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Floral Resources and Bumble Bee Abundance in Lowbush Blueberry Field Margins

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ABSTRACT

Honey bees (*Apis mellifera* Linnaeus) are used extensively for lowbush blueberry (*Vaccinium angustifolium* Aiton) (Ericaceae) pollination, yet recent bee health concerns coupled with rising hive rental costs have led to increased interest in a diversified pollinating force, including bumble bee (*Bombus*) species (Hymenoptera: Apidae). Bumble bees are effective pollinators of lowbush blueberry but require floral resources for the duration of the season, pre- and post- blueberry bloom. Five *Bombus* species were observed along field margins at three commercial lowbush blueberry sites on New Brunswick's Acadian Peninsula from 25 May to 22 August 2012. We determined relative abundance of the five bee species as well as floral visitation and the duration bees foraged on each flowering plant species. Based on average visits per hour, *Bombus impatiens* Cresson was most abundant, followed in decreasing abundance by *Bombus ternarius* Say, *Bombus vagans* Smith, *Bombus borealis* Kirby and *Bombus terricola* Kirby. Buckwheat (*Fagopyrum esculentum* Moench) (Polygonaceae), goldenrod (*Solidago* spp.) (Asteraceae), brambles (*Rubus* spp.) (Rosaceae), and rhodora (*Rhododendron canadense* (L.) Torr.) (Ericaceae) received the most *Bombus* visits per hour while red clover (*Trifolium pratense* L.) (Fabaceae), vetch (*Vicia* spp.) (Fabaceae), alfalfa (*Medicago sativa* L.) (Fabaceae), and St. John's Wort (*Hypericum* spp.) were visited for the longest duration by bees. This information can be used to guide management decisions to retain and implement flowering plants that support bumble bees in lowbush blueberry field margins.

RÉSUMÉ

L'abeille domestique (*Apis mellifera* Linnaeus) est utilisée à grande échelle pour la pollinisation des bleuetiers nains (*Vaccinium angustifolium* Aiton, famille des Éricacées); toutefois, les préoccupations récentes liées à la santé des abeilles combinées à la hausse des coûts de location des ruches ont mené à un accroissement de l'intérêt à l'égard du recours à des pollinisateurs diversifiés, dont différentes espèces de bourdons (*Bombus*) (Hymenoptera: Apidae). Les bourdons pollinisent efficacement les bleuetiers nains, mais ils ont besoin d'autres sources de fleurs durant la saison, avant et après la floraison des bleuetiers. Nous avons observé cinq espèces du genre *Bombus* en bordure des champs dans trois bleuetières commerciales situées dans la Péninsule acadienne du Nouveau-Brunswick, du 25 mai au 22 août 2012. Nous avons déterminé l'abondance relative de ces cinq espèces et avons consigné le nombre de visites des fleurs ainsi que la durée de l'alimentation pour chaque espèce de plante à fleurs. D'après le nombre moyen de visites par heure, le *Bombus impatiens* Cresson était l'espèce la plus abondante, suivie, par ordre décroissant, du *Bombus ternarius* Say, du *Bombus vagans* Smith, du *Bombus borealis* Kirby et du *Bombus terricola* Kirby. Le nombre de visites de bourdons par heure était le plus élevé dans le cas du sarrasin (*Fagopyrum esculentum* Moench, famille des Polygonacées), des verges d'or (*Solidago* spp., famille des Astéracées), des ronces (*Rubus* spp., famille des Rosacées) et du rhododendron du Canada (*Rhododendron canadense* (L.) Torr., famille des Éricacées), alors que la durée des visites a été la plus élevée dans le cas du trèfle rouge (*Trifolium pratense* L., famille des Fabacées), des vesces (*Vicia* spp., famille des Fabacées), de la luzerne (*Medicago sativa* L., famille des Fabacées) et des millepertuis (*Hypericum* spp.). Ces renseignements peuvent servir à orienter les décisions de gestion concernant le maintien et l'établissement des plantes à fleurs pouvant favoriser les bourdons dans les marges des champs de bleuetiers nains.

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INTRODUCTION

Lowbush or 'wild' blueberry, *Vaccinium angustifolium* Aiton (Ericaceae), is a native crop grown commercially in Eastern Canada and the Northeastern United States that depends on insect pollinators, particularly bees, for fruit set, (Aras et al. 1996; Delaplane and Mayer 2000; Eaton and Nams 2012, Asare et al. 2017). Market demand for lowbush blueberries is growing, in large part due to the health benefits from the fruit (Agriculture and Agri-Food Canada 2011), and pollinator demand is subsequently increasing (Province of New Brunswick 2013). Large fields and variable wild bee populations have led many producers to rely on the managed honey bee (*Apis mellifera* L.) for pollination (Eaton and Murray 1997; Stubbs et al. 1997, Asare et al. 2017). Yet, increased hive rental costs, coupled with pest and disease pressures associated with honey bees (e.g., *Varroa* mite), have caused certain blueberry growers to investigate alternative pollinators (Whidden 1996; Stubbs and Drummond 2001; Desjardins and Oliveira 2006; Drummond 2012) and consider the benefits of a diverse pollinating force (e.g., Greenleaf and Kremen 2006, Drummond 2016). Bumble bees (*Bombus* spp.*)* (Hymenoptera: Apidae), particularly queens, are effective pollinators of lowbush blueberry (Stubbs and Drummond 2001; Javorek et al. 2002; Heinrich 2004; Desjardins and Oliveira 2006, Drummond 2016), and commercially available *Bombus impatiens* Cresson has been used in recent years as a managed pollinator for this crop (Kevan 1999; Drummond 2012). Bumble bees are able to withstand the spring conditions under which lowbush blueberry blooms, and are more active in the morning and early evening, times when honey bees are generally less active (Delaplane and Mayer 2000; Stubbs and Drummond 2001; Heinrich 2004). Bumble bees are also able to buzz pollinate, which releases more pollen from flowers with poricidal anthers, such as blueberry (Delaplane and Mayer 2000; Heinrich 2004; Jesson et al. 2014, Drummond 2016). Furthermore, bumble bees display high fidelity to the blueberry crop, even when other flowering plants are present (Stubbs et al. 1992; Whidden 1996; but see Drummond 2012). In order to reach their full potential as blueberry pollinators, however, bumble bees require flowering plants for nectar and pollen throughout the season (Delaplane and Mayer 2000; Thorp et al. 2002; Heinrich 2004; Michener 2007), particularly before and after blueberry bloom (Stubbs et al. 1992). Identification of flowering plants that support bumble bee populations near blueberry fields may encourage management to sustain and enhance wild pollinator populations. We observed five *Bombus* species and the flowering plants they visited at three lowbush blueberry sites before and after blueberry bloom along the Acadian Peninsula in New Brunswick (NB), a substantial blueberry-growing region in Eastern Canada (Province of New Brunswick 2013). We were interested in 1) relative abundance among the bee species, measured by average flower visits per hour, 2) which flowering plants were visited by bumble bees, and 3) the foraging duration on each plant, measured by the total number of days each plant was visited by bees. We predicted that certain flowering plants would be visited more frequently than others by bumble bees, especially perennial resources, and that relative abundance among the five bee species would differ.

MATERIALS AND METHODS

The five *Bombus* spp. observed were *Bombus borealis* Kirby, *Bombus impatiens* Cresson, *Bombus ternarius* Say, *Bombus terricola* Kirby, and *Bombus vagans* Smith. Three mature, commercial lowbush blueberry sites in the fruit-bearing (crop) year of production were selected on NB's Acadian Peninsula: Haut Tilley Road (47°30'23" N, 65°08'33" W), Petit Gaspereau (47°33'24" N, 64°57'09" W) and Robichaud Road (47°14'18" N, 65°06'51" W). A 25 m by 2 m transect was established along the blueberry field margin at each site and floral composition was monitored throughout the season. Bumble bee activity was observed by walking slowly along the transects and recording bee species and the flowers visited. Photographs were taken to document floral visitation. Bee identification during field observation was based on several keys including Laverty and Harder (1988), Heinrich (2004), and Colla et al. (2010), while plants were identified using Sampson et al. (1990) and Zinck (1998).

Observations were recorded between 25 May 2012 (before blueberry bloom) and 22 August 2012, with the exception of the period of blueberry bloom (approximately three weeks). Observations occurred between 0900 hours and 1600 hours during sunny conditions with no precipitation, and when the temperature was 15 ˚C or warmer with little to no wind. Sites were visited at varying times of the day: for example, if Haut Tilley Road was visited in the morning on one day, it was next visited in the afternoon. Haut Tilley Road was sampled twelve times, Petit Gaspereau nine times, and Robichaud Road six times. Bee visitation to flowering plants was recorded per unit time so that total mean visits per hour could be used to estimate relative bumble bee abundance by species.

RESULTS

Relative Abundance

Based on total average visits per hour for each individual *Bombus* species, *Bombus impatiens* was the most abundant bee, accounting for more than half of all visits, followed by *Bombus ternarius* and *Bombus vagans* (Table 1). *Bombus impatiens* visited more than twice as many flowers per hour as *Bombus ternarius*, the next most abundant bumble bee (Table 1). *Bombus borealis* and *Bombus terricola* both had low average visits per hour (Table 1), indicating their low relative abundance in comparison to other bumble bee species. Each of the five bumble bee species were recorded at all three sites. *Bombus vagans* was observed most frequently at Haut Tilley Road and Petit Gaspereau sites, followed by *Bombus impatiens*. *Bombus ternarius*, *Bombus borealis*, and *Bombus terricola* comprised the third, fourth, and fifth most frequent bumble bee observations for these two sites, respectively. *Bombus impatiens* was recorded most often at Robichaud Road, followed by *Bombus ternarius*, *Bombus vagans*, *Bombus borealis*, and *Bombus terricola*. Bumble bee sex was not determined in this study, but it is possible that many of the bumble bees observed in mid-summer were males and new queens, as bumble bee colonies begin to produce new queens and males at this time (Laverty and Harder 1988; Heinrich 2004).

Floral Visitation

Bumble bees were recorded on 21 flowering plants from a total of eight families (Asteraceae, Clusiaceae, Ericaceae, Fabaceae, Onagraceae, Polygonaceae, Rosaceae and Scrophulariaceae), although not all plants were found at each site (Figure 1; Table 1). Of the 21 flowering plants recorded with bumble bee visits, only four are considered native to the region, while the remaining 17 plants are considered exotic or invasive (Table 1). Plant visitation ranged from six to seventeen different plants visited by each bee species (Table 1). Only rhodora (*Rhododendron canadense* L. (Torr.)) (Ericaceae) and dandelion (*Taraxacum officinale* Wigg) (Asteraceae) were visited by bumble bees (queens) before blueberry bloom (Figure 1). Rhodora had one of the highest total average visits per hour of all recorded plants, but was only observed at one site (Table 1; Figure 1). Visits to dandelion were observed at one site for one day in late May and this plant was only visited by *Bombus impatiens*, although visits were not recorded during blueberry bloom (Table 1; Figure 1). Buckwheat (*Fagopyrum esculentum* Moench) (Polygonaceae) received the highest total *Bombus* visits overall, followed by goldenrod (*Solidago* spp. and *Euthamia* spp.) (Asteraceae), brambles (*Rubus* spp.) (Rosaceae), and rhodora, each with more than thirty visits per hour (Table 1).

Six plants within the Asteraceae family were foraged upon and visitation rate varied among the five bee species; for example, goldenrod was visited the second most frequently of all plants, while bull thistle (*Cirsium vulgare* (Savi) Tenore) was visited least (Table 1). St. John's Wort (*Hypericum* spp.) was the only flower visited within the Clusiaceae family and received moderate visitation (Table 1). Rhodora, within the same family as lowbush blueberry (Ericaceae), was highly visited (Table 1). The Fabaceae family was well represented by seven different plant species and received moderate visits by a variety of bees (Table 1). Buckwheat and fireweed (*Chamerion angustifolium* (L.) Holub) were the only flowering plants documented from the Polygonaceae and Onagraceae families respectively, and were highly visited, with buckwheat receiving the most visits from all flowers recorded (Table 1). Visitation to three plants within the Rosaceae family varied widely (Table 1). Toadflax (*Linaria vulgaris* P. Mill.) was the only flowering plant noted from the Scrophulariaceae family and was among the least visited flowers observed (Table 1).

Duration of Foraging

Red clover (*Trifolium pratense* L.) (Fabaceae) was visited by bumble bees for the longest duration (10 weeks), followed by vetch (*Vicia* spp.) (Fabaceae) (7 weeks) (Figure 1). Alfalfa (*Medicago sativa* L.) (Fabaceae), St. John's Wort, and white sweet clover (*Melilotus albus* L.) (Fabaceae) were each visited for 4—6 weeks, while yellow sweet clover (*Melilotus officinalis* L. (Lam)) (Fabaceae), fireweed, goldenrod, wild rose (*Rosa* spp.) (Rosaceae), Canada thistle (*Cirsium arvense* (L.) Scop.) (Asteraceae), and buckwheat were visited for 2—3 weeks (Figure 1). Rhodora, golden clover (*Trifolium aureum* Pollich) (Fabaceae), white clover (*Trifolium repens* L.) (Fabaceae), dandelion, brambles including raspberries, bull thistle, chokecherries (*Prunus* spp.) (Rosaceae), toadflax, yarrow (*Achillea millefolium* L.) (Asteraceae), and tansy (*Tanacetum vulgare* L.) (Asteraceae) were visited for <2 weeks (Figure 1). Flowers that were visited for the longest duration (>weeks) were legumes (Fabaceae), with the exception of St. John's Wort.

DISCUSSION

Relative abundance varied among the five bee species, as predicted, and generally agreed with previous studies (Cameron et al. 2011; Colla et al. 2012; Williams et al. 2014). Low abundances of *Bombus borealis* and *Bombus terricola* in our study corresponded to noted declines (e.g., Grixti

Table 1. Average number of visits per hour to flowers by five *Bombus* species along lowbush blueberry field margins in New Brunswick from 25 May 2012 to 22 August 2012. The range of average visits per hour are provided in parentheses when observations were made for a flowering plant on more than one date.

Plant species[1]	Family[2]	n	Average visits per hour (range of min to max)					
			Bombus borealis	***Bombus impatiens***	***Bombus ternarius***	***Bombus terricola***	***Bombus vagans***	**Total *Bombus***
Buckwheat[i]	P	2	0.0	6.0 (0-12)	28.0 (26-30)	3.0 (0-6)	3.0 (0-6)	40.0 (32-48)
Goldenrod[n]	A	9	2.0 (0-10)	16.7 (0-66)	12.1 (0-36)	0.0	5.6 (0-18)	36.6 (2-138)
Brambles[i]	R	1	0.0	36.0	0.0	0.0	0.0	36.0
Rhodora[n]	E	2	0.0	21.0 (6-36)	11.0 (4-18)	0.0	2.0 (0-4)	34.0 (24-44)
Canada thistle[i]	A	3	5.4 (1-8)	7.9 (0-21.6)	6.3 (2-12)	0.0	7.5 (2-14.4)	27.0 (9-48)
Dandelion[i]	A	1	0.0	20.0	0.0	0.0	0.0	20.0
Fireweed[i]	O	4	0.6 (0-2.4)	7.6 (0-26.4)	3.2 (0-9.6)	0.3 (0-1)	7.0 (0-12)	18.6 (4-50.4)
Wild rose[n]	R	7	2.2 (0-12)	8.7 (0-48)	1.1 (0-8)	1.4 (0-4)	2.0 (0-10)	15.4 (3.6-48)
Yellow s. clover[i]	F	3	0.0	8.0 (3-18)	0.0	0.0	5.3 (0-12)	13.3 (3-22)
St. John's Wort[i]	C	1 3	0.2 (0-2)	1.0 (0-6)	5.6 (0-24)	0.8 (0-10)	4.8 (0-24)	12.3 (1-36)
Vetch[i]	F	1 1	2.9 (0-8)	2.1 (0-8)	0.3 (0-3.1)	0.6 (0-2.4)	5.9 (2-16.8)	11.9 (3.6-26.4)
White s. clover[i]	F	5	0.0	8.7 (2-18)	0.0	0.0	1.4 (0-4)	10.1 (2-22)
Alfalfa[i]	F	6	0.0	7.9 (0-33.6)	0.2 (0-1)	0.0	1.3 (0-6)	9.4 (0-33.6)
Red clover[i]	F	1 4	1.3 (0-6)	2.6 (0-12)	1.2 (0-12)	0.1 (0-2)	4.2 (0-24)	9.4 (1-36)
Tansy[i]	A	1	0.0	0.0	4.0	0.0	4.0	8.0
White clover[i]	F	3	0.0	3.5 (0-8)	0.0	0.0	1.0 (0-3)	4.5 (2.4-8)
Golden clover[i]	F	3	1.0 (0-3)	0.0	2.4 (0-6)	0.0	0.7 (0-2)	4.1 (1.2-8)
Chokecherry[n]	R	1	0.0	0.0	0.0	0.0	4.0	4.0
Yarrow[i]	A	1	0.0	0.0	2.0	0.0	0.0	2.0
Toadflax[i]	S	1	0.0	0.0	0.0	0.0	2.0	2.0
Bull thistle[i]	A	1	1.0	0.0	0.0	0.0	0.0	1.0
Average			0.8	7.5	3.7	0.3	2.9	15.2
Number of plant species visited			9	15	13	6	17	21

[1]Superscript 'n' indicates plant is native to New Brunswick while superscript 'i' indicates plant is invasive (non-native or exotic) (Munro et al. 2014)

Figure 1. *Bombus* visitation to flowering plants along lowbush blueberry field margins on New Brunswick's Acadian Peninsula from 25 May 2012 until 22 August 2012. Duration of observed visits in days and number of sites with observed visits are indicated. Observations were not recorded during blueberry bloom (early to mid-June).

Flowering Plant	Duration of Observed Visitations by *Bombus*										Total range of days with observed visits	Number of sites observed
	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early August	Mid August	Late August		
		(Blueberry bloom)										
Rhodora	✓										8	1
Dandelion	✓										1	1
Chokecherry				✓							1	1
Red clover				✓	✓	✓	✓	✓	✓	✓	70	2
Vetch				✓	✓	✓	✓	✓			50	3
Wild rose				✓	✓	✓	✓				22	3
Golden clover				✓	✓						6	1
White clover				✓	✓						6	2
White s. clover					✓	✓	✓	✓			29	2
Yellow s. clover					✓	✓	✓				27	2
Alfalfa						✓	✓	✓	✓		38	1
Brambles						✓					1	1
Fireweed							✓	✓	✓		27	1
St. John's Wort							✓	✓	✓	✓	34	3
Canada thistle							✓	✓	✓		20	1
Toadflax							✓				1	1
Goldenrod							✓	✓	✓	✓	23	3
Bull thistle								✓			1	1
Buckwheat								✓	✓	✓	14	1
Yarrow									✓		1	1
Tansy										✓	1	1

et al. 2009; Cameron et al. 2011; Colla et al. 2012; Williams et al. 2014) but we demonstrate which flowering plants are foraged upon by individual *Bombus* species, potentially guiding management decisions to boost these pollinators.

Flowering plant visitation by bumble bees largely matched previous studies (Dramstad and Fry 1995; Backman and Tiainen 2002; Colla et al. 2010; Moisan-Deserres et al. 2014; Bushmann and Drummond 2015; Drummond et al. 2017). The five bee species visited many plants, likely due to their generalist nature (Delaplane and Mayer 2000; Thorp et al. 2002). Of the 21 flowering plants recorded, only four are considered native to the Maritime region (Munro et al. 2014). 'Bumblebee economics' implies that bees optimize their foraging behaviour to maximize reproductive and nutritional success (Heinrich 2004), and therefore floral visitation is also likely to shift over the season in order to maximize nectar and pollen rewards from flowers (Thorp et al. 2002; Heinrich 2004). It is possible that buckwheat was frequently visited as it provided food at a time in the season when other flowers such as sweet clover were no longer flowering, particularly at the one site buckwheat was planted, and buckwheat may have provided a high concentration of flowers compared to other plants, making foraging more efficient. Research on nutritional requirements of bumble bees is lacking compared to honey bees, but by extrapolating nutritional requirements (e.g., Somerville 2000; Somerville 2001), buckwheat does not supply adequate protein to bumble bees for larval development. Despite this, *Bombus terricola* visited buckwheat more than any other plant, suggesting buckwheat could provide an important, concentrated food source to this bee and potentially play a role in *Bombus terricola* conservation through floral plantings.

Brambles including blackberries and raspberries (Rosaceae family) grow naturally and could be retained along field margins after clearing land for blueberry development; further study into food provision by brambles for bees is warranted. Only rhodora and dandelion were visited by bees before blueberry bloom along field margins. Rhodora bloom often extends into lowbush blueberry bloom and may compete with this crop for pollinators, or may supplement nourishment needs; further investigation is needed to clarify this. Lowbush blueberry pollen does not provide adequate protein for honey bees (Somerville 2000; Pernal and Currie 2001), and nutritious flowering plants before, after, and even during blueberry bloom may be essential to optimize bee health. Dandelion does not require pollinators, and therefore does not benefit from attracting bees through plentiful nectar and/ or pollen provision. Honey bee brood production on dandelion pollen has been found to be poor (Loper and Berdel 1980), potentially due to inadequate pollen protein content. In contrast, buckwheat is cross-pollinated (Oplinger et al. 1989) and may require more attractive nectar or pollen to entice insect pollinators, potentially explaining the high bee visitation observed. In lowbush blueberry-growing regions, however, spring forage is often lacking, and any food supply can be helpful to bees, particularly newly-emerging queens. Additionally, dandelions are within the Asteraceae family, and could provide protection from parasitism (Spear et al. 2016), although this has yet to be tested for bumble bees. Specialization by certain solitary *Osmia* bees (Hymenoptera: Megachilidae) on Asteraceae pollen in Colorado, USA was found to reduce parasitism by *Sapyga* wasps (Hymenoptera: Sapygidae); the trade-off of poor quality pollen from aster flowers was the protection from natural enemies (Spear et al. 2016). Bumble bee visitation to plants in the Asteraceae family was high overall, including to goldenrod and Canada thistle. Although Canada thistle and goldenrod are poor providers of nectar and crude protein in the pollen, their simple structure may have appealed to inexperienced and inefficient foraging bees (Pernal and Currie 2001; Heinrich 2004).

Planting or retaining the most frequently visited flowers along blueberry field margins may provide valuable floral resources for bees at critical times (Kevan 1999; Drummond et al. 2017), but minimizing invasion of these flowers into blueberry fields and the subsequent need for weed control is important for plants including fireweed, Canada thistle and goldenrod. Buckwheat was particularly appealing for declining *Bombus terricola* populations as it was frequently visited by this bee and is relatively easy to establish by blueberry growers. Buckwheat can be controlled in its planting to minimize invasion into crop fields, and is able to tolerate low soil pH and poor soil fertility (Oplinger et al. 1989), typical of lowbush blueberry land (Agriculture and Agri-Food Canada 2011). As an annual, buckwheat may be more enticing to plant by a blueberry grower than a perennial as an introduction to habitat management. However, a recent study in Maine on bumble bee attraction to clover plantings near blueberry field edges, the majority of which were biennial or perennial in nature (Venturini et al. 2017), suggested a mixture of annuals and perennials may be best suited to support a diversity of bees.

Early-flowering plants are important for maintaining bee populations, as early-emerging bumble bee queens require a food source to initiate a colony (Delaplane and Mayer 2000; Thorp et al. 2002). Only rhodora and dandelion

received bee visits before blueberry bloom in our study. It is possible that bees were able to forage on surrounding trees, such as maple (Stubbs et al. 1992), but these trees were not present within our study transects. A New Brunswick study examining the planting of willows (*Salix* spp.) (Salicaceae) to support pollinators demonstrated numerous willow species could provide nectar and pollen to support bees early in the season (Ostaff et al. 2015).

Lowbush blueberry fields can host diverse bee communities that differ temporally throughout the season, and flowering plants must therefore be available outside of blueberry bloom (Bushmann and Drummond 2015; Cutler et al. 2015; Groff et al. 2016). The greatest bee abundance is found at the forest/ field interface (Cutler et al. 2015), suggesting that field margin management of floral resources can cater to large bee communities. When canola (*Brassica* spp.) fields in Alberta, Canada were surrounded with 15% pastureland within 800 m of field edges, there were significantly more bumble bees observed, demonstrating the importance of undisturbed habitat surrounding agricultural crop fields to support bumble bees throughout the season (Morandin et al. 2007). Field size also impacts bumble bee abundance; there were significantly more bumble bees in small highbush blueberry fields in Michigan, USA compared to large fields (Isaacs and Kirk 2010). As lowbush blueberry development continues to expand, growers should consider landscape characteristics to optimize conditions for wild bees. The potential provision of nesting and overwintering sites by field margin flower refuges (Kevan 1999; Delaplane and Mayer 2000; Backman and Tiainen 2002; Jesson et al. 2014) could be an additional avenue to explore, as well as habitat management for other beneficial insects, including alternative pollinators (e.g., butterflies) and natural enemies (e.g., beetles) (Dramstad and Fry 1995; Fiedler et al. 2008). More investigation on this whole-systems approach could be beneficial to blueberry growers seeking to address pollination and pest control simultaneously. Further study is needed to evaluate the best implementation techniques to provide forage for bumble bees without distracting pollinators from blueberry pollination.

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