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Research article

Evidence for *Bombus occidentalis* (Hymenoptera: Apidae) Populations in the Olympic Peninsula, the Palouse Prairie, and Forests of Northern Idaho

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Abstract

Since the mid-1990s, *Bombus occidentalis* (Green) has declined from being one of the most common to one of the rarest bumble bee species in the Pacific Northwest of the United States. Although its conservation status is unresolved, a petition to list this species as endangered or threatened was recently submitted to the U.S. Fish and Wildlife Service. To shed light on the conservation situation and inform the U.S. Fish and Wildlife Service decision, we report on the detection and abundance of *B. occidentalis* following bumble bee collection between 2012 and 2014 across the Pacific Northwest. Collection occurred from the San Juan Islands and Olympic peninsula east to northern Idaho and northeastern Oregon, excluding the arid region in central Washington. *B. occidentalis* was observed at 23 collection sites out of a total of 234. With the exception of three sites on the Olympic peninsula, all of these were in the southeastern portion of the collection range.

Key words: *Bombus occidentalis*, native bee conservation, native bee, *Bombus* conservation, pollinator

Bee species decline is an issue of global concern due to the vital ecosystem service and function provided by pollinators (Biesmeijer et al. 2006, Potts et al. 2010, Lebuhn et al. 2013, Kleijn et al. 2015). Bumble bees (Hymenoptera: Apidae, *Bombus*) are a conspicuous and charismatic group, and declines in abundance and range contraction have been observed in Europe and North America (Williams 1982, Rasmont et al. 2005, Colla and Packer 2008, Grixti et al. 2009, Cameron et al. 2011).While comprehensive analyses of bee species abundance and conservation status at continental scales continue to accumulate (Cameron et al. 2011, Kleijn et al. 2015), intensive local and regional assessments are sorely lacking (Tripodi and Szalanski 2015). Systematic surveys of bumble bees at local scales have the capacity to discover rare and declining bumble bee species (Colla and Packer 2008, Tripodi and Szalanski 2015) and therefore greatly contribute to a thorough assessment of conservation status.

In North America, *Bombus occidentalis* Green, along with several other *Bombus* species, has undergone recent dramatic range contraction and reduction in relative abundance possibly due to disease (Committee on the Status of Pollinators in North America, National Research Council 2007, Rao and Stephen 2007, Cameron et al. 2011, Colla et al. 2012, Koch and Strange 2012). *B. occidentalis* was once a very common bee in North America, evidenced by the abundance of pinned specimens associated with natural history collections throughout the United States (Cameron et al. 2011). Although there are no explicit baseline records of historic relative abundance (i.e., community-level study, e.g., Colla and Packer 2008), Stephen (1957, p.71) described the species as "... abundant throughout the Pacific Northwest and Northern California becoming less numerous in the southern Rocky Mountain area." Now the species is rare across its historic range having substantially declined in relative abundance and in geographic range by 28% (Cameron et al. 2011). The historic range of *B. occidentalis* extended from Arizona to Alaska and from the western parts of the Great Plains to the Pacific (Stephen 1957), but it is currently rare west of the Sierra-Cascade Crest (Rao and Stephen 2007, Cameron et al. 2011). The species is listed as "Vulnerable" by the International Union for Conservation of Nature (IUCN) (IUCN 2015) and has an active petition for federal listing under the endangered species act. Decline of *B. occidentalis* may be caused by spread of *Nosema bombi* into wild populations from commercially reared colonies used for greenhouse pollination (Colla et al. 2006, Winter et al. 2006). However, in Alaska, *B. occidentalis* along with *Bombus cryptarum* (=*Bombus moderatus*) is abundant, despite high disease prevalence

(Koch and Strange 2012). Localized decline in abundance has been observed in the Fraser Valley of British Columbia between 1981 and 2004 (Colla and Ratti 2010). Localized decline in Washington State may have happened in the early 1990s (Fig. 2). The species was not detected in Washington state between 2002 and 2009 despite intensive surveying (Cameron et al. 2011, Hatten et al. 2013; but see Doughton 2013). A survey in the Zumwalt Prairie in northeastern Oregon did detect *B. occidentalis* in both years of a 2-yr study, albeit at fairly low levels (1.83% of total collected *Bombus*) (Rao et al. 2011). The current range, conservation status, and habitat associations of *B. occidentalis* is not fully known in the Pacific Northwest. Monitoring for further decline or recovery is important to inform conservation efforts. Herein we present data collected between 2012 and 2014 at 234 sites across Washington, Oregon, and Idaho and provide evidence for the persistence of *B. occidentalis* populations on the Olympic peninsula as well as in the Palouse Prairie and highland areas of Northern Idaho and Eastern Washington.

Materials and Methods

Data were collected in three phases.

Phase 1—Palouse Prairie Collection Sites

The Core Palouse Prairie is located in Northern Idaho and adjacent Eastern Washington (Donovan et al. 2009) (Fig. 1). Historically, this region was dominated by extensive bunchgrass prairie, but the fertility of the area led to near complete conversion to agriculture, leaving a mosaic of fragments mostly on land too steep or rocky to farm (Looney and Eigenbrode 2012). Collection sites were densely located in this region but never less than 1 km apart (Fig. 2). Blue vane traps (SpringStar LLC, Woodinville, WA) and colored pan traps (bee bowls, 3.25 oz. soufflé cups (Dart Container Corporation, Mason MI) painted fluorescent yellow, fluorescent blue or left white, Wilson et al. 2008) were placed for 24 h at 32 locations in Palouse Prairie fragments four times each year in the summers of 2012 and 2013 (Fig. 2). Aerial netting was performed during trap placement and removal. All bumble bees collected in this manner were pinned and identified to species.

Phase 2—Inland Northwest Collection Sites

Collection also occurred throughout the Inland Northwest. These sites were mostly restricted to wooded upland areas ringing the arid lowlands of central Washington but included additional Palouse Prairie sites (Figs. 1 and 2). Blue vane traps were placed for 24 h at 167 locations in July and August 2014. Traps were more widely spaced than in Phase 1, generally about 20 km apart, except for those immediately north or south of the Palouse prairie, which were more closely spaced, about 2 km apart (Fig. 2). The purpose of this phase of collection was to obtain genetic material from *Bombus bifarius* for population genetics analysis, but the abundance of certain other bumble bee species were noted. To limit impact on bumble bee populations in sampled areas, most bees were released unharmed. Bees were chilled with ice and only bees that could be rapidly and reliably identified from hair color patterns were noted. The brief period in which bees were incapacitated following chilling prevented a comprehensive analysis of the *Bombus* community during this collection phase.

Phase 3—National Park Collection Sites

Finally, collection occurred in 2013 and 2014 at 35 locations in seven National Parks in Washington State (Fig. 1). These collection sites were clumped spatially. Twenty-three of 35 total sites were in one of three national parks (North Cascades, 5 sites; Mt. Rainier 7 sites; or Olympic, 11 sites). Bees were netted for 0.5–6 collector-hours (mean 1.5 collector-hours). Collected *Bombus* were identified in the field. Voucher specimens were retained, and the remainder were released. Overall, these collections yielded two types of data: relative abundance data from Phase 1 and Phase 3 and presence–absence data from Phase 2.

Collections during all three phases took place in 10 ecological sections (Cleland et al. 1997): Oregon and Washington Coast Ranges (M242A), Willamette Valley (242B), Puget Trough (242A), Northern, (M242D), Western (M242B) and Eastern (M242C) Cascades, Okanogan Highland (M333A), Bitterroot Mountains (M333D), Blue Mountains (M223G), and Palouse Prairie (331A). Ecological sections are a fine-scale ecological classification and mapping unit used by the National Framework of Ecological Units.

To assess historic relative abundance of *B. occidentalis* and to determine when the species decline began in Washington State, we extracted information from the Global Biodiversity Information Facility (GBIF; http://gbif.org). Extracted data was drawn from 14 providers (Supplementary Table S1). GBIF is a major repository of georeferenced bumble bee records in North America and has been used in a variety of contemporary studies (e.g., Kerr et al. 2015). After eliminating records that lacked location or year of collection, we were left with 12,047 records of bumble bee occurrence in the state of Washington from 1888 to 2014. To determine collection effort of *B. occidentalis*, we combined data available on GBIF with our collection efforts from 2012 to 2014 in Washington ($n = 1{,}918$). Our contemporary survey data have not been deposited onto GBIF. We estimated the proportion of *B. occidentalis* captured over time from 1888 to 2014 by simply dividing the number of *B. occidentalis* detected by the total bumble bees that have been recorded on GBIF.

Results and Discussion

Historic Relative Abundance of *B. occidentalis*

Prior to 1990, the abundance of *B. occidentalis* reported in Natural History Collections relative to all bumble bees surveyed, digitized, and deposited on GBIF is estimated to be 27% (Fig. 2). However, after 1990, the abundance of *B. occidentalis* in combined survey efforts across the state is estimated to be <0.1%. We chose 1990 as a useful cut-off of decline because the prevailing hypothesis associated with the decline of *B. occidentalis* is tied to the spread of pathogens into wild populations from commercial colonies (Colla et al. 2006). It was in the early 1990s that commercial bumble bees were introduced into the North American continent to deliver pollination services in greenhouse and open field crops (Velthuis and Van Doorn 2006). Although the date of decline in Washington State is slightly earlier than suggested by data from southern Oregon and California (Evans et al. 2008), our survey of natural history collection records supports the hypothesis that the general decline of wild *B. occidentalis* occurred in the 1990s.

Phase 1—Palouse Prairie Collection Sites

In 2012, 439 bumble bees were collected at Palouse Prairie sites representing 16 species. Ten *B. occidentalis* were collected at six sites making up about 2.3% of total collected *Bombus*. In 2013, 316 bumble bees were collected representing 14 species. Two *B. occidentalis* were collected at two sites making up 0.63% of total collected *Bombus*. Over 2 yr, *B. occidentalis* was observed at seven sites in the Palouse Prairie (Fig. 1b).

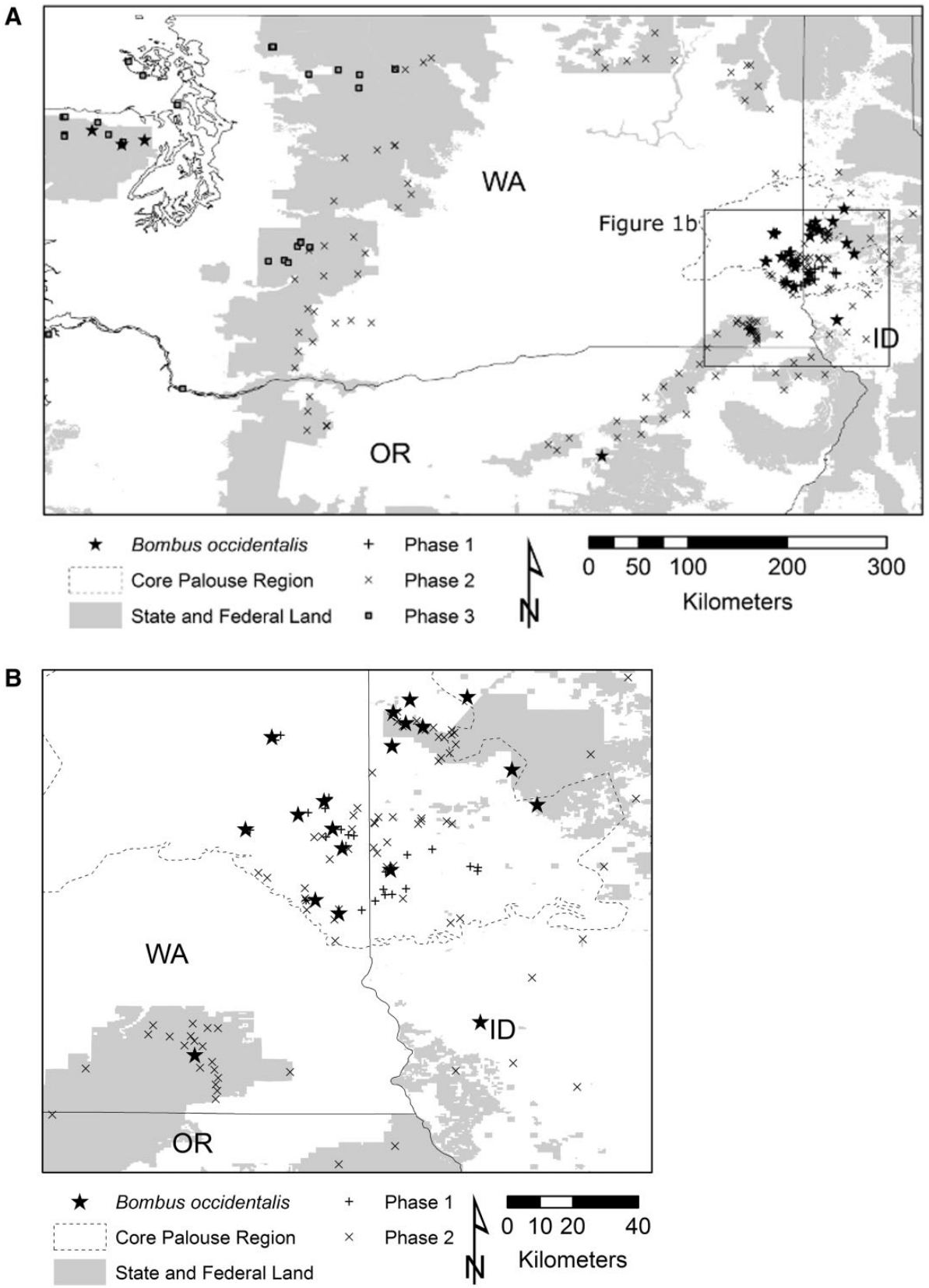

Fig. 1. (A) Locations of bumble bee sampling sites across the Pacific Northwest. (B) Locations bumble bee sampling sites in and around the Palouse Prairie. The dashed line denotes the Palouse Prairie where sampling site density was high. Phases 1, 2, and 3 denote different types of sampling regimes: Sampling at Phase 1 site includes netting, blue vane traps, and colored pan traps; sampling at Phase 2 site used only blue vane traps; and sampling at Phase 3 site used only an aerial net. Stars denote sites where *B. occidentalis* was collected.

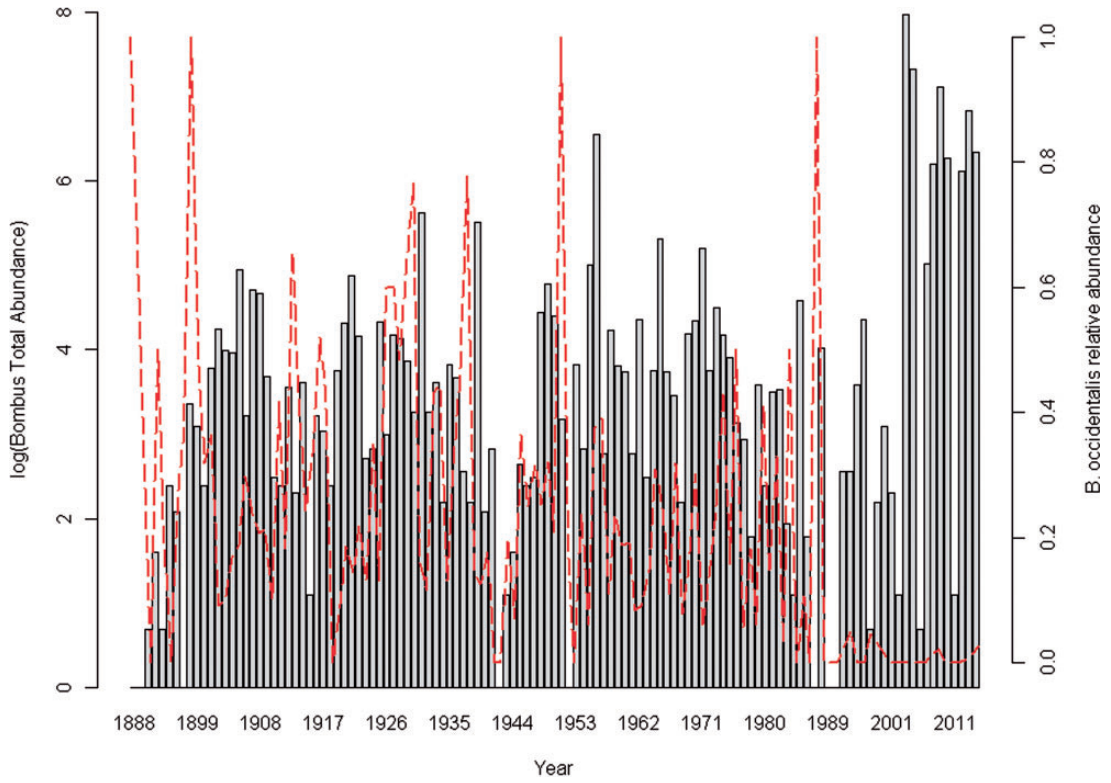

Fig. 2. Survey of bumble bee collection effort in Washington from 1888 to 2014. The log of total bumble bee abundance (all species) is represented by a gray bar and relative abundance of *B. occidentalis* relative to total bumble bee abundance is represented by dashed red line.

Phase 2—Inland Northwest Collection Sites

Out of 167 collection sites, 25 *B. occidentalis* were observed at 14 sites, all in the southeastern portion of the sampling area (Fig. 1a and b). Because the occurrence of only *B. occidentalis*, *Bombus nevadensis,* and *B. bifarius* were noted, relative abundance data are not available.

Phase 3—National Park Collection Sites

In 2013, 774 bumble bees representing 15 species were collected at 28 sites (Fig. 1a). Six *B. occidentalis* were collected at two sites both within Olympic National Park comprising about 3.5% of total *Bombus* collected in Olympic National Park in 2013 and. In 2014, 531 bumble bees representing 12 species were collected at 12 sites. Four *B. occidentalis* were collected at one site in Olympic National Park comprising 1% of total *Bombus* collected within the park in 2014. Of the seven national parks from which collection occurred, *B. occidentalis* was only observed in Olympic National Park.

Throughout all three phases of this study, *B. occidentalis* was recovered on 4 of the 10 ecological sections on which collection took place including Oregon and Washington Coast Ranges (M242A), Blue Mountains (M223G), Palouse Prairie (331A), and adjacent locations in Okanogan Highlands (M333A).

Observance of *B. occidentalis* was mostly restricted to the southeastern portion of the sampling area with one occurrence in central Oregon and 10 individuals observed at three sites on the Olympic Peninsula. However, the area in southeastern Washington and adjacent Idaho had far more closely spaced collection sites (Fig. 1b); about half of all collection sites were situated in this relatively small area. Moreover, some of these sites were sampled over a longer period of time. Failure to recover *B. occidentalis* in other parts of the northwest may be due to lower sampling effort, rather than the absence of the species in those areas.

Despite fairly intense sampling effort, *B. occidentalis* was not detected in the Cascade Range. Natural history data and species distribution models suggest that the area is suitable habitat for the species (Stephen 1957, Koch and Strange 2009, Koch et al. 2012), and occurrence in the Cascade Range has been noted in contemporary surveys (Cameron et al. 2011). Our failure to detect it suggests any remaining populations may be isolated and small.

B. occidentalis was not observed in bees collected in the Palouse Prairie in 2002–2003, but sampling effort was less intense, and the sampling technique (pitfall trapping) may be less suitable for bee collection (Hatten et al. 2013). While the presence of *B. occidentalis* in the Palouse is encouraging, it has declined in relative abundance from one of the more common to one of the more rare *Bombus* species in the Pacific Northwest (Cameron et al. 2011).

Similar rates of relative abundance of *B. occidentalis* were detected in both the Palouse Prairie and the Zumwalt Prairie in Northeastern Oregon (Rao et al. 2011). Higher rates of relative abundance of *B. occidentalis* in both the core Palouse and in the Zumwalt Prairie suggest that it may be particularly suited to less disturbed prairie habitats, underscoring the need for conservation both of the Zumwalt and of the remaining fragments of Palouse Prairie.

While we have established populations of *B. occidentalis* exist in the Palouse Prairie and in Olympic National Park, we are unable to comment on the sustainability of these populations. Sampling bumble bees at the same sites in future years can help determine population trajectories, which are still unknown. Additionally, examining patterns of genetic diversity to evaluate levels of geneflow and the severity of any genetic bottlenecks the species has endured will help assess the long-term persistence of detected populations.

Supplementary Data

Supplementary data are available at *Journal of Insect Science* online.

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