Impact of habitat restorations on pollinators in Metro Vancouver Parks

Elizabeth Elle, Hannah Gehrels, and Lindsey Button
Simon Fraser University
eelle@sfu.ca

SFU

metrovancouver

Executive Summary

- Pollinators are essential to the reproduction of over 87% of flowering plants worldwide
- Invasive plants can disrupt plant-pollinator interactions, and are one of the causes of native pollinator decline
- Metro Vancouver's Ecological Health Action Plan of 2011 acknowledged the need to supplement ecosystem services and support pollinator populations
- We assessed pollinators and plants in restored and non-restored areas within parks in Metro-Vancouver
- Metro Vancouver restorations increased pollinator abundance by 30% and species richness by 26% relative to non-restored areas
- Some native plants are especially good at supporting pollinators and should be used in future restoration efforts

October 2014

Background

Pollinator decline

Pollinators provide essential ecosystem services by facilitating the reproduction of over 87% of the world's flowering plants (Ollerton et al. 2011). However, multiple factors have led to the decline in pollinators worldwide (Kearns et al. 1998). To prevent further declines, the needs of pollinators must be considered, and the main consideration is food availability (flowers) throughout the season of pollinator activity (early Spring to late Summer).

The threat of invasive species

The spread of invasive species is facilitated by anthropogenic disturbance associated with urban growth, and this spread modifies the structure and stability of communities (Hierro et al. 2006, Kneitel and Perrault 2006). Not only do invasive plants alter the composition of native plant communities by outcompeting native species for nutrients, water, and light (Abraham et al. 2009), they also compete with native species for access to pollinators (Traveset and Richardson 2006). This competition between native and invasive plants can result in reduced seed and fruit production by native plants. Invasive plants can also reduce pollinator diversity because when they form monocultures (e.g. Himalayan blackberry) there is a reduction of the total time forage is available for bees (limited to the short bloom time of the invasive species). Pollinators whose normal period of activity does not overlap with the invasive will be excluded from the area. Non-native pollinators (including honey bees) can also be of concern, as they can outcompete native pollinators for access to floral resources (Thomson 2004). In sum, the presence of non-native plant and pollinator species can disrupt plant-pollinator interactions, and is therefore linked to native pollinator diversity loss (Kearns et al. 1998).

Purpose

Assessing ecological restorations for pollinators

Ecological restorations have been used by Metro Vancouver Parks to prevent native species loss and to re-establish aspects of ecosystem function. In most cases, restorations involved removal of invasive species (often growing in near-monoculture conditions) and replanting with a diverse mixture of native plants. Although some restorations have been assessed for their impact on some forms of wildlife (birds, voles) the importance of habitat restoration for pollinators had not been assessed. Because the Ecological Health Action Plan of 2011 acknowledged the need to supplement ecosystem services and support pollinator populations, we partnered with Metro Vancouver in 2013 to assess the pollinators using restored areas at 11 sites in 8 parks.

Actions

Paired restored and un-restored sites

We conducted this study from April 24-August 22, 2013 in 8 parks (Appendix Figure 1 and Table 1). Each of the 11 sites included a pair of plots, one restored and one control, with plots matched in shape and area. One location (BB-2) was an old-field restoration, while the remainder were shrub-based restorations. Plots were an average of 187m apart from each other (range: 30-440m, Table 1). Bees are considered "central place foragers", foraging for pollen and nectar and returning to a central nest site. Solitary bees forage, on average, 200-400m from their nests, and social bees like bumble bees and honey bees forage further (Greenleaf et al. 2007). We therefore considered our paired control and restored plots to be sampling the same pollinator community, and that we were assessing pollinator foraging 'choices'. We also sampled at a 12th site (Lower Seymour Conservation Reserve), and a third plot at Colony Farm (the berm planted in 2011 near the Vancouver Avian Research Centre) but did not include these plots in our statistical comparison of control to restored because the paired plots available were not similar enough for an accurate comparison. These additional plots are included in the species lists and other summaries.

Vegetation and pollinator sampling

Details of vegetation and pollinator sampling methods are included in the Appendix. We estimated floral abundance and flowering plant species richness only from potentially pollinator-attractive plants with open flowers (grasses, ferns, trees were ignored although they can be important parts of restoration efforts). We then sampled floral visitors (hereafter pollinators) directly from flowers using nets. Two individuals collected pollinators for 15 minutes (30 min total per sample) on each of the control and restored plots at a site; each site was sampled approximately every two weeks. We then compared abundance and species richness of plants and pollinators between control and restored plots using analysis of variance (ANOVA). The analysis included site, year of restoration, and date of sample to control for variation due to these factors. We predicted that abundance and richness of both plants and pollinators would be higher in restored compared to control plots.

Findings

Metro Vancouver's pollinator community is diverse

We netted 3617 pollinators across all Metro Vancouver sites, comprising 142 species (73 species of bees, 39 of flower flies, and the remainder a mix of wasps, other flies, butterflies, etc.). We made no assumption about effectiveness of these different floral visitors but as visit rate is a good predictor of pollination success (e.g. Sahli and Conner 2006), it is worth noting that 89% of visits were by bees and 6% by flower flies, with only 5% of recorded visits by the remaining 30 species observed. A species-by-site matrix (including sites not in the paired control/restored comparison) is in Appendix Table 4.

Restored sites have higher abundance and richness of plants and native pollinators

Plant and pollinator abundance and richness were higher in restored plots, richness significantly so when year of restoration, site, and time of sampling were controlled for in the analysis (Figure 1; values by treatment and site Appendix Table 2). For pollinators that could be categorized as native or introduced, we found that 62% of those collected in restored plots were native, compared to 47% native in control plots.

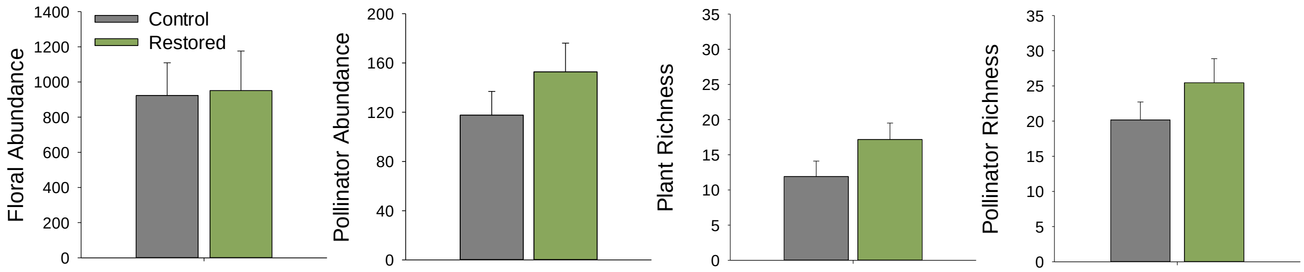
Himalayan blackberry is common and visited by both native and introduced insects

Restorations included a large number of introduced plant species; 54% of the flowers counted in restored plots were from non-native plants (70% in control plots; see also Appendix Table 3). Himalayan blackberry (*Rubus discolor*) produces a large number of flowers, was frequently present in restored plots, and was often dominant in control plots. We collected more insects (438, 12% of all observations) from Himalayan blackberry than any other single plant species. This was in proportion to flower production (12% of all flowers across all plots were Himalayan blackberry). Of collected insects, about half (217, 49.5%) were native, mostly bumble bees and small sweat bees. Of the remaining (introduced) insects collected on Himalayan blackberry, 163 of 221 were honey bees (*Apis mellifera*).

Pollinator-attractive plants

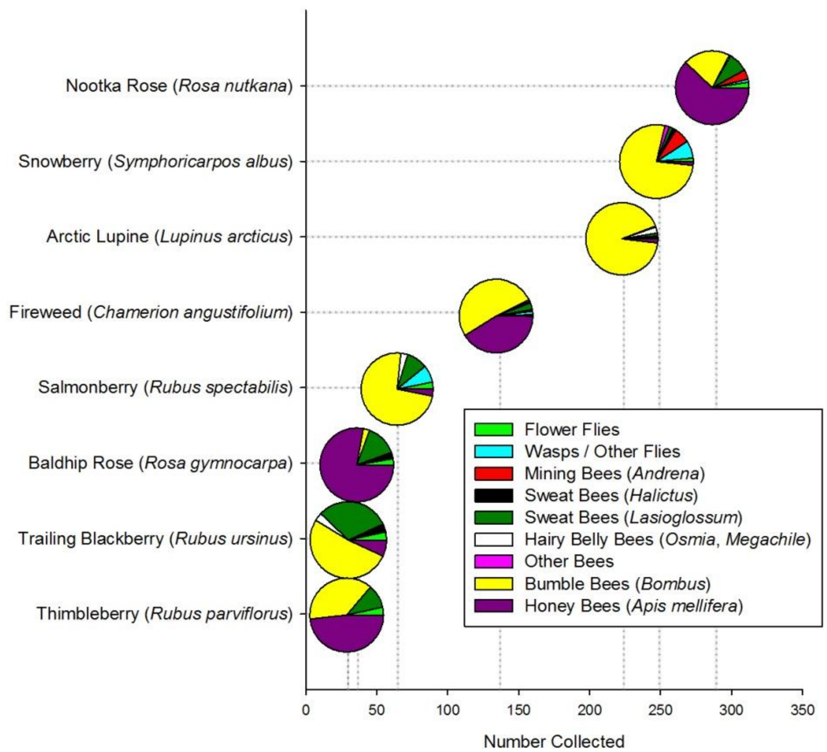
Considering all plots and sites, we found the most pollinator-attractive native plants to include roses (Nootka rose, baldhip rose), snowberry, various species of *Rubus* (salmonberry, thimbleberry, trailing blackberry), fireweed, and arctic lupine (Figure 2, next page). These 8 species accounted for less than 10% of flowers available (including invasive plant flowers) but received 27% of observed pollinator visits. Other native plants that were visited disproportionate to their flower production included yarrow (*Achillea millefolium*), pearly everlasting (*Anaphalis margaritacea*), red-osier dogwood (Cornus stolonifera), beach strawberry (*Fragaria chiloensis*), salal (*Gaultheria shallon*), common avens (*Geum aleppicum*), black twinberry (*Lonicera involucrata*) and American cranberrybush (*Viburnum trilobum*).

Figure 1



Flower/plant and pollinator abundance and richness were higher in restored plots. (note: graphs are on different scales).

Figure 2



The total number of pollinators collected for 8 pollinator-attractive native plants. The diversity of visiting pollinators is displayed in a pie chart for each plant, with each pollinator group represented by a different color. All sites and both treatments are included in the data. Plants ideal for pollinators are those on which we caught a large number of individuals from a diverse array of pollinator groups (e.g. snowberry, salmonberry). Because honey bees are not native to North America, plants with a high proportion of visits by honey bees (in purple) may not be ideal for restoration.

Summary

Habitat restorations in Metro Vancouver Parks benefit wild pollinators

In general, pollinator communities are expected to track plant communities that provide food resources (Potts et al. 2004, Hennig and Ghazoul 2011). We found that richness of plants and pollinators was higher after restoration, as has been found by other researchers (Carvell et al. 2007, Hopwood 2008). Although abundance of flowers and bees also increased with restoration, these differences were not significant. In addition to a greater number of pollinator species present after restoration, there was also a higher frequency of native pollinators collected in restored plots. Our data therefore show that habitat restoration in Metro Vancouver Parks is beneficial to wild pollinators.

Flower types that are good for pollinators

The plant species used by the greatest diversity of pollinators tend to have wide open flowers with easy access to nectar and pollen, the resources female bees collect to feed their offspring. Roses, *Rubus* species (salmonberry, thimbleberry, trailing blackberry), yarrow, dogwood, and common avens all are in this category. Less accessible flowers include lupines, which require a heavy pollinator to push open the petals to access pollen, and black twinberry, which has a long nectar tube making it accessible only by long-tongued bees or hummingbirds. Bumble bees are capable of acquiring resources from both of these relatively inaccessible flower types and are responsible for these plants being visited relatively more than we would expect based on the number of flowers available.

The most common invasive plant species in the study, Himalayan Blackberry (*Rubus discolor*), also has easy-access flowers and produces large numbers of them, but was visited in proportion to flower production. When restorations include removal of Himalayan blackberry, planting of native plants with easy-access flowers can provide important food resources for native pollinators. New plantings should also provide a continuous source of flowers from spring to fall; the lack of resources early and late in the season is likely one reason why locations heavily invaded by Himalayan blackberry have lower species richness than restored areas in parks.

Nest sites are readily available in Metro Vancouver Parks

In addition to requiring food, all pollinators require locations to build nests. Nest sites are notoriously difficult to assess and few researchers attempt it (see Potts et al 2005; Wray and Elle submitted). The presence of several different families of bees with different nest requirements (ground, wood, both excavators and species that use existing cavities; see caption on Appendix Table 4) suggests nest sites are readily available in Metro Vancouver Parks. Continued restoration of plant communities should therefore be sufficient to support native pollinator communities.

Management Recommendations for Pollinators

1. Expand efforts to remove Himalayan blackberry and other invasives, and monitor restorations for re-invasion.

2. Native plant restorations should include the following to benefit pollinators:

    a. Species with flowers with easy access to nectar and pollen for pollinators, and those we have shown are visited disproportionately to flowers available:
        - *Achillea millefolium*, yarrow
        - *Anaphalis margaritacea*, pearly everlasting
        - *Chamerion angustifolium*, fireweed
        - *Cornus stolonifera*, red-osier dogwood
        - *Fragaria chiloensis*, beach strawberry
        - *Gaultheria shallon*, salal
        - *Geum aleppicum*, common avens
        - *Lonicera involucrata*, black twinberry
        - *Lupinus arcticus*, arctic lupine
        - *Rosa gymnocarpa*, baldhip rose
        - *Rosa nutkana*, nootka rose
        - *Rubus parviflorus*, thimbleberry
        - *Rubus spectabilis*, salmonberry
        - *Rubus ursinus*, trailing blackberry
        - *Symphoricarpos albus*, snowberry
        - *Viburnum trilobum*, American cranberrybush

    b. Continuous flowers from spring to fall. Early-flowering species that were not in our data due to our start time (but which we recommend) include:
        - *Mahonia aquifolium*, tall Oregon grape
        - *Ribes sanguineum*, red-flowering currant

Acknowledgements

Field and lab assistance was provided by J. Avery, A. Fortune, and T. Haapalainen. We are indebted to Metro Vancouver for funding for the project and access to Parks. Additional funding was provided by the Natural Sciences and Engineering Research Council (NSERC) of Canada, via an NSERC-USRA award to HG and a Discovery Grant to EE. Report cover photo of endangered *Bombus occidentalis* on snowberry by Lindsey Button.

Works Cited

Abraham, J. K., J. D. Corbin, and C. M. D. Antonio. 2009. California native and exotic perennial grasses differ in their response to soil nitrogen, exotic annual grass density, and order of emergence. Plant Ecology 201:445–456.

Carvell, C., W. R. Meek, R. F. Pywell, D. Goulson, and M. Nowakowski. 2007. Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. Journal of Applied Ecology 44:29–40.

Greenleaf, S. S., N. M. Williams, R. Winfree, and C. Kremen. 2007. Bee foraging ranges and their relationship to body size. Oecologia 153:589–96.

Hennig, E. I., and J. Ghazoul. 2011. Pollinating animals in the urban environment. Urban Ecosystems 15:149–166.

Hierro, J. L., D. Villarreal, Ö. Eren, J. M. Graham, and R. M. Callaway. 2006. Disturbance Facilitates Invasion: The effects are stronger abroad than at home. The American Naturalist 168:144–156.

Hopwood, J. L. 2008. The contribution of roadside grassland restorations to native bee conservation. Biological Conservation 141:2632–2640.

Kearns, C. A., D. W. Inouye, and N. M. Waser. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. Annual Review of Ecology and Systematics 29:83-112.

Kneitel, J. M., and D. Perrault. 2006. Disturbance-induced changes in community composition increase species invasion success. Community Ecology 7:245–252.

Litt, A. R., and R. J. Steidl. 2010. Insect assemblages change along a gradient of invasion by a nonnative grass. Biological Invasions 12:3449–3463.

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

Potts, S. G., B. Vulliamy, S. Roberts, C. O'Toole, a Dafni, G. Ne'Eman, and P. Willmer. 2005. Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. Ecological Entomology 30:78–85.

Potts, S. G., B. Vulliamy, S. Roberts, C. O'Toole, A. Dafni, G. Ne'eman, and P. G. Willmer. 2004. Nectar resource diversity organises flower-visitor community structure. Entomologia Experimentalis et Applicata 113:103–107.

Sahli, H. F. and J. K. Conner. 2006. Characterizing ecological generalization in plant-pollination systems. Oecologia 148:365-372.

Thomson, D. 2004. Competitive interactions between the invasive European honey bee and native bumble bees. Ecology, 85:458–470.

Traveset, A., and D. M. Richardson. 2006. Biological invasions as disruptors of plant reproductive mutualisms. Trends in ecology & evolution 21:208–16.

Valdovinos, F. S., R. Ramos-Jiliberto, J. D. Flores, C. Espinoza, and G. López. 2009. Structure and dynamics of pollination networks: the role of alien plants. Oikos 118:1190–1200.

Wray, J., and Elle, E. submitted. Flowering phenology and nesting resources influence pollinator community composition in a fragmented ecosystem. Landscape Ecology.

APPENDICES
IMPACT OF HABITAT RESTORATIONS ON POLLINATORS IN METRO VANCOUVER PARKS

Elizabeth Elle and Hannah Gehrels
Simon Fraser University
eelle@sfu.ca

Part 1: Field Methods

Vegetation sampling

Only potentially pollinator-attractive plants with open flowers were sampled for this research, and so grasses, ferns, etc were not included. Floral abundance and flowering plant species richness for each plot were sampled on the same days pollinators were assessed. For the seven sites that had plots with linear hedgerows, vegetation was sampled along a 50 m transect along the hedgerow edge, with samples taken at 1-m intervals. The line intercept method was used such that the number of open flowers intersecting a 1m line perpendicular to the transect (into the hedgerow) was counted by species. For the four sites that had plots with approximately rectangular areas, the vegetation was sampled using the same line intercept method, but at regular intervals along 5 parallel transects placed in a stratified random manner. Length of transects varied with the size of the plot. Densely clustered floral heads (e.g. Asters, Mustards) were considered a single "flower" for the purposes of this study.

Pollinator sampling

We caught floral visitors (hereafter pollinators) with hand-nets directly from flowers. We sampled each site approximately every two weeks on warm, sunny days (temperature ≥ 14, low wind, and sunny to partly cloudy). Pollinators were collected for 15 minutes by each of two people (= 30 minutes per plot per sample date), in the morning (1000 – 1200h), midday (1200 – 1400h) or late afternoon (1400 – 1600h). Paired plots were sampled on the same day, and most sites were sampled three times in each of the three times of day, for a total of 9 sample episodes (4.5 hours) per site. Two of the sites (BB-1, BB-2) were not restored or accessible until after we had started sampling, so were sampled for 7 sample episodes only (3.5 hours). Lower Seymour Conservation Reserve was sampled only 5 times and not included in analysis because the restored plot was too different in elevation and surrounding landscape from the control plot for the comparison to be useful. At this location there was an additional plot where honey bees were kept; the site was included in our design because the pollinators in this location were of interest to LSCR. All bees were identified to species except those for which revised keys were not available. Flies and wasps were identified at least to family, but to genus or species where possible.

Part 2: Figures, Tables, and species lists

Figure 1: Map of study sites; each park included one restored and one non-restored control plot.

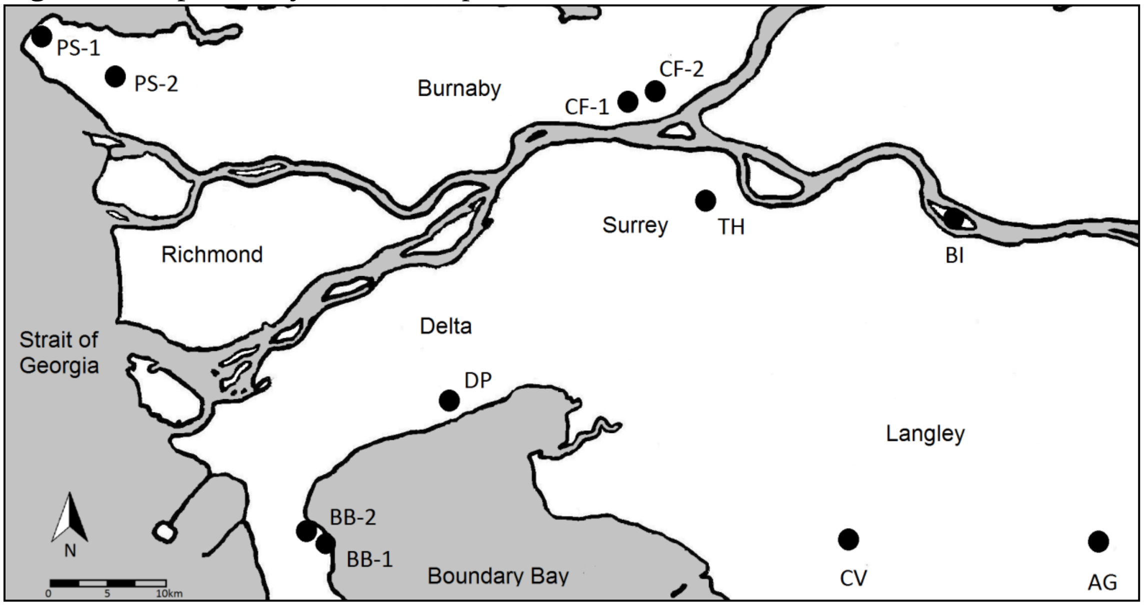


Table 1: Information about parks included in the study.

Park Name	Code	Plot Shape	Location	Year restored	Inter-plot distance
Aldergrove Regional	AG	Hedgerow	49°00’34.21”N 122°27’03.72”W	2002-3	100m
Boundary Bay (Centennial Beach)	BB-1	Polygon	49°00’57.15”N 123°02’28.33”W	2013	165m
Boundary Bay (Old Field)	BB-2	Polygon	49°01’02.55”N 123°03’07.59”W	1990s	380m
Brae Island Regional	BI	Hedgerow	49°10’30.90”N 122°34’48.55”W	2007	190m
Colony Farm Regional (Near entry)	CF-1	Hedgerow	49°14’27.41”N 122°48’30.74”W	1999	120m
Colony Farm Regional (Avian rsch)	CF-2	Hedgerow	49°14’21.46”N 122°47’49.64”W	2007	300m
Campbell Valley Regional	CV	Hedgerow	49°01’03.15”N 122°39’48.44”W	2002-4	60m
Delta Heritage Air	DP	Hedgerow	49°04’44.15”N 122°56’16.16”W	2005	120m
Pacific Spirit (Anthropology Museum)	PS-1	Hedgerow	49°16’14.86”N 123°15’32.20”W	2006-7	440m
Pacific Spirit (Camosun Bog)	PS-2	Polygon	49°15’13.54”N 123°11’46.24”W	2010	30m
Tynehead Regional	TH	Polygon	49°11’02.30”N 122°44’59.36”W	2012	260m

Table 2. Plant and pollinator abundance and richness (number of species) by site and treatment.

		Plants		Pollinators	
		Abundance	Richness	Abundance	Richness
Aldergrove Regional	Control	533	5	157	11
	Restored	655	18	229	28
Boundary Bay (Centennial Beach)	Control	1584	24	120	29
	Restored	1385	33	242	49
Boundary Bay (old field)	Control	114	10	105	18
	Restored	1349	15	116	17
Brae Island Regional	Control	574	14	85	18
	Restored	373	10	65	16
Colony Farm Regional (Near entry)	Control	905	18	121	25
	Restored	871	15	58	13
Colony Farm Regional (Avian rsch)	Control	555	4	94	14
	Restored	608	9	80	17
Campbell Valley Regional	Control	2139	14	98	23
	Restored	431	10	128	22
Delta Heritage Air	Control	930	4	63	8
	Restored	811	14	131	21
Pacific Spirit (Anthropology Museum)	Control	535	14	53	20
	Restored	2940	28	288	39
Pacific Spirit (Camosun Bog)	Control	607	3	108	18
	Restored	697	14	137	22
Tynehead Regional	Control	1683	21	290	38
	Restored	339	23	207	36
Control Average		**924**	**12**	**118**	**20**
Restored Average		**951**	**17**	**153**	**25**

Table 3. Data on plant species sampled in the plots at all sites. Abundance is the number of flowers or inflorescences counted in 50, 1-m line transects on each sample date, combined over time. Site names in Table 1, except LSCR (Lower Seymour Conservation Reserve), which was not included in analysis. C = control plot, R = restored plot. R* in CF2 was the berm restored in 2011 (not included in analysis). The "A" treatment in LSCR was where honey bees are kept. Origin of plants was either: N = Native, or I = Introduced.

		AG		BB1		BB2		BI		CF1		CF2			CV		DP		LSCR			PS1		PS2		TH	
	Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
Achillea millefolium	N			6	2																						
Achillea sp.	I			21		13																					
Amelanchier alnifolia	N	7	38																		2		3				
Anaphalis margaritacea	N																			5	5						
Anthemis cotula	I				16																						
Anthemis sp.	I				29																						
Arctostaphylos uva-ursi	N																				60						
Artemisia sp.	I				8																						
Barbarea orthoceras	N																										25
Bellis perennis	I																					20					
Brassica campestris	I						64																				
Brassica sp. 1	I				2																						
Brassica sp.2	I																										4
Cakile maritima	I				197																						
Cardamine oligosperma	N		60		8																						
Cerastium glomeratum	I													3	13											15	
C. semidecandrum	I						1				2																
Chamerion angustifolium	N					35						12															5
Cichorium intybus	I																						37				
Cirsium arvense	I		6		11		13																8				
Cirsium vulgare	I		4	1	8		14																16				
Convolvulus sepium	N																					3	6		18	1	1
Cornus stolonifera	N	25	14	52					47	6		4						58									
Craetaegus douglasii	N	343									39							11									
Crataegus monogyna	I																	9							71		
Crepis capillaris	I				5														1	15						2	
Cytisus scoparius	I			623																126							
Digitalis purpurea	I													9						21	1					3	
Epilobium ciliatum	N		64		61		7							131											2	2	8

		AG		BB1		BB2		BI		CF1		CF2			CV		DP		LSCR			PS1		PS2		TH	
	Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
Erodium cicutarium	N				7																						
Fragaria chiloensis	N				49																						
Galeopsis tetrahit	I		7										177														
Galium aparine	I			16		36	2	59														37	954		16		94
Gaultheria shallon	N																										31
Geranium robertianum	I																					6	43				
Geranium sp.	I					2	0																				
Geum aleppicum	N													7													
Geum macrophyllum	N							2		8	7			14								7			58	3	
Hesperis matronalis	I										17																25
Hieracium aurantiacum	I									2										1	2						
Holodiscus discolor	N								12														66				
Hyacinthoides sp.	I																					4			2		23
Hypericum anagalloides	I			78						9					8	3											
Hypochaeris radicata	I			10	1	3				2					13			32	12	121	44		18			69	2
Impatiens parviflora	I							39																			
Lamium purpureum	I			1																			59				
Lathyrus palustris	N			86	57																			26			
Lepidium densiflorum	I				17																						
Leucanthemum vulgare	I							16							3											7	
Lonicera involucrata	N		59					2			62			49									68				
Lotus corniculatus	I																			174	232		31			1099	17
Lupinus arcticus	N			176										90							163		1				
Lysimachia punctata	I																								20		
Lythrum salicaria	I				1																						
Mahonia aquifolium	N								28		22		57														
Malus sp.	I				3					4																	10
Matricaria discoidea	I				29						14																
Medicago lupulina	I		7	54	2	3		5	1	34												1					3
Melilotus alba	I				122																						
Montia linearis	N						47																				
Myosotis discolor	I			23		2	43				5				2												
Packera paupercula	N																						1				

		AG		BB1		BB2		BI		CF1		CF2			CV		DP		LSCR			PS1		PS2		TH	
	Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
Parentucellia viscosa	I			72																							
Physocarpus capitatus	N										3					41											
Plantago lanceolata	I				7					42													8			8	
Polygonum lapathifolium	I				14																						
Polygonum persicaria	I				40		12						8	21													34
Potentilla anserina	N			4		8																					
Prunella vulgaris	I		3										43		2								9			1	
Prunus emarginata	N																						38				
Ranunculus acris	I														361	73							59		3	12	
Ranunculus repens	I	7	3	27				10	27	58	536			51	179	23						105	144		383	367	9
Ribes sanguineum	N								54									341									
Rosa gymnocarpa	N		125																				1				
Rosa nutkana	N	151	34	11	66			11	7					1		37		124					109				
Rubus discolor	I			180		7	15	244		467	36	454	58		333	138	197	57				90		560		13	17
Rubus laciniatus	I			13												10	311	15									
Rubus parviflorus	N																	31				3	13			1	7
Rubus spectabilis	N							40		4	66		82							40		2	18		14		1
Rubus ursinus	N																			7						6	
Sambucus racemosa	N		3								46	85	21				19										
Senecio sylvaticus	I				329																						
Solanum dulcamara	I				1																						
Sonchus arvensis	I				9																						
Sonchus oleraceus	I				2																						
Sonchus sp.	I				20													2									
Spiraea douglasii	N			4	28					6			40		3	73	403	15									
Stellaria graminea	I														1134												
Symphoricarpos albus	N		136		230			141	189							32							770		56		2
Symphytum sp.	I																	62									
Tanacetum vulgare	I			3	4			1		9													54				
Taraxacum officinale	I							1	5	18	10											40	7		7	11	3
Tellima grandiflora	N																					208					
Trifolium pratense	I						205			11					6				244	3	10					16	
Trifolium repens	I		17	2			299	3	3	11	6			75	1	1		5	559	43	2	9	14			45	14

		AG		BB1		BB2		BI		CF1		CF2			CV		DP		LSCR			PS1		PS2		TH	
	Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
Veronica beccabunga	N												122	49	81										1	1	
Veronica serpyllifolia	N		73							169																	
Viburnum trilobum	N		2																								
Vicia cracca	I									45								49					385	21	46	1	
Vicia hirsuta	I			27		5	551																				2
Vicia sativa	I			94			76																				2
Floral Abundance		533	655	1584	1385	114	1349	574	373	905	871	555	608	500	2139	431	930	811	816	556	521	535	2940	607	697	1683	339
Species Richness		5	18	24	33	10	15	14	10	18	15	4	9	12	14	10	4	14	4	11	10	14	28	3	14	21	23
% introduced (abundance)		1	7	79	63	62	96	66	10	79	72	82	47	32	96	58	55	28	100	91	56	58	63	96	79	99	76

Table 4. Data on pollinator species sampled in the plots at all sites. Site names in Table 1, except LSCR (Lower Seymour Conservation Reserve), which was not included in analysis. C = control plot, R = restored plot. R* in CF2 was the berm restored in 2011 (not included in analysis). The "A" treatment in LSCR was where honey bees are kept. Origin of pollinators is: N = Native, I = Introduced, or ? = unknown. Andrenidae and Halictidae primarily nest in the ground in holes excavated by female bees. Megachilidae primarily nest in existing holes in wood. *Bombus* spp. use existing holes (e.g. abandoned rodent nests) either underground or near the ground surface.

				AG		BB-1		BB-2		BI		CF-1		CF-2			CV		DP		LSCR			PS-1		PS-2		TH	
			Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
Apoidea (Bees)																													
Andrenidae	*Andrena*	*amphibola*	N				1											1											
(Mining bees)	*Andrena*	*angustitarsata*	N																								1		
	Andrena	*candida*	N		1		1																						
	Andrena	*columbiana*	N																				2						
	Andrena	*crataegi*	N																								3		
	Andrena	*cressonii*	N																						1				
	Andrena	*hemileuca*	N																						1				
	Andrena	*miserabilis*	N		2													1									55		
	Andrena	*nigrocaerulea*	N				4																						
	Andrena	*nivalis*	N	1							1														5		12		
	Andrena	*prunorum*	N				2																		2				
	Andrena	*rufosignata*	N																					1					
	Andrena	*saccata*	N				1									1									2	4			
	Andrena	*salicifloris*	N			1	1				2							1								1			
	Andrena	*trevoris*	N		3		1			1	5														5		1		
	Andrena	sp. 10	N			1																			1				
Apidae	*Anthophora*	*terminalis*	N			2			1																				
(Digger, bumble,	*Apis*	*mellifera*	I	143	111	31	38	47	35	21	10	20	5	46	10	3	9	31	37	57	54	23	27	17	21	20	9	72	34
honey bees)	*Bombus*	*californicus*	N			4	7		25			1			1	2			2	12									
	Bombus	*fernaldae*	N		1		1																						
	Bombus	*flavifrons*	N		41	15	14	2	10	7	4	20	7	2	16	33	1	3		6	20	10	72	3	97	17	26	19	49
	Bombus	*impatiens*	I			2	11	3	5			1							6	5					1				1
	Bombus	*melanopygus*	N			8	2	1			1		3			1	1				17	5	4	1	8	5		4	2
	Bombus	*mixtus*	N	1	21	19	54	31	20	24	25	21	29	25	17	69	10	17	9	13	23	7	23	1	63	9	2	56	19
	Bombus	*occidentalis*	N			1																							
	Bombus	*vosnesenskii*	N			5	2	5		3		8		2	7	5		2	6	2	7		12	3	11	4		13	23

				AG		BB-1		BB-2		BI		CF-1		CF-2			CV		DP		LSCR			PS-1		PS-2		TH	
			Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
	Ceratina	*acantha*	N		1	2	4	1	1	7		2		4	7		1		1	1				1				1	10
	Melissodes	*microsticta*	N				5		1																				
	Melissodes	sp. 1	N			1	2																						
	Nomada	sp.	N																								1		
<u>Halictidae</u>	*Agapostemon*	*texanus*	N				8					1													1				
(Sweat bees)	*Halictus*	*confusus*	N						1			2				1	2					7	6	1	3		1		3
	Halictus	*rubicundus*	N		1	1	1	1	2	2	2	6	1			1	4	1		1		1		1	3	7	5	7	3
	Lasioglossum	*brunneiventre*	N																			2	6						
	Lasioglossum	*cressonii*	N							1		1		1				1		1							2	1	1
	Lasioglossum	*knereri*	N	1	2																								
	Lasioglossum	*laevissimum*	N		1		2					1			1	4	1									29	1		1
	Lasioglossum	*macroprosopum*	N																		1	1	1	1					
	Lasioglossum	*nevadense*	N																			1							
	Lasioglossum	*pacatum*	N		3		3				2	5		4	1	7	3	5	1	1		17	4	6	11	4		26	11
	Lasioglossum	*punctatoventre*	N	1	3																		1					1	
	Lasioglossum	*zonulum*	I		14	1	5		3	6	2	1		2	1	3	42	43		1			1	7	6	1		28	7
	Lasioglossum	sp. 1	N														1								2				
	Lasioglossum	sp. 2	N								1			1															
	Lasioglossum	sp. 3	N							1												2							
	Lasioglossum	sp. 4	N	2	1		2		1			1	1				7	1		14	24	32	27		1			14	11
	Lasioglossum	sp. 5	N																			1							
	Lasioglossum	sp. 6	N																			1							1
	Sphecodes	sp.	N				1																1						
<u>Megachilidae</u>	*Anthidium*	*manicatum*	I				5									2							1		7			4	1
(Hairy belly bees)	*Coelioxys*	*porterae*	N																						1	1			
	Heriades	*carinatus*	N		4																								
	Hoplitis	*producta*	N											3															
	Megachile	*frigida*	N			1	1										1											1	
	Megachile	*gemula*	N																					1				1	2
	Megachile	*melanophaea*	N			5	1									1							2		2			1	
	Megachile	*montivaga*	N					1																					

	Megachile	*perihirta*	N			1	5	1																					
	Megachile	*relativa*	N				4	1																					
	Megachile	*rotundata*	I				1																		1				
	Osmia	*albolateralis*	N			2																							
	Osmia	*bucephala*	N			2	3																						
	Osmia	*caerulescens*	I																						8		1		
	Osmia	*dolerosa*	N							1				1	1		2											3	1
	Osmia	*hurdi*	N						3																				
	Osmia	*lignaria*	N														1												
	Osmia	*odontogaster*	N			1																							
	Osmia	*pusilla*	N			1																				1		1		1	1
	Osmia	*tristella*	N																									1	
Colletidae	*Colletes*	*fulgidus*	N				1															1							
(Plasterer bees)	*Colletes*	*kincaidii*	N			1	4															1		1	5				
	Hylaeus	*basalis*	N				2																						
	Hylaeus	*modestus*	N						1	1																		2	1
Syrphidae	*Allograpta*	*micrura*	I																										1
(Flower Flies)	*Bacchus*	*elongatus*	N										1																
	Brachypalpus	*oarus*	N																						1				
	Cheilosia	sp.	?	2	1																								
	Dasysyrphus	*venustus*	I																				1						
	Epistrophe	*xanthostoma*	N																										1
	Eristalis	*dimidiatus*	N																					1					1
	Eristalis	*tenax*	I		1																2	1	5						1
	Eristalis	*transversa*	I		1												1	1										1	
	Eumerus	*narcissi*	N																		3								
	Eupeodes	*lapponicus*	I												2								4						
	Eupeodes	*latifasciatus*	I	1	1		1	2				3	2		1	1	3	1					1	2		1		2	8	2
	Helophilus	*intentus*	N									1																	
	Helophilus	*latifrons*	N					1							1				1										
	Lejops	sp.	?	1			2																						
	Melanostoma	*mellinum*	I							2	3	12	1		6	1		1						1			3	4	
	Meliscaeva	*cinctella*	I							1													4			1	1		1

				AG		BB-1		BB-2		BI		CF-1		CF-2			CV		DP		LSCR			PS-1		PS-2		TH	
			Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
	Merodon	*equestris*	I		1							1												2					2
	Orthonevra	*stigmata*	N		1																								
	Platycheirus	*hyperboreus*	I			1						2		1														1	
	Platycheirus	sp.	N					1																1	1				
	Platycheirus	sp. 3	N										2																
	Platycheirus	sp. 4	N																									1	
	Platycheirus	sp. 5	N								1		1					1											
	Platycheirus	sp. 6	N														1	1											
	Scaeva	*pyrastri*	I													1													
	Sericomyia	*slossanae*	N																									1	1
	Sphaerophoria	*philanthus*	N					3				3				1					2							1	1
	Sphaerophoria	*pyrrhina*	N			1			1													1							
	Sphaerophoria	*sulphuripes*	N				1													2	1	1						2	2
	Sphaerophoria	*weemsi*	N									4			5			1											
	Spilomyia	*interrupta*	N																				1		1				
	Syritta	*pipiens*	I				1											9											
	Syrphus	*opinator*	N										2	1	1	1						5	2	1	3			1	
	Syrphus	*ribesii*	I		1																	4						1	1
	Toxomerus	*marginatus*	N		1												1			3								1	
	Toxomerus	*occidentalis*	N														1	2								1		1	4
	Villa	sp. 1	N																		1		1			1			
	Volucella	*bombylans*	I		1		1																						
Other Flies	*Gymnosoma*	*fuliginosa*	n																				1						
	Tachina	sp. 1	?																		1	1							
	Trichopoda	sp. 1	?																									1	
	Calliphoridae		?	1								2		1						2					1				
	Muscidae		?	3	6			2			2		3			1	3	2		1		1	7	1	3		4	5	2
	Sarcophagidae		?				2									1									2			1	1
	Tachinidae		?						2																				
	Other Diptera		?		2							1			2		1					1							

				AG		BB-1		BB-2		BI		CF-1		CF-2			CV		DP		LSCR			PS-1		PS-2		TH	
			Origin	C	R	C	R	C	R	C	R	C	R	C	R	R*	C	R	C	R	A	C	R	C	R	C	R	C	R
Other hymenoptera	*Ancistrocerus*	sp.	?																						1			1	1
(wasp, ant, sawfly)	*Bembix*	*americana*	N			2	18	1	4																				
	Bembix	*occidentalis*	N			6	2			2																			
	Crabronidae	sp. 1	?				3			2																			
	Crabronidae	sp. 4	?				1																						
	Crabronidae	sp. 8	?									1																	
	Dolichovespula	*maculata*	N								1																		
	Ectemnius	sp.	?																		1								
	Eumenes	sp.	?				1											1											
	Polistes	*gallica*	I			1	1													2									
	Symphyta	sp. (sawfly)	?														1												
	Vespula	sp.	?		2			1		2	3							2							1	1	4		
	Formicidae	(ant)	?																									1	
	Ichneumonidae		?																	1					2				
	Sphecidae		?			1	5																		1				
	Other wasp		?																										1
Other	Coleoptera	(beetles)	?																									2	
	Hemiptera	(bugs)	?																								1	1	
(Butterflies)	*Aglais*	*milberti*	N																			1							
	Papilio	*rutulus*	N																						1				
	Pieris	*rapae*	I				3			1										1				2					3
(Hummingbird)	*Selasphorus*	*rufus*	N																							1			
		Abundance		157	229	120	242	105	116	85	65	121	58	94	80	141	98	128	63	131	154	142	205	53	288	108	137	290	207
		Species Richness		11	28	29	49	18	17	18	16	25	13	14	17	22	23	22	8	21	14	29	23	20	39	18	22	38	36