The Canadian Field-Naturalist

Overall and repeated floral visitation by insects suggests flower flies (Syrphidae) as the major pollinator group of Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*; Polygonaceae) in Northwest Territories, Canada

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Catling, P.M., B. Kostiuk, and J.H. Skevington. 2021. Overall and repeated floral visitation by insects suggests flower flies (Syrphidae) as the major pollinator group of Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*; Polygonaceae) in Northwest Territories, Canada. Canadian Field-Naturalist 135(2): 186–191. https://doi.org/10.22621/cfn.v135i2.2489

Abstract

Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*; Polygonaceae) is a native Arctic, subarctic, and alpine plant of northwestern North America. Although the plant has some economic and ecological importance, its biology is poorly known. At 11 sites in the northeast corner of its range in Northwest Territories, we found that 87% of its floral visitors were flies, mostly Syrphidae, a diverse family known to be important pollinators. Insects visiting consecutive flowers on different plants and, thus, likely effecting pollination were also flies (78.6%) and also mostly Syrphidae (72.7%) followed by Hymenoptera (20%). Although syrphids were the dominant potential pollinators at most sites, there was some variation among sites. Our results provide quantitative support for pollinator diversity and the major role of Syrphidae in pollination of Alaska Wild Rhubarb. We suggest that pollination is not a limiting factor in this plant's spread, nor its rare and local occurrence and restricted distribution, because the majority of its pollinators are widespread.

Key words: Alaska Wild Rhubarb; *Koenigia alaskana* var. *glabrescens*; pollination; crop; flies; Syrphidae; Northwest Territories

Introduction

Alaska Wild Rhubarb, *Koenigia alaskana* (Small) T.M. Schuster & Reveal var. *glabrescens* (Hultén) T.M. Schuster & Reveal (previously recognized as *Polygonum alaskanum* (Small) Wright var. *glabrescens* Hultén and *Aconogonon alaskanum* (Small) Sojak var. *glabrescens* (Hultén) H.R. Hinds; Shuster *et al.* 2015), known as Quaugaq in Gwichin, has a restricted distribution in northwestern North America, being largely confined to the unglaciated subarctic and alpine regions of Beringia in Alaska, Yukon, and Northwest Territories (NWT; e.g., Porsild and Cody 1980, map 455; Hinds and Freeman 2005). In NWT, it occurs only in the extreme northwest from the Richardson Mountains and the Husky Lakes (Eskimo Lakes, known as Imaryuk in Inuvialuktun) region north of Inuvik and the tree line and south along the Mackenzie River and in the Mackenzie Mountains to the latitude of Tulita (64.9132°N; P.M.C. pers. obs.).

All plants of Alaska Wild Rhubarb that we have seen in NWT are var. *glabrescens*, which is glabrous instead of densely retrorsely pubescent on the stems and also glabrous instead of densely pubescent on the leaves (Hinds and Freeman 2005).

The flowers, 8–10 mm in diameter, have five white tepals, 6–8 well-developed stamens, and three stigmas on top of a superior ovary (Figure 1a; Hinds and Freeman 2005). Inflorescences comprise hundreds of flowers (Figure 1b), and there may be up to 5000 flowers on a plant (Figure 1c). Plants reach more than 2 m (6.6 ft) in height in a single growing season (Figure 1c).

The plants are confined to areas of substrate disturbance, such as eroding banks, rockslides, landslides, roadsides, piles of rich organic debris, and bulldozed or dumped substrate (Figure 1d). Currently, most known locations and most plants are associated with human disturbance (P.M.C. and B.K. pers. obs.). *Koenigia alaskana* var. *glabrescens* is rare on the

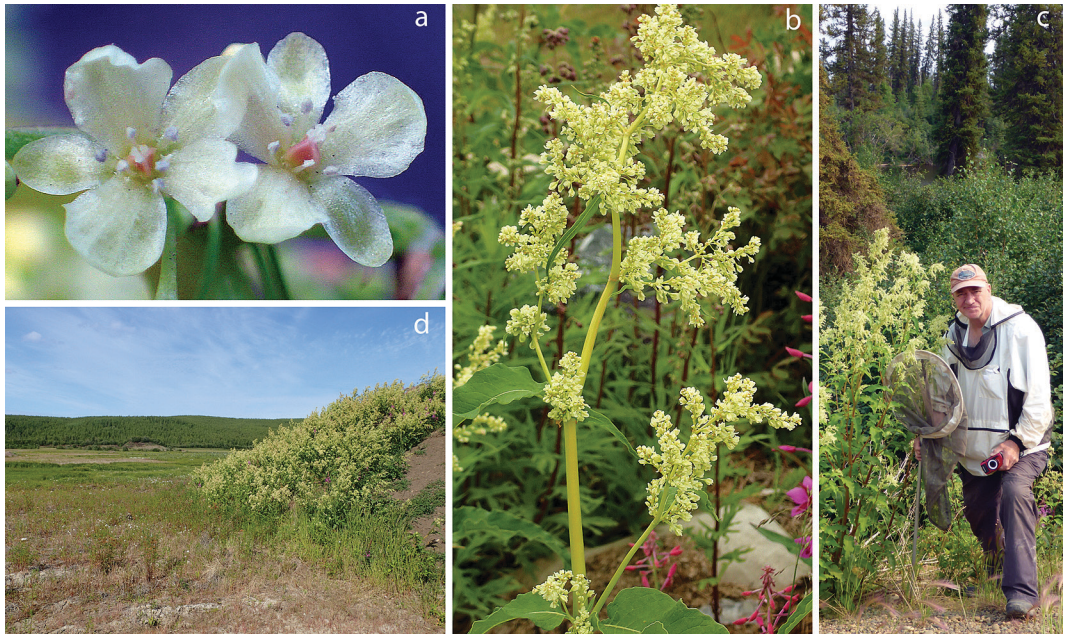

FIGURE 1. Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*). a. Flowers, 8 mm in diameter. b. Inflorescence, ~20 cm in length with ~400 flowers. c. Plant, 1.83 m tall. d. Population of over 100 plants on a pile of bulldozed and fertilized topsoil. Photos: P.M. Catling and B. Kostiuk.

NWT landscape in its general region of occurrence, which is dominated by boreal forest and shrub tundra. It is restricted to landslides along the Mackenzie River, steep slopes in the Richardson Mountains, roadsides, and disturbed areas in towns (P.M.C. and B.K. pers obs.). Where it occurs, there may be a few, hundreds, or even many thousands of plants (P.M.C. and B.K. pers. obs.).

This perennial plant has been used as a food source and medicine by Indigenous People and early explorers (e.g., Porsild 1953; Kuhlein and Turner 1991). Characteristics, such as its hardiness in the north (P.M.C. pers. obs.), substantial annual productivity (P.M.C. pers. obs.), and frequent tendency to produce pure stands (P.M.C. pers. obs.), suggest ease of cultivation as a northern crop. A potential limitation to its production, the availability of pollinators, is understudied but explored here.

Methods

Sampling

During sunny, mild (15–23°C) periods of low wind (0–15 k/h) in the second week of July 2019, P.M.C. and B.K. spent 1 h near midday at each of 11 sites in the Mackenzie Delta region (Table 1) recording all individual insects visiting flowers of *K. alaskana* var. *glabrescens* and collecting as many as possible of the insects that visited two flowers on two different plants consecutively. These insects were potentially carrying pollen from one plant to another.

Identification

Flies were identified by J.H.S. The moth *Scopula seritinaria* (Geyer) was identified by C. Schmidt. The two Ichneumonidae: *Itoplectis viduata* (Gravenhorst) and *Exyston chamaeleon* Mason were identified by A. Bennett. The sawfly, *Tenthredo piceocincta* (Norton), was identified by H. Goulet. Other insects were identified by P.M.C. using Environment and Natural Resources (2017) and Williams *et al.* (2014) for species of *Bombus*, Bohart (1976) for *Crabro latipes* F. Smith, and Buck *et al.* (2008) for *Dolichovespula norwegica* (Fabricius) = *D. pallida* Sladen. Vouchers of all insects (57 individuals, listed in Table 1) were placed in the Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, Ottawa (CNC). Not all of these insects have common names.

Where identification of flies to species was not possible using morphological characters (e.g., male *Syrphus rectus* Osten-Sacken 1875 and *Syrphus vitripennis* Meigen 1822 specimens cannot be separated morphologically) or identification was outside our area of expertise (non-syrphid Diptera), we generated DNA barcodes from specimens and matched them against the BOLD database using the BOLD identification engine (available at http://v4.boldsystems.org/

TABLE 1. Sites in Northwest Territories, Canada, where floral visitors to Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*) were recorded and collected. Plant voucher accessions are indicated.

Site no.	CAN plant accession no.	Site name	Latitude °N	Longitude °W
1		Tuktoyaktuk highway	68.3476	133.6830
2		Tuktoyaktuk highway	68.6284	133.6777
3		North Inuvik, industrial area, Navy Road	68.3758	133.7511
4		North Inuvik, industrial area, Navy Road	68.3706	133.7459
5		North Inuvik, industrial area, Navy Road	68.3664	133.7410
6		Inuvik community garden refuse pile	68.3596	133.7188
7		South Inuvik, west side of golf course	68.3483	133.6911
8	10104548	South Inuvik, east of driving range	68.3505	133.6849
9	10104545	Fort McPherson, along road 27 km east of town	67.4067	134.3575
10	10104547	Fort McPherson town site	67.4322	134.8816
11	10104546	Richardson Mountains	67.1509	135.9213

index.php/IDS_OpenIdEngine). All but two taxa were identified to species in this way. The other two were identified to genus.

Four voucher specimens (listed in Table 1) of *K. alaskana glabrescens* were deposited in CAN (Canadian Museum of Nature, Aylmer, Quebec).

Generating DNA barcodes

A single leg (the right midleg where possible) was removed from specimens and the 5′ end of the cytochrome *c* oxidase I mitochondrial gene (COI) was sequenced at CNC. Extraction, cycling, and sequencing conditions are available from Motamedinia *et al.* (2019). For DNA amplification and sequencing, we largely used primers developed for use in Diptera (Table 2). Barcodes were variously recovered in a single fragment or in three smaller segments that were assembled as a full barcode.

All sequence data are stored on the BOLD website (http://www.boldsystems.org/) in the Pollinators of Alaska Wild Rhubarb, *Koenigia alaskana* var. *glabrescens* dataset (BOLD n.d.). All complete sequences used in this project are also available on GenBank (https://www.ncbi.nlm.nih.gov/genbank/); accession numbers are listed in Table 3.

Results

General observation of flower visitation by insects

In the 161 insect visits (Table 4), 31 species of potential pollinators were identified (Table 5) representing three major insect families. Twenty-six individuals of at least 12 species (Table 3) were identified or confirmed using barcode data and the remainder using morphology. Flies (Diptera) were present on flowers at most sites and represented 87% of insects recorded on flowers (Table 4). Most of the fly visitors were Syrphidae (73%) and they were primary visitors at most sites (Table 4). This large group of insects (over 6000 species), usually called flower flies, feed mostly on nectar and pollen as adults. Wasps were the next largest group, representing 10.3% of insects on flowers, and were the largest group of floral visitors at a site in the Richardson Mountains.

Collections of insects moving between flowers on different plants

Fifty-seven insects were collected after moving from a flower on one plant to a flower on another (Table 5). These were mostly flies (45 of 57, 78.9%), and most of them were among the 13 species of syrphids recorded (33 of 45, 73.3%). The second largest group

TABLE 2. Primers used to sequence the cytochrome *c* oxidase (COI) barcoding region of insects collected when visiting Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*) in Northwest Territories, Canada.

Primer name	Primer design	Primer sequence
Heb-F	Folmer *et al.* 1994	GGT CAA CAA ATC ATA AAG ATA TTG G
COI-Fx-A-R Kelso	Young *et al.* 2020	CGD GGR AAD GCY ATR TCD GG
COI-Fx-B-F Kelso	Young *et al.* 2020	GGD KCH CCN GAY ATR GC
COI-Fx-B-R Kelso	Young *et al.* 2020	GWA ATR AAR TTW ACD GCH CC
COI-Fx-C-F Kelso	Young *et al.* 2020	GGD ATW TCH TCH ATY YTA GG
COI-780R	Gibson *et al.* 2011	CCA AAA AAT CAR AAT ARR TGY TG

TABLE 3. Species of insects collected when visiting Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*) in Northwest Territories, Canada, specimen identification (unique identifiers), GenBank number, and sequence lengths for species identified or confirmed using DNA barcoding. There were no ambiguous base calls in any of the sequences. Available common names are provided.

Species	Specimen ID	GenBank number	Sequence length
Cheilosia sp. NWT1*	CNC1078275	MT216206	662
Cheilosia sp. NWT1	CNC1078267	MT216195	645
Cheilosia sp. NWT1	CNC1078265	MT216190	662
Delia fabricii (Holmgren, 1872)	CNC1078279	MT216193	662
Delia fabricii	CNC1078278	MT216209	662
Eristalis obscura (Loew, 1866) (Dusky Drone Fly)	CNC1078269	MT216201	662
Graphomya sp.	CNC1078280	MT216200	662
Hydrotaea pilitibia Stein, 1916	CNC1078274	MT216197	662
Lispe tentaculate (De Geer, 1776)	CNC1078266	MT216189	662
Phaonia hybrida Schnabl, 1888	CNC1078242	MT216192	662
Phaonia lugubris Meigen, 1826	CNC1078277	MT216204	662
Phaonia lugubris Meigen, 1826	CNC1078276	MT216211	662
Protophormia terraenovae Robineau-Desvoidy, 1830	CNC1078251	MT216210	662
Protophormia terraenovae	CNC1078241	MT216203	662
Stratiomys normula (Loew, 1866)	CNC1078240	MT216194	662
Syrphus vitripennis Meigen, 1822 (Black-legged Flower Fly)	CNC1078262	MT216213	662
Syrphus vitripennis	CNC1078261	MT216196	662
Syrphus vitripennis	CNC1078260	MT216198	659
Syrphus vitripennis	CNC1078258	MT216214	419
Syrphus vitripennis	CNC1078257	MT216207	662
Syrphus vitripennis	CNC1078255	MT216199	662
Syrphus vitripennis	CNC1078252	MT216191	661
Syrphus vitripennis	CNC1078249	MT216208	662
Syrphus vitripennis	CNC1078248	MT216202	662
Syrphus vitripennis	CNC1078247	MT216212	659
Tetanocera sp.	CNC1078270	MT216205	662

**Cheilosia* (Blacklets) requires revision. We could not place this definitively to species so gave it a morphospecies name.

TABLE 4. Numbers of individuals of various insect groups seen on flowers of Alaska Wild Rhubarb (*Koenigia alaskana* var. *glabrescens*) in Northwest Territories, Canada, at sites indicated in Table 1. This table includes unidentified floral visitors of single flowers, visitors of two or more plants that were not caught and specifically identified (counted as single individual visits), and captured insects visiting flowers on two consecutive plants that were specifically identified (also counted as a single individual visit).

Insect group	Site											Total
	1	2	3	4	5	6	7	8	9	10	11	
Diptera—flies												
Syrphidae	13	16	10	4	15	11	24	3	3	3	6	108
Other Diptera		6	2		7	5	8	6				34
Hymenoptera—bees and wasps												
Apidae	1					1	1					3
Crabronidae	1											1
Ichneumonidae		1		1			1	4				7
Vespidae	1								1	1	7	7
Lepidoptera—moths												
Geometridae								1				1

of potential pollinators was Hymenoptera (11 of 57, 19.3%). The potential pollinators, and notably those more frequently recorded, are widespread species.

Discussion

Our results provide quantitative support for a major role of Syrphidae in pollination of *K. alaskanum* var. *glabrescens*. Flower flies play a major role as pollinators in Arctic and boreal regions (e.g., Larson *et al.* 2001) and have also been reported as important pollinators in other species of Polygonaceae. For example, Chen and Zhang (2010) reported flower flies as the principal floral visitors of *Polygonum jucundum* Meisner (no English common name) from east-central China, a heterostylous species with flowers similar in morphology to those of *K. alaskanum* var. *glabrescens*. They noted that the flies harvest pollen from *P. jucundum* with their mouthparts from short-styled

TABLE 5. Identification of 57 specimens collected after moving from a flower on one plant of Alaska Wild Rhubarb (*Koenigia alaskanum* var. *glabrescens*) to a flower on another plant, thus indicating potential pollination. The rows are in alphabetical order by family, subfamily, then species.

Group/family	Subfamily	Taxon (common names provided where possible)	No.
Diptera—flies			45
Anthomyiidae		*Delia fabricii* (Holmgren 1872)	2
Calliphoridae	Chrysomyiinae	*Protophormia terraenovae* (Robineau-Desvoidy 1830)	2
Muscidae		*Graphomya* Robineau-Desvoidy 1830	1
		Hydrotaea pilitibia Stein 1916	1
		Lispe tentaculata (De Geer 1776)	1
		Phaonia hybrida (Schnabl 1888)	1
		Phaonia lugubris (Meigen 1826)	2
Sciomyzidae		*Tetanocera* Dumeril 1800	1
Stratiomyidae		*Stratiomys normula* (Loew 1866)	1
Syrphidae	Eristalinae	*Cheilosia* sp. NWT1	3
		Eristalis (*Eoseristalis*) *anthophorina* (Fallén 1817) (Orange-spotted Drone Fly)	2
		Eristalis (*Eoseristalis*) *obscura* (Loew 1866) (Dusky Drone Fly)	1
		Eristalis (*Eoseristalis*) *rupium* (Fabricius 1805) (Spot-winged Drone Fly)	1
Syrphidae	Syrphinae	*Epistrophe* (*Epistrophe*) *nitidicollis* (Meigen 1822) (Straight-banded Smoothtail)	2
		Eupeodes (*Metasyrphus*) *curtus* (Hine 1922) (Comma-spot Aphideater)	1
		Eupeodes (*Metasyrphus*) *perplexus* (Osburn 1910) (Bare-winged Aphideater)	1
		Meligramma guttata (Fallén 1817) (Spotted Roundtail)	4
		Meligramma triangulifera (Zetterstedt 1843) (Variable Roundtail)	1
		Meliscaeva cinctella (Zetterstedt 1843) (Common Thintail)	1
		Parasyrphus tarsatus (Zetterstedt 1838) (Holarctic Bristleside)	1
		Sphaerophoria (*Sphaerophoria*) *abbreviata* (Zetterstedt 1849) (Variable Globetail)	1
		Sphaerophoria sp. 1828 (*S. abbreviata*, *S. asymmetrica* Knutson 1972 or *S. philanthus* (Meigen 1822) females)	3
		Syrphus (*Syrphus*) *vitripennis* Meigen 1822 (Black-legged Flower Fly)	11
Hymenoptera—bees and wasps			11
Apidae	Apinae	*Bombus bifarius* (Cresson 1878) (Black-notched Bumble Bee)	1
		Bombus occidentalis Greene 1858 (Western Bumble Bee)	1
Crabronidae	Crabroninae	*Crabro latipes* F. Smith 1856	1
Ichneumonidae	Pimplinae	*Itoplectis viduata* (Gravenhorst 1829)	1
Ichneumonidae	Tryphoninae	*Exyston chamaeleon* Mason 1959	1
Tenthredinidae	Nematinae	aff. *Tenthredo piceocincta* (Norton 1860)	2
Vespidae	Vespinae	*Dolichovespula albida* Sladen 1918) (Arctic Yellowjacket)	4
Lepidoptera—moths			1
Geometridae	Sterrhinae	*Scopula sentinaria* (Geyer 1837)	1

morphs while hovering for 2–8 s, during which time some pollen sticks to their legs, thorax, and abdomen. This pollen is later deposited on flowers of other *P. jucundum* plants. Our observations of potential pollination in *K. alaskanum* var. *glabrescens* involved many cases of insects landing on flowers, rather than hovering. The predominance of flies as visitors across most of our sites reinforces their importance as potential pollinators, but the slight predominance of vespid wasps at one site in the Richardson Mountains also suggested some local variation.

In a study of dimorphic heterostyly in the related Bellflower Knotweed (*Koenigia campanulata* (Hook. f.) T.M. Schuster & Reveal (previously *Aconogonum campanulata*)), Hong (1991) observed that small solitary bees were the primary pollinators of its campanulate flowers. He considered these flowers shape-adapted to melittophily. He further noted that most other species of *Aconogonon* are pollinated to a large extent by flies and have non-campanulate flowers agreeing with a general syndrome of fly pollination. He finally noted, based on his general observations, that the flowers of species of *Aconogonon* may attract a large number of different insects to feed on their nectar. Hong's (1991) suggestions regarding fly pollination and pollinator diversity are supported by the 31 species of potential pollinators reported here for Alaskan Wild Rhubarb.

Acknowledgements

Expert identifications were supplied by scientists from the Canadian National Collection of Insects, Arachnids and Nematodes including C. Schmidt, A. Bennett, and H. Goulet. Help to process plant vouchers was provided by O. Lonsdale and J. Doubt. Funding for sequencing was provided by an A-base grant to J.H.S. by Agriculture and Agri-Food Canada (AAFC). Scott Kelso of AAFC assisted with DNA sequencing.

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Received 19 March 2020
Accepted 8 July 2021
Associate Editor: J.M. Saarela