Monitoring Bumble Bee Pollinators in the Pacific Northwest

A product of the USDA-ARS Pollinating Insects Research Unit

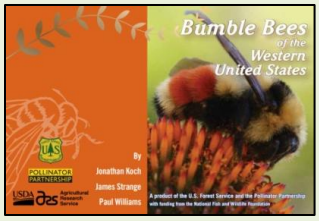
Figure 1. *Bombus melanopygus* worker sipping on nectar from a blossom near Port Angeles, WA.[1]

WORKSHOP GOALS

1. Bumble Bee Biology

- How many species are there?
- How do they live?
- Do all bumble bees sting?
- Are they all declining?

2. Identification & Curation



- How do I identify a bumble bee to species?
- How do I tell the difference between a male and female bumble bee?

3. Survey Techniques & Data Collection

- What is a standard collection?
- What data should I collect?
- Where should I collect?
- How do I safely handle bees?

Bumble Bee Facts

- There are 240 described species worldwide
- Central Asia boast the highest diversity of bumble bees
- *Bombus occidentalis* has not been detected for over a decade in the Pacific Northwest
- Serial mimicry complexes make bumble bee ID difficult
- ~19 bumble bee species are found throughout the NCCN

Who are the Bumble Bees?

Bumble bees account for less than 1% of the some 20,000 described bee species on our planet. However, the lack of species diversity does not equate bumble bees as insignificant members of terrestrial ecosystems. On the contrary, bumble bees belong to an illustrious group of "ecosystem service" providers, the pollinators. They are a conspicuous group of bees, especially in temperate and alpine environments where they are diverse and abundant. Bumble bees are generalist foragers, that is, they have the ability to access and consume pollen and nectar from a diversity of flowering plants. Thus, a single species of bumble bee has the capacity to be a courier of pollen across many species of plants possessing a variety of flower shapes, colors, sizes and bloom periods. Despite the insurmountable evidence supporting the importance of bumble bees as pollinators, they are at great extinction risk from the effects of human growth and development.

Bumble Bee Decline & the Pacific Northwest

Within the past 20 years, reports of bumble bee decline have accumulated on a global scale. Contemporary surveys of North American bumble bee fauna documented up to 94% decline in relative abundance of wild bumble bee populations. In the Pacific Northwest, *Bombus occidentalis* has not been detected for more than a decade. Furthermore, a high elevation bumble bee, *B. balteatus*, may be distributed in the North Cascades, but very few natural history records exist to support this claim. In consideration of the inherent ecological value of bumble bee pollinators, evaluating incidence, community composition, and genetic diversity will elucidate the health of bumble bees in the North Coast and Cascades Network (NCCN) of National Parks .

The NCCN is host to a rich distribution of terrestrial ecosystems, and is an ideal location to study bumble bee community dynamics and diversity. At least 19 bumble bee species are distributed throughout the Pacific Northwest, including species that are extremely abundant, as well as species that are rare or likely extinct. Establishing baseline survey data in the NCCN will provide novel information on bumble bee community composition and genetic diversity, two indicators of pollinator health and conservation status.

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Bumble Bee Biology

The life cycle. Bumble bees have an annual life cycle. Depending on the species, latitude, and elevation, mated bumble bee queens will emerge from their hibernacula in the late winter or early spring. Upon emergence bumble bee queens will first forage for nectar to power their nest searching activities. Bumble bee queens may be seen flying low to the ground in a zigzag pattern, evaluating the suitability of potential nest sites. However, when they are in transit between nest searching activities, they tend to fly extremely fast, and are almost impossible to capture and identify.

Once a bumble bee queen finds a suitable nest site, she will begin gathering pollen to bring back to the nest to feed her developing young. Be sure not to disturb bumble bee queens that have pollen on their hind legs as it is usually a sign that she has already initiated a nest. In her nest, the bumble bee will encase her laid eggs in a pollen mass. She will lay between 8 to 16 eggs in her first batch. The queen will also form a wax cup from wax derived from her abdominal wax glands to store nectar. She incubates her developing young by keeping them close to the ventral region of her abdomen and maintains her body temperature between 37 – 39°C.

The development time from egg to full adult bumble bee is about 4-5 weeks. After the nest achieves adult workers, the bumble bee queen will no longer go on foraging flights. The queen will depend entirely on her offspring to bring food back to the nest to feed developing young. Recently emerged workers will first take on nest duties such as feeding and incubating developing larva. Once the nest reaches a sufficient size, the queen will begin producing reproductive bees: drones (males) and gynes (unmated queens). Reproductive bees will eventually go on mating flights. As the fall season wanes, the mated queens will search for a hibernacula to overwinter. Her mother, worker sisters, and brothers do not overwinter and eventually expire.

Figure 2. Generalized bumble bee life cycle.

Male or Female? There are several defining characteristics that differentiate bumble bee males from females, some of which are species-specific. However, in general, bumble bee males are typically much 'fuzzier' than females. This characteristic is useful when observing bumble bees foraging on flowers out in the field. Upon closer inspection, you will find that males also have longer antennae than females, as well as seven visible tergites, instead of six (females). **Table 1** outlines the biological and ecological characteristics that differentiate males from female bumble bees.

Figure 3. Female *B. vosnesenskii* collects pollen from a blossom. Notice how full her pollen baskets (corbicula) are on her hind leg.[1]

Figure 4. Male *B. mixtus* sips nectar from Shasta daisy. Notice it's 'fuzzy' appearance.[1]

Figure 5. Female *B. mixtus* visits fireweed.[2]

Table 1. Differentiating male and female bees

Character	Male	Female
Gestalt appearance	Fuzzy & Yellow	Clean Cut
Ovipositor present?	No	Yes
Antennae Length	Long	Short
Eyes	Large	Small
Corbicula present?	No	Yes
No. of Tergites	7	6
Seasonality	Late Season	All Seasons
Foraging strategy	Mostly Nectar	Nectar & Pollen

Identifying bumble bees to species. Differentiating between bumble bees is notoriously known for causing consternation among seasoned taxonomist and even more so, citizen scientists. The difficulty in distinguishing between species is due to Müllerian mimicry complexes, a natural phenomenon in which poisonous species converge on similar body colors or behaviors to enforce toxicity as an assemblage. In the Pacific Northwest, four bumble bee species converge on black and yellow banded color form (Figure. 6). Of the four, *B. vosnesnskii* is by far the most abundant, and it is easy to misidentify the other three rarer species as *B. vosnesnskii*. For example, in one major Natural History Collection, 16% of approximately 1700 specimens of *B. vosnesensnkii* were misidentified. To avoid misidentifications, take the time to learn about key morphological characters listed on the next page.

B. vosnesnskii

B. vandykei

B. caliginosus

B. californicus

Figure 6. Black and yellow banded bumble bee Müllerian mimicry complex. Top artwork from Heinrich (2004). [2 ~ 5]

The big four. Bumble bees come in a variety of colors and sizes. To assist you in identifying bumble bees to species, be sure to get comfortable with the following characteristics: (1) color pattern, (2) malar space, (3) ocelli orientation, and (4) hind leg morphology. Of the four characteristics, color pattern of the body will be heavily used in your species identifications, especially when you are out in the field. However, there will be instances when the other three characters will prove crucial in making your final decisions on differentiating species that are part of a Müllerian mimicry complex (Figure 6). Finally, the constancy of these four characteristics in species determinations is in large part, limited to female bumble bees. To identify male bumble bees, it becomes increasingly important to examine the genitalia to arrive at a species name. The figures below are modified from Koch et al. (2012) Bumble bees of the western United States.

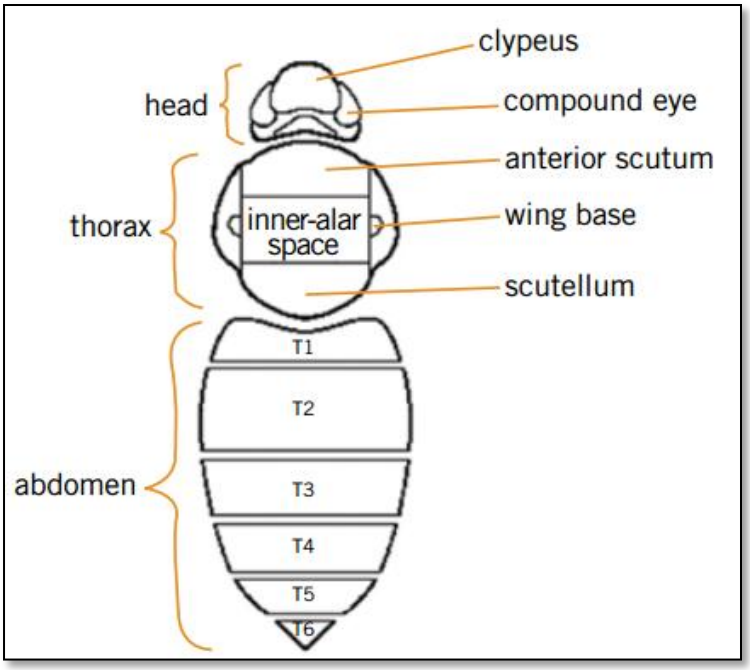

Figure 7. Body plan for female bumble bees. Characterizing the color patterns associated with the abdomen, thorax, and head is a necessary first step towards species identifications.

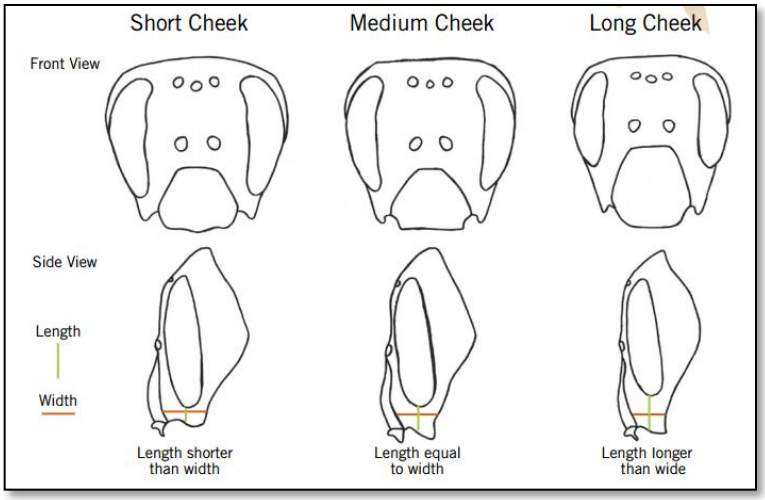

Figure 8. Measuring the malar space or "cheek" of the bumble bee will help you distinguish between several bumble bee subgenera. It is especially useful when identifying mimics.

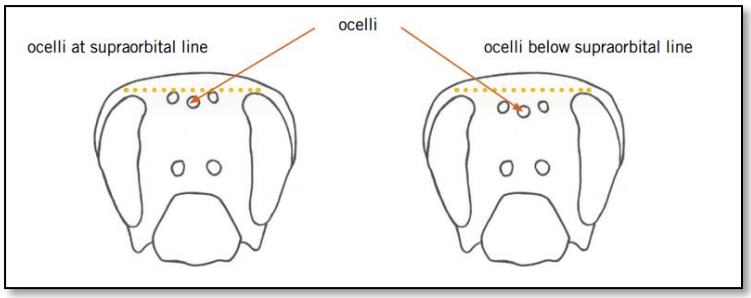

Figure 9. Locating the position of the ocelli relative to the height of the compound eye is a useful character when distinguishing between species. The ocelli are the simple eyes of an insect.

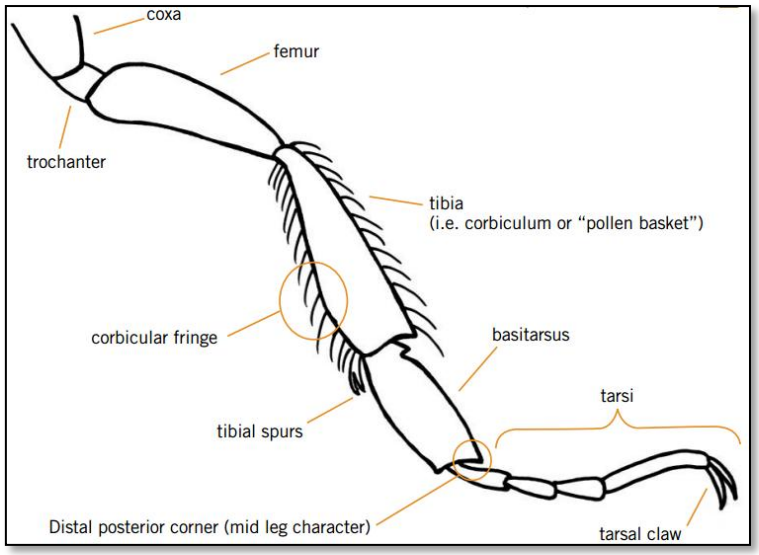

Figure 10. Recognizing the presence or absence of the pollen basket on the hind leg will assist you greatly in differentiating between males and females. In males, the tibia is convex, as they lack a pollen basket. In females, the tibia is concave and shiny, thus allowing for pollen retention. Parasitic bumble bees also lack a pollen basket.

Survey Techniques & Data Collection

Where to survey bumble bees. When looking for bumble bees in the Pacific Northwest, you will have the most success finding them in places where flowers are blooming. It is unlikely you will find a bumble bee nest in the wild, as they are often underground where they can develop and grow undisturbed. Bumble bees will be found foraging for nectar and pollen on a diversity of flowering plants in meadows, recently burned or logged areas, and along stream courses and roadsides. We suggest locating sites where an assortment of flowers are in bloom for optimal bumble bee detection. Sampling on multiple species of flowers will also increase the diversity of bumble bees that you detect in your survey efforts.

Figure 11. Field of fireweed near North Cascades National Park. Road margins are great places to survey bumble bees.[3]

When to survey bumble bees. Picking a time to survey for bumble bees can be tricky, especially in the Pacific Northwest where snowmelt and flower bloom periods correspond to elevation changes. Sampling too early in the spring will result in few bumble bee observations, usually limited to nest-searching queens recently emerged from their hibernacula. If you were to sample between the late summer and early fall, it is likely that you will encounter queens going on mating flights, as well as an abundance of drones. To maximize bumble bee species diversity and increase the probability of encountering a non-reproductive bumble bee, we suggest surveying bumble bee populations between early to mid summer (June – July). During this timeframe, it is probable that flowers will be blooming at multiple elevation gradients found across National Parks and Monuments in the Pacific Northwest. Refer to **Bumble Bees of the Western United States** for an authoritative description of bumble bee phenology.

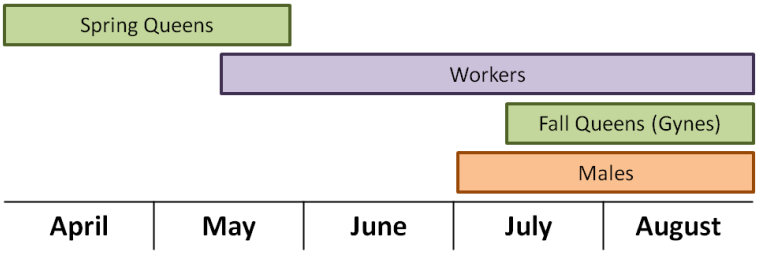

Figure 12. Generalized bumble bee phenology diagram.

How to survey bumble bees. Standardized surveys are to be conducted for a total of 1.5 collector hours in a ~100 m diameter plot. Collectors will survey with an aerial insect net and collect bumble bees directly into a 20 mL plastic vial and chill immediately on ice. Upon completion of the survey period, the bumble bees are to be sexed and identified to species. While the specimens are immobilized, DNA may be sampled non-lethally by removing the mid-leg from the individual. The mid-leg should be stored in 70% ethanol for down-stream DNA analysis. Associate tissue samples with necessary species and locality information. At each site, a worker and male of each captured species are to be sacrificed and retained as voucher specimens. All queens are to be released. During the survey period, be sure to associate and record floral hosts to each bee specimen. A voucher of the flowering plants in the immediate area should be collected and pressed for identification in the lab. Each survey event should be associated with a unique locality description and georeferenced with a GPS. Be sure to collect temperature (°C), relative humidity (%), and wind speed (kph) data with a weather meter for site characterization. The standard methods described have been used for both national and local bumble bee surveys by the Dr. James Strange and colleagues.

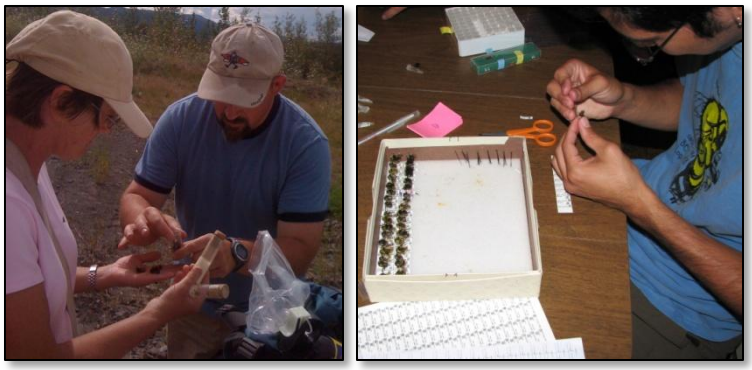

Figure 13. Sacrificing a worker and male of each species for a voucher collection will confirm identifications of non-lethally sampled bumble bees.[1,3]

Figure 14. Record weather data to characterize survey event.[3]

Contact Information

James "Jamie" Strange is a Research Entomologist with the USDA- Agricultural Research Service in Logan, UT at the Pollinating Insect Research Unit. Dr. Strange specializes on issues related to bumble bees, especially the management of bumble bees in agricultural settings and issues related to the conservation and genetics of declining species. He received his Ph.D. from Washington State University where he worked on the conservation genetics of honey bees. His 2012 publication, a Guide to the Bumble Bees of the Western United States, co-authored with Jonathan Koch and Paul Williams was recently named a notable government publication by the American Library Association.

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Walter Sheppard is a Professor and Department Chair of Entomology at Washington State University. His primary research interests are population genetics and evolution of the honey bee genus *Apis*. In the Old World, his research is centered on phylogeograhic studies of honey bee subspecies lineages, the speciation process and the systematics of the group. As honey bees are an introduced species in the New World, many of the molecular tools we developed have applicability to other invasive insects of agricultural significance. Reproductive biology of the honey bee includes the fascinating ability to store sperm for years of subsequent use following mating flight(s) and multiple mating that take place in early adult life. The population genetic and evolutionary implications of asymmetrical sperm survival and utilization are an emerging topic within my laboratory.

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Jonathan Koch is a Ph.D. student at Utah State University (USU) where he collaborates with the USDA- Agricultural Research Service Pollinating Insect Research Unit in Logan, UT. He is interested in conservation biology and population genetics, specializing on bee pollinators. During his Master's program, he applied species distribution modeling techniques and GIS to over 50,000 natural history and contemporary specimen records to estimate bumble bee decline in the United States. He is currently investigating patterns of bumble bee genetic diversity in the intermountain west. He is an advocate for citizen and open science, serving as a coordinator for the USU Insect Tours, which attracts over a thousand preK-12 students each year from Utah and Idaho.

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