The Use of Native Willows to Enhance Native Bee Pollinators in Blueberry Fields

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INTRODUCTION

Wild blueberries (*Vaccinium angustifolium*) are a major agricultural economic driver for eastern Canada, with acreages expanding annually and a market value in excess of $56 million. Wild blueberry plants are essentially insect-pollinated and pollination by bees (Apoidea) is critical for good fruit set and high yields. Most berry producers use honeybees (*Apis mellifera*) to augment native pollinators, as they can provide excellent pollination service for blueberries. However, increased berry production coupled with mounting management challenges with honeybees (e.g., new parasites, viruses and diseases) and general hive shortages, means additional strategies are desirable to sustain optimal pollination. Thus, there is increasing interest in conserving and promoting native pollinators for crop production. In wild blueberry, wild bees are often more efficient pollinators than honey bees and tend to cope better with poor spring weather that is common on Canada's east coast (Garibaldi et al 1013). At the same time, wild native bee populations have been declining due to loss and degradation of nesting sites and floral resources, landscape fragmentation, intensive agronomic and monoculture practice, displacement of native floral hosts by exotic plants, use of pesticides, decimation of host plants by high deer populations, and loss of open habitats due to suppression of fires and other checks to forest succession (Kearns et al. 1998; Larsson and Franzén 2007; Grundel et al. 2010; Pendleton et al. 2011; Williams 2011; Brousseau et al. 2013). Maintaining or supporting diverse wild pollinator populations is important to a broad range of agricultural crops for which honey bees alone may be insufficient to maximize pollination and associated fruit and seed set (Garibaldi et al. 2013)

There is surprisingly little data demonstrating the usefulness of habitat management for building natural and native bee communities that benefit crop production. We propose to build on existing relationships with berry growers to test the hypotheses that planting of native willows (*Salix* spp.) around wild blueberry fields can increase the diversity and abundance of native pollinators within and adjacent to the crop and, thereby, significantly increase natural pollination and fertilization success of blueberry flowers. Willows have many attributes that make them an ideal choice for enhancing native bee populations. They are fast-growing, propagation is easy and economical, they flower early and prolifically, and they are easily managed and adapted to a wide range of nutrient, moisture and climatic conditions. Willows provide excellent forage for bees (Ostaff et al 2015) and have highly palatable foliage that is useful to leafcutter species (Megachilidae), thereby supporting a rich diversity of pollinators. There are very early- and late-flowering species, allowing flowering phenology to be precisely tailored around the flowering phenology of the fruit crop of interest. The addition of native willows to landscapes being developed for blueberry production provides an off-season food supply of pollen and nectar for the promotion of resident pollinator populations. The objective of this study is to establish willow populations in blueberry fields; determine the diversity and abundance of native pollinators foraging on these willows, and their ability to forage on and serve as effective pollinators of blueberry.

METHODS

Willow Planting

Rooted cuttings of willow seedlings from *Salix cordata* (COR), *Salix discolor* (DIS), *Salix eriocephala* (ERI) and *Salix viminalis* (VIM) were planted on 13 and 21 June 2016 at four separate sites in blueberry fields belonging to John Schenkels. The fields were located 12 km along a dirt road, 3 km west of Lavillette (18 clones x 3 ramet plots x 5 blocks at a 1 m x 1 m spacing at four test sites). Willow plantings were taken from a population genetics test established at the Atlantic Forestry Centre (AFC) near Fredericton, NB in 2008. The planting design allowed for future testing of willow species survival and development, the enhancement of blueberry pollination by these willows, and their associated insect-pollinator communities. Survival and growth in these field tests continues to be monitored through the growing season, and survival has been very good. At the end of the 2017 growing season, the aboveground biomass in these field tests was harvested in order to promote coppice regrowth and promote flowering and catkin production to attract insect pollinators. Coppice shoot production will continue to be monitored over the 2018 growing season.

On 7 June 2017, two blocks of male willow clones were planted in wet areas in blueberry fields in Printz Cove Berry Farm near Chipman, NB. Three hundred and sixty plants, started from cuttings from male clones of five species

of native willow (*Salix cordata*, *Salix eriocephala*, *Salix bebbiana*, *Salix humilis*, and *Salix discolor*) were planted at one meter spacing in blocks 29 m x 5 m and 31 m x 6 m, respectively. The same five species were also planted in two blocks at an additional site on John Schenkels' blueberry farm. Survival was visually assessed at the end of the 2017 growing season and survival was good.

In late fall of 2017, two additional sites were located on Printz Cove Berry Farm and will be planted with the male clones of the five willow species plus an additional species, *Salix petiolaris*.

Insect Monitoring

The diversity and abundance of native insect species were monitored by trapping and assessing foraging on flowers, both blueberry and other flowering plants in and around the four willow sites. On 17 May bee traps were set up at three willow planting sites on Schenkels Blueberry Farm to determine what bee species are active before blueberry flowering. Bee traps consisted of plastic 14 oz. cups suspended in a ¾" section of a 3" diameter plastic sewer pipe mounted on to a 9" length of ½" electrical conduit pipe. The interior of cups were plain white or painted with yellow or blue fluorescent paint to attract and trap bees at each sampling location. Three replicates of each color of trap (white, yellow, and blue) were deployed at each site in a row at 5 m intervals in an area free of competing vegetation. These colors have been shown to attract more than 80% of the bee (Apoidea) fauna and are used in many localities to survey bee populations (Leong and Thorp 1999; Wilson et al. 2008; Droege et al. 2010). Propylene glycol/water mix with a drop of dish detergent to break surface tension of the medium was used in the traps. On 29 May, insects in all traps were collected and stored in alcohol, labeled as to site, trap color and date, and returned to our laboratories. Traps were removed from the field. Baited traps were placed at each site for a ten-day period during early July to sample insect populations after blueberry flowering and September to determine late season insect populations. Contents of each bag were washed in soapy water, cleared in 95% alcohol, dried with a hair dryer to enhance the body hairs, pinned, labeled and identified to genera and, where possible, to species.

At each visit to the blueberry fields, a 15-minute cruise was carried out at all willow planting sites. All flowering vegetation was carefully observed and insects foraging on them were either identified visually, i.e., *Bombus ternarius* and *Apis mellifera* are easily identified by its body coloration pattern, or collected using a hand-held battery operated vacuum aspirator, stored in alcohol and returned to the lab for subsequent identification. Insect collections or observations were separated as to the type of flower it was foraging on. Sampling commenced on 17 May, at which time only native willow, male and female Salix bebbiana were flowering in the blueberry fields.

In addition to the 15-min cruises in and around willow planting sites, cruises were also conducted weekly during the blueberry flowering (6, 14, 22, and 29 June) at three blueberry fields adjacent to the willow planted sites. Any bee actively foraging on the blueberry flowers were either identified and tallied or collected with the hand-held aspirator and stored in alcohol for later identification.

RESULTS

Willow Planting

The 2017 survival of our 2016 willow plantings varied by species and site, but ranged from a high of 97% at site 1 to a low of 31% at site 2 for an overall survival of 70% across all four sites planted. We could not measure biomass yields due to severe moose browsing, rendering a biomass yield assessment meaningless. We hope that a coppice biomass assessment will be possible in future years if moose browsing is not too severe.

Insect Monitoring

Cup Traps

In 2017, 1008 bees (839 females and 169 males) belonging to five families were collected in colored traps on willow-planted sites (Table 1). The collection of male bees increased throughout the field season while female bees were more common in spring and fall (Figure 1). Halictidae (sweat bees) represented 56% of the collection; Apidae 37%, Andrenidae 6% and Colletidae and Megachilidae <1%. *Lasioglossum* (*Dialictus*) (61%) and *Lasioglossum* spp. (31%) were the most common halictid bee collected; *Bombus ternarius* (84%) and *Bombus impatiens* (4%) the most common Apidae; and *Andrena* spp. the most common Andrenidae (Table 2). Three cleptoparasites, *Sphecodes* spp. (Halictidae), and *Nomada* spp. (Apidae) were also collected (Table 1). Eighty-eight percent of all bees collected belonged to genera, *Lasioglossum* (*Dialictus*) spp. (34%), *Bombus ternarius* (30%), *Lasioglossum* spp. (18%), and *Andrena* spp. (6%) (Table 1).

Fifty-five percent of the bees were collected in September, with 29% in spring and 16% during mid-summer (Table 1). Trap collections of bees varied among families and individual bee genus (Figures 2 and 3). The greatest

Table 1. Bee (Apoidea) pollinators collected in coloured traps at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

Family	May		July		September		Total	
Bee	Female	Male	Female	Male	Female	Male	Female	Male
Andrenidae								
Andrena spp.	53	3	3	0			**56**	**3**
Calliopsis andreniformes					1	0	**1**	**0**
Apidae								
Bombus ternarius	30	0	9	0	244	31	**283**	**31**
Bombus impatiens			10	1	3	0	**13**	**1**
Bombus terricola			1	0			**1**	**0**
Bombus borealis					1	0	**1**	**0**
Bombus spp.			2	1	9	8	**11**	**9**
Nomada spp.	3	7	3	0			**6**	**7**
Apis mellifera			1	0	3	0	**4**	**0**
Anthophora spp.			0	2	1	0	**1**	**2**
Ceratina spp.			1	0	1	0	**2**	**0**
Melissodes spp.					2	0	**2**	**0**
Halictidae								
Lasioglossum (*Dialictus*) spp.	178	0	70	24	68	6	**316**	**30**
Lasioglossum spp.	11	0	18	0	74	75	**103**	**75**
Sphecodes spp.	2	0	10	0	4	3	**16**	**3**
Halictus rubicundus	1	0	2	0	8	4	**11**	**4**
Augochlora pura			3	0	3	2	**6**	**2**
Megachilidae								
Megachile spp.			0	1	2	0	**2**	**1**
Osmia spp.			1	0			**1**	**0**
Coelioxys spp.					0	1	**0**	**1**
Colletidae								
Hylaeus basalis					2	0	**2**	**0**
Colletes validus					1	0	**1**	**0**
Totals	**278**	**10**	**134**	**29**	**427**	**130**	**839**	**169**

number of Andrenid bees, 93% of which belonged to the genus *Andrena*, were collected in traps during the middle of May; halictid bees varied slightly throughout the season; and Apidae collections increased dramatically in September (Figure 2), due mainly to the activity of *Bombus ternarius* (Figure 3). Of the four most common bees collected, *Lasioglossum* (*Dialictus*) and *Andrena* spp. were collected in May, with *Lasioglossum* spp. and *Bombus ternarius* collections greater in the fall (Figure3).

Live Trapping/Flowering Vegetation

In 2017, 1127 bees were collected or identified foraging on flowering vegetation, 93% of the bees being females (Table 2). Bees belonged to five different families, Apidae (85%), Andrenidae (10%), Halictidae (5%), and Megachilidae and Colletidae (<1%). Ninety-four percent of all bees collected from flowering plants belonged to four genera,

Figure 1. Number of male and female bees (Apoidea) collected in coloured traps at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

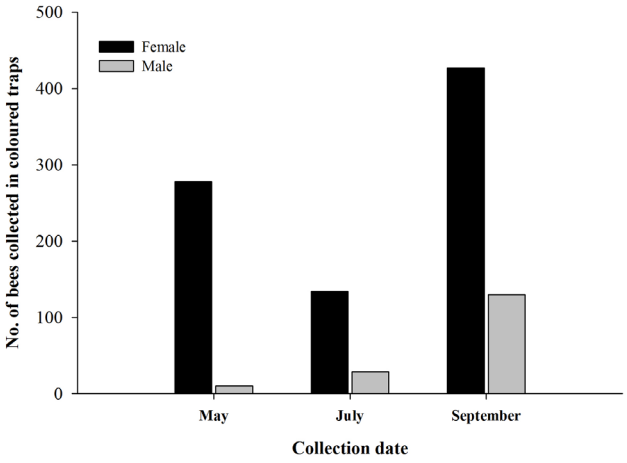
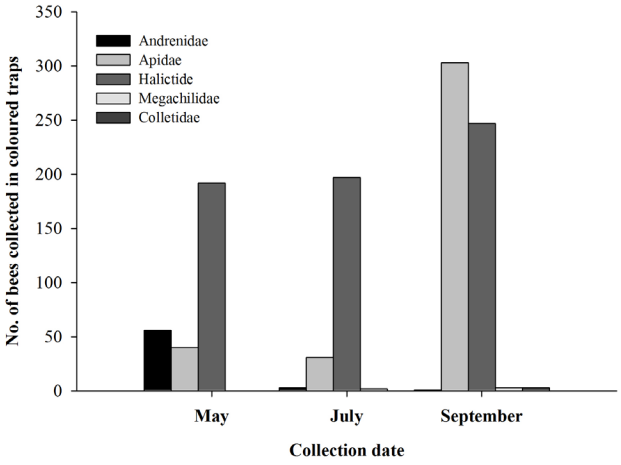


Figure 2. Number of bees (Apoidea) belonging to five families collected in coloured traps at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.



Bombus ternarius (46%); *Bombus ternarius* (46%); and two imported bees, *Bombus impatiens* (25%) and *Apis mellifera* (13%) (Table 2). Each of these four bees had very different phenologies (Figure 4). Peak activity of *Andrena* was early in the year (17 May). The honey bee, *Apis mellifera* peaked at beginning of June, corresponding to the placing of the hives in the blueberry fields. *Bombus impatiens* activity peaked at the end of June/early July. *Bombus ternarius* was more active later in the summer and fall (Figure 4).

Table 2. Number of male and female bees (Apoidea) collected or identified foraging on flowering plants at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

Family	Bee	Females	Males	Total
Andrenidae	*Andrena* spp.	76	32	**108**
	frigida Smith, 1853	38	0	**38**
	carlini Cockerell, 1901	1	10	**11**
	clarkella (Kirby, 1802)	11	0	**11**
	vicina Smith. 1853	0	8	**8**
	dunningi Cockerell, 1898	1	4	**5**
	carolina Viereck, 1909	0	3	**3**
	kalmiae Atwood, 1934	1	1	**2**
	rufosignata Cockerell, 1902	0	2	**2**
	rugosa Robertson, 1891	0	2	**2**
	forbesii Robertson, 1891	0	1	**1**
	w-*scripta* Viereck, 1904	0	1	**1**
	unidentified	24	0	**24**
Apidae	**Bombus ternarius* Say, 1837	515	0	**515**
	Bombus impatiens Cresson, 1863	283	0	**283**
	Bombus borealis Kirby, 1837	1	1	**2**
	**Apis mellifera* Linnaeus, 1761	144	0	**144**
	Nomada spp.	4	8	**12**
Halictidae	*Lasioglossum* spp.	5	25	**30**
	Sphecodes spp.	6	15	**21**
	Lasioglossum (*Dialictus*) spp.	3	2	**5**
	Halictus rubicundus (Christ, 1791)	1	0	**1**
Megachilidae	*Osmia* spp.	3	0	**3**
Colletidae	*Colletes validus* Cresson, 1868	3	0	**3**
Totals		**1044**	**83**	**1127**

*imported colonies

Twenty-eight different flowering plants were identified on the willow-planted sites (Table 3). However, bees were observed foraging on eighteen of these with flat top goldenrod (25%), field hawkweed (22%), willow, *Salix bebbiana* (10%), *Solidago speciosa* (8%), sweet fern (8%) being the most common flowering plants visited by foraging bees (Table 3). Of the four commonly observed bees foraging on flowering plants, *Bombus impatiens* foraged on the greatest diversity of plants visited (11 of 18), with an appeared preference for field hawkweed (78%) and sheep laurel (9%). *Bombus ternarius* collected from 9 of the 18 available flowering plants, displayed a preference for flat top goldenrod (50%), *Solidago speciosa* (17%), Tall white aster (13%) and New England aster (10%). *Apis mellifera*, 5 of 18 flowering plants, was found more commonly foraging on sweet fern (58%) and bog rhododendron (33%). *Andrena* spp. (2 of 18) was the most specific with the plants visited being found visiting only 2 of 18 flowering plants with 95% of collections coming from willow, *Salix bebbiana* (Table 4).

Figure 3. Number of bees (Apoidea) belonging to four common genera collected in coloured traps at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

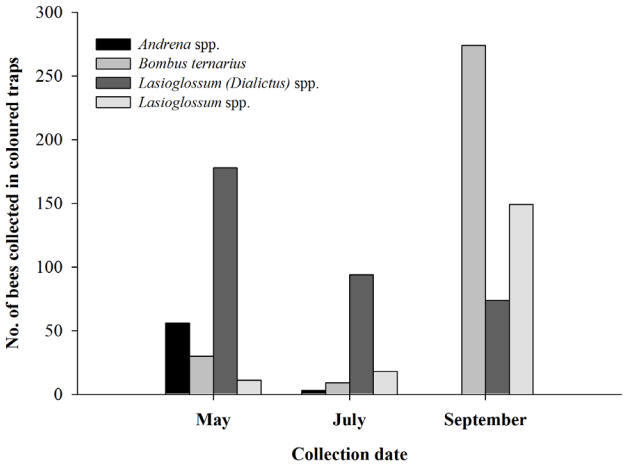
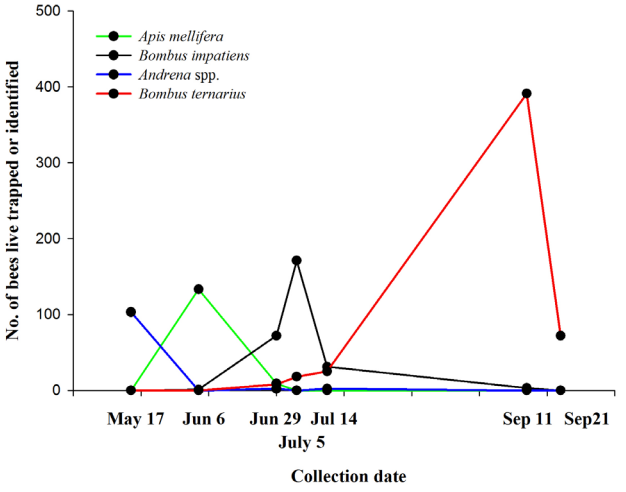


Figure 4. Number of bees (Apoide) belonging to four genera commonly live trapped or identified foraging on flowering plants at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.



Blueberry Field Cruises

Cruises through blueberry fields during the presence of blueberry flowers showed, as expected, the majority of

Table 3. Flowering plants found growing at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

Earliest Recorded Flowering					
Late May	Early June	Mid June	Late June	Mid July	Early September
Salix bebbiana*	**bog rhododendron***	bunchberry	**sheep laurel***	**fireweed***	***Solidago* spp.***
Pin cherry	**sweet fern***	pink lady slipper	**field hawkweed***	**spread dogbane***	**tall white aster***
Serviceberry	**jackpine***	star flower	**willow herb***	blackberry	**flat-top goldenrod***
		Prunus	**wild sarsaparilla***	**cow-wheat***	**Canada goldenrod***
			cinquefoil	pearly everlasting	**New York aster***
					New England aster*
					gall of the earth
					pink spirea*

*** indicates plants from which bees were collected**

Table 4. Floral preference of four common bees (Apoidea) collected or identified foraging on flowering plants at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

Plant	Flowering*	Bee Pollinator				Total
		Andrena spp.	*Bombus ternarius*	*Bombus impatiens*	*Apis mellifera*	
Flat top goldenrod	ES		256		2	**258**
Field hawkweed	LJ		1	221	9	**231**
Salix bebbiana	LM	103				**103**
Solidago speciosa	ES		88			**88**
Sweet fern	EJ			1	84	**85**
Tall white aster	ES		66			**66**
Sheep laurel	LJ	5	35	25		**65**
New England aster	ES		52			**52**
Bog rhododendron	EJ			3	48	**51**
Spreading dogbane	JM		11	13		**24**
Fireweed	JM			7		**7**
New York aster	ES		4	2		**6**
Wild sarsaparilla	LJ			6		**6**
Willow herb	LJ		2			**2**
Cow-wheat	JM			2		**2**
Spirea	ES			2		**2**
Canada goldenrod	ES			1		**1**
Jack pine	LM				1	**1**
Total		**108**	**515**	**283**	**144**	**1050**

*** LM = late May; EJ = early June; MJ = mid-June; LJ = late June; JM = mid-July; ES = early September**

insects observed or collected were *Apis mellifera* (60%) and *Bombus impatiens* (24%) (Table 5). In addition to these two imported species, *Bombus ternarius* (5%), *Andrena* spp. (3%), and insects belonging to Syrphidae (4%) and Bombyliidae (<1%) were also found (Table 5). The majority of bees were collected one week after flowering commenced (59%), with only 17% and 8% collected mid-flowering and near end of flowering, respectively (Table 5). The greatest

Figure 5. Mean number per 10m^2 of two imported bees identified foraging on blueberry flowers at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

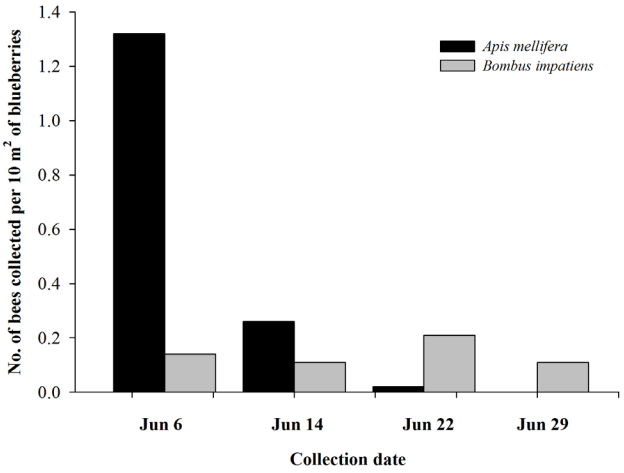
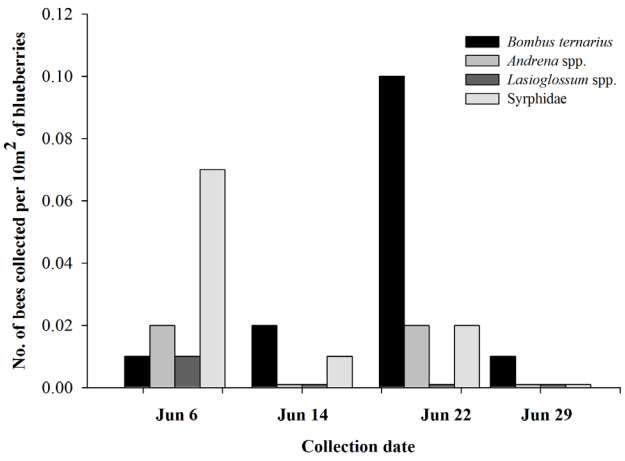


Figure 6. Mean number per 10m^2 of four common insects collected or identified foraging on blueberry flowers at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.



density of honey bees (1.32 per 10m^2 of blueberries) occurred one week after the start of flowering, falling to 0.26 per m^2 one week later (Figure 5). Peak collections of *Bombus impatiens* occurred three weeks after the start of flowering (Figure 5). *Bombus ternarius* was collected with the greatest density of non-imported bees three weeks after the start of flowering (0.10 per 10 m^2). *Andrena* spp. were collected one and three weeks after the start of flowering indicating that more than one species may be involved (Figure 6).

Table 5. Weekly live trap collections of insects foraging on blueberry flowers at three sites on John Schenkels Blueberry Farm near Lavillette, NB in 2017.

Insect	6-Jun				14-Jun				22-Jun				29-Jun				
Site	1	2	3	Total	1	2	3	Total	1	2	3	Total	1	2	3	Total	TOTALS
Apis mellifera	32	105	46	**183**	2	34	4	**40**	1	1	1	**03**	0	0	0	**0**	**226**
Bombus impatiens	1	7	12	**20**	0	11	6	**17**	3	21	9	**33**	3	14	2	**19**	**89**
Bombus ternarius			1	**1**	1		2	**3**	5	7	4	**16**	2	1		**3**	**23**
Andrena spp.	2	1		**3**							2	**2**					**5**
Andrena carolina	1			**1**					1		2	**3**	1	2		**3**	**7**
Andrena rufosignata		1		**1**													**1**
Lasioglossum sp.		1		**1**													**1**
Sphecodes													1	1		**2**	**2**
Nomada													1			**2**	**3**
Syrphidae		9	1	**10**	1	1		**2**	1	2		**3**					**15**
Bombyliidae		1		**1**		1		**1**									**2**
Totals	**36**	**125**	**60**	**221**	**4**	**47**	**12**	**63**	**11**	**31**	**18**	**60**	**8**	**18**	**2**	**29**	**374**

DISCUSSION

The early success of willow establishment, good height growth and vigor, and the observation of *Andrena* spp. foraging on blueberry flowers is encouraging, showing promise as an excellent management tool for blueberry growers. Some eastern North American bee species use willows as their main source of pollen, notably several oligolectic (specializing in collecting pollen from one genus or species of flowering plants) *Andrena* species (LaBerge 1980; Ribble 1968; LaBerge and Bouseman 1970; LaBerge and Ribble 1972. LaBerge 1973; Miliczky 1988). Planting or cultivating native willows in areas surrounding crop fields could provide a consistent source of pollen and nectar to support pollinator populations early in the growing season when crops and most alternative native floral hosts are not yet flowering. In our study to date, we have identified 11 species of *Andrena* collected from willow (Table 2) six of which have been shown to forage on blueberry (*Andrena frigida*, *Andrena carlini*, *Andrena vicina*, *Andrena carolina*, *Andrena rufosignata*, and *Andrena w-scripta* – Javorek, personal communication). *Andrena* spp. were collected before blueberry flowers were available and after blueberries ceased flowering (Figure 3 and 4) as well as during the flowering period (Figure 4 and 6). With *Andrena* being considered to show a preference for willows, the observation of *Andrena* actively foraging on blueberry flowers suggests that the addition of willows to blueberry fields could enhance populations of this important pollinator. *Andrena* use low-bush blueberry as a major pollen source and have been shown to have the highest average pollination percentage of pollen-harvesting bees (95%), along with *Bombus* spp., which are limited in number in spring when only queens are present (Stubbs et al 1992; Javorek et al. 2002). Interestingly, foraging females of *Bombus ternarius* were collected during mid-blueberry flowering (Figure 6), unlike the previous year when those collected in traps or observed foraging on blueberry were queens. This suggests that this species emerges early enough in the spring for queens being able to start a brood which can forage on blueberries.

Most of the bees found in our study are opportunistic and will forage on flowers that are readily available. In our study there were 14 flowering plants that could compete with blueberries, however these occur in low enough density to not compete with the vast density of blueberry flowers. It was interesting to see large numbers of honey bees foraging on sweet fern at of one of our sites. These bees were found less than 50 meters from the hives.

The presence of *Andrena* is encouraging to our study. Given the fact that we were able to collect more than 100 specimens in three 15-min cruises from sites where willow numbers were less than 10 individuals per site, suggests that when our willows, numbering in excess of 300 plants per site, start producing flowers the density

of andrenids should be quite significant and provide a potential resource for pollinating blueberries. Also, two of the *Andrena* species, *Andrena carolina* and *Andrena rufosignata*, collected from blueberry plants were also collected from the native willow growing on our sites. The addition of our willows should help to promote populations of these two species. Syrphidae (flower flies) may also be important pollinators of blueberry however, most species lack the abundance of body on which pollen could adhere. Ostaff et al. (2015) showed that flower flies were common visitors to male willow flowers. Flower flies require protein-rich pollen to produce reproductive tissues and the carbohydrate-rich nectar to power flight and other activities (Holloway 1976; Gilbert 1981; Kevan and Baker 1983; Branquart and Hemptine 2000; Larson et al. 2001).

The provision of *Salix* species in these landscapes not only provides an important vernal food source but encourages nest initiation close to crops, enhancing native pollinator availability when flowering commences. Increasing both *Andrena* spp. and flower fly populations should benefit the pollination of low bush blueberries.

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