A PETITION TO THE STATE OF CALIFORNIA
FISH AND GAME COMMISSION

For action pursuant to Section 670.1, Title 14, California Code of Regulations (CCR) and Sections 2072 and 2073 of the Fish and Game Code relating to listing and delisting endangered and threatened species of plants and animals.

I.   SPECIES BEING PETITIONED:

1. Common Name: Crotch bumble bee
    Scientific Name: *Bombus crotchii*
2. Common Name: Franklin's bumble bee
    Scientific Name: *Bombus franklini*
3. Common Name: Suckley cuckoo bumble bee
    Scientific Name: *Bombus suckleyi*
4. Common Name: Western bumble bee
    Scientific Name: *Bombus occidentalis occidentalis*

II.   RECOMMENDED ACTION:

1. Common Name: Crotch bumble bee As Endangered <u>X</u>
    Scientific Name: *Bombus crotchii*
2. Common Name: Franklin's bumble bee As Endangered <u>X</u>
    Scientific Name: *Bombus franklini*
3. Common Name: Suckley cuckoo bumble bee As Endangered <u>X</u>
    Scientific Name: *Bombus suckleyi*
4. Common Name: Western bumble bee As Endangered <u>X</u>
    Scientific Name: *Bombus occidentalis occidentalis*

III.   AUTHOR OF PETITION:

Name: The Xerces Society, including: Rich Hatfield, Sarina Jepsen, Sarah Foltz Jordan, Michele Blackburn, Aimée Code

Address: 628 NE Broadway, Portland, OR 97232

Phone Number: 503-232-6639

I hereby certify that, to the best of my knowledge, all statements made in this petition are true and complete.
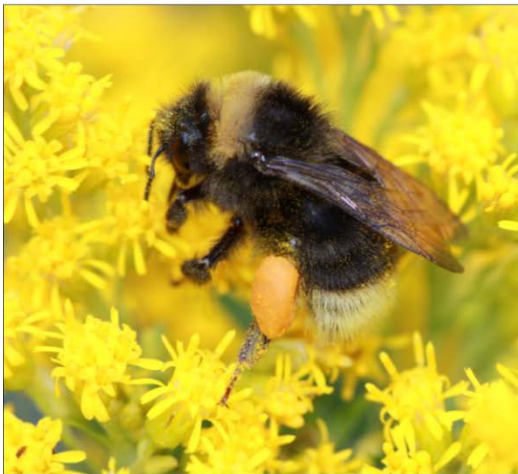
Signature:

Date: 16 October 2018

FGC - 670.1 (3/94)

A PETITION TO THE STATE OF CALIFORNIA
FISH AND GAME COMMISSION TO LIST

The Crotch bumble bee (*Bombus crotchii*), Franklin's bumble bee (*Bombus franklini*), Suckley cuckoo bumble bee (*Bombus suckleyi*), and western bumble bee (*Bombus occidentalis occidentalis*) as Endangered under the California Endangered Species Act

Bombus crotchii, by Stephanie McKnight, the Xerces Society (top left); *Bombus franklini*, by Pete Schroeder (top right); *Bombus occidentalis occidentalis*, by Rich Hatfield, the Xerces Society (bottom left); *Bombus suckleyi*, by Hadel Go/www.discoverlife.org (bottom right).

Submitted by
The Xerces Society for Invertebrate Conservation, Defenders of Wildlife,
Center for Food Safety

October 2018

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

The Crotch bumble bee (*Bombus crotchii*), Franklin's bumble bee (*Bombus franklini*), Suckley cuckoo bumble bee (*Bombus suckleyi*), and western bumble bee (*Bombus occidentalis occidentalis*) are endangered with extinction throughout their ranges, including in California. Recent research has shown a significant reduction in both the range and relative abundance of these species, and where they still persist, they are far less common than they were historically. **The Crotch bumble bee (*Bombus crotchii*)** was historically common in the southern two-thirds of California, but now appears to be absent from most of it, especially in the center of its historic range (Hatfield et al. 2014; Richardson et al. 2014); analyses suggests sharp declines in both relative abundance (98% decline) and persistence (80% decline) over the last ten years. **Franklin's bumble bee (*Bombus franklini*)** is in imminent danger of extinction and notably has the most limited geographic distribution of any bumble bee in North America and possibly the world (Williams 1998). Extensive surveys since 1998 have demonstrated that there has been a precipitous decline in the number of individuals and localities in the past several decades; this species has not been seen in California since 1998, and has not been seen anywhere since 2006. The **western bumble bee (*Bombus occidentalis occidentalis*)** has recently undergone a dramatic decline in abundance and distribution, and is no longer present across much of its historic range. Declines suggest it has been lost from 53% of its historic range and has experienced an 84% decline in relative abundance (Hatfield et al., unpublished data); in

California, *B. o. occidentalis* populations are currently largely restricted to high elevation sites in the Sierra Nevada (Xerces Society 2012). The **Suckley cuckoo bumble bee (*Bombus suckleyi*),** relies upon western bumble bees to complete its life cycle, and thus is uniquely susceptible to extinction (Suhonen et al. 2015).

Bumble bees are among the most iconic and well understood group of native pollinators in North America. They are generalist pollinators that play a valuable role in the reproduction of a wide variety of plants, including California specialty crops such as tomato, squash, melon, and pepper, and numerous wildflowers. Pollinators are critical components of our environment and essential to our food security. Insects – and primarily bees – provide the indispensable service of pollination to more than 85% of flowering plants (Ollerton et al. 2011), contributing to 35% of global food production (Klein et al. 2007). Many vitamins and other nutrients essential to human nutrition are found primarily in plants that require insect pollination (Eilers et al. 2011); as such, the loss of pollinators may pose challenges to human nutrition.

Each of the following factors pose a substantial threat to the survival of the four species of bumble bees included in this petition: present or threatened modification or destruction of its habitat; overexploitation; competition; disease; and other natural events and human-related activities, including pesticide use, population dynamics and structure, global climate change, and for the Suckley cuckoo bumble bee, loss of its host species.

While each of these four bumble bee species have been placed on California Department of Fish and Wildlife's Special Animal List, and their extinction risk has been recognized by the International Union for the Conservation of Nature (IUCN) and the global network of bumble bee researchers engaged in IUCN's Bumblebee Specialist Group, these species receive no formal protection. This petition presents information that each of these four bumble bee species is experiencing dramatic declines and protections under the California Endangered Species Act are necessary to conserve their populations and protect and restore their habitat throughout their ranges in California.

II. POPULATION TRENDS, ABUNDANCE, RANGE, AND DISTRIBUTION

Current Conservation Status
The conservation status and extinction risk of the petitioned species has been evaluated by the International Union for the Conservation of Nature (IUCN) Bumblebee Specialist Group, a global network of bumble bee researchers dedicated to the conservation of bumble bees, and published on the IUCN's Red List of Threatened Species (Hatfield et al. 2015a, 2015b, 2015c; Kevan 2008).The IUCN Bumblebee Specialist Group utilized methods published in the 2001 IUCN Red List Categories and Criteria version 3.1, a standard, global method to evaluate the conservation status of plant and animal species worldwide. Each species was assessed according

to the IUCN Red List criteria by multiple bumble bee experts, and the methods used in the assessments were peer-reviewed by additional bumble bee experts (see reviewers and assessors listed in Hatfield et al. 2015a, 2015b, 2015c), with the exception of the Red List profile for *B. franklini*, which was added to the Red List in 2008, before the IUCN Bumblebee Specialist Group existed.

The IUCN Bumble Bee Specialist Group (BBSG) measured changes in each species' range and relative abundance between historic (1805-2001) and recent (2002-2012) time periods for *B. crotchii*, *B. occidentalis*, and *B. suckleyi* (Hatfield et al. 2015a; 2015b; 2015c). *Bombus franklini* was listed on the IUCN Red List previously (Kevan 2008).

A database of more than 200,000 electronic specimen records of North American bumble bee species was assembled from academic, research and private collections (Richardson 2014) and analyzed to evaluate the change in each species' range between the recent and historic time periods. Once these analyses were completed, quantitative thresholds for extinction risk were used (IUCN 2012) to determine the extinction risk of each bumble bee species (IUCN Red List 2016).

The petitioned species are listed on the IUCN Red List as: Critically Endangered (*Bombus franklini* and *Bombus suckleyi*) and Endangered (*Bombus crotchii*) (Table 1) (Kevan 2008; Hatfield et al. 2015a; 2015c). An IUCN Red List category has not yet been formally assigned for the southern subspecies of the western bumble bee (*B. occidentalis occidentalis*), but the full species (*B. occidentalis*) is listed as Vulnerable to extinction on the IUCN Red List (Hatfield et al. 2015b), and a more recent analysis of changes in range and relative abundance of *B. o. occidentalis* suggests that this subspecies would meet the criteria of Endangered on the IUCN Red List (Hatfield et al. 2018a, unpublished data).

Species	CNDDB State Rank	NatureServe global (G) and national (T) ranks	ESA Status	IUCN Red List Status
Crotch bumble bee (*Bombus crotchii*)	S1S2	G3G4	None	Endangered
Franklin's bumble bee (*Bombus franklini*)	S1	G1	None (SSA phase)	Critically Endangered
Western bumble bee, southern subspecies (*Bombus occidentalis occidentalis*)	S1*	G4T1T3	None (parent species SSA phase)	Subspecies not evaluated, but meets the criteria of Endangered**
Suckley cuckoo bumble bee (*Bombus suckleyi*)	S1	G1G3	None	Critically Endangered

Changes in Range, Distribution, and Relative Abundance

In Table 2, we summarize the changes in range (extent of occurrence, or EOO, and persistence) and relative abundance for each of the petitioned species (Kevan 2008; Hatfield et al. 2015a; 2015c; IUCN Red List 2016; Hatfield 2018a and 2018b, unpublished data).

Table 2: Summary of changes in species' ranges, persistence, and relative abundance between recent (2002-2012) and historic (pre-2002) time periods.

Species	Historic Distribution	Range Decline: Extent of Occurrence	Range Decline: Persistence	Relative Abundance Decline	Average Decline	Reference
Crotch bumble bee (*Bombus crotchii*)	**United States** (CA) **Mexico** (B.C.)	25%	79%	98%	67%	Hatfield et al. 2015a
Franklin's bumble bee (*Bombus franklini*)	**United States** (CA, OR)	44%	67%	85%	65%	Hatfield 2018b, unpublished data
Western bumble bee, southern subspecies (*Bombus occidentalis occidentalis*)	**United States** (AZ, CA, CO, ID, MT, NE, NV, NM, OR, SD, UT, WA, WY) **Canada** (AB, BC, SK)	53%	33%	84%	57%	Hatfield 2018a, unpublished data
Suckley cuckoo bumble bee (*Bombus suckleyi*)	**United States** (AK, CA, CO, ID, MT, NY, ND, OR, SD, UT, WA, WY) **Canada** (AB, BC, MB, NL, NT, NS, ON, QC, SK, YT)	57%	84%	90%	77%	Hatfield et al. 2015c

Each of the species included in this petition have experienced dramatic declines in their ranges, relative abundance, and persistence, and these sharp decreases have likely been driven by population declines. The life history of *Bombus suckleyi*, a cuckoo bumble bee, makes it uniquely susceptible to extinction (Suhonen et al. 2015). Below we provide more information on the distribution and population status of each species in this petition.

The Crotch bumble bee (*Bombus crotchii*)

Distribution
Bombus crotchii has a limited distribution in southwestern North America. This species occurs primarily in California, including the Mediterranean region, Pacific Coast, Western Desert, Great Valley, and adjacent foothills through most of southwestern California (Williams et al. 2014). It also occurs in Mexico (Baja California and Baja California Sur) (Williams et al. 2014) and has been documented in southwest Nevada, near the California border.

Population Status
This species was historically common throughout much of the southern two-thirds of California, but now appears to be absent from most of it, especially in the center of its historic range (Hatfield et al. 2014, Richardson et al. 2014). In the Central Valley there has been extensive agricultural intensification and the southern part of its range is experiencing rapid urbanization.

Average decline for this species was calculated by averaging the changes in relative abundance and two measures of range: persistence and Extent of Occurrence (EOO) between a recent time period (2002-2012) and a historic (1805-2001) time period (for an explanation of methods, see below). This analysis yielded the following results:

- Current range size relative to historic range (EOO): 74.67% (25.33% decline)
- Persistence in current range relative to historic occupancy: 20.48% (79.52% decline)
- Current relative abundance compared to historic relative abundance: 2.32% (97.68% decline)
- **Average decline: 67.51%**

This analysis suggests sharp declines in both relative abundance and persistence over the last ten years.
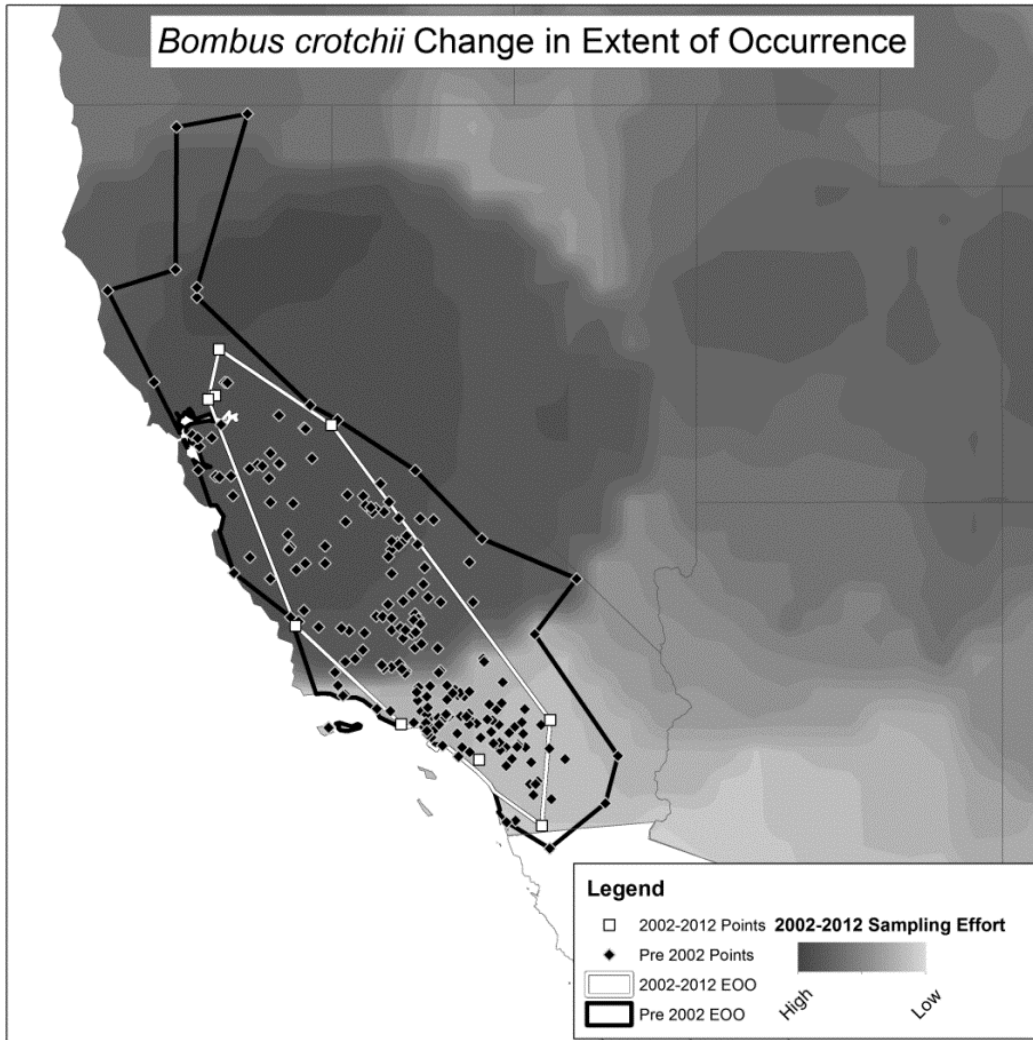
Figure 1: Recent and historical range map for *Bombus crotchii* displayed with a map of sampling effort across its range.
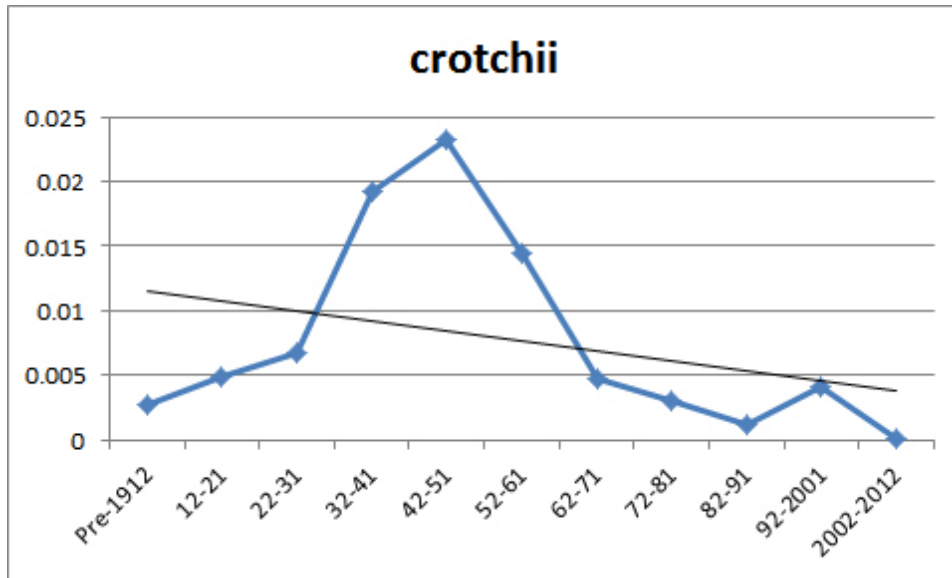
Figure 2: Relative abundance of *Bombus crotchii* by 10-year periods.

Franklin's bumble bee (Bombus franklini)

Distribution
Bombus franklini has the most limited geographic distribution of any bumble bee in North America and possibly the world (Williams 1998). *B. franklini* is known only from southern Oregon and northern California between the Coast and Sierra-Cascade Ranges. Stephen (1957) recorded it from the Umpqua and Rogue River Valleys of Oregon. Thorp et al. (1983) also recorded it from northern California and suggested its restriction to the Klamath Mountain region of southern Oregon and northern California. Its entire distribution, including recent range extensions (Thorp 1999; 2001; 2004) can be covered by an oval of about 190 miles north to south and 70 miles east to west between 122° to 124° west longitude and 40° 58' to 43° 30' north latitude. It is known from Siskiyou and Trinity counties in California. Elevations of localities where it has been found range from 540 feet (162 m) in the north to above 7,800 feet (2,340 m) in the south of its historic range. Although the number of populations that existed prior to 1998 is unknown, there are several historic records for this species, both published and in museums, including two in 1925 (Gold Hill and Roseburg, OR), one in 1930 (Roseburg, OR), two in 1950 (Gold Hill and Medford, OR), two in 1958 (Ashland, OR), two in 1968 (Mt. Ashland and near Copper, OR), one in 1980 (Ashland, OR), two in 1988 (Ashland and Merlin, OR), two in 1989 (Hilt and Yreka, CA), four in 1990 (Ashland, Ruch, Central Point, and Gold Hill, OR), one in 1992 (Ashland, OR), two in 1997 (Roxy Ann Peak near Medford and Ashland Pond in Ashland, OR), and four in 1998 (Roca Canyon in Ashland, Lost Creek Reservoir, and Grizzly Peak near Shale City, OR). Additional records with unknown dates and or localities are also available, including the 1917 type specimen whose locality (Nogales, AZ) has been determined to be erroneous.

Population Status
Evidence for the decline in this species is based on intensive and extensive surveys, primarily by R.W. Thorp (Thorp 1999, 2001, 2004, 2005a, b, 2008) from 1998 through 2017. Surveys for the Bureau of Land Management were also conducted in 2005 (Code and Haney 2006). R.W. Thorp surveyed from nine to seventeen historic sites (average 13.8 sites) per year from 1998 to 2009; reports of surveys completed since 2009 are not available, although it has been confirmed that no *B. franklini* have been found in surveys that have occurred since 2009 (Thorp 2010-2017, pers. comm. with S. Jepsen). Dr. Thorp also surveyed from six to nineteen additional sites (average 12.8 sites) each year, some of which were visited more than once per year and some of which were visited in multiple years (Table 3).

Bombus franklini has not been seen in California since surveys by R.W. Thorp for the species at Hilt in Siskiyou County in 1998 documented two individuals (Table 3). Between 1998 and 2005, the number of sightings of *B. franklini* throughout its range declined precipitously from ninety-four individuals in 1998 to twenty in 1999, nine in 2000 and one in 2001. In Oregon, twenty were found in 2002, although only three were sighted in 2003, all at a single locality at Mt. Ashland in southern Oregon. None were found in 2004 and 2005 in Oregon or California. A single worker of *B. franklini* was sighted in 2006 at Mt. Ashland in Oregon, which is the same locality where *B. franklini* were found in 2003 (Table 3). None have been found from 2007-2017. R.W. Thorp's unpublished surveys have revealed that, since 1998, the populations have decreased to the point of being not seen at all in 2004 or 2005, with only one individual found in 2006. Because extensive surveys of the area within which *B. franklini* exists have, as of 2006, uncovered only one individual, but similar surveys in the first three years (1998-2000) uncovered individuals at many historic and seven new sites, it can be concluded that the extent of population is decreasing severely. Though further investigation would be required to determine the exact number of extant *B. franklini*, based on their limited range, it can be assumed that their populations have decreased to dangerously low levels.

Table 3: Historic and new* localities surveyed for *Bombus franklini* and numbers of *B. franklini* observed from 1998 through 2007 (Thorp 2008). Bolded entries denote that *B. franklini* was observed. Surveys were conducted by Dr. Thorp during 2008 and 2009, but no *B. franklini* were encountered.

Site	ST	Year	# times visited / # *Bombus franklini* found									
			1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
		CO										
Sutherlin, W of	OR	Douglas	**1/1***	1/0	1/0	2/0	1/0		2/0	3/0		1/0
Ashland	OR	Jackson			1/0	2/0	**3/1**		4/0	7/0	5/0	2/0
Ashland, ENE (3)	OR	Jackson	1/0	1/0	1/0	2/0	5/0	1/0			1/0	1/0
Buncom, E of	OR	Jackson		**1/1***	3/0	1/0	1/0					
Gold Hill, E of	OR	Jackson	**4/44***	2/0	**7/5**	7/0	3/0	4/0	2/0	4/0	2/0	2/0
Grizzly Peak	OR	Jackson	2/0	2/0	1/0	2/0	2/0	2/0	2/0	3/0	1/0	2/0
Jackson Campground	OR	Jackson	**2/2***	2/0	1/0		1/0			1/0		
Kenney Meadows	OR	Jackson	**2/3***	2/0	2/0	2/0	1/0	1/0		1/0		
Lost Creek Reservoir	OR	Jackson		1/0		1/0			1/0	1/0		
Medford	OR	Jackson			3/0	3/0		1/0	1/0			
Mt. Ashland (2)	OR	Jackson	**3/37**	**6/19**	**7/2**	**5/1**	**10/19**	**9/3**	13/0	11/0	**8/1**	7/0
Phoenix, E of	OR	Jackson			1/0	2/0						
Ruch	OR	Jackson	**3/3**	2/0	**2/1**	1/0	2/0		2/0			
Ruch, S of (2)	OR	Jackson	1/0	2/0			1/0	2/0	2/0	1/0		
Ruch, SSE of	OR	Jackson		2/0	**3/1***	2/0	1/0	2/0		1/0		
Union Creek	OR	Jackson		1/0								
Selma, S of	OR	Josephine	**1/2***	1/0	1/0							
Wonder, W of	OR	Josephine			1/0							
Mt. Shasta	CA	Siskiyou	1/0	1/0	1/0		1/0			1/0	2/0	1/0
Hilt	CA	Siskiyou	**2/2**	3/0	3/0	1/0	2/0	1/0	1/0	2/0	2/0	1/0
Montague	CA	Siskiyou		1/0					1/0		1/0	
Total *B. franklini* seen			94	20	9	1	20	3	0	0	1	0
New sites for *franklini*			5	1	1	0	0	0	0	0	0	0
B. franklini site visits			22	32	41	33	36	20	31	36	22	17
Other sites visited			19	23	14	7	6	8	9	19	14	2

13
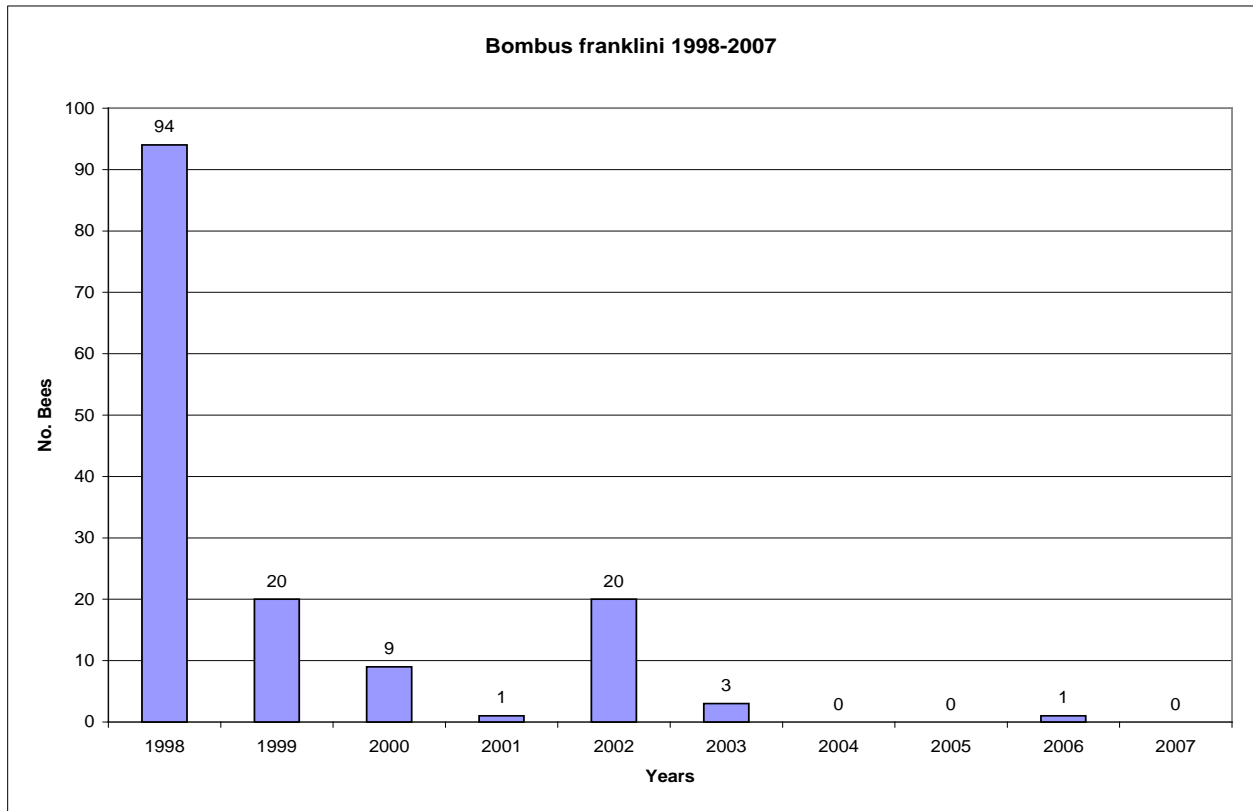
Figure 3: Number of *Bombus franklini* observed in surveys from 1998-2007 (Thorp 2008). Surveys were also conducted by Dr. Thorp from 2008-2017, but no *B. franklini* were found.
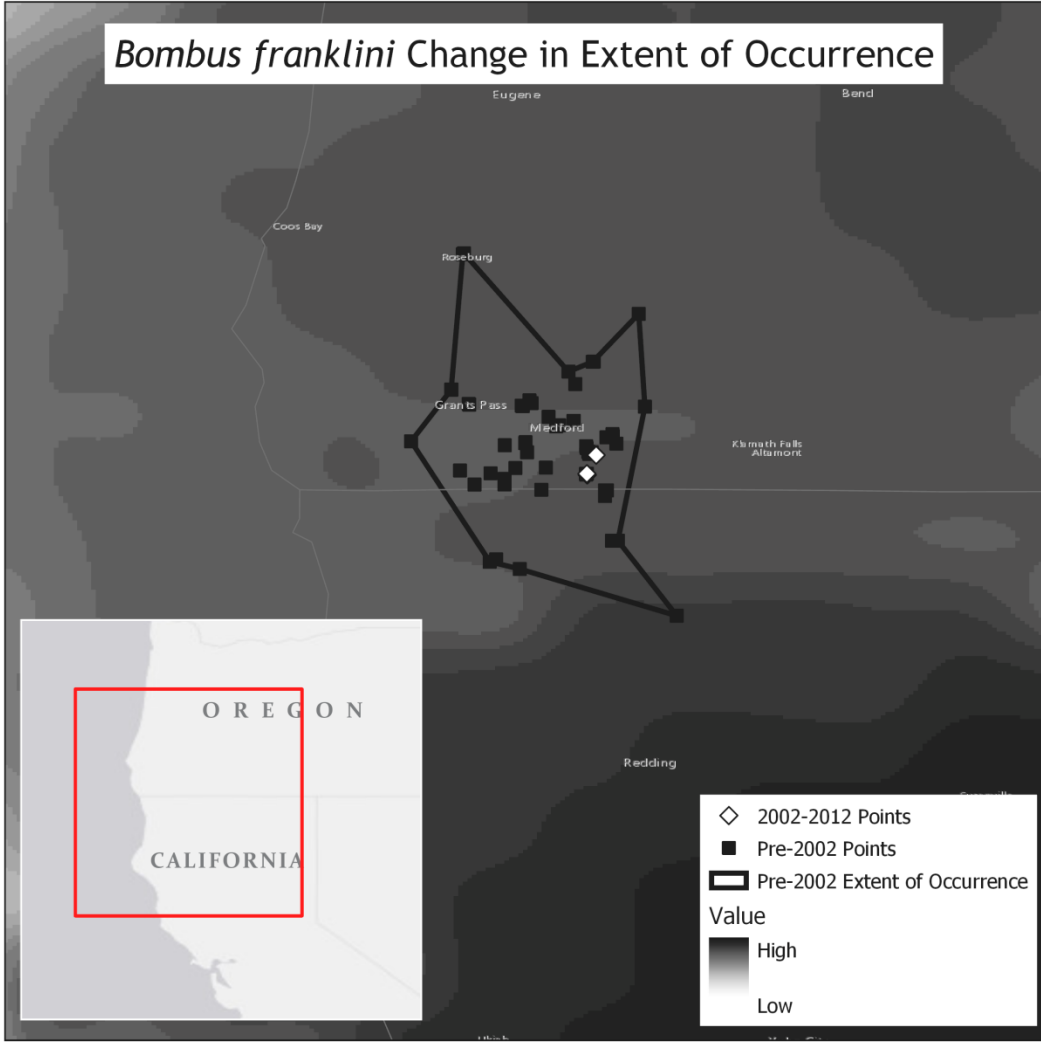
Figure 4: Current and historical range map for *Bombus franklini*.
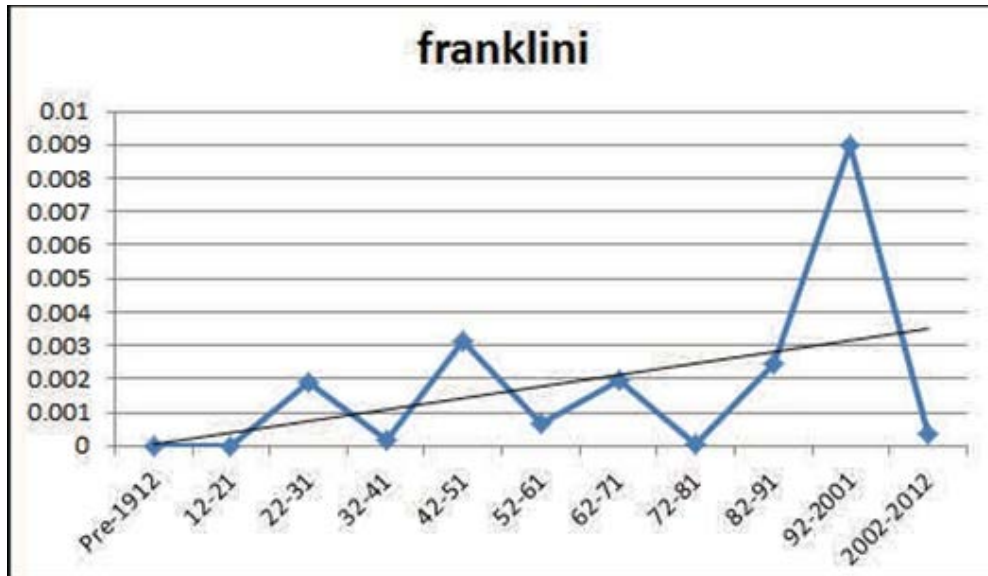
Figure 5: Relative abundance of *Bombus franklini* by 10-year periods. Note that a targeted survey effort for *B. franklini* began in 1998, probably explaining the spike in this species' relative abundance in the *Bombus* specimen database during the decade from 1992-2001.

The Western bumble bee (Bombus occidentalis occidentalis)

Bombus occidentalis consists of two subspecies: *B. occidentalis mckayi*, which occurs in Alaska, Yukon Territory, Northwest Territories, northern British Columbia, and northern Alberta, and *B. occidentalis occidentalis*, which occurs from southern British Columbia, southern Alberta, and southwestern Saskatchewan south to multiple western U.S. states (Sheffield et al. 2016). Existing evidence suggests that it is the southern subspecies, *B. occidentalis occidentalis*, which has undergone a dramatic range contraction and population decline, especially in the western part of its range. The authors of this petition are not aware of any evidence suggesting that *B. occidentalis mckayi* has undergone any range reduction or population decline. The IUCN Bumblebee Specialist Group recently completed analyses of changes in range, persistence, and relative abundance of both *B. occidentalis* (Hatfield et al. 2015b) and *B. occidentalis occidentalis* (Hatfield 2018 unpublished data) between recent and historic time periods.

Distribution

Bombus occidentalis occidentalis was historically broadly distributed across the west coast of North America from southern British Columbia to central California, east through Alberta and western South Dakota, and south to Arizona and New Mexico (Williams et al. 2014; Sheffield et al. 2016). In California, it has been documented in Alameda, Alpine, Butte, Calaveras, Contra Costa, Del Norte, El Dorado, Fresno, Humboldt, Lake, Lassen, Madera, Marin, Mariposa, Mendocino, Modoc, Monterey, Napa, Nevada, Placer, Plumas, Sen Benito, San Francisco, San Joaquin, San Luis Obispo, San Mateo, Santa Clara, Santa Cruz, Shasta, Sierra, Siskiyou, Solano, Sonoma, Tehama, Trinity, Tulare, Yolo, and Yuba counties (Bumble Bee Watch 2017; Richardson 2017; Rickman 2017).

16

Population Status
Bombus occidentalis occidentalis was once very common in the western United States but has recently undergone a dramatic decline in abundance and distribution, and is no longer present across much of its historic range. A rangewide analysis including more than 73,000 records of eight bumble bee species suggests that the parent species, *B. occidentalis* has undergone a 28% range decline between recent (2007-2009) and historic (1900-1999) time periods (Cameron et al. 2011a). A separate analysis comparing the current (2002-2012) and historic (1805-2001) ranges of *B. occidentalis occidentalis* (using a database of more than 200,000 records of 43 species of North American bumble bees developed by Williams et al. 2014) suggests that the southern subspecies has been lost from 53% of its historic range, or EOO (Hatfield et al., unpublished data). The relative abundance of *B. o. occidentalis* has declined by 84% (Hatfield et al., unpublished data). Declines were found to be most significant at the edges of this species' range (Hatfield et al., unpublished data). In California, *B. o. occidentalis* populations are currently largely restricted to high elevation sites in the Sierra Nevada (Xerces Society 2012), though there have been a couple of observations of this species on the northern California coast (Xerces Society et al. 2017).

Average decline for this species was calculated by averaging the change in abundance, persistence, and EOO. This analysis yielded the following results (see also the graph of relative abundance and map of change in EOO over time below):

- Current EOO (range) relative to historic EOO: 47% (53% decline)
- Persistence in current range relative to historic occupancy: 57% (33% decline)
- Current relative abundance relative to historic values: 16% (84% decline)
- Average decline: 57%

Figure 6: Current and historical range map for *Bombus occidentalis occidentalis*.
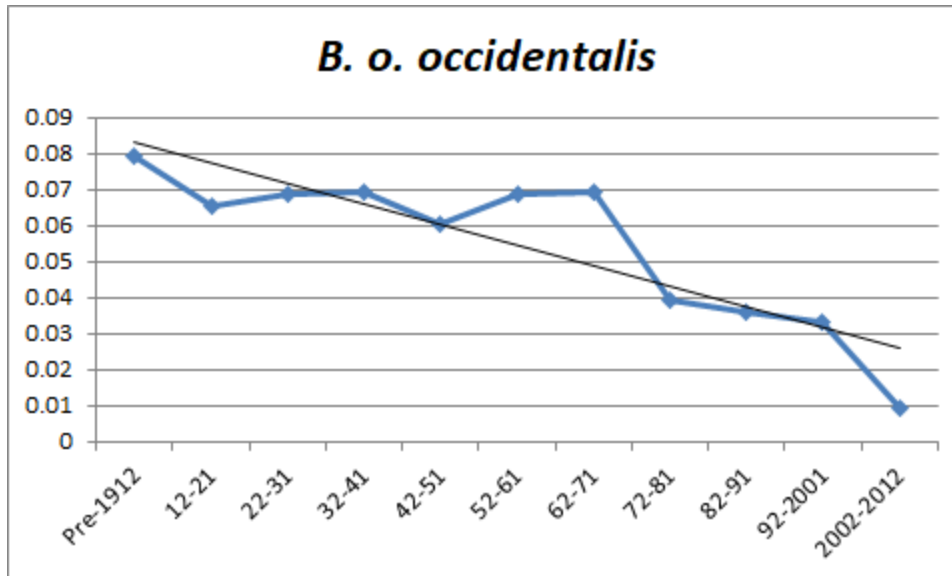
Figure 7: Relative abundance of *Bombus occidentalis occidentalis* by 10-year periods.

The Suckley cuckoo bumble bee (Bombus suckleyi)

Distribution
This species has a broad distribution centered in western North America and also including several scattered localities in the northeast. It occurs in the Mountain West from California and Colorado to Alaska, east to the Canadian Great Plains, with a disjunct subpopulation in Newfoundland (Williams et al. 2014). In California *Bombus suckleyi* has a very limited distribution, occurring only in the Klamath Mountain region in the northern part of the state.

Population Status
Bombus suckleyi has experienced dramatic population declines throughout its range and has declined by over 80%, according to criteria established by the IUCN (Hatfield et al. 2015c). The decade by decade relative abundance regression shows a gradual decline since the 1940s, and the relative abundance regression over just the past 50 years is highly significant (R-squared value of nearly 1; showing a continued steep decline). If we project the 50 year relative abundance regression into the future, it falls below the x-axis in the next 10 years. Notably, this species' declines are likely due – at least in part – to the rapid disappearance of its host, the **western bumble bee (*Bombus occidentalis occidentalis*)**, which has declined by 84% (Hatfield et al., unpublished data). Both the past decline in relative abundance (90.11% over the past 10 years) and predicted future decline in relative abundance (based on 50-year regression) indicate dramatic, rapid declines. Note that the range and persistence of this species have also declined, however, since some historic sites have not been re-sampled and since we only have records of this species in approximately six general localities for the current time period, we were not comfortable using those measures of decline.

Average decline for this species was calculated by averaging the change in abundance, persistence, and EOO. This analysis yielded the following results (see also the graph of relative abundance and map of change in EOO over time below):

- Current range size relative to historic range: 42.61% (57.39% decline)
- Persistence in current range relative to historic occupancy: 15.95% (84.05% decline)
- Current relative abundance relative to historic values: 9.89% (90.11% decline)
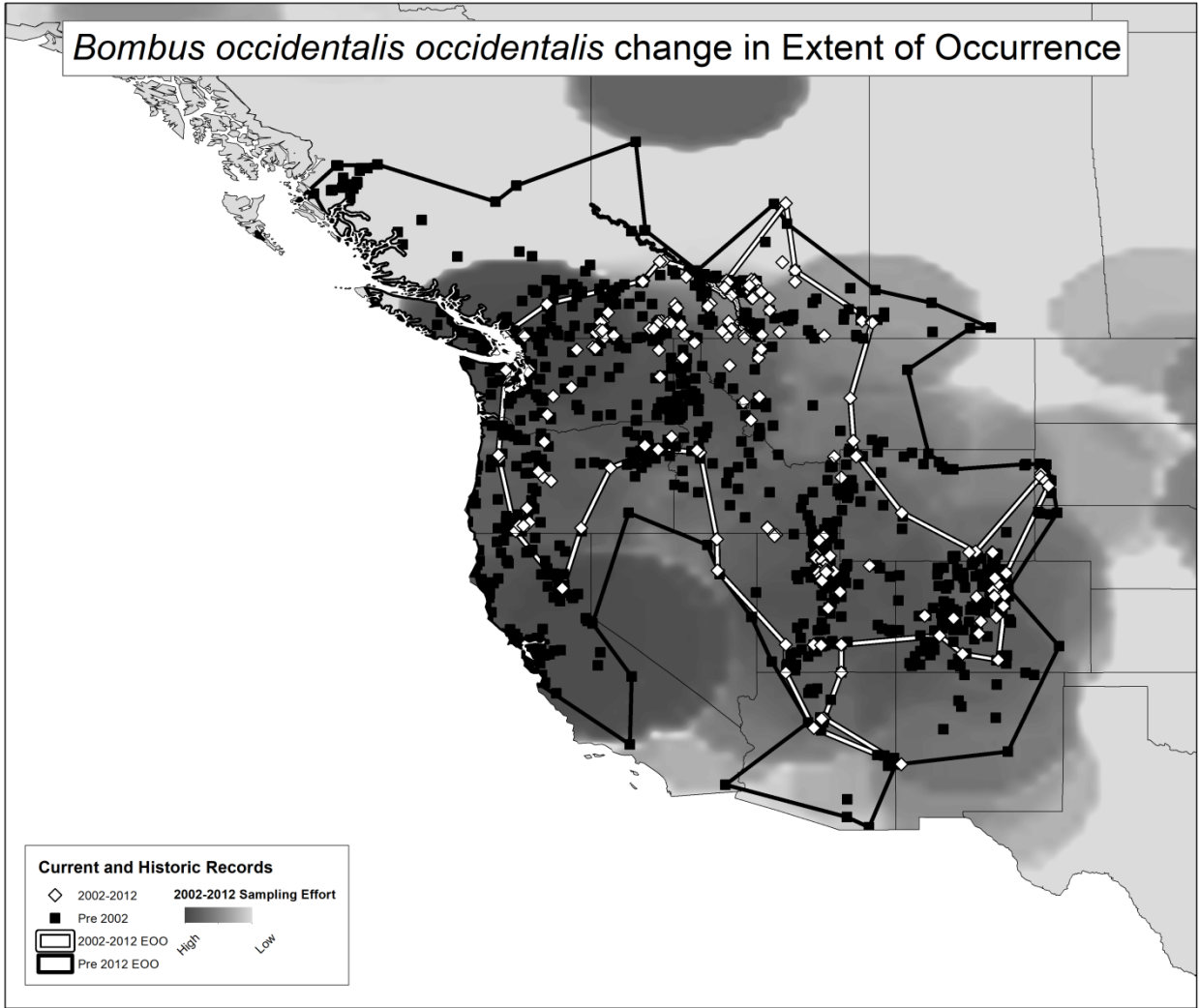- Average decline: 77.18%
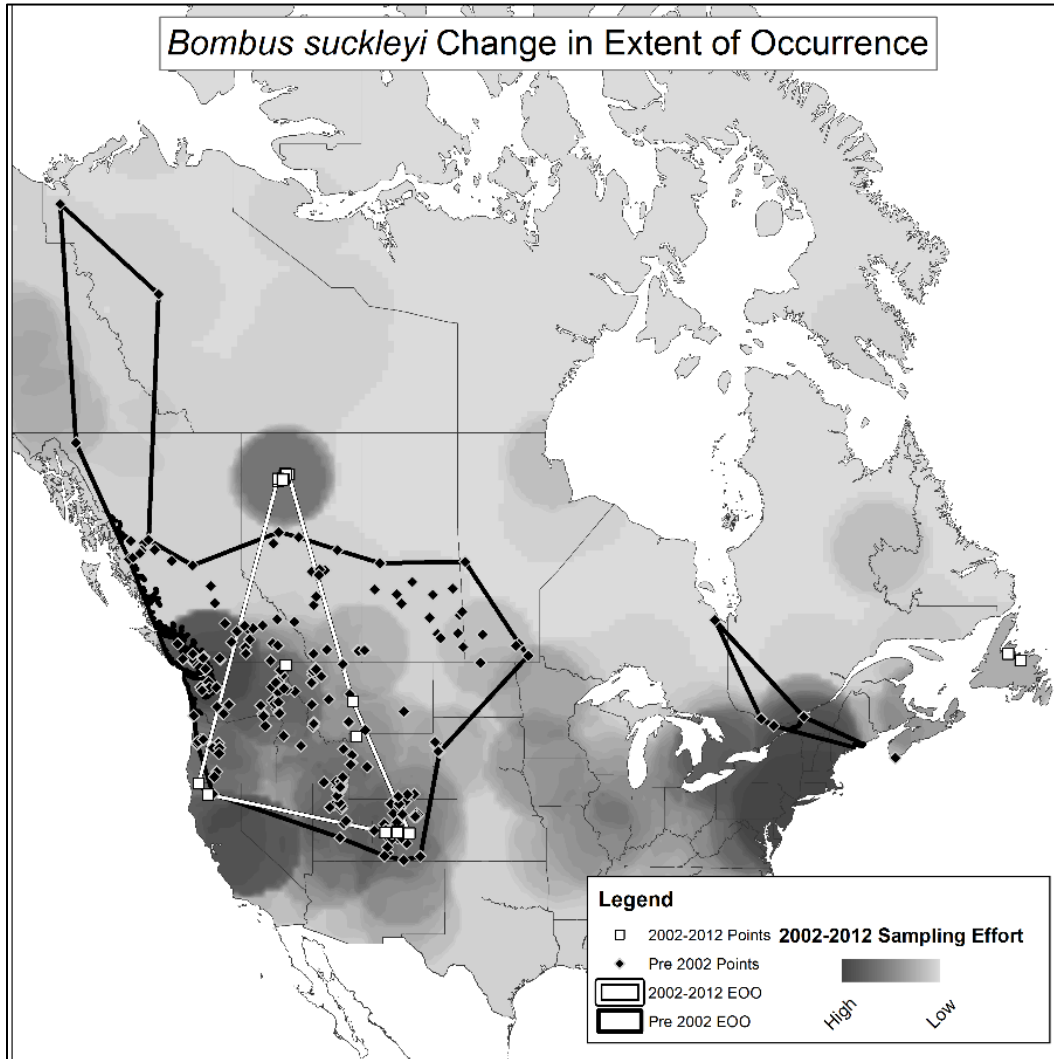
Figure 8: Current and historical range map for the Suckley cuckoo bumble bee (*Bombus suckleyi*).
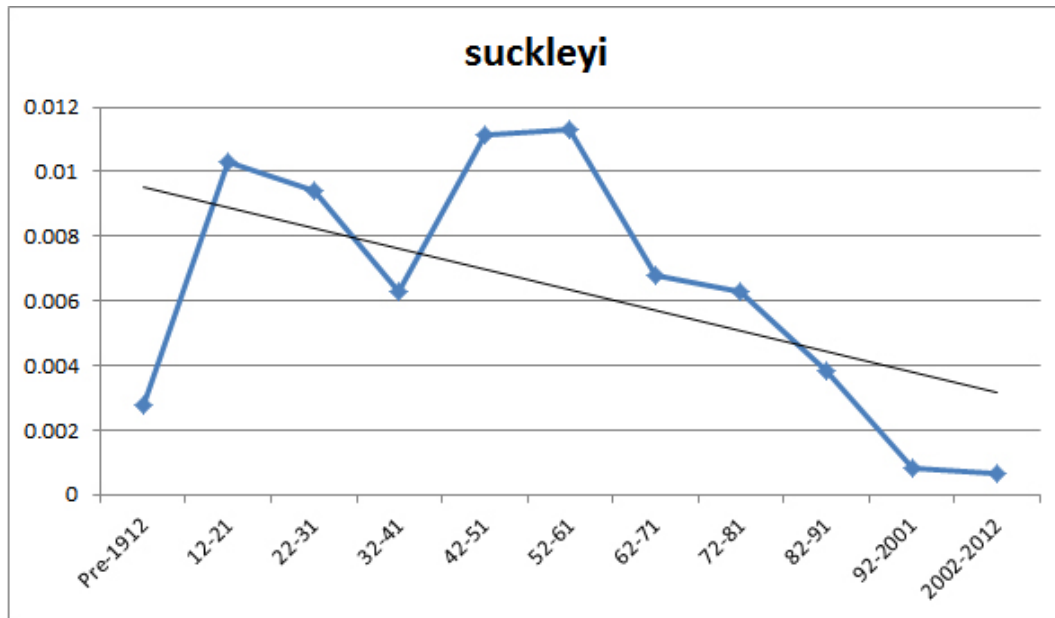
Figure 9: Relative abundance of the Suckley cuckoo bumble bee (*Bombus suckleyi*) by 10-year periods.

METHODS USED

Analyses

Hatfield et al. (2014) evaluated changes between recent and historic time periods in each species': overall Extent of Occurrence (EOO), persistence within 50km grid cells, and relative abundance. For both the EOO and persistence calculations, a database of >200,000 specimen records (Richardson et al. 2014) was divided into historical (1805 – 2001, N=128,572) and current (2002-2012, N=73,626) records (Hatfield et al. 2014, Hatfield et al 2018c).

Extent of Occurrence (EOO)

Since the historical database had significantly more records, and therefore could lead to an over estimate of range loss due to an increased chance of including more records near the edge of each species' range, Hatfield et al. (2014) rarefied the historic data set by randomly selecting 73,626 records from the historical time period to use in the EOO measurement. Using z-tests for differences in proportion, it was ensured that the relative abundance of each species in the subsampled historical data was not significantly different from the relative abundance of that species in the original database. To measure changes in each species' EOO, Hatfield et al. (2014) first used a k-nearest neighbors approach to create local convex hulls for each species in each time period (Getz et al. 2007). Generally, the "minimum spurious hole covering" rule proposed in Getz et al. (2007) was used. However, since the ranges of most North America bumble bees are large, "spurious holes" frequently included large expanses of inhospitable habitat for bumble bees (e.g., The Gulf of Alaska) (Hatfield et al. 2014). After the local convex hull polygons were created, the polygons were clipped to the North American continent to remove large patches of

21

unoccupied habitat (e.g., Great Lakes) (Hatfield et al. 2014). Using the areas calculated from these polygons, Hatfield et al. (2014) compared the current area to the historical area to determine change in home range size (see Figures 1, 4, 6, and 8).

Persistence
To determine species' persistence within their home range, Hatfield et al. (2014) divided the continent into 50 km x 50 km grid cells. Hatfield et al. (2014) used 50 km grid cells to be consistent with previous European and North American *Bombus* spp. analyses (Williams et al. 2007; Colla et al. 2012) and because the data in the historical database were georeferenced from specimen label locality descriptions, which are sometimes inaccurate at smaller spatial scales (Wieczorek et al. 2004). For each time period the number of grid cells occupied by each species was divided by the total number of grid cells occupied by all species (Hatfield et al. 2014). Then, the value from the current time period was divided by the value from the historic time period to detect changes in persistence over time. While the metric that Hatfield et al. (2014) report is not truly a measure of range size, it does provide a measure of each species' persistence within its home range.

Relative Abundance
To evaluate changes in the relative abundance (RA) of each species, Hatfield et al. (2014) divided the full database into historical (1805-2001) and current (2002-2012) time periods and calculated the RA of each species in each time period. Then, to estimate changes in RA, they divided the current RA by the historical RA. In addition to comparing the historical time period to the most recent decade, Hatfield et al. (2014) also broke the database up into ten ten-year periods, plus one time period covering all records prior to 1913 and calculated the RA of each species in each time period (e.g., pre-1913 = period 1, 1913-1922 = period 2). Then, using time as the explanatory variable and RA as the independent variable, a linear regression was conducted to assess longer-term trends in each species' RA (see Figures 2, 5, 7, and 9) (Hatfield et al. 2014). To evaluate extinction risk for several species Hatfield et al. (2014) used a linear trendline to project future declines and used the x-intercept as the theoretical point of extinction.

Sampling Effort
Specimen records were used for the analysis of change in range size, sampling effort likely played a significant role in determining species presence or absence (Hatfield et al. 2014). To account for varying sampling effort and avoid overestimating range loss, Hatfield et al. (2014) created sampling density rasters from the presence points, in both the current time period, and the random sample of the historical time period (using ArcGIS 10.2). For each species Hatfield et al. (2014) calculated the relative difference in sampling density in areas where the historical EOO did not overlap with the current period EOO. Using the area of this non-overlapping polygon, the average sampling density for both time periods was calculated (Hatfield et al. 2014). Species that experienced range loss in the current time period that had a lower sampling

density than historically had their range loss estimates adjusted by the relative difference in average sampling density to account for the change in effort. Hatfield et al. (2014) did not adjust the change in range estimates for species that had a higher sampling density in the current time period.

Since most records available for the bumble bee species included in this petition are from incidental observations or museum specimen records rather than from quantitative studies, population estimates at specific sites are unavailable. Furthermore, using field estimates of abundance to understand bumble bee population stability can be problematic because observations of multiple individuals may represent a single reproductive unit (because of the colonial life history of bumble bees).

III. LIFE HISTORY (SPECIES DESCRIPTION, BIOLOGY, AND ECOLOGY)

Bumble Bee Biology
Most bumble bees are primitively eusocial insects that live in colonies composed of a queen, workers, and, near the end of the season, reproductive members of the colony (new queens, or gynes, and males). There is a division of labor among these three types of bees. Queens are responsible for initiating colonies and laying eggs. Workers are responsible for most food collection, colony defense, and feeding of the young. Males' sole function is to mate with queens. Colonies are annual, starting from colony initiation by solitary queens in the spring, to production of workers, and finally to production of queens and males. Queens produced at the end of the colony cycle mate before entering diapause, which is a form of hibernation.

Bumble Bee Pollination Ecology
Bumble bee colonies depend on floral resources for their nutritional needs. Bumble bees collect both nectar and pollen of the plants that they pollinate. Nectar provides them with carbohydrates and pollen provides them with protein. Bumble bees are generalist foragers, meaning that they gather pollen and nectar from a wide variety of flowering plants; although individual species can vary greatly in their plant preferences, largely due to differences in tongue length.

During collection of pollen and nectar from flowers, bumble bees also transport pollen between flowers, facilitating seed and fruit production. Bumble bees have many qualities that contribute to their suitability as agricultural pollinators. They are able to fly in cooler temperatures and lower light levels than many other bees, which extends their work day and improves the pollination of crops during inclement weather (Corbet et al. 1993). Bumble bees are well-known to engage in "buzz pollination," a very effective foraging technique in which they sonicate the flowers to vibrate the pollen loose from the anthers. This activity causes the flower to vibrate, which in turn dislodges pollen that would have otherwise remained trapped in the flower's anthers (Buchmann 1983). Tomatoes (Solanaceae), blueberries (Ericaceae), and many other

important food plants are pollinated by bumble bees in this way. In addition to commercially important crops, bumble bees also play a vital role as generalist pollinators of native flowering plants, and their loss may have far ranging ecological impacts. Below we provide life history accounts, species identification, taxonomy, phenology, reproductive biology, habitat relationships, and vulnerability of populations to certain natural or human-caused adverse impacts for each of the petitioned species.

Crotch bumble bee (*Bombus crotchii*) Cresson 1878

Taxonomy
This species was described by Cresson (1878) and upheld as a distinct species in the subgenus *Cullamonobombus* by more recent analyses (Cameron et al. 2007; Williams et al. 2008a).

Identification
Bombus crotchii is most easily distinguished from other *Bombus* species based on hair coloration. Technical descriptions below are adapted from Williams et al. (2014):

> Queens: The queen is 22 to 25 mm in length. Their hair of the face is black with a yellow vertex (top of the head). Their hair is yellow on the front part of the thorax (scutum), usually with black hairs between and below the wings as well as at the back of the thorax (scutellum). On the abdomen, the first tergal (T-dorsal plate) segment is black, at least medially. T2 is yellow, sometimes with black medially and anteriorly. T3 has black anteriorly, sometimes with red posteriorly. T4 and T5 are either entirely red or black.

> Workers: The worker is 12 to 20 mm in length. Their color patterns are identical to the queens.

> Males: The male is 14 to 19 mm in length. The hair of the head and face are yellow with a yellow scutum and scutellum and a black band between the wings. T1 and T2 are yellow sometimes with yellow laterally and posteriorly on T3. T4-T7 are either entirely black or entirely red. Males of this species are greatly enlarged and bulbous.
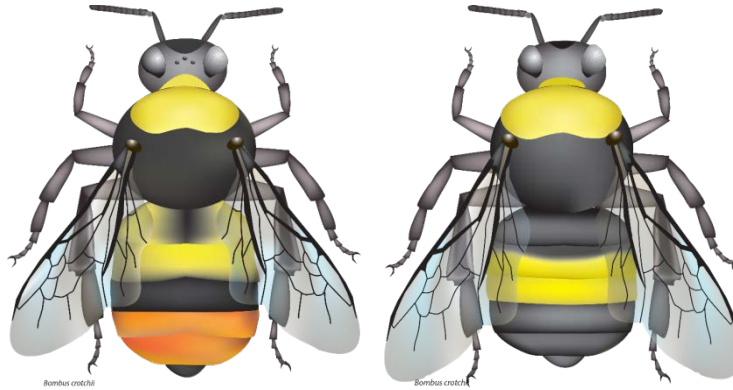
Franklin's bumble bee (*Bombus franklini*) (Frison, 1921)

Taxonomy

Bombus franklini is a valid species and its taxonomic status is uncontested. In 1971, Milliron questioned the taxonomic status of *Bombus franklini* as a valid species. Without presenting any evidence for his taxonomic decision, Milliron (1971) placed *B. franklini* in synonymy under *B. occidentalis* (Greene 1858) and then placed *B. occidentalis* in synonymy with *B. terricola*, which occurs in the eastern U.S. (Kirby 1837) on the basis of presumed overlapping color variation. This question has been addressed through studies of morphometrics by Plowright and Stephen (1980), the lack of intergradation (color/morphological) in areas of sympatry with *B. occidentalis* by Thorp et al. (1983), structure of the male genitalia by Williams (1991), and genetics (allozymes) by Scholl et al. (1992) and Cameron et al. (2007). All five studies between 1980 and 2007 concluded that *B. franklini* was indeed a valid species and distinct from *B. occidentalis*. *B. franklini* is currently recognized as a valid species by Williams et al (2014).

The original description by Frison (1921) was based on two queens sent to him by a commercial collector, E. J. Oslar and labeled by Oslar as having been collected at Nogales, Arizona in July 1917. Subsequently, Frison (1923) found additional specimens in the collections of the U.S. National Museum from "Oregon" (without more specific locality data) collected by C. F. Baker which he designated as a worker "Morphotype" and a male "Allotype." In 1926, Frison published additional records of one worker each from Roseburg and Gold Hill, Oregon, collected by H. A. Scullen. The same two records were published by Scullen (1927). Subsequently, evidence was marshaled by Thorp (1970) to dispute the putative Arizona records of *B. franklini* and to propose Gold Hill, Jackson County, Oregon the realistic type locality. Evidence included finding specimens of many other west coast bumble bee species labeled by Oslar as having been collected in southern Arizona about the same time, but representing a great disjunction for each of the species. Field studies by R. W. Thorp also failed to turn up *B. franklini* or any of the other

dozen species of bumble bees also labeled by Oslar as having been collected in southern Arizona. This is supported by evidence presented on species of *Andrena* by LaBerge (1980; 1986) and the lack of specimens from the area in major bee collections (in Thorp et al. 2010).

Identification

Bombus franklini is readily distinguished from other bumble bees in its range by the extended yellow on the anterior thorax which extends well beyond the wing bases and forms an inverted U-shape around the central patch of black, lack of yellow on the abdomen, predominantly black face with yellow on top of the head, and white at the tip of the abdomen. Other bumble bees with similar color patterns in the range of *B. franklini* have the yellow extending back to the wing bases or only slightly beyond and usually have one or more bands of yellow on the middle or slightly behind the middle of the abdomen (most on T-4). Females of most species have yellow hair on the face, in contrast to black on *B. franklini*. Females of *B. occidentalis* and *B. fervidus* that have black hair on the face also have black hair on the vertex in contrast to the yellow hair on the vertex in *B. franklini*. Females of *B. fervidus* have a long face in contrast to the round face of *B. franklini* and *B. occidentalis*.

Queens & Workers

Face round with area between bottom of compound eye and base of mandible (= malar space) shorter than wide; hair predominantly black with some shorter light hairs intermixed above and below antennal bases. Hair on top of head (= vertex) yellow. Hair of thorax (= mesosoma) on anterior two-thirds above (= scutum) yellow extending rearward laterally inside and beyond the wing bases (= tegulae) to rear third (= scutellum), but interrupted medioposteriorly by inverted U-shaped patch of black; hair on posterior third above (= scutellum) black; hair of thorax laterally (= mesopleura) black, except for small patch of yellow in upper anterior corner in area of pronotal lobes. Hair of abdomen (= metasoma) black except for whitish or silvery hair at sides and apex of 5th plate above (= tergum 5, = T-5).

Males

As for female, except malar space as long as wide, face below antennae with predominantly yellow hair, and T-6 with some pale hair laterally.

Figure 11: Female *Bombus franklini*. Illustration by Elaine Evans, The Xerces Society.

Western bumble bee (*Bombus occidentalis occidentalis*) Greene, 1858

Taxonomy

Bombus occidentalis is considered a valid species (Franklin 1913; Thorp 2005c; Cameron et al. 2007; Bertsch et al. 2010; Williams et al. 2012). *Bombus occidentalis* consists of two valid subspecies: *Bombus occidentalis occidentalis* and *Bombus occidentalis mckayi* (Williams et al. 2012; Sheffield et al. 2016).

Identification

B. occidentalis occidentalis is most easily distinguished from other *Bombus* species based on hair coloration. Note, however, that coloration in this species can be highly variable, and eight female and seven male color forms have been described (Sheffield et al. 2016). There are two prominent color forms of *B. o. occidentalis* most likely to be encountered in California. Those found in the mountains ("*occidentalis*" form) are likely to have bright white coloration on the posterior end of the abdomen (Thorp 2013, pers. comm.); this character is unusual and obvious. The "*occidentalis*" form (without any yellow on T1-4) is found throughout in the eastern part of the state in the Sierra-Cascade Range from near Yosemite to Oregon and west along the northern tier of counties into Humboldt County (Thorp 2017, pers. comm.). Specimens found closer to the coast ("*nigroscutatus*" form) replace the bright white hairs with yellowish orange hairs (Williams et al. 2014). The "*nigroscutatus*" form includes all populations on the coast and Coast Ranges from Monterey County north into Humboldt County where the yellow banding becomes narrower (Thorp 2017, pers. comm.). However, some of these yellow-banded individuals have recently been located on the Eagle Lake Ranger District of the Lassen National Forest (Rickman 2017, pers. comm.). Technical descriptions below are adapted from Williams et al. (2014):

> Queens: The queen is 20 to 21 mm in length. Their hair is entirely black on the head sometimes with a minority of yellow or gray hairs mixed in above the antennae. Their hair is yellow on the front part of the thorax (scutum), usually with black, or a minority of yellow hairs at the back of the thorax (scutellum). The majority of the hairs between and

27

below the wings are black. On the abdomen, the first two tergal (dorsal plate) segments (T1-T2) are black. If T3 is entirely yellow, then T4 is black, T5 white. If T3 is black, or with a minority of yellow, T4 and T5 are white.

Workers: The worker is 9 to 15 mm in length. Their hair is entirely black on the head sometimes with a minority of yellow or grayish hairs mixed in above the antennae. Their hair is yellow on the front part of the thorax (scutum), usually with black, or a minority of yellow hairs at the back of the thorax (scutellum). The majority of the hairs between and below the wings are black. On the abdomen, the first tergal (T1-dorsal plate) segment is black. T2 has at least some black on it centrally and anteriorly. If T3 is entirely yellow, the white hairs on T4 (if applicable) and T5 seen in queens will be replaced with yellowish orange hairs. If T3 with at most a minority of yellow hairs, T4 and T5 are white.

Males: The male is 13 to 17 mm in length. The hair on the head is pale yellowish on the front of the face. The top of the head has pale yellowish hairs medially, with some black hairs, especially laterally. The hair on the front of the thorax is pale yellowish. The hair on T1 is black with at least some black centrally and anteriorly on T2. If T3 is black the basal part of the fourth abdominal segment is black, with the remainder, as well as segments five to seven, whitish – although sometimes a yellowish orange. If T3 is entirely yellow, T5 is black basally, and the remainder, as well as T6-T7 are yellowish orange.
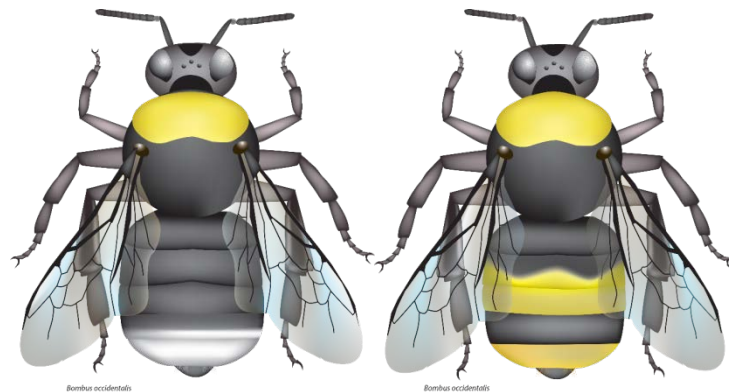
Figure 12: *Bombus. o. occidentalis* (female) worker, nominate color form ("*occidentalis*" - left), coastal color form ("*nigroscutatus*" - right). Although eight color forms for females of this species have been described (Sheffield et al. 2016), the two color forms illustrated above are representative of the two color forms of female *B. o. occidentalis* that occur in California. Illustrations by Elaine Evans and Rich Hatfield, the Xerces Society.

Suckley Cuckoo Bumble Bee (*Bombus suckleyi*) Greene, 1860

Taxonomy
This species was described by Greene (1860) and recent analyses have confirmed that it is a

valid species in the subgenus *Psithyrus* (Cameron et al. 2007; Williams et al. 2008a).

Identification

As a social parasite of other *Bombus* species, the females of this species do not collect pollen and do not have a corbicula (pollen carrying basket) on their hind leg tibia. There is also no worker caste in this species; all individuals are either male or reproductive females. *Bombus suckleyi* is most easily distinguished in the field from other *Bombus* species based on hair coloration and physical characteristics. The species that look similar to *B. suckleyi* with overlapping ranges in California are *B. insularis* and *B. flavidus*. The differences between these species and *B. suckleyi* are noted in the detailed description below (descriptions compiled in part from Williams *et al.* 2014).

> Females: *Bombus suckleyi* females are 18 to 23 mm in length. Cuckoo bumble bees, members of the subgenus *Psithyrus* (including *B. suckleyi*), do not have a corbicula (pollen carrying basket on their hind leg), unlike the true bumble bees (pollen collecting, social species). Instead, their hind leg tibia is convex and densely covered in hairs. *B. suckleyi*'s hair is short and even. The hair of the head (including the vertex – top of the head) is black (contrast *B. insularis* – yellow face and vertex, and *B. flavidus* – yellow vertex). The hair of the thorax (including below the wings) is mostly yellow, with a black spot or band between the wings, sometimes with a black triangular notch behind, and between the wings. The first two tergal (T-dorsal plate) segments on the abdomen are black (contrast most *B. flavidus*), usually with at least some yellow (laterally and posteriorly) on T3 – no yellow centrally. T4 has predominantly yellow hairs, with a patch of black centrally and anteriorly (contrast *B. flavidus*). T5 is usually black, but can have yellow laterally; T6 is black.

> Males: The male is 13 to 16 mm in length. The color patterns for males of this species are extremely variable. The only consistent features are yellow on all of T1 and T4 (contrast *B. insularis*), with some (or all) yellow on T2, T3, T5 and T6. T7 is black (contrast *B. flavidus*).

> The illustration below represents the color patterns exhibited by females. Males tend to have more yellow on the abdomen, especially on the first (anterioral) abdominal segment. The hair of the face on both males and females of this species is black (contrasted with *B. insularis* – a sympatric and common member of the *Psithyrus* subgenus and look-alike species).

IV. KIND OF HABITAT NECESSARY FOR SURVIVAL

Habitat Requirements
All bumble bees have three basic habitat requirements: suitable nesting sites for the colonies, availability of nectar and pollen from floral resources throughout the duration of the colony period (spring, summer, and fall), and suitable overwintering sites for the queens. In addition, their populations can be negatively affected by both pathogens and pesticides; thus, they may require habitat that is free from exposure to high levels of both native and exotic pathogens, and pesticides that cause harm to colonies. Bumble bees are found in a wide variety of natural, agricultural, urban, and rural habitats, although species richness tends to peak in flower-rich meadows of forests and subalpine zones (Goulson 2010).

Nest and Overwintering Sites
Bumble bee colony success is often limited by the availability of suitable nesting and overwintering sites. Diverse habitat features will increase the likelihood of nesting and overwintering success. Bumble bee queens emerge from hibernation in the early spring and immediately start foraging for pollen and nectar and begin to search for a nest site. Nesting preferences vary by species and local habitat conditions. Nests are often located underground in abandoned holes made by ground squirrels, mice, and rats, or occasionally abandoned bird nests (Osborne et al. 2008). Some species nest on the surface of the ground (in tufts of grass) or in empty cavities. Bumble bees that nest aboveground may require undisturbed areas with nesting resources such as grass and hay to protect nests (Williams et al. 2014). Furthermore, areas with woody cover, or other sheltered areas provide bumble bees sites to build their nest (e.g., downed wood, rock walls, brush piles, etc.).

Although little is known about the overwintering habits of most bumble bee species, some species are known to dig a few centimeters into soft, disturbed soil and form an oval shaped chamber in which the queen will spend the duration of the winter. Other species may overwinter

in small cavities just below or on the ground surface. Compost in gardens, leaf litter, or mole hills may provide suitable protection for queens to overwinter (Goulson 2010) before they emerge to begin a new colony (Williams et al. 2014). While there is still much to be learned about the nesting and overwintering biology of bumble bees, any near-surface or subsurface disturbance of the ground can be disastrous for bumble bee colonies or overwintering queens. This includes mowing, fire, tilling, grazing, and planting. Having large areas of land free from such practices is essential for sustaining bumble bee populations. Since bumble bees usually nest in abandoned rodent nests, nesting sites may be limited by the abundance of rodents; thus it is also important to retain landscape features that will support rodent populations. Furthermore, reducing ground disturbance can promote overwintering habitat for bumble bees (McFrederick and LeBuhn 2006).

Floral Resources
Bumble bees depend on the availability of habitats with a rich supply of floral resources that bloom continuously during the entirety of the colony's life. The queen collects nectar and pollen from flowers to support the production of her eggs, which are fertilized by sperm she has stored since mating the previous fall. In the early stages of colony development, the queen is responsible for all food collection and care of the young. As the colony grows, workers take over the duties of food collection, colony defense, and care of the young. The queen then remains within the nest and spends most of her time laying eggs. Colonies typically consist of between 50 and 500 workers at their peak (Plath 1927; Thorp et al. 1983; Macfarlane et al. 1994) along with the queen. Queen production is dependent on access to sufficient quantities of pollen. Thus, the amount of pollen available to bumble bee colonies directly affects the number of queens that can be produced (Burns 2004). Furthermore, since queens are the only bumble bees capable of forming new colonies, pollen availability directly impacts future bumble bee population levels. In fact, landscape level habitat quality has been shown to influence bumble bee species richness and abundance, indicating that isolated patches of habitat are not sufficient to fully support bumble bee populations (Hatfield and LeBuhn 2007; Öckinger and Smith 2007).

Bumble bees play the vital role of pollinators as they transfer pollen between native flowering plants when they are foraging. As generalist foragers, bumble bees do not depend on any one flower type. However, some plants do rely on bumble bees to achieve pollination. The loss of bumble bees can have far ranging ecological impacts due to their role as pollinators. An examination of the theoretical effect of removal of specialist and generalist pollinators on the extinction of plant species concluded that the loss of generalist pollinators poses the greatest threat to pollinator networks (Memmott et al. 2004). In Britain and the Netherlands, where multiple bumble bee species, as well as other bees, have gone extinct, there is evidence of decline in the abundance of insect pollinated plants (Biesmeijer et al. 2006).

Since bumble bee colonies obtain all of their nutrition from pollen and nectar, they need a

constant supply of flowers in bloom. Not all flowers are of equal value to bumble bees. Many varietal hybrids do not produce as much pollen and/or nectar as their wild counterparts (Frankie et al. 2005). Bumble bees do have preferences for certain species of plants. Generally, they prefer flowers that are purple, blue, or yellow; they are essentially blind to the color red and will not forage on red flowers (unless there are UV cues on the petals). Having plants with a diversity of corolla tube lengths will support bumble bees with varying tongue lengths. Bumble bees also show a strong preference to perennial plants as opposed to annuals; perennials tend to have higher quantities of nectar (Fussel and Corbet 1992). In addition to flowers, many bumble bee species may benefit from the presence of native bunch grasses. Bunch grasses will add multiple textures and heights to a garden or landscape and provide places for bumble bees to nest and overwinter.

Crotch Bumble Bee (*Bombus crotchii*) Habitat Requirements
In California, *B. crotchii* inhabits open grassland and scrub habitats. This species occurs primarily in California, including the Mediterranean region, Pacific Coast, Western Desert, Great Valley, and adjacent foothills through most of southwestern California (Williams et al. 2014). This species was historically common in the Central Valley of California, but now appears to be absent from most of it, especially in the center of its historic range (Hatfield et al. 2014; Richardson et al. 2014).

Nest Sites
The size of *Bombus crotchii* colonies has not been well documented. *B. crotchii*, like most other species of bumble bees, primarily nests underground (Williams et al. 2014).

Floral Resources
Bumble bees, including *Bombus crotchii*, are generalist foragers and have been reported visiting a wide variety of flowering plants. *B. crotchii* has a very short tongue, and thus is best suited to forage at open flowers with short corollas. The plant families most commonly associated with *B. crotchii* observations or collections from California include Fabaceae (66 observations), Apocynaceae (47), Asteraceae (28), Lamiaceae (27), Boraginaceae (12) (Richardson 2017). Similarly, in an analysis largely based on records from California, Thorp et al. (1983) reports that *B. crotchii* records are primarily associated with plants in the Leguminosae (=Fabaceae), Labiatae (=Lamiaceae), Hydrophyllaceae (=Hydrophylloideae), Asclepiadaceae (=Asclepiadoideae), and Compositae (=Asteraceae). Williams et al. (2014) report plants in the genera *Asclepias, Chaenactis, Lupinus, Medicago, Phacelia,* and *Salvia* as example food plants. Note that these floral associations do not necessarily represent *B. crotchii's* preference for these plants over other flowering plants, but rather may represent the prevalence of these flowers in the landscape where this species occurs.

Overwintering Sites
Very little is known about the hibernacula, or overwintering sites utilized by *Bombus crotchii*. Generally, bumble bees overwinter in soft, disturbed soil (Goulson 2010), or under leaf litter or other debris (Williams et al. 2014).

Phenology
According to Thorp et al. (1983), the flight period for *Bombus crotchii* queens in California is from late February to late October, peaking in early April, with a second pulse in July. The flight period for workers and males in California is from late March through September; worker and male abundance peak in early July (Thorp et al. 1983).

Franklin's Bumble Bee (*Bombus franklini*) Habitat Requirements
Bombus franklini has the most limited geographic distribution of any bumble bee in North America and possibly the world (Williams 1998). It is known from Siskiyou and Trinity counties in California. *Bombus franklini* inhabits open grassy coastal prairies and Coast Range meadows from southern Oregon to northern California. Elevations of localities where it has been found range from 540 feet (162 m) in the north to above 7800 feet (2340 m) in the south of its historic range.

Nest Sites
The nesting biology of *B. franklini* is unknown, but it probably nests in abandoned rodent burrows as is typical for other members of the subgenus *Bombus sensu stricto* (Hobbs 1968).

Floral Resources
Like other bumble bees, *Bombus franklini* is a generalist forager and has been reported visiting a wide variety of flowering plants. *B. franklini* has been observed collecting pollen from lupine (*Lupinus* spp.) and California poppy (*Eschscholzia californica*), and collecting nectar from horsemint or nettle-leaf giant hyssop (*Agastache urticifolia*) and mountain monardella (*Monardella odoratissima*) (Thorp et al. 2010). This species may collect both pollen and nectar from vetch (*Vicia* spp.) as well as rob nectar from it (Thorp et al. 2010).

Overwintering Sites
Very little is known about the hibernacula, or overwintering sites, utilized by *B. franklini*, although generally bumble bee females are known to overwinter in soft, disturbed soil (Goulson 2010), or under leaf litter or other debris (Williams et al. 2014).

Phenology
The flight season of *B. franklini* is from mid-May to the end of September (Thorp et al. 1983).

Western Bumble Bee (*Bombus occidentalis occidentalis*) Habitat Requirements
Meadows and grasslands with abundant floral resources are the appropriate habitat for this

subspecies. While *Bombus occidentalis occidentalis* was historically known throughout the mountains and northern coast of California, it is now largely confined to high elevation sites and a small handful of records on the northern California coast (Cameron et al. 2011a; Xerces Society 2012; Williams et al. 2014; Xerces Society et al. 2017).

Nest Sites

Reports of *Bombus occidentalis occidentalis* nests are primarily in underground cavities such as old squirrel or other animal nests and in open west-southwest slopes bordered by trees, although a few nests have been reported from above-ground locations such as in logs among railroad ties (Plath 1922; Hobbs 1968; Thorp et al. 1983; Macfarlane et al. 1994). Thus, *B. o. occidentalis* nesting sites may be limited by rodent abundance (Evans et al. 2008). Nest tunnels have been reported to be up to 2.1 m long for this species and the nests may be lined with grass or bird feathers (MacFarlane et al. 1994). *Bombus o. occidentalis* colonies can contain as many as 1,685 workers and produce up to 360 new queens; this colony size is considered large relative to many other species of bumble bees (MacFarlane et al. 1994).

Floral Resources

Bumble bees, including *Bombus occidentalis occidentalis*, are generalist foragers and have been reported visiting a wide variety of flowering plants. *B. o. occidentalis* has a very short tongue, and thus is best suited to forage at open flowers with short corollas and has also been documented 'nectar robbing' – biting through the corolla tube and drinking nectar through the hole without contacting the anthers, or stigma of the plant – several species of flowers with longer corolla tubes. Bumble bees require plants that bloom and provide adequate nectar and pollen throughout the colony's life cycle, which is from early February to late November for *B. o. occidentalis* (although the actual dates likely vary by elevation and local climatic conditions, including interannual variation). The plant genera most commonly associated with *B. o. occidentalis* observations or collections from California include *Cirsium* (36 observations), *Erigonum* (18), *Solidago* (16), "Aster" (14), *Ceanothus* (13), *Centaurea* (13), and *Penstemon* (13) (Richardson 2017). Similarly, in an analysis largely based on records from California, Thorp et al. (1983) reports that *B. o. occidentalis* records are primarily associated with plants in the Leguminosae (=Fabaceae), Compositae (=Asteraceae), Rhamnaceae, and Rosaceae families. Note that these floral associations do not necessarily represent *B. o. occidentalis*' preference for these plants over other flowering plants, but rather may represent the abundance of these flowers in the landscape.

Overwintering Sites

Very little is known about the hibernacula, or overwintering sites utilized by most bumble bees, although Hobbs (1968) reported *B. occidentalis* hibernacula that were two inches deep in a "steep west slope of the mound of earth." The closely related *B. terrestris* reportedly hibernates beneath trees (Sladen 1912; *In* Hobbs 1968).

Phenology
According to Thorp et al. (1983), the flight period for *Bombus occidentalis occidentalis* queens in California is from early February to late November, peaking in late June and late September. The flight period for workers and males in California is from early April to early November; worker abundance peaks in early August, and male abundance peaks in early September (Thorp et al. 1983). Rangewide, including the entire species complex (including *B. o. mckayi*), queens peak in late June, workers peak in early August, and males peak in late August (Williams et al. 2014).

Suckley Cuckoo Bumble Bee (*Bombus suckleyi*) Habitat Requirements
Bombus suckleyi habitat includes western meadows largely confined to mountainous regions. *B. suckleyi*, and other species of bumble bee in the subgenus *Psithyrus,* are unique in that they have an obligate dependency on social bumble bees (Goulson 2010) to collect pollen on which to rear their young. As such, *B. suckleyi* are a cuckoo species that are nest parasites of other species of bumble bees and are not primitively eusocial themselves – there is no division of labor within the species; all members of the species have equal status, and are reproductive. Cuckoo bumble bees typically emerge from their hibernacula later in the spring than other bumble bee species. Once the female cuckoo bumble bee does emerge, she forages for herself and begins searching for occupied nests. When she finds a suitable host (*B. suckleyi* utilizes *B. occidentalis* hosts [Thorp et al. 1983]) she enters the nest, kills or subdues the queen of that colony, and forcibly (using pheromones and/or physical attacks) "enslaves" the workers of that colony. Then she lays her own eggs and forces the workers of the native colony to feed her and her developing young. Since all of the resulting cuckoo bee offspring are reproductive (not workers), they leave the colony to mate, and the mated females seek out a place to overwinter, then repeat the cycle the following spring/early summer (Goulson 2010).

Cuckoo bumble bees often attack a broad range of host species, but some species specialize in attacking the members of just one species or subgenus. *B. suckleyi* has been recorded in nests of bumble bees in six different subgenera, but the most common association is with the subgenera *Pyrobombus* and *Bombus,* and the only nests in which *B. suckleyi* adults have been produced are those of *B. occidentalis* (reviewed in Thorp et al. 1983). As such, *B. suckleyi* has been documented breeding as a parasite of colonies of *Bombus occidentalis,* and has been recorded as present in the colonies of *B. terricola, B. rufocinctus, B. fervidus, B. nevadensis,* and *B. appositus* (Williams et al. 2014). Males of this species patrol circuits in search of mates (Thorp et al. 1983).

Nest Sites
Bombus suckleyi has been detected in the nests of several species of bumble bees, but it has only ever been observed reproducing in nests of *B. occidentalis* (Thorp et al. 1983). *B. occidentalis* nests are primarily in underground cavities such as old squirrel or other animal nests and in open

west-southwest slopes bordered by trees, although a few nests have been reported from above-ground locations such as in logs among railroad ties (Plath 1922; Hobbs 1968; Macfarlane et al. 1994; Thorp et al. 1983). Availability of nest sites for *B. occidentalis* may depend on rodent abundance (Evans et al. 2008). *B. occidentalis* nest tunnels have been reported to be up to 2.1 m long and the nests may be lined with grass or bird feathers (Macfarlane et al. 1994). *Bombus suckleyi* depends upon not only the presence of suitable nesting sites for *B. occidentalis*, but also upon extant populations of that species.

Floral Resources

Bumble bees require plants that bloom and provide adequate nectar and pollen throughout the colony's life cycle. In order for *B. suckleyi* to survive, there must also be early season resources for its host, *B. occidentalis*. There are records of *B. occidentalis* from early February to late November. The amount of pollen available in the landscape directly affects the number of new queens that a bumble bee colony can produce, and since queens are the reproductive members of the colony, pollen availability is directly related to future bumble bee population size (Burns 2004). Early spring and late fall are often periods with lower floral resources; the presence of flowering plants at these critical times is essential.

Bombus suckleyi is a generalist forager and has been reported to visit a wide variety of flowering plants. The known plant associations for this species in California are scarce, but generally this species is associated with plants in the following genera: "Aster", *Chrysothamnus*, *Cirsium*, *Solidago,* and *Centaurea* (Williams et al. 2014; Richardson 2017). Plant genera that are associated with *B. occidentalis occidentalis* – its known host, and a prerequisite for the survival of *B. suckleyi* include: *Cirsium* (36 observations), *Erigonum* (18), *Solidago* (16), "Aster" (14), *Ceanothus* (13), *Centaurea* (13), and *Penstemon* (13) (Richardson 2017). Note that these floral associations do not necessarily represent *B. occidentalis'* or *B. suckleyi*'s preference for these plants over other flowering plants, but rather may represent the abundance of these flowers in the landscape.

Overwintering Sites

Very little is known about the hibernacula, or overwintering sites, utilized by *Bombus suckleyi*, although generally bumble bee females are known to overwinter in soft, disturbed soil (Goulson 2010), or under leaf litter or other debris (Williams et al. 2014).

Phenology

According to Thorp et al. (1983), the flight period for *B. suckleyi* females in California is from late May to late October, peaking in June. The flight period for males in California is from early July to late September; peaking late July, with a second pulse late August and early September (Thorp et al. 1983).

V. FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

Each of the following factors pose a substantial threat to the survival of the four species of bumble bees included in this petition: present or threatened modification or destruction of its habitat; overexploitation; competition; disease; and other natural events and human-related activities, including pesticide use, genetic factors, and climate change (reviewed *in* Williams and Osborne 2009; Williams et al. 2009; Goulson 2010; Cameron et al. 2011b; Hatfield et al. 2012; Fürst et al. 2014). In addition, the cuckoo bumble bee species (*Bombus suckleyi*) is threatened by loss of its primary host species, *B. occidentalis occidentalis*. Below we summarize the rationale and available evidence that each factor poses a threat to these four bumble bee species.

A. Present or Threatened Modification or Destruction of Habitat

1. The Loss of Habitat Due to Human Induced Landscape Scale Modifications

Many North American bumble bees face threats from habitat alterations that can interfere with primary habitat requirements, including access to: sufficient food (nectar and pollen from flowers), nesting sites (such as underground abandoned rodent cavities or above ground in clumps of grasses), and overwintering sites for hibernating queens (undisturbed soil and leaf litter).

Many bumble bees historically occupied the grasslands and prairies of the continent, including California, which have largely been lost or fragmented by agricultural conversion and urban development or transformed by fire suppression, invasive species, and livestock grazing. Noss et al. (1995) considers all native grasslands in California to be a critically endangered ecosystem, having declined by more than 98%. *Bombus crotchii* was historically known from throughout California's Central Valley, which once contained vast prairies rich with wildflowers. Indeed, historic accounts of the San Joaquin Valley describe abundant and widespread wildflowers; in 1868 John Muir wrote: "the valley of the San Joaquin is the floweriest piece of world I ever walked, one vast level, even flower-bed, a sheet of flowers…". The U.S. Geological Survey reports that more than 260,000 acres of grassland and shrubland habitat within California's Central Valley ecoregion were either developed for housing or converted to agriculture between 1980 and 2000 (Sleeter 2016) – accounting for nearly 4% of the 7 million acres that make up the Central Valley. A more recent study (Lark et al. 2015) highlights the rate of grassland conversion to agriculture across the U.S. from 2008-2012, and the rate of loss is more severe in California's Central Valley than any other ecoregion in the western US.
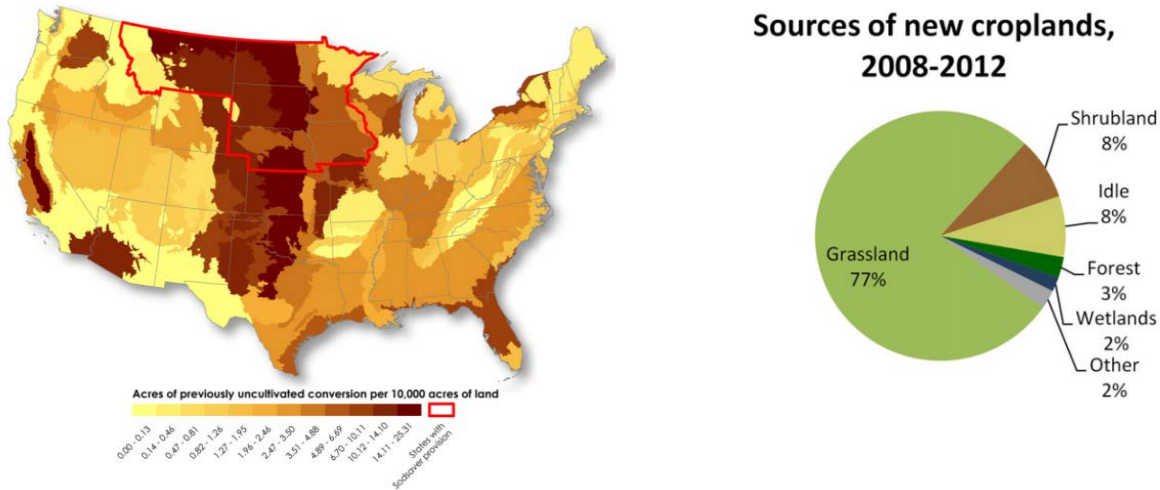
Figure 14: Left: 2008–2012 conversion of previously uncultivated land. The map identifies the amount of conversion to cropland from land that had not previously been used for agriculture (cropland or pasture), confirmed back to the early 1970s. Display units represent average number of previously uncultivated acres converted per 10 000 acres of total land within each EPA Level III Ecoregion. Red outline is of the six states covered under the 2014 US Farm Bill 'Sodsaver' provision, which aims to reduce conversion of previously uncultivated land. The observed patterns of elevated nationwide conversion suggest that the new policy's limited geographic coverage will likely be insufficient to prevent the majority of new breakings. Right: Types of land converted to crop production. Grasslands were the most common land cover to be converted to cropland, followed by shrubland and long term (10+ year) idle land. Figures from Lark et al. (2015).

In addition to the endangerment of critical prairie ecosystems, mountain meadows throughout the western United States are also a highly imperiled ecosystem, and are experiencing continued threats from climate change (Field et al. 2007; Parry et al. 2007; Saunders et al. 2008), livestock grazing (Belsky et al. 1999; Hayes & Holl 2003; Stoner & Joern 2004; Hatfield & LeBuhn 2007), and forest encroachment (Skinner 1995; Coop & Givnish 2007; Zald et al. 2012; Highland & Jones 2014). Recent analyses of western meadows in Oregon and Washington, which provide important habitat for bumble bees (Goulson 2010; Williams et al. 2014), indicate that they have lost between 18% and 40% of their area due to encroaching conifers (Skinner 1995; Coop & Givnish 2007). Several of the bees in this petition are known from montane meadows (including: *Bombus occidentalis occidentalis*, *B. franklini*, and *B. suckleyi*). Montane meadows may become particularly important habitats for declining bumble bee species as the climate warms and habitat loss in valleys and low elevation prairies increases.

Bumble bee species richness, abundance, and genetic diversity are influenced by the quality of habitat on a landscape level. While bumble bees can forage and disperse over relatively long distances, isolated patches of habitat may not be sufficient to support bumble bee populations (Hatfield & LeBuhn 2007; Öckinger & Smith 2007). Because of their unique method of sex determination and their colonial life cycle, bumble bees are particularly sensitive to habitat fragmentation and populations of bumble bees existing in fragmented habitats can also face

38

problems with inbreeding depression (Darvill et al. 2006; 2012; Ellis et al. 2006). Specifically, Darvill et al. (2012) found that bumble bee populations limited to less than 15 km^2 of habitat were more likely to show signs of inbreeding. Goulson (2010) suggests that a viable population of bumble bees probably requires approximately 3.3-10 km^2 of suitable habitat. Habitat fragmentation has been shown to reduce bumble bee foraging rates and alter their foraging patterns (Rusterholz and Baur 2010). Fragmented habitats may not support healthy metapopulation structures and may eliminate or decrease source populations of bumble bees for recolonization (National Research Council 2007). A study in California found that inbreeding in one common species of bumble bee (*B. vosnesenskii*) was lower in landscapes with increasing natural woodland cover relative to other landscape types (Jha 2015). Thus, agricultural intensification, livestock grazing, urban development, as well as other habitat modifications, can jeopardize the habitat needs of bumble bees and lead to the fragmentation of habitat into pieces that are too small or too distant to support diverse bumble bee communities (Goulson et al. 2008). The major landscape-scale modifications and their threats to bumble bees are outlined below.

i. Agricultural Intensification
The biggest changes within the range of the species in this petition have come from modern farming techniques that have enabled more intensive use of agricultural lands, widespread grazing of grasslands and meadows, and increased use of insecticides (reviewed in Hatfield et al. 2012). Agricultural intensification has been shown to have a negative impact on species richness, abundance and diversity of wild bees (Le Féon et al. 2010). Agricultural intensification is primarily blamed for the decline of bumble bees in Europe (Williams 1986; Carvell et al. 2006; Diekötter et al. 2006; Fitzpatrick et al. 2007; Kosior et al. 2007; Goulson et al. 2008), and may also pose a significant threat to bumble bees in the US (Hines & Hendrix 2005; Grixti et al. 2009). In fact, agricultural intensification and rapid urbanization in California's Central Valley may have reduced populations of *B. crotchii*, since this species was historically common in the Central Valley but now appears to be absent from much of its historic range, especially in the central part (Thorp 2014, pers. comm.; Hatfield et al. 2015a). Furthermore, increases in farm size and changes in technology and operating efficiency have led to many practices that can be detrimental to bumble bees. This has led to the loss of pollinator friendly hedgerows, weed cover, and legume pastures through more modern practices including more effective land leveling, irrigation, tilling, and pesticide and fertilizer usage. Tilling may directly destroy bumble bee overwintering sites and bumble bee nests may be at risk of being destroyed by farm machinery (Goulson 2003). One site within *Bombus franklini*'s historic range near Gold Hill in Jackson County, OR had significant excavation and deposited soil that altered approximately 50% of the bumble bee foraging habitat. The widespread application of the herbicide glyphosate in conjunction with increased planting of genetically modified crops that are tolerant to glyphosate has reduced the availability of milkweeds in agricultural field margins (Pleasants & Oberhauser 2013), and has probably had a similar effect on other wildflower species, which

would have also provided important nectar resources for bumble bees. In northern Alberta, one study found that genetically modified herbicide tolerant canola fields had a lower abundance of wild bees than conventional or organic canola fields (Morandin and Winston 2005). The broad scale use of pesticides, including a novel class of systemic insecticides (neonicotinoids), poses a unique threat to bumble bees; this topic is discussed in detail below under Factor E *Other Natural Events or Human-related Activities*.

Both floral abundance and grasslands are frequently reduced in agriculturally intensive landscapes. Hines and Hendrix (2005) found that bumble bee diversity in Iowa prairies was linked to floral abundance and the presence of grasslands in the surrounding landscape, both of which have been reduced in modern agricultural landscapes. Although some flowering crops provide nectar and pollen resources for bumble bees, which can lead to increased densities of bumble bees and colony growth (Westphal et al. 2003; 2009), large monocultures do not necessarily improve the reproductive success of bumble bees (Westphal et al. 2009); likely because the resources they provide are typically only available for a short period of time. Monocultures may in fact serve as population sinks since bumble bee colonies need floral resources throughout their colony cycle from early spring to fall (Goulson et al. 2008).

ii. Livestock Grazing

Ungulate grazing can significantly alter the landscape. Studies have shown that grazing can have both indirect and direct effects on bumble bee populations. Indirect effects include removing floral resources (Morris 1967; Sugden 1985; Kruess and Tscharntke 2002a; 2002b; Vazquez and Simberloff 2003; Hatfield and LeBuhn 2007; Xie et al. 2008; Kimoto 2010; Scohier et al. 2012) and potentially reducing populations of nesting rodents (e.g., Bueno et al. 2011), which in turn may reduce the number of nest sites available to bumble bees (Johnson & Horn 2008; Schmidt et al. 2009). Ungulates can directly affect above ground bumble bee nests by trampling (Sugden 1985). The habitat, type of grazer, as well as the timing, intensity, and length of livestock grazing are all factors that can influence how the practice affects flora and fauna (Gibson et al. 1992; Carvell 2002; Sjodin 2007). Numerous studies have found intensive sheep grazing to be particularly detrimental to bumble bee populations (Carvell 2002; Hatfield and LeBuhn 2007; Scohier et al. 2012), an effect that is likely due to the selective removal of flowers by sheep. In California, BLM and Forest Service lands historically occupied by *Bombus franklini* are periodically subject to substantial livestock impact. Although livestock grazing has differing impacts on flora and fauna based on the type, habitat, intensity, timing and length of livestock grazing (Gibson et al. 1992), several studies of livestock grazing on bees suggest increased intensity of livestock grazing negatively affects the species richness of bees (Morris 1967; Sugden 1985; Carvell 2002; Vazquez & Simberloff 2003; Hatfield & LeBuhn 2007).

iii. Urban Development

The conversion of the landscape to urban and suburban uses continues to transform and fragment

habitat, which has likely had a negative effect on populations of many bumble bee species, including the species listed in this petition. Roads and railroads fragment plant populations and thus restrict the movement of bumble bees (Bhattacharya et al. 2003). Recent research in northern California found that the overall area of the landscape covered by pavement had a negative effect on the density of bumble bee nests. In addition, bumble bee colony density was greater in natural oak chaparral than other landscape types, including urban areas (Jha & Kremen 2012). The western bumble bee has been found in some natural areas within urban environments, such as parks, restored prairies, and other natural areas near urban centers (Williams et al. 2014). Some residential gardens and urban parks can provide valuable floral, and in some cases, nesting and overwintering resources, and may serve as important habitat refuges for bumble bees (Frankie et al. 2005; McFrederick & LeBuhn 2006; Goulson 2010), even though they may not support the species richness that was found historically (McFrederick & LeBuhn 2006).

iv. Fire and Fire Suppression
Fire is an important natural and managed disturbance throughout natural areas in the United States. Historically, fires maintained forbs and grasses within meadows and prairies, and prevented shrubs and trees from encroaching. Due to decades of fire suppression and the growing proximity of housing developments to wildlands, suppression of wildfire is seen as necessary to protect natural resources, homes, and businesses (Radeloff et al. 2018). Fire suppression can lead to extensive changes in vegetation structure, including degradation and loss of grasslands and herbaceous species as the shrub community matures (Schultz & Crone 1998; Panzer 2002). The practice of fire suppression has compromised grassland habitats that formerly supported diverse communities of bumble bees. In forests, these changes include an increase in combustible fuel loads, increase in tree density, increase in fire intolerant species, and loss of the herbaceous layer as the shrub community matures (Huntzinger 2003). In forested meadows fire suppression can lead to invasion and maturation of shrubs and trees and an increase in invasive plants species. Eventually continued succession results in the degradation and loss of the grasslands (Schultz & Crone 1998; Panzer 2002). Forest encroachment not only reduces available bumble bee habitat, but also closes off corridors between meadows, which reduces dispersal and foraging opportunities (Roland & Matter 2007). Continued fire suppression not only results in habitat alteration, but also renders the habitat susceptible to catastrophic, large scale, and high temperature fires due to increases in combustible fuel loads, tree density, and fire intolerant species (Huntzinger 2003). Catastrophic, large scale, and high intensity fires may be particularly harmful to already vulnerable populations of bumble bees listed in this petition. The threat is particularly acute for *B. franklini*, as a single fire event in an area where *B. franklini* are concentrated could extirpate an entire population. Prescribed fire can be a valuable tool in restoring native prairie and meadow plant fauna, which in turn has the potential to benefit bumble bees. However, natural or introduced fire can be detrimental to bumble bee populations if not planned and executed carefully with the life history needs of bumble bees considered.

2. The Loss of Habitat Due to Increased Use of Herbicides

Herbicides are often used within invasive weed management, and can be more cost effective than other management methods. However, the use of herbicides to control weeds can indirectly harm pollinators through removal of flowers that once provided them with pollen and nectar resources (Williams 1986; Shepherd et al. 2003, Pleasants & Oberhauser 2013). In addition to indirect effects, some herbicides can directly harm pollinators.

Just as pollinators can influence the plant community, changes in vegetation can have an impact on pollinators (Kearns & Inouye 1997). The broadcast application of a non-selective herbicide can indiscriminately reduce floral resources for all bumble bees and nesting habitat for species that nest above ground, such as the American bumble bee (Smallidge & Leopold 1997). Bumble bees require consistent sources of nectar, pollen, and nesting material during times adults are active, typically from mid-February to late September in temperate areas. The reduction in resources caused by non-selective herbicide use could cause a decline in bumble bee reproductive success and/or survival rates. Kevan (1999) found that herbicides reduced Asteraceae and Lamiaceae flowers in France, contributing to a decline in bumble bee populations. Kevan (1999) also found that herbicide applications have reduced the reproductive success of blueberry pollinators by limiting alternative food sources that can sustain the insects when the blueberries are not in bloom. Kearns et al. (1998) state "herbicide use affects pollinators by reducing the availability of nectar plants. In some circumstances, herbicides appear to have a greater effect than insecticides on wild bee populations… Some of these bee populations show massive declines due to the lack of suitable nesting sites and alternative food plants."

The use of the herbicide glyphosate has dramatically increased with the widespread planting of genetically modified glyphosate-tolerant corn, soybean, and cotton, which were introduced in the late 1990s (Pleasants & Oberhauser 2013). With the introduction of genetically modified glyphosate tolerant (Roundup Ready™) soybeans in 1996 and corn in 1998, a 20-fold increase in the use of the herbicide glyphosate has occurred on these two crops from 1995-2013 (Center for Biological Diversity et al. 2014). Increased use of glyphosate in agricultural areas has likely led to the reduced availability of wildflowers in field margins – which otherwise would have been an important resource for bumble bees. Moreover, recent research showed that genetically modified glyphosate-tolerant soybean fields with standard and recommended application rates of glyphosate had lower diversity of flowering weeds than control fields (Scursoni et al. 2006). The loss of flowering weeds from agricultural areas that have become genetically modified during the period from 1996-present has likely deprived many of these species of bumble bees of significant amounts of nectar and pollen, and the continued loss of these critical resources presents a threat to the future survival of these species. Moreover, recent research within the Midwest has shown that simplification of landscapes through intensive agriculture leads to more pest pressure, and

thus increased application of insecticides (Meehan et al. 2011). Thus, the conversion of habitat to intensive agriculture throughout much of the United States, the increased use of glyphosate resistant crops, and the subsequent increase in insecticide use has likely had a compounding negative effect on bumble bees. Research has shown that genetically modified glyphosate-tolerant soybean fields with standard and recommended application rates of glyphosate had lower diversity of flowering weeds than control fields (Scursoni et al. 2006). Other studies have shown that agricultural lands without native habitat host a less diverse pollinator community (Kremen et al. 2002; Winfree et al. 2008; Morandin & Kremen 2013).

Recent studies (Dai et al. 2018; Motta et al. 2018) also raise the novel concern that glyphosate can negatively affect the beneficial bacterial colonies found in the honey bee gut thus indirectly affecting the health of bees. Motta et al. 2018 found that young worker bees exposed to field realistic levels of glyphosate experienced increase mortality with subsequent exposure to pathogens. The researchers' results indicate that the increased mortality was due to glyphosate reducing the protective effect of the gut microbiota.

Bumble bees could also be further threatened by the introduction of new herbicide-resistant crops that are genetically engineered to be resistant to multiple herbicides including 2,4-D and dicamba; many growers are switching to dicamba as weeds develop resistance to the herbicide glyphosate. The U.S. Department of Agriculture has recently approved a suite of 'next generation' genetically engineered (GE) herbicide resistant corn and soybeans developed by Dow Agrosciences and soy and cotton developed by Monsanto, which will be sold in conjunction with new combinations of herbicides. These GE crops are resistant to the herbicides 2,4-D, dicamba, and glyphosate (Roundup Ready Xtend[TM] by Monsanto). The use of herbicides is expected to increase with the adoption of these 'next generation' GE crops (Mortensen et al. 2012). Dicamba and 2,4-D are already among the leading herbicides that cause drift-related crop injury because of their volatility (Freese and Crouch 2015 and references therein). Because of the increased volatility of dicamba and 2,4-D over glyphosate (which is currently the most widely used herbicide in the U.S.), the loss of flowering weeds and wildflowers growing within and adjacent to agricultural land within the range of imperiled bumble bees is expected to be more significant than at present.

As recently as 2015, 2,4-D and dicamba were already used widely within California's Central Valley on multiple crops (USGS 2017a; 2017b), and expanded use of these herbicides is expected to have a major negative impact on populations of already vulnerable bumble bees collecting nectar and pollen from weeds and wildflowers growing near crops. It is likely that the non-target effects of the new uses of these weed control technologies may have a dramatic impact on populations of imperiled bumble bees, given the portion of their selected ranges that overlap with modified corn, soybean, and cotton production.

Beyond impacts to forage, paraquat, 2,4-D, and dicamba may also be directly toxic to bumble bees. Paraquat was found to negatively affect honey bee larvae (Cousin et al. 2013). While 2,4-D has been designated by the U.S. EPA as practically non-toxic to bees it is on the cusp of being ranked as moderately toxic. Dicamba's toxicity ranges from moderately toxic to practically non-toxic depending on the route of exposure (U.S. EPA 2000). The toxicity classification that U.S. EPA uses is driven by a pesticide's LD50 (the lethal dose that kills 50% of the test population). If the pesticide's LD50 is 2 µg/bee or less it is considered highly toxic to bees. If the LD50 is greater than 2 µg/bee but less than 11 µg/bee it is moderately toxic. It is considered practically non-toxic if the LD50 is 11 µg/bee or more. 2,4_D has a reported LD50 of 11.5 µg/bee. Dicamba has an oral LD50 of 3.6 µg/bee, but a contact LD50 of >100 µg/bee. This very blunt measure of risk may underestimate the direct impacts that 2,4-D and dicamba could have on bumble bees, especially since the test subject for these chemicals was the European honey bee, which has been shown to be a poor surrogate for non-*Apis* bees (Wisk et al. 2014). The increasing use of these herbicides should be considered a threat to the continued survival of these imperiled bumble bees due to both the anticipated indirect effects (through destruction of floral resources) and direct effects (through direct toxicity).

The range of two of the species listed in this petition (*Bombus crotchii* and *B. occidentalis occidentalis*) overlaps, at least in part, with the Central Valley of California, which has been subjected to high uses of glyphosate; which is the most commonly used pesticide within the state of California (CA DPR 2014). *B. crotchii* has experienced more significant declines in the Central Valley than it has at the edges of its range (Hatfield et al. 2015a; see Figure 1in Section II); intensive agriculture and associated herbicide use may be responsible for this pattern. Moreover, glyphosate was used for agricultural purposes in 98% of counties in the lower 48 states. The widespread use of glyphosate is a threat to the continued existence of all four petitioned bumble bee species.

In summary, the evidence presented above shows clearly that 1) the use of herbicides has both direct (2,4-D, paraquat dichloride and dicamba are toxic to bees) and indirect (removal of floral resources) effects on bumble bee populations; and 2) the use of herbicides is widespread and pervasive throughout the range of all the bumble bees listed in this petition. As such, herbicides pose a direct threat to the continued existence of each species included in this petition.

B. Overexploitation
While specimens of female workers or males are occasionally collected for research purposes, scientific and/or recreational collection probably does not pose a threat to the overall survival of the species in this petition. In fact, collection of female workers of each of these species since the late 1800s has contributed essential information to understanding species' historic ranges and

conservation statuses. However, if bumble bee queens are collected, the entire colony will be effectively eliminated. Collection of queens or large numbers of workers or males from populations that are already small and isolated could threaten these species with extinction, although there is no evidence that this practice is occurring with these species.

To the best of the petitioners' knowledge, none of the petitioned species are currently being produced or sold commercially. However, in the early 1990s, *B. occidentalis* was produced commercially (Flanders et al. 2003) by both of the two primary commercial bumble bee producers operating in North America (Koppert Biological Systems and Biobest) and distributed for pollination use in the western U.S. In 1995, one company reported a mass outbreak of the fungal pathogen *Nosema bombi* in commercial colonies of *B. occidentalis* (Flanders et al. 2003). By 1997, commercial production of the western bumble bee stopped, as producers were no longer able to contend with the pathogen outbreaks (Velthius & Van Doorn 2006). Currently in North America, the common eastern bumble bee (*Bombus impatiens*) is produced on a large scale; over a million commercially produced bumble bee colonies are imported annually across the globe to pollinate greenhouse crops (Velthius and Van Doorn 2006). Commercial bumble bees are used in both greenhouse and open field pollination throughout the U.S. (except in Oregon, where use is prohibited, and California, where only greenhouse use is allowed), and two western species – Hunt's bumble bee (*Bombus huntii*) (APHIS 2014; Biobest Group 2018a [advertises *B. huntii* for use in indoor crops; though at the time of submission of this petition it is not currently available in the western U.S.]; 2018b) and the yellow faced bumble bee (*Bombus vosnesenskii*) (I. Noell, USFS, pers. comm. with R. Hatfield 2016) are being developed for larger scale commercial production. The commercial production and release into the wild of these three species of bumble bees poses a threat to the petitioned species because pathogens may be amplified in commercial rearing facilities and then spill over into wild populations, or novel pathogens may be introduced, since commercial bumble bees are currently reared in facilities outside of their native ranges or moved to areas beyond their native ranges (Meeus et al. 2011). The risk of disease transfer via commercial bumble bees is further discussed in Factor D: *Disease.*

Though overexploitation does not currently pose a substantial threat to the species included in this petition, there is strong evidence to suggest that historically the commercial production of one subspecies petitioned here – *Bombus occidentalis occidentalis* – and the associated amplification of fungal pathogens in commercial colonies led to the dramatic decline of populations of this subspecies from the wild (Cameron et al. 2016). Furthermore, the commercial propagation and release of other species of bumble bees (*Bombus impatiens*, *Bombus vosnesenskii*, and *Bombus huntii* in the U.S.) poses a significant threat to all of the species in this petition via amplification and spread of disease and competition, and thus this factor is considered in this petition.

C. Competition with Managed Honey Bees

A single honey bee colony requires substantial resources to survive. Estimates of single hive consumption vary from 20-130 lbs/year for pollen and 45-330 lbs/year of honey – representing 120-900 lbs/year of nectar (Goulson 2003, and references therein). Cane and Tepedino (2016) estimate that in three months a 40 hive apiary would remove enough pollen resources from the surrounding area that would have supported the development of 4,000,000 native bees. Depending on the environment and the density of honey bee hives in an area and the time of year, this could represent a substantial percentage of the resources available and has the potential to affect native bee populations. Recent research has also documented that under controlled conditions honey bees displaced native bees from flowers, altered the suite of flowers that native bees were visiting, and had a negative impact on native bee reproduction (Hudewenz and Klein 2015). The proportion of resources used by honey bees, as well as the effects of this resource depletion on the native bee community are likely to vary by location, the time of year, the species involved, floral abundance and diversity, and climatic and other environmental conditions.

A recent comprehensive review of the effects of managed bees (including honey bees) on native bee populations found that the majority of studies conclude that managed bees have a negative effect on native bees via competition, change in plant community, and disease transmission (Mallinger et al. 2017). Mallinger et al. (2017) also acknowledge the need for additional research investigating the effects of managed bees on bee fitness, as well as population and community level effects. While there remains a need for additional research, there is evidence that honey bees can potentially impact the native bee community by removing the available supplies of pollen and nectar (Anderson & Anderson 1989; Paton 1990, 1996; Wills et al. 1990; Dafni & Shmida 1996; Horskins & Turner 1999; Cane & Tepedino 2016), or by competitively excluding native bees, thus forcing them to switch to other, less abundant, and less rewarding plant species (Wratt 1968; Eickwort & Ginsberg 1980; Pleasants 1981; Ginsberg 1983; Paton 1993; 1996; Buchmann 1996; Horskins & Turner 1999; Dupont et al. 2004; Thomson 2004; Walther-Hellwig et al. 2006; Tepedino et al. 2007; Roubik 2009; Shavit et al. 2009; Hudewenz & Klein 2013; Rogers et al. 2013; but see Butz-Huryn 1997; Steffan-Dewenter & Tscharntke 2000; Minckley et al. 2003) – but none of these studies have addressed population level effects on native bees.

Additional research demonstrates that honey bees are regularly using, and depleting, the most abundant resources in the surrounding environment (Paton 1996; Mallick & Driessen 2009; Shavit et al. 2009), and that upon removal of honey bees, native bees exhibit signs of competitive release by returning to plants that were formerly used by honey bees (Pleasants 1981; Wenner & Thorp 1994; Thorp 1996; Thorp et al. 2000). The long-term implications of this shift in resource use are not entirely clear, although there is a growing body of research on bumble bees that

demonstrates negative competitive effects of honey bees on bumble bees, including lower reproductive success, smaller body size, and changes in bumble bee foraging behavior – notably a reduction in pollen gathering (Evans 2001; Goulson et al. 2002; Thomson 2004; 2006; Paini & Roberts 2005; Walther-Hellwig et al. 2006; Goulson & Sparrow 2009; Elbgami et al. 2014).

Because of the threats mentioned above, one recent review paper concludes that honey bees are inappropriate in protected areas where they pose the biggest threat to wild bee populations (Geldmann and González-Varo 2018); the same could be said for the placement of honey bees near species of conservation concern. In summary, competition with honey bees, along with the threat of disease transmission pose a significant threat to the four petitioned bumble bee species.

D. Disease

1. Pathogens and Parasites of Bumble Bees
The spillover, spillback, and facilitation of infectious diseases from domesticated livestock to wildlife populations is one of the main sources of emerging infectious disease, which pose a major threat to a wide variety of wildlife species (Daszak et al. 2000; Fürst et al. 2014; Graystock et al. 2015a; McMahon et al. 2015), including high profile declines of many bat and amphibian species caused by emerging infectious diseases. While this phenomenon has not been well studied in invertebrates, there is recent evidence of the transmission of pathogens from commercial bumble bees to wild bumble bees and pathogens have been implicated in the decline of both *B. franklini* and *B. occidentalis occidentalis* (Colla et al. 2006; Otterstatter & Thomson 2008; Murray et al. 2013; Graystock et al. 2015a; Cameron et al. 2016). Worldwide, reported pathogens and parasites of bumble bees include: viruses, bacteria, fungi, protozoa, nematodes, hymenopteran and dipteran parasitoids, one lepidopteran parasite, and mites (Acari) (Schmid-Hempel 2001). Pathogen prevalence and fitness effects in wild North American bumble bees are generally not well understood. However, the microparasites and macroparasites that have been identified as pathogens of concern to wild North American bumble bees (Cameron et al. 2011b) are discussed below. Pathogens and parasites pose a substantial threat to the continued survival of all of the species included in this petition.

i. Microparasites

Nosema bombi
Nosema bombi is a microsporidian parasite that infects bumble bees primarily in the malpighian tubules, but also in fat bodies, nerve cells, and sometimes the tracheae (Macfarlane et al. 1995). Colonies can appear to be healthy but still carry *N. bombi* (Larsson 2007) and transmit it to other colonies. *N. bombi* can reduce colony fitness, as well as reduce individual reproduction rate and life span in bumble bees (Schmid-Hempel & Loosli 1998; Schmid-Hempel 2001; Colla et al. 2006; Otti & Schmid-Hempel 2007; 2008; van der Steen 2008; Rutrecht & Brown 2009). This

parasite has been observed recently in wild bumble bees throughout North America (Colla et al. 2006; Gillespie 2010; Cameron et al. 2011a; Kissinger et al. 2011; Cordes et al. 2012).

Cameron et al. (2011a) found a significantly higher prevalence of *N. bombi* in declining North American bumble bee species (*Bombus occidentalis* and *B. pensylvanicus* [American bumble bee]). In the same study, *N. bombi* infection was significantly lower in species that have not exhibited recent declines in range and relative abundance (Cameron et al. 2011a). Blaker et al. (2014) also found an increased prevalence of *N. bombi* in *B. occidentalis* than sympatric species that have not exhibited population declines. These studies indicate that *N. bombi* is a threat to the continued existence of *B. occidentalis*. Since the western bumble bee is host to the Suckley cuckoo bumble bee (Williams et al. 2014) – *N. bombi* is a threat to the continued existence of this species as well.

Nosema ceranae

While the primary disease implicated in recent bumble bee declines is the microsporidian *Nosema bombi*, bumble bees have recently been seen to harbor *Nosema ceranae*, a common disease of honey bees that can be particularly virulent to honey bee colonies, and has been implicated as a factor in Colony Collapse Disorder (Paxton 2010; Fürst et al. 2014). *N. ceranae* has recently been detected in honey bees in Canada, and the United States (Williams et al. 2008b), and more recently been detected in bumble bees in South America (Plischuk et al. 2009) and Europe (Graystock et al. 2013a; Fürst et al. 2014). It is likely only a matter of time until this pathogen is detected in wild bumble bees in North America. Recent studies have shown that *N. ceranae* is easily transferred to bumble bees, and was found in all species of bumble bees tested in Europe (Graystock et al. 2013a). In laboratory experiments, virulence of *N. ceranae* in infected bumble bees was very high, reducing survival by 48% (Graystock et al. 2013a). Graystock et al. (2013a) conclude that *N. ceranae* represents a real and emerging threat to bumblebees, with the potential to have devastating consequences for their already vulnerable populations.

While to our knowledge *N. ceranae* has not been detected in any of the species in this petition, this microsporidian represents a current and potential threat to their populations. Recent studies have shown that pathogen transmission (including *N. ceranae*) between honey bees and bumble bees is readily occurring at flowers (Graystock et al. 2015b) and the range of all bumble bees in this petition overlaps with the range of both feral and managed honey bees. Furthermore, honey bees are both resident and regular migrants throughout the range of all of these bumble bees, thus, there is a clear vector for transmission of *N. ceranae* to all of the bumble bees in this petition. The uncertainty around the effects that this pathogen may have on wild bumble bees deserve further scrutiny and cautionary action; they should not be dismissed as a threat to the continued survival of the species in this petition.

Crithidia species

Crithidia bombi is a trypanosome protozoan that can dramatically reduce bumble bee longevity and colony fitness (Brown et al. 2003; Otterstatter & Whidden 2004), interfere with learning among bumble bee foragers (Otterstatter et al. 2005), increase ovary development in workers (Shykoff & Schmid-Hempel 1991), and decrease pollen loads carried by workers (Shykoff and Schmid-Hempel 1991). In the UK, researchers found a higher prevalence of the pathogen *C. bombi* in bumble bee populations with reduced genetic diversity, suggesting that as populations become smaller and lose heterozygosity, the impact of this parasite will increase (Whitehorn et al. 2011), pushing already at-risk populations closer to extinction. Moreover, there may be a synergistic effect between the effects of pesticides and disease. A recent laboratory study demonstrated that chronic exposure to low, realistic doses of two neonicotinoid insecticides, when combined with a sublethal infection of *C. bombi*, significantly reduced bumble bee queen survival (Fauser-Misslin et al. 2014).

Crithidia expoeki is a recently identified protozoan characterized from bumble bees collected in North America (Alaska) and Switzerland (Schmid-Hempel & Tognazzo 2010) that may also present a serious threat to wild populations of bumble bees. The increasing prevalence of these two species of *Crithidia* is an emerging and increasing threat to the bumble bees included in this petition.

B. occidentalis, the parent species to *B.occidentalis occidentalis* in this petition has been shown to be infected with *Crithidia bombi* (or *C. expoeki*) (Gillespie 2010; Cordes et al. 2012). One additional species in this petition was tested for infection by Cordes et al. (2012), however, because of their extreme rarity in the landscape, collection rates were very low for this species (*B. suckleyi,* N=4) and *C. bombi* was not detected (Cordes et al. 2012). Cordes et al. (2012) found *Crithidia sp.* in all regions of the United States in 15 different bumble bee host species.

Apicystis bombi

Apicystis bombi is a neogregarine protozoa that has been shown to infect 7.4% of American bumble bee queens in Ontario, Canada (Macfarlane et al. 1995). This parasite is associated with rapid death of infected bumble bee queens early in the season (Macfarlane et al. 1995; Rutrecht & Brown 2008). It has also been shown to inhibit ovary development and reduce queen longevity (Rutrecht & Brown 2008). More research is needed to understand causal effects that this parasite has on bumble bees and how this parasite is transmitted. This parasite has been found in commercial bumble bee colonies (Meeus et al. 2011), and researchers suggest that this pathogen may have been introduced from Europe to NW Patagonia, Argentina on commercial bumble bees, potentially causing an observed population collapse in a native bumble bee species (Arbetman et al. 2013; Maharramov et al. 2013). In a study in Mexico, *A. bombi* was the most frequently encountered pathogen in commercial bumble bee colonies (of *Bombus impatiens* - the

species of bumble bee most commercially available in the United States) that were tested for emerging infectious diseases (Sachman-Ruiz et al. 2015). As shown above, because of its virulence, its apparent widespread infection of wild bumble bees throughout North America, and its high prevalence in commercial bumble bees, *A. bombi* poses a serious potential threat to the continued survival of the bumble bees named in this petition.

Apicystis bombi has recently been detected in northern California and Oregon (Kissinger et al. 2011), which is within the current range of all of the species included in this petition, except *Bombus crotchii*. It is notable that in 2006-2007 all species included in this petition and within the range of the study were so rare (or absent) that they were not detected in the surveys by Kissinger et al. (2011). Since this pathogen has a detrimental effect on queens it can directly impact entire colonies of bumble bees. As such, it is a threat to the continued existence of all of the species in this petition.

RNA viruses

RNA viruses that have historically been considered to be specific to honey bees (*Apis mellifera*), including Israeli acute paralysis virus, black queen cell virus, sacbrood virus, Deformed Wing Virus (DWV), and Kashmir bee virus, have been recently detected in wild North American bumble bees foraging near apiaries (Singh et al. 2010). Recent research has emerged that documents the transmission of diseases from managed bees (both European honey bees and commercial bumble bees) to wild pollinators. These studies have demonstrated the threat that RNA viruses pose (Fürst et al. 2014; Manley et al. 2015; McMahon et al. 2015). DWV, which is associated with severe winter losses in honey bees (Highfield et al. 2009), was also detected in bumble bees in Germany, and the infected bumble bees displayed the same deformities that are typical of infected honey bees (Genersch et al. 2006). To understand the extent of the threat to wild bumble bees, the prevalence of these viruses in wild populations of bumble bees, as well as their effects on bumble bee fitness, are in urgent need of further study. While further study is needed, RNA viruses such as DWV have been shown to be virulent to bumble bees, resulting in malformed wings, non-viable offspring, and reduced longevity (Fürst et al. 2014). And, there is a growing body of evidence that RNA viruses can be transmitted between managed bees and wild bees on flowers (Manley et al. 2015).

While most of the recent research has been conducted in Europe, these same pathogens exist within the historic and current range of the bumble bees in this petition, and the pathogen spillover from honey bees and commercial bumble bees poses a significant threat to them. Since honey bees and commercial bumble bees (documented vectors for RNA viruses) are used throughout the United States, and within the range of all four species in this petition, RNA viruses are a clear threat to the continued existence of all of these animals.

ii. Macroparasites

Locustacarus buchneri

Bumble bees are often infected by mites. While many external mites can be relatively benign, many internal mites can be particularly virulent (Plischuk et al. 2013). This includes *Locustacarus buchneri*, a species that parasitizes the trachea of bumble bees (Husband & Shina 1970). *L. buchneri* is associated with reduced foraging and lethargic behavior (Husband & Shina 1970) and a significantly reduced lifespan in male bumble bees (Otterstatter & Whidden 2004). Otterstatter and Whidden (2004) reported that this mite was most prevalent in bumble bees of the subgenus *Bombus sensu stricto* (*B. occidentalis, B. moderatus, B. terricola*) in a study in southwestern Alberta. The internal mite was also reported in *B. bellicosus* and one of *B. atratus* (both in the subgenus *Thoracobombus*) from Argentina (Plischuk et al. 2013) and from the majority of populations of *B. jonellus* (subgenus *Pyrobombus*) and *B. muscorum* (subgenus *Thoracobombus*) in the United Kingdom (Whitehorn et al. 2014). Significantly, populations in this study that had high infection rates of *L. Buchneri* also had lower genetic diversity than populations that were not infected (Whitehorn et al. 2014). This suggests that small populations that may already be suffering from reduced genetic diversity may be particularly susceptible to this tracheal mite. Importantly *L. buchneri* was also detected in commercial *Bombus impatiens* colonies found in greenhouses in Mexico (Sachman-Ruiz et al. 2015) suggesting that commercial bumble bees may be a source of this tracheal mite for wild bumble bees. The presence of this mite in commercial bumble bee colonies in North America (Mexico), and the apparent susceptibility of populations with reduced genetic diversity to infection, suggest that this macroparasite is a threat to the continued existence of the four petitioned bumble bee species.

Sphaerularia bombi

Sphaerularia bombi is an entomopathogenic nematode that infects hibernating bumble bee queens and sterilizes them (Schmid-Hempel 2001). In a literature review, Macfarlane et al. (1995) notes that bumble bee queens infected with this parasite in New Zealand colonized new areas at a rate of less than 1% of that of healthy queens. Infected queens do not initiate a nest, but do continue to visit flowers (Kadoya & Ishii 2015). Because queens are foraging later in the summer there is evidence that through manipulation of behavior infected queens can negatively affect uninfected workers of conspecific and sympatric *Bombus* species through competition (Kadoya & Ishii 2015). This parasite has been detected in 16 species in North America (Macfarlane et al. 1995; Maxfield-Taylor et al. 2011), and may pose a threat to the long-term survival of the species in this petition.

2. Pathogen Spillover

The spread of pathogens to bumble bees from the domesticated common eastern bumble bee (*Bombus impatiens*) and other species of bumble bees that are currently being developed for commercial use threatens the species included in this petition with extinction. In addition, RNA

viruses from the domesticated honey bee (*Apis mellifera*) can be transmitted to bumble bees at shared flowers (Singh et al. 2010; Graystock et al. 2015a, 2015b; Manley et al. 2015; McMahon et al. 2015), and pose a novel threat to bumble bees.

i. Commercial Bumble Bees
The dramatic decline in numerous species of North American bumble bees, including *B. franklini* and *B. occidentalis occidentalis* has been attributed to pathogen infection from managed bumble bees (Evans et al. 2008; Thorp 2005c). Robbin Thorp first developed the hypothesis that an exotic strain of the fungal pathogen *Nosema bombi* escaped from commercial bumble bee rearing operations in the late 1990s and subsequently spread to wild populations of bumble bees in the subgenus *Bombus* (including *B. occidentalis*, *B. franklini*, *B. affinis*, and *B. terricola*) (Thorp 2005c). This hypothesis was supported by the timing, speed and severity of declines observed in wild populations of *B. occidentalis* and *B. franklini*, coincident with reports by commercial producers of *N. bombi* outbreaks in their facilities (Flanders et al. 2003). Cameron et al. (2016) tested Thorp's hypothesis and found that although the prevalence of *Nosema bombi* increased in bumble bees during the 1990s - the same time period that researchers reported that *B. occidentalis* and *B. franklini* were disappearing in the wild – they did not find evidence that an exotic strain of this pathogen was introduced to the U.S.

Commercial bumble bees are used primarily to pollinate greenhouse tomatoes, and increasingly to pollinate a wide variety of other greenhouse and open field vegetable and fruit crops in the US and worldwide (Velthius & Van Doorn 2006; Koppert Biological Systems 2018), though California only permits commercial bumble bees to be imported into the state for greenhouse use. The commercial bumble bee industry has grown dramatically in the past two decades (Velthius & Van Doorn 2006), coincident with the growth of the greenhouse tomato industry. In 2004 55,000 colonies of the common eastern bumble bee (*Bombus impatiens*) were commercially reared in the United States, and nearly 1,000,000 colonies were produced world-wide (Velthius & Van Doorn 2006) and demand is ever increasing (Sachman-Ruiz et al. 2015). Commercial bumble bees often escape greenhouses to forage on nearby plants (Whittington et al. 2004; Morandin et al. 2001), where they interact with wild bumble bees and have the opportunity to transmit pathogens at shared flowers. Commercially raised bumble bees frequently harbor high pathogen loads (Goka et al. 2000; Whittington & Winston 2003; Niwa et al. 2004; Colla et al. 2006; Graystock et al. 2013b) and the spillover of pathogens from commercial bumble bees in greenhouses to wild, native bumble bees foraging near greenhouses has been documented (Colla et al. 2006; Goka et al. 2006; Otterstatter & Thomson 2008; Graystock et al. 2014). Moreover, recent analysis has shown that many of the pathogens transmitted from commercial colonies are virulent to bumble bees (Graystock et al. 2013b).

Commercially reared bumble bees frequently harbor significantly more pathogens than their wild counterparts and their escape from greenhouses leads to infections in nearby wild native species

(Colla et al. 2006). In fact, Colla et al. (2006) found that bumble bees far away from greenhouses had zero *Crithidia bombi* infections, while their counterparts found close to greenhouses had infection rates of 5.3% – 75%. An additional study demonstrated that commercial bumble bees in greenhouses regularly escape greenhouses; 73% of the pollen found on bumble bees within a greenhouse originated from plants outside of the greenhouse (Whittington et al. 2004). A more recent study in the UK found that three bumble bee pathogens (*Nosema ceranae*, *Apicystis bombi*, and *Crithidia bombi*) were more prevalent around greenhouses using commercially produced bumble bees (Graystock et al. 2014). Notably this study also found that the species of bumble bee did not affect infection rates, indicating that these two pathogens infect all species equally, and that the presence of commercial bumble bees was the best measured predictor of infection rates (Graystock et al. 2014). Bumble bee diseases can be spread from bee to bee at shared flowers (Gorbunov 1987; Lipa & Triggiani 1988; Graystock et al. 2015a; 2015b).

Meeus et al. (2011) reviewed the effects of invasive parasites on bumble bee declines. They report that the commercial production of bumble bees has the potential to lead to bumble bee declines in three ways: commercial colonies may have high parasite loads, which could then infect wild bumble bee populations; commercial production may allow higher parasite virulence to evolve, leading to the introduction of parasites that are potentially more harmful to wild bumble bees than naturally occurring parasites; and the global transport of commercial bumble bees can introduce novel parasites to which resident, native bumble bees have not adapted. Pathogens reported from commercial bumble bee colonies worldwide include: *Apicystis bombi*, *Crithidia bombi*, *Locustacarus buchneri*, *Nosema bombi*, Black Queen Cell Virus (BQCV), Deformed Wing Virus (DWV), Israeli Acute Paralysis Virus (IAPV), and Kashmir Bee Virus (KBV) (Meeus et al. 2011). Commercial bumble bee colonies in North America have tested positive for *Crithidia bombi*, *Nosema bombi*, *Locustacarus buchneri*, DWV, BQCV, Sacbrood Virus (SBV) (Morkeski & Averill 2012; Averill unpublished data), and IAPV (Singh et al. 2010).

When tested, commercial bumble bee colonies in the U.S. have repeatedly been found to harbor parasites and pathogens harmful to wild bees (reviewed in Graystock et al. 2015a). In 2010, Morkeski and Averill reported results from testing bumble bees from the commercial vendors Koppert Biological Systems and BioBest. They found the commercially reared bumble bees were infected with *N. bombi, C. bombi, L. buchneri*, and viruses that also affect honey bees, including DWV and BQCV. Averill (unpublished data) also reported that commercial bumble bee colonies have tested positive for SBV. Singh et al. (2010) reported that commercial bumble bee colonies tested positive for IAPV. Furthermore, a recent study of commercially produced bumble bees (*Bombus impatiens*) in Mexico found that the colonies were infected with *L. buchneri*, *N. bombi*, Acute Bee Paralysis Virus (ABPV), Chronic Bee Paralysis Virus (CBPV), DWV, IAPV and KBV (Sachman-Ruiz et al. 2015). Since *B. impatiens* is native to the eastern

U.S. and Canada but not native to Mexico, and used in commercial bumble bee rearing facilities in both the U.S. and Canada, it is likely that these pathogens originated in rearing facilities in either the U.S. or Canada, and may also occur in managed bumble bee colonies in these two countries.

Examples from multiple continents exist demonstrating that pathogens from managed bumble bees can spread to wild bumble bees with catastrophic results (Graystock et al. 2015a). In South America, the commercial buff-tailed bumble bee (*Bombus terrestris*) was first introduced into Chile from Europe in 2006 and has since spread to Argentina (Morales et al. 2013; Schmid-Hempel et al. 2014). Researchers suggest that the highly pathogenic *Apicystis bombi* hitchhiked on the commercial bumble bees and spread to wild bumble bees, potentially causing the observed population collapse in the world's largest native bumble bee – *Bombus dahlbomii* (Arbetman et al. 2013; Schmid-Hempel et al. 2014). Indeed, scientists have found that wherever *B. terrestris* invades, the native bumble bee species disappears (Morales et al. 2013; Schmid-Hempel et al. 2014). In Japan, researchers found that commercially raised bumble bees had a higher infestation rate of the tracheal mite *L. buchneri* than wild bumble bees. Their findings also suggested that a European strain of this mite has likely invaded native Japanese bumble bee populations and may help explain its decline (Yoneda et al. 2008; Goka 2010; Graystock et al. 2015a). In Canada, higher levels of the protozoan parasite *Crithidia bombi* were detected in wild bumble bees foraging near greenhouses that used commercial bumble bees (Colla et al. 2006; Otterstatter & Thomson 2008), and it was suggested that this pathogen may be implicated in the sudden, widespread decline observed in North American bumble bees in the subgenus *Bombus sensu stricto* (Otterstatter & Thomson 2008). However, a more recent analysis of pathogen prevalence in wild bumble bees did not find evidence that *Crithidia* infections are involved in the decline of U.S. bumble bee species (Cordes et al. 2012).

In other regions of the world—where the two major North American bumble bee producers also operate—commercial bumble bee colonies have been more widely tested and have routinely been found to be infected with numerous parasites and pathogens, including: *Apicystis bombi, Crithidia bombi*, *Nosema bombi*, *N. ceranae*, DWV, and three honey bee specific parasites (Graystock et al. 2013b; Meeus et al. 2011; Murray et al. 2013; Sachman-Ruiz et al. 2015). In a 2013 European study, scientists tested commercially produced bees imported into the UK. Although the bees were sold as "disease-free," the scientists found that 77 percent of the colonies tested were infected with at least five parasites and an additional three parasites were present in pollen that was supplied as food for the bumble bee colonies (Graystock et al. 2013b).

Should non-native *Bombus impatiens*, which California currently allows to be imported for greenhouse use only, escape greenhouses, the pathogens they harbor may pose a risk to wild bumble bees, including the four species included in this petition.

ii. Honey Bees

In addition to competitive effects listed above, honey bees may pose a risk to the four bumble bees listed in this petition by transmitting pathogens to them. Recent evidence has emerged demonstrating that honey bees can transmit diseases to many different species of native bees, including bumble bees, when they interact at shared flowers (Singh et al. 2010; Fürst et al. 2014). Bumble bees placed close to honey bee hives were found to have an 18% higher prevalence of *Crithidia bombi*, than bumble bees placed away from honey bees (Graystock et al. 2014). A number of RNA viruses that were formerly thought to be specific to honey bees have now been reported to infect bumble bees (Genersch et al. 2006; Morkeski & Averill 2010; Singh et al. 2010; Meeus et al. 2011; Evison et al. 2012; and see RNA Viruses in section D: Diseases above). In addition, while the primary disease implicated in recent bumble bee declines is the microsporidian *Nosema bombi*, bumble bees have recently been seen to harbor *Nosema ceranae*, a common disease of honey bees that can be particularly virulent to honey bee colonies, and has been implicated as a factor in Colony Collapse Disorder (Paxton 2010; Fürst et al. 2014; and see *Nosema ceranae* in section D: Diseases above.).

Two recent review papers that investigated disease transmission between managed (including honey bees and commercial bumble bees) and wild bees concluded that the commercial use of pollinators is a key driver of emerging disease in wild pollinators, and that avoiding anthropogenic induced pathogen spillover is crucial to preventing disease emergence in native pollinators (Graystock et al. 2015a; Manley et al. 2015). To help mediate this potential, the authors suggest that it is crucial to prevent wild bees from interacting with managed bees (Graystock et al. 2015a; Manley et al. 2015). Graystock et al. (2015b) also documented that pathogen transmission occurs between bumble bees and honey bees at shared flowers, showing a clear mechanism and vector for infection. Since small, fragmented, and declining populations are especially susceptible to infectious disease (Fürst et al. 2014), and disease is already implicated as a likely causal factor of some native bee declines in North America (Cameron et al. 2011b), this emerging body of research suggests that caution should be exercised when considering the placement of managed bees of any species in habitat that supports vulnerable or declining native bee populations or that strict regulations should be implemented that include regular screening and clear actions for diseased managed bees to prevent further infection (Graystock et al. 2015a).

The continental distribution, transport, and use of commercially reared honey bees throughout the United States presents a clear vector for disease transmission to the four species of bumble bees included in this petition. Several of the diseases harbored by honey bees have been shown to be pathogenic and virulent to bumble bees, posing a significant risk. Since the populations of the bumble bee species included in this petition are already small and fragmented, any further stressor threatens each species with local extirpation, and perhaps extinction. As such, continued unrestricted use of commercial honey bees poses a threat to the continued existence of each

species included in this petition.

E. Other Natural Events or Human-related Activities

1. Pesticides
Pesticides are used widely in agricultural, urban, and even natural areas and can exert both direct effects (lethal and sublethal) and indirect effects (harm via the effect on another species) on bumble bees. Foraging bumble bees can be poisoned by pesticides when they absorb toxic substances directly through their exoskeleton, drink contaminated nectar, gather contaminated pollen, or when larvae consume contaminated pollen. Because bumble bees nest in the ground, they may be uniquely susceptible to pesticides used on lawns or turf (National Research Council 2007). Pesticides applied in the spring, when bumble bee queens are foraging and colonies are small, are likely to be most detrimental to bumble bee populations (Goulson et al. 2008; Stoner 2016). Since males and queens are produced at the end of the colony cycle, sublethal doses of pesticides applied at any time during the bumble bee lifecycle can have substantial adverse effects on subsequent generations. Any application of pesticides can threaten bumble bees, but pesticide drift from aerial spraying can be particularly harmful. One study demonstrated that 80% of foraging bees close to the source of an insecticide application were killed, and drift can continue to be dangerous for well over a mile from the spray site (Johansen and Mayer 1990). In Europe, the recent declines in bumble bees have been partially attributed to the use of pesticides (Williams 1986; Thompson and Hunt 1999; Rasmont et al. 2006).

Bumble bees are threatened by the widespread use of pesticides across their range. Insecticides are designed to kill insects directly and herbicides can indirectly affect bumble bees by removing floral resources (see Section A.2: The Loss of Habitat Due to Increased Use of Herbicides). There is very little data available on the effect of fungicides on bumble bees, although a growing body of evidence suggests fungicides may be linked with sublethal concerns including weakening the immune system of bumble bees. Below, we outline the threats posed to bumble bee populations by insecticides and fungicides.

i. Insecticides
Of the various pesticide groups, insecticides are most likely to directly harm bees. Many commonly used insecticides are broad spectrum and thus could kill or otherwise harm exposed bumble bees. Systemic insecticides, such as neonicotinoids, have the added concern of causing exposure months to years after a treatment as they are taken up by the plant and expressed in the pollen, nectar and leaves. Extensive research into the effects of neonicotinoids has been performed. Below is a brief summary of a subset of this body of research.

Neonicotinoids
Neonicotinoids are a relatively new class of systemic insecticides that are used widely to combat

insect pests of agricultural crops, turfgrass, gardens, and pets (Cox 2001). Colla & Packer (2008) suggested that neonicotinoids may be one of the factors responsible for the decline of the rusty patched bumble bee (*Bombus affinis*; recently listed as an Endangered species under the U.S. Endangered Species Act), noting the use of this class of insecticides began in the U.S. in the early 1990s, shortly before the decline of the rusty patched bumble bee was first observed.

A recent study exposing bumble bees to field-realistic levels of the neonicotinoid imidacloprid found an 85% reduction in the production of new queens and significantly reduced colony growth rates compared to control colonies (Whitehorn et al. 2011). The authors suggest that neonicotinoids "may be having a considerable negative impact on wild bumble bee populations across the developed world" (Whitehorn et al. 2011). Another study of bumble bees exposed to varying levels of imidacloprid found a dose-dependent decline in fecundity and documented that field realistic levels of this pesticide were capable of reducing brood production by one-third (Laycock et al. 2012). The authors speculate that this decline in fecundity is a result of individual bumble bees failing to feed, which raises concerns about the impact of this pesticide on wild bumble bees (Laycock et al. 2012). In another study (Fauser et al. 2017) the researchers found that early lifestage exposure to low dose, field realistic levels of thiamethoxam and its metabolite clothianidin significantly reduced the survival of hibernating queens. Other toxicity studies have demonstrated that contact exposure of imidacloprid and clothianidin to bumble bees can be very harmful (Marletto et al. 2003; Gradish et al. 2009; Scott-Dupree et al. 2009), and an acute oral dose of imidacloprid is highly toxic to bumble bees (Marletto et al. 2003, *In* Hopwood et al. 2016). Mommaerts et al. (2010) found that chronic exposure of three neonicotinoids to bumble bees was dose dependent, and another study by Incerti et al. (2003) found that one third of bumble bees in a flight cage exposed to blooming cucumbers treated with a "field dose" of imidacloprid died within 48 hours (*In* Hopwood et al. 2016). A study by Gill et al. (2012) examining the effects of the combined exposure of bumble bees to field realistic levels of two pesticides – an imidacloprid and a pyrethroid – found that foraging behavior was impaired, worker mortality increased, and both brood development and colony success were significantly reduced.

Other studies have also documented sublethal effects of neonicotinoids on bumble bees, including: reduced foraging ability (Morandin & Winston 2003; Stanley et al. 2016); reduced drone production and longer foraging times (Mommaerts et al. 2010; Arce et al. 2016; Stanley et al. 2016); reduced foraging activity, reduced food storage and reduced adult survival (Al-Jabr 1999); and lower worker survival and reduced brood production (Tasei et al. 2000; Fauser-Misslin et al. 2014; *In* Hopwood et al. 2016). Studies have also shown that neonicotinoid exposures can lead to impaired learning and memory (Stanley et al 2015a) as well as impaired crop pollination services (Stanley et al. 2015b). Bumble bees appear to be affected by dietary concentrations of the systemic insecticide imidacloprid at levels lower than honey bees, perhaps

because, unlike honey bees, bumble bees do not metabolically degrade imidacloprid effectively while continuing to ingest it (Cresswell et al. 2014; *In* Hopwood et al. 2016).

Neonicotinoids are widely used on agricultural crops that are attractive to pollinators, as well as on horticultural plants and lawns in urban and suburban areas. Thus, this class of insecticide is likely to affect all bumble bees, which were historically found in all of these landscapes. Of particular concern is a finding in a recent review of the impact of neonicotinoid pesticides on pollinating insects which found that some products approved for home and garden use may be applied to ornamental and landscape plants at significantly higher concentrations (as much as 120 times higher) than the allowable concentration of the similar products applied on agricultural crops (Hopwood et al. 2016).

Nitroguanidine neonicotinoids (clothianidin, dinotefuran, imidacloprid and thiamethoxam) are highly toxic to bumble bees and their use has dramatically increased over the last 20 years (USGS 2017c), especially in California's Central Valley, where *B. crotchii* and *B. o. occidentalis* occur. In fact, imidacloprid is the fourth most commonly used insecticide in California, with reported uses on more than 140 crops and other non-crop locations. Its use has increased from 5,179 pounds (658 applications) in 1994 to 441,304 pounds (70,054 applications) in 2015. While not as commonly used as imidacloprid, the other neonicotinoids are also becoming more widely used. For example, thiamethoxam use has increased from 11,090 pounds (2,826 applications) in 2002 when it was first used in California, to 41,908 pounds (26,932 applications) of reported use in 2015 (CA DPR 2014). Throughout the U.S., nitroguanidine neonicotinoids were used to some degree for agricultural purposes in 94% (2,930 out of 3,109) of counties in the lower 48 states (the states for which this study collected data) in 2012 (Baker & Stone 2015). This level of use suggests that there are very few large refuges left in the country for bumble bees to access insecticide free forage – which is necessary to avoid the lethal, and sub-lethal effects of these toxic substances. As such neonicotinoid insecticides pose a direct threat to the continued existence of the bumble bee species included in this petition. Other insecticides, including new systemic insecticides, may also jeopardize these species. Standardized testing completed for registration demonstrates moderate to high toxicity for most insecticides to terrestrial insects. Still, significantly less data is available on sub-lethal effects and field realistic impacts.

ii. Fungicides
A growing body of research demonstrates how some fungicides, especially the multi-site contact activity fungicides like chlorothalonil and the ergosterol inhibiting fungicides (like tebuconazole) can harm bees, including bumble bees. McArt et al. (2017) found that fungicide usage was the strongest predictor of range contractions for four declining bumble bees and that one particular fungicide, chlorothalonil was more closely associated with prevalence of the pathogen *Nosema bombi*--an infection that was about twenty times higher in declining versus stable bumble bee species. Bernauer et al. (2015) found that bumble bees exposed to chlorothalonil produced fewer

workers, lower total bee biomass, and had lighter mother queens than control colonies. Sprayberry et al. (2013) determined that the presence of the fungicide product Manzate (active ingredient mancozeb) decreased bumble bees' ability to locate food within a maze. Bartlewicz et al. (2016) document negative impacts of fungicides on microflora, particularly yeasts, in nectar, that could affect pollinator gut microbiota. As in humans, gut microbial communities affect nutritional health, development, detoxification abilities, and parasite susceptibility (Kwong and Moran 2016; Schwarz et al. 2016). A review of research into the combined effects of pesticides on honey bees found ergosterol inhibiting fungicides significantly contribute to the spread and abundance of honey bee pathogens and parasites (Sánchez -Bayo et al. 2016). The authors also stated that these same concerns are likely to exist for bumble bees and many other wild insects. Contrary to the above mentioned studies, one literature review suggests that most active ingredients in fungicides are compatible with commercial bumble bees (Mommaerts & Smagghe 2011).

In summary, the evidence presented above shows clearly that 1) pesticides, particularly nitroguanidine neonicotinoid insecticides, are highly toxic to bumble bees and exhibit both lethal and sub-lethal effects on bumble bee populations; and 2) the use of pesticides is widespread and pervasive throughout the range of all of the species listed in this petition; As such, pesticides pose a direct threat to the continued existence of each species included in this petition.

2. Population Dynamics and Structure
Bumble bees may be more vulnerable to extinction than other species due to their unique system of reproduction (haplodiploidy with single locus complementary sex determination) (Zayed and Packer 2005; reviewed in Zayed 2009). Therefore, reduced genetic diversity resulting from any of the threats summarized in this petition can be particularly concerning for bumble bees since genetic diversity already tends to be low in this group due to the colonial life cycle (i.e., even large numbers of bumble bees may represent only one or a few queens) (Goulson 2010; Hatfield et al. 2012; but see Cameron et al. 2011a and Lozier et al. 2011). Since the bumble bees listed in this petition have undergone dramatic declines in range and relative abundance (Kevan 2008; Hatfield et al. 2015a; 2015c; unpublished data).), genetic factors (including reduced genetic diversity, inbreeding depression, and the method of sex determination utilized by bumble bees) are likely among the most significant threats to the long-term survival of these species (reviewed in Zayed 2009).

i. Impacts of Genetic Factors on Bumble Bees
Recent research indicates that populations of the declining western bumble bee (*Bombus occidentalis*) have lower genetic diversity compared to populations of co-occurring stable species (Cameron et al. 2011a; Lozier et al. 2011). It is reasonable to expect that the other three species of bumble bees in this petition may have suffered a similar loss of genetic diversity and increase in population structure, although this has not been examined directly.

Loss of genetic diversity, which is frequently the result of inbreeding or random drift, can pose significant threats to small, isolated populations of bumble bees (Whitehorn et al. 2009). A loss of genetic diversity limits the ability of a population to adapt and reproduce when the environment changes and can lead to an increased susceptibility to pathogens (Altizer et al. 2003).

Bumble bees have a single locus complementary sex determination system, meaning that the gender of an individual bee is determined by the number of unique alleles at the sex-determining locus (van Wilgenburg et al. 2006). Normally this gender determination comes through a haplodiploid genetic structure in which female bees are diploids and are produced from fertilized eggs with two different copies of an allele at the sex-determining locus. Most male bees are haploid, and they are produced from unfertilized eggs (with only a single copy of an allele at the sex-determining locus). However, when closely related bumble bees mate, the offspring can have two copies of the exact same allele (or be homozygous) at the sex-determining locus, which causes a diploid male to be produced instead of a diploid female. These diploid males may have reduced viability or may be sterile (van Wilgenburg et al. 2006). When diploid males are able to mate, they produce sterile triploid offspring, which has been found to be negatively correlated with surrogates of bumble bee population size (Darvill et al. 2012). Diploid males are produced at the expense of female workers and new queens, and the production of diploid males can reduce colony fitness (including slower growth rates, lower survival, and colonies that produce fewer offspring) in bumble bees (Whitehorn et al. 2009). Diploid male production in inbred populations can substantially increase the risk of extinction in bumble bee populations compared to other animal taxa (Zayed & Packer 2005).

Inbreeding and loss of genetic diversity can also increase parasite prevalence in populations and parasite susceptibility in individuals (Frankham et al. 2010 *in* Whitehorn et al. 2011). Populations of bumble bees with low genetic diversity have been found to have a higher prevalence of pathogens (Cameron et al. 2011a; Whitehorn et al. 2011; 2014), suggesting that as populations lose genetic diversity, the impact of parasitism will increase and threatened populations will become more prone to extinction.

In summary, the unique method of sex determination, along with the fact that small populations have lower genetic diversity make bumble bees highly susceptible to extinction and thus a rapid extinction vortex that is not experienced in other animals (Zayed & Packer 2005). As such, bumble bees are perhaps more at-risk of extinction than non-haplodiploid animals of similar population size and the threshold for action should necessarily be more conservative.

3. Global Climate Change
Climate change may pose a significant threat to the continued survival of the bumble bees listed

in this petition. Changes to the climate that are expected to have the most significant effects on bumble bee populations include: increased temperature and precipitation, increased drought, increased variability in temperature and precipitation extremes, early snow melt, and late frost events. These changes may lead to increased pathogen pressure, decreased resource availability (both floral resources and hibernacula), and a decrease in nesting habitat availability due to changes in rodent abundance or distribution (Cameron et al. 2011b).

Variability in climate can lead to phenological asynchrony between bumble bees and the plants they use (Memmott et al. 2007; Thomson 2010). There is evidence of mismatch between early blooming plants and their bumble bee pollinators (Kudo et al. 2004). Early spring is a critical time for bumble bees since that is the time when the foundresses emerge from hibernation and initiate nests. Since bumble bees are generalist foragers, they do not require synchrony with a specific plant, but asynchrony could lead to diminished resource availability at times that are critical to bumble bee colony success. For example, as the climate in the Rocky Mountains has become warmer and drier in the past 30 years, researchers have observed a mid-season period of low floral resources, a change which can negatively impact pollinators (Aldridge et al. 2011). Furthermore, changes in the distributions of plants visited by bumble bees have been correlated with a changing climate (Inouye 2008; Forrest et al. 2010). There is further evidence that this shift in climate has led to altered bumble bee morphology by reducing the tongue length of bumble bees in response to the changed availability of food plants (Miller-Struttmann et al. 2015). The effects of this shift on bumble bee populations, or native plant populations – which have not experienced a concordant shift in morphology (Miller-Struttmann et al. 2015) – needs further investigation. However, if long-tongued bumble bees like the American bumble bee (*Bombus pensylvanicus*, which occurs in California) are getting shorter tongues, this will lead to increased competition with shorter tongued bees (like *B. occidentalis occidentalis* and *B. crotchii*—included in this petition) for food plants as there will be greater niche overlap.

In modeling studies, Kirilenko and Hanley (2007a; 2007b) predict that the ranges of three bumble bee species will change in size and shift in response to predicted changes in the North American climate. In a more recent study Kerr et al. (2015) found that as the climate warms in North America that the southern range of bumble bees is contracting, while at the same time there is no evidence that populations are moving northward. The reason that bumble bees are not responding to this climactic cue by moving northward is unknown, but has dramatic implications for bumble bees; it suggests that range contraction from the south is a severe threat to the continued existence of North America's bumble bees. Other research in Europe has suggested that bumble bees are particularly susceptible to heat waves, and other effects of a changing climate (Rasmont & Iserbyt 2012). In California, increasing aridity may be particularly detrimental for *B. franklini* since this species has a very narrow climatic specialization compared to most bumble bees (NatureServe 2017a).

Climate change can also affect the quality of nectar produced by flowers. Pumpkin flowers grown under experimental conditions mimicking predicted climate futures were altered in attractiveness and nutritional quality (Hoover et al. 2012). Bumble bees foraging on these plants suffered a 22% reduction in survival. Although this study was based on predicted future conditions, similar effects may be occurring presently at levels that are undetected but may still affect bumble bee populations.

In summary, there is evidence that a shifting climate is 1) altering the timing of food plant availability for bumble bees; 2) changing the morphology of bumble bee mouth parts in response to food-plant availability; 3) reducing the habitable area of bumble bees in the southern portion of their ranges without a concordant range expansion to the north; and 4) altering the quality of food plants. Each of these landscape scale factors threaten the four bumble bee species included in this petition.

4. Loss of Host Species - Co-Extinction

One species included in this petition is in the subgenus *Psithyrus* (cuckoo bumble bees - Suckley cuckoo bumble bee [*Bombus suckleyi*]), which means that it is dependent on a bumble bee host species for its life-cycle; thus the disappearance, or increasing rarity of that host would represent a threat to species existence. This relationship was recently examined by Suhonen et al. (2015), who found that cuckoo bumble bees were more vulnerable to extinction than their host species. Unsurprisingly, the conclusions of this research were that the conservation of the host species for these animals was essential to the short and long-term persistence of cuckoo bumble bees (Suhonen et al. 2015).

The cuckoo bumble bee included in this petition is dependent on bumble bees that have recently documented range declines. *B. suckleyi* uses *B. occidentalis occidentalis* and the yellow banded bumble bee (*B. terricola*) as hosts (Williams et al. 2014) - both of which have been identified as in decline by recent research (Evans et al. 2008; Cameron et al. 2011b; Hatfield et al. unpublished data). The continued decline of the host species is a severe and permanent threat to the continued existence of this cuckoo bumble bee. The host species (*B. o. occidentalis*) mentioned above is included in this petition to be listed as an endangered species.

VI. DEGREE AND IMMEDIACY OF THREAT

Bumble bees, as a whole, are threatened by a number of factors discussed above in section V, including agricultural intensification, habitat loss and degradation, pesticide use, pathogens from managed pollinators, competition with non-native bees, climate change, genetic factors, and loss of host species (reviewed *in* Goulson 2010; Williams et al. 2009; Williams and Osborne 2009; Cameron et al. 2011b; Hatfield et al. 2012; Fürst et al. 2014). The magnitude of loss and rate of

decline that each of these species have experienced is outlined above in section II. Current regulations and regulatory mechanisms are inadequate to protect these species of bumble bees against the threats they face within California. Without protective measures, *Bombus crotchii*, *B. franklini*, *B. suckleyi*, and *B. occidentalis occidentalis* are likely to go extinct in California.

VII. IMPACT OF EXISTING MANAGEMENT EFFORTS

Currently none of the four species included in this petition receive substantive protection under federal law or California state law. None have legal protection under the U.S. Endangered Species Act. No known specific management actions, recovery plans, or research in the state of California have been implemented for any of these species. California Department of Fish and Wildlife lists all four bumble bees included in this petition on their "Special Animals List". In addition, *Bombus occidentalis* is listed as a "Sensitive Species" by the US Forest Service in California (USFS 2013); thus the Forest Service will consider this species when implementing any management actions proposed in the forests where this species occurs.

Below, we list the known candidate status or special status, if any, for each species.

Crotch Bumble Bee (*Bombus crotchii*)
Bombus crotchii is on the "Special Animals List" of the California Department of Fish and Wildlife (CDFW 2017) and is listed as Endangered by the IUCN Red List of endangered species (Hatfield et al. 2015a). The species has a NatureServe Global Status rank of G3G4 (Vulnerable/Apparently Secure) and a state rank of S1S2 in California (NatureServe 2017a). Although *B. crotchii* is widely recognized as a vulnerable species, it receives no formal or informal protection.

Franklin's bumble bee (*Bombus franklini*)
Until 1996, the U.S. Fish and Wildlife Service classed *Bombus franklini* as a "Category 2" Candidate Species which indicates that listing may be warranted, but not enough information was known to federally list the species. This status was based on the recognition of the narrow endemism of the species and the lack of knowledge on the specific biological characteristics, habitat requirements, potential threats to its existence, and other critical parameters that affect the persistence and viability of its populations. In 2010, this species was petitioned for endangered species status, has received a positive 90-day finding, and is currently the focus of a Species Status Assessment by USFWS to determine if the species warrants ESA listing (USFWS 2011).

B. franklini is included on the California Department of Fish and Wildlife "Special Animals List" (CDFW 2017). The species has a NatureServe Global Status rank of G1 (Critically Imperiled), and has a state rank of S1 (Critically Imperiled) in both Oregon and California (NatureServe 2017b). It is listed as Critically Endangered on the IUCN Red List (Kevan 2008)

and critically imperiled on the *Red List of Pollinator Insects of North America*, produced by the Xerces Society for Invertebrate Conservation (Thorp 2005c). Although *B. franklini* is widely recognized as a vulnerable species, it receives no formal or informal protection.

Western bumble bee (*Bombus occidentalis occidentalis*)
Bombus occidentalis occidentalis is on the "Special Animal List" of the California Department of Fish and Wildlife (CDFW 2017) and is listed as a "Sensitive Species" by the US Forest Service in California, where it has been documented on the following National Forests: Eldorado, Klamath, Lassen, Modoc, Plumas, Shasta-Trinity, Six Rivers, Tahoe, and Lake Tahoe (USFS 2013). The subspecies has a NatureServe Global Status rank of G4T1T3 (Apparently Secure/"T1T3 is assigned because the subspecies has almost certainly declined by more than 95% since 1998 and is not secure") and SNR (Unranked) in California (NatureServe 2017c); the parent species *B. occidentalis* is ranked S1 (Critically Imperiled) in California (NatureServe 2017d). An IUCN Red List category has not yet been formally assigned for the southern subspecies of the western bumble bee (*B. occidentalis occidentalis*), but the full species (*B. occidentalis*) is listed as Vulnerable to extinction on the IUCN Red List (Hatfield et al. 2015b), and an analysis of changes in range and relative abundance of *B. o. occidentalis* suggest that the species would meet the criteria of Endangered on the IUCN Red List (Hatfield et al., unpublished data). The parent species *B. occidentalis* has been petitioned for endangered species status, has received a positive 90-day finding, and is currently the focus of a Species Status Assessment by the USFWS to determine if the species warrants ESA listing (USFWS 2016). Though this species receives no formal protection, any conservation or management actions implemented due to its "Sensitive Species" status on National Forests in California may provide some benefit to this species.

Suckley bumble bee (*Bombus suckleyi*)
Bombus suckleyi is on the "Special Animal List" of the California Department of Fish and Wildlife (CDFW 2017) and was listed as Critically Endangered by the IUCN Red List of endangered species (Hatfield et al. 2015c). The species has a NatureServe Global Status rank of G1G3 (Critically Imperiled/Vulnerable; the rank changed from GU to "G1G3?" to highlight the recognized major decline but uncertainty about its status in the most northern section of its range) and a state rank of S1 (Critically Imperiled) in California (NatureServe 2017e).

Restoration of Bee Habitat in California
Currently, extensive efforts exist to restore habitat for pollinators near insect-pollinated crops in California, especially in the agriculturally intensive Central Valley. These efforts have the potential to provide resources that will benefit the petitioned bumble bee species – especially *B. crotchii* and *B. occidentalis occidentalis*, which occur or historically occurred in parts of the Central Valley. The petitioners recommend that, should these bumble bees be protected under

California's Endangered Species Act, this listing should not hinder efforts to restore bee habitat. As such, a programmatic Safe Harbor agreement should be developed between CDFW and the NRCS, so that private landowners enrolled in Farm Bill incentive programs will not be discouraged from restoring pollinator habitat by fears that they may attract an endangered species to their property.

VIII. SUGGESTIONS FOR FUTURE MANAGEMENT

To prevent extinction in California of each of the four species of bumble bees listed in this petition, all extant populations of each species need to be identified and their habitat should be protected and managed to benefit the species. Surveys throughout the historic ranges of each species are recommended in order to accomplish this. To rebuild populations of *Bombus crotchii*, *B. franklini*, *B. suckleyi*, and *B. occidentalis occidentalis*, habitat should be restored within their historic ranges, prioritizing habitat closest to extant populations of each species. These efforts will be most effective if both public land managers and private landowners engage in habitat restoration and species recovery efforts.

The following general guidelines include management practices that will maintain and restore habitat for *B. crotchii*, *B. franklini*, *B. suckleyi*, and *B. o. occidentalis*:

General Guidelines for Bumble Bees
Due to the inherent vulnerability of many bumble bee species and importance of supporting wild bee populations for pollination services, the following general conservation practices are recommended:

1. Identify, protect, enhance, and restore natural high-quality habitats to include suitable forage, nesting and overwintering sites.
2. Promote farming practices that increase of nitrogen-fixing fallow (legumes) and other pollinator-friendly plants along field margins.
3. Restrict pesticide use on or near each species' habitat, particularly while treated plants are in flower.
4. Minimize exposure of wild bees to diseases transferred from managed bees.
5. Avoid honey bee introduction to high-quality native bee habitat.

Creating High-Quality Habitat
There are three things that bumble bees need in the landscape to thrive: flowers on which to forage, somewhere to nest, and a place to overwinter. Each of these habitat requirements is vital for different phases of the bees' annual life cycle.

Pollen and Nectar Sources
Bumble bees need a rich supply of flowers during the entirety of the colony's life. Bumble bees

are generalist foragers and will gather pollen and nectar from a variety of flowering plants. However, individual bumble bees do show high fidelity to particular flowers within a bloom period. The flight season of different species varies, but generally queens emerge in the late winter or early spring and the colony continues through to late summer or early fall. This requirement makes bumble bees sensitive to differing management practices throughout the course of the year. Monoculture crops, grazing, mowing, and weed control can interfere with the long-term health of bumble bee populations.

Careful selection of plants that are beneficial to bumble bees is essential to creating valuable habitat. Native plants are an excellent choice to provide nectar and pollen sources. They provide several benefits:
- Bumble bees coevolved with native plants and therefore know how to use them as a resource.
- Once established, native plants typically need less maintenance (less water, reduced use of fertilizers and pesticides).
- Native plants usually do not spread to become weedy species in natural areas.

Nesting and Overwintering Habitat
Most bumble bees nest underground, often in abandoned holes made by rodents, or occasionally abandoned bird nests (Osborne et al. 2008). Some species do nest on the surface of the ground (in grass tussocks) or in empty cavities (hollow logs, dead trees, under rocks, etc.). Queens most likely overwinter in small cavities just below or on the ground surface. While there is still much to be learned about the nesting and overwintering biology of bumble bees, it is clear that any near-surface or subsurface disturbance of the ground is likely disastrous for bumble bee colonies or overwintering queens. This includes mowing, fire, tilling, grazing, and planting. Protecting areas of land from such practices is essential for sustaining bumble bee populations. Since bumble bees usually nest in abandoned rodent nests, it is also important to retain landscape features that will support rodent populations (McFrederick and LeBuhn 2006).

Restoring and Managing Habitat
The following management recommendations are designed to be synchronous with the bumble bee life cycle and minimize risks to colonies, while maintaining flower-rich foraging areas and secure nest sites. Mowing, fire, and grazing are all widely used and valuable tools for maintaining the open, meadow-like conditions that bumble bees prefer. However, if done inappropriately (such as too frequently, or over too wide of an area), these activities can also remove too many floral resources and destroy nesting habitat for bumble bees, as well as harm butterflies, moths, and other invertebrates whose life cycles depend on the plants being disturbed (Mäder et al. 2011). Two key principals that apply irrespective of which management action is being employed include: do not treat the entire site at one time and when a treatment is being applied, do not treat more than one third of the site per year.

Mowing

Grassy areas such as meadows, forest edges, hedgerows, and lawns may all be subject to mowing. Research in Britain has shown that unmanaged meadows and garden areas with a high proportion of grass and different layers of habitat have the highest diversity of bumble bees (*in* Mäder et al. 2011), and that mowed sites have significantly fewer bumble bee nests (Potts et al. 2009). When mowing is a necessary management action, the following guidelines may be adopted:

- Leave one or more patches—as large as possible—of meadow, lawn, or edge habitat unmowed for the entire year.
- If you need to mow during the flight season (March-September), try to create a mosaic of patches with structurally different vegetation.
- Mow at the highest cutting height possible to prevent disturbance of established nests or overwintering queens. A minimum of 12-16 inches is ideal.

Fire is an important management tool for many meadows or open habitats, but requires care to avoid disturbance to plant and animal populations. The following recommendations will maximize the benefit to bumble bees.

- Only burn a specific area once every 3-6 years.
- Burn from October through February.
- Burn small sections at a time.
- No more than one third of the land area should be burned each year.
- If possible mow fire breaks that will result in patches of unburned or lightly burned areas to serve as refuge for animals within the burn area.
- Avoid high intensity fires.

Grazing

A common practice in natural areas and agricultural landscapes, grazing has been shown to have dramatic effects on the structure, diversity, and growth habits of plants. When carefully applied, grazing can be beneficial for limiting shrub and tree succession, encouraging the growth of nectar rich plants, and providing the structural diversity that creates nesting habitat. However, grazing animals have the potential to remove flowering resources, as well as trample nesting and overwintering sites—and in turn harm the animal communities that depend on them (Black et al. 2011).

Grazing is usually only beneficial to bumble bees at low to moderate levels and when the site is grazed for a short period followed by ample recovery time. We make the following general recommendations, but stress the importance of assessing local and historical conditions before implementing a plan.

- Grazing management strategies should be completed according to the characteristics of

the site and the animals being used.

- Grazing on a site should occur for a short period of time, giving an extended period for recovery.
- Grazing should only occur on approximately one third of the property each year.
- Establish exclosures and rotate grazing to allow recovery of the vegetation community.

Tillage

Any surface or subsurface disturbance can be harmful to bumble bee colonies. In order to ensure the long-term health of bumble bee populations at least some areas under management must remain permanently free of tillage. These areas could be fence margins, hedgerows, debris piles, ditches, compost heaps, etc. Nesting surveys in Britain showed that gardens and linear features like hedgerows (i.e., places free from tillage) provided important bumble bee nesting habitat (Osborne et al. 2008).

Using Pesticides

Decision-making systems such as Integrated Pest Management can be important for developing less toxic responses to pests, and ensure that actual pest damage is taking place before chemicals are used. It is important to note that it is not just cropland and rangeland that experience high use and concentrations of pesticides. Surveys of urban streams suggest heavy use of pesticides in urban and suburban areas (USGS 2014). Also, for some pesticides allowable application rates are higher for home use relative to their agricultural counterparts (Hopwood et al. 2016).

For situations when pesticides must be used (e.g. an economic or public health pest having reached an established threshold), the following recommendations will reduce harm to these bumble bee species:

- Follow the manufacturer's directions.
- Choose the least toxic option:
    - ➢ Avoid dusts and microencapsulated products
- Use the lowest effective application rate.
- Apply the pesticide as directly and locally as possible.
- Apply when bumble bees are not active (keeping in mind that bumble bees can fly at cold temperatures, and are often active in the early morning and early spring):
    - ➢ Late fall or winter.
    - ➢ At dusk or at night (if the pesticide is short lived).
- Do not spray or allow drift to move onto field margins or boundaries.
- Do not apply pesticides when plants are in bloom.
- Reduce spray drift:
    - ➢ Avoid aerial spraying and mist blowers.
    - ➢ Spray on calm days (winds between 2 and 9 mph) to minimize spray drift from

targeted applications.
- Avoid the use of systemic insecticides, such as neonicotinoids.

Commercial Use of Bumble Bees

Increasingly, as the cost of honey bee rental increases and the benefits of bumble bees as pollinators are realized, bumble bees are being shipped throughout the world for pollination of greenhouse and field crops. Pathogens harbored by commercially reared bumble bees have been implicated in the decline of multiple species of North American bumble bees, including two species included in this petition (*Bombus occidentalis occidentalis* and *B. franklini*). Currently, there is only one species of bumble bee being used for managed pollination, the common eastern bumble bee, which is native to the eastern U.S., but used in California for pollination of greenhouse crops. Should the common eastern bumble bee escape greenhouses and establish in the wild, as it has in southern B.C., it may spread pathogens to wild bumble bees, or outcompete native species for nest sites or floral resources (Whittington et al. 2004; Colla et al. 2006). In addition, commercial bumble bee producers are actively developing species that could be used for open-field pollination in California (Biobest 2018a; 2018b; APHIS 2014), and should that occur, these commercial bumble bees may pose a considerable risk to the four species of bumble bees listed in this petition.

Any use of commercially reared bumble bees for crop pollination should focus on minimizing the exposure of wild native species to managed species.
- Do not allow commercial bumble bees to be used outside of the native range of the species; if native bumble bees are allowed, ensure that they are produced within their native ranges.
- Only use commercial bumble bees in greenhouses; do not use them for open-field crops.
- Screens should be placed over window, vents, and other openings in greenhouses to prevent commercial bumble bees from escaping and interacting with wild bumble bees.
- Commercially acquired colonies should be killed (for example, by being placed in a freezer overnight) after their period of use and NOT released into the wild.

Honey Bees

Honey bees may pose a significant threat to at-risk bumble bees in this petition through competition for floral resources and spread of pathogens (Mallinger et al. 2017). Significantly, honey bees have been shown to extract vast quantities of pollen from the environment; an averaged sized apiary (40 hives) effectively removes nutritional resources that could have produced 4,000,000 wild bees over the course of three months (Cane & Tepedino 2016).

Recommendations for Land Managers

Where local and federal laws permit the placement of honey bees, and managers are deciding

whether to include hives on their land, we suggest that managers consider the following potential impacts of honey bees.

Are populations of endangered or threatened pollinators present on the land?
- If rare species of bees and butterflies, including threatened or endangered species, are known to exist within the flight area where the hives are to be placed, assessment of potential risks to these populations should be undertaken.
- If it is possible that rare or declining pollinator species can be found in the area, efforts should be made to determine if they are present. Consulting scientists with expertise in pollinator surveys and species identification is recommended. In cases where a particular pollinator species is critically imperiled, every remaining population and individual may be essential to the species' immediate and long-term survival. There is potential that honey bees may transmit diseases to native bees (e.g., spread of deformed wing virus from honey bees to bumble bees causing wing damage) and may compete for floral resources (e.g. decreased fecundity in bumble bees).
- We recommend that land managers discourage the placement of honey bee hives in natural areas, especially if populations of imperiled pollinators are present. Areas with diverse wildflowers are likely to also be hosts to diverse populations of native pollinators including imperiled bumble bees, and as such are not appropriate for honey bee apiaries; this is particularly true in protected areas (Geldmann & González-Varo 2018).
- If this recommendation cannot be followed, we recommend that honey bee hives be placed as far as practicable from areas receiving specialized management treatment for bumble bees.
  - ➢ Especially important will be to distance honey bee apiaries from potential bumble bee nesting sites, such as unmowed and untilled areas, old rock walls, fencerows or hedgerows, treed field margins, and hollow trees.
  - ➢ Where possible, distances greater than 2.4 miles (4 kilometers) will substantially reduce the competitive effects of managed hives on bumble bees (Cane & Tepedino 2016).

Are there invasive plant populations, or ongoing efforts to eradicate invasive plant species, that would be affected by the inclusion of honey bees?
- Honey bees may not be compatible with invasive plant species management. If honey bees pollinate and increase seed production of the invasive species in question (e.g., yellow star thistle), land managers may want to exclude honey bees during periods of bloom.

What are the potential impacts to other wildlife?
- Are there bears in the area that will be attracted to the apiary as a food source? Land managers need to work with beekeepers to determine if placement of an apiary will

increase the potential for human–bear conflicts. If this is a risk, then electric fencing and maintenance of that fencing to prevent intrusion from bear should be mandated on public lands to avoid bear damage to apiaries and to prevent habituation of bears to hives.

Is there sufficient infrastructure to support the drop-off and storing of the proposed operation?
- Commercial beekeepers may bring anywhere between 4 and 400 hives, depending upon the size of the operation. Hives are delivered using a range of vehicles from flatbed trucks to semi-tractor trailers. Access roads must be appropriate for the required transport, and should not result in excess erosion, road damage, or other infrastructure challenges.
- Apiary sites also must be of sufficient size, with level and firm ground to accommodate small forklifts or bobcats used to move pallets of bees. An apiary location will also need sufficient space for trucks to turn around.

Inventory, Research & Management Needs
Inventory, research, and management needs for each species listed in this petition are outlined below:

Crotch Bumble Bee (Bombus crotchii)
Inventory needs: Once very common in central and southern California, *B. crotchii* has recently undergone a dramatic decline, and is no longer present across much of its historic range. In order to better understand this species' distribution, in order to conserve existing populations, comprehensive surveys of this species at historic sites and other locations within its historic range are needed.

Research needs: Research needs for North American bumble bees (as a whole) are summarized in Cameron et al. (2011a), the final report for the 2010 North American Bumble Bee Species Conservation Planning Workshop. More research is needed to understand basic life history of *B. crotchii*, including nesting preferences, overwintering needs, and important host plants in California.

Management needs: Known and potential sites should be protected from threats. In the Central Valley, known populations should be protected from insecticide use. Practices such as livestock grazing and other factors that may interfere with the habitat requirements of this species (availability of nectar and pollen throughout the colony season and availability of underground nest sites and hibernacula) should be minimized where this species is extant. Carefully consider the placement of non-native European honey bees in areas that may be occupied by *B. crotchii* (see Hatfield et al. 2016 for more detail).

Franklin's bumble bee (Bombus franklini)
Inventory needs: Comprehensive surveys in *B. franklini*'s historic range should continue (Dr.

Robbin Thorp conducts annual bumble bee surveys within the range of this species).

Research needs: Research to address critical conservation questions for this species has been hindered by the fact that this bee may be extinct – it has not been observed since 2006 despite extensive annual surveys throughout its historic range. Should an extant population of *B. franklini* be discovered, more research would be recommended to gain a better understanding of the species' ecology, biology, and habitat requirements, especially any that might be limiting factors. Additionally, studying the pathology, control, and cross-infectivity of different suspected disease agents of *B. franklini*, including *Nosema bombi, Locustacarus buchneri, and Crithidia bombi* (Otterstatter et al. 2005; Colla et al. 2006) would allow for better understanding of the risks to the bumble bee populations and the preventative measures that should be taken.

Management needs: The habitat of *B. franklini* should be protected, including an abundance of suitable pollen and nectar sources such as, but not limited to: *Lupinus, Eschscholzia, Agastache, Monardella* as sources of pollen and nectar for the bees to feed on. Proximity to a natural source of fresh water would also be beneficial as it would increase the flowering season of the plants upon which the bees feed. Also, suitable nest sites are needed, such as abandoned rodent burrows.

Western bumble bee (Bombus occidentalis occidentalis)
Inventory needs: Once very common in the western United States and western Canada, *B. o. occidentalis* has recently undergone a dramatic decline in abundance and distribution, and is no longer present across the western portions of its historic range. In order to better understand the causes and extent of this species' decline, as well as the conservation needs of remaining populations, additional comprehensive surveys of this species at historic and potential sites are needed throughout California.

Research needs: Despite the widespread nature of this bumble bee, more research is needed to evaluate basic life history and ecological questions, including nesting preferences, overwintering needs, and important host plants in California.

Management needs: Protect known and potential sites from practices, such as livestock grazing, and threats such as conifer encroachment, that can interfere with the habitat requirements of this species (availability of nectar and pollen throughout the colony season and availability of underground nest sites and hibernacula). Carefully consider the placement of non-native European honey bees in areas that may be occupied by *B. o. occidentalis* (see Hatfield et al. 2016 for more detail).

Suckley bumble bee (Bombus suckleyi)
Research needs: *Bombus suckleyi* is a cuckoo bumble bee, dependent upon a bumble bee host

species to complete its life-cycle; thus the disappearance, or increasing rarity of that host would represent a threat to species existence. *B. suckleyi* is dependent on bumble bees that have recently documented range declines. The continued decline of these host species are a severe and permanent threat to continued existence of these cuckoo bumble bees. Efforts to conserve their hosts should be prioritized. While this species has only been documented as reproducing in nests of *B. o. occidentalis* it has been observed in the nests of several other species. More research is needed to determine if *B. suckleyi* could use other species as a successful host would help to better understand this species ecology. Additional life history information would also help to better understand this species' biological needs. This includes important host plants, location and details of overwintering sites, and specific habitat associations.

Inventory needs: Records of this species in California have been quite rare in recent collections. This species would benefit from targeted or more general bumble bee surveys to better understand its distribution throughout the state.

Management needs: Protect known and potential sites from practices, such as livestock grazing, and threats such as conifer encroachment, that can interfere with the habitat requirements of this species and its host (availability of nectar and pollen throughout the colony season and availability of underground nest sites and hibernacula). Efforts to conserve hosts species should be prioritized.

IX. INADEQUACY OF EXISTING REGULATORY MECHANISMS

Current regulations and regulatory mechanisms are wholly inadequate to protect these four species of bumble bees against the immediate threats that they face, including pathogen infection from commercial bees and the use of pesticides such as systemic insecticides. As emerging infectious disease has been implicated as one of the main threats to bumble bees (Evans et al. 2008; Hatfield et al. 2015a; 2015b; 2015c; Goulson & Hughes 2015), and pesticides including systemic insecticides have also been implicated in bumble bee declines (Whitehorn et al. 2012; Gill & Raine 2014; Pisa et al. 2014; Goulson 2015; Rundlöf et al. 2015), existing regulations need to be strengthened in order to adequately protect imperiled bumble bees from threats that, if unaddressed, have the potential to drive these bumble bees to extinction. Inadequacy of regulations to protect bumble bees from these immediate threats are summarized below.

Disease
Due to the immediate and potentially catastrophic effect that emerging infectious disease can have on bumble bee populations, more careful screening for diseases in commercial bees, as well as better management strategies and policy are needed to protect native bees from the threat of pathogen spillover (Graystock et al. 2013b; Sachman-Ruiz et al. 2015). Since small, fragmented, and declining populations are especially susceptible to infectious disease (Fürst et al. 2014), and

disease is already implicated as a likely causal factor of some native bee declines in North America (Cameron et al. 2011a), the emerging body of research summarized in Section V (Factors Affecting Ability to Survive and Reproduce) underscores the inadequacy of existing regulatory mechanisms to protect bumble bees from extinction.

The failing of current local and federal regulatory mechanisms is evidenced not just in their absence but in the continued decline of native bees across North America, including the western bumble bee, most likely caused by the spread of such pathogens that cause disease (Cameron et al. 2011a; Goulson & Hughes 2015). The emerging body of research linking decline of native bumble bees with the spread of pathogens underscores the inadequacy of existing regulatory mechanisms to protect bumble bees from extinction. Disease is a serious threat for bumble bees, as we explain above, because small, fragmented, and declining populations—which exist for all of the species included in this petition—are especially susceptible to infectious disease (Fürst et al. 2014).

Federal Regulations are Inadequate to Protect Wild California Bumble Bees

The Plant Protection Act
The Plant Protection Act (PPA) was passed in 2000 with the stated purpose of preventing the dissemination of plant pests. In order to control and prevent of the spread of plant pests for the protection of agriculture, the environment, and the U.S. economy, the PPA gives the Secretary of Agriculture the authority to facilitate "interstate commerce in agricultural products and other commodities that pose a risk of harboring plant pests or noxious weeds in ways that will reduce…the risk of dissemination of plant pests or noxious weeds. (7 USC § 7701(3))" The PPA authorizes the Secretary of Agriculture to promulgate regulations to prohibit or restrict the interstate movement of any plant pest if the Secretary determines the prohibition is necessary to prevent the dissemination of a plant pest within the U.S. The PPA broadly defines plant pests to include fungi, viruses, infectious agents and other pathogens, and any similar articles "that can directly or indirectly injure, cause damage to, or cause disease in any plant or plant product." Articles such as pathogens and parasites that infect or attack bumble bees cause indirect injury to plants that rely on these bees for pollination.

Although the Act was intended to protect agricultural goods, it could potentially directly or indirectly help control the spread of bumble bee diseases and pathogens. However, it has not done so. Currently, the USDA does not regulate either the disease status or interstate movement of U.S. commercial bumble bees, despite repeated requests to use its authority under the PPA to do so (Xerces Society et al. 2010; Xerces Society et al. 2013, 2014a, 2014b). This lack of regulation is a fact reflected in the absence of bumble bees, or their pathogens, from the list of pests and diseases regulated by USDA APHIS (USDA 2018). There is no indication that this will change in the near future, and so the PPA, which provides for the facilitation of "interstate

commerce in agricultural products," remains ineffective at slowing the spread of disease from commercial bumble bees to their native counterparts, including the bumble bees listed in this petition, and this inadequacy is reflected in the ongoing spread of disease from commercial to native bumble bees across the United States.

The USDA does regulate the international movement of Canadian bumble bees into the United States. Currently, the USDA allows the common eastern bumble bee (*Bombus impatiens*) and the western bumble bee (*Bombus occidentalis*) to be imported from Canada (7 CFR § 322.5). The USDA recently reviewed a request to allow Hunt's bumble bee (*B. huntii*) to also be imported into the U.S. from Canadian bumble bee production facilities (USDA 2014). The USDA regulations fail to protect the bumble bees included in this petition for two reasons: 1) Commercial colonies are not tested for pathogens upon importation (7 CFR § 322.5), and any pathogens present in commercial bumble bees could spread to bumble bees that visit the same flowers as commercial bumble bees (Graystock et al. 2015b); 2) Commercial bumble bees (*B. impatiens*) are produced both in Canada and the U.S., and colonies produced in the U.S. are also not required to be inspected for any pathogens.

The Honeybee Act
The Honeybee Act (7 USC 281) gives the Secretary of Agriculture the authority to regulate the interstate commerce of honey bees in order to control the spread of bee diseases: "The Secretary of Agriculture is authorized to prohibit or restrict the importation or entry of honeybees and honeybee semen into or through the United States in order to prevent the introduction and spread of diseases and parasites harmful to honeybees, the introduction of genetically undesirable germ plasm of honeybees, or the introduction and spread of undesirable species or subspecies of honeybees and the semen of honeybees." For example, the USDA uses its authority under the Honeybee Act to prevent movement of honey bees into Hawaii in order to control the spread of honey bee pests like the Varroa mite (summarized in Xerces Society et al. 2010). However, the Honey bee Act is specific to honey bees, and does not extend authority to the USDA to regulate diseases of managed bumble bees. Thus, the Honeybee Act fails to protect imperiled bumble bees from pathogens harbored by commercial bumble bees that are used throughout North America.

There is clear evidence that honey bees can transmit pathogens to bumble bees (Graystock et al. 2013a, 2013b; Graystock et al. 2015a, 2015b; Fürst et al. 2014; McMahon et al. 2015). However, any indirect protection of bumble bees flowing from regulation of honey bees under the Honeybee Act is limited in scope, and inadequate for protection. First, pathogens that impact the bumble bees may come from multiple sources beyond honey bees; second, the Honeybee Act does not apply to the movement of pollen for use by the commercial bumble bee trade (the risks of this practice are reviewed in Manley et al. 2015); and third, the laws seeking to prevent the spread of disease among honey bees suffer in their lack of uniformity and enforcement. State

laws regulating interstate movement of honey bees vary considerably from state to state (Gegner 2003). For example, Massachusetts requires bees imported into the state to be certified disease free within 60 days (State of Massachusetts 2018), while Minnesota does not have any similar requirements, and only offers fee for service apiary inspections (State of Minnesota 2017). In addition, responsibility for disease control remains with the beekeeper, who should routinely examine colonies for disease as a regular part of his or her management program and do what is necessary when disease is found. Yet there are not clear regulations that determine how often hives should be screened, or for which pathogens. Significantly, there are not consistent, effective mitigative actions for beekeepers to employ upon disease discovery (Graystock et al. 2015a).

California State Regulations Governing Commercial Bumble Bees
The California Department of Food and Agriculture currently allows multiple species of managed, commercial bumble bees to be imported for commercial use in the state – the nonnative common eastern bumble bee (*B. impatiens*) for greenhouse use, and the native Hunt's bumble bee (*B. huntii*) and yellow faced bumble bee (*B. vosnesenskii*) for open field or greenhouse use. Although the Hunt's and yellow faced bumble bees are native to California, they are currently produced outside of their native ranges, in facilities that also rear common eastern bumble bees, and thus could be exposed to nonnative pathogens, which they then could spread to wild bumble bees, including the four bumble bees included in this petition. Thus, CDFA's regulations are currently inadequate to protect these for species of wild bumble bees from the threat they face from pathogen infection from managed bumble bees.

In addition, CDFA routinely allows honey bees to be imported into California for use in open field settings, where pathogens (in particular, RNA viruses) may spill over and infect wild bumble bees.

Although the state of California has passed regulations to protect bees (https://www.cdfa.ca.gov/plant/pollinators/docs/Regulations-for-Protection-of-Bees.pdf), these regulations only consider effects of pesticides on honey bees, and how to mitigate those effects, and thus are inadequate to protect these four species of wild bumble bees.

Pesticide Regulations
In June 2014, the US EPA published the *Guidance for Assessing Pesticide Risks to Bees* (U.S. EPA 2014). The guidelines provide recommendations to assist researchers in designing studies to evaluate the risks that pesticides pose to bees. Such studies are in turn used by the EPA to assess risk and determine appropriate regulation. This new guidance document could add new research to the current battery of tests required for pesticides. Still, it fails to address many concerns specific to bumble bees and other native bees. As such, pesticide risk assessments performed by the EPA could underestimate risk to bumble bees and other native bee species. For example, the

guidelines state: "This section summarizes the overall risk assessment process for characterizing the risks of pesticides to honey bees (*Apis mellifera*), which are used as a surrogate species for other *Apis* and non-*Apis* bees and other insect pollinators." (USEPA 2014). However, the differential physiological, biological and behavioral differences of honey bees from other native bees (Osborne 2012; Vaughan et al. 2014) make honey bees poor surrogates for assessing toxicity of pesticides to bumble bees. In particular, the life-history of many non-*Apis* species (including bumble bees) including nest site location, foraging time and distance, food sources, life-cycle, and size may expose bumble bees and other non-*Apis* bee species to alternative exposure routes not considered when tests are only applied to honey bees (Wisk et al. 2014). Furthermore, unlike honey bees, bumble bees do not process pollen or nectar before feeding it to immature bees, which exposes developing bumble bees to a greater concentration of pesticides than honey bees—whose larvae are fed primarily royal jelly (processed secretions from nurse bees), and perhaps a small amount of pollen and nectar (Fischer & Moriarty 2011). For example, bumble bees appear to be affected by dietary concentrations of the systemic insecticide imidacloprid at levels lower than honey bees, perhaps because, unlike honey bees, bumble bees do not metabolically degrade imidacloprid effectively while continuing to ingest it (Cresswell et al. 2014). This range of exposure routes was not considered during the EPA's registration process for neonicotinoids (USEPA 2012). Thus, the current mechanism that regulates the safety of pesticides to bees fails to take into account attributes specific to bumble bees and is therefore inadequate to protect bumble bees from the threat of pesticides.

Further demonstrating how current federal pesticide regulation fails to address risks to bumble bees is underscored by the fact that the EPA has not adequately responded to the numerous bumble bee kills caused by on-label, legal uses of neonicotinoid insecticides to *Tilia* trees. Specifically, in most of these cases, large numbers of bumble bees were killed by the legal applications of neonicotinoid insecticides; in one case more than 50,000 bumble bees were killed in a single incident (Hilburn 2013). Since June of 2013, there have been numerous completed investigations into bumble bee kills that occurred in Oregon. Responding to the risks associated with two of the incidents, U.S. EPA halted foliar use of nitroguanidine neonicotinoids on non-agricultural plants (including *Tilia* trees) <u>while plants are flowering</u> (US EPA 2013). However, because neonicotinoid insecticides can remain in plant tissue for weeks to months, and in some cases even years (Mach et al 2017), this change in regulation remains inadequate to protect bumble bees from nitroguanidine neonicotinoids applied to bumble bee-attractive plants prior to flowering. No federal action has been taken in response to the risks demonstrated by five other bee-kill incidents in Oregon caused by non-foliar, systemic applications <u>weeks to months prior to flowering</u>. Of these five incidents, only one was linked with an off-label use. The state of Oregon did respond to this risk by halting all uses of nitroguanidine neonicotinoids to *Tilia* trees within the state of Oregon (ODA 2015). However, not all imperiled bumble bees listed in this petition have a range that includes the state of Oregon, and therefore are not protected by this state's

regulation. Even after the Oregon Department of Agriculture wrote to EPA to point out the inadequacy of the federal regulation, the EPA did not take action to protect bumble bees from long-term residues of systemic insecticides in woody plants such as *Tilia*.

An additional failure of the federal regulations to protect imperiled bumble bees from the threat of pesticides is that the U.S. EPA's Office of Pesticide Program conducts chemical-specific risk assessments for bees. Yet, research has begun to elucidate threats that pesticide mixtures pose to bees. While the majority of studies have been conducted on honey bees, these studies demonstrate an area of significant uncertainty that could lead to an underestimation of risk to other species of bees. For example, there can be different risks between active ingredients and full formulations (Mullin et al. 2015). There are also additive and synergistic effects between chemicals that might be found jointly in tank mixes or in the field. For example, research has raised concern for synergistic effects of the combination of ergosterol biosynthesis inhibiting fungicides and pyrethroids (Vandame and Belzunces 1998). Neonicotinoids are also known to be additively or synergistically toxic when they occur together (Andersch et al. 2010). The findings by Zhu et al. (2014) led the researchers to recommend that pesticide mixtures in pollen be evaluated by adding their toxicities together until complete data on interactions can be accumulated. Further, a recent study by Hladik et al. (2015) showed that within a single sample that non-*Apis* bees are exposed to mixtures of several pesticides, including neonicotinoids, pyrethroids, and fungicides. This provides clear evidence that native bees are exposed to multiple pesticides in their foraging bouts, yet, because of a lack of appropriate regulatory mechanisms and testing protocols, the EPA does not understand how exposure to multiple pesticides affects bumble bees – despite evidence that there are significant deleterious effects (See references above). Current EPA risk assessment regulations for pesticide effects on bees do not consider additive, or synergistic effects of pesticides, and are therefore inadequate to protect bumble bees from the threat of pesticides.

In summary, it is clear that 1) different species of bees have different responses to different insecticides; 2) current regulations for insecticide approval from the EPA only consider the effects of insecticides on honey bees – which are used as a surrogate for non-*Apis* bees; 3) the EPA has not adequately responded to a known and realized threat that nitroguanidine neonicotinoids applied to cosmetic plantings pose to bees; 4) EPA does not address the known synergistic and additive effect of multiple pesticides, despite evidence that bees are exposed to multiple chemicals in their foraging bouts. As such, current regulatory mechanisms and testing protocols for pesticides are inadequate to protect the four species of bumble bees in this petition from the widespread and prophylactic use of insecticides that are highly toxic to them.

X. AVAILABILITY AND SOURCES OF INFORMATION

Literature Cited

Aldridge G., D. W. Inouye, J. R. K. Forrest, W. A. Barr, and A. J. Miller-Rushing. 2011. Emergence of a mid-season period of low floral resources in a montane meadow ecosystem associated with climate change. Journal of Ecology 99(4): 905-913.

Al-Jabr, A.M. 1999. Integrated pest management of tomato/potato psyllid, *Paratrioza cockerelli* (Sulc) (Homoptera: Psyllidae), with emphasis on its importance in greenhouse grown tomatoes. Ph.D dissertation, Deparment of Bioagricultural Sciences and Pest Management, Colorado State University. 107 pp.

Altizer, S., D. Harvell, and E. Friedle. 2003. Rapid evolutionary dynamics and disease threats to biodiversity. Trends in Ecology & Evolution 18:589–596.

Andersch, W., P. Jeschke, and W. Thielert. 2010, August 26. Synergistic Insecticide Mixtures. 20100216637 A1. Available from https://www.google.com/patents/US20100216637. [Available 25 September 2018].

Anderson, G. J. and M. K. Anderson. 1989. Assaying pollinator visitation to *Solanum* flowers. Solanaceae newsletter 3(1):71.

[APHIS] Animal and Plant Health Inspection Service. 2014. Pest Risk Assessment for bumble bees from Canada. Importation of Bumble Bee Species *Bombus huntii* Greene (Hunt bumble bee) and *B. vosnesenskii* Radoszkowski (Vosnesensky bumble bee) from Canada into the Continental United States. A Qualitative, Pathway-Initiated Pest Risk Assessment. Version 1.1.

Arbetman, M. P., I. Meeus, C. L. Morales, M. A. Aizen, and G. Smagghe. 2013. Alien parasite hitchhikes to Patagonia on invasive bumblebee. Biological Invasions 15:489–494.

Arce, A. N., T. I. David, E. L. Randall, A. Ramos Rodrigues, T. J. Colgan, Y. Wurm, and R.J. Gill. 2016. Impact of controlled neonicotinoid exposure on bumblebees in a realistic field setting. Journal of Applied Ecology 54(4): 1199-1208.

Baker, N.T. and W. W. Stone. 2015, Estimated annual agricultural pesticide use for counties of the conterminous United States, 2008–12: U.S. Geological Survey Data Series 907, 9 p.

Bartlewicz, J., M. I. Pozo, O. Honnay, B. Lievens, and H. Jacquemyn. 2016. Effects of agricultural fungicides on microorganisms associated with floral nectar: susceptibility assays and field experiments. Environmental Science and Pollution Research 23(19): 19776-19786.

Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54:419–431.

Berenbaum, M., P. Bernhardt, S. Buchmann, N. Calderone, P. Goldstein, D. W. Inouye, P. Kevan, C. Kremen, R. A. Medellin, and T. Ricketts. 2007. Status of pollinators in North America. The National Academies Press, Washington, DC.

Bernauer, O. M., H. R. Gaines-Day, and S. A. Steffan. 2015. Colonies of bumble bees (*Bombus impatiens*) produce fewer workers, less bee biomass, and have smaller mother queens following fungicide exposure. Insects 6(2): 478-488.

Bertsch, A., Hrab'e de Angelis, M. & Przemeck, G.K.H. 2010. A phylogenetic framework for the North American bumblebee species of the subgenus *Bombus* sensu stricto (*Bombus affinis, B. franklini, B. moderatus, B. occidentalis & B. terricola*) based on mitochondrial DNA markers. Beitr¨age zur Entomologie 60:229–242.

Bhattacharya, M., R. B. Primack, and J. Gerwein. 2003. Are roads and railroads barriers to bumblebee movement in a temperate suburban conservation area? Biological Conservation 109:37–45.

Biesmeijer, J. C., S. P. M. Roberts, M. Reemer, R. Ohlemüller, M. Edwards, T. Peeters, A. P. Schaffers, S. G. Potts, R. Kleukers, C. D. Thomas, J. Settele, and W. E. Kunin. 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 313: 351-354.

Biobest Group. 2018a. North American growers count on Biobest for great pollination results in open field fruit production. Website: https://www.biobestgroup.com/en/page/295650/north-american-growers-count-on-biobest-for-great-pollination-results-in-open-field-fruit-production. [Accessed 15 March 2018].

Biobest Group. 2018b. Hive Types. https://www.biobestgroup.com/en/biobest/pollination/things-to-know-about-bumblebees-7052/hive-types-6683/. [Accessed 15 March 2018].

Black, S. H., M. Shepherd, and M. Vaughan. 2011. Rangeland management for pollinators. Rangelands 33(3):9-13.

Blaker, E. A., J. P. Strange, R. R. James, F. P. Monroy, and N. S. Cobb. 2014. PCR reveals high

prevalence of non/low sporulating Nosema bombi (microsporidia) infections in bumble bees (*Bombus*) in Northern Arizona. Journal of invertebrate pathology 123:25–33.

Brown, M. J. F., R. Schmid-Hempel, and P. Schmid-Hempel. 2003. Strong context-dependent virulence in a host-parasite system: reconciling genetic evidence with theory. Journal of Animal Ecology 72: 994-1002.

Buchmann, S. L. 1983. Buzz pollination in angiosperms. Pages 73-113 i*n* C. E. Jones and R. J. Little, editors. Handbook of experimental pollination biology. Van Nostrand Reinhold Company, New York, NY.

Buchmann, S. L. 1996. Competition between honey bees and native bees in the Sonoran Desert and global bee conservation issues. Pages 125–142 *in* A. Matheson, S. L. Buchmann, C. O'Toole, P. Westrich, and I. H. Williams, editors. The conservation of Bees. Available from http://www.cabdirect.org/abstracts/19960200662.html [Accessed January 8, 2014].

Bueno, C., K. E. Ruckstuh, N. Arrigo, A. N. Aivaz, and P. Neuhaus. 2011. Impacts of cattle grazing on small-rodent communities: an experimental case study. Canadian Journal of Zoology 90:22-30.

Bumble Bee Watch. 2017. Bumble Bee Sightings. http://www.bumblebeewatch.org/app/#/bees/lists Query: {"Provinces/States": "California"; "Species": "occidentalis / Western bumble bee"; "Status": "Verified"}. [Accessed 20 June 2017].

Burns, I. 2004. Social development and conflict in the North American bumblebee *Bombus impatiens* Cresson. University of Minnesota. Ph.D. Thesis.

Butz-Huryn, V. M. 1997. Ecological impacts of introduced honey bees. Quarterly Review of Biology: 275–297.

[CA DPR] California Department of Pesticide Regulation. 2014. Summary of Pesticide Use Report Data 2012 *Indexed by Chemical*. 726 pp. Available from: http://www.cdpr.ca.gov/docs/pur/pur12rep/chmrpt12.pdf [Accessed 15 February 2018].

Calvin, L. and R. Cook. 2005. North American greenhouse tomatoes emerge as a major market force. Amber Waves: US Department of Agriculture Economic Research Service. 8 pp.

Cameron, S. A., H. M. Hines, and P. H. Williams. 2007. A comprehensive phylogeny of the bumble bees (Bombus). Biological Journal of the Linnean Society. Linnean Society of London

91:161–188.

Cameron, S., S. Jepsen, E. Spevak, J. Strange, M. Vaughan, J. Engler, and O. Byers (eds.). 2011a. North American Bumble Bee Species Conservation Planning Workshop Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Cameron, S. A., H. C. Lim, J. D. Lozier, M. A. Duennes, and R. Thorp. 2016. Test of the invasive pathogen hypothesis of bumble bee decline in North America. Proceedings of the National Academy of Sciences of the United States of America.

Cameron, S.A., Lozier, J.D., Strange, J.P, Koch, J.B., Cordes, N., Solter, L.F. and Griswold, T.L. 2011b. Patterns of widespread decline in North American bumble bees. Proceedings of the National Academy of Science (USA) 108(2): 662-667.

Cane, J. H. and V.J. Tepedino. 2016. Gauging the effect of honey bee pollen collection on native bee communities. Conservation Letters 10(2):205-210.

Carvell, C. 2002. Habitat use and conservation of bumblebees (Bombus spp.) under different grassland management regimes. Biological Conservation 103: 33-49.

Carvell, C., D. B. Roy, S. M. Smart, R. F. Pywell, C. D. Preston, and D. Goulson. 2006. Declines in forage availability for bumblebees at a national scale. Biological Conservation 132:481–489.

[CDFW] California Department of Fish and Wildlife. 2017. California Natural Diversity Database. October 2017. Special Animals List. Periodic publication. 65 pp.

Center for Biological Diversity, Center for Food Safety, Xerces Society for Invertebrate Conservation, and L. Brower. 2014. Petition to protect the monarch butterfly (*Danaus plexippus plexippus*) under the Endangered Species Act. Available from http://www.xerces.org/wp-content/uploads/2014/08/monarch-esa-petition.pdf.

Code, B. H. and S. L. Haney. 2006. Final Report: Franklin's Bumble Bee Inventory in the Southern Cascades of Oregon. Prepared for: The Bureau of Land Management, Medford, Oregon, 4 Oct. 2006. Available from: http://www.fs.fed.us/r6/sfpnw/issssp/documents/inventories/inv-rpt-iihy-bofr-med-southerncascades-inventory-2006-10.pdf [Accessed 20 February 2018).

Colla, S. R., Gadallah, F., Richardson, L., Wagner, D. and Gall, L. 2012. Assessing the Conservation Status of North American bumble bees using museum records. Biodiversity and

Conservation 21(14): 1379-1391.

Colla, S. R., M. C. Otterstatter, R. J. Gegear, and J. D. Thomson. 2006. Plight of the bumble bee: pathogen spillover from commercial to wild populations. Biological conservation 129:461–467.

Colla, S. R. and L. Packer. 2008. Evidence for the decline of Eastern North American Bumble Bees, with special focus on *Bombus affinis* Cresson. Biodiversity and Conservation 17:1379-1391.

Coop, J. D., and T. J. Givnish. 2007. Spatial and temporal patterns of recent forest encroachment in montane grasslands of the Valles Caldera, New Mexico, USA. Journal of biogeography 34:914–927. Blackwell Publishing Ltd. Available from: http://dx.doi.org/10.1111/j.1365-2699.2006.01660.x.

Cousin, M. E. Silva-Zacarin, A. Kretzschmar, M. El Maataoui, J. L. Brunet, and L. Belzunces. P. 2013. Size Changes in Honey Bee Larvae Oenocytes Induced by Exposure to Paraquat at Very Low Concentrations. PLOS ONE 2013. 8(5):p.e65693

Corbet S. A., M. Fussell, R. Ake, A. Fraser, C. Gunson, A Savage, and K Smith. 1993. Temperature and the pollinating activity of social bees. Ecological Entomology 18:17-30.

Cordes, N., W.-F. Huang, J. P. Strange, S. A. Cameron, T. L. Griswold, J. D. Lozier, and L. F. Solter. 2012. Interspecific geographic distribution and variation of the pathogens *Nosema bombi* and *Crithidia* species in United States bumble bee populations. Journal of Invertebrate Pathology, 109(2), 209-216.

Cox, C. 2001. Insecticide factsheet: Imidacloprid. Journal of Pesticide Reform. 21:15-22.

Cresson, E. T. 1878. Descriptions of new species of North American bees. *Proceedings of the Academy of natural Sciences of Philadelphia* 1878: 181-221.

Cresswell, J. E., F. X. L. Robert, H. Florance, N. Smirnoff. 2014. Clearance of ingested neonicotinoid pesticide (imidacloprid) in honey bees (*Apis mellifera*) and bumblebees (*Bombus terrestris*). Pest management science 70(2): 332-337.

Dafni, A. and A. Shmida. 1996. The possible ecological implications of the invasion of *Bombus terrestris* (L.) (Apidae) at Mt. Carmel, Israel. *In* A. Matheson, S. L. Buchmann, C. O'Toole, P. Westrich, and I. H. Williams (eds.). The Conservation of Bees. Academic Press 183-200 pp.

Darvill, B., J. S. Ellis, G. C. Lye, and D. Goulson. 2006. Population structure and inbreeding in a rare and declining bumblebee, *Bombus muscorum* (Hymenoptera: Apidae). Molecular Ecology 15: 601-611.

Darvill, B., O. Lepais, L. C. Woodall, and D. Goulson. 2012. Triploid bumblebees indicate a direct cost of inbreeding in fragmented populations. Molecular Ecology, 21(16), 3988-3995.

Daszak, P., A. A. Cunningham, and A. D. Hyatt. 2000. Emerging infectious diseases of wildlife–threats to biodiversity and human health. Science 287:443–449. Available from: http://www.sciencemag.org/content/287/5452/443.short [Accessed 13 March 2014].

Dai, P., Z. Yan, S. Ma, Y. Yang, Q. Wang, C. Hou, Y. Wu, Y. Liu, and Q. Diao. 2018. The herbicide glyphosate negatively affects midgut bacterial communities and survival of honey bee during larvae reared in vitro. Journal of Agriculture and Food Chemistry 66(29): 7786-7793.

Diekötter, T., K. Walther-Hellwig, M. Conradi, M. Suter, and R. Frankl. 2006. Effects of landscape elements on the distribution of the rare bumblebee species *Bombus muscorum* in an agricultural landscape. Arthropod Diversity and Conservation 15: 57-68.

Dupont, Y. L., D. M. Hansen, A. Valido, and J. M. Olesen. 2004. Impact of introduced honey bees on native pollination interactions of the endemic *Echium wildpretii* (Boraginaceae) on Tenerife, Canary Islands. Biological Conservation 118:301–311.

Eickwort, G. C. and H. S. Ginsberg. 1980. Foraging and mating behavior in Apoidea. Annual Review of Entomology 25:421–446.

Eilers E. J., C. Kremen, S. S. Greenleaf, A. K. Garder, and A. Klein. 2011. Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS ONE 6(6):e21363.

Elbgami, T., W. E. Kunin, W. O. H. Hughes, and J. C. Biesmeijer. 2014. The effect of proximity to a honeybee apiary on bumblebee colony fitness, development, and performance. Apidologie: 1–10.

Ellis, J. S., M. E. Knight, B. Darvill, and D. Goulson. 2006. Extremely low effective population sizes, genetic structuring and reduced genetic diversity in a threatened bumblebee species, *Bombus sylvarum* (Hymenoptera: Apidae). Molecular Ecology 15(14): 4375-4386.

Evans, E. C. 2001. Competition between European honey bees and native bumblebees: resource overlap and impact on reproductive success. University of Minnesota.

Evans, E., R. Thorp, S. Jepsen, and S. H. Black. 2008. Status review of three formerly common species of bumble bee in the subgenus/Bombus. The Xerces Society.

Evison, S. E. F., K. E. Roberts, L. Laurenson, S. Pietravalle, J. Hui, J. C. Biesmeijer, J. E. Smith, G. Budge, and W. O. H. Hughes. 2012. Pervasiveness of Parasites in Pollinators. PLoS ONE 7:e30641.

Fauser, A., C. Sandrock, P. Neumann, and B. M. Sadd. 2017. Neonicotinoids override a parasite exposure impact on hibernation success of a key bumblebee pollinator. Ecological Entomology 42(3): 306-314.

Fauser-Misslin, A., B. M. Sadd, P. Neumann, and C. Sandrock. 2014. Influence of combined pesticide and parasite exposure on bumblebee colony traits in the laboratory. Journal of Applied Ecology 51(2): 450-459.

Field, C. B., D. B. Lobell, H. A. Peters, and N. R. Chiariello. 2007. Feedbacks of Terrestrial Ecosystems to Climate Change*. Annual review of environment and resources 32:1–29. Available from: http://www.annualreviews.org/doi/abs/10.1146/annurev.energy.32.053006.141119 [Accessed 20 February 2018].

Fischer, D. and T. Moriarty (Eds). 2011. Pesticide risk assessment for pollinators: Summary of a SETAC Pellston workshop. 15-21 January 2011, Pensacola, Florida, USA.

Fitzpatrick, Ã., T. E. Murray, R. J. Paxton, and M. J. F. Brown. 2007. Building on IUCN Regional Red Lists to Produce Lists of Species of Conservation Priority: a Model with Irish Bees. Conservation Biology 21: 1324–1332.

Flanders, R. V., W. F. Wehling, and A. L. Craghead. 2003. Laws and regulations on the import, movement and release of bees in the United States. pp. 99-111. In K. Strickler and J. H. Cane (eds.) For Nonnative Crops, Whence Pollinators of the Future? Thomas Say Publications in Entomology: Proceedings. Entomological Society of America, Lanham, MD.

Forrest, J., Inouye, D. W., Thomson, J. D. 2010. Flowering phenology in subalpine meadows: Does climate variation influence community co-flowering patterns? Ecology 91:431–440.

Frankham, R., J. D. Ballou, and D. A. Briscoe. 2010. Introduction to Conservation Genetics Second Edition, Cambridge University Press, 618 pages.

Frankie, G. W., R. W. Thorp, M. Schindler, J. Hernandez, B. Ertter, and M. Rizzardi. 2005. Ecological patterns of bees and their host ornamental flowers in two northern California cities. Journal of the Kansas Entomological Society 78: 227-246.

Franklin, H. J. 1913. The Bombidae of the New World. Transactions of the American Entomological Society 38: 177-486.

Freese, B. and Crouch, M. 2015. Monarchs in peril: Herbicide resistant crops and the decline of monarch butterflies in North America. Center for Food Safety. 88 pp.

Frison, T. H. 1921. New distribution records for North American Bremidae, with the description of a new species (Hym.) Entomological News 32: 144-148.

Frison, T. H. 1923. Systematic and biological notes on bumblebees (Bremidae; Hymenoptera). Transactions of the American Entomological Society 48: 307-326.

Frison, T. H. 1926. Descriptions and records of North American Bremidae together with notes on the synonymy of certain species (Hymenoptera). Transactions of the American Entomological Society 52: 129-145.

Fürst, M. A., D. P. McMahon, J. L. Osborne, R. J. Paxton, and M. J. F. Brown. 2014. Disease associations between honeybees and bumblebees as a threat to wild pollinators. Nature 506:364–366. Available from: http://www.nature.com/nature/journal/v506/n7488/abs/nature12977.html [Accessed 20 February 2018].

Fussell, M., and S. A. Corbet. 1992. Flower usage by bumble-bees: a basis for forage plant management. *Journal of Applied Ecology* 29:451-465.

Gegner, L. 2003. Beekeeping/Apiculture. ATTRA. Available from https://attra.ncat.org/attra-pub/summaries/summary.php?pub=76. [Accessed 25 September 2018].

Geldmann, J. and González-Varo, J. P. 2018. Conserving honey bees does not help wildlife. Science 359:392–393.

Genersch, E., C. Yue, I. Fries, and J. R. de Miranda. 2006. Detection of deformed wing virus, a honey bee viral pathogen, in bumble bees (*Bombus terrestris* and *Bombus pascuorum*) with wing deformities. Journal of Invertebrate Pathology 91:61–63.

Getz, W. M., S. Fortmann-Roe, P. C. Cross, A. J. Lyons, S. J. Ryan, and C. C. Wilmers. 2007. LoCoH: nonparameteric kernel methods for constructing home ranges and utilization distributions. PloS one 2:e207.

Gibson, C., V. Brown, L. Losito, and G. McGavin. 1992. The response of invertebrate assemblies to grazing. Ecography 15: 166-176.

Gill, R. J. and N. E. Raine. 2014. Chronic impairment of bumblebee natural foraging behaviour induced by sublethal pesticide exposure. Functional ecology 28:1459–1471. Available from http://onlinelibrary.wiley.com/doi/10.1111/1365-2435.12292/epdf. [Accessed 28 February 2018].

Gill, R. J., O. Ramos-Rodriguez, and N. E. Raine. 2012. Combined pesticide exposure severely affects individual- and colony-level traits in bees. Nature 491(7422): 105-108.

Gillespie, S. 2010. Factors affecting parasite prevalence among wild bumblebees. Ecological entomology 35:737–747.

Ginsberg, H. S. 1983. Foraging ecology of bees in an old field. Ecology:165–175.

Goka, K. 2010. Introduction to the Special Feature for Ecological Risk Assessment of Introduced Bumblebees: Status of the European bumblebee, *Bombus terrestris*, in Japan as a beneficial pollinator and an invasive alien species. Applied Entomology and Zoology 45:1–6.

Goka, K., Okabe, K., Niwa, S., Yoneda, M. 2000. Parasitic mite infestation in introduced colonies of European bumblebees, *Bombus terrestris*. Japanese Journal of Applied Entomology and Zoology 44(1):47-50.

Goka, K., Okabe, K., Yoneda, M. 2006. Worldwide migration of parasitic mites as a result of bumblebee commercialization. Population Ecology 48:285–291.

Gorbunov, P. S. 1987. Endoparasitic flagellates of the genus *Crithidia* (Trypanosomatidae, Zoomastigophorea) from alimentary canal of bumblebees. Zoologicheskii zhurnal.

Goulson, D. 2003. Conservation of bumblebees. *In:* Species Management: Challenges and Solutions for the 21st Century. ed. by J.M. Baxter and C.A. Galbraith. TSO Scotland, Edinburgh. pp. 477-492.

Goulson, D. 2010. *Bumblebees: behaviour, ecology, and conservation*. Oxford University Press,

New York. 317pp.

Goulson, D. 2015. Neonicotinoids impact bumblebee colony fitness in the field; a reanalysis of the UK's Food & Environment Research Agency 2012 experiment. PeerJ 3:e854.

Goulson, D., and W. O. H. Hughes. 2015. Mitigating the anthropogenic spread of bee parasites to protect wild pollinators. Biological conservation 191:10–19.

Goulson, D., G. C. Lye, and B. Darvill. 2008. Decline and conservation of bumble bees. Annu. Rev. Entomol. 53:191–208.

Goulson, D. and K. R. Sparrow. 2009. Evidence for competition between honeybees and bumblebees; effects on bumblebee worker size. Journal of Insect Conservation 13:177–181.

Goulson, D., J. C. Stout, and A. R. Kells. 2002. Do exotic bumblebees and honeybees compete with native flower-visiting insects in Tasmania? Journal of Insect Conservation 6: 179–189.

Gradish, A. E., C. D. Scott-Dupree, L. Shipp, C. R. Harris, and G. Ferguson. 2009. Effect of reduced risk pesticides for use in greenhouse vegetable production on *Bombus impatiens* (Hymenoptera: Apidae). Pest Management Science 66:142-146.

Graystock, P., E. J. Blane, Q. S. McFrederick, D. Goulson, and W. O. H. Hughes. 2015a. Do managed bees drive parasite spread and emergence in wild bees? International journal for parasitology. Parasites and Wildlife 5(1): 64-75.

Graystock, P., D. Goulson, and W. O. H. Hughes. 2015b. Parasites in bloom: flowers aid dispersal and transmission of pollinator parasites within and between bee species. Proc. R. Soc. B 282:1-6. The Royal Society. Available from http://rspb.royalsocietypublishing.org/content/royprsb/282/1813/20151371.full.pdf. [Accessed 28 February 2018].

Graystock, P., D. Goulson, and W. O. H. Hughes. 2014. The relationship between managed bees and the prevalence of parasites in bumblebees. PeerJ 2:e522. Available from http://dx.doi.org/10.7717/peerj.522.

Graystock, P., K. Yates, B. Darvill, D. Goulson, and W. O. H. Hughes. 2013a. Emerging dangers: deadly effects of an emergent parasite in a new pollinator host. Journal of invertebrate pathology 114:114–119.

Graystock, P., K. Yates, S. E. F. Evison, B. Darvill, D. Goulson, and W. O. H. Hughes. 2013b. The Trojan hives: pollinator pathogens, imported and distributed in bumblebee colonies. The Journal of applied ecology 50:1207–1215. Available from: http://onlinelibrary.wiley.com/doi/10.1111/1365-2664.12134/full [Accessed 6 August 2014].

Greene, J. W. 1858. Descriptions of several new hymenopterous insects from the North west coast of America. Annals of Lyceum of Natural History of New York 7: 11-12.

Greene, J. W. 1860. XXI. Review of the American Bombidae, together with a description of several species heretofore undescribed, being a synopsis of this family of Hymenopterous insects thus far known to inhabit North America. Annals of the Lyceum of Natural History of New York 7: 168-176.

Grixti, J. C., L. T. Wong, S. A. Cameron, and C. Favret. 2009. Decline of bumble bees (Bombus) in the North American Midwest. Biological conservation 142:75–84. Available from http://www.sciencedirect.com/science/article/pii/S0006320708003698 [Accessed 5 February 2014].

Hatfield, R, S. Colla, S. Jepsen, L. Richardson, R. Thorp, and S. Foltz Jordan. 2014. Draft IUCN Assessments for North American *Bombus* spp. for the North American IUCN Bumble Bee Specialist Group. The Xerces Society for Invertebrate Conservation, www.xerces.org, Portland, OR.

Hatfield, R., S. Jepsen, E. Mader, S. H. Black, and M. Shepherd. 2012. Conserving Bumble Bees: Guidelines for Creating and Managing Habitat for America's Declining Pollinators. The Xerces Society for Invertebrate Conservation. Available from: http://www.xerces.org/bumblebees/guidelines.

Hatfield, R., Jepsen, S., Thorp, R., Richardson, L. and Colla, S. 2015a. *Bombus crotchii*. The IUCN Red List of Threatened Species 2015: e.T44937582A46440211. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T44937582A46440211.en. Downloaded on 9 February 2018.

Hatfield, R., Jepsen, S., Thorp, R., Richardson, L., Colla, S. and Foltz Jordan, S. 2015b. *Bombus occidentalis*. The IUCN Red List of Threatened Species 2015: e.T44937492A46440201. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T44937492A46440201.en. Downloaded on 9 February 2018.

Hatfield, R., S. Jepsen, R. Thorp, L. Richardson, and S. Colla, 2015c. *Bombus suckleyi*. The

IUCN Red List of Threatened Species 2015: e.T44937699A46440241. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T44937699A46440241.en. Downloaded on 9 February 2018.

Hatfield, R. G., S. Jepsen, M. Vaughan, S. Black, and E. Mader. 2016. An overview of the potential impacts of honey bees to native bees, plant communities, and ecosystems in wild landscapes: Recommendations for land managers. Available from: http://www.xerces.org/wp-content/uploads/2016/09/Xerces_policy_statement_HB_Final.pdf.

Hatfield, R. G., and G. LeBuhn. 2007. Patch and landscape factors shape community assemblage of bumble bees, Bombus spp.(Hymenoptera: Apidae), in montane meadows. Biological conservation 139:150–158.

Hatfield, R. G. Analysis the conservation status of *Bombus occidentalis occidentalis*. 2018a. Unpublished data.

Hatfield, R. G. Analysis the conservation status of *Bombus franklini*. 2018b. Unpublished data.

Hatfield, R.G., S. Colla, S. Jepsen, L. Richardson, R. Thorp. 2018c. Red Listing North America's Bumble Bees *In* Bumblebee Specialist Group Report 2017. Pp. 3-9. Available from: https://bumblebeespecialistgroup.org/wp-content/uploads/2018/02/BBSG-Annual-Report-2017.pdf

Hayes, G. F. and K. D. Holl. 2003. Cattle Grazing Impacts on Annual Forbs and Vegetation Composition of Mesic Grasslands in California. Conservation biology: the journal of the Society for Conservation Biology 17:1694–1702. Blackwell Science Inc. Available from: http://dx.doi.org/10.1111/j.1523-1739.2003.00281.x.

Highfield, A. C., A. El Nagar, L. C. Mackinder, M. L. N. Laure, M. J. Hall, S. J. Martin, and D. C. Schroeder. 2009. Deformed wing virus implicated in overwintering honeybee colony losses. Applied and environmental microbiology 75(22): 7212-7220.

Highland, S. A., and J. A. Jones. 2014. Extinction debt in naturally contracting mountain meadows in the Pacific Northwest, USA: varying responses of plants and feeding guilds of nocturnal moths. Biodiversity and conservation 23:2529–2544. Springer Netherlands. Available from: http://link.springer.com/article/10.1007/s10531-014-0737-z [Accessed 20 February 2018].

Hilburn, D. 2013. Lessons learned from the Wilsonville Bee Kill by Dan Hilburn, Oregon Department of Agriculture. In Oregon Invasive Species Blog. Available at:

http://oregoninvasivespecies.blogspot.com/2013/07/lessons-learned-from-wilsonville-bee.html [Accessed 25 September 2018].

Hines, H. M. and S. D. Hendrix. 2005. Bumble bee (Hymenoptera: Apidae) diversity and abundance in tallgrass prairie patches: effects of local and landscape floral resources. Environmental entomology 34:1477–1484.

Hladik, M. L., M. Vandever, and K. L. Smalling. 2015. Exposure of native bees foraging in an agricultural landscape to current-use pesticides. The Science of the total environment 542:469–477.

Hobbs, G. A. 1968. Ecology of species of *Bombus* (Hymenoptera: Apidae) in southern Alberta. VII. Subgenus *Bombus*. Canadian Entomologist 100: 156-164.

Hoover, S. E. R., J. J. Ladley, A. A. Shchepetkina, M. Tisch, S. P. Gieseg and J. M. Tylianakis. 2012. Warming, CO2, and nitrogen deposition interactively affect a plant-pollinator mutualism. Ecology Letters 15(3): 227-234.

Hopwood J., M. Vaughan, M. Shepherd, E. Lee-Mäder, and S.H. Black. 2016. How Neocicotinoids Can Kill Bees, the Science Behind the Role These Insecticides Play in Harming Bees. Tech. rep., The Xerces Society. Available from: http://www.xerces.org/neonicotinoids-and-bees/ [Accessed 20 February 2018].

Horskins, K. and V. B. Turner. 1999. Resource use and foraging patterns of honeybees, *Apis mellifera*, and native insects on flowers of *Eucalyptus costata*. Australian Journal of Ecololgy 24: 221–27.

Hudewenz, A., and A.-M. Klein. 2013. Competition between honey bees and wild bees and the role of nesting resources in a nature reserve. Journal of Insect Conservation 17:1275–1283.

Hudewenz, A., and A.-M. Klein. 2015. Red mason bees cannot compete with honey bees for floral resources in a cage experiment. Ecology and Evolution 5(21): 5049-5056.

Huntzinger M. 2003. Effects of fire management practices on butterfly diversity in the forested western United States. Biological Conservation 113: 1-12.

Husband, R. W. and R. N. Shina. 1970. A review of the genus *Locustacarus* with a key to the genera of the family Podapolipidae (Acarina), Annals of the Entomological Society of America

63:1152–1162.

Incerti, F., L. Bortolotti, C. Porrini, A. Micciarelli Sbrenna, and G. Sbrenna. 2003. An extended laboratory test to evaluate the effects of pesticides on bumblebees, preliminary results. Bulletin of Insectology 56:159-164.

Inouye, D. W. 2008. Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers Ecology 89(2):353-362.

[IUCN] International Union for the Conservation of Nature. 2012. Red List categories and criteria: Version 3.1Second. IUCN Species Survival Commision, Gland, Switzerland and Cambridge, UK. Available from: http://www.iucnredlist.org/static/categories_criteria_3_1#introduction [Accessed 20 February 2018].

[IUCN Red List] International Union for the Conservation of Nature. 2016. The IUCN Red List of Threatened Species. Available from http://www.iucnredlist.org/.

Jha, S. 2015. Contemporary human-altered landscapes and oceanic barriers reduce bumble bee gene flow. Molecular Ecology 24:993-1006.

Jha, S. and C. Kremen. 2013. Resource diversity and landscape-level homogeneity drive native bee foraging. Proceedings of the National Academy of Sciences 110:555–558.

Johansen, C. A. and D. F. Mayer. 1990. Pollinator protection: a bee & pesticide handbook. Wicwas Press. Cheshire, Connecticut. 212 pp.

Johnson, M. D. and C. M. Horn. 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. Western North American Naturalist 68: 444-452.

Kadoya, E. Z. and H. S. Ishii. 2015. Host manipulation of bumble bee queens by Sphaerularia nematodes indirectly affects foraging of non-host workers. Ecology 96:1361–1370. Eco Soc America. Available from http://www.ncbi.nlm.nih.gov/pubmed/26236849.

Kearns, C.A. and D.W. Inouye. 1997. Pollinators, flowering plants, and conservation biology. BioScience 47:297-307.

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

Kerr, J.T., A. Pindar, P. Galpern, L. Packer, S. G. Potts, S.M., Roberts, P. Rasmont, O. Schweiger, S. R. Colla, L.L. Richardson, and D. L. Wagner. 2015. Climate change impacts on bumblebees converge across continents. Science 349(6244): 177-180.

Kevan, P.G. 1999. Pollinators as bioindicators of the state of the environment: species, activity and diversity. Agriculture Ecosystems and Environment 74:373-393.

Kevan, P.G. 2008. *Bombus franklini*. The IUCN Red List of Threatened Species 2008: e.T135295A4070259. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T135295A4070259.en. Accessed 9 February 2018.

Kirby, W. 1837. The Insects. *In* Richardson, J., Swainson, W., and Kirby, W. (eds.), Fauna Boreali-Americana, part 4. 325 pp. Josiah Fletcher, Norwich.

Kimoto C. 2010. Effect of livestock grazing on native bees in a Pacific Northwest bunchgrass prairie. MS Thesis, Oregon State University.

Kirilenko, A. and R. S. Hanley. 2007a. Predicting climate change impact on insect biodiversity: comparison of scenarios. pp. 453-457 In Proceedings of the 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica (June 25-29, 2007).

Kirilenko, A. and R. S. Hanley. 2007b. Using multiple methods to predict climate change impacts on bumblebees in North America. pp. 42-47, In Proceedings of the International Conference on Environmental Modeling and Simulation.

Kissinger, C. N., S. A. Cameron, R. W. Thorp, B. White, and L. F. Solter. 2011. Survey of bumble bee (*Bombus*) pathogens and parasites in Illinois and selected areas of northern California and southern Oregon. Journal of invertebrate pathology 107:220–224.

Klein A., B. Vaissiere, J. Cane, I. Steffan-Dewenter, S. Cunningham, C. Kremen, et al. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences, 274:303-313.

Koppert Biological Systems. 2018. Natural Pollination. https://www.koppert.com/pollination/. [Accessed 19 March 2018].

Kosior, A., W. Celary, P. Olejniczak, J. Fijal, W. Krol, W. Solarz, and P. Plonka. 2007. The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of Western and

Central Europe. Oryx 41:79.

Kremen, C., N. M. Williams, R. W. and Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences 99(26): 16812-16816.

Kruess, A. and T. Tscharntke. 2002a. Contrasting responses of plant and insect diversity to variation in grazing intensity. Biological Conservation 106: 293-302.

Kruess, A, and T. Tscharntke. 2002b. Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. Conservation Biology 16: 1570-80.

Kudo, G., Y. Nishikawa, T. Kasagi, and S. Kosuge. 2004. Does seed production of spring ephemerals decrease when spring comes early? Ecological Research 19:255–259.

Kwong, W. K. and N. A. Moran. 2016. Gut microbial communities of social bees. Nature Reviews Microbiology 14(6): 374.

LaBerge, W. E. 1980. A revision of the bees of the genus *Andrena* of the Western Hemisphere. Part X. Subgenus *Andrena*. Transactions of the American Entomological Society 106: 395-525.

LaBerge, W. E. 1986. A revision of the bees of the genus *Andrena* of the Western Hemisphere. Part XI. Minor subgenera and subgeneric key. Transactions of the American Entomological Society 111: 441-567.

Lark, T. J., J. M. Salmon, and H. K. Gibbs. 2015. Cropland Expansion Outpaces Agricultural and Biofuel Policies in the United States. Environmental Research Letters 10: 1-11.

Larsson, J. I. 2007. Cytological variation and pathogenicity of the bumble bee parasite *Nosema bombi* (Microspora, Nosematidae). Journal of invertebrate pathology 94:1–11. Available from: http://www.sciencedirect.com/science/article/pii/S002220110600156X [Accessed 6August 2014].

Laycock, I., K. M. Lenthall, A. T. Barratt, and J. E. Cresswell. 2012. Effects of imidacloprid, a neonicotinoid pesticide, on reproduction in work bumble bees (*Bombus terrestris*) Ecotoxicology 21(7): 1937-1945.

Le Féon, V., A. Schermann-Legionnet, Y. Delettre, S. Aviron, R. Billeter, R. Bugter, F. Hendrick, and F. Burel. 2010. Intensification of agriculture, landscape composition and wild bee

communities: A large scale study in four European countries. Agriculture, Ecosystems & Environment 137: 143-150.

Lipa, J. J. and O. Triggiani. 1988. *Crithidia bombi* sp. n. a flagellated parasite of a bumble-bee *Bombus terrestris* L.(Hymenoptera, Apidae). Acta protozoologica 27:287–290.

Lozier, J. D., J. P. Strange, I. J. Stewart, and S. A. Cameron. 2011. Patterns of range-wide genetic variation in six North American bumble bee (Apidae: *Bombus*) species. Molecular Ecology. Retrieved February 1, 2013, from http://onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2011.05314.x/full.

Macfarlane, R. P., K. D. Patten, L. A. Royce, B. K. W. Wyatt, and D. F. Mayer. 1994. Management potential of sixteen North American bumble bee species. Melanderia 50: 1-12.

Macfarlane, R. P., J. J. Lipa, and H. J. Liu. 1995. Bumble bee pathogens and internal enemies. Bee World 76(3): 130-148.

Mach, B. M., S. Bondarenko, and D. A. Potter. 2017. Uptake and dissipation of neonicotinoid residues in nectar and foliage of systemically treated woody landscape plants. Environmental Toxicology 37(3): 860-870.

Mäder, E., M. Shepherd, M. Vaughan, S. H. Black, and G. LeBuhn. 2011. *Attracting Native Pollinators. Protecting North America's Bees and Butterflies.* 384 pp. North Adams, MA: Storey Publishing.

Maharramov, J. et al. 2013. Genetic variability of the neogregarine *Apicystis bombi*, an etiological agent of an emergent bumblebee disease. PloS one 8:e81475. Available from: http://dx.doi.org/10.1371/journal.pone.0081475. [Accessed 28 February 2018].

Mallick, S. A. and M. M. Driessen. 2009. Impacts of hive honeybees on Tasmanian leatherwood *Eucryphia lucida* Labill.(Eucryphiaceae). Austral Ecology 34:185–195.

Mallinger, R. E., Gaines-Day, H. R., Gratton, C. 2017. Do managed bees have negative effects on wild bees?: A systematic review of the literature. PloS one 12:e0189268.

Manley, R., M. Boots, and L. Wilfert. 2015. REVIEW: Emerging viral disease risk to pollinating insects: ecological, evolutionary and anthropogenic factors. The Journal of applied ecology 52:331–340.

Marletto, F., A. Patetta, and A. Manino. 2003. Laboratory assessment of pesticide toxicity to bumblebees. Bulletin of Insectology 56:155-158.

Maxfield-Taylor, S., K. M. Skyrm, and S. Rao. 2011. First record of *Sphaerularia bombi* (Nematoda: Tylenchida: Sphaerularidae), a parasite of bumble bee queens, in the Pacific Northwest. The Pan-Pacific entomologist 87:134–137.

McArt, S. H., C. Urbanowicz, S. McCoshum, R. E. Irwin, and L.S. Adler. 2017. Landscape predictors of pathogen prevalence and range contractions in US bumblebees. Proceedings of the Royal Society B 284(1867): 1-8.

McFrederick, Q. S. and G. LeBuhn. 2006. Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera: Apidae)? *Biological Conservation* 129:372-382.

McMahon, D. P., M. A. Fürst, J. Caspar, P. Theodorou, M. J. F. Brown, and R. J. Paxton. 2015. A sting in the spit: widespread cross-infection of multiple RNA viruses across wild and managed bees. The Journal of Animal Ecology. 84(3): 615-624.

Meehan, T. D., B. P. Werling, D. A. Landis, and C. Gratton. 2011. Agricultural landscape simplification and insecticide use in the Midwestern United States. Proceedings of the National Academy of Sciences of the United States of America 108:11500–11505. Available from http://dx.doi.org/10.1073/pnas.1100751108.

Meeus, I., M. J. F. Brown, D. C. De Graaf, and G. U. Y. Smagghe. 2011. Effects of invasive parasites on bumble bee declines. Conservation biology: the journal of the Society for Conservation Biology 25:662–671.

Memmott J., P. G. Craze, N. M. Waser, and M. V. Price. 2007. Global warming and the disruption of plant-pollinator interactions. Ecology Letters 10:710-717.

Memmott J., N. M. Waser, and M. V. Price. 2004. Tolerance of pollination networks to species extinctions. Proceedings of the Royal Society B 271:2605-2611.

Miller-Struttmann, N. E., J. C. Geib, J. D. Franklin, P. G. Kevan, R. M. Holdo, D. Ebert-May, A. M. Lynn, J. A. Kettenbach, E. Hedrick, and C. Galen. 2015. Functional mismatch in a bumble bee pollination mutualism under climate change. Science 349:1541–1544.

Milliron, H. E. 1971. A monograph of the Western Hemisphere bumblebees. I. The genera *Bombus* and *Megabombus* subgenus *Bombias*. Memoirs of the Entomological Society of Canada

82: 1-80.

Minckley, R. L., J. H. Cane, L. Kervin, and D. Yanega. 2003. Biological impediments to measures of competition among introduced honey bees and desert bees (Hymenoptera: Apiformes). Journal of the Kansas Entomological Society: 306–319.

Mommaerts, V., S. Reynders, J. Boulet, L. Besard, G. Sterk and G. Smagghe. 2010. Risk assessment for side-effects of neonicotinoids against bumblebees with and without impairing foraging behavior. Ecotoxicology 19:207-215.

Mommaerts, V. and G. Smagghe. 2011. Side-Effects of Pesticides on the Pollinator *Bombus*: An Overview. In: Stoytcheva, M. (ed), Pesticides of the Modern World. – Pests Control and Pesticides Exposure and Toxicity Assessment. InTech, Rijeka. 507-552 pp.

Morales, C. L., M. P. Arbetman, S. A. Cameron, and M. A. Aizen. 2013. Rapid ecological replacement of a native bumble bee by invasive species. Frontiers in Ecology and the Environment, 11(10): 529-534.

Morandin, L. A. and C. Kremen. 2013. Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields. Ecological Applications 23(4): 829-839.

Morandin, L. A., Laverty, T. M., Kevan, P. G., Khosla, S., Shipp, L. 2001. Bumble bee (Hymenoptera : Apidae) activity and loss in commercial tomato greenhouses. Canadian Entomology 133(6):883-93.

Morandin, L. A. and M. L. Winston. 2003. Effects of novel pesticides on bumble bee (Hymenoptera: Apidae) colony health and foraging ability. Environmental Entomology 32(3):555-563.

Morandin, L. A. and M.L. Winston. 2005. Wild bee abundance and seed production in conventional, organic, and genetically modified canola. Ecological applications 15(3): 871-881.

Morkeski, A. and A. L. Averill. 2010. Managed pollinator CAP-coordinated agricultural project: Wild bee status and evidence for pathogen 'spillover' with honey bees. American Bee Journal 150(11): 1049-1052.

Morkeski, A. and A. Averill. 2012. Wild bee status and evidence for pathogen spillover with honey bees. CAP Updates: 12. Oregon State University Extension. Available online: http://www.extension.org/pages/30998/wild-bee-status-and-evidence-for-pathogen-spillover-

with-honey-bees. [Accessed 19 March 2018].

Morris, M. G. 1967. Differences between invertebrate faunas of grazed and ungrazed chalk grassland. I. Responses of some phytophagous insects to cessation of grazing. Journal of Applied Ecology 4: 459-474.

Mortensen, D. A., J. F. Egan, B. D. Maxwell, M. R. Ryan, and R. G. Smith. 2012. Navigating a critical juncture for sustainable weed management. BioScience 62(1): 75-84.

Motta, E. V. S., K. Raymann, and N. A. Moran. 2018. Glyphosate perturbs the gut microbiota of honey bees. PNAS. 10.1073/pnas.1803880115.

Mullin, C. A., J. Chen, J. D. Fine, M. T. Frazier, and J. L. Frazier. 2015. The formulation makes the honey bee poison. Pesticide Biochemistry and Physiology 120: 27-35.

Murray, T. E., M. F. Coffey, E. Kehoe, and F. G. Horgan. 2013. Pathogen prevalence in commercially reared bumble bees and evidence of spillover in conspecific populations. Biological conservation 159:269–276.

National Research Council. 2007. Status of Pollinators in North America. The National Academies Press, Washington, DC.

NatureServe. 2017a. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. "*Bombus crotchii*". NatureServe, Arlington, Virginia. Available from: http://explorer.natureserve.org. [Accessed 13 February 2018].

NatureServe. 2017b. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. "*Bombus franklini*". NatureServe, Arlington, Virginia. Available from: http://explorer.natureserve.org. [Accessed 13 February 2018].

NatureServe. 2017c. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. "*Bombus occidentalis occidentalis*". NatureServe, Arlington, Virginia. Available from: http://explorer.natureserve.org. [Accessed 13 February 2018].

NatureServe. 2017d. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. "*Bombus occidentalis*". NatureServe, Arlington, Virginia. Available from: http://explorer.natureserve.org. [Accessed 13 February 2018].

NatureServe. 2017e. NatureServe Explorer: An online encyclopedia of life [web application].

Version 7.1. "*Bombus suckleyi*". NatureServe, Arlington, Virginia. Available from: http://explorer.natureserve.org. [Accessed 13 February 2018].

Niwa, S., H. Iwano, S. Asada, M. Matsuurra, and K. Goka. 2004. A microsporidian pathogen isolated from a colony of the European bumblebee, *Bombus terrestris*, and infectivity on Japanese bumblebee. Japanese Journal of Applied Entomology and Zoology 48:60-64 (in Japanese with English abstract).

Noss, R. F., E. T. LaRoe, and J. M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. US Department of the Interior, National Biological Service Washington, DC, USA. Available from: http://noss.cos.ucf.edu/papers/Noss%20et%20al%201995.pdf.

Öckinger, E. and H. G. Smith. 2007. Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. Journal of Applied Ecology 44: 50-59.

[ODA] Oregon Department of Agriculture. 2015. Oregon Administrative Rules (OAR 603-057-0388). Available from: http://arcweb.sos.state.or.us/pages/rules/oars_600/oar_603/603_tofc.html [Accessed 25 September 2018].

Ollerton J., R. Winfree, and S. Tarrant. 2011. How many flowering plants are pollinated by animals. Oikos 120:321-326. DOI: 10.1111/j.1600-0706.2010.18644.x

Osborne JL. 2012. Bumblebees and pesticides. Nature: News & Views. Nature 491: 43-45.

Osborne, J. L., A. P. Martin, C. R. Shortall, A. D. Todd, D. Goulson, M. E. Knight, R. J. Hale, and R. A. Sanderson. 2008. Quantifying and comparing bumble bee nest densities in gardens and countryside habitats. Journal of Applied Ecology 45:784-792.

Otterstatter, M. C., and J. D. Thomson. 2008. Does pathogen spillover from commercially reared bumble bees threaten wild pollinators? PloS one 3:e2771.

Otterstatter, M. C., and T. L. Whidden. 2004. Patterns of parasitism by tracheal mites (*Locustacarus buchneri*) in natural bumble bee populations. Apidologie 35:351–357. Available from: http://www.edpsciences.org/10.1051/apido:2004024. [Accessed 28 February 2018].

Otterstatter, M. C., R. J. Gegear, S. R. Colla, and J. D. Thomson. 2005. Effects of parasitic mites and protozoa on the flower constancy and foraging rate of bumble bees. Behavioral ecology and sociobiology 58:383–389. Available from: http://link.springer.com/article/10.1007/s00265-005-

0945-3 [Accessed 20 February 2018].

Otti, O., and P. Schmid-Hempel. 2007. *Nosema bombi*: A pollinator parasite with detrimental fitness effects. Journal of invertebrate pathology 96:118–124.

Otti, O. and P. Schmid-Hempel. 2008. A field experiment on the effect of *Nosema bombi* in colonies of the bumblebee *Bombus terrestris*. Ecological entomology 33:577–582.

Paini, D. R. and J. D. Roberts. 2005. Commercial honey bees (*Apis mellifera*) reduce the fecundity of an Australian native bee (*Hylaeus alcyoneus*). Biological conservation 123:103–112.

Panzer, R. 2002. Compatibility of prescribed burning with the conservation of insects in small, isolated prairie reserves. Conservation Biology 16:1296–1307.

Parry, M. L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. 2007. IPCC, 2007: climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.

Paton, D. C. 1990. Budgets for the use of floral resources in mallee heath. *In* The Mallee Lands: A Conservation Perspective, eds. J. C. Noble, P. J. Joss, G. K. Jones, Melbourne: CSIRO. 189–93 pp.

Paton, D. C. 1993. Honeybees in the Australian environment. Bioscience **43**:95–103.

Paton, D. C. 1996. Overview of feral and managed honeybees in Australia: distribution, abundance, extent of interactions with native biota, evidence of impacts and future research. Australian Nature Conservation Agency, Canberra, Australian Capital Territory. 77 pp.

Paxton, R. J. 2010. Does infection by *Nosema ceranae* cause "Colony Collapse Disorder" in honey bees (*Apis mellifera*)? Journal of Apicultural Research 49:80–84.

Pisa, L. W. et al. 2014. Effects of neonicotinoids and fipronil on non-target invertebrates. Environmental Science and Pollution Research International. Environmental Science and Pollution Research 22(1): 68-102.

Plath, O. E. 1922. Notes on the nesting habits of several North American bumblebees. Psyche 29(5-6):189-202.

Plath, O. E. 1927. Notes on the nesting habits of some of the less common New England bumblebees. Psyche 34: 122-128.

Pleasants, J. M. 1981. Bumblebee response to variation in nectar availability. Ecology:1648–1661.

Pleasants, J. M. and K. S. Oberhauser. 2013. Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population. Insect conservation and diversity / Royal Entomological Society of London 6:135–144.

Plischuk, S. et al. 2009. South American native bumblebees (Hymenoptera: Apidae) infected by *Nosema ceranae* (Microsporidia), an emerging pathogen of honeybees (*Apis mellifera*) Environmental Microbiology Reports 1(2): 131-135.

Plischuk, S., M. E. Pocco, and C. E. Lange. 2013. The tracheal mite *Locustacarus buchneri* in South American native bumble bees (Hymenoptera: Apidae). Parasitology International 62:505–507.

Plowright, R. C. and W. P. Stephen. 1980. The taxonomic status of *Bombus franklini* (Hymenoptera: Apidae). Canadian Entomologist 112: 475-479.

Radeloff, V. C. et al. 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. Proceedings of the National Academy of Sciences 201718850; DOI: 10.1073/pnas.1718850115.

Rasmont, P., A. Pauly, M. Terzo, S. Patiny, D. Michez, S. Iserbyl, Y. Barbier, and E. Haubruge. 2006. The survey of wild bees (Hymenoptera, Apoidea) in Belgium and France. p.18 *In* Status of the World's Pollinators. Food and Agriculture Organization of the United Nations, Rome.

Rasmont, P. and S. Iserbyt. 2012. The Bumblebees Scarcity Syndrome: Are heat waves leading to local extinctions of bumblebees (Hymenoptera: Apidae: Bombus)? Annales de la Société Entomologique de France. 48(3-4): 275–280. Available from: http://www.tandfonline.com/doi/abs/10.1080/00379271.2012.10697776. [Accessed 1 March 2018].

Richardson, L. 2014. Data Contributors. Available from http://www.leifrichardson.org/bbna.html [Accessed 23 September 2015].

Richardson, L. 2017. Unpublished database. Information on database and data contributors Available from: http://www.leifrichardson.org/bbna.html [Accessed 22 February 2017).

Rickman, T. 2017. U.S. Forest Service — Eagle Lake Ranger District *Bombus occidentalis* observations for 2013 and 2014. Unpublished Data.

Rogers, S. R., P. Cajamarca, D. R. Tarpy, and H. J. Burrack. 2013. Honey bees and bumble bees respond differently to inter-and intra-specific encounters. Apidologie 44:621–629.

Roland, J. and S. F. Matter. 2007. Encroaching forests decouple alpine butterfly population dynamics. Proceedings of the National Academy of Sciences 104:13702–13704.

Rundlöf, M. et al. 2015. Seed coating with a neonicotinoid insecticide negatively affects wild bees. Nature 521:77–80.

Roubik, D. W. 2009. Ecological impact on native bees by the invasive Africanized honey bee. Acta Biológica Colombiana 14:115–124.

Rusterholz, H. P. and Baur, B. 2010. Delayed response in a plant–pollinator system to experimental grassland fragmentation. Oecologia 163: 141-152.

Rutrecht, S. T. and M. J. F. Brown. 2008. The life-history impact and implications of multiple parasites for bumble bee queens. International journal for parasitology 38:799–808.

Rutrecht, S. T. and M. J. F. Brown. 2009. Differential virulence in a multiple-host parasite of bumble bees: resolving the paradox of parasite survival? Oikos 118:941–949.

Sánchez-Bayo, F., D. Goulson, F. Pennacchio, F. Nazzi, K. Goka, and N. Desneux. 2016. Are bee diseases linked to pesticides?—A brief review. Environment International 89: 7-11.

Sachman-Ruiz, B., V. Narváez-Padilla, and E. Reynaud. 2015. Commercial *Bombus impatiens* as reservoirs of emerging infectious diseases in central México. Biological invasions:1–11. Springer International Publishing. Available from http://link.springer.com/article/10.1007/s10530-015-0859-6 [Accessed 1 March 2018].

Saunders, S., C. Montgomery, and T. Easley. 2008. Hotter and drier: the West's changed climate. Prepared for The Rocky Mountain Climate Organization and Natural Resources Defense Council. Page 64. Available from: http://www.nrdc.org/globalWarming/west/west.pdf [Accessed 20 February 2018].

Schmid-Hempel, P. 2001. On the evolutionary ecology of host–parasite interactions: addressing the question with regard to bumblebees and their parasites. Die Naturwissenschaften 88:147–158.

Schmid-Hempel, P. and R. Loosli. 1998. A contribution to the knowledge of *Nosema* infections in bumble bees, *Bombus* spp. Apidologie 29:525–535. Available from: http://hal.archives-ouvertes.fr/docs/00/89/15/54/PDF/hal-00891554.pdf [Accessed 1 March 2018].

Schmid-Hempel, R. and Tognazzo, M. 2010. Molecular divergence defines two distinct lineages of *Crithidia bombi* (Trypanosomatidae), parasites of bumblebees. Journal of Eukaryotic Microbiology 57(4): 337-345.

Schmid-Hempel, R., M. Eckhardt, D. Goulson, D. Heinzmann, C. Lange, S. Plischuk, L. R. Escudero, R. Salathé, J. J. Scriven, and P. Schmid-Hempel. 2014. The Invasion of Southern South America by Imported Bumblebees and Associated Parasites. The Journal of Animal Ecology 83 (4): 823–37.

Schmidt, N. M., H. Olsen, and H. Leirs. 2009. Livestock grazing intensity affects abundance of Common shrews (*Sorex araneus*) in two meadows in Denmark. BMC Ecology 9:2doi:10.1186/1472-6785-9-2. Available from: http://www.biomedcentral.com/1472-6785/9/2 [Accessed 20 February 2018].

Scholl, A., R. W. Thorp, and E. Obrecht. 1992. The genetic relationship between *Bombus franklini* (Frison) and other taxa of the subgenus *Bombus* s. str. (Hymenoptera: Apidae). Pan-Pacific Entomologist 68: 46-51.

Schultz, C. B. and E. E. Crone. 1998. Burning prairie to restore butterfly habitat: a modeling approach to management tradeoffs for the Fender's blue. Restoration Ecology 6: 244-252.

Schwarz, R. S. N. A. Moran, and J. D. Evans. 2016. Early gut colonizers shape parasite susceptibility and microbiota composition in honey bee workers. Proceedings of the National Academy of Sciences 113(33): 9345-9350.

Scohier, A., A. Ouin, A. Farruggia, and B. Dumont. 2012. Is there a benefit of excluding sheep from pastures at flowering peak on flower-visiting insect diversity? Journal of Insect Conservation 17(2): 287-294.

Scott-Dupree, C. D., L. Conroy, and C. R. Harris. 2009. Impact of currently used or potentially

useful insecticides for canola agroecosystems on *Bombus impatiens* (Hymenoptera: Apidae), *Megachile rotundata* (Hymenoptera: Megachilidae), and *Osmia lignaria* (Hymenoptera: Megachilidae). Journal of Economic Entomology 102:177-182.

Scullen, H. A. 1927. Bees belonging to the family Bremidae taken in western Oregon, with notes. Pan-Pacific Entomologist Pan-Pacific Entomologist4(2): 69-76, 121-128.

Scursoni, J., F. Forcella, J. Gunsolus, M. Owen, R. Oliver, R. Smeda, and R. Vidrine. 2006. Weed diversity and soybean yield with glyphosate management along a north-south transect in the United States. Weed Science 54:713–719.

Shavit, O., A. Dafni, and G. Ne'eman. 2009. Competition between honeybees (*Apis mellifera*) and native solitary bees in the Mediterranean region of Israel—Implications for conservation. Israel Journal of Plant Sciences 57:171–183.

Sheffield, C. S., L. Richardson, S. Cannings, H. Ngo, J. Heron, P. H. Williams. 2016. Biogeography and designatable units of *Bombus occidentalis* Greene and *B. terricola* Kirby (Hymenoptera: Apidae) with implications for conservation status assessments. Journal of Insect Conservation: 1–11.

Shepherd, M., S. L. Buchmann, M. Vaughan, and S. H. Black. 2003. Pollinator Conservation Handbook. The Xerces Society, Portland, Oregon.

Shykoff, J. A., and P. Schmid-Hempel. 1991. Parasites delay worker reproduction in bumblebees: consequences for eusociality. Behavioral ecology: official journal of the International Society for Behavioral Ecology 2:242–248.

Singh, R., A. L. Levitt, E. G. Rajotte, E. C. Holmes, N. Ostiguy, W. I. Lipkin, A. L. Toth, D. L. Cox-Foster, and Others. 2010. RNA viruses in hymenopteran pollinators: evidence of inter-taxa virus transmission via pollen and potential impact on non-Apis hymenopteran species. PloS one 5:e14357.

Sjodin, N. E. 2007. Pollinator behavioural responses to grazing intensity. Biodiversity Conservation 16:2103-2121.

Skinner, C. N. 1995. Change in spatial characteristics of forest openings in the Klamath Mountains of northwestern California, USA. Landscape ecology 10:219–228. Available from: http://www.springerlink.com/index/T4U3205640483310.pdf [Accessed 20 February 2018].

Sladen, F. L. W. 1912. The Humblebee: Its life history and how to domesticate it. Macmillan and Co., London 283p.

Sleeter, B. M. 2016. Central Valley Report. U.S. Geological Survey, Western Geographic Science Center, Menlo Park, CA. Available from: https://landcovertrends.usgs.gov/west/eco7Report.html. [Accessed 20 March 2018].

Smallidge, P. J. and D. J. Leopold. 1997. Vegetation management for the maintenance and conservation of butterfly habitats in temperate human-dominated habitats. Landscape and Urban Planning 38:259-280.

Sprayberry, J. D., K.A. Ritter, and J.A. Riffell. 2013. The Effect of olfactory exposure to non-insecticidal agrochemicals on bumblebee foraging behavior. PloS one 8(10): e76273.

Stanley, D. A., M. P. Garratt, J. B. Wickens, V. J. Wickens, S. G. Potts, and N. E. Raine. 2015a. Neonicotinoid pesticide exposure impairs crop pollination services provided by bumblebees. Nature 528(7583): 548-550.

Stanley, D. A., A. L. Russell, S. J. Morrison, C. Rogers, and N. E. Raine. 2016. Investigating the impacts of field-realistic exposure to a neonicotinoid pesticide on bumblebee foraging, homing ability and colony growth. Journal of Applied Ecology 53(5): 1440-1449.

Stanley, D. A., K. E. Smith and N.E. Raine. 2015b. Bumblebee learning and memory is impaired by chronic exposure to a neonicotinoid pesticide. Scientific Reports 5(16508): 1-10.

State of Massachusetts. 2018. General Laws: CHAPTER 128, Section 35. Available from https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIX/Chapter128/Section35. [Accessed 25 September 2018].

State of Minnesota. 2017. 17.445 INSPECTIONS AND SERVICES; FEES. Available from https://www.revisor.mn.gov/statutes/cite/17.445 [Accessed 25 September 2018].

Steffan-Dewenter, I. and T. Tscharntke. 2000. Resource overlap and possible competition between honey bees and wild bees in central Europe. Oecologia 122:288–296.

Stephen, W. P. 1957. Bumble bees of western America (Hymenoptera: Apoidea). Oregon State College Agr. Exp. Sta.: Tech. Bull. No. 40. 163pp.

Stoner, K. J. L., and A. Joern. 2004. Landscape vs. local habitat scale influences to insect

communities from tallgrass prairie remnants. Ecological applications: a publication of the Ecological Society of America 14:1306–1320.

Stoner, K. A. 2016. Current pesticide risk assessment protocols do not adequately address differences between honey bees (*Apis mellifera*) and bumble bees (*Bombus* spp.). Frontiers in Environmental Science 4: 79.

Sugden, E. 1985. Pollinators of *Astragalus monoensis* Barneby (Fabaceae) - New host records - Potential impact of sheep grazing. Great Basin Naturalist 45: 299-312.

Suhonen, J., J. Rannikko, and J. Sorvari. 2015. The Rarity of Host Species Affects the Co-Extinction Risk in Socially Parasitic Bumblebee *Bombus* (*Psithyrus*) Species. Annales zoologici Fennici 52:236–242.

Tasei, J. N., J. Lerin, and G. Ripault. 2000. Sub-lethal effects of imidacloprid on bumblebees, *Bombus terrestris* (Hymenoptera: Apidae), during a laboratory feeding test. Pest Management Science 56:784-788.

Tepedino, V. J., D. G. Alston, B. A. Bradley, T. R. Toler, and T. L. Griswold. 2007. Orchard pollination in Capitol Reef National Park, Utah, USA. Honey bees or native bees? Biodiversity and conservation 16: 3083–3094.

Thompson, H. M. and L. V. Hunt. 1999. Extrapolating from honeybees to bumblebees in pesticide risk assessment. Ecotoxicology 8(3): 147-166.

Thomson, D. 2004. Competitive Interactions between the Invasive European Honey Bee and Native Bumble Bees. Ecology 85:pp. 458–470.

Thomson, D. M. 2006. Detecting the effects of introduced species: a case study of competition between *Apis* and *Bombus*. Oikos 114:407–418.

Thomson, J. D. 2010. Flowering phenology, fruiting success and progressive deterioration of pollination in an early-flowering geophyte. Philosophical Transactions of the Royal Society B: Biological Sciences 365:3187–3199.

Thorp, R. W. 1970. The type locality of *Bombus franklini* and notes on putative Arizona records of other Bombini (Hymenoptera: Apidae). Pan-Pacific Entomologist 46: 177-180.

Thorp, R. W. 1996. Resource overlap among native and introduced bees in California. Pages

143–152. Linnean Society Symposium Series.

Thorp, R. W. 1999. Franklin's bumble bee, *Bombus franklini* (Frison 1921): a species of special concern. Unpublished Report to USDA Forest Service, Ashland. OR on 1998 season (submitted 23 Nov 99).

Thorp, R. W. 2001. Franklin's bumble bee, *Bombus franklini* (Frison 1921): a species of special concern. Unpublished Report to US Fish and Wildlife Service, Portland, OR on 1999-2000 seasons (submitted 14 May 2001).

Thorp, R. W. 2004. Franklin's bumble bee, *Bombus* (*Bombus*) *franklini* (Frison). Unpublished Report to US Fish and Wildlife Service, Portland, OR on 2001-2003 seasons (submitted 29 June 2004).

Thorp, R. W. 2005a. Franklin's bumble bee, *Bombus* (*Bombus*) *franklini* (Frison). Unpublished Report to US Fish and Wildlife Service, Portland, OR on 2004 season (submitted 29 March 2005).

Thorp, R. W. 2005b. Franklin's bumble bee, *Bombus* (*Bombus*) *franklini* (Frison). Unpublished Report to US Fish and Wildlife Service, Portland, OR on 2005 season (submitted 7 November 2005).

Thorp, R. W. 2005c. Species Profile: *Bombus franklini*. *In* Shepherd, M. D., D. M. Vaughan, and S. H. Black (Eds). Red List of Pollinator Insects of North America. CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation. Available from: http://www.xerces.org/wp-content/uploads/2011/02/bombus_franklini.pdf [Accessed 20 February 2018].

Thorp, R. W. 2008. Franklin's Bumble Bee, *Bombus* (*Bombus*) *franklini* (Frison) (Hymenoptera: Apidae), Report on 2006-2007 Seasons (Submitted 10 March 2008).

Thorp, R. W., D. S. Horning, Jr., and L. L. Dunning. 1983. Bumble bees and cuckoo bumble bees of California. Bulletin of the California Insect Survey 23: 1-79.

Thorp, R. W., S. Jepsen, S. F. Jordan, E. Evans, and S. H. Black. 2010. Petition to list Franklin's bumble bee as an Endangered Species under the U.S. Endangered Species Act, Submitted by The Xerces Society for Invertebrate Conservation. Available from: http://www.xerces.org/wp-content/uploads/2010/06/bombus-franklini-petition.pdf. [Accessed 20 March 2018].

Thorp, R. W., A. M. Wenner, and J. F. Barthell. 2000. Pollen and nectar resource overlap among bees on Santa Cruz Island. Pages 261–267 *In*: Proceedings of the Fifth California Islands Symposium (Browne et al., eds).

[USDA] U.S. Department of Agriculture. 2014. Pest Risk Assessment for Bumble Bees from Canada. February, 2014. Version 1.1. 36 pp.

[USDA] U.S. Department of Agriculture. Animal and Plant Health Inspection Service. U.S. Regulated Plant Pest Table. 2018. Available from https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/rppl/rppl-table. [Accessed 25 September 2018].

[U.S. EPA] United States Environmental Protection Agency. 2000. *Effect of 3,6-Dichloro-2methyoxybenzoic acid on Apis mellifera Mortality*; U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, Office of Pesticide Programs, Environmental Fate and Effects Division, U.S. Government Printing Office: Washington, DC.

[U.S. EPA] United States Environmental Protection Agency. 2012, May 10. OCSPP 850.3020: Honey Bee Acute Contact Toxicity Test [EPA 712-C-019]. Available from http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0154-0016. [Accessed 25 September 2018].

[U.S. EPA] United States Environmental Protection Agency. 2013. Available from: http://www2.epa.gov/sites/production/files/2013-11/documents/bee-label-info-ltr.pdf. [Accessed 25 September 2018].

[U.S. EPA] United States Environmental Protection Agency. 2014, June 19. Guidance for Assessing Pesticide Risks to Bees. Available from http://www2.epa.gov/sites/production/files/2014-06/documents/pollinator_risk_assessment_guidance_06_19_14.pdf. [Accessed 25 September 2018].

[USFS] U.S. Department of Agriculture Forest Service. 2013. Region 5 Forester's 2013 Sensitive Animal Species List. Available from: https://www.fs.usda.gov/main/r5/plants-animals/wildlife. [Accessed 13 February 2018].

[USFWS] U.S. Fish and Wildlife Service. 2011. Endangered and Threatened Wildlife and Plants; 90-Day Findings on a Petition to List the Franklin's Bumble Bee as Endangered. 76 FR 56381-56391. September 13, 2011.

[USFWS] U.S. Fish and Wildlife Service. 2016. Endangered and Threatened Wildlife and Plants;

90-Day Findings on 29 Petitions. 81 FR 14058 14072. March 16, 2016.

[USGS] United States Geological Survey. 2014. An Overview Comparing Results from Two Decades of Monitoring for Pesticides in the Nation's Streams and Rivers, 1992–2001 and 2002–2011. National Water-Quality Assessment (NAWQA) Project. Available from: https://pubs.usgs.gov/sir/2014/5154/pdf/sir2014-5154.pdf. [Accessed 4 October 2018].

[USGS] United States Geological Survey. 2017a. Estimated Annual Agricultural Pesticide Use. Pesticide Use Maps: 2,4-D. National Water-Quality Assessment (NAWQA) Project. Available from:
http://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2015&map=24D&hilo=L&disp=2,4-D [Accessed 9 March 2018].

[USGS] United States Geological Survey. 2017b. Estimated Annual Agricultural Pesticide Use. Pesticide Use Maps: dicamba. National Water-Quality Assessment (NAWQA) Project. Available from: https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2015&map=DICAMBA&hilo=L&disp=Dicamba [Accessed 9 March 2018].

[USGS] United States Geological Survey. 2017c. Estimated Annual Agricultural Pesticide Use. Pesticide Use Maps. National Water-Quality Assessment (NAWQA) Project. Available from: https://water.usgs.gov/nawqa/pnsp/usage/maps/compound_listing.php. [Accessed 9 March 2018].

Vandame, R., and L. P. Belzunces. 1998. Joint actions of deltamethrin and azole fungicides on honey bee thermoregulation. Neuroscience letters 251:57–60.

Van der Steen, J. J. M. 2008. Infection and transmission of *Nosema bombi* in *Bombus terrestris* colonies and its effect on hibernation, mating and colony founding. Apidologie 39:273–282.

van Wilgenburg, E., G. Driessen, and L. W. Beukeboom. 2006. Single locus complementary sex determination in Hymenoptera: an "unintelligent" design? Frontiers in Zoology 3(1): 1-15. Available from: http://www.frontiersinzoology.com/content/3/1/1. [Accessed 20 March 2018].

Vaughan, M., B. E. Vaissi`ere, G. Maynard, M. Kasina, R. C. F. Nocelli, C. Scott-Dupree, E. Johansen, C. Brittain, M. Coulson, and A. Dinter. 2014. Overview of Non-Apis Bees. D. Fischer and T. Moriarty, editors. Pesticide Risk Assessment for Pollinators. pp. 5-18.

Vazquez, D. P. and D. Simberloff. 2003. Changes in interaction biodiversity induced by an introduced ungulate. Ecology Letters 6: 1077-1083.

Velthius, H. H. W. and A. Van Doorn. 2006. A century in advances in bumblebee domestication and the economic and environmental aspects of its commercialization for pollination. Apidologie 37:421-451.

Walther-Hellwig, K., G. Fokul, R. Frankl, R. Büchler, K. Ekschmitt, and V. Wolters. 2006. Increased density of honeybee colonies affects foraging bumblebees. Apidologie 37:517–532.

Wenner, A. M. and R. W. Thorp. 1994. Removal of feral honey bee (*Apis mellifera*) colonies from Santa Cruz Island. Pages 513–522. The fourth California islands symposium: update on the status of resources.

Westphal, C., I. Steffan-Dewenter, and T. Tscharntke. 2003. Mass flowering crops enhance pollinator densities at a landscape scale. Ecology Letters 6(11): 961-965.

Westphal, C., I. Steffan-Dewenter, and T. Tscharntke. 2009. Mass flowering oilseed rape improves early colony growth but not sexual reproduction of bumblebees. Journal of Applied Ecology 46: 187-193.

Whitehorn, P. R., S. O'Connor, F. L. Wackers, and D. Goulson. 2012. Neonicotinoid pesticide reduces bumble bee colony growth and queen production. Science 10.1126/science.1215025.

Whitehorn, P. R., M. C. Tinsley, M. J. F. Brown, B. Darvill, and D. Goulson. 2009. Impacts of inbreeding on bumblebee colony fitness under field conditions. BMC Evolutionary Biology 9:152.

Whitehorn, P. R., M. C. Tinsley, M. J. F. Brown, B. Darvill, and D. Goulson. 2011. Genetic diversity, parasite prevalence and immunity in wild bumblebees. Proceedings of the Royal Society B 278:1195–1202. Available from: http://dx.doi.org/10.1098/rspb.2010.1550. [Accessed 1 March 2018].

Whitehorn, P. R., M. C. Tinsley, M. J. F. Brown, B. Darvill, and D. Goulson. 2014. Genetic diversity and parasite prevalence in two species of bumblebee. Journal of Insect Conservation 18:667–673.

Whittington, R. and Winston, M. L. 2003. Effects of *Nosema bombi* and its treatment fumagillin on bumble bee (*Bombus occidentalis*) colonies. Journal of Invertebrate Pathology 84(1): 54-58.

Whittington, R., M. L. Winston, C. Tucker, and A. L. Parachnowitsch. 2004. Plant-species

identity of pollen collected by bumblebees placed in greenhouses for tomato pollination. Canadian journal of plant science. Revue Canadienne de Phytotechnie 84:599–602.

Wieczorek, J., Q. Guo, and R. Hijmans. 2004. The point-radius method for georeferencing locality descriptions and calculating associated uncertainty. International journal of geographical information science 18:745–767.

Williams, P. H. 1986. Environmental change and the distributions of British bumble bees (*Bombus* Latr.). Bee World 67:50–61.

Williams, P. H. 1991. The bumble bees of the Kashmir Himalaya (Hymenoptera: Apidae, Bombini). Bulletin of the British Museum of Natural History (Entomology) 60: 1-204.

Williams, P. H. 1998. An annotated checklist of bumble bees with an analysis of patterns of description (Hymenoptera: Apidae, Bombini). Bulletin of the Natural History Museum, London (Ent.) 67:79-152. Updated at: www.nhm.ac.uk/research-curation/projects/bombus/. [Accessed 28 February 2018].

Williams, P. H., M. B. Araújo, and P. Rasmont. 2007. Can vulnerability among British bumblebee (*Bombus*) species be explained by niche position and breadth? Biological Conservation **138**:493–505.

Williams P. H., M. J. F. Brown, J. C. Carolan, J. An, D. Goulson, A. Murat Ayetkin, L. R. Best, A. M. Byvaltsev, B. Cederberg, R. Dawson, J. Huang, M. Ito, A. Monfared, R. H. Raina, P. Schmid-Hempel, C. S. Sheffield, P. Sima, and Z. Xie. 2012. Unveiling cryptic species of the bumblebee subgenus *Bombus* s. str. Worldwide with COI barcodes (Hymenoptera: Apidae). Systematics and Biodiversity. Available from: http://dx.doi.org/10.1080/14772000.2012.664574 [Accessed 20 February 2018].

Williams, P. H., S. A. Cameron, H. M. Hines, B. Cederberg, and P. Rasmont. 2008a. A simplified subgeneric classification of the bumblebees (genus *Bombus*). Apidologie 39:46–74.

Williams, P. S. Colla, and Z. Xie. 2009. Bumblebee vulnerability: Common correlates of winners and losers across three continents. Conservation Biology: The Journal of the Society for Conservation Biology 23:931–940.

Williams, P. H. and J. L. Osborne. 2009. Bumblebee vulnerability and conservation world-wide. Apidologie 40:367–387.

Williams, G. R., A. B. A. Shafer, R. E. L. Rogers, D. Shutler, and D. T. Stewart. 2008b. First detection of *Nosema ceranae*, a microsporidian parasite of European honey bees (*Apis mellifera*), in Canada and central USA. Journal of invertebrate pathology 97:189–192.

Williams, P. H., R. W. Thorp, L. L. Richardson, and S .R. Colla. 2014. The Bumble bees of North America: An Identification guide. Princeton University Press, Princeton.

Wills, R. T., Lyons, M. N., and Bell, D. T. 1990. The European honey bee in Western Australian Kwongan: foraging preferences and some implications for management. Proceedings of the Ecological Society of Australia 16:167–76.

Winfree, R., N. M. Williams, H. Gaines, J. S. Ascher, C. and Kremen, C. 2008. Wild bee pollinators provide the majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA. Journal of Applied Ecology 45(3): 793-802.

Wisk, J. D. et al. 2014. Assessing Exposure of Pesticides to Bees. *In* Pesticide Risk Assessment for Pollinators. Eds: D. Fischer and T. Moriarty, John Wiley & Sons, Inc., Hoboken, NJ, USA. 45-74 pp.

Wratt, E. C. 1968. The pollinating activities of bumble bees and honey bees in relation to temperature, competing forage plants, and competition from other foragers. Journal of Apicultural Research 7:61–6.

Xerces Society, Natural Resources Defense Council, Defenders of Wildlife, and Dr. Robbin Thorp. 2010. Petition to the USDA-APHIS seeking regulation of bumble bee movement. 26 pp. Available from: http://www.xerces.org/petition/xerces-bumblebee-petition-to-aphis.pdf. [Accessed 25 September 2018].

Xerces Society, Natural Resources Defense Council, Defenders of Wildlife, and Dr. Robbin Thorp. 2013, October 29. Letter to Secretary Vilsack regarding January 2010 petition to regulate the movement of commercial bumble bees. 4 pp.

Xerces Society, Natural Resources Defense Council, Defenders of Wildlife, and Dr. Robbin Thorp. 2014a, January 16. Letter to Secretary Vilsack regarding January 2010 petition to regulate the movement of commercial bumble bees. 2 pp.

Xerces Society, Natural Resources Defense Council, Defenders of Wildlife, and Dr. Robbin Thorp. 2014b, August 26. Letter to Osama El-Lissy regarding meeting to regulate commercial bumble bees. 16 pp.

Xerces Society. 2012. Database of records from Bumble Bee Citizen Monitoring Project (2008-2012). Maintained by Rich Hatfield, Xerces Society.

Xerces Society, Wildlife Preservation Canada, York University, The Montreal Insectarium, The London Natural History Museum, BeeSpotter. 2017. Data accessed from Bumble Bee Watch, a collaborative website to track and conserve North America's bumble bees. Available from: http://www.bumblebeewatch.org/app/#/bees/lists [Accessed 22 February 2017].

Xie, Z., P. Williams, and Y. Tang. 2008. The effect of grazing on bumblebees in the high rangelands of the eastern Tibetan Plateau of Sichuan. Journal of Insect Conservation 12(6): 695-703.

Yoneda, M., H. Furuta, Y. Kanbe, K. Tsuchida, K. Okabe, and K. Goka. 2008. Reproduction and transmission within a colony of bumblebee tracheal mite *Locustacarus buchneri* (Acari: Podapolipidae) in *Bombus terrestris* (Hymenoptera: Apidae). Applied Entomology and Zoology 43:391–395. Available from: http://jlc.jst.go.jp/JST.JSTAGE/aez/2008.391?from=Google. [Accessed 1 March 2018].

Zald, H. S. J., T. A. Spies, M. Huso, and D. Gatziolis. 2012. Climatic, landform, microtopographic, and overstory canopy controls of tree invasion in a subalpine meadow landscape, Oregon Cascades, USA. Landscape ecology (27): 1197-1212. Available from: http://bit.ly/2okar3v [Accessed 20 February 2018].

Zayed, A. 2009. Bee genetics and conservation. Apidologie 40:237–262.

Zayed, A. and L. Packer. 2005. Complementary sex determination substantially increases extinction proneness of haplodiploid populations. Proceedings of the National Academy of Sciences of the United States of America 102:10742–10746.

Zhu, W., D. R. Schmehl, C. A. Mullin, and J. L. Frazier. 2014. Four common pesticides, their mixtures and a formulation solvent in the hive environment have high oral toxicity to honey bee larvae. PloS one 9:e77547. Available from http://dx.doi.org/10.1371/journal.pone.0077547. [Accessed 25 September 2018].

Personal Communications
Rickman, T. 2017. District Wildlife Biologist at US Forest Service, Mt. Lassen National Forest. Personal Communication with Rich Hatfield, Xerces Society. 20 August 2017.

Thorp, R. W. 2013. Professor emeritus, University of California, Davis. Personal communication

with Sarina Jepsen, Xerces Society.

Thorp, R. W. 2014. Professor emeritus, University of California, Davis. Personal communication with Sarah Foltz Jordon, Xerces Society.
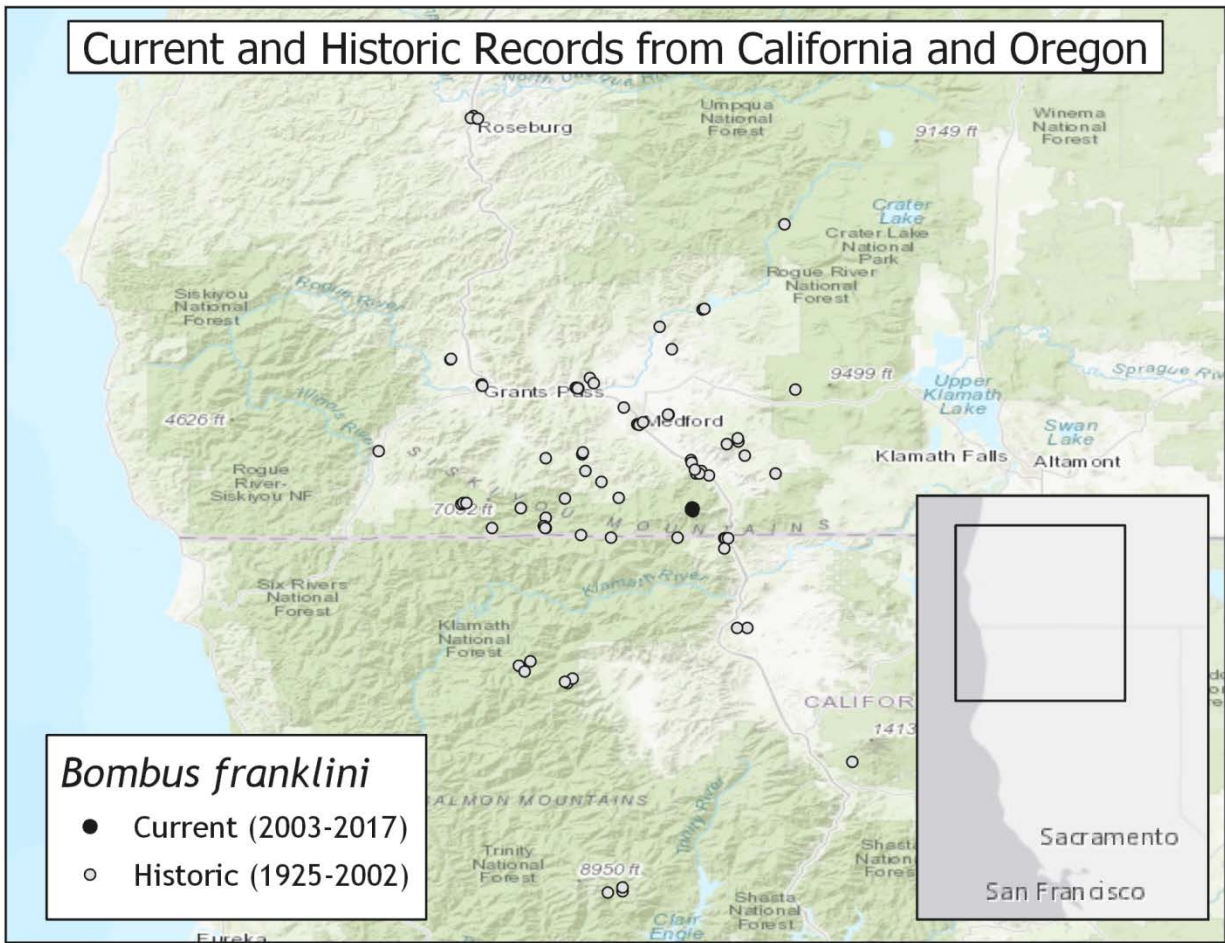
Thorp, R. W. 2017. Professor emeritus, University of California, Davis. Personal communication with Rich Hatfield, Xerces Society. 13 March 2017.

XI. DETAILED DISTRIBUTION MAPS

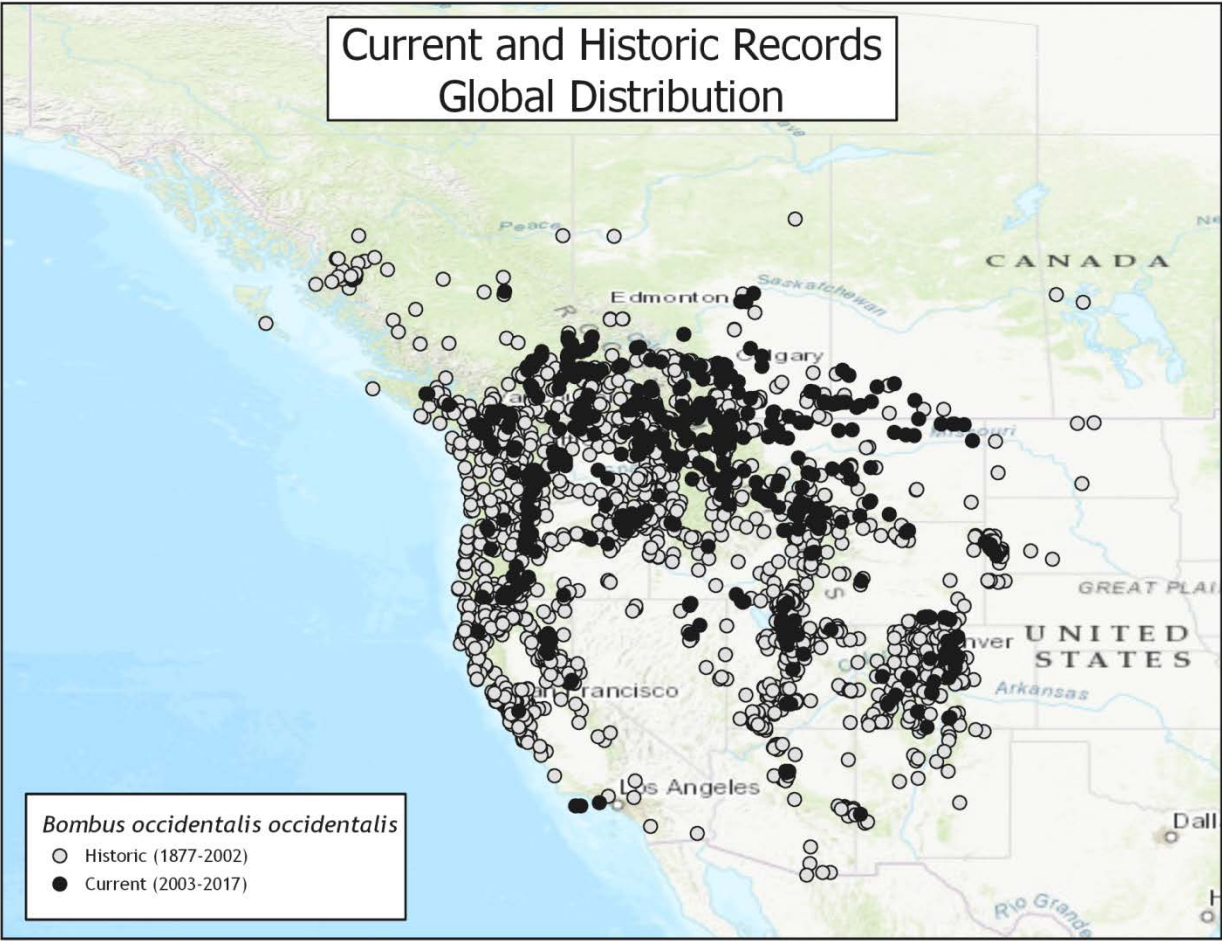**Crotch bumble bee (*Bombus crotchii*) Global Distribution**
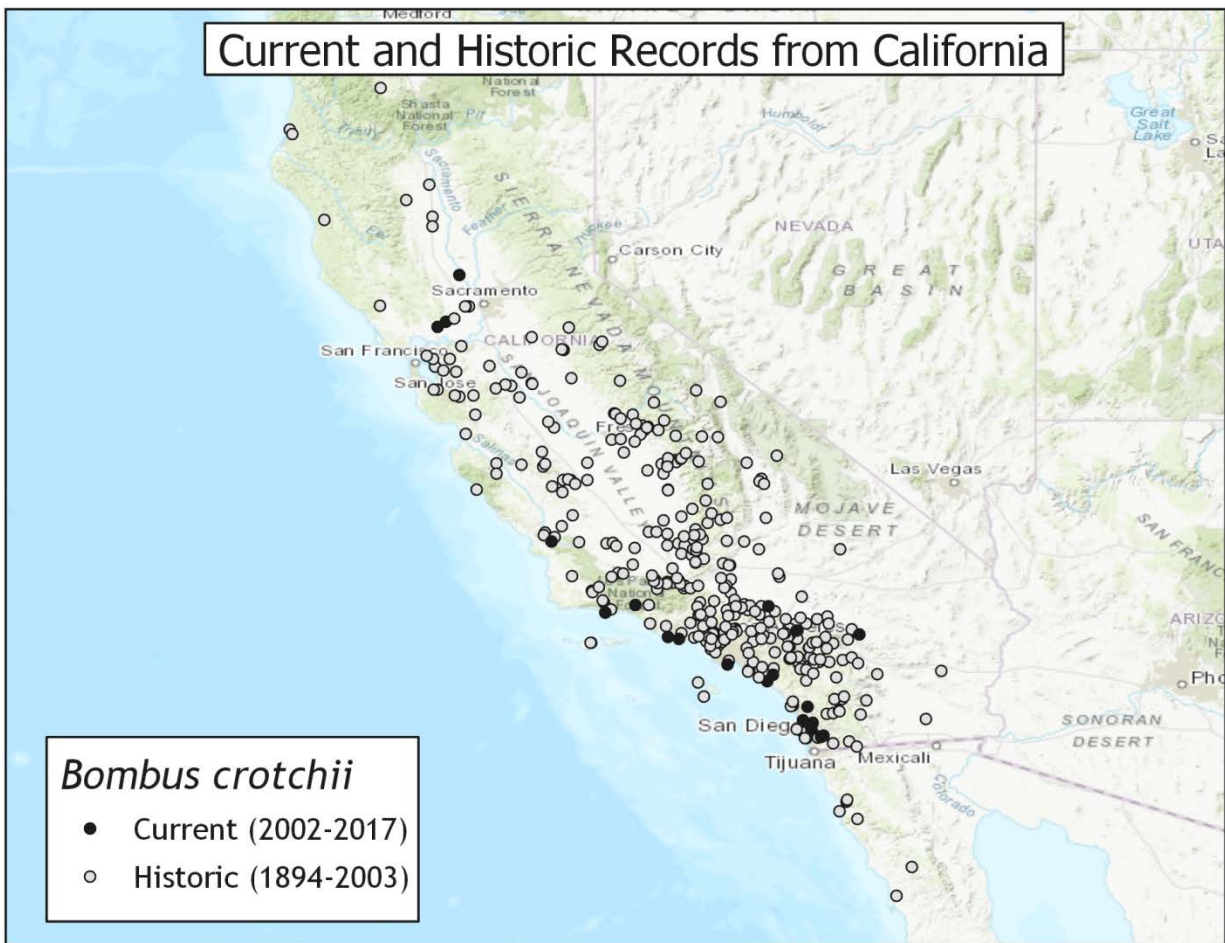
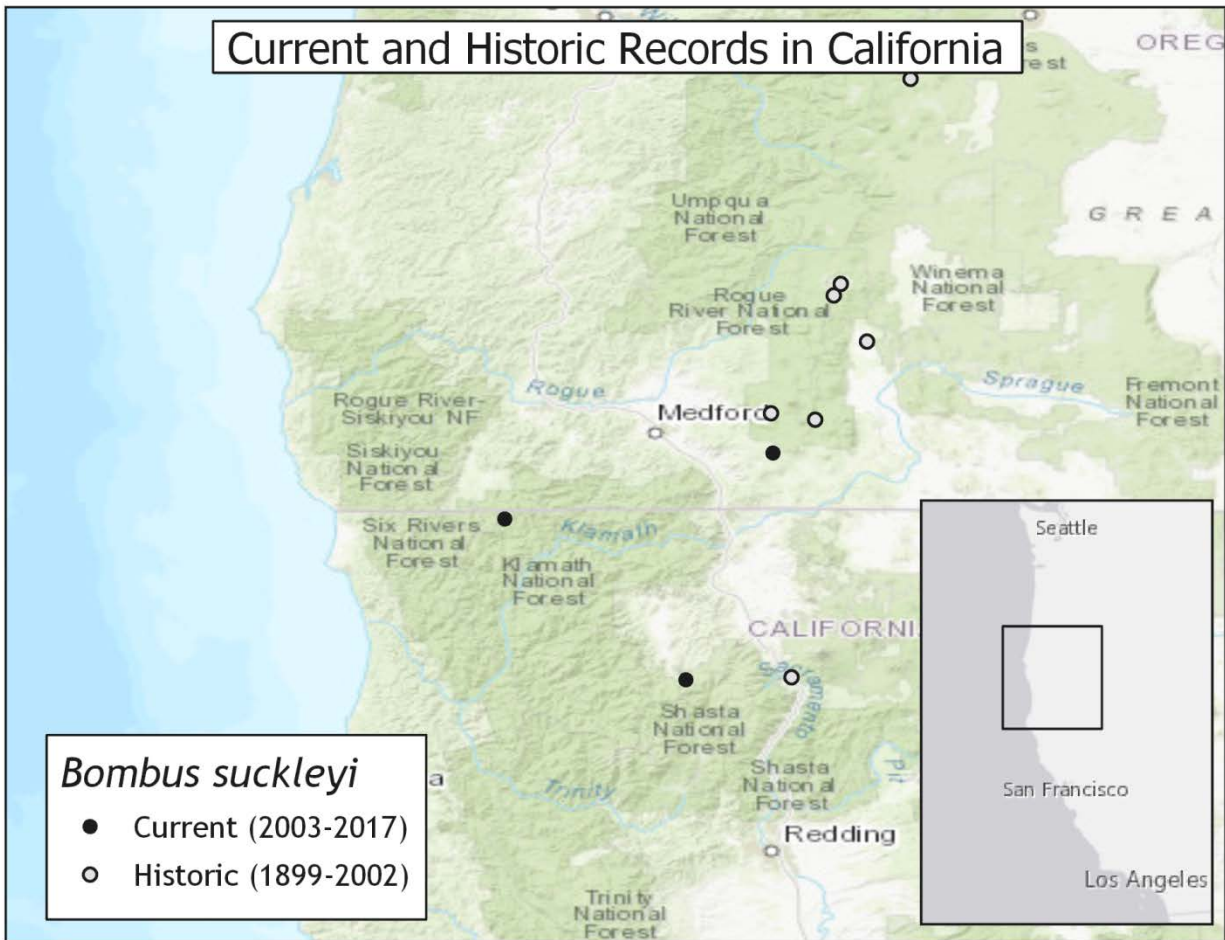**Franklin's bumble bee (*Bombus franklini*) Global Distribution**

Western bumble bee (*Bombus occidentalis occidentalis*) California Distribution

Western bumble bee (*Bombus occidentalis occidentalis*) Global Distribution

Current and Historic Records
Global Distribution

Bombus occidentalis occidentalis
○ Historic (1877-2002)
● Current (2003-2017)

Suckley Cuckoo Bumble Bee (*Bombus suckleyi*) California Distribution

Current and Historic Records in California

Bombus suckleyi
- ● Current (2003-2017)
- ○ Historic (1899-2002)

Suckley Cuckoo Bumble Bee (*Bombus suckleyi*) Global Distribution

Current and Historic Records
Global Distribution

Bombus suckleyi
- ● Current (2003-2017)
- ○ Historic (1899-2002)