



Pollinator Diversity and Floral Associations in Subarctic Sand Dunes of Kobuk Valley National Park, Alaska

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ON THIS PAGE

Top: Hunt River Dunes located along the Kobuk River in Kobuk Valley National Park. Bottom: Kavet Creek flows along the western boundary of the Great Kobuk Sand Dunes.

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ON THE COVER

Clockwise from upper left: Al Smith expertly netting a bee; Kobuk locoweed (*Oxytropis kobukensis*), an endemic plant in the Kobuk Valley sand dunes; Ahnewetut Creek bisects the GKSD; the mason bee *Osmia tarsata*, a common pollinator on Kobuk locoweed.

NPS / JESSICA RYKKEN

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Executive Summary

Active sand dunes in Kobuk Valley National Park are a regionally rare and ecologically distinct landscape feature occurring within the northern boreal biome. The sand dunes harbor a rich diversity of plants, including several rare and disjunct species and the endemic Kobuk locoweed (*Oxytropis kobukensis*). Pollinators associated with these dune plants have not been studied in Kobuk Valley, despite their essential role in transporting pollen which many plants rely on for successful reproduction.

In order to gain a better understanding of pollinator diversity and plant-pollinator associations in this unique ecosystem north of the Arctic Circle, we conducted surveys of bees (Hymenoptera: Anthophila) and syrphid flies (Diptera: Syrphidae) in several places along the Kobuk River and in two active dune areas, the Hunt River Dunes and the Great Kobuk Sand Dunes, in late June-early July of 2017 and 2019. We used active and passive collecting methods to sample pollinators at 21 different sites and along five walking transects, and we documented plant associations for net-collected specimens.

In all, we collected 326 bees and 256 syrphid flies, representing 27 and 37 taxa, respectively. The most abundant and widespread species collected among syrphid flies were *Lapposyrpus lapponicus* and *Eristalis obscura*. For bees, three soil-nesting solitary species, *Andrena barbilabris*, *Megachile circumcincta*, and *Osmia tarsata* made up 60% of the total bee catch.

Dryas integrifolia, a widespread plant on the dunes, hosted the highest number of bee and syrphid fly taxa (13 and 20, respectively). Bumble bees (*Bombus*) and megachilid bees (*Megachile*, *Osmia*) favored several plants in the Fabaceae family, while mining bees (*Andrena*) were abundant on *Salix* species (willow). A high diversity of syrphid flies were collected on the composite *Packera ogorukensis*, and *Salix* species.

Our collections indicate that the endemic *Oxytropis kobukensis* was primarily visited by the mason bee, *Osmia tarsata* (44% of all visitors) and the leafcutter bee, *Megachile circumcincta* (27%). Bumble bees (genus *Bombus*) made up another 13% of all visitors to this plant.

Our study confirms that the active sand dunes in Kobuk Valley provide an ecologically unique habitat both for plants and their associated insect pollinators. For example, many of the solitary bees living in the dunes rely on deep sands for nesting and thus are limited in their distribution across Arctic and boreal landscapes.

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Many thanks to Al Smith and Just Jensen for their expert pollinator-catching assistance and good companionship in the field.

Gates of the Arctic National Park and Preserve supported our travel to the Kobuk Valley sand dunes.

I received much needed assistance with identifications of solitary bees from Terry Griswold at the USDA ARS Bee Biology and Systematics Lab in Logan, Utah, and of syrphid flies from Kevin Moran at the Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Canada.

Introduction

Active sand sheets and dunes covered more than 30,000 km² of northern Alaska during the late Pleistocene (Dijkmans and Koster 1990). These dunes were formed from glacially eroded sediments in the Brooks Range which were carried by wind and water down into ice-free lowland river valleys (Dijkmans and Koster 1990). Today, taiga and tundra vegetation stabilize and cover most of these ancient aeolian deposits, however, a few relict active inland sand dunes persist. The largest of these are the Great Kobuk Sand Dunes in the Kobuk River valley and the Nogahabara Sand Dunes in the Koyukuk National Wildlife Refuge.

Active sand dunes in the Kobuk River valley, lying 65 km above the Arctic Circle, represent rare and ecologically distinct landscape features within the northern boreal biome. The dunes are protected in Kobuk Valley National Park (NP), established in 1980. Botanical surveys dating back to the 1930's have documented a rich diversity of more than 115 species of plants (summarized in Racine 1976, Parker and Mann 1999, Parker 2006). These include widespread boreal and circumpolar species (e.g., *Eurybia sibiricus*, *Astragalus alpinus*, *Chamerion latifolium*); alpine/arctic species (e.g., *Silene acaulis*, *Dryas integrifolia*); and Beringian endemics (e.g., *Tanacetum bipinnatum*, *Armeria maritima*, *Cnidium cnidiifolium*, *Bupleurum americanum*; Parker and Mann 1999). Four plant species found in the dunes are listed as imperiled or rare by the Alaska Natural Heritage Program, including an endemic found only in open sandy habitats of the central Kobuk River valley, *Oxytropis kobukensis* (Parker and Mann 1999, Nawrocki et al. 2013).

Despite ongoing interest in the flora of the Kobuk Valley sand dunes, virtually nothing is known about the insect pollinators critical to the successful reproduction of many of these plants. Bees (Hymenoptera: Anthophila) and syrphid flies (Diptera: Syrphidae) comprise two important groups of plant pollinators in northern Alaska, yet their diversity and habitat associations at these high latitudes have been scarcely documented (Koch and Strange 2012, Rykken 2017). Boreal and tundra landscapes predominate above the Arctic Circle, where bumble bees are some of the most conspicuous pollinators. However, solitary bees are known to occur in areas with suitable nesting habitat, especially deep sands for ground-nesting species (Armbruster and Guinn 1989). Recent pollinator inventory work in Gates of the Arctic National Park and Preserve (NPP) along the Killik, Noatak, and Koyukuk Rivers (Rykken 2017 and unpublished data) has documented a high diversity of solitary and parasitic bees associated with river banks and bluffs, as well as dunes. In comparison to bees, syrphid flies were more diverse in all habitats in Gates of the Arctic NPP, but even less published information exists on this important group of pollinators in Alaska (Fluke 1949, Rykken 2015, 2017, 2020, 2021).

In order to gain a better understanding of the pollinator diversity and plant-pollinator associations in a rare, sandy, and floristically rich northern boreal habitat, we designed a survey with the following objectives: (1) document the bee and syrphid fly fauna of the Kobuk Valley sand dunes; (2) record floral associations for pollinator species where possible; and (3) determine the dominant pollinator visitors to the regionally endemic plant, *Oxytropis kobukensis*.

Methods

Study Area

Located in the Kobuk River valley, Great Kobuk Sand Dunes (GKSD; 62km²) and Hunt River Dunes (HRD; 2km²) are two relict active dune areas from a 650 km² Quaternary-aged sand sheet, composed of primarily aeolian sand deposits (Figure 1). A third active dune area, Little Kobuk Sand Dunes (8 km²), was not sampled in this study. All three dune sites are protected within a designated wilderness area in Kobuk Valley NP. The sand sheet surrounding these isolated patches of active dunes has been stabilized and covered by boreal vegetation, primarily white spruce forest, wet and dry tundra, and open lichen woodland (Parker 2006).

The GKSD, by far the largest area of active dunes in the Kobuk valley, consists primarily of N-S and NW-SE oriented dune ridges, with flat interdune areas that are often vegetated (Dijkmans and Koster 1990). On the west side, GKSD is bordered by Kavet Creek, and GKSD is divided in its southern third by Ahnewetut Creek (Figure 1). Within the dunes, several geomorphic settings (described by Parker and Mann 1999) were targeted for pollinator searches: the lower sections of slipfaces, often with *Tanacetum bipinnatum*, *Eurybia sibirica*, *Astragalus alpinus*, *Artemisia borealis*, and *Cinidium cnicifolium*; flat, vegetated sand sheets with a high diversity of plant species such as *Oxytropis kobukensis*, *Bupleurum americanum*, *Dianthus repens*, *Anticlea elegans*, *Packera ogotorukensis*, and *Silene acaulis*; and dune ‘oases,’ or patches of well-developed vegetation within the dunes that support species such as *Dryas integrifolia*, *Arctous rubra*, as well as more typical boreal forest species (Figures 2 & 3). We also sampled several wetter riparian and spring areas within or alongside the dunes.

The climate of the Kobuk valley is subarctic and semi-arid, with most of the precipitation falling as rain during summer months (Dijkmans and Koster 1990). Summers are brief but can get warm and winters are long and cold. In 2017, the Ambler weather station recorded a mean July temperature of 14.6°C and maximum July temperature of 25.6°C, while the average January temperature was –16.5°C and minimum January temperature was –45°C (accessed from <https://xmacis.rcc-acis.org>). Winds have a bimodal pattern, they are westerly (and weaker) in the summer, with stronger sand-transporting easterlies the rest of the year (Dijkmans and Koster 1990).

Pollinator Sampling

Sampling sites for pollinators were located along the Kobuk River and within active sand dunes. The easternmost sites (# 1–3) were on sandy beaches and banks of the Kobuk River near Onion Portage, one site (# 4) was in the Hunt River Dunes (~15 km downstream on the Kobuk River), while the majority of sites (#5–21) were located throughout the Great Kobuk Sand Dunes, several kilometers south of the Kobuk River (Figure 1, Table 1). Pollinator sampling occurred June 26–July 1, 2017 and June 27–July 2, 2019.

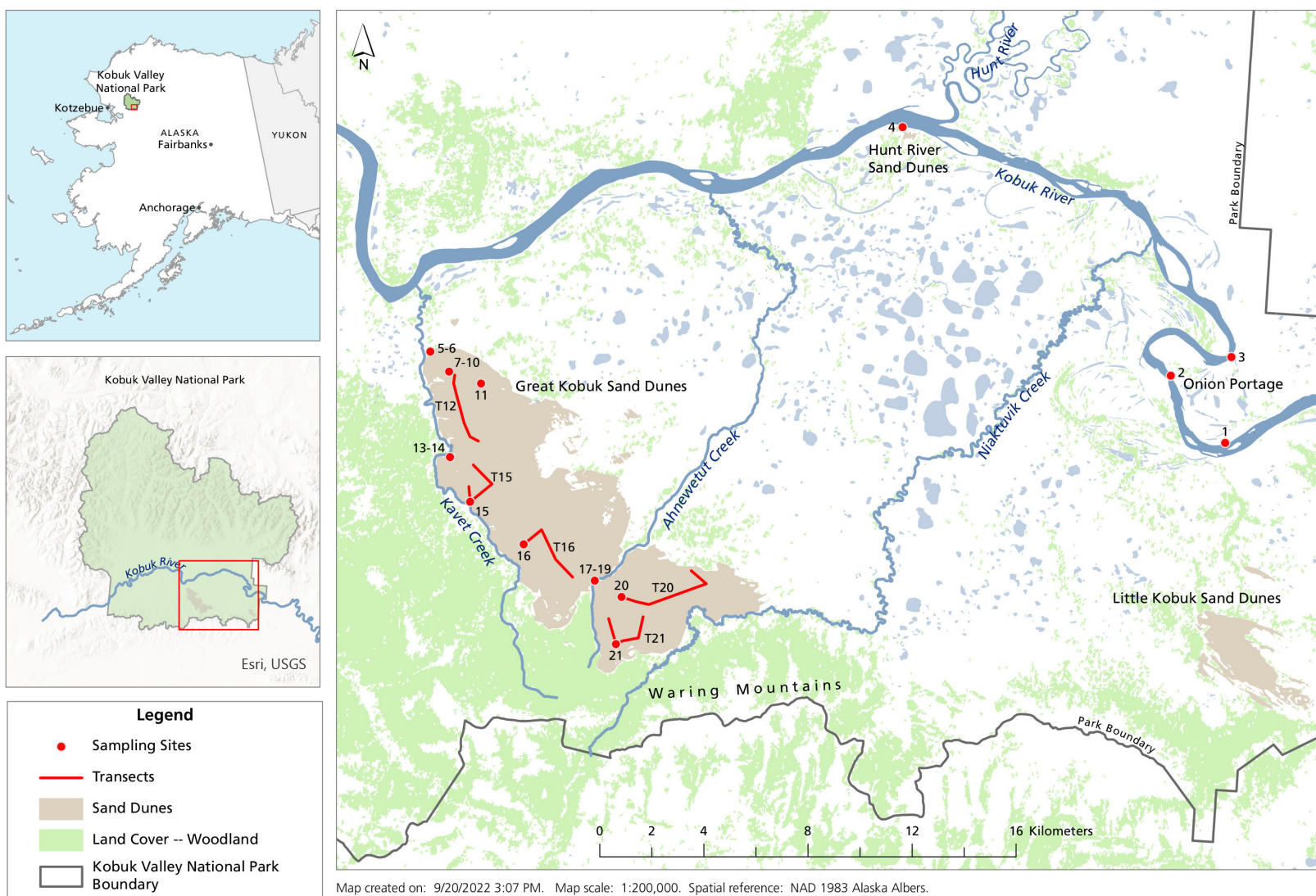


Figure 1. Map of areas sampled in 2017 and 2019 in Kobuk Valley NP. Red dots represent sampling sites (sites clustered close together are shown by a single dot on the map) and red lines represent sampling transects, labeled with a “T” before the transect number. See Table 1 for sampling site and transect descriptions. (Map credit: Gregory Dixon).



Figure 2. Examples of sampling sites within the Great Kobuk Sand Dunes. Oases at the base of leeward dune faces (A, D, E); leeward slip face (B); sand sheets (C, F).



Figure 3. Some plants associated with pollinators of the Kobuk Valley sand dunes. Clockwise from upper left: *Packera ogotorukenis*, *Oxytropis kobukensis*, *Eurybia sibirica*, *Cnidium cnidiifolium*, *Parrya nudicaulis*, *Pedicularis lanata*, *Silene acaulis*, *Eritrichium splendens*, *Lupinus* sp. Middle photo: *Tanacetum bipinnatum*.

Table 1. Pollinator sampling locations, habitats, dates, and collection methods in Kobuk Valley NP. Site and transect numbers correspond to those shown on map in Figure 1.

Site	Latitude	Longitude	Elev. (m)	Locality	Habitat	Net sample date (# specimens)	Bowl sample date (# specimens)
1	67.0944	-158.3161	18	Kobuk River; Onion Portage	Sandy beach	6/26/2017 (4)	6/26/2017 (2)
2	67.1164	-158.3677	19	Kobuk River; Onion Portage	Sandy river bluff	6/26/2017 (1)	–
3	67.1242	-158.3155	19	Kobuk River; Onion Portage	Sandy bluff and forest	6/26/2017 (1)	–
4	67.1960	-158.6185	18	Kobuk River; Hunt River Dunes	Sand dunes	6/26/2017 (1), 6/27/2017 (36)	6/27/2017 (5)
5	67.1075	-159.0176	46	Great Kobuk Sand Dunes (GKSD)	Sand dunes	–	6/30/2017 (7)
6	67.1057	-159.0214	31	GKSD	Sand dunes	–	6/29/2017 (6) 7/1/2017 (12)
7	67.1012	-158.9965	47	GKSD	Sand sheet	6/28/2017 (1)	–
8	67.1002	-159.0037	49	GKSD	Sand sheet	6/29/2017 (72)	–
9	67.1001	-159.0031	46	GKSD	Sand sheet	7/1/2017 (83)	6/29/2017 (16)
10	67.0984	-159.0053	45	GKSD	Sand sheet	–	7/1/2017 (24)
11	67.0969	-158.9729	51	GKSD	Sand sheet	6/28/2017 (1)	–
T12	67.0828	-158.9852	50	GKSD	Sand sheets/dunes	6/30/2017 (50)	–
13	67.0719	-158.9908	43	GKSD	Sand sheet	7/2/2019 (2)	–
14	67.0695	-158.9997	147	GKSD	Forest edge, sand sheet	–	7/1/2019 (1)
T15	67.0686	-158.9743	138	GKSD	Sand sheets/dunes	7/1/2019 (14)	7/1/2019 (0)
15	67.0558	-158.9747	43	GKSD	Forest at edge of dunes	7/1/2019 (4)	–
T16	67.0324	-158.8800	81	GKSD	Sand dunes	6/29/2019 (43)	–
16	67.0425	-158.9250	73	GKSD	Sand sheet	6/29/2019 (20)	–
17	67.0313	-158.8686	97	GKSD	Sand dunes	–	6/29/2019 (2)
18	67.0324	-158.8567	78	GKSD	Edge of stream	6/28/2019 (1)	6/28/2019 (19)
19	67.0307	-158.8526	95	GKSD	Sand sheet	–	6/29/2019 (10)
T20	67.0268	-158.8359	85	GKSD	Sand sheets/dunes	6/28/2019 (61)	–
20	67.0268	-158.8359	85	GKSD	Sand sheet	6/28/2019 (33)	6/28/2019 (7)
T21	67.0190	-158.8458	106	GKSD	Sand sheets/dunes	6/27/2019 (15)	–
21	67.0104	-158.8378	98	GKSD	Wet meadow	6/27/2019 (28)	–

In 2017, two people sampled sites 1–11 and transect 12 (Figure 1, Table 1) using a combination of active netting and passive trapping with small painted “bee bowls.” Sampling was non-random and opportunistic, with a focus on accessible areas rich in floral blooms. These areas included microhabitats within dune areas described above (Parker and Mann 1999). Net collecting was typically confined to a particular microhabitat and ranged in effort between 30 minutes to two hours. Transect 12 passed through several microhabitats. Generally, we attempted to collect every bee or syrphid fly seen, but in some instances we stopped collecting the most abundant species. We kept track of the floral association for each netted specimen where possible.

Bee bowls were 2 oz. plastic cups, colored white, blue, or yellow (Figure 4). Cups were laid out in transects of 30, spaced 5 m apart, alternating in color. Each cup was filled about 2/3 with soapy water. The cups were left out for a minimum of 8 hours at a site, then drained, and strained specimens were stored in Whirl-paks with 70% ETOH.

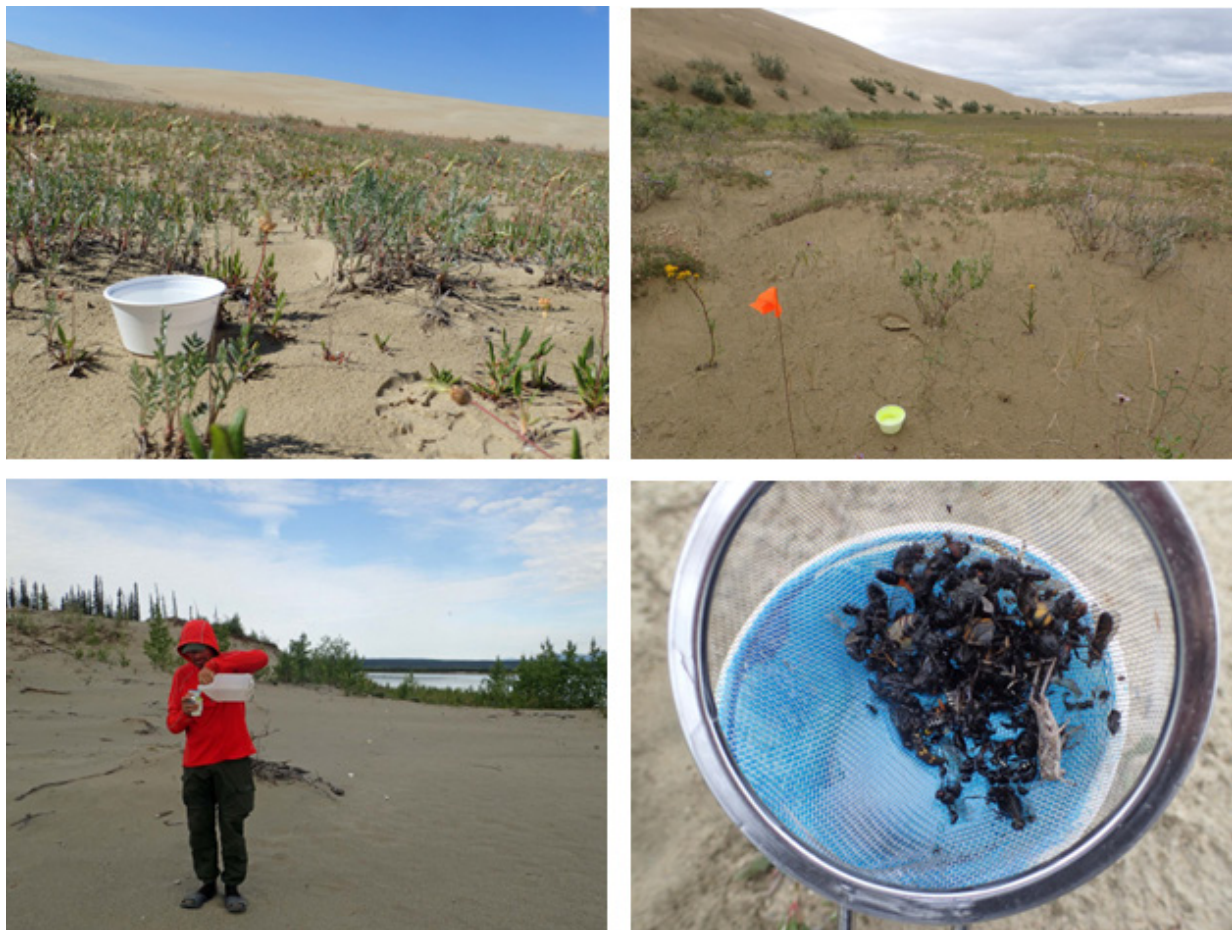


Figure 4. Bee bowls sampling pollinators in sand dunes in Kobuk Valley NP. Bottom images show A. Smith setting up a transect (left) and a strainer with insects collected in a blue bowl (right).

In 2019, three people sampled sites 13–22, in a similar manner to 2017 (Figure 1, Table 1). On several days in 2019, our net samples comprised 3–7 kilometer walking transects through the dunes,

which passed through several different microhabitats. Again, floral associations were recorded where possible. If plants could not be identified in the field, photos were taken and identifications were made through communication with botanists, from field guides (Pratt and Pratt 1993, Nawrocki et al. 2013, Pojar and MacKinnon 2013), or from online resources (Ecological Atlas of Denali's Flora).

Netted insect specimens were kept dry and packed in paper towels until they could be pinned up at the Bettles ranger station at the end of the field trips. Specimens from bee bowls were washed, blow-dried, and mounted on pins in the lab at Denali National Park and Preserve. Bees were identified by J. Rykken using published and online keys (Mitchell 1960, 1962, Sheffield et al. 2011, Gibbs et al. 2013, Dumesh and Sheffield 2014, Williams et al. 2014, Discover Life online bee guides). A subset of bees were sent out for confirmation and identification to T. Griswold at the USDA ARS Pollinating Insects Research Unit in Logan, UT. Syrphid flies were identified by K. Moran at the Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Canada. All specimens were deposited, via a loan agreement, at the University of Alaska Museum (UAM) insect collection and collection data were submitted to NPS Interior Collections Management System. Specimen data from UAM are available publicly through the online database Arctos (arctos.database.museum), which serves data to the Global Biodiversity Information Facility (GBIF) and other online aggregators.

Results

We collected a total of 256 syrphid flies and 326 bees over 11 days of sampling in 2017 and 2019 (Table 2, Figures 5 & 6). Catches for both groups were proportionally similar in both years. Although syrphid flies made up 44% of the total catch, they were more diverse than bees (37 fly taxa versus 27 bee taxa). Specimens in several genera could not be identified to species due to taxonomic challenges (e.g., for some species only males can be identified): the fly genera *Anasimyia*, *Eupeodes*, *Paragus*, *Platycheirus*, *Sphaerophoria*, and the bee genus *Nomada*.

Among syrphid flies, three subfamilies were represented: Eristalinae (16 taxa; 115 specimens), Pipizinae (one species; one specimen); and Syrphinae (20 taxa; 140 specimens). The most abundant and widespread species was *Lapposyrphus lapponicus*, collected from 11 plant genera and 7 sites, followed by *Eristalis obscura*, collected from 6 plant genera and 7 sites. Almost half the syrphid taxa (17) were represented by just one or two individuals. Females made up 69% of the total syrphid catch.

Five bee families were represented (Table 2), with megachilids (mason, leafcutter, and cuckoo bees) making up more than half (52%) the bee total. The most abundant and widespread bee in our collections was the mason bee, *Osmia tarsata*, which we collected from 9 plant genera and 13 sites (Table 2). Other common, widespread bees included the leafcutter bee, *Megachile circumcincta*, the bumble bees *Bombus frigidus* and *B. lapponicus sylvicola*, the mining bee, *Andrena barbilabris*, and the polyester bee, *Colletes impunctatus lacustris*. Less than one third of the bee taxa (7) were represented by just one or two individuals. Females comprised 91% of the total bee catch.

Dryas integrifolia, an abundant and widespread plant on the dunes, hosted the highest number of syrphid fly and bee taxa (19 and 13, respectively; Table 3). For bees, plants in the Fabaceae family (*Astragalus alpinus*, *Hedysarum alpinum*, *Oxytropis kobukensis*) and *Salix* sp. (willows) also hosted many taxa; while for syrphid flies, *Packera ogorukensis*, *Salix* sp., *Cnidium cnidiifolium*, and *Anticlea elegans* hosted high diversity (Table 3).

From our collection data, *Oxytropis kobukensis*, a plant endemic to the dunes in Kobuk Valley, was primarily visited by the mason bee, *Osmia tarsata* (44% of all visitors) and the leafcutter bee, *Megachile circumcincta* (27%; Table 3). Bumble bees (genus *Bombus*) made up 13% of all visitors (Table 3).

We collected far fewer pollinators with bowl traps than with nets (Table 2). Of the syrphid flies, just 11% were collected in bowls, the majority of these were in the sub-family Eristaline. Of bees, 26% were collected in bowls. While 34% of all megachilids and 26% of all andrenids (mining bees) were trapped in bowls, no bumble bees landed in bowls.

Table 2. Bees and syrphid flies collected in Kobuk Valley NP in 2017 and 2019. For each species (or genus), the table presents the total number of specimens collected; the number of different sites at which it was collected; the sampling areas (GKSD—Great Kobuk Sand Dunes; HRD—Hunt River Dunes; OP—Onion Portage) in which it was collected; the number of plant genera from which it was netted; larval diet and habitat for syrphid flies; nesting habitat for bees; and the social category for bees (soc—social; sol—solitary; par—parasitic). * Indicates new record for AK.

Taxonomic group	Pollinator species	No. specimens	No. sites	Sampling areas	No. plant genera	Larval diet/habitat (Syrphids) Nesting habit (Bees)	Sociality (Bees)
Order Diptera	–	–	–	–	–	–	–
Family Syrphidae	<i>Anasimyia</i> sp.	6	3	GKSD	2	wet decaying organic material	NA
Subfamily Eristalinae	<i>Cheilosia latrans</i> (Walker)	4	3	GKSD	2	phytophagous	NA
	<i>Cheilosia rita</i> (Curran)	2	2	GKSD	2	phytophagous	NA
	<i>Eristalis anthophorina</i> (Fallén)	2	2	GKSD	1	wet decaying organic material	NA
	<i>Eristalis flavipes</i> Walker	9	5	GKSD	4	wet decaying organic material	NA
	<i>Eristalis hirta</i> Loew	18	7	GKSD	8	wet decaying organic material	NA
	<i>Eristalis interrupta</i> (Poda)	3	2	GKSD	3	wet decaying organic material	NA
	<i>Eristalis obscura</i> Loew	33	7	GKSD	6	wet decaying organic material	NA
	<i>Eristalis rupium</i> Fabricius	2	1	GKSD	2	wet decaying organic material	NA
	<i>Eurimyia lineata</i> (Fabricius)*	6	3	GKSD	–	wet decaying organic material	NA
	<i>Helophilus groenlandicus</i> (Fabricius)	5	3	GKSD	1	wet decaying organic material	NA
	<i>Helophilus lapponicus</i> Wahlberg	5	4	GKSD	4	wet decaying organic material	NA
	<i>Helophilus obscurus</i> Loew	14	5	GKSD	3	wet decaying organic material	NA
	<i>Sericomyia nigra</i> Portschesky	1	1	GKSD	1	wet decaying organic material	NA
	<i>Volucella facialis</i> Williston	3	2	GKSD	3	detritus in nests of social wasps and bees	NA
	<i>Xylota naknek</i> Shannon	2	2	GKSD	1	sap runs and under tree bark	NA
Subfamily Pipizinae	<i>Pipiza atrata</i> Curran	1	1	GKSD	1	predator of aphids	NA

Table 2 (continued). Bees and syrphid flies collected in Kobuk Valley NP in 2017 and 2019. For each species (or genus), the table presents the total number of specimens collected; the number of different sites at which it was collected; the sampling areas (GKSD—Great Kobuk Sand Dunes; HRD—Hunt River Dunes; OP—Onion Portage) in which it was collected; the number of plant genera from which it was netted; larval diet and habitat for syrphid flies; nesting habitat for bees; and the social category for bees (soc—social; sol—solitary; par—parasitic). * Indicates new record for AK.

Taxonomic group	Pollinator species	No. specimens	No. sites	Sampling areas	No. plant genera	Larval diet/habitat (Syrphids) Nesting habit (Bees)	Sociality (Bees)
Subfamily Syrphinae	<i>Chrysotoxum derivatum</i> Walker	1	1	GKSD	–	detritus in nests of social wasps, bees	NA
	<i>Chrysotoxum plumeum</i> Loew*	1	1	GKSD	1	predator of aphids	NA
	<i>Dasysyrphus intrudens</i> (Osten Sacken)	2	2	GKSD	1	predator of aphids	NA
	<i>Dasysyrphus limatus</i> (Hine)	2	2	GKSD	1	predator of aphids	NA
	<i>Eupeodes</i> sp.	11	6	GKSD, HRD	5	predator of aphids	NA
	<i>Lapposyrphus lapponicus</i> (Zetterstedt)	35	7	GKSD	11	predator of aphids, adelgids on trees	NA
	<i>Melangyna arctica</i> (Zetterstedt)	1	1	GKSD	1	predator of aphids	NA
	<i>Paragus</i> sp.	1	1	GKSD	1	predator of aphids	NA
	<i>Parasyrphus genualis</i> (Williston)	1	1	GKSD	1	predator of aphids, adelgids on trees	NA
	<i>Parasyrphus groenlandicus</i> (Nielsen)	1	1	GKSD	1	predator of aphids on shrubs	NA
	<i>Parasyrphus tarsatus</i> (Zetterstedt)	2	1	GKSD	2	predator of aphids on <i>Salix</i> , <i>Betula</i>	NA
	<i>Platycheirus hyperboreus</i> (Staeger)	1	1	GKSD	–	predator of aphids	NA
	<i>Platycheirus naso</i> (Walker)	2	2	GKSD	2	predator of aphids	NA
	<i>Platycheirus pictipes</i> (Bigot)	1	1	GKSD	–	predator of aphids	NA
	<i>Platycheirus</i> sp.	11	8	GKSD	5	predator of aphids	NA
	<i>Pyrophaena granditarsis</i> (Forster)	1	1	OP	–	predator of aphids	NA
	<i>Sphaerophoria</i> sp.	50	6	GKSD	10	predator of aphids	NA

Table 2 (continued). Bees and syrphid flies collected in Kobuk Valley NP in 2017 and 2019. For each species (or genus), the table presents the total number of specimens collected; the number of different sites at which it was collected; the sampling areas (GKSD—Great Kobuk Sand Dunes; HRD—Hunt River Dunes; OP—Onion Portage) in which it was collected; the number of plant genera from which it was netted; larval diet and habitat for syrphid flies; nesting habitat for bees; and the social category for bees (soc—social; sol—solitary; par—parasitic). * Indicates new record for AK.

Taxonomic group	Pollinator species	No. specimens	No. sites	Sampling areas	No. plant genera	Larval diet/habitat (Syrphids) Nesting habit (Bees)	Sociality (Bees)
Subfamily Syrphinae (continued)	<i>Syrphus ribesii</i> (Linnaeus)	4	3	GKSD	4	predator of aphids, adelgids	NA
	<i>Syrphus torvus</i> Osten Sacken	1	1	HRD	1	predator of aphids	NA
	<i>Syrphus vitripennis</i> Meigen	11	4	GKSD	3	predator of aphids on trees	NA
Order Hymenoptera	—	—	—	—	—	—	—
Family Andrenidae	<i>Andrena algida</i> Smith	3	3	GKSD, HRD	—	soil	sol
	<i>Andrena barbilabris</i> (Kirby)	37	9	GKSD, HRD	5	soil	sol
	<i>Andrena clarkella</i> (Kirby)	3	2	GKSD	1	soil	sol
	<i>Andrena nigrihirta</i> (Ashmead)	3	2	GKSD, OP	—	soil	sol
Family Apidae	<i>Anthophora terminalis</i> Cresson	1	1	HRD	—	pithy stems or rotting wood	sol
	<i>Bombus cryptarum</i> (Fabricius)	3	3	GKSD, HRD	2	underground	soc
	<i>Bombus flavifrons</i> Cresson	4	3	GKSD, OP	2	underground	soc
	<i>Bombus frigidus</i> Smith	16	6	GKSD	7	underground or aboveground	soc
	<i>Bombus jonellus</i> (Kirby)	5	4	GKSD, HRD	4	underground	soc
	<i>Bombus kirbiellus</i> Curtis	6	2	GKSD, HRD	3	underground	soc
	<i>Bombus lapponicus sylvicola</i> Kirby	11	7	GKSD, HRD, OP	5	underground	soc
	<i>Bombus mckayi</i> Ashmead	11	3	GKSD	6	underground	soc
	<i>Bombus melanopygus</i> Nylander	5	2	GKSD	2	underground or aboveground	soc
	<i>Bombus mixtus</i> Cresson	1	1	GKSD	1	underground or aboveground	soc
	<i>Bombus neoboreus</i> Sladen	2	2	GKSD, HRD	1	underground	soc
	<i>Bombus polaris</i> Curtis	1	1	GKSD	1	underground	soc
	<i>Nomada</i> sp.	10	6	GKSD, HRD	3	nests of <i>Andrena</i>	par

Table 2 (continued). Bees and syrphid flies collected in Kobuk Valley NP in 2017 and 2019. For each species (or genus), the table presents the total number of specimens collected; the number of different sites at which it was collected; the sampling areas (GKSD—Great Kobuk Sand Dunes; HRD—Hunt River Dunes; OP—Onion Portage) in which it was collected; the number of plant genera from which it was netted; larval diet and habitat for syrphid flies; nesting habitat for bees; and the social category for bees (soc—social; sol—solitary; par—parasitic). * Indicates new record for AK.

Taxonomic group	Pollinator species	No. specimens	No. sites	Sampling areas	No. plant genera	Larval diet/habitat (Syrphids) Nesting habit (Bees)	Sociality (Bees)
Family Colletidae	<i>Colletes impunctatus lacustris</i> Swenk	14	6	GKSD	5	soil	sol
	<i>Hylaeus annulatus</i> (Linnaeus)	5	4	GKSD	2	hollow stems, twigs, other holes	sol
Family Halictidae	<i>Halictus rubicundus</i> (Christ)	12	2	GKSD, HRD	2	soil	sol
Family Halictidae	<i>Lasioglossum boreale</i> Svensson, Ebmer and Sakagami	2	2	GKSD	–	soil	sol
Family Megachilidae	<i>Coelioxys sodalis</i> Cresson	1	1	GKSD	1	parasite in nests of <i>Megachile</i>	par
	<i>Megachile circumcincta</i> (Kirby)	26	7	GKSD, HRD	4	soil	sol
	<i>Megachile relativa</i> Cresson	1	1	GKSD	1	existing cavities	sol
	<i>Osmia nigriventris</i> (Zetterstedt)	11	5	GKSD, HRD, OP	2	existing holes in wood	sol
	<i>Osmia tarsata</i> Provancher	131	13	GKSD, HRD, OP	9	soil	sol
	<i>Stelis nitida</i> Cresson	1	1	GKSD	1	Parasite in nests of <i>Osmia</i> or <i>Megachile</i>	par

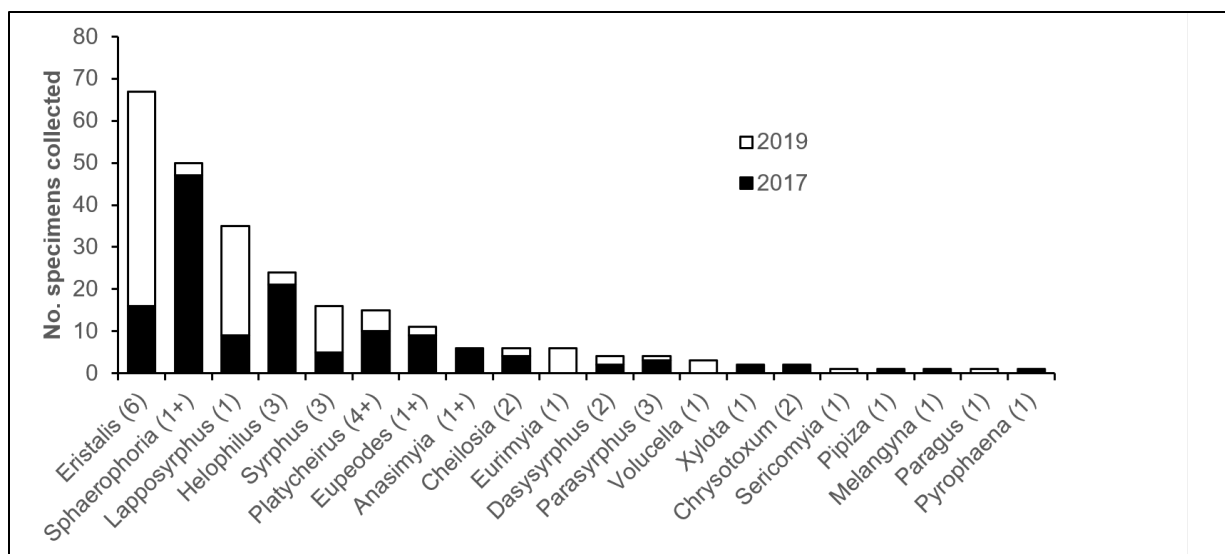


Figure 5. Number of syrphid flies collected in each genus in 2017 and 2019 in Kobuk Valley NP. Number in parentheses after each generic name represents the total number of species collected in that genus, a “+” indicates that some specimens were not identified to species.

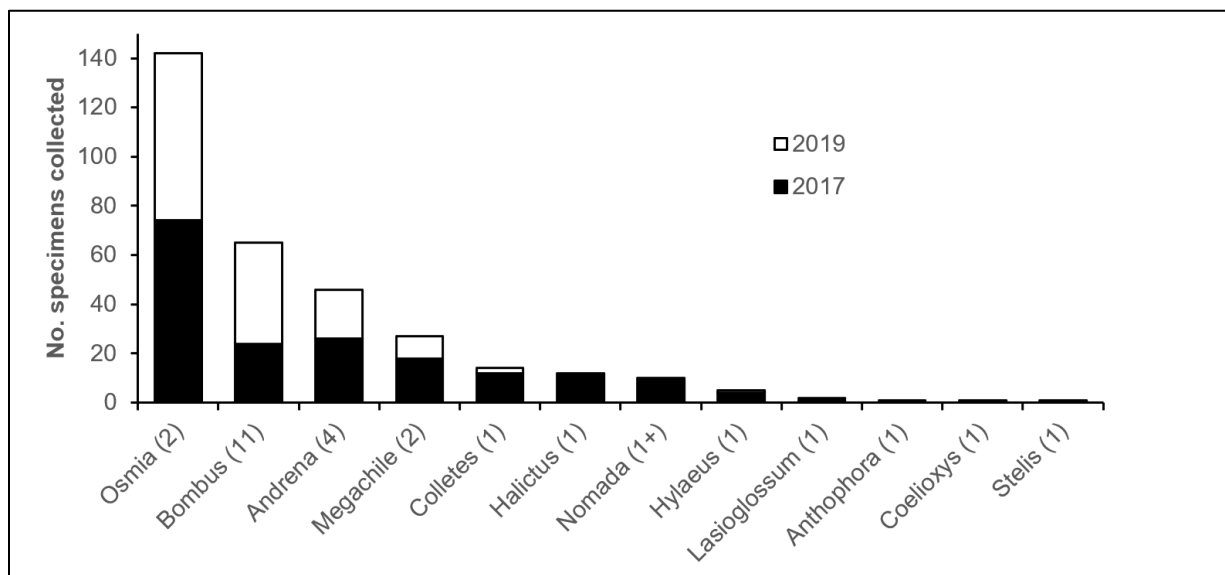


Figure 6. Number of bees collected in each genus in 2017 and 2019 in Kobuk Valley NP. Number in parentheses after each generic name represents the total number of species collected in that genus, a “+” indicates that some specimens were not identified to species.

Table 3. Plant-pollinator associations documented for syrphid flies and bees collected in Kobuk Valley NP. Abbreviations for plant names are ordered by family as follows, APIACEAE: Bup_ame = *Bupleurum americanum*; Cni_cni = *Cnidium cnidiifolium*; ASTERACEAE: Art_bor = *Artemesia borealis*; Eur_sib = *Eurybia sibirica*; Pac_ogo = *Packera ogorukensis*; Sol_mul = *Solidago multiradiata*; Tan_bip = *Tanacetum bipinnatum*; BORAGINACEAE: Ere_spl = *Eritrichium splendens*; BRASSICACEAE: Par_nud = *Parrya nudicaulis*; CARYOPHYLLACEAE: Dia_rep = *Dianthus repens*; Min_sp = *Minuartia* sp.; ERICACEAE: Pyr_asa = *Pyrola asarifolia*; FABACEAE: Ast_alp = *Astragalus alpinus*; Hed_alp = *Hedysarum alpinum*; Lup_sp = *Lupinus* sp.; Oxy_kob = *Oxytropis kobukensis*; MELANTHICEAE: Ant_ele = *Anticlea elegans*; ONAGRACEAE: Cha_ang = *Chamerion angustifolium*; Cha_lat = *Chamerion latifolium*; OROBANCHACEAE: Ped_ver = *Pedicularis verticillata*; PLUMBAGINACEAE: Arm_mar = *Armeria maritima*; ROSACEAE: Das_fru = *Dasiphora fruticosa*; Dry_int = *Dryas integrifolia*; Ros_aci = *Rosa acicularis*; SALICACEAE: Sal_sp = *Salix* sp.

Family	Pollinator species	Bup_ame	Cni_cni	Art_bor	Eur_sib	Pac_ogo	Sol_mul	Tan_bip	Ere_spl	Par_nud	Dia_rep	Min_sp	Pyr_asa	Ast_alp	Hed_alp	Lup_sp	Oxy_kob	Ant_ele	Cha_ang	Cha_lat	Ped_ver	Arm_mer	Das_fru	Dry_int	Ros_aci	Sal_sp
Syrphidae	<i>Anasimyia</i> sp.	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Cheilosia latrans</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	1	–	–
	<i>Cheilosia rita</i>	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Eristalis anthophorina</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
	<i>Eristalis flavipes</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	3	–	5
	<i>Eristalis hirta</i>	–	2	–	1	2	2	–	–	–	–	–	–	–	–	–	–	6	–	1	–	–	–	2	–	2
	<i>Eristalis interrupta</i>	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Eristalis obscura</i>	–	5	–	–	1	–	–	–	–	–	–	–	–	–	–	–	13	–	1	–	–	–	4	–	8
	<i>Eristalis rupium</i>	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Eurimyia lineata</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Helophilus groenlandicus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–
	<i>Helophilus lapponicus</i>	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	2	–	–
	<i>Helophilus obscurus</i>	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2
	<i>Sericomyia nigra</i>	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Volucella facialis</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	1	–	–
	<i>Xylota naknek</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Pipiza atrata</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Chrysotoxum derivatum</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Chrysotoxum plumeum</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
	<i>Dasysyrphus intrudens</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
	<i>Dasysyrphus limatus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
	<i>Eupeodes</i> sp.	–	–	–	–	1	–	–	–	–	–	2	–	–	–	–	2	–	–	–	–	–	–	4	1	–
	<i>Lapposyrphus lapponicus</i>	–	1	1	–	2	1	1	1	–	–	–	–	1	–	–	1	–	–	1	–	–	–	11	–	9
	<i>Melangyna arctica</i>	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Paragus</i> sp.	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Parasyrphus genualis</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
	<i>Parasyrphus groenlandicus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
	<i>Parasyrphus tarsatus</i>	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Platycheirus hyperboreus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Platycheirus naso</i>	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Platycheirus pictipes</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Platycheirus</i> sp.	–	–	–	–	1	1	–	–	–	–	2	–	–	1	–	–	–	–	–	–	–	–	1	–	–
	<i>Pyrophaena granditarsis</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Sphaerophoria</i> sp.	1	–	–	–	15	–	2	–	–	–	6	–	3	–	1	2	3	–	–	–	–	–	4	–	3
	<i>Syrphus ribesii</i>	–	1	–	–	1	–	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–

Table 3 (continued). Plant-pollinator associations documented for syrphid flies and bees collected in Kobuk Valley NP. Abbreviations for plant names are ordered by family as follows, APIACEAE: Bup_ame = *Bupleurum americanum*; Cni_cni = *Cnidium cnidiifolium*; ASTERACEAE: Art_bor = *Artemesia borealis*; Eur_sib = *Eurybia sibirica*; Pac_ogo = *Packera ogorukensis*; Sol_mul = *Solidago multiradiata*; Tan_bip = *Tanacetum bipinnatum*; BORAGINACEAE: Ere_spl = *Eritrichium splendens*; BRASSICACEAE: Par_nud = *Parrya nudicaulis*; CARYOPHYLLACEAE: Dia_rep = *Dianthus repens*; Min_sp = *Minuartia* sp.; ERICACEAE: Pyr_asa = *Pyrola asarifolia*; FABACEAE: Ast_alp = *Astragalus alpinus*; Hed_alp = *Hedysarum alpinum*; Lup_sp = *Lupinus* sp.; Oxy_kob = *Oxytropis kobukensis*; MELANTHICEAE: Ant_ele = *Anticlea elegans*; ONAGRACEAE: Cha_ang = *Chamerion angustifolium*; Cha_lat = *Chamerion latifolium*; OROBANCHACEAE: Ped_ver = *Pedicularis verticillata*; PLUMBAGINACEAE: Arm_mar = *Armeria maritima*; ROSACEAE: Das_fru = *Dasiphora fruticosa*; Dry_int = *Dryas integrifolia*; Ros_aci = *Rosa acicularis*; SALICACEAE: Sal_sp = *Salix* sp.

Family	Pollinator species	Bup_ame	Cni_cni	Art_bor	Eur_sib	Pac_ogo	Sol_mul	Tan_bip	Ere_spl	Par_nud	Dia_rep	Min_sp	Pyr_asa	Ast_alp	Hed_alp	Lup_sp	Oxy_kob	Ant_ele	Cha_ang	Cha_lat	Ped_ver	Arm_mer	Das_fru	Dry_int	Ros_aci	Sal_sp	
Syrphidae (continued)	<i>Syrphus torvus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	
	<i>Syrphus vitripennis</i>	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	4	
Andrenidae	<i>Andrena algida</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	<i>Andrena barbilabris</i>	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	13	1	14	
	<i>Andrena clarkella</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	
	<i>Andrena nigrihirta</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Apidae	<i>Anthophora terminalis</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	<i>Bombus cryptarum</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	1	–	
	<i>Bombus flavifrons</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–	
	<i>Bombus frigidus</i>	–	–	–	–	1	1	–	–	–	–	–	–	1	5	–	–	–	–	2	–	–	–	5	–	1	
	<i>Bombus jonellus</i>	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	1	–	–	–	–	–	–	2	–	–	
	<i>Bombus kirbiellus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	3	–	–	–	1	–	–	–	–	–	
	<i>Bombus lapponicus sylvicola</i>	–	–	–	–	–	–	–	–	–	–	–	–	1	2	–	3	–	1	–	–	–	–	4	–	–	
	<i>Bombus mckayi</i>	–	–	1	–	–	–	–	–	–	–	–	–	3	–	–	1	–	–	–	–	1	–	–	2	–	1
	<i>Bombus melanopygus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–	–	–	–	–	–	–	–	–	
	<i>Bombus mixtus</i>	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	<i>Bombus neoboreus</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	
	<i>Bombus polaris</i>	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	<i>Nomada</i> sp.	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	1	
Colletidae	<i>Colletes impunctatus lacustris</i>	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	5	–	2	
	<i>Hylaeus annulatus</i>	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	
Halictidae	<i>Halictus rubicundus</i>	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	
	<i>Lasioglossum ?boreale</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Megachilidae	<i>Coelioxys sodalis</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	
	<i>Megachile circumcincta</i>	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	13	–	–	–	–	–	–	1	–	–	
	<i>Megachile relativa</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	
	<i>Osmia nigriventris</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	
	<i>Osmia tarsata</i>	–	–	–	1	3	–	–	1	–	–	1	–	36	1	–	21	–	–	1	–	–	–	6	–	–	
	<i>Stelis nitida</i>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	
Total no. pollinators collected from plant		1	16	2	4	42	8	4	2	2	1	16	3	46	18	2	50	25	1	7	2	3	1	88	8	60	

Discussion

Our limited pollinator inventories in Kobuk Valley NP, conducted over two years, provided us with new information and insights on the pollinator fauna and host-plant relationships in these ecologically unique northern sand dunes, and highlighted the scientific value of short duration field surveys in remote Alaska. Of ten sampling days (not including travel days), we had only eight good weather days. Weather affected our collecting success, with overcast, cool, windy, and/or rainy days decreasing the catch considerably. In 2019, flowering phenology appeared to be advanced compared to the same dates in 2017, with many of the *Dryas integrifolia* and other plants already gone to seed. Given the many challenges (weather, remote access, unpredictable phenology), our brief but intense sampling efforts produced a wealth of new discoveries, plant-pollinator associations, and new insights into the ecology of an endemic Kobuk sand dunes plant. It is worth noting that many taxa were collected only in one year. In 2017, 55% of collected syrphid taxa were collected only in that year, and in 2019, 38% were unique to that year. Among bees, 38% of taxa were collected only in 2017, and 32% were unique to 2019. Thus sampling two years, even within the same seasonal window, increased the overall species lists appreciably for both pollinator groups.

Pollinator Diversity in the Sand Dunes

We collected eleven bumble bee (*Bombus*) species in the Kobuk Valley sand dunes, half the known bumble bee diversity known from Alaska. However, unusual for most boreal/Arctic pollinator surveys, bumble bees made up only 20% of the bee catch. Among them were three species in the subgenus *Alpinobombus* (*B. polaris*, *B. neoboreus*, *B. kirbiellus*) which have limited distributions in Arctic and/or alpine ecosystems. The remaining species are more widely distributed across Alaska. Of note, we collected several *Bombus mckayi*, until recently considered a subspecies of *B. occidentalis* (Sheffield et al. 2016, Williams 2021). Known as the western bumble bee, *Bombus occidentalis* is undergoing rapid decline in the western U.S. and is currently a candidate under consideration for listing under the Endangered Species Act (Graves et al. 2020). *Bombus mckayi* is found throughout Alaska and much of western Canada, where populations appear to be stable at present. Almost one third of the bumble bees were collected in wetter spring-fed habitats in the dunes with favored plants like *Hedysarum alpinum*.

In contrast to bumble bees which nest and live in social colonies, the vast majority of bees we collected in the sand dunes are solitary species. Many of these solitary bees are known to nest in sandy soil, with females either excavating their own nests (e.g., mining bees in the genus *Andrena* and *Colletes*) or nesting in preexisting holes dug by other insects (e.g., some *Osmia* and *Megachile*). Nests are often lined with a variety of materials, including glandular secretions that waterproof the nest by *Colletes* bees (earning them the name “polyester” or “cellophane” bees), or plant resins, hairs, and leaves used by mason (*Osmia*) and leafcutter (*Megachile*) bees (Figure 7). We confirmed that *Osmia tarsata*, an abundant pollinator on the endemic Kobuk locoweed, nests in the sand (Figure 8), as does the other common visitor to this plant, *Megachile circumcincta* (Cane et al. 2007). Alternatively, *Osmia nigriventris* and *Megachile relativa*, which we collected in smaller numbers, are known to nest in existing cavities in other substrates including wood (Cane et al. 2007, Sheffield et al. 2011).



Figure 7. The tell-tale signs of *Megachile* leafcutter bees, who have cut discs from these *Arctous rubra* (red bearberry) and *Salix* (willow) leaves to line their nests.



Figure 8. A nest entrance for the mason bee, *Osmia tarsata*, underneath one of its primary host plants, *Oxytropis kobukensis* (Kobuk locoweed). A female was observed emerging from the nest on June 29, 2019.

We also collected several kleptoparasitic bees. Females of these “cuckoo” species lay their eggs in the nests of host species; their larvae feed off nectar and pollen stores intended for the host larvae, developing to adulthood in the host nest. We collected cuckoo bees in the genera *Stelis* and *Coelioxys*, which both parasitize leafcutter bees (*Megachile*), and also *Nomada*, which often parasitize *Andrena* mining bees.

Deep sands are sparsely distributed across the Arctic and northern boreal landscape, occurring primarily on beaches, cliffs and bluffs along larger rivers, as well as exposed relict dunes. Thus sand-nesting bees are likewise limited in their distributions. Interestingly, *Osmia tarsata*, an abundant pollinator on endemic Kobuk locoweed, has a very broad geographic range that stretches across North America to the Great Lakes, but is primarily associated with sandy habitats within that range. To date, other known locations for this species in Alaska include: the Nogahabara Dunes, an inland dune complex approximately 100 km southeast of GKSD in the Koyukuk-Nowitna National Wildlife

Refuge; small exposed dunes in Selawik National Wildlife Refuge, 35 km to the southeast; the Copper River Basin near Chitina; and sandy bluffs above the Nenana River in Denali National Park and Preserve (locations retrieved from Arctos 2023). It has also been documented in a small active dune area near the town of Carcross in the Yukon, Canada (Polak 1989)

A few other common sand nesting bee species found in the Kobuk Valley dunes are known to occur in sandy habitats elsewhere in northern Alaska. The mining bee *Andrena barbilabris*, has been collected along the sandy shores of the Middle Fork of the Koyukuk River in Gates of the Arctic NPP (Rykken 2017). The cellophane bee, *Colletes impunctatus lacustris*, was found in sandy bluffs along the Noatak and Killik Rivers in Gates of the Arctic NPP, as well as in the Nogahabara dunes and Selawik dunes (data accessed from <https://arctos.database.museum>). Lastly, the leafcutter bee, *Megachile circumcincta*, has been collected in the Killik River dunes in Gates of the Arctic NPP, the Nogahabara dunes, the Noatak River, and also along several rivers in the interior of Alaska further south (data accessed from <https://arctos.database.museum>).

Armbruster and Guinn (1989) conducted comprehensive solitary and cuckoo bee inventories in various habits in interior Alaska, including sandy subarctic steppe bluff habitat above the Tanana and Yukon rivers. Their species list from these sites shared eight species with the Kobuk Valley sand dunes, representing all five bee families known from Alaska: *Andrena algida*, *A. barbilabris* (Andrenidae); *Anthophora terminalis* (Apidae); *Hylaeus annulatus* (Colletidae); *Halictus rubicundus* (Halictidae); *Coelioxys sodalis*, *Megachile circumcincta*, and *M. relativa* (Megachilidae).

Syrphid flies were less abundant but more diverse than bees in our collections. Most syrphid flies are mimics of bees or wasps, fooling predators into thinking they can sting to defend themselves. Like bees, they are often seen on flowers, feeding on nectar and pollen. Also known as flower flies or hover flies, syrphids are important pollinators at northern latitudes (Catling et al. 2021, Vezsenyi et al. 2021). An important difference between bees and syrphids is that the larvae of syrphids are free living and do not feed on nectar and pollen.

The most abundant and species-rich syrphid fly genus in our collections was *Eristalis*. These are commonly known as drone flies and larvae feed on decaying organic matter in stagnant pools of water or marshes. We observed some isolated pools out on the dunes, but larval habitat may also be provided in surrounding forests and wetlands. *Helophilus*, or marsh flies, were also relatively abundant and these syrphid flies also require saturated habitats for larval development. Other commonly collected syrphid genera were *Sphaerophoria* (globetails) and *Lapposyrphus* (aphideaters). The larvae of both of these groups are predaceous on aphids. We collected a few individuals of *Volucella facialis* (yellow-faced swiftwing), an interesting species in that its larvae live in the nests of social Hymenoptera (e.g., bumble bees or yellowjackets) where they feed off detritus as well as being predators of larvae and pupae (Skevington et al. 2019). Adult *Volucella* are almost perfect mimics of bumble bees.

We collected several uncommon and rare syrphid species. *Sericomyia nigra* (polar pond fly) is a northern species found across Canada as well as in Europe and Asia, typically in tundra and open boreal forest. *Chrysotoxum derivatum* (narrow-banded meadow fly) was formerly considered quite

common but the species concept was recently revised so that *C. derivatum* now comprises a rare boreal species distributed across Canada, while *Chrysotoxum plumeum* (broad-banded meadow fly) was resurrected as a separate, and much more common and widespread species, especially in eastern North America (Skevington et al. 2019). We collected both species of *Chrysotoxum* species in the dunes. The uncommon syrphid, *Dasysyrphus limatus* (narrow-banded conifer fly), is known from sand dunes as well as marshes and forests, with a disjunct distribution in North America, Alaska south to Colorado in the west and in the eastern Canadian provinces (Skevington et al. 2019). Our surveys yielded two new species records for the state, *Chrysotoxum plumeum* and *Eurimyia lineata*.

Pollinator-Host Plant Associations

In all, we documented 412 pollinator-host plant associations, involving 55 pollinator taxa and 25 plant taxa. It should be noted that collecting an insect from a flower is not sufficient evidence to prove that the insect is affecting pollination for that plant. However, these flower visitors can be considered potential pollinators.

Dryas integrifolia was a widespread plant on the sand dunes and hosted by far the highest number of bee and syrphid fly species in our collections. The open structure of the *Dryas* flower attracts both short- and long-tongued flower visitors. In a circumpolar study, Tiusanen et al. (2019), found that *D. integrifolia* flowers attracted more than 1,300 species of insects—mostly Diptera (flies) and Hymenoptera (bees and wasps). Willows (*Salix* spp.) were another common shrub that attracted many bees and flies. The Holarctic mining bee, *Andrena barbilabris*, was collected almost exclusively on both *Dryas* and *Salix*, in equal proportions.

Long-tongued bees, *Bombus*, *Osmia*, and *Megachile*, favored pink and purple leguminous plants with deeper corollas, for example, *Astragalus alpinus*, *Hedysarum alpinum*, and *Oxytropis kobukensis*. Whereas shorter-tongued bees like *Colletes* were found on more open flowers of plants like *Dryas*, *Salix*, *Chamerion* (fireweed), and *Packera ogorukensis*.

Syrphid flies also feed on nectar and/or pollen, but unlike bees they do not bring these resources back to a nest to provision their young. Like bees, syrphid flies exhibit a range of tongue lengths which influences which flowers they visit to forage (Proctor et al. 1996, Larson et al. 2001). Gilbert (1981) observed that species with longer tongues had less pollen in their diet and focused on flowers with deeper corollas for nectar. For example, we collected longer-tongued *Volucella* off *Hedysarum*, which is primarily pollinated by bumble bees. Drone flies (*Eristalis*) also have longer tongues, but in our study visited a broad selection of flower types, including plants in the Apiaceae, Asteraceae, *Chamerion*, *Dryas*, and *Salix*. Of note, almost 20 specimens of *Eristalis* were collected on *Anticlea elegans*, commonly known as mountain death camas because all parts of the plant are toxic to many animals, including the nectar and pollen.

Syrphid flies comprised the majority of specimens collected on three plants with yellow flowers in the Asteraceae: *Packera ogorukensis* (Ogotoruk Creek ragwort), *Solidago multiradiata* (northern goldenrod), and *Tanacetum bipinnatum* (dune tansy). They were also the exclusive flower-visitors to two plants in the Apiaceae, yellow *Bupleurum americanum* (thoroughwax) and white *Cnidium*

cnidiifolium; these species have small flowers in umbels. Both white and yellow flowers are known to be attractive to many flies, including syrphids (Kevan and Baker 1983, Proctor et al. 1996).

Another white flower with many syrphid visitors was *Minuartia* sp. (sandwort). In an alpine study in New Hampshire, Levesque and Burger (1982) kept track of flower visitors to *Minuartia groenlandica*. Of the total, 97% were flies (Diptera) and of these, 14% were syrphids, most of the remainder were muscids (house flies and relatives) and anthomyiids (root-maggot flies). These latter two families, although not generally as efficient at carrying pollen as some of the syrphid species, become increasingly important pollinators in alpine and Arctic environments due to their sheer abundance (Elberling and Olesen 1999, Tiusanen et al. 2016, Lefebvre et al. 2018).

The genus *Platycheirus* is interesting because it is one of two syrphid genera known to feed on the pollen of primarily wind-pollinated plants, such as grasses (Poaceae) and sedges (Cyperaceae; Proctor et al. 1996, Larson et al. 2001). Despite the abundance and diversity of both plant families on the sand dunes, we did not collect *Platycheirus* off of either.

Pollinators of Endemic Kobuk Locoweed

One of our objectives was to determine primary pollinators for the endemic plant, *Oxytropis kobukensis* (Kobuk locoweed). This species is known only from sand dunes and a few old river bars in the Kobuk Valley, and was previously believed to be pollinated primarily by bumble bees (*Bombus* spp.), as is typical for many Arctic plants (Nawrocki et al. 2013). Our investigations revealed that the primary bee visitors to *O. kobukensis* were the mason bee, *Osmia tarsata*, and the leafcutter bee, *Megachile circumcincta*, both of which are known to nest in sand or soil (Figure 8; Cane et al. 2007). We also collected several syrphid flies, one mining bee (*Andrena barbilabris*), and a few bumble bees from *O. kobukensis*. Interestingly, we also collected many *Osmia tarsata* off a related member of the Fabaceae (legume family), *Astragalus alpinus*, but only one *Megachile circumcincta* was collected from this plant species.

Conclusions and Recommendations

- Given the wealth of pollinator information we collected during these two short, intensive surveys, and the high proportion of unique bee and syrphid taxa found during both years, we recommend additional inventory work to document more of the pollinator diversity and gain a deeper understanding of plant-pollinator networks in the sand dunes. Slightly longer surveys, spanning more of the short growing season (especially when bad weather can affect collecting efforts so severely) would undoubtedly yield valuable information as different plants come into bloom and attract their own suites of flower visitors and pollinators.
- Future surveys could include additional insect taxa that are associated with deep sandy habitats. For example, tiger beetles (Family Carabidae: Subfamily Cicindelinae) are usually found in open, sandy habitats, including beaches along oceans, rivers and lakeshores. Loss and degradation of these habitats, especially for species with restricted ranges, has resulted in several U.S. species being listed as endangered or threatened. While the State of the Park report (National Park Service 2017) for Kobuk Valley NP does mention the presence of an isolated population of tiger beetles, we did not observe any during our surveys and there are no records in the University of Alaska Museum's database, Arctos. However, there are 25 records of *Cicindela limbata nympha*, from the Nogahabara sand dunes to the south.
- More comprehensive insect surveys in the Kobuk Valley sand dunes may also yield species of conservation interest. As an example, Polak's inventory (1989) of the Carcross dunes in the Yukon, yielded eight insect species thought to be endemic to the dunes: six flies (including one syrphid) and two moths. These finds highlight the biodiversity significance of the Pleistocene dunes, likely a relict Beringian habitat. Endemic plants in the Kobuk Valley dunes (e.g., *Oxytropis kobukensis*) suggest there may also be endemic insects, including pollinators.
- The Kobuk Valley sand dunes attract visitors, many of whom arrive in wheeled planes that land on the dunes. The State of the Park Report (2017) acknowledges that "the sand dunes act as islands of accessibility in comparison with the rest of the wilderness" and that they receive greater levels of use than the surrounding area. Parker (1999) predicted that visitor usage and demands for amenities such as trails, campsites, and landing strips may increase, and urged NPS to adopt management policies that ensure the geomorphic processes, landforms, and flora are not threatened by human disturbance. While visitor usage of the dunes remains relatively low for now, pollinators and other insects strongly associated with these unique dune flora and habitats face similar threats.
- Climate change is the most pressing human-caused disturbance likely to affect the Kobuk Valley sand dunes (National Park Service 2017). It is unclear how this will affect the extent and geomorphology of the dunes, but plant populations will likely respond with shifts in phenology and ranges, which will also affect pollinator populations. Changes in the amount of winter and summer precipitation may also increase the intensity and severity of fires in surrounding forests. A structured sampling protocol for pollinators, establishing sites (perhaps coincident with existing vegetation plots) that can be revisited at intervals, is critical

for monitoring pollinator populations, plant-pollinator relationships, and ecosystem resilience.

- This study provided further evidence that deep sand deposits are hotspots for bee (and other insect) diversity in Alaska. In addition to learning more about pollinators in Kobuk Valley NP, launching a state-wide insect inventory of Pleistocene aeolian sand deposits (e.g., see Lea and Waythomas 1990) would undoubtedly yield many new biodiversity discoveries and insights into the ecology of these unique and fascinating Alaska ecosystems.

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