Oregon Bee Atlas: wild bee findings from 2019

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Abstract

The Oregon Bee Atlas is a new volunteer-led effort to characterize the bee fauna of Oregon State by collecting, preparing, and databasing specimens of wild bee species and their plant host records. In 2019, volunteers submitted 25,022 bee specimens across all Oregon counties, representing 224 unique bee species and 45 unique bee genera. Specimens were collected from a total of 352 unique flowering plant genera, resulting in the largest contemporary state-level database of bee-host plant interactions. Volunteers produced valuable occurrence records for species poorly known for the state, and species of conservation concern. The 2019 data builds on the efforts of 2018 in demonstrating the power of a specimen-focused, volunteer wild bee survey.

Introduction

Beginning in 2018, the Oregon Bee Atlas has been generating museum-quality bee specimens for the state of Oregon (Best et al., 2021). The Oregon Bee Atlas (OBA) is a volunteer-focused initiative to survey the bee fauna of Oregon. The mission of the OBA is to train and equip citizen scientists to: (a) create and maintain a comprehensive, high quality and publicly accessible inventory of the state's wild bees and their plant-host preferences, (b) to educate Oregonians on the state's bee biodiversity, and (c) to conduct an on-going survey of wild bee populations to monitor their health. Started in 2018 by Oregon State University (OSU), Oregon Department of Agriculture (ODA), and Oregon Department of Forestry (ODF), the OBA was established as a response to the general lack of knowledge about the status of Oregon's wild bees.

Through the framework of the OBA, volunteers receive the necessary training to collect and prepare bee specimens and to upload their records through a centralized and standardized database. Volunteers are partnered with expert taxonomists and database managers to ensure quality records are created and maintained. All observational records generated by the OBA are based on identified specimens with voucher specimens deposited in the Oregon State Arthropod Collection (OSAC) so that identifications can be confirmed into the future and used as comparative reference material. All records are made publicly available.

Here we represent the findings from the second year of the OBA, including a review of the spacial distribution of sampling, the species detected, and notable wild bee discoveries.

Methods

Methods used in 2019 follow those described in Best et al. (2021), with some minor changes.

Volunteers

Volunteer recruitment continued through presentations to OSU Master Gardeners, Master Naturalists, and local beekeepers. Recruitment was assisted because of the release of a documentary featuring the Oregon Bee Atlas on March 29, 2019, through the Oregon Public Broadcasting series Oregon Field Guide (https://www.opb.org/news/article/oregon-bee-atlas-project). We conducted eight trainings consisting of 101 students which were held in the cities of Corvallis, Grants Pass, La Grande, McMinnville, Mosier, Portland (x2), and St Helens. Training took place between November 2018 and March 2019 and in most instances training events lasted one full day. Topics covered at training events included: project background, bee biology, insect collection and specimen preparation, and data entry. Two additional five-day taxonomy courses were held on July 8—12 and 15—19, 2019 that covered genera-level identification of most common wild bees in Oregon, with species-level identification for bumble bees.

Sampling methods and effort

Unlike 2018, volunteers in 2019 only conducted undirected, free sampling, and directed sampling used the previous year. The reason directed sampling was dropped in 2019 was to better address the tasks of the Oregon Bee Atlas at this stage, namely, to detect bee species and delimit their range in Oregon. As described in Best et al. (2021), bees were primarily collected using a variable transect aerial netting, with a small subset collected using trap nests, blue vane, or pan traps (see Westphal et al. 2008 for description of each method). Volunteers conducting aerial netting were encouraged to pool bees sampled from each host plant and to separate those samples into killing jars to document the association of the bees with the host plant. In all cases, however, all sampling conducted within a 1 ha radius of where sampling started was pooled together into a common sample (e.g., aerial netting from a given plant host species growing within a 1 ha area were pooled). All bees caught from a collector within this 1 ha unit, at a given date and time, and where applicable, from a given plant, were provided with a unique identifying number (Sample ID).

Observational data entry, specimen preparation and labeling

As in 2018 (Best et al. 2021), volunteers recorded the following core data: (a) full name of collector, (b) a Sample ID identifier, (c) the date and time when sampling was initiated, (d) the name of the closest geographic or civic landmark to the sampling area, (e) latitude and longitude coordinates in degree decimal format, and (f) the number of bees collected. For volunteers installing traps the date and time that traps were removed was also included and when netting was conducted from a specific host plant, the family, genus, and species of the host plant was recorded. Beginning in 2019, volunteers were provided the option of generating plant host names using fields in iNaturalist (see below).

Volunteer data continued to be recorded using two methods, namely written notebooks or using iNaturalist, although volunteers were strongly encouraged to use iNaturalist for records of netted bees. The use of iNaturalist to generate location records and plant host records is described in detail in Best et al. (2021).

As in 2018, we ensured standardized and archival labels were placed on all specimens. The final labels were generated at Oregon State University on acid free cardstock paper and then sent to volunteers to place on specimens. Label information was pulled from the verified and corrected database and printed using BarTender software (Seagull Scientific, Bellevue, Washington) on 8.5" x 11" cardstock using a laser printer. Unlike 2018, each label was associated with a unique Oregon Bee Atlas field number. The field number consisted of a 7-digit number. It was composed of a prefix year code (19) followed by a 5-digit sequential unique specimen number (e.g., specimen 1918520 is the record of a female *Agapostemon texanus* collected on *Grindelia stricta* by volunteer Marty Stein in Newport, Oregon on July 23, 2019).

Once labeled, volunteers worked to provisionally identify and sort their specimens and were encouraged to bring material to Oregon Bee Atlas for monthly open microscope sessions (September 2019 – February 2020) at Oregon State University for assistance with genus-level identification. Volunteers were instructed to turn their collections into Oregon State University by March 2020 for authoritative specimen identification and voucher selection.

Specimen determinations were made by three of the authors: Lincoln Best (various taxa), Joe Engler (*Lasioglossum*), and Briana Lindh (*Melissodes*). Individual volunteer collections were graded (where applicable) by Best based on accuracy of the identification, and quality of specimen preparation. Every volunteer who submitted a collection received an individual evaluation grading sheet. Feedback was provided on misidentifications and issues with specimen preparation. Voucher specimens that covered both the taxonomic and geographic breadth of the sampling were accessioned into the Oregon State Arthropod Collection and excess material was then used to create regionally relevant reference collections for the volunteer teams.

Data and metadata

Once the annual data were collated into a single table, the data and metadata were checked for typographical errors and fields were mapped to darwinCore biodiversity data standards (https://dwc.tdwg.org/).

The final dataset contains the following 38 fields:

occurenceID: this is a globally unique identification number for the observational record. It is cast differently depending on whether the voucher specimen was retained or not. For occurrence records based on specimens now housed in the collection, the occurrenceID has the prefix: http://osac.oregonstate.edu/ followed by 'SP/OSAC_' followed by the 10 digit museum-issued catalog number for the voucher specimen, e.g.; http://osac.oregonstate.edu/SP/OSAC_0001275241. This globally unique string, which is also a URL, serves as a hyperlink to access the museum specimen record.

Observations made from specimens that were not retained as vouchers at the OSAC, were also issued unique ID's as URLs with the same prefix, however the "SP/[catalogNumber]" has been replaced with “OBS/OBA_[fieldNumber]”. These will also retrieve a copy of the observation record but are not tied into the museum’s specimen-based inventory: e.g.; http://osac.oregonstate.edu/OBS/OBA_1918520.

catalogNumber: if a voucher specimen for an observation was deposited into the OSAC, it is provisioned with a unique catalog number, which is presented on a printed label in both arabic human readable digits and a datamatrix barcode. As with the occurrenceID, the catalogNumber is represented in the datamatrix as a URL: http://osac.oregonstate.edu/SP/OSAC_XXXXXXXXXX, where the X’s correspond to a unique 10-digit number. Observations based on specimens that were not accessioned into the museum (i.e., not retained) are not associated with a catalog number.

disposition: Whereas all observational records were based on specimens examined by a taxonomist (Lincoln Best, Joe Engler or Briana Lindh), not all specimens were retained. Observations for which a voucher specimen was not retained (e.g., accessioned into the museum) the catalogNumber is necessarily left blank. The disposition field indicates if a specimen is ‘confirmedPresent’ or ‘not-retained’ in the museum.

datasetName: The dataset name, OBA_OSAC_2019[version], is recorded in each record, in the event that these records are combined with other observational datasets.

basisOfRecord: all observational records in the OBA dataset are based on actual pinned specimens, although as noted, not all specimens were archived.

fieldNumber: This is the Oregon Bee Atlas specimen ID number. It is created when the observation is created and a label is issued.

bibliographicCitation: Each record in the dataset is provisioned with the full bibliographic citation for the dataset, enabling downstream users to cite the record explicitly. Doing so, provides an explicit means to access the source of the data record and attribute proper credit to the creators of those records.

license: these data are released under a creative commons license that makes them useable for non-commercial purposes with proper and appropriate attribution (eg., cited using bilbiographicCitation above. Details on the license can be found at: http://creativecommons.org/licenses/by-nc-sa/4.0/

institutionCode: OSAC

ownerInstitutionCode: OSAC

rightsHolder: Oregon State University

Collecting Date: The collecting date is stored in two forms, three separate parsed fields: day (1-31), month (1-12) and year (2019); an eventDate is included for ease of sorting by date.

locality data: locality data is stored in 6 fields: country, state, county, location, decimalLatitude, and decimalLongitude. Georeferencing was provided by the collector and was either recorded in the field during the collecting event or determined subsequently based on maps and field notes. In all cases, they are recorded in decimal degrees with an accuracy of 3 decimal places (approximately +/- 100m).

Full georeference data is available via request to the lead author, however publicly shared records were rounded to the nearest integer, so as to provide visualization on GBIF mapping, while better ensuring that more detailed uses of the data directly attribute these records to the appropriate source (i.e, the dataset creators, not the data aggregator). This information is provided in each record via the *dataGeneralization* field.

samplingProtocol: the collecting method is typically aerial net, where other means were used: eg., sweep net or pan trap, these were indicated.

Associated plant information: any bees that were collected in direct association with known plants had this information recorded in one of two ways. If a bee or bees were collected directly from a plant while foraging, this information is placed into the "*associatedTaxa*" field, using standard language recommended by DarwinCore, in which the type of relationship is stated followed by a colon and then the plant taxon, eg., "foraging on" : "*Grindelia stricta*". In cases where a sweep net or pan trap or bees were netted in the vicinity of known plants (e.g., bees were not directly observed visiting floral resources on these plants), this is placed in fieldNotes.

Additional data and metadata associated with the plant association is available via request to the lead author, including voucher photographs. This information was shared in each record via the *informationWithheld* field.

recordedBy: provides the collector's name

Taxon: All names were crosschecked against GBIF's species name tool prior to being uploaded. Fields included are: *phylum*, *class*, *order*, *family*, *subfamily*, *tribe*, *genus*, and *species*. The full binomial with authority and date of publication is provided in *scientificName*.

rank: lowest taxonomic rank the record is identified to
sex and caste are recorded if known.

repository: The repository is considered OSAC if voucher material was deposited in the museum. For observations for which the voucher was not retained, this field is left blank.

Determination information: identification data is provided in the identifiedBy and dateIdentified fields. In all cases, the final 2019 dataset records were determined by Lincoln R. Best, Joe Engler or Briana C. Lindh.

Findings/Results

Volunteers

A total of 128 volunteers submitted collections of bees, with approximately 60% submitting collections over 50 bees, 10% submitting collections more than 500 bees, and 5% submitting collections over 1,000 bees submitted.

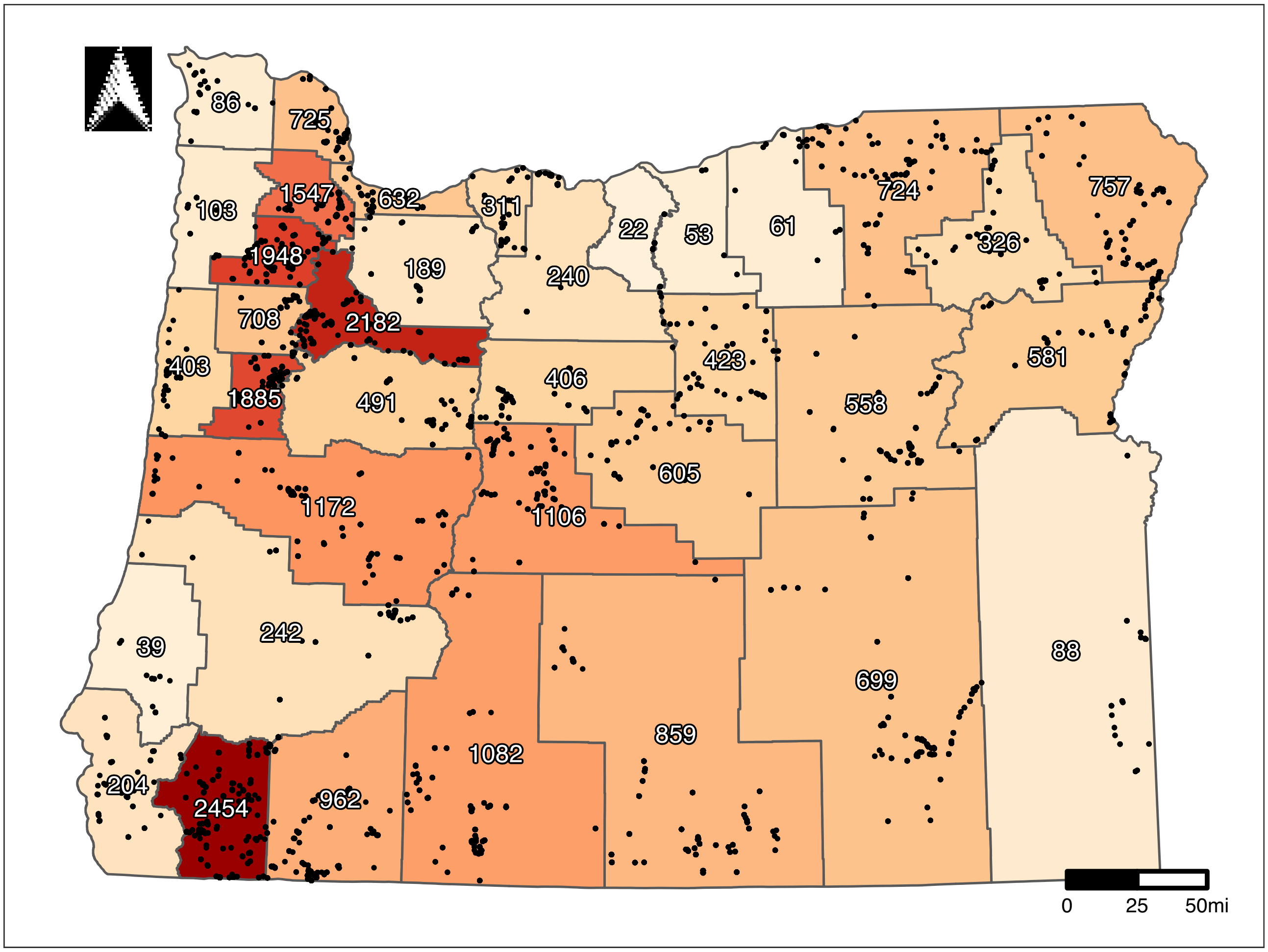


Figure 1. Heat map of 2019 volunteer sampling effort. Each dot represents a distinct sample event, which is a distinct collection within a specific bounded 1 ha area on a given date and time. The increasing red color of the county corresponds to the total number of specimens collected in the county (with totals appearing in the center of each county).

Spatial distribution of sampling

Wild bee specimens were collected from all 36 Oregon counties (Figure 1). Although specimen collection was spatially uneven across the state, 97% of specimens were collected outside of the Multnomah County where most of our collectors live. Moreover, 33% of specimens were collected in the four ecoregions (level III) east of the Cascade Mountain range (Figure 2).

Description of the wild bee data

Volunteers collected 25,022 bees from March 02, 2019 to December 23, 2019 (Figure 3). Bees were predominantly collected from four bee families, Apidae, Halictidae, Megachilidae, and Andrenidae (Figure 4). In total, volunteers collected bees from 45 genera, with the top five collected genera being *Andrena* (3,705 specimens), *Bombus* (3,517), *Lasiglossum* (3,259), *Osmia* (2,784), and *Halictus* (2,465) (Figure 4). There are 224 species listed in the dataset although many specimens from a number of species-rich genera (e.g., *Andrena*, *Melissodes* and *Lasioglossum*) were only determined to the generic level at the time of publication. We estimate that more than 400 species were collected by volunteers in 2019. A species abundance curve of volunteer collections suggests that further sampling effort is required to detect all the species in state (Figure 5). Notably, volunteers identified 31% of their

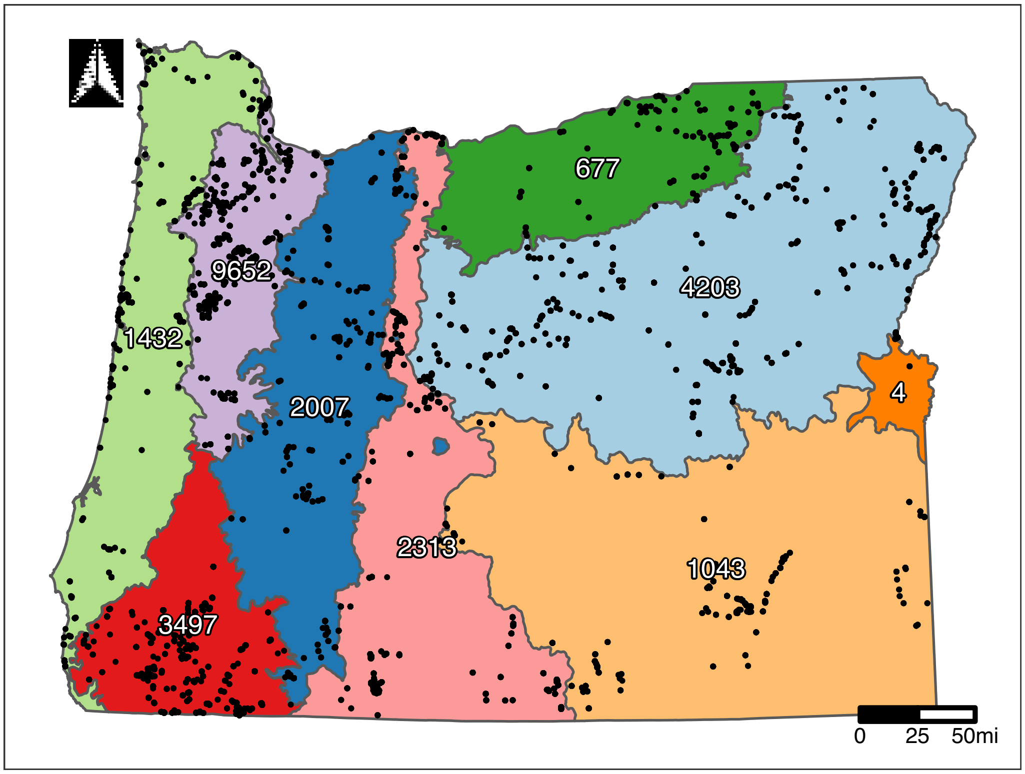


Figure 2. . Map of 2019 volunteer sampling effort by ecoregion (level III). Each dot represents a distinct sample event, which is a distinct collection within a specific bounded 1 ha area on a given date and time. The number of specimens collected per ecoregion appear in the middle of each region.

specimens to genera and 10% to species (Supplement 1). While volunteer determinations were largely correct at the genus level (94% correct), their species level determinations had notable errors (77% correct).

Notable wild bee discoveries

This state-wide survey effort produced valuable occurrence records for species poorly known for the state, and species of conservation concern. Among the Megachilidae, new state records include *Ashmeadiella altadenae* Michener, 1936, *Ashmeadiella prosopidis* (Cockerell, 1897), *Hoplitis boharti* (Timberlake & Michener, 1950), *Hoplitis emarginata* (Griswold, 1983), and *Hoplitis remotula* (Cockerell, 1910). *A. altadenae*, *H. boharti*, and *H. remotula* have demonstrated fidelity to *Plagiobothrys* (Boraginaceae), while *H. emarginata* have only been recovered from *Sedum* (Crassulaceae), with a documented preference for species with cream-colored inflorescences. One record of the adventive exotic species *Pseudoanthidium nanum* (Mocsáry, 1881) is provided from Troutdale, which adds to a short but growing number of records known from the greater Portland Area.

The Oregon Bee Atlas continues to generate species occurrence data with floral associations for species of conservation concern including 25 records from 10 plant genera for *Bombus occidentalis* Greene, 1858, and 9 records from 4 plant genera for *Bombus morrisoni* Cresson, 1879. Twenty-one species of *Bombus* are documented in this dataset. Three additional records are provided for the squash bee, *Eucera* (*Peponapis*) *pruinosa* (Say, 1837), expanding its known range into the Willamette Valley.

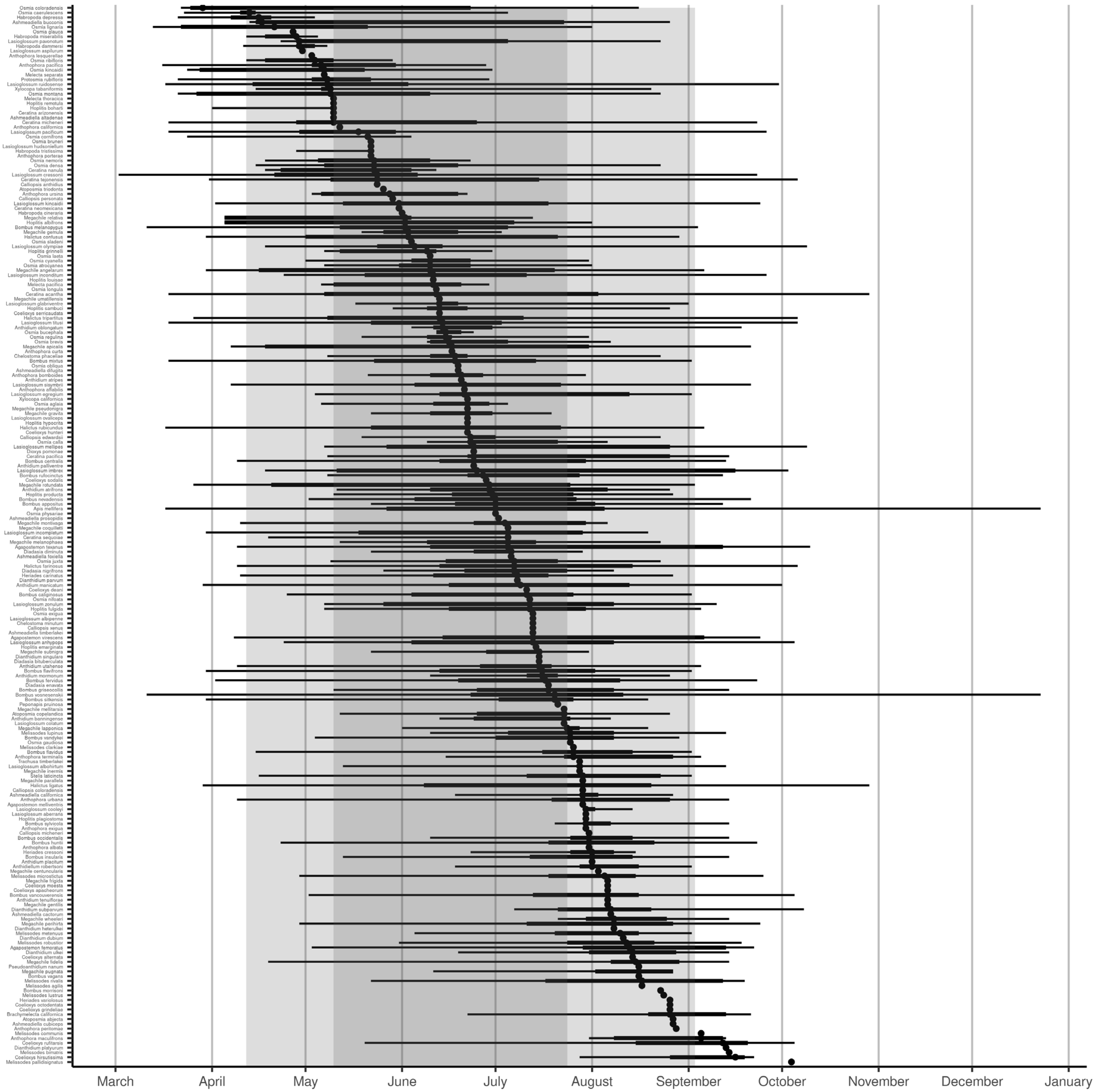


Figure 3. Phenology plot for all bee species (y axis), sorted by median abundance times. Percentiles of overall activity of each bee species (50th & 90th) are shown in grey shaded regions. Date ranges for each species (minimum, first, second, third quartiles, and maximum) are shown only for species with >10 specimens.

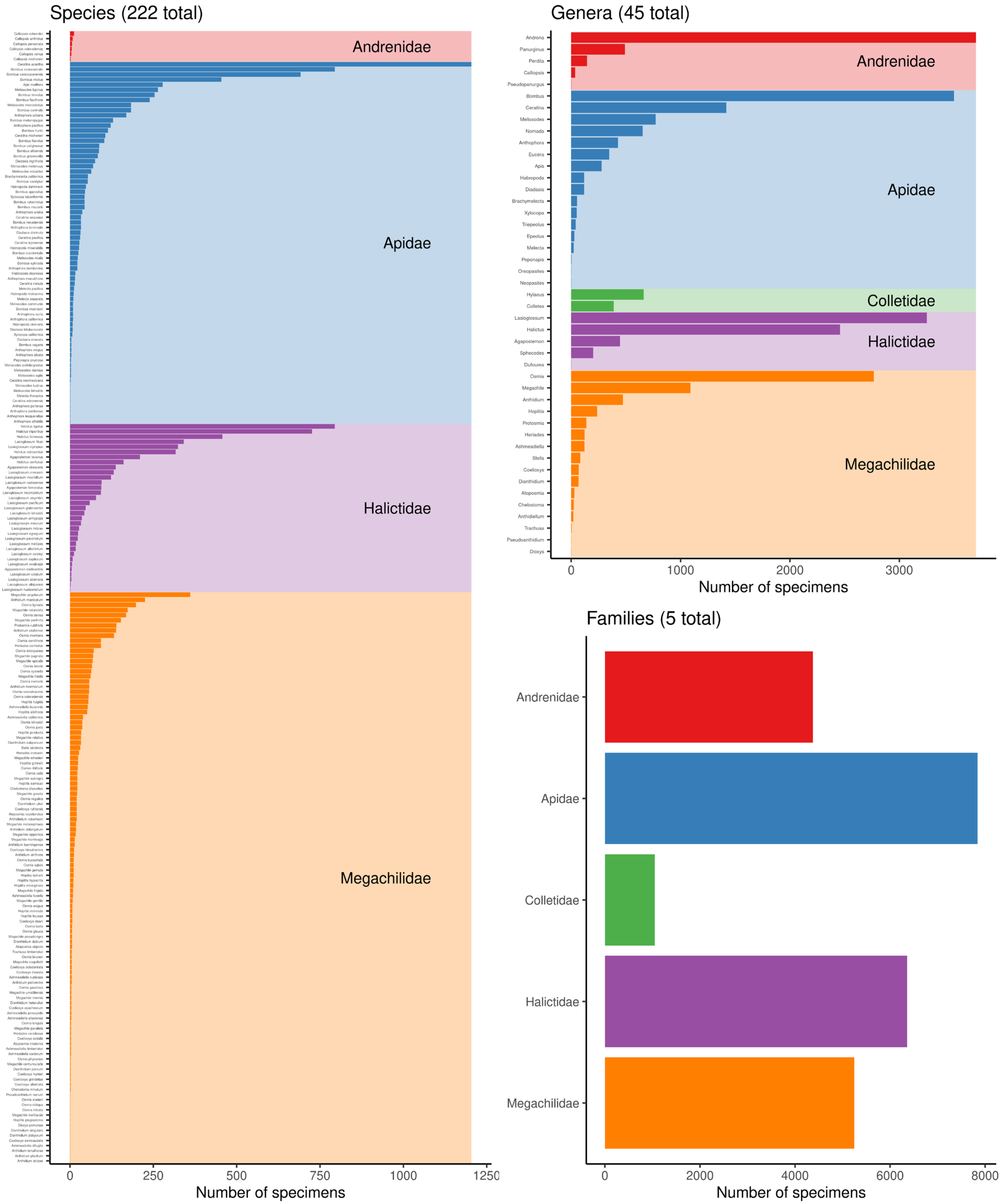
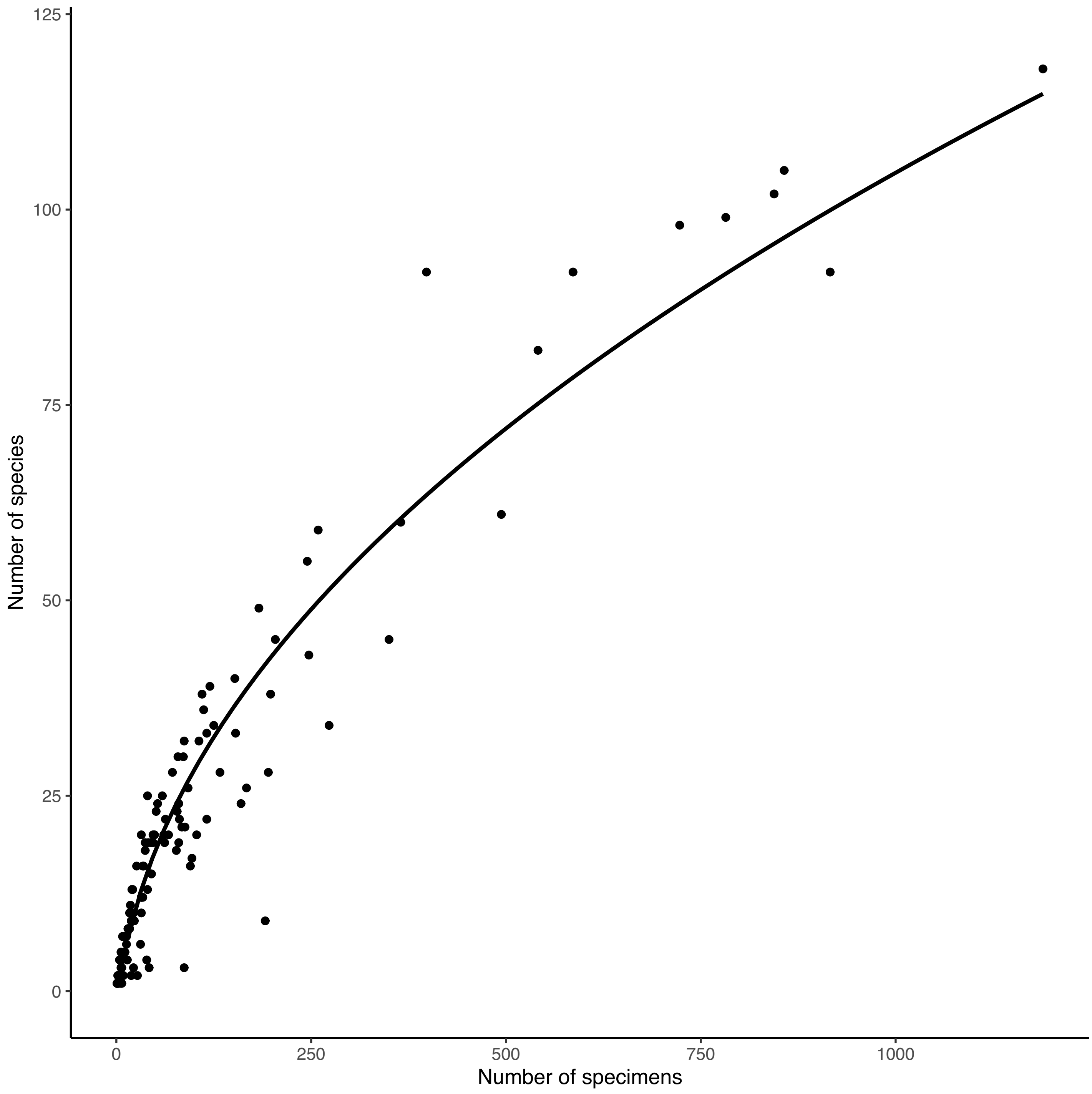


Figure 4. Number of specimens collected per taxon (y axis) by volunteers in 2018, broken down by species, genus and family.



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indicated by a dot. A linear-square root regression and 95% confidence intervals are shown by the line and shaded region.

Data for the rare *Calliopsis xenus* (Rozen, 1958) in Oregon is published here for the first time. This species is presumed endemic to the Cascade and Sierra Nevada Ranges. It has been previously detected by Dr. Andrew Moldenke and August Jackson in the Oregon Cascades, and both have produced specimens (pers. comm. to L.R.Best). Both investigators have expressed concerns that the populations they documented may now be extirpated, in the former case by landscaping, and the latter by the 2020 wildfires that swept the Oregon Cascades.

The minute Arizona small carpenter bee, *Ceratina arizonensis* Cockerell, 1898, is new to Oregon. This species and several other new state records are known only from the vicinity of Eight Dollar Mountain, a significant botanical area known for high rates of endemism. Our early survey results support this phenomenon being shared with the pollinator fauna, with several suspected novel bee species awaiting further study.

Description of host plant data

A total of 16,755 bee specimens were associated with 350 unique genera of flowering plant hosts, within 80 families (Supplement 2). The greatest number of specimens were collected from *Ericameria* spp. (5% of plant records), followed by *Phacelia* spp. (4% of plant records) and *Salix* spp. (4% of plant records). Surveys across plant genera varied considerably among counties (Figure 6). The plant genera producing the greatest bee species richness were *Phacelia*, *Ericameria,* and *Cirsium*, hosting a total of 82, 73, and 64 unique bee species.

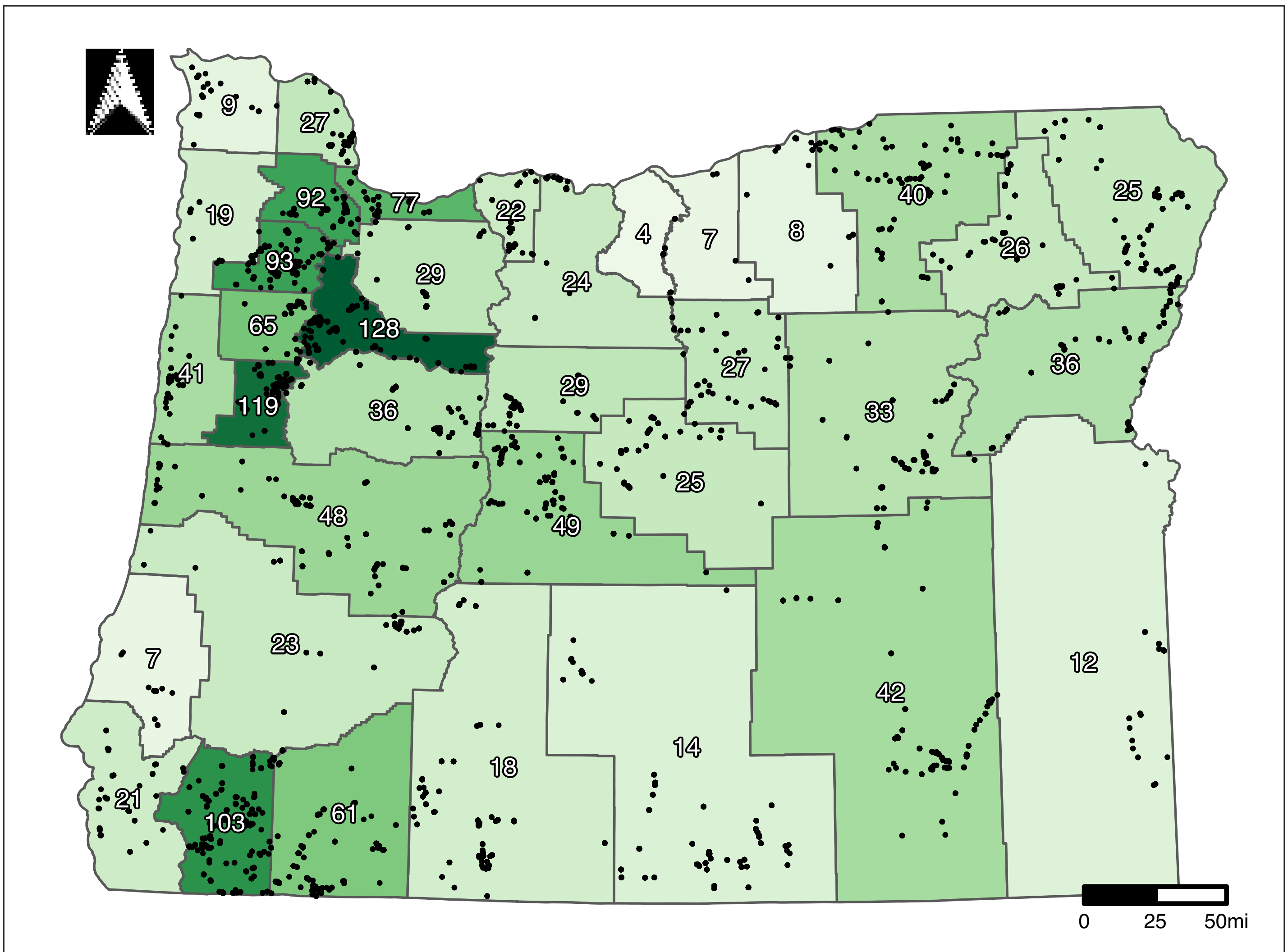

Figure 6. Heat map of 2019 volunteer sampling effort. Each dot represents a distinct sample event, which is a distinct collection within a specific bounded 1 ha area on a given date and time. The increasing green color of the county corresponds to the total number of plant genera that bees were caught from in the county (with totals appearing in the center of each county).

Discussion

The second annual cycle of the Oregon Bee Atlas continues to demonstrate the potential of volunteers to create contemporary records of wild bees and their plant hosts on a state-wide level. To our knowledge, the Oregon Bee Atlas remains unique with respect to the number of collectors and the quality of the material they collected, but also in terms of the large extent of plant-host associations. Results suggest considerable return of high value data from lethal sampling that would otherwise not be captured by lower intensity non-lethal sampling or sentinel plant monitoring, as advocated by Tepedino and Portman (2021).

These results, which are biased in taxonomic identification effort towards the genus *Bombus* and the family Megachilidae, have provided new spatio-temporal and floral data for much of the state fauna, and have detected new state records and suspected new species. Nearly 300 species from 47 genera have been identified among the specimens produced from 2018 and 2019. It is estimated that more than 250 additional species remain among unidentified specimens from this field season. It is estimated that during the 2019 field season, volunteers produced specimens representing nearly 500 species. Investing additional morphological and molecular resources to unassessed genera is expected to increase our state fauna to nearly 700 species among at least 55 genera.

There has recently been a call by Portman et al. (2020) for a targeted approach to bee monitoring that includes key ecological information such as associated host plant records. Compared to 2018, volunteers continued to collect a high number of specimens that are associated with host-plant records. Approximately 67% of our bee occurrence records in 2019 were associated with a host plant. Moreover, more of the plant host records, compared to 2018, also exist in a photo vouchered format in iNaturalist. In 2020, we changed our protocols to ensure that all plant host records were recorded with a photo-voucher in iNaturalist. The bee plant-host dataset we describe here is one of the largest published. Our 2019 data alone, for example, exceeds the number of bee plant-host interactions from a Great Plains region survey (Vilella-Arnizaut et al. 2021) by 1.7 times, with 3 times the number of plant genera recorded in our network. Such datasets can be of high value to identify key forage plants for restoration efforts (e.g., Cane and Love, 2016; Purvis et al., 2021).

The Oregon Bee Atlas will continue to develop and refine its training programs to prepare volunteers to conduct more targeted surveys associated with unique plant communities in Oregon and use historical records to guide volunteers. Beginning in 2020, we conducted a large overhaul in our training program and created the Master Melittologist program, the first master certificate program in the Extension service dedicated to the study of wild bees.

Acknowledgement

The Oregon Bee Atlas would not be possible without the hard work and dedication of its volunteers (see Supplement 3 for a listing of volunteers who contributed to this dataset). We are particularly grateful for the Oregon Bee Atlas Advisory Committee in 2019; Judi Maxwell, Missy Martin, Michael O'Loughlin, Jerry Paul, Pete and Gretchen Peterson, Nicole Sanchez, and Bonnie Shoffner. We are grateful to the Foundation for Food and Agriculture Research Pollinator Health Fund and Oregon Department of Agriculture for supporting the Oregon Bee Atlas.

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