Bumble Bee Surveys in the Columbia River Gorge National Scenic Area of Oregon and Washington

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Abstract

Bumble bees (*Bombus* spp.) are among the most charismatic of our native bees, providing the essential service of pollination to countless species of wildflowers and crops. Yet, many North American bumble bees have declined precipitously in recent years, including the western bumble bee (*B. occidentalis*), Morrison's bumble bee (*B. morrisoni*) and the suckley cuckoo bumble bee (*B. suckleyi*). All three of these species are sensitive species, or have pending sensitive species status, on U.S. Forest Service and Bureau of Land Management land in Oregon and Washington. While we have a fair understanding of the gross distribution of bumble bee species in Oregon and Washington, the fine distribution of most species throughout these states is largely unknown as many areas have been relatively unsurveyed. The Columbia River Gorge National Scenic Area (CRGNSA) is a nearly 300,000 acre Scenic Area set aside by Congress for its natural and scenic resources, with explicit goals to inventory, protect, and enhance natural resources. Yet, to our knowledge, no comprehensive bumble bee surveys have taken place in the CRGNSA, so basic information about their local distributions are lacking. Since pollination is an essential ecosystem function, efforts to document baseline information about the pollinator community will enhance management and conservation goals within the Scenic Area. We surveyed 11 locations in the CRGNSA three times during the flight season and documented 15 species of bumble bees from 887 individuals visiting 55 species of flowering plants. No sensitive species or pending sensitive species were detected during the surveys. The results of this survey will enable the CRGNSA to consider the conservation needs of bumble bees in future management decisions while providing important baseline information.

Introduction

Pollinators are essential to our environment. The ecological service they provide is necessary for the reproduction of nearly 75 percent of the world's flowering plants, including more than two-thirds of the world's crop species (Klein et al. 2007; Ollerton et al. 2011). Increasingly, however, the essential service of pollination is at risk (Berenbaum et al. 2007). Habitat loss, alteration, and fragmentation, as well as pesticide use and infectious diseases are all contributing to pollinator declines (Williams et al. 2009; Graystock et al. 2013; Vanbergen & Initiative 2013; Goulson et al. 2015).

In recent years, the story of vanishing bees has become a common theme in news reports and popular culture. In most cases, these reports have focused on the disappearance of honey bees, a non-native species introduced to North America from Europe. The larger, untold story is that while honey bees are a popular and iconic species, other important native bees are also suffering, and in some cases, their fates are far worse. This is particularly true of some of North America's native bumble bees (Hatfield et al. 2014a). One bumble bee, *Bombus affinis* – native to the Eastern United States, was recently added to the Endangered Species Act as an endangered species (USF&WS 2017). Bumble bees are among our most important pollinators of high-value crops such as blueberries, cranberries, and clover (which is essential forage for dairy cows), and they are the exclusive insect pollinators of most tomato varieties. They are essential to the reproduction of countless native wildflowers – creating the seeds and fruits that feed wildlife as diverse as songbirds and grizzly bears. This is especially true at higher elevations and latitudes as bumble bees have physiologies that are well adapted to the cold and wet weather conditions found in those locations (Heinrich 2004; Goulson 2010).

The western bumble bee was once one of the most common bumble bees in the Western United States – so common that it had been domesticated for commercial use (Evans et al. 2008). Since the mid-1990s, however, it has undergone a precipitous and widespread decline; this species is notably absent from most areas in Washington, Oregon, and California west of the Cascade-Sierra Crest, where it was once common and widespread (Hatfield et al. 2015).

The conservation status of the western bumble bee is currently under consideration by the USF&WS. It has no official status under the U.S. Endangered Species Act (ESA), although it has been petitioned for endangered species status (DOI USFWS 2017). Additionally, biologists from the Xerces Society and other institutions, as part of the International Union for Conservation of Nature (IUCN) Bumblebee Specialist Group, evaluated this species as Vulnerable on the IUCN Red List (Hatfield et al. 2015). NatureServe lists this species as G2G3, or Imperiled/Vulnerable, and suggests that it has declined by 70->90% in the short term and 50-90% in the long term (NatureServe 2017). The Oregon Biodiversity Information Center assigned the western bumble bee a rank of S1/S2, or Critically Imperiled/Imperiled, within the state (ORBIC 2016). The U.S. Forest Service recently listed the western bumble bee as a Sensitive species in Oregon and Washington (ISSSSP 2017, also see Jepsen 2013 for more information).

A rangewide analysis including more than 73,000 records of eight bumble bee species suggests that the western bumble bee has undergone a 28% range decline between recent (2007-2009) and historic (1900-1999) time periods (Cameron et al. 2011). A separate analysis comparing the current (2002-2012) and historic (1805-2001) ranges of the western bumble bee (using a database of more than 200,000 records of 47 species of North American bumble bees developed by Williams et al. 2014) suggests that this species has declined from 50% of its historic range (Hatfield et al. 2015). Hatfield et al. (2015) also found that relative abundance of the western bumble bee has declined by 75%. Declines were found to be most significant at the edges of this species' range, specifically along the West Coast of the continental United States (Hatfield et al. 2015). In Oregon, Washington, and California, western bumble bee populations are currently largely restricted to high elevation sites east of the Sierra-Cascade crest (Xerces Society 2012), and the species is rarely found in the western portions of these states where it was once common.

Recent taxonomic changes to the western bumble bee may change its conservation status, making the southern subspecies *Bombus occidentalis occidentalis* more susceptible to extinction risk. A recent analysis of mitochondrial DNA by Williams et al. (2012) suggested that the western bumble bee could be divided into northern (including Alaska and northern British Columbia) and southern (including the western contiguous United States and southern British Columbia) populations, each of which have distinctive haplotype groups. These distinct haplotypes correspond with morphological differences; shorter pile (hair) has been noted in the southern populations and longer pile in the northern populations (Williams et al. 2012). Later taxonomic work formally distinguished two subspecies of the western bumble bee (Sheffield et al. 2016). The southern subspecies *B. o. occidentalis* – which includes all individuals from southern British Columbia south to Washington, Oregon, and California, and to the eastern extent of its range – has been lost from an estimated 62% of its historic range (Hatfield et al., unpublished data).

The hypothesized cause of the decline of this and other closely related species is that a disease (the fungal pathogen *Nosema bombi*) likely spread from commercial, domesticated bumble bees to wild bumble bees (Cameron et al. 2016). *Nosema bombi* has been shown to reduce colony size in bumble bees and reduce the production of reproductive members of the colony (Otti & Schmid-Hempel 2007, 2008). Regardless of the cause of the initial decline, extant populations of the western bumble bee in Oregon and Washington are likely small and are currently threatened by a variety of different land management practices. A body of research indicates that bumble bees are especially vulnerable to extinction because of their unique life history (reviewed in Zayed 2009) – that risk is further intensified in small populations. In addition, it is possible that the remaining populations of western bumble bees are resistant to the pathogen that may have initially caused the observed declines and if so, these populations will be essential to the species' sustainable recovery. It is critically important to protect any remaining populations of western bumble bees from the risks they currently face.

Although we know that the western bumble bee has declined dramatically across its range (which covers parts of more than 15 states and provinces), we know very little about its detailed status and distribution within the states of Oregon and Washington. Thousands of historic records exist for the western bumble bee in a wide variety of locations, yet despite efforts in many areas to find this species, the western bumble bee has only been observed in a few places in recent years. In Oregon, this includes areas near Mt. Hood, Mt. Ashland, the Zumwalt Prairie, Crater Lake, and McKenzie Pass (The Xerces Society et al. 2016). In Washington, the western bumble bee has been observed primarily in the southern Cascades roughly from Mt. Rainier to Mt. Adams - east of the Cascade Crest, and in the NE portion of the state, north of Spokane. There are a handful of observations in and near Seattle, as well as on the Olympic peninsula (The Xerces Society et al. 2016). In order to be able to conserve and manage habitat for this and other species, land managers must know current distributions.

In addition to the western bumble bee, there is growing evidence that additional western species may be experiencing population declines (Hatfield et. al. 2014a). Of particular concern in Oregon and Washington are *Bombus suckleyi* and *B. morrisoni*. *B. suckleyi* is a cuckoo bumble bee that has only been documented as breeding in nests of *B. occidentalis* (Williams et al. 2014). This species has experienced declines of nearly 80% and is listed on the IUCN Red List as Critically Endangered (Hatfield et al. 2015). *B. morrisoni* is historically present throughout the Desert West, especially at higher elevations (Williams et al. 2014). It has experienced declines of nearly 60% throughout its range and is listed as Vulnerable on the IUCN Red List (Hatfield et al. 2014b). While there are no historic records of these two species within the boundaries of the CRGNSA, historic records from other regions, coupled with Maxent climate models, suggest that the western half of the CRGNSA is climatically suitable for *B. suckleyi* and the eastern half is climatically suitable for *B. morrisoni* (Williams et al. 2014).

The Columbia River Gorge National Scenic Area (CRGNSA) is an 80-mile corridor spanning both Oregon and Washington along the Columbia River through the heart of the Cascade Mountains; it provides the only sea level passage through the Cascades. This area was designated as a National Scenic Area in 1986, encompassing nearly 300,000 acres of land in a patchwork of public and private land holdings that are managed by the U.S. Forest Service and the Columbia River Gorge Commission. The Scenic Area Act directs the Columbia River Gorge Commission and the U.S. Forest Service to inventory, protect, and enhance natural resources (Columbia River Gorge National Scenic Area 1986). To our knowledge, no

comprehensive survey of bumble bees, or other pollinators, has been conducted within the boundaries of the CRGNSA. Pollinators are an essential part of any functioning ecosystem and are integral to the natural resources of the CRGNSA, as well as to existing and future agricultural operations within the CRGNSA. In order to properly protect and enhance natural resources that include pollinators, a comprehensive survey of existing resources is necessary. Surveys within the CRGNSA will establish important baseline information as well as potentially identify management opportunities that are consistent with the existing Management Plan (USDA, Columbia River Gorge Commission 2011).

Range maps published by the IUCN show 23 species whose ranges overlap with the CRGNSA (see Appendix C). However, several of these species would only be expected at higher elevations: *Bombus frigidus, B. sylvicola,* and *B. balteatus* (Williams et al. 2014). This puts the likely maximum number of species within the CRGNSA at 20, but several of these are likely rare, either naturally (*Bombus insularis* - the only nearby record is on Mt. Hood at much higher elevation), and/or due to decreasing populations (*B. occidentalis*, *B. suckleyi*, and *B. morrisoni* - see above). Historic collection records place nine species of bumble bees within the boundaries of the CRGNSA (Richardson 2017) (see Table 1). It is likely that a comprehensive survey effort will increase the documented number of species within the boundaries of the CRGNSA and provide important baseline information about the pollinator community.

Of additional interest is the potential range expansion of *Bombus impatiens* into Washington. *B. impatiens* is the only species of bumble bee available for commercial pollination services in the United States and is regularly shipped throughout North America despite the fact that it is only native to the Eastern United States. While Oregon prohibits the importation of non-native bumble bees into the state, Washington has no similar restrictions. Citizen scientists have helped to confirm that *B. impatiens* has become established in the northwest portion of Washington (starting in 2017) and southern British Columbia (starting in 2013) (The Xerces Society et al. 2016) likely due to escaped individuals from importation by commercial greenhouse operations. Regular surveys throughout the region will help document its potential range expansion. While it is not expected that this species will have expanded this far south by 2017, documenting lack of detection this year could become important should *Bombus impatiens* begin to expand its range throughout the Pacific Northwest in future years.

Methods

Site Selection

In March of 2017, in consultation with CRGNSA biologists Brett Carré and Robin Dobson, we used historic bumble bee observations, aerial photography, local knowledge of flora and phenology, and maps to select a subset of 20 possible areas to target for bumble bee surveys. These areas covered the CRGNSA from the eastern to western extent with sites in both Oregon and Washington. We made site visits in early May 2017 and selected 11 final sites at which to conduct surveys (see Site Descriptions below and Figure 1). A stated goal of the surveys was to use historic western bumble bee (*Bombus occidentalis*) observations to help guide site selection. To our knowledge there are eight *B. occidentalis* observations within the CRGNSA at four different locations from 1923 to 1985 (the most recent sighting of which we are aware); three of those locations are on private lands (Richardson 2017). The only observation on USFS land was at the Larch Mountain picnic area, which is largely forested, and was not deemed a suitable site for comprehensive bumble bee surveys due to lack of open spaces and consistent

foraging habitat. Given the amount of time since the last detection (22 years) and lack of high quality habitat at that site, we did not resurvey historic *B. occidentalis* sites, but rather focused on nearby areas with high quality forage to increase the chances of detection (see Figure 1). We considered all lands within the CRGNSA for these surveys (not just federal lands) as all lands within the boundary of are subject to the conditions of the CRGNSA Management Plan.

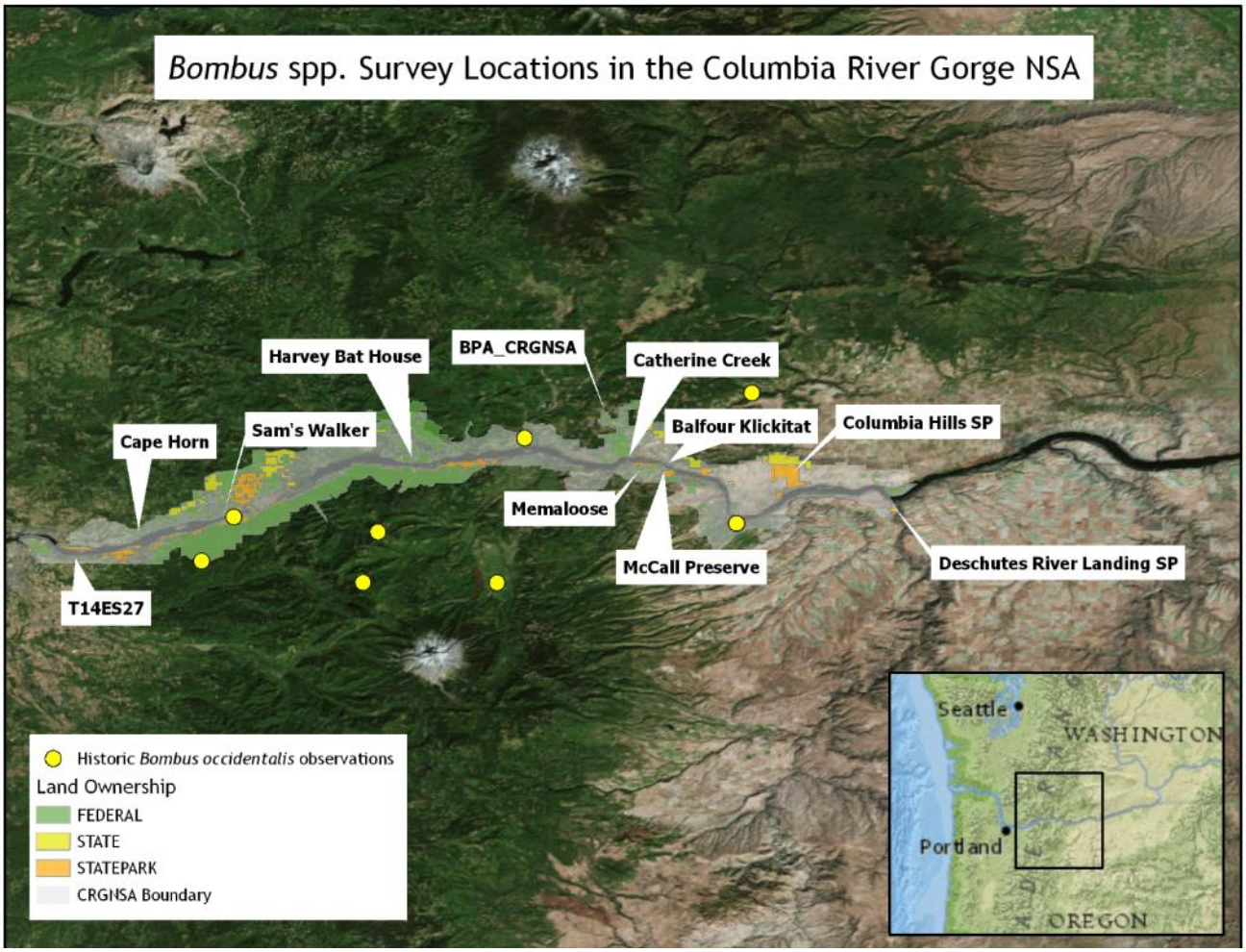

Figure 1: Map of surveyed sites within the CRGNSA.

Site Descriptions (west to east)

T14ES27 (USFS)

This site is an open meadow surrounded by active cattle pasture lands (private) and forest. The habitat can loosely be considered a xeric grassy meadow dominated by non-native vegetation, though there is a wet riparian area on the northern border of the site. The most dominant plants throughout the survey period were meadow grasses, but the meadow is nearly surrounded by Himalayan blackberry (*Rubus armeniacus*) and intermixed with the grasses were Canada thistle (*Cirsium arvense*), tansy ragwort (*Senecio jacobaea*), red clover (*Trifolium pretense*), birdsfoot trefoil (*Lotus corniculatus*) and hairy vetch

(*Vicia villosa*). There were very few flowering plants in the early part of the season (early June), but abundant flowering resources during the second (late June) and final (late July) visits to the meadow.

Cape Horn (USFS)

This site is a mix of open grassy meadows intermixed with what appears to be a restoration effort on the southern edge of the property with a deciduous oak canopy. A large plantation of snowberry (*Symphoricarpos alba*) and flowering red current (*Ribes sanguineum*) was located adjacent to the site. Flowering resources were abundant on the property throughout the flight season. Noted native vegetation of known interest to bumble bees and other pollinators included fireweed (*Chamaenerion angustifolium*), varileaf phacelia (*Phacelia heterophylla*), lupine (*Lupinus* sp.), and Oregon grape (*Mahonia aquifolium*). There were also several non-native plant species that provide flowering resources for bumble bees and other pollinators including tansy ragwort (*Senecio jacobaea*) and common tansy (*Tanacetum vulgare*). Notably, the grassy areas surrounding the path on the northern edge of the property were mowed sometime between 29 June and 25 July. While this did not remove a tremendous amount of flowering resources from the site, it is possible that it disturbed nesting sites for bumble bees – both those that nest under the surface of the ground and those that are known to nest on the surface of the ground. It also could disturb butterfly and moth larvae. As those grassy areas are managed by the USFS, delaying the mowing until after the flight season, or mowing in a patchier distribution (only mowing ~1/3rd of the site at a time) would provide a better opportunity for pollinators and other wildlife to thrive (see Hatfield et al. 2012 for more details).

Sam's Walker (USFS)

This site is composed of riparian habitat along the Columbia River mixed with open meadow areas. The area surveyed was an open xeric grassy area at the northeastern portion of the recreation area. The area was surrounded by Himalayan blackberry, which was interspersed with snowberry, especially near the western edge of the survey area. There was very little in bloom in early June, but flowering resources increased throughout the flight season and were abundant in late June and late July. Although the site was dominated by non-native vegetation (Himalayan blackberry, Canada thistle, oxeye daisy – *Leucanthemum vulgare*, and meadow knapweed – *Centaurea pratensis*), there were a number of important native plants interspersed as well including Nootka rose (*Rosa nutkana*), selfheal (*Purnella vulgaris*), and snowberry.

Harvey Bat House (USFS)

This site is a disturbed open meadow area dominated mostly by non-native vegetation. There is also a pond at the western end of the site. It is surrounded by a mixed conifer forest and adjacent to another larger meadow system with a pond to the east. The dominant flowering vegetation in the meadow included oxeye daisy, meadow knapweed, Canada thistle, and vetch. Interspersed were bull thistle (*Cirsium arvense*), selfheal, and Himalayan blackberry. While flowering resources were scarce in early summer, there were abundant flowering resources throughout the remainder of the sampled flight period.

BPA_CRGNSA (BPA/USFS)

This site is managed by the Bonneville Power Administration (BPA) in a power line right of way. This is a relatively high elevation site (~600 m) with diverse native vegetation and some non-native vegetation

mixed in. There was high quality forage for bumble bees and other pollinators throughout the sampled flight season. Dominant native vegetation included lupine, Oregon grape, spreading dogbane (*Apocynum androsaemifolium*), larkspur (*Delphinium menziesii*), snowberry, and phacelia (*Phacelia hastata*). Other important non-native pollinator plants included bachelor's buttons (*Centaurea cyanaus*), and St. John's wort (*Hypericum perforatum*). There was a small timber operation adjacent to the site in late July, but this did not appear to affect the ecological integrity of the sampling area, though it could have an impact on nesting habitat for bumble bees and other pollinators. The site is surrounded to the east by a continuing BPA corridor with abundant flowering resources, to the west by a river gorge (likely providing abundant foraging and nesting resources), and to the north and south by mixed confer forest.

Catherine Creek (USFS)

This site is a popular recreation area with abundant native flowering resources – at least in the early part of the year. The site dried out quickly, but patches of flowering resources remained throughout the sampled flight period, which provided ample food resources for bumble bee and other pollinators. Abundant early season resources (May) included small headed clover (*Trifolium microcephalum*), and rosy plectritis (*Plectritis congesta*). There was not much in bloom in the middle of the flight season (mid-June), but a large patch of pea (*Lathyrus latifolius*) and hairy vetch provided ample resources. Later in the season (July), the site was dominated by large patches of narrow-leaf milkweed (*Asclepias fascicularis*). This site is surrounded by large open spaces and by the riparian areas of the Columbia River to the south. There appears to be ample nesting and flowering resources nearby.

Memaloose (USFS)

This site is located south of the Memaloose overlook at the top of the hill. It is a xeric site, but with abundant flowering resources in the early and middle part of the flight period, though the site did not appear floristically diverse. In the early season (May), the site was dominated by arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine, and vetch. In June the site was dominated by bachelor's buttons and yarrow (*Achillea millefolium*), and by July all that remained were some bachelor's buttons and a few common yampah (*Perideridia montana*). This site is surrounded by mixed conifer forest as well as an oak savanna area with intermittent streams. There appears to be abundant flowering and nesting resources available for pollinators.

Tom McCall Nature Preserve (Nature Conservancy/USFS/Mayer State Park)

This site is a patchwork of ownership which includes the Nature Conservancy, Mayer State Park, and national forest lands. These three groups also manage the Preserve in partnership. It provided ample flowering resources throughout the sampled flight period. This is a varied site, but largely sits on a plateau above the Columbia River surrounded by canyons below and open hillsides above. Dominant early vegetation included arrowleaf balsamroot and lupine, while later during the sampled flight period the site was dominated with vetch and bachelor's buttons. By mid-July, flowering resources were more widely dispersed, but still available. This site is quite exposed and is subject to high winds flowing through the CRGNSA.

Balfour Klickitat (USFS)

This is a recreation site at the confluence of the Klickitat and Columbia Rivers. It had abundant and diverse flowering resources throughout the sampled flight period. The site is mixed conifers and oak

savannah. There is a lot of non-native vegetation, but it appears a restoration effort to reintroduce additional native species is underway. In early May, dominant flowering plants included arrowleaf balsamroot, lupine, and California poppy (*Eschscholzia californica*). In June, the site was dominated by large patches of vetch. By July many of the restoration plants were the dominant flowering plants – these included Oregon sunshine (*Eriophyllum lanatum*) and penstemon (*Penstemon* sp.), with a minority of lupine mixed in. With the varied terrain and vegetation there appeared to be abundant flowering and nesting resources nearby.

Columbia Hills SP (Washington State Parks)

This site is a large open area with xeric meadows and riparian areas. Because of changes in vegetation, we ended up sampling two different areas at this site. The first area was sampled in early May and was a xeric area dominated by arrowleaf balsamroot and woodland star (*Lithophragma parviflorum*). Upon the June visit there was very little in bloom, which led us to survey the riparian area to the east of the original site. The riparian area was dominated by oceanspray (*Holodiscus discolor*), Douglas hawthorn (*Crataegus douglasii*) and white sweet clover (*Melilotus alba*) with a minority of narrow-leaf milkweed nearby. Later in July, the same riparian area had few flowering resources, but there was some white sweet clover and bull thistle patchily distributed through the area.

Deschutes River Landing SP (Oregon State Parks)

This site is a mix of xeric grasslands/plateaus and riparian corridors at the confluence of the Deschutes and Columbia Rivers. The original site selected for survey (xeric plateau) in May had almost no flowering resources by the third visit in July, so we changed the location to a riparian corridor along the Deschutes River. In May, the xeric plateau was dominated by a mix of arrowleaf balsamroot, lupine, and antelope bitterbrush (*Purshia tridentata*). In June, the dominant flowering plant was vetch. In July along the riparian corridor, there were sparse populations of flowering plants including chicory (*Cichorium intybus*), teasel (*Dipsacus fullonum*), bull thistle, blanket flower (*Gaillardia aristata*) and dense-flowered willowherb (*Epilobium densiflorum*). While many of the plants found at this site are non-native, they appear to provide sufficient flowering resources throughout the sampled flight period.

Bumble Bee Surveys

Once a site was selected, we chose an approximately one-hectare area with abundant flowering resources within which to conduct bumble bee surveys. To capture the bulk of the flight season and the majority of the significant flowering resources at each site we visited each site three times between May 1st and July 31st. While the flight period may vary from year to year due to environmental fluctuations, this time period was the most productive in 2017; before May temperatures were cool and it was generally wet, after July there was very little in bloom throughout the CRGNSA. We conducted all surveys between 8:30 and 18:00 with ambient temperatures greater than 60° F and with average wind speeds below 15 mph. At each visit we sampled bumble bees for 90 minutes within the ~ 1 ha site. We captured each bumble bee in an insect net, and recorded any floral associations. We placed each bee in a plastic vial and then into a chilled cooler for later identification.

At the end of each survey period we identified and sexed each bumble bee. We collected unknown or questionable specimens and photo documented each species and gender of bumble bee at each site. We also collected at least one individual of each species detected throughout the CRGNSA (see

exception below). When possible this included both a male and female of the species. Males were not detected of all species so this was not always possible. Since we observed only queen *Bombus sitkensis* individuals, there are no specimens in the voucher collection – only photos (The Xerces Society et al. 2017). Voucher specimens are available at the Xerces Society for Invertebrate Conservation, or with CRGNSA USFS biologists. Voucher photos are available at the Xerces Society.

Results

The surveys documented fifteen different species from 887 individual bumble bees within the CRGNSA. The three most common species of bumble bee were *Bombus vosnesenskii* (341 individuals at 11 sites), *B. fervidus* (195 individuals at 10 different sites), and *B. griseocollis* (97 individuals at 5 sites). The four least common species were *B. huntii* (5 individuals at 1 site), *B. sitkensis* (4 individuals at 1 site), *B. melanopygus* (3 individuals at 1 site), and *B. centralis* (1 individual). Overall bumble bee species abundance increased with each successive visit (visit 1: 220 individuals 2: 307, 3: 360), but overall species richness decreased with each successive visit (visit 1: 14 species, 2: 12, 3: 11). The most species rich site was the Tom McCall Nature Preserve (n=10), and the least species rich site was Columbia Hills State Park (n=3). The surveys did not detect *B. occidentalis*, *B. morrisoni*, or *B. suckleyi* (Sensitive Species, or pending Sensitive Species in OR and WA) within the CRGNSA (see Appendix A).

Table 1: Bumble bee species abundance by date and location.

	Balfour Klickitat			BPA CRGNSA			Cape Horn			Catherine Creek			Columbia Hills SP			Deschutes Boat			Harvey Bat House			McCall Preserve			Memaloose			Sam's Walker			T14ES27		
Species	5/8/2017	6/21/2017	7/13/2017	5/8/2017	6/28/2017	7/20/2017	5/9/2017	6/29/2017	7/25/2017	5/9/2017	6/22/2017	7/20/2017	5/4/2017	6/21/2017	7/13/2017	5/4/2017	6/21/2017	7/13/2017	6/7/2017	6/28/2017	7/20/2017	5/4/2017	6/22/2017	7/21/2017	5/8/2017	6/22/2017	7/21/2017	6/7/2017	6/29/2017	7/25/2017	6/7/2017	6/29/2017	7/25/2017
Bombus appositus			3								2	2											19		1	3						2	1
Bombus caliginosus		1					2	9	9																	1				1	2		4
Bombus centralis		1																															
Bombus fervidus		27	1	1		1	1		4		5	5				1	13	1	2	9	6	9	29	4	24	29	6	2	1	4	3	2	2
Bombus flavidus				2		8				1										1		1		2									
Bombus flavifrons				11	3	6		5	1		1								1	4	2					1			2		3	7	
Bombus griseocollis		2	2			1				1	5	56				21		2				6	1										
Bombus huntii																5																	
Bombus melanopygus							1																								2		
Bombus mixtus				18	2	3	3	3	2	1									1		1		1				1	3		1	3	3	1
Bombus nevadensis		17	1								12	2	2		1								1										
Bombus rufocinctus			2										1	1	1							1		3									
Bombus sitkensis				4																													
Bombus vandykei		12	3		2						2			1				1					2	1	1	2	2						
Bombus vosnesenskii	3	5	22	16	4	12	2	9	26	25	13	5	1	2	4	9			2	12	55	12	3	11	2	3	21	1	2	4	6	7	41
Grand Total	**3**	**65**	**34**	**52**	**11**	**31**	**9**	**26**	**42**	**28**	**40**	**70**	**4**	**4**	**6**	**36**	**13**	**4**	**6**	**26**	**64**	**29**	**56**	**21**	**28**	**39**	**30**	**6**	**5**	**10**	**19**	**21**	**49**

The search effort documented bumble bees visiting 55 different plant species throughout the CRGNSA. The three most attractive plant species were bachelor's buttons (*Centaurea cyanus* - 139 observations from 4 sites), hairy vetch (*Vicia villosa* - 138 observations from 8 sites), and narrow-leaf milkweed (*Asclepias fascicularis* - 67 observations from 1 site). The site which had the greatest number of plant species observed as bumble bee host plants was Cape Horn (n=16). The site which had the least number of plant species observed as bumble bee host plants was Memaloose (n=4). The majority of bumble bee observations were on non-native plants (as determined by the USDA PLANTS database: USDA and NRCS

2017), (n=506 on 20 species of plants), but the species richness of bumble bees was equal on native and non-native plants (n=13) (see Appendix B).

Historically, there were records of nine different species of bumble bees in the CRGNSA (Richardson 2017). The only species that was present in historical records and not detected in our surveys in 2017 was *B. occidentalis*. These surveys add six new species records to the CRGNSA (*B. appositus, B. caliginosus, B. centralis, B. huntii, B. nevadensis,* and *B. rufocinctus*).

Discussion

These surveys represent the most thorough bumble bee surveys in the CRGNSA to date and provide important baseline information. The results of these surveys add six previously undocumented species to the CRGNSA species list, while one species that was present historically, *Bombus occidentalis*, was not detected. As expected, we did not detect *Bombus impatiens*, but given its recent establishment in northwestern Washington feel it is important to document a lack of detection within the CRGNSA in 2017. While neither historical records nor 2017 surveys are comprehensive, and should not be interpreted as such, there are notable differences in relative abundance between the two time periods (see Table 1).

Table 1: Historic and 2017 bumble bee abundance and relative abundance ranks (1 is most common, 16 is least common). A negative difference indicates a decrease in relative abundance between historic and current surveys. Green filled cells indicate a new species; red filled cells indicate a species that was present historically, but not detected in 2017. Historic data from (Richardson 2017).

	Total Abundance		**Relative Abundance Rank**		
Species	**Historic**	**2017**	**Historic**	**2017**	**Difference**
Bombus appositus	0	33	16	7	9
Bombus caliginosus	0	28	16	8	8
Bombus centralis	0	1	16	15	1
Bombus fervidus	3	195	7	2	5
Bombus flavidus	2	14	9	10	-1
Bombus flavifrons	3	51	7	4	3
Bombus griseocollis	11	97	2	3	-1
Bombus huntii	0	5	16	12	4
Bombus melanopygus	2	3	9	14	-5
Bombus mixtus	5	47	6	5	1
Bombus nevadensis	0	36	16	6	10
Bombus occidentalis	8	0	3	16	-13
Bombus rufocinctus	0	9	16	11	5
Bombus sitkensis	6	4	4	13	-9
Bombus vandykei	6	27	4	9	-5
Bombus vosnesenskii	64	341	1	1	0

Most notably *Bombus occidentalis* was historically the third most common bumble bee in collections, but was absent in the 2017 surveys despite a broad survey effort across spatial and temporal scales within the CRGNSA. This does not confirm that *B. occidentalis* is absent from the CRGNSA, but suggests that if it is present, it persists at significantly lower abundance levels than it did historically. Since the CRGNSA is generally located at lower elevations and/or west of the Cascade-Sierra crest, this is consistent with recent surveys that have only found the western bumble bee at higher elevations, east of the Cascade-Sierra crest (Rao & Stephen 2007; Hatfield et al. 2015; Rhoades et al. 2016; Sheffield et al. 2016). Occurrences from the Olympic Peninsula in Washington are the exception to this (e.g. Rhoades et al. 2016). When comparing the historical relative abundance of previously documented species to the relative abundance in the 2017 survey *B. fervidus* is more common than it was historically, and *B. sitkensis, B. melanopygus* and *B. occidentalis* are less common than they were historically (see Table 1).

The six species added to the CRGNSA are *Bombus appositus, B. caliginosus, B. centralis, B. huntii, B. nevadensis,* and *B. rufocinctus.* The presence of these species in the CRGNSA is expected based on published range maps (Williams et al. 2014), but they were all previously undocumented within the boundaries of the CRGNSA. These surveys also add 887 records of bumble bees and their floral associations (see Appendix B), all of which will help inform future management and potential restoration opportunities. Given that the first step in most conservation plans is to establish reliable detection records and habitat associations, these surveys will be useful in achieving the stated goals of the CRGNSA Management Plan and the Act itself, which include provisions for wildlife and habitat conservation.

The majority of bumble bee observations were on non-native plant species. Bachelor's buttons (*Centaurea cyanus,* n= 139 observations) and hairy vetch (*Vicia villosa*, n= 138 obs.) were the two most frequently used resources on which we observed bumble bees. Both bachelor's buttons and vetch were locally common across large areas and had extended bloom times well beyond many other observed plant species. Neither bachelor's buttons nor hairy vetch are on Oregon or Washington's noxious weed list, though another plant on which bumble bees were observed visiting regularly is—Himalayan blackberry (*Rubus armeniacus*). If management efforts are made to eradicate non-native plant species, careful attention should be paid to replacing the vast floral resource that these non-native plants are currently providing to bumble bees and other pollinators. It is important to note that quantifying floral resources at each site was beyond the scope of this study and thus the number of observations per plant species does not necessarily represent bumble bee species preferences for particular plant species (though it could). These observations may be more representative of availability of resources on the landscape - bumble bees were using the only resources that were available to them, or were more likely to be detected on plants that were more abundant at a particular site. This is worthy of further investigation.

As expected, the sites chosen as survey sites varied widely in their local and landscape attributes that may be important to bumble bees. While a thorough investigation of the specific attributes that may have contributed to bumble bee species richness and abundance was beyond the scope of this project, floral resources are a necessary component to support bumble bees. From our observations, the sites with the greatest species richness of bumble bees—Tom McCall Nature Preserve (10 species), Balfour Klickitat (9 species), and the BPA_CRGNSA site (8 species)—all had abundant and diverse floral resources

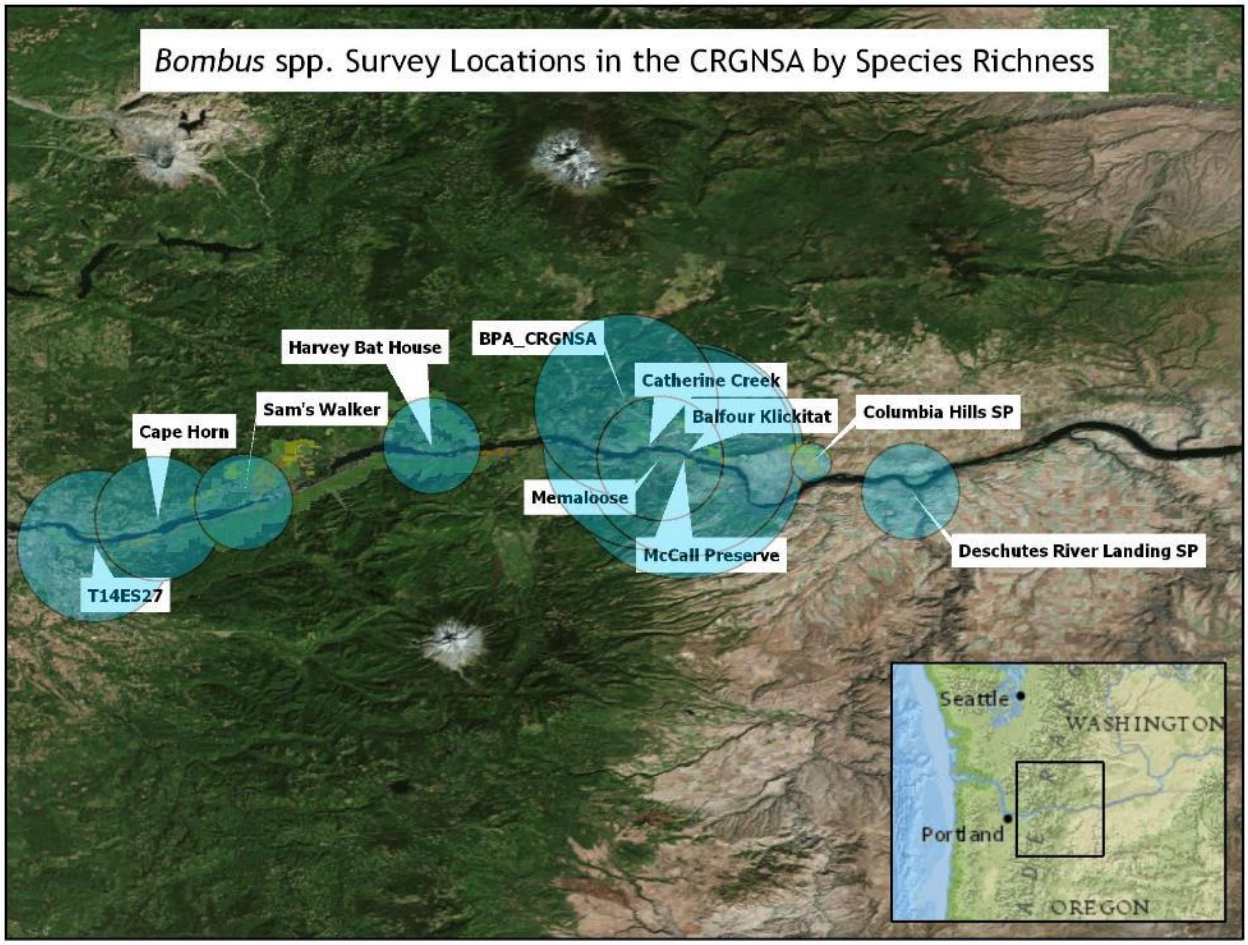

Figure 2: Number of bumble bee species by site. Each site is represented by a blue circle. The size of the circle reflects the number of bumble bee species detected at the site. The largest circle represents 10 species, and the smallest circle represents 3 species.

upon all three site visits. The sites with the lowest bumble bee species richness—Columbia Hills SP (3 species), Deschutes Boat Launch, Sam's Walker, and Harvey Bat House (all with 5 species)—had significant floral resources during parts of the flight season, but were lacking floral resources at others. Columbia Hills SP had abundant arrowleaf balsamroot in the early season, but floral resources were scarce after that. Deschutes Boat Launch State Park had abundant bitterbrush (*Purshia tridentata*) in the early season, and abundant vetch in the middle of the season, but very few floral resources at the end of the season. Both Sam's Walker and the Harvey Bat House had scarce floral resources in the early season, but had abundant blackberry and knapweed toward the end of the season. While these observations are all anecdotal, it is possible that the lack of floral resources at certain times of the season, both this year and in the recent past, contributed to low bumble bee species richness, and is worth further investigation.

In addition to the potential effect of floral resource availability, it also appears as though the sites with the highest bumble bee species richness in the CRGNSA are more centrally located near the transition from west side flora and fauna to east side flora and fauna (see Figure 2). While these are anecdotal observations, those sites situated on the far western and eastern edges of the CRGNSA generally have

lower species richness, though it is not a consistent pattern. For example, the Memaloose site was located at a similar longitude as several of the higher species richness sites, but only had 6 species - a more moderate total. Likewise, Columbia Hills SP was more centrally located than Deschutes Boat Launch SP, but only 3 species were detected at that site (the lowest species richness at any site surveyed). As such, it is likely not just longitude, nor only floral resources, but a combination of factors (including those not discussed) that contribute to bumble bee species richness in the CRGNSA. These questions warrant further investigation to help inform management and conservation goals, as well as to more clearly describe and understand bumble bee ecology in the CRGNSA.

These surveys, while not a complete picture of the bumble bee distribution, are the most comprehensive effort to document the bumble bee fauna within the CRGNSA to date. These surveys added six species to the species list for the Scenic Area, provided floral associations for nearly 900 bumble bees, and will contribute significantly to the current and future management and restoration goals shared between the USFS and the Columbia River Gorge Commission, and in concert with the Scenic Area Act. Ideally, these surveys would serve as a starting point for a long-term monitoring effort. This would provide additional information about species distribution trends, potentially document additional species to the list, and provide more information about individual species - and community - phenology. The need for long-term surveys is particularly pertinent given the human-induced Eagle Creek Fire that has burned over 48,000 acres of the CRGNSA as of this writing (InciWeb 2017). Monitoring pollinators and other natural resources in the face of future natural and anthropogenic changes will be essential to preserving the natural and scenic integrity of the Columbia River Gorge National Scenic Area.

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Appendix A: Bumble bee species richness and abundance by site

	Site	*Bombus appositus*	*Bombus centralis*	*Bombus caliginosus*	*Bombus fervidus*	*Bombus flavifrons*	*Bombus flavidus*	*Bombus griseocollis*	*Bombus huntii*	*Bombus melanopygus*	*Bombus mixtus*	*Bombus nevadensis*	*Bombus rufocinctus*	*Bombus sitkensis*	*Bombus vandykei*	*Bombus vosnesenskii*	Visit 1 Abundance	Visit 1 Richness
Visit 1	Balfour Klickitat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	**3**	**1**
	BPA_CRGNSA	0	0	0	1	11	2	0	0	0	18	0	0	4	0	16	**52**	**6**
	Cape Horn	0	0	2	1	0	0	0	0	1	3	0	0	0	0	2	**9**	**5**
	Catherine Creek	0	0	0	0	0	1	1	0	0	1	0	0	0	0	25	**28**	**4**
	Columbia Hills SP	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	**4**	**3**
	Deschutes Boat Launch	0	0	0	1	0	0	21	5	0	0	0	0	0	0	9	**36**	**4**
	Harvey Bat House	0	0	0	3	0	0	0	0	0	1	0	0	0	0	2	**6**	**3**
	McCall Preserve	0	0	0	9	0	1	6	0	0	0	0	1	0	0	12	**29**	**5**
	Memaloose	1	0	0	24	0	0	0	0	0	0	0	0	0	1	2	**28**	**4**
	Sam's Walker	0	0	0	2	0	0	0	0	0	3	0	0	0	0	1	**6**	**3**
	T14ES27	0	0	2	3	3	0	0	0	2	3	0	0	0	0	6	**19**	**6**
	Grand Total	**1**	**0**	**4**	**44**	**18**	**4**	**28**	**5**	**3**	**29**	**2**	**2**	**4**	**1**	**79**	224	14
	Number of Sites	1	0	2	8	2	3	3	1	2	6	1	2	1	1	11		

	Site	*Bombus appositus*	*Bombus centralis*	*Bombus caliginosus*	*Bombus fervidus*	*Bombus flavifrons*	*Bombus flavidus*	*Bombus griseocollis*	*Bombus huntii*	*Bombus melanopygus*	*Bombus mixtus*	*Bombus nevadensis*	*Bombus rufocinctus*	*Bombus sitkensis*	*Bombus vandykei*	*Bombus vosnesenskii*	Visit 2 Abundance	Visit 2 Richness
Visit 2	Balfour Klickitat	0	1	1	27	0	0	2	0	0	0	17	0	0	12	5	**65**	**7**
	BPA_CRGNSA	0	0	0	0	3	0	0	0	0	2	0	0	0	2	4	**11**	**4**
	Cape Horn	0	0	9	0	5	0	0	0	0	3	0	0	0	0	9	**26**	**4**
	Catherine Creek	2	0	0	5	1	0	5	0	0	0	12	0	0	2	13	**40**	**7**
	Columbia Hills SP	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	**4**	**2**
	Deschutes Boat Launch	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	**13**	**1**
	Harvey Bat House	0	0	0	9	4	1	0	0	0	0	0	0	0	0	12	**26**	**4**
	McCall Preserve	19	0	0	29	1	0	1	0	0	1	1	0	0	2	3	**57**	**8**
	Memaloose	3	0	0	30	1	0	0	0	0	0	0	0	0	2	3	**39**	**5**
	Sam's Walker	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2	**5**	**3**
	T14ES27	2	0	0	2	7	0	0	0	0	3	0	0	0	0	7	**21**	**5**
	Grand Total	**26**	**1**	**10**	**116**	**24**	**1**	**8**	**0**	**0**	**9**	**30**	**1**	**0**	**20**	**61**	**307**	**12**
	Number of Sites	4	1	2	8	8	1	3	0	0	4	3	1	0	5	10		

	Site	*Bombus appositus*	*Bombus centralis*	*Bombus caliginosus*	*Bombus fervidus*	*Bombus flavifrons*	*Bombus flavidus*	*Bombus griseocollis*	*Bombus huntii*	*Bombus melanopygus*	*Bombus mixtus*	*Bombus nevadensis*	*Bombus rufocinctus*	*Bombus sitkensis*	*Bombus vandykei*	*Bombus vosnesenskii*	Visit 3 Abundance	Visit 3 Richness
Visit 3	Balfour Klickitat	3	0	0	2	0	0	2	0	0	0	1	2	0	3	21	**34**	**7**
	BPA_CRGNSA	0	0	0	1	6	8	1	0	0	3	0	0	0	0	12	**31**	**6**
	Cape Horn	0	0	9	4	1	0	0	0	0	2	0	0	0	0	26	**42**	**5**
	Catherine Creek	2	0	0	5	0	0	56	0	0	0	2	0	0	0	5	**70**	**5**
	Columbia Hills SP	0	0	0	0	0	0	0	0	0	0	1	1	0	0	4	**6**	**3**
	Deschutes Boat Launch	0	0	0	1	0	0	2	0	0	0	0	0	0	1	0	**4**	**3**
	Harvey Bat House	0	0	0	6	2	0	0	0	0	1	0	0	0	0	55	**64**	**4**
	McCall Preserve	0	0	0	4	0	1	0	0	0	0	0	3	0	1	11	**20**	**5**
	Memaloose	0	0	0	6	0	0	0	0	0	1	0	0	0	1	22	**30**	**4**
	Sam's Walker	0	0	1	4	0	0	0	0	0	1	0	0	0	0	4	**10**	**4**
	T14ES27	1	0	4	2	0	0	0	0	0	1	0	0	0	0	41	**49**	**5**
	Grand Total	**6**	**0**	**14**	**35**	**9**	**9**	**61**	**0**	**0**	**9**	**4**	**6**	**0**	**6**	**201**	**360**	**11**
	Number of Sites	3	0	3	10	3	2	4	0	0	6	3	3	0	4	10		

	Site	*Bombus appositus*	*Bombus centralis*	*Bombus caliginosus*	*Bombus fervidus*	*Bombus flavifrons*	*Bombus flavidus*	*Bombus griseocollis*	*Bombus huntii*	*Bombus melanopygus*	*Bombus mixtus*	*Bombus nevadensis*	*Bombus rufocinctus*	*Bombus sitkensis*	*Bombus vandykei*	*Bombus vosnesenskii*	Total Abundance	Total Richness
Site Totals	Balfour Klickitat	3	1	1	29	0	0	4	0	0	0	18	2	0	15	29	**102**	**9**
	BPA_CRGNSA	0	0	0	2	20	10	1	0	0	23	0	0	4	2	32	**94**	**8**
	Cape Horn	0	0	20	5	6	0	0	0	1	8	0	0	0	0	37	**77**	**6**
	Catherine Creek	4	0	0	10	1	1	62	0	0	1	14	0	0	2	43	**138**	**9**
	Columbia Hills SP	0	0	0	0	0	0	0	0	0	0	3	3	0	0	8	**14**	**3**
	Deschutes Boat Launch	0	0	0	15	0	0	23	5	0	0	0	0	0	1	9	**53**	**5**
	Harvey Bat House	0	0	0	18	6	1	0	0	0	2	0	0	0	0	69	**96**	**5**
	McCall Preserve	19	0	0	42	1	2	7	0	0	1	1	4	0	3	26	**106**	**10**
	Memaloose	4	0	0	60	1	0	0	0	0	1	0	0	0	4	27	**97**	**6**
	Sam's Walker	0	0	1	7	2	0	0	0	0	4	0	0	0	0	7	**21**	**5**
	T14ES27	3	0	6	7	10	0	0	0	2	7	0	0	0	0	54	**89**	**7**
	Grand Total	**33**	**1**	**28**	**195**	**51**	**14**	**97**	**5**	**3**	**47**	**36**	**9**	**4**	**27**	**341**	**887**	**15**
	Number of Sites	5	1	4	10	8	4	5	1	2	8	4	3	1	6	11		

Appendix B: Plant associations of bumble bees in the CRGNSA

Plant Species	*Bombus appositus*	*Bombus caliginosus*	*Bombus centralis*	*Bombus fervidus*	*Bombus flavidus*	*Bombus flavifrons*	*Bombus griseocollis*	*Bombus huntii*	*Bombus melanopygus*	*Bombus mixtus*	*Bombus nevadensis*	*Bombus rufocinctus*	*Bombus sitkensis*	*Bombus vandykei*	*Bombus vosnesenskii*	Total Observations
Achillea millefolium							2									2
Amsinckia lycopsoides															1	1
Apocynum androsaemifolium					4										2	6
*Arctium minus**				2												2
Asclepias fascicularis	2			5			55				2				3	67
Balsamorhiza sagittata				1	1		10	2				1			15	30
*Centaurea cyanus**	19	1		59	5	3	1			2	1	3		7	38	139
*Centaurea pratensis**				5		2				1					55	63
*Centaurea solstitialis**															2	2
Chamaenerion angustifolium						1									7	8
*Cichorium intybus**														1		1
*Cirsium arvense**		2			2	4	1			2					5	16
*Cirsium vulgare**				1							1					2
Claytonia sibirica															1	1
Delphinium menziesii				1												1
Dicentra formosa				1												1
*Dipsacus fullonum**				1			1									2
Disporum hookeri									1	2						3
Eriophyllum lanatum															1	1
Erysimum occidentale															1	1
Eschscholzia californica															1	1
Flying															1	1
Fragaria virginiana															1	1
Gaillardia aristata							1									1
*Geranium molle**				1												1
Grass						1										1
*Helianthus sp.**							2									2
Holodiscus discolor														1	2	3
*Hypericum perforatum**				1						1					3	5

Plant Species	*Bombus appositus*	*Bombus caliginosus*	*Bombus centralis*	*Bombus fervidus*	*Bombus flavidus*	*Bombus flavifrons*	*Bombus griseocollis*	*Bombus huntii*	*Bombus melanopygus*	*Bombus mixtus*	*Bombus nevadensis*	*Bombus rufocinctus*	*Bombus sitkensis*	*Bombus vandykei*	*Bombus vosnesenskii*	Total Observations
*Lathyrus latifolius**				2			4				12			2	12	32
*Leucanthemum vulgare**															1	1
Lithophragma parviflorum												1				1
*Lotus corniculatus**															5	5
Lupinus sp.		1		3		2				2				2	8	18
Mahonia aquifolium					2	4				16			2		15	39
Marah oregana		1														1
*Melilotus officinalis**												2			4	6
Mertensia sp.						1										1
Nest Searching				4						3	2				3	12
Patrolling	1			4											3	8
Penstemon sp.	3			1							1	2		3	18	28
Perideridia montana															9	9
Phacelia hastata		17				9				3			2			31
Plectritis congesta					1					1					2	4
Polygonum sp.															1	1
Prunella vulgaris		1		9		4									11	25
Purshia tridentata				1			17	3							6	27
Rosa nutkana				1						2						3
*Rubus armeniacus**	1	2		1		3			2	6					24	39
*Senecio jacobaea**		2		1						1					27	31
Symphoricarpos alba				1		4				4					9	18
*Tanacetum vulgare**															8	8
Trifolium microcephalum							1								21	22
*Trifolium pratense**				4											2	6
Triteleia hyacinthina				6												6
Urtica dioica		1														1
*Vicia villosa**	7	1	1	76		9	2			1	17			13	12	139
Yellow Composite*															1	1
Total Native	**6**	**21**	**0**	**38**		**26**	**86**	**5**	**1**	**33**	**5**	**4**	**4**	**6**	**142**	**385**
Total Non-native*	**27**	**8**	**1**	**154**	**15**	**21**	**11**	**0**	**2**	**14**	**31**	**5**	**0**	**23**	**198**	**502**
Grand Total	**33**	**29**	**1**	**192**	**15**	**47**	**97**	**5**	**3**	**47**	**36**	**9**	**4**	**29**	**340**	**887**

Appendix C: Potential bumble bee species list for the CRGNSA

As predicted by published IUCN Range Maps, compared with detections from the 2017 surveys and data from historic databases (Richardson 2017). Species in **bold** have range maps that overlap with the CRGNSA, but whose presence would likely be rare as other nearby records are either scarce, or the species is known to exist only at higher elevations at this latitude. Starred (*) species are unexpected due to recently documented declines (Hatfield et al. 2014a).

Potential Species	**2017 Surveys**	**Historic Data**
Bombus appositus	X	
Bombus balteatus		
Bombus bifarius		
Bombus caliginosus	X	
Bombus centralis	X	
Bombus fervidus	X	X
Bombus flavidus	X	X
Bombus flavifrons	X	X
Bombus frigidus		
Bombus griseocollis	X	X
Bombus huntii	X	
Bombus insularis		
Bombus melanopygus	X	X
Bombus mixtus	X	X
*Bombus morrisoni**		
Bombus nevadensis	X	
*Bombus occidentalis**		X
Bombus rufocinctus	X	
Bombus sitkensis	X	X
Bombus suckleyi*		
Bombus sylvicola		
Bombus vandykei	X	X
Bombus vosnesenskii	X	X