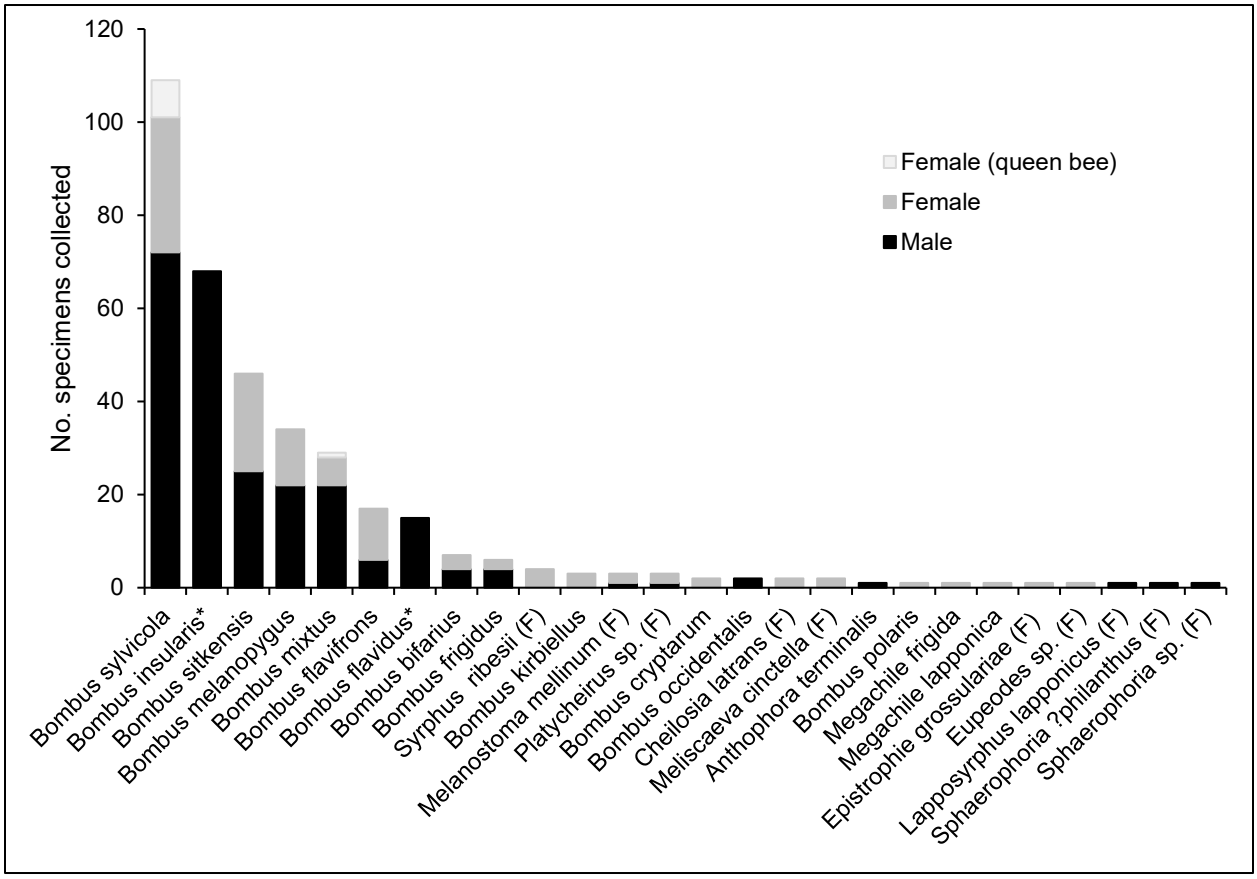

Figure 3. Abundance of males and females (workers and queens for bumble bees) of 16 bee species and 10 flower fly taxa collected along the Chilkoot Trail, July 9-14, 2019. Bumble bee names followed by an asterisk (*) are social parasites. Names followed by (F) are flower flies.

Community Patterns

Pollinator communities appeared to differ between ecozones (Figure 4). Alpine tundra had far lower species richness than either of the forest ecozones (Figure 4). A few species stood out as strongly associated with particular ecozones, including *Bombus sitkensis* in the coastal forest, *B. sylvicola* in the tundra, and *B. insularis* (a parasite) and *B. mixtus* in the subalpine forest. *Bombus melanopygus* appeared to be more of a habitat generalist, making up 6-11% of the pollinators in each ecozone. All three solitary bee species (*Anthophora terminalis, Megachile frigida*, and *M. lapponica*) were found only in the coastal forest. Flower flies were collected only in the coastal and boreal forest ecozones.

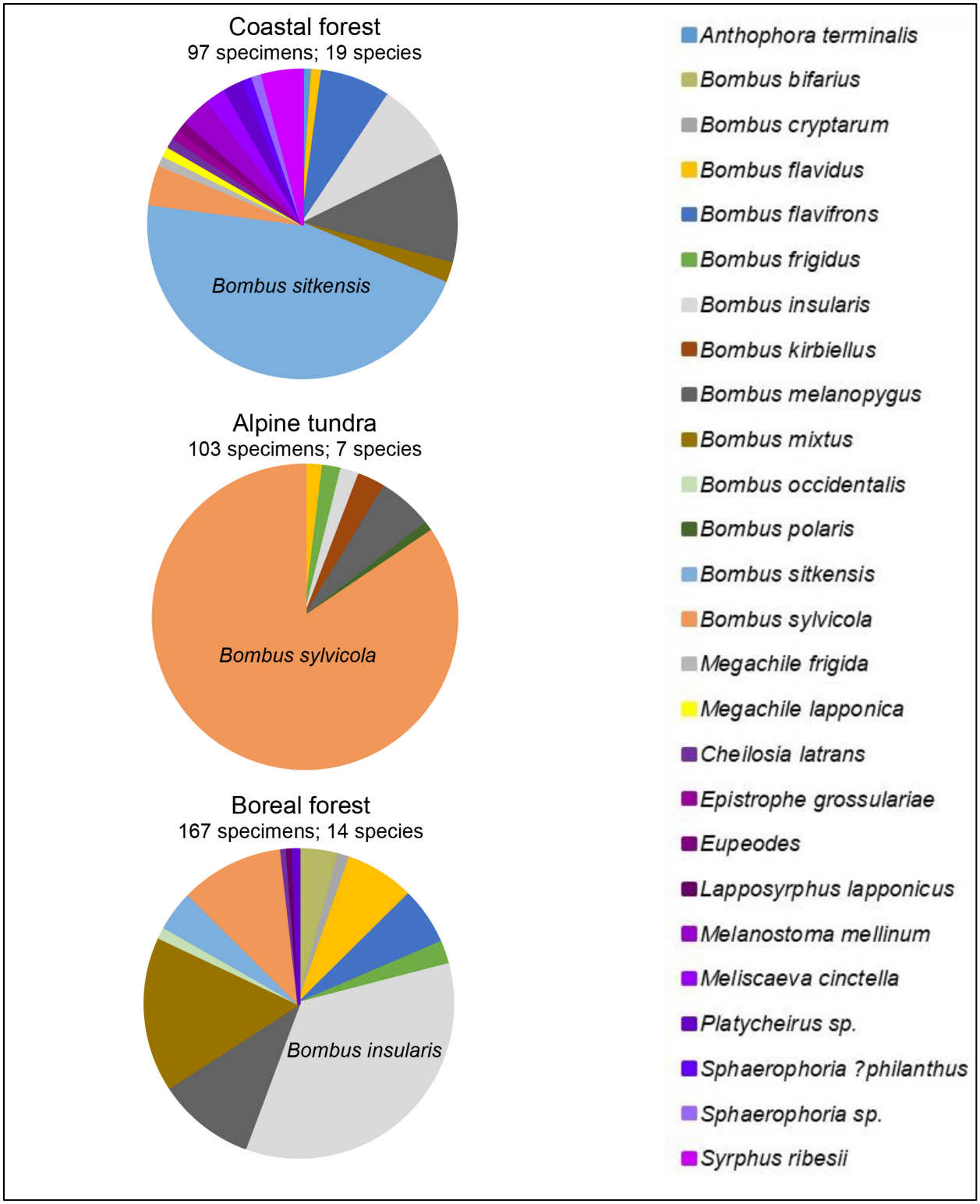

Figure 4. Proportional representation of pollinator species collected in each ecozone along the Chilkoot Trail, July 9-14, 2019. Pink and purple colors (from *Cheilosia latrans* down) represent all flower fly species. Dominant species in each ecozone is labeled.

Elevation

Most of the more abundant species occurred across a wide range of elevations, however all *Bombus bifarius* and *B. frigidus* were collected at or above 643 m, and *B. flavidus* and *B. sylvicola* were not collected below 449 m (Figure 5). All flower flies were collected at elevations at or below 643 m.

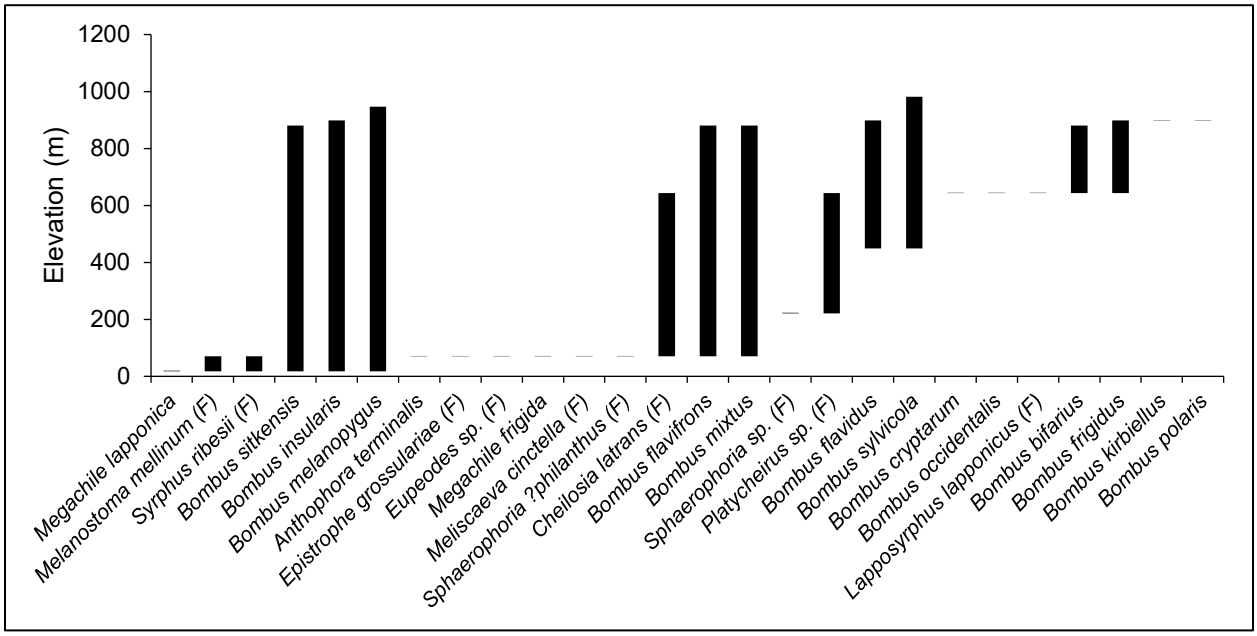

Figure 5. Range in elevation where each pollinator species was collected. Names followed by (F) are flower flies.

Host Plant Associations

We collected pollinators from flowers of 17 different plant genera (Tables 2, 3, and 4), the most ubiquitous of these being *Chamerion* (fireweed and dwarf fireweed), which was sampled at 11 sites across all three ecozones. The only other plant genus sampled in all ecozones was *Aconitum* (monkshood), although it was sampled at only half as many sites. Not surprisingly, *Chamerion* hosted the highest diversity of pollinator species (12), *Achillea* (yarrow) was next with 11 species, while *Senecio* (groundsel) and *Trifolium* (clover) each had eight species (Tables 3 and 4). Clover was sampled at only one site.

Bombus sylvicola, the most abundant bumble bee, was collected off the highest diversity of host plants (10) and this pattern held true for all the more abundant bee species (Table 3). Flower flies (9 species) were only collected from *Achillea* (Table 4).

Pollinators were collected off more plant genera in the boreal forest (13 genera) than in either of the other ecozones (Table 2). The least number of plant genera sampled was in the coastal forest, where many plants had already gone to seed.

Table 2. Ecozones where host plant genera were sampled (x). Three-letter code after plant name refers to plant family: Ast = Asteraceae, Cam = Campanulaceae, Cap = Caprifoliaceae, Eri = Ericaceae, Fab = Fabaceae, Ona = Onagraceae, Orc = Orchidaceae, Ran = Ranunculaceae, Ros = Rosaceae, Sal = Salicaceae.

	Host plant genus (Family)																
Ecozone	***Achillea* (Ast)**	***Arnica* (Ast)**	***Erigeron* (Ast)**	***Prenanthes* (Ast)**	***Senecio* (Ast)**	***Solidago* (Ast)**	***Campanula* (Cam)**	***Valeriana* (Cap)**	***Orthilia* (Eri)**	***Harrimanella* (Eri)**	***Trifolium* (Fab)**	***Chamerion* (Ona)**	***Platanthera* (Orc)**	***Aconitum* (Ran)**	***Luetkea* (Ros)**	***Sanguisorba* (Ros)**	***Salix* (Sal)**
Coastal forest	x	–	–	x	–	–	x	–	–	–	–	x	–	x	–	–	–
Alpine tundra	–	x	–	–	x	–	–	x	x	x	–	x	–	x	x	–	x
Boreal forest	x	x	x	–	x	x	x	x	–	–	x	x	x	x	–	x	–

Table 3. Number of bee specimens collected from each host plant genus. Three-letter code after plant name refers to plant family: Ast = Asteraceae, Cam = Campanulaceae, Cap = Caprifoliaceae, Eri = Ericaceae, Fab = Fabaceae, Ona = Onagraceae, Orc = Orchidaceae, Ran = Ranunculaceae, Ros = Rosaceae, Sal = Salicaceae.

	Host plant genus (Family)																	**No. host plant genera**
Bee species	***Achillea* (Ast)**	***Arnica* (Ast)**	***Erigeron* (Ast)**	***Prenanthes* (Ast)**	***Senecio* (Ast)**	***Solidago* (Ast)**	***Campanula* (Cam)**	***Valeriana* (Cap)**	***Orthilia* (Eri)**	***Harrimanella* (Eri)**	***Trifolium* (Fab)**	***Chamerion* (Ona)**	***Platanthera* (Orc)**	***Aconitum* (Ran)**	***Luetkea* (Ros)**	***Sanguisorba* (Ros)**	***Salix* (Sal)**	
Anthophora terminalis	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1
Bombus bifarius	–	2	–	–	2	–	–	–	–	–	1	2	–	–	–	–	–	4
Bombus cryptarum	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	1
Bombus flavidus	–	–	–	–	4	1	–	2	–	–	5	1	–	–	–	–	–	5
Bombus flavifrons	–	–	–	–	–	–	–	–	–	–	–	3	–	11	–	–	–	2
Bombus frigidus	–	–	–	–	3	–	–	–	–	–	2	1	–	–	–	–	–	3
Bombus insularis	–	3	1	2	22	9	–	–	–	–	10	18	–	1	–	–	–	8
Bombus kirbiellus	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	1

Table 3 (continued). Number of bee specimens collected from each host plant genus. Three-letter code after plant name refers to plant family: Ast = Asteraceae, Cam = Campanulaceae, Cap = Caprifoliaceae, Eri = Ericaceae, Fab = Fabaceae, Ona = Onagraceae, Orc = Orchidaceae, Ran = Ranunculaceae, Ros = Rosaceae, Sal = Salicaceae.

Bee species	Host plant genus (Family)																	No. host plant genera
	Achillea **(Ast)**	***Arnica*** **(Ast)**	***Erigeron*** **(Ast)**	***Prenanthes*** **(Ast)**	***Senecio*** **(Ast)**	***Solidago*** **(Ast)**	***Campanula*** **(Cam)**	***Valeriana*** **(Cap)**	***Orthilia*** **(Eri)**	***Harrimanella*** **(Eri)**	***Trifolium*** **(Fab)**	***Chamerion*** **(Ona)**	***Platanthera*** **(Orc)**	***Aconitum*** **(Ran)**	***Luetkea*** **(Ros)**	***Sanguisorba*** **(Ros)**	***Salix*** **(Sal)**	
Bombus melanopygus	2	–	–	–	2	–	3	–	1	–	3	21	–	–	–	1	–	7
Bombus mixtus	–	1	–	–	5	–	1	1	1	–	–	18	–	–	–	1	–	7
Bombus occidentalis	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	2
Bombus polaris	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1
Bombus sitkensis	5	–	–	15	3	1	1	–	–	–	–	20	–	2	–	–	–	7
Bombus sylvicola	–	3	–	–	9	–	–	15	1	2	1	59	2	–	8	–	1	10
Megachile frigida	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Megachile lapponica	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Total bee species	2	4	1	4	8	3	3	3	3	1	8	12	1	4	1	2	1	n/a

Table 4. Number of flower fly specimens collected from each host plant genus. Three-letter code after plant name refers to plant family: Ast = Asteraceae, Cam = Campanulaceae, Cap = Caprifoliaceae, Eri = Ericaceae, Fab = Fabaceae, Ona = Onagraceae, Orc = Orchidaceae, Ran = Ranunculaceae, Ros = Rosaceae, Sal = Salicaceae.

Flower fly species	Host plant genus (Family)																	No. host plant genera
	Achillea **(Ast)**	***Arnica*** **(Ast)**	***Erigeron*** **(Ast)**	***Prenanthes*** **(Ast)**	***Senecio*** **(Ast)**	***Solidago*** **(Ast)**	***Campanula*** **(Cam)**	***Valeriana*** **(Cap)**	***Orthilia*** **(Eri)**	***Harrimanella*** **(Eri)**	***Trifolium*** **(Fab)**	***Chamerion*** **(Ona)**	***Platanthera*** **(Orc)**	***Aconitum*** **(Ran)**	***Luetkea*** **(Ros)**	***Sanguisorba*** **(Ros)**	***Salix*** **(Sal)**	
Cheilosia latrans	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Epistrophe grossulare	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Eupeodes sp.	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Lapposyrphus lapponicus	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Melanostoma mellinum	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Meliscaeva cinctella	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Platycheirus sp.	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
*Sphaerophoria philanthus**	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Sphaerophoria sp.	-	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Syrphus ribesii	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Total flower fly species	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a

* tentative identification

Discussion

Pollinator Diversity and Distribution

Our preliminary investigation into pollinator diversity along the Chilkoot Trail provided us with some important insights into distribution patterns of bees and flower flies across three distinct ecozones.

The dominant pollinators encountered in all three ecozones along the Chilkoot Trail were bumble bees (genus *Bombus*). Each ecozone had one or more relatively abundant bumble bee species that were strongly associated with it: *Bombus sitkensis* in the coastal forest; *B. insularis, B. flavidus,* and *B. mixtus* in the boreal forest; and *B. sylvicola* in the alpine tundra. There were also several more cosmopolitan species, such as *Bombus melanopygus*, which was relatively common in all three ecozones (less so in the tundra).

Most species were represented by three or fewer specimens, thus habitat associations were inconclusive. Further complicating analysis of habitat association, our sampling design was nonrandom and opportunistic, flowering phenology varied among ecozones, and our survey efforts coincided with variable weather conditions, affecting pollinator activity.

As a group, all flower flies were collected only in the two forest ecozones (mostly in the coastal forest), from a single host plant, *Achillea millefolium* (common yarrow). The color and form of this plant, white with small, clustered flowers, is especially attractive to fly pollinators (Skevington et al. 2019). The absence of flower flies in the tundra was likely due to the cool, rainy weather encountered there during sampling efforts. All three solitary bee species were found in the coastal forest, and at least two of these species (*Anthophora terminalis* and *Megachile frigida*) are known to nest in rotting wood.

We collected a surprising number of parasitic bumble bees in the boreal forest (70 total). All were males, and they were collected off many different plants and at different locations. The two species, *Bombus insularis* and *B. flavidus*, are widespread throughout Alaska. Females are much more rarely encountered (see natural history information in next section), but the high numbers of males suggest robust populations of these species. Because their success depends on healthy populations of host bees, parasitic bees can serve as good indicators of the overall health of bee communities (Sheffield et al. 2013).

One parasitic bumble bee we did not observe during our survey is *Bombus bohemicus*. This species is listed as Endangered in Canada (COSEWIC 2014). Reasons for observed declines in Canada include the concurrent decline of host bumble bee species (including *Bombus occidentalis*), pesticide use, and the escape of pathogen infected bumble bees from commercial greenhouses (COSEWIC 2014). None of these threats are likely to be significant in Alaska or far northwestern British Columbia. We have documented this species in both Denali and Gates of the Arctic National Parks and Preserves.

The tundra stood out as having the most unique pollinator community of the three ecozones, partially due to a *lack* of species (seven species in the tundra versus 19 and 14 in the coastal and boreal

forests, respectively). In addition to the very abundant *Bombus sylvicola*, which occurred in much lower numbers in the two forest ecozones, two known Arctic/high elevation species in the subgenus *Alpinobombus*, *B. kirbiellus* and *B. polaris*, were collected in low numbers in the tundra. There are five species in this subgenus in North America, including *Bombus kluanensis*, a new species described in 2016, known only from Denali National Park and Preserve and the Kluane region of the Yukon Territory.

The coastal forest had the highest pollinator diversity of all, even though the number of different host plants sampled in it was relatively low. This diversity was reflected in the variety of pollinator groups, including nine species of flower flies and three species of solitary bees. The boreal forest had a much higher diversity of host plants in flower than either of the two other ecozones, and most of the pollinator diversity was among bumble bees.

Sampling artefacts likely influenced some of the patterns we documented among pollinator communities and ecozones. The timing of our six-day trip in mid-July coincided well with peak bloom in the tundra and boreal forest, but most of the herbaceous plants in the coastal forest had already gone to seed (e.g., *Streptopus amplexifolius*, *Oplopanax horridus*), likely lessening the diversity of our catch in this ecozone. To capture the full spectrum of host plant phenology for all three ecozones across almost 1,000 m of elevation would require a substantially longer survey or multiple shorter trips.

The four days we spent in the tundra and boreal forest coincided with cool (11-12ºC), sometimes rainy and/or windy weather, less than ideal for collecting flying insects. Thus, we collected many pollinators that were not necessarily feeding on flowers, but instead, using them as shelter. This is a common strategy for male bees especially, who will not return to the nest once they have emerged as adults. We collected high proportions of males among the abundant bumble bees in these two ecozones.

Our sampling design was, by necessity, nonrandom and opportunistic. We had six days to cover 53 km, and thus we stopped where and when we could to sample, but individual sampling events were variable in intensity and effort and yielded highly variable numbers of specimens. Sampling sites within an ecozone could also be quite different from each other floristically.

Floral diversity and composition influenced pollinator diversity at the site scale. Disturbed open sites in both coastal and boreal forest ecozones were especially productive. The Canyon City site, with five host plant genera, yielded 14 pollinator species (the highest diversity for any site), including seven flower flies and two of the three solitary bees. The weedy open ground surrounding the train station at Bennett Lake gave us all three species of flower flies collected in the boreal forest, and the highest diversity of bumble bees (10 species) from any site along the trail, including two species (*Bombus cryptarum* and *B. occidentalis*) collected nowhere else. The Bennett Lake site was the only site with non-native white clover (*Trifolium repens*), which hosted eight bumble bee species, rivaled for pollinator diversity only by arrowleaf groundsel (*Senecio triangularis*) and fireweed (*Chamerion*), both of which occurred in many sites.

Natural History of Focal Pollinator Taxa

Bumble Bees

As expected, bumble bees made up the vast majority (99%) of the bees in the survey. Bumble bees are well-adapted to the harsh climates of high latitudes and altitudes because of their comparatively large body size, long, dense pelage, and ability to warm their thoracic muscles through shivering which allows them to fly at lower temperatures than most insects (Kearns and Thomson 2001). Bumble bees are typically generalist foragers with relatively long tongues and these traits are also beneficial in northern landscapes where the flowering season is compressed. Bumble bees are social insects with nests that last just one season. New queens, produced at the end of the season, leave the nest to mate, then hibernate under the ground over the winter. The rest of the colony (the founding queen, workers, and males) die before cold temperatures set in. New nests are established the following spring by the surviving new queens. Bumble bees generally build their nests in abandoned burrows or under tussocks.

In addition to social bumble bees, we documented two species of social parasites, *Bombus insularis* and *B. flavidus*. These bees do not build nests of their own, nor do they have a worker caste. Instead, a female will invade the nest of a host (social) species, kill or incapacitate the queen, and usurp the nest, so that host workers will raise her young. Thus, the female bees do not collect pollen and nectar for the nest and have no special structures on their legs (corbiculae) for pollen transport. Likely hosts for *Bombus insularis* include *B. flavifrons and B. occidentalis* (both collected in the boreal ecozone where *B. insularis* was abundant); suspected hosts for *B. flavidus* include *B. occidentalis* and species in the subgenus *Pyrobombus* (Williams et al. 2014).

Solitary Bees

We collected only three species and specimens of solitary bees. Unlike social bumble bees that build up nests with different castes, solitary bees have smaller nests initiated by individual females. Each female provisions her own brood, and there is no differentiation into queens and workers. The solitary bees we collected in the coastal ecozone included *Anthophora terminalis*, a species of digger bee that is widely distributed across North America. This is a relatively large, hairy bee that is also able to warm itself by shivering. It is unusual among digger bees in that it nests by excavating pithy stems or rotting wood rather than digging in the ground. The two other solitary species were leafcutter bees in the genus *Megachile*. As their common name suggests, leafcutter bees cut discs of leaves with their large mandibles to line nests they make in pre-existing holes. *Megachile frigida* is nests in rotten logs while *M. lapponica* nests in various cavities (Sheffield et al. 2011).

Flower Flies (Syrphidae)

We collected low numbers of flower flies (19 total), likely due to the cool weather, but a relatively high richness (10 taxa). Most adult flower flies are superb bee and wasp mimics and visit flowers to feed on pollen and/or nectar just like bees. Their mobile larvae, however, lead very different lives from immature bees (which are provisioned with all the nectar and pollen needed for development from egg to adulthood by family members). All but one of the flower fly species we collected have predaceous larvae which feed mainly on aphids and other soft-bodied insects. The larvae of the remaining species, *Cheilosia latrans*, are likely plant feeders (Skevington et al. 2019).

Educating Park Staff and Visitors About Pollinators

An important goal of the survey was to foster awareness and appreciation of insect pollinator diversity and natural history among staff and visitors along the Chilkoot Trail. People hike this historic trail to learn more about the culture and challenges of late 19th century gold prospectors even as they enjoy the wilderness setting of the trail and any wildlife they encounter along it. With our nets and collecting gear, our pollinator survey activities and objectives were of interest to most people we met along the trail, and we engaged with hikers as well as rangers and wardens while we did our work and at camp in the evenings. Creating a pollinator specimen display for the visitor center in Skagway or providing content for the park website are possible follow-up activities.

Threats to Pollinators and the Need for Monitoring

Insect pollinators are intimately linked to their host plants in complex ecological networks, and thus they may serve as effective indicators of ecosystem integrity. One of the most urgent threats facing northern ecosystems in protected areas is climate change. Species in environments with compressed growing seasons and extreme climates have evolved a variety of complementary physiological adaptations and behaviors to survive such conditions, and thus responses to changes in temperature and moisture may be complex and difficult to predict (Danks 2004). 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 pollinator species with a narrower range of host plants (Bartomeus et al. 2011, Iler et al. 2013, Gillespie et al. 2016).

Climate change may also drive shifts in geographical ranges of pollinators, especially northwards in latitude or upwards in elevation. There is a growing body of research looking at effects of climate change on pollinator distribution and diversity in arctic and alpine systems (e.g., Dirnböck et al. 2011, Franzén and Öckinger 2012). For example, Kerr et al. (2015) showed that southern range limits for many northern bumble bee species in Europe and North America have shifted northwards while their northern range limits have remained static (thus compressing the overall range) over the last century. Richman et al. (2020) suggest that asynchronous range shifts of alpine plants and pollinators may affect species interactions and plant reproductive success. One of the common conclusions and recommendations of alpine and northern studies is that structured survey and monitoring on both local and global scales is imperative.

Bumble bee declines have received significant attention worldwide (Kosior et al. 2007, Goulson et al. 2008, Cameron et al. 2011). Williams et al. (2009) concluded that bees at highest risk of decline include species that are climate specialists and species that live close to the edge of their climatic range. For bees along the Chilkoot Trail, we might expect that the species most susceptible to decline in the face of a changing climate would be those restricted to alpine habitats, such as species in the subgenus *Alpinobombus*: *Bombus kirbiellus* and *B. polaris*. This subgenus includes five species in North America (all of which occur in Alaska) and four species in Europe; all nine species have exclusively arctic and/or alpine distributions (Williams et al. 2019). Recent assessments by Rasmont et al. (2015) have predicted that the four European species are under high to extremely high threat

from climate change, with some species facing extirpation or possible extinction. We currently have too little information on the five North American species to assess their status (IUCN 2019).

Conclusions and Recommendations

This preliminary survey of pollinators along the Chilkoot Trail, although a brief snapshot, established a baseline database for the diversity and distribution of two key pollinator groups, bees and flower flies. The fauna we documented along the trail suggest that multiple species of bumble bees comprise a large proportion of pollinators in all sampled habitats, foraging on a wide variety of plant hosts. Among the three ecozones traversed by the trail, tundra stood out as the least diverse, however it yielded several bumble bee species that were strongly associated with that habitat. Coastal and boreal forests were somewhat more similar in their sampled fauna, both yielded at least some flower flies and shared most of their bumble bee species, although relative abundances differed.

Clearly, there is still much work to be done along the Chilkoot Trail in order to gain a more comprehensive understanding of the current pollinator fauna, as well as to monitor changes over time.

Future priorities should include:

1. Conduct additional basic survey work of bees, flower flies, and other pollinators along the trail with a structured sampling design. Such a design could include passive traps such as bee bowls or vane traps that might be tended by citizen scientists and set up near campgrounds. This would allow a much more robust analysis of pollinator community patterns along elevational gradients and across ecozone boundaries. The timing of sampling should extend to coincide with peak bloom time in all three ecozones.

2. Keep a look out for the newly described bumble bee, *Bombus kluanensis*, in the tundra ecozone. The species is currently known only from the Kluane region in the western Yukon Territory and Denali National Park, but very likely has a wider distribution. More surveys are needed.

3. Establish a long-term pollinator monitoring program to document changes in pollinator diversity, species composition, abundance, phenology, and distribution over time. Tundra communities may be of particular interest as this ecozone is especially vulnerable to warming temperatures associated with climate change.

4. Share pollinator data collected in this and future surveys with state (https://arctos.database.museum/), provincial, national (https://bison.usgs.gov/#home), and global arthropod biodiversity databases (https://www.gbif.org/, https://www.discoverlife.org/).

5. Continue to educate park staff and visitors about the importance of and threats to pollinators along the Chilkoot Trail. Strategies could include developing a pollinator page (or story map) on the park website with links to outside resources, an interpretive display at the visitor center, and special activities for National Pollinator Day.

Literature Cited

Bartomeus, I., J. S. Ascher, D. L. Wagner, B. N. Danforth, S. Colla, S. Kornbluth, and R. Winfree. 2011. Climate-associated phenological advances in bee pollinators and bee-pollinated plants. PNAS 108:20645-20649.

Biesmeijer, J. C., S. P. M. Roberts, M. Reemer, R. Ohlemüller, M. Edwards, T. Peeters, A. P. Schaffers, S. G. Potts, R. Kleukers, C. D. Thomas, J. Settele, and W. E. Kunin. 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 313:351-354.

Burkle, L. A., J. C. Marlin, and T. M. Knight. 2013. Plant-pollinator interactions over 120 years: loss of species, co-occurrence, and function. Science 339:1611-1615.

Cameron, S. A., J. D. Lozier, J. P. Strange, J. B. Koch, N. Cordes, L. F. Solter, and T. Griswold. 2011. Patterns of widespread decline in North American bumble bees. PNAS 108:662-667.

Chao, A., R. L. Chazdon, R. K. Colwell, and T.-J. Shen. 2005. A new statistical approach for assessing similarity of species composition with incidence and abundance data. Ecology Letters 8:148-159.

Chao, A., L. Jost, S.-C. Chiang, Y.-H. Jiang, and R. L. Chazdon. 2008. A two-stage probabilistic approach to multiple-community similarity indices. Biometrics 64:1178–1186.

Chapin, F. S. I., S. F. Trainor, P. Cochran, H. Huntington, C. Markon, M. McCammon, A. D. McGuire, and M. Serreze. 2014. Alaska. Pages 514-536 in J. M. Melillo, T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program.

COSEWIC. 2014. COSEWIC assessment and status report on the Gypsy Cuckoo Bumble Bombus bohemicus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 56 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Danks, H.V. 2004. Seasonal adaptations in arctic insects. Integrative and Comparative Biology 44:85-94.Goulson, D., E. Nicholls, C. Botías, and E. L. Rotheray. 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 347.

Dirnböck, T., F. Essl, and W. Rabitsch. 2011. Disproportional risk for habitat loss of high-altitude endemic species under climate change. Global Change Biology 17:990–996

Franzén, M., and E. Öckinger. 2012. Climate-driven changes in pollinator assemblages during the last 60 years in an Arctic mountain region in Northern Scandinavia. Journal of Insect Conservation 16:227-238.

Gillespie, M., N.S. Baggesen, and E.J. Cooper. 2016. High Arctic flowering phenology and plant–pollinator interactions in response to delayed snow melt and simulated warming. Environmental Research Letters 11:1-12

Goulson, D., G.C. Lye, and B. Darvill. 2008. Decline and conservation of bumble bees. Annual Review of Entomology 53:191-208.

Iler, A. M., D. W. Inouye, T. T. Høye, A. J. Miller-Rushing, L. A. Burkle, and E. B. Johnston. 2013. Maintenance of temporal synchrony between syrphid flies and floral resources despite differential phenological responses to climate. Global Change Biology 19:2348-2359.

IUCN 2019. The IUCN Red List of Threatened Species. Version 2019-3. http://www.iucnredlist.org. Downloaded on 30 December 2019.

Kearns, C. A., and J. D. Thomson. 2001. The natural history of bumblebees: a sourcebook for investigations. The University Press of Colorado, Boulder, CO.

Kerr, J. T., A. Pindar, P. Galpern, L. Packer, S. G. Potts, L. L. Richardson, D. L. Wagner, L. F. Gall, D. S. Sikes, and A. Pantoja. 2015. Climate change impacts on bumblebees converge across continents. Science 349:177-180.

Kosior, A., W. Celary, P. Olejniczak, J. Fijal, W. Król, W. Solarz, and P. Plonka. 2007. The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of western and central Europe. Oryx 41:79-88.

Mader, E., M. Shepherd, M. Vaughan, S. Hoffman Black, and G. LeBuhn. 2011. Attracting native pollinators. Storey Publishing, North Adams, MA.

Natural Research Council. 2007. Status of pollinators in North America. The National Academies Press, Washington D.C.

Ollerton, J., R. Winfree, and S. Tarrant. 2011. How many flowering plants are pollinated by animals? Oikos 120:321-326.

Potts, S. G., J. C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger, and W. E. Kunin. 2010. Global pollinator declines: trends, impacts and drivers. Trends in Ecology and Evolution 25:345-353.

Rasmont, P., M. Franzén, T. Lecocq, A. Harpke, S. P. M. Roberts, J. C. Biesmeijer, L. Castro, B. Ceterberg, L. Dvorák, Ú. Fitzpatrick, Y. Gonseth, E. Haubruge, G. Mahé, A. Manino, D. Michez, J. Neumayer, F. Ødegaard, J. Pakkunen, T. Pawlikowski, S. G. Potts, M. Reemer, J. Settele, J. R. Straka, and O. Schweiger. 2015. Climatic risk and distribution atlas of European bumblebees.

Richman, S.K., J.M. Levine, L. Stefan, and C.A. Johnson. 2020. Asynchronous range shifts drive alpine plant–pollinator interactions and reduce plant fitness. Global Change Biology 00:1-13.

Serreze, M. C., J. E. Walsh, F. S. Chapin, T. Osterkamp, M. Dyurgerov, V. Romanovsky, W. C. Oechel, J. Morison, T. Zhang, and R. G. Barry. 2000. Observational evidence of recent change in the northern high-latitude environment. Climatic Change 46:159-207.

Sheffield, C. S., C. Ratti, L. Packer, and T. Griswold. 2011. Leafcutter and mason bees of the Genus *Megachile* Latreille (Hymenoptera: Megachilidae) in Canada and Alaska. Canadian Journal of Arthropod Identification No. 18, 29 November 2011.

Sheffield, C. S., A. Pindar, L. Packer, P. G. Kevan. 2013. The potential of cleptoparasitic bees as indicator taxa for assessing bee communities. Apidologie 44:501-510.

Skevington, J.H., M.M. Locke, A.D. Young, K. Moran, W.J. Crins, and S.A. Marshall. 2019. Field guide to the flower flies of Northeastern North America. Princeton University Press, Princeton, NJ. 511 pages.

Soroye, P., T. Newbold, and J. Kerr. 2020. Climate change contributes to widespread declines among bumble bees across continents. Science 367:685-688.

Vockeroth, J. R., and F. C. Thompson. 1987. Syrphidae. Pages 713-743 in J. F. McAlpine, editor. Manual of the Nearctic Diptera. Research Branch, Agriculture Canada.

Williams, P. H., M. V. Berezin, S. G. Cannings, B. Cederberg, F. Ødegaard, C. Rasmussen, L. L. Richardson, J. Rykken, C. S. Sheffield, C. Thanoosing, and A. M. Byvaltsev. 2019. The arctic and alpine bumblebees of the subgenus Alpinobombus revised from integrative assessment of species' gene coalescents and morphology (Hymenoptera, Apidae, *Bombus*). Zootaxa 4625:1-68.

Williams, P.H., S. Colla, and Z. Xie. 2009. Bumblebee vulnerability: common correlates of winners and losers across three continents. Conservation Biology 23:931-940.

Williams, P. H., R. W. Thorp, L. L. Richardson, and S. R. Colla. 2014. Bumble bees of North America: an identification guide. Princeton University Press, Princeton, NJ. 208 pages.

Appendix A. List of Bee and Flower Fly Species Collected, July 9-14, 2019

Table A1. List of bee species collected along the Chilkoot Trail, July 9-14, 2019. Numbers in ecozone columns represent number of specimens collected in that ecozone.

Species	Authority	Common name	Coastal forest	Alpine tundra	Boreal forest	Total no. specimens	Total no. sites	Min elev. (m)	Max elev. (m)
Anthophora terminalis	Cresson	Orange-tipped wood-digger	1	–	–	1	1	70	70
Bombus bifarius	Cresson	Two form bumble bee	–	–	7	7	2	643	940
Bombus cryptarum	(Fabricius)	Cryptic bumble bee	–	–	2	2	1	643	643
Bombus flavidus	Eversmann	Fernald cuckoo bumble bee	1	2	12	15	5	449	940
Bombus flavifrons	Cresson	Yellow head bumble bee	7	–	10	17	6	70	940
Bombus frigidus	Smith	Frigid bumble bee	–	2	4	6	3	643	940
Bombus insularis	(Smith)	Indiscriminate cuckoo bumble bee	8	2	58	68	9	18	940
Bombus kirbiellus	Dahlbom	High country bumble bee	–	3	–	3	1	898	898
Bombus melanopygus	Nylander	Black tail bumble bee	11	6	17	34	9	70	947
Bombus mixtus	Cresson	Fuzzy-horned bumble bee	2	–	27	29	6	70	940
Bombus occidentalis	Greene	Western bumble bee	–	–	2	2	1	643	643
Bombus polaris	Curtis	Polar bumble bee	–	1	–	1	1	898	898
Bombus sitkensis	Nylander	Sitka bumble bee	44	–	7	51	7	18	940
Bombus sp.	–	Bumble bee	1	–	–	1	1	449	449
Bombus sylvicola	Kirby	Forest bumble bee	4	87	18	109	7	449	982
Megachile frigida	Smith	Frigid leafcutter bee	1	–	–	1	1	70	70
Megachile lapponica	Thomson	Leafcutter bee	1	–	–	1	1	18	18

Table A2. List of flower fly species collected along the Chilkoot Trail, July 9-14, 2019. Numbers in ecozone columns represent number of specimens collected in that ecozone.

Species	Authority	Common name	Coastal forest	Alpine tundra	Boreal forest	Total no. specimens	Total no. sites	Min elev. (m)	Max elev. (m)
Cheilosia latrans	(Walker)	Steely blacklet	1	–	1	2	2	70	643
Epistrophe grossulariae	(Meigen)	Black-horned smoothtail	1	–	–	1	1	70	70
Eupeodes sp.	–	Aphideater	1	–	–	1	1	70	70
Lapposyrphus lapponicus	(Zetterstedt)	Common loopwing aphideater	–	–	1	1	1	643	643
Melanostoma mellinum	(Linnaeus)	Variable duskyface	3	–	–	3	2	18	70
Meliscaeva cinctella	(Zetterstedt)	Common thintail	2	–	–	2	1	70	70
Platycheirus sp.	–	Sedgesitter	2	–	1	3	2	221	643
*Sphaerophoria philanthus**	(Meigen)	Black-footed globetail	1	–	–	–	–	70	70
Sphaerophoria sp.	–	Globetail	1	–	–	1	1	221	221
Syrphus ribesii	(Linnaeus)	Common flower fly	4	–	–	4	2	18	70

* tentative identification

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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