THE *MEGACHILE* (HYMENOPTERA: MEGACHILIDAE) OF MONTANA AND CHECKLIST OF BEES (HYMENOPTERA: APOIDEA) FROM THE SOUTHERN WOLF MOUNTAINS, MONTANA AND WYOMING

by

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ABSTRACT

Wild bees are a diverse group of important pollinators, yet several aspects of their biology remain understudied. In particular, baseline data on the diversity and geographic ranges of wild bees is not available for much of Montana. These baseline faunistic data are the first step to understanding the regional biodiversity of bees and to eventually assess their conservation status. We conducted faunal surveys of the genus *Megachile* in Montana and the bees of the southern Wolf Mountains. Specimens from collecting trips in 2019-2020, historic museum specimens, research collections, and published data records comprise the foundation for the inventory of Montana's *Megachile* species. We documented 35 species of *Megachile* in Montana based on 4,968 specimens and present an illustrated identification key and county distribution maps. In the Wolf Mountains, we documented 138 bee species from 4,996 specimens collected on trips in 2019-2020 in Montana and Wyoming. These two studies contribute eight new state records and add important data to the growing list of bee species in Montana.

CHAPTER ONE

THE *MEGACHILE* (HYMENOPTERA: MEGACHILIDAE) OF MONTANA

Introduction

Wild bees are a diverse group of important pollinators to both agricultural crops (Klein *et al*. 2003, Winfree *et al*. 2008, Garibaldi *et al*. 2013) and native plants (Tepedino *et al*. 1997, Tepedino 2000, Fowler 2016). In North America, there are over 4,000 species of wild bees (Michener 2007), but much remains unknown of the taxonomy, distribution, and biology of many species. Wild bees are of recent conservation concern due to potential population declines driven by a hypothesized combination of pesticides, pathogens, habitat loss, climate change, and competition with non-native bees (Colla and Packer 2008, Grixti *et al*. 2010, Potts *et al*. 2010, Goulson *et al*. 2015, Kerr *et al*. 2015). However, historical bee population data is often lacking, so it is difficult to analyze how bee populations have changed over time (but see Burkle *et al*. 2013). With growing conservation concern and a lack of data on bee species and populations, there is increasing interest in documenting wild bee diversity, especially in understudied areas.

Montana is likely to support a diverse assemblage of wild bee species because of its large area, diversity of landscapes and vegetation, and lack of urbanization in much of the state. It includes the Crown of the Continent, the three-way divide that drains to the Pacific, Arctic, and Atlantic Oceans. There are around 1.4 million hectares of wilderness areas (Tidwell 2014), 910 million hectares of forests, and 225 million hectares of agricultural lands comprised of orchards and agronomic crops to pastures and rangelands in the state. Montana contains extensive public holdings, including National Parks, Monuments, Wild and Scenic Rivers, National Forests, National Wildlife Refuges, an extensive State Park System, and other protected areas. A large part of Montana is managed by the Bureau of Land Management, and good private land stewardship has preserved the biodiversity of much of the private lands as well. The eastern Great Plains region is characterized by a semi-arid climate and predominantly grasslands and sagebrush steppe, alongside coniferous forests and riparian/wetland areas. The western mountainous region of the state contains montane, alpine, and subalpine zones that support wetland and riparian areas, grasslands, sagebrush steppe, meadows, aspen forests, and coniferous forests (Lesica 2012). Certain unique regions in Montana, especially in the Great Plains and Badlands, are of particular interest from the standpoint of the bee fauna.

Megachile Latrielle *s. l.* (Hymenoptera: Megachilidae) is a large, cosmopolitan bee genus comprising over 2,000 described species in 58 subgenera (Michener 2007, Gonzalez 2008). Diagnostic characters of genus *Megachile* include two submarginal cells in the forewing, stigma over twice as long as broad, and a lack of an arolium between the tarsal claws of both sexes, female with an abdominal scopa, female mandible with 3-5 teeth, and male T6 with a preapical carina (Michener 2007, Burrows *et al*. 2020). Species of *Megachile* are found on every continent except Antarctica in a diversity of landscapes and habitats, and they exhibit a wide range of floral preferences, behaviors, and morphological traits (Michener 2007, Gonzalez 2008).

Megachile species nest in cavities, including hollow plant stems, tunnels excavated by beetles, cavities excavated by the bees themselves in soil, rotting wood, or pithy plant stems, or in the case of the commercially managed alfalfa leafcutting bee, *Megachile rotundata* Fabricius, nesting boxes provided by farmers that use them for pollination (Michener 2007, Pitts-Singer and Cane 2011). Many species of *Megachile* use their mandibles to cut leaf pieces with which they line their nests and partition brood cells. Other species use mud, resin, flower petals, wood fibers, or other materials for this purpose (Gonzalez 2008). Sheffield *et al.* (2011) summarized what is known about nesting biology and floral use by many of the species of *Megachile* found in Montana, but there are several species for which little is known about various aspects of their life history.

Bees in the genus *Megachile* are of particular agricultural interest. The best-known species, *M. rotundata,* is an Old World native, introduced and managed widely for alfalfa [*Medicago sativa* (L.); Fabaceae] seed production (e.g., Gerber and Akre 1969, Pitts-Singer and Cane 2011). It is the second most economically important managed field crop pollinator behind the honey bee, *Apis mellifera* L. (Pitts-Singer and Cane 2011). Though there is a large body of research on *M. rotundata*, other species remain less known.

Species of *Megachile* may be of conservation interest, as one study showed that over 120 years, bees in the family *Megachilidae* declined at a higher rate than those of other families within a community, potentially because of habitat alteration impeding nesting (Burkle *et al.* 2013). However, there remains much to be studied about the biology, ecology, taxonomy, and distribution of *Megachile* species.

Theodore Bertis Mitchell (1890–1983) contributed a series of revisions, keys, and records of Nearctic *Megachile* species (1924, 1926, 1927a, 1927b, 1934, 1935a, 1935b, 1936, 1937a, 1937b, 1937c, 1937d, 1943, 1956). After Mitchell's work, Ivanochko (1979), followed by Sheffield *et al.* (2011), wrote keys to the *Megachile* of Canada with biological information, distributional records, and species treatments. Gonzalez and Griswold (2007) reviewed the subgenus *Argyropile* Mitchell of North and Central America. Bzdyk (2012) revised the subgenus *Litomegachile* Mitchell, making several taxonomic changes, and Gonzalez *et al*. (2019) proposed new combinations within the Megachilini. There are still many subgenera of *Megachile* that need revision (Gonzalez *et al*. 2019), and a general lack of regional keys and up-to-date distributional records.

The history of the study of Montana *Megachile* dates back only to 1899. The oldest Montana *Megachile* record we know of is an 1899 specimen collected at the Montana Experiment Station in Bozeman, now housed in the Montana Entomology Collection (MTEC) at Montana State University. Many early twentieth-century *Megachile* specimens in the MTEC were collected in Musselshell, Powderville, Florence, Bozeman, and Conrad, usually associated with early Montana Agricultural Experiment Station work. Much of this early material in the MTEC was identified by T. B. Mitchell and Grace Adelbert Sandhouse (1896–1940). William Livingston Jellison (1906–1995), a Montana bacteriologist with the U.S. Public Health Service, collected several early *Megachile* specimens from Ravalli, Beaverhead, and Flathead Counties in the 1930's. Yet, it took into the 1930's to accumulate 150 specimens from all sources we found.

The first published *Megachile* record for Montana was *Megachile pascoensis* Mitchell, published by Mitchell (1934). Between 1935 and 1944, T. B. Mitchell (1934, 1935a, 1935b, 1936, 1937a, 1937c, 1942) added 24 more Montana records of *Megachile* species (Table 1). The alfalfa leafcutting bee, *M. rotundata*, was first recorded in Montana in 1969, as a species being assessed for management in alfalfa seed production in the region (Gerber and Akre 1969).

Normal collecting work continued to expand the available, but unpublished, records of *Megachile* in Montana, mostly deposited in the MTEC, represented in a wide number of collections (Table 2). A few major efforts contributed a disproportionate amount of the whole.

Starting in 1984, Catherine Elaine Seibert has collected *Megachile* widely in Montana and maintains an extensive personal collection. The 1988 Red Bench Fire Project (Ivie *et al*. 1998), in Glacier National Park, yielded a large collection of *Megachile* from 1989 to 1993. From 1996–2015, Kevin M. O'Neill's ecological projects contributed documentation and specimens of *Megachile* (O'Neill and Seibert 1996, Jensen *et al*. 2003, O'Neill and O'Neill 2003, O'Neill *et al*. 2004, Fultz 2005, O'Neill *et al*. 2010, O'Neill and O'Neill 2011, O'Neill *et al*. 2011, Pearce *et al*. 2012, O'Neill *et al*. 2014, O'Neill *et al*. 2015). Most recently, Blanchette's (2019) thesis contributed extensive specimens from poorly-known eastern Montana.

Beginning with Kuhlman and Burrows (2017), a series of local faunal and ecological publications included a burst of new Montana records of *Megachile* (Kuhlman and Burrows 2017, Reese *et al*. 2018, Adhikari *et al*. 2019, Delphia *et al*. 2019a, LaManna *et al*. 2020) from Chouteau, Flathead, Gallatin, Lewis and Clark, Missoula, and Park Counties. These papers added an additional six species to the Montana list, contributing nearly 1,650 specimens to the pool.

Starting in 2014 and based at the MTEC, an effort to inventory the bees of Montana began (the Wild Bees of Montana Project or WBMT). The overarching goal of the WBMT is to collect representative material of all species across Montana, provide checklists, distributional data, and identification tools, as well as create an exhaustive dataset of specimens from Montana. The first product was Dolan *et al*.'s (2017) study of *Bombus* Latreille, documenting 28 species in the state. Further records resulting from the WBMT have been published by Delphia (2019), Delphia *et al*. (2019b), and Delphia and Griswold (2021).

As part of the overall goal of the WBMT, the objectives of the research presented in this thesis were to more fully document the diversity and distribution of species of *Megachile* in Montana, with emphasis on collecting in all 56 counties.

Material and Methods

Megachile Inventory

We first compiled a reference list and dataset of all known Montana records and specimens. This included collections known to hold Montana specimens, literature, theses, gray literature reports, and online data aggregators (Tables 1–3). We gave all specimens examined (including newly collected material as well as historical specimens without unique identifiers) a unique identifier label tied to the dataset. We incorporated literature records with unique specimen identifiers into the dataset, and these determinations were trusted without examination of the specimens (Kuhlman and Burrows 2017, Reese *et al*. 2018, Delphia *et al*. 2019a, Burkle *et al*. 2020, LaManna *et al*. 2020). When a publication mentioned occurance of a *Megachile* species, not linked to individual specimen data (e.g., MONTANA: 1♂, 1♀) (Mitchell 1934, 1935a, 1935b, 1936, 1937a, 1937b, 1937c, 1942, 1944, Butler 1965, Gerber and Akre 1969, Hurd 1979, O'Neill and Seibert 1996, O'Neill and O'Neill 2003, O'Neill *et al*. 2004, O'Neill *et al*. 2010, O'Neill and O'Neill 2011, O'Neill *et al*. 2011, Delphia and O'Neill 2012, O'Neill *et al*. 2014, O'Neill *et al*. 2015, Donahoo *et al*. 2021) we added pertinent information to first publication records (Table 1), but not the main dataset or corresponding figures utilizing specimen counts. We did not consider thesis or gray literature records for first published records.

We requested loans from collections that had online records of Montana *Megachile* and sent out a general request for Montana *Megachile* specimens to entomological museum collection managers via the Entomological Collections Network listserv. We attempted to borrow and verify all possible Montana *Megachile* specimens (Table 2).

After checking for repetition among specimen data from loans, online data sources (Symbiota Collections of Arthropods Network [SCAN], Global Biodiversity Information Facility [GBIF], Discover Life, and Biodiversity Information Serving Our Nation [BISON]), and publication records, we incorporated into our dataset those Montana *Megachile* specimen data from the online data aggregators SCAN and GBIF that met certain criteria (Table 3). (Data in BISON and Discover Life were not incorporated because all records were repeated in other sources.) If a SCAN or GBIF record had a unique specimen identifier, was housed in a specimen repository, and we were not able to borrow the physical specimen, we considered the data for inclusion in our dataset. If the species listed was already known to occur within a particular Montana county, we included the record in our dataset. If the occurance was a known Montana species but a new county record and there was a trusted determiner listed with the specimen, we included the specimen in our dataset. We did not incorporate data from specimens representing new county records with unknown determiners that we were unable to examine.

Repositories of either specimens examined or data records in databases (Tables 2, 3) (curators/staff responsible for loans are listed in parentheses):

AMNH – American Museum of Natural History, New York, New York (Jerome G. Rozen, Jr. and Corey S. Smith).

BBSL – U.S. National Pollinating Insects Collection housed in the USDA-ARS Pollinating Insects Collection, Logan, Utah (Terry Griswold).

BMEC – Bohart Museum of Entomology, University of California Davis, Davis, California

CAS-ENT – California Academy of Sciences Collection, San Francisco, California (Robert L. Zuparko).

CESC – Catherine E. Seibert Personal Collection, Belgrade, Montana (Catherine E. Seibert).

CUIC – Cornell University Insect Collection, Ithaca, New York.

EMEC – Essig Museum of Entomology, University of California, Berkeley, California (Peter T. Oboyski).

INHS – Illinois Natural History Survey Insect Collection, University of Illinois Urbana-Champaign, Champaign, Illinois (Tommy McElrath).

MCZC – Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts (Crystal A. Maier).

MSBA – Museum of Southwestern Biology, University of New Mexico, Albuquerque, New Mexico.

MTEC – Montana Entomology Collection, Montana State University, Bozeman, MT (Michael A. Ivie, Casey M. Delphia, and Kevin M. O'Neill, including the CMDC and KMOC).

OSUC – C.A. Triplehorn Insect Collection, The Ohio State University, Columbus, Ohio (Luciana Musetti).

SEMC – Snow Entomological Museum Collection, University of Kansas, Lawrence, Kansas (Jennifer C. Thomas, Victor H. Gonzalez, Zachary H. Falin).

SMRC – Severin McDaniel Insect Research Collection, South Dakota State University, Brookings, South Dakota (Paul J. Johnson).

TAMUIC – Texas A&M University Insect Collection, College Station, Texas (Karen W. Wright).

UCMC – University of Colorado Museum of Natural History, Boulder, Colorado (Virginia L. Scott).

UCRC – University of California Riverside Entomology Research Museum, Riverside, California (Douglas Yanega).

USDA-ARS NPARL – United States Department of Agriculture - Agriculture Research Service, Northern Plains Agricultural Research Laboratory, Sidney, Montana (Alexandra Morphew and Joshua Campbell).

USGS DRO – USGS Patuxent Wildlife Research Center, Laurel, Maryland (Sam Droege).

UTEP – University of Texas El Paso Entomology Collection, El Paso, Texas.

WFBM – William F. Barr Entomological Collection, University of Idaho, Moscow, Idaho (Luc Leblanc).

Field Collection of Montana *Megachile*

In 2019 and 2020 we prioritized collecting in eastern Montana counties lacking prior *Megachile* records, and Montana regions likely to hold potential new state *Megachile* records. We predicted new state records for *Megachile* species that were recorded from trusted records very near the Montana border, from two "sides" of Montana (e.g., Saskatchewan and Wyoming, or Idaho and South Dakota), or from habitats continuous with Montana landscapes. Examples of habitats similar to and continuous with Montana's habitats include prairie potholes in the western Dakotas and southern Prairie Provinces, Dakota shortgrass prairies, the Missouri Breaks and other Badland habitats, xeric regions of the western Dakotas and/or northern Wyoming, and the areas from the northern Wasatch Mountains into southwestern Idaho. Predictions of potential new Montana records led us to targeted collecting near Baker, Caldera, Medicine Rocks State Park, and Bridger in the summers of 2019 and 2020.

We collected bees from May through September each year using several collecting methods: pan traps ("bee bowls"), netting, trap nests, bee buckets, Lindgren funnels, and vane traps, with an emphasis on pan traps and netting. At pan-trap sites we placed a series of 15 colored (7 yellow, 6 blue, and 2 white), 20 oz. ice-cream bowls filled 75% with soapy water (modified from Droege 2015) at ground level for approximately 24 hours. We then retrieved the samples and stored them in 70% EtOH until being brought to the lab for processing (see Specimen Processing). We attached trap nests [bundles of cardboard tubes within which solitary bees will create nests (Staab *et al*. 2018)] to tree branches approximately 2 m from the ground with their openings facing southeast. Traps were placed in the spring and retrieved in the fall or following spring. Cardboard tubes that appeared to have nesting activity were put in plastic containers with screen lids and placed in cold storage (6°C) to induce diapause, after which they were removed and brought to room temperature to initiate bee emergence. Bycatch from the statewide Montana Pest Survey Program's bucket traps (Brambila *et al*. 2021), Lindgren funnels (Lindgren 1983), and crossvane-panel traps (Czokajlo *et al*. 2001) was added to the dataset. Pan trapping kits were sent to one-room schoolhouses with a lesson plan on sampling bees. These schools represented areas identified as having low prior sampling.

Specimen Processing

Bees netted in the field were pinned the same day. Alcohol preserved bees from pan traps, lindgren funnels, and vane traps were washed and blow-dried following Droege (2015) before pinning or point mounting. We labeled mounted specimens with locality information and unique specimen identifier labels (barcodes). We recorded these data in an Excel spreadsheet (See Data Entry and Analysis) and archived the specimens in the MTEC.

Species Identification

We identified *Megachile* specimens using the most current taxonomic keys available (Mitchell 1934, 1935a, 1935b, 1936, 1937a, 1937b, 1937c, 1937d, 1962, 1980, Sheffield *et al*. 2011, Bzdyk 2012, Sheffield 2020) and with comparison to reference specimens including those species identified as potential new state records. Terry Griswold, at the USDA-ARS Pollinating Insects Research Unit in Logan, UT, verified species identifications of material collected before 2020. We follow the classification of Hurd (1979) and Michener (2000) as clarified by Raw (2002) and incorporated by Michener (2007) (but see Gonzalez *et al*. 2019 for alternative combinations).

Data Entry and Analysis

We entered Darwin-compliant data for each specimen according to the xBio:D format (https://xbiod.osu.edu/). For specimens and records lacking georeferencing data, we used Google Earth® (http://earth.google.com) to approximate localities and entered them in the dataset as "polygons." Locality information from previously databased records were checked and corrected as needed using Google Earth®.

We included published specimen data for specimens we did not examine in our dataset from Kuhlman and Burrows (2017), Reese *et al.* (2018), Delphia *et al.* (2019a), and LaManna *et al.* (2020). For records appearing in more than one publication, records were reported under the last publication. If no exact collection date was available, we used the last year of collecting recorded in the publication.

Female specimens identified as *Megachile latimanus* Say/*Megachile perihirta* Cockerell or identifications without sex listed were treated in analyses as *M. perihirta*. Males identified as *Megachile lapponica* Thomson/*Megachile relativa* Cresson or identifications without sex listed were treated in analyses as *M. relativa*. See "Taxonomic Challenges" below.

The dataset was used to analyze history of species discovery, specimen accumulation, species accumulation, county-level occurance, and first county records. Literature records that did not have unique specimen identifiers were not used in the analysis of specimen numbers. When the literature provided earliest county records, we included them in the county record accumulation graph and county-level distribution maps. In the absence of specimen data, we used the year corresponding to the publication for earliest county records.

We generated a Chao1 species richness predictor from our dataset using EstimateS (Colwell 2013). We considered the state a single sample, ran the data as an "individual-based abundance sample" with specimen counts for each species, and randomized the sample 100 times. EstimateS generated a Chao1 mean species richness predictor and the species accumulation curve.

Upon publication of this work, we will deposit the data in xBioD, The Ohio State University biodiversity cyberinfrastructure, a publicly accessible database operated by The Ohio State University (https://xbiod.osu.edu/).

Key Creation

We wrote and illustrated taxonomic keys and accompanying notes based on the accumulated Montana *Megachile* specimens, reference material, and characters used in publications (Mitchell 1924, 1926, 1927a, 1927b, 1934, 1935a, 1935b, 1936, 1937a, 1937b, 1937c, 1937d, 1962, Ivanochko 1979, Sheffield *et al*. 2011, Bzdyk 2012, and Sheffield 2020). Our keys build on these works, and we acknowledge them as the source of some of the terminology and wording used. We used entomological terms according to Torre-Bueno (1989). Variation of Montana specimens from published data is reflected in the wording of our key.

We created illustrations in Adobe Illustrator (with an XP-PEN Deco 01-V2 tablet) based on photos taken with a Canon 6D DLSR with an MP-E 65mm lens and an iPhone 11, illustrations from Bzdyk (2012), and photos from Sheffield *et al*. (2011). Any images traced from Bzdyk (2012) or Sheffield *et al*. (2011) are labeled accordingly.

Nomenclatural Records

Synonymical tables were created for all species recorded from Montana. Citations are limited to those that have Montana records or are critical to understanding the names used here. For more complete citations, see Hurd (1979), Raw (2002), Michener (2007), Sheffield *et al*. (2011), Bzdyk (2012), and Gonzalez *et al*. (2019).

Results

We document 35 species of *Megachile* in Montana, based on 4,968 specimens from all 56 counties (Table 4, Fig. 1, Supplemental File A). This includes new state records for six species: *Megachile casadae* Cockerell, *Megachile centuncularis* Linnaeus, *Megachile gentilis* Cresson, *Megachile mellitarsis* Cresson, *Megachile mendica* Cresson, and *Megachile snowi* Mitchell. Based on our analyses, we identified 10 additional potential species that may be found in the state with future sampling, mainly from records in the Wasatch, Great Plains, and northern Wyoming (see Discussion).

We included specimen data from 9 publications, 15 natural history collections, and digital data from 14 institutions and individuals (Tables 1–3). Based on our qualifiers for use of digital data, we excluded two records from our dataset, as they were new county records with unknown determiners that we did not reexamine (SEMC469014, *Megachile parallela* Smith from Ravalli Co. and BBSL988318, *Megachile dentitarsus* Sladen from Cascade Co.). Supplemental File A includes the entire dataset of Montana *Megachile*.

Mitchell literature records of Montana *Megachile* (1934, 1935a, 1935b, 1936, 1937a, 1937b, 1937c, 1942, 1944) did not have unique specimen identifiers and were not used in the analysis of specimen numbers. We did include Mitchell county records in the county record accumulation graph and county-level distribution maps.

Documented localities of Montana *Megachile* specimens are shown in Figure 2. The largest fraction of *Megachile* specimens has been collected in the two western counties of Gallatin and Missoula, together accounting for 2,091 specimens, or 42.1% of the total (Figs. 3, 5). In contrast, 8 (of 56) counties have less than 10 specimens of *Megachile*, and 46 have less than 100 (Fig. 5). Gallatin, Missoula, Lewis and Clark, Jefferson, and Ravalli Counties, all in the west, also have five of the six highest counts of *Megachile* species documented (Figs. 6, 7). Most specimens (55.27%) were collected from 2015–2020, as part of the WBMT project and other recent studies (Figs. 3, 8).

The Chao1 analysis predicts 35–39 species of *Megachile* to occur in Montana (Fig. 9) (mean = 35.2 [SD: ± 0.62; 95% CI: 35.01, 39.08]). Supplemental File B contains the EstimateS input data.

<u>Result of Recent Sampling Effort</u>

In 2019–2020, the WBMT group prioritized *Megachile* specimen collecting statewide, especially in eastern counties. This was strengthened by the efforts of other research groups working in specific areas on ecological projects. Together, these collecting efforts from 2015 to 2020 resulted in significantly increased *Megachile* county records, state species records, and specimen collection (Figs. 3, 4, 5, 6, 8, 10, 11).

Records predating the WBMT project (1899–2014) documented 2,217 *Megachile* specimens (Fig. 3a). From 2015–2020, the number of specimens increased by 2,746 to 4,968 (124%) (Figs. 3b, 5, 8). Thirty-one species of Megachile were recorded in the state in 2014 (Fig.

4a), which increased to 35 by 2020 (Figs. 4b, 6, 10). Before the WBMT project, there were 272 county records (i.e., species by county), representing 43 counties (out of 56). By 2020, this increased by 214 (79%) to 486 county records (Fig. 11) representing all 56 counties (Figs. 3, 4).

Independent of the WBMT, the number of specimens especially increased in Missoula County after 2014, as intensive sampling on the MPG Ranch added 11 species of *Megachil*e and 1,010 specimens (Kuhlman and Burrows 2017). Large increases in *Megachile* specimens also occurred with targeted collecting by the WBMT group in Big Horn, Carbon, and Fallon Counties (Fig. 5). As late as 2019–2020, targeted *Megachile* sampling added the first specimen records to five Montana counties (Blaine, Custer, Daniels, Dawson, and Sheridan Counties) and added a statewide total of 1,106 specimens (22% of the total) and 124 county records (26% of the total) (Figs. 5, 8, 11). Targeted collecting at Medicine Rocks State Park resulted in collection of two specimens of *Megachile dakotensis* Mitchell, which had not been found in the state for 85 years (Mitchell 1936) and was predicted to occur in the area based on the known distribution of the species (see Discussion). Total specimens collected for each species are shown in Figure 12, and the accumulation of specimens per species in Figure 13.

Collecting Methods

Our project and other contributing data used many different methods to capture *Megachile* specimens. We pan-trapped *Megachile* at 77 localities in 2019 and 157 in 2020. We netted *Megachile* at 51 localities in 2019 and 34 in 2020. We deployed 25 trap nests in May and June of 2019 at widespread sites in Montana. These were collected in August and September 2019 (16) or spring 2020 (9). In 2019, bycatch from 5 bucket traps, 58 Lindgren funnels, and 29 vane traps across 29 sites was processed. In 2020, bycatch from 50 Lindgren funnels and 25 vane traps across 25 sites was processed.

Eight schools, located in Bloomfield (Dawson Co.), Spring Creek (Big Horn Co.), Molt (Stillwater Co.), Cooke City (Park Co.), Wolf Creek (Lewis and Clark Co.), Miami (Pondera Co.), Polaris (Beaverhead Co.), and Pass Creek (Gallatin Co.), contributed bee samples that were integrated into the WBMT.

We cannot analyze the efficacy of different collecting methods to trap *Megachile* from this project, as standardized protocols were not used. However, we present the number of specimens taken by different collecting methods recorded in our dataset in Table 5. Pan traps accounted for most of the *Megachile* records, while netting was the second most common. Notably, the new state record of *M. snowi* is represented by a single specimen collected in a Lindgren funnel with an EtOH lure.

Erroneous Records

Six erroneous historical records were identified and vouchers were either reassigned or excluded from the dataset. See Discussion below.

Key to the *Megachile* Species of Montana

This key was written based on previous works by Mitchell (1924, 1926, 1927a, 1927b, 1934, 1935a, 1935b, 1936, 1937a, 1937b, 1937c, 1937d, 1962, 1980), Ivanochko (1979), Sheffield *et al*. (2011), and Bzdyk (2012).

Difficulties in identifying *Megachile* to species often arise with specimens that were old when collected (i.e., they display wing and mandibular wear), grimy specimens, and specimens with closed mandibles or leg positioning that may obscure characters. Specimens may be re-washed in hot water and soap to remove grime from setae or teeth and then carefully blow-dried. If the mandibles are closed, opening the mandibles of a relaxed specimen using a pin may be useful. Similarly, repositioning the legs away from the body of a relaxed specimen can help for viewing certain characters, especially in males, as can pulling the terga, especially T6, in females.

The genus *Megachile* is characterized by having two submarginal cells subequal in length, no arolium between the tarsal claws, a labrum that is longer than wide, an apically depressed first abdominal tergite, and 3-jointed maxillary palpi. Females display scopa on the sternites, and males display a preapical carina on T6 (Mitchell 1934, Michener 2007, Burrows *et al*. 2020). Users should refer to Michener, McGinley, and Danforth (1994) to first identify a specimen to the genus *Megachile*. Entomological terms follow Torre-Bueno (1989). Certain species key out multiple times to account for variation in characters.

Abbreviations used in key:

Pd: Puncture diameter, a metric used to measure spacing between punctures.

S1-S6: Sternal segments (sterna) on the ventral surface of the metasoma.

T1-T6: Tergal segments (terga) on the dorsal surface of the metasoma.

<u>Key to *Megachile* species of Montana: male specimens</u>.

1. Front basitarsus not excavated ventrally, usually narrow (Fig. 14A), often brown to black 2

1'. Front basitarsus excavated ventrally, usually widely expanded (Fig. 14B), often white to yellow (except *M. gemula* which has an excavated but narrow, dark brown to black front basitarsus) 19

2(1). T6 (anterior to the transverse carina, Fig. 20) with tomentose, pale setae 3
2'. T6 (anterior to the transverse carina) bare or with sparse setae 12

3(2). T2 with lateral, ovate fovea 4
3'. T2 without lateral, ovate fovea 5

4(3). T3 with lateral, ovate fovea ....*Megachile* (*Eutricharaea*) *apicalis* Spinola
4'. T3 without lateral, ovate fovea .... *Megachile* (*Eutricharaea*) *rotundata* (Fabricius)

[Note: *Megachile* (*Eutricharaea*) *concinna* Smith also keys out at 4'. This species has not been recorded from Montana but is an introduced species that could potentially occur in the state. *Megachile concinna* has a genal tooth posterior to the ventrad point of mandibular attachment that is longer than wide, whereas *M. rotundata* has a genal tooth that is as long as wide.]

5(3'). T5 with white apical setal band, sometimes reduced to lateral sides, sometimes in depressed apical groove 6
5'. T5 without white apical setal band 11

6(5). T6 transverse carina deeply emarginate medially (Fig. 19A) 7
6'. T6 transverse carina weakly emarginate, often appearing as a continuous jagged edge (Fig. 19B) .... *Megachile* (*Litomegachile*) *brevis* Say

7(6). Mandible 4-toothed; apical margin of T6 (ventrad the transverse carina) with two pairs of prominent teeth laterally (Fig. 20A) .... *Megachile* (*Argyropile*) *parallela* Smith
7'. Mandible 3-toothed; apical margin of T6 (ventrad the transverse carina) with two pairs of small teeth laterally (Fig. 20B) 8

8(7'). Front tarsomeres 2-4 light to dark yellow .... *Megachile* (*Litomegachile*) *coquilletti* Cockerell
8'. Front tarsomeres 2-4 brown to black 9

9(8'). Apical margin of T6 (ventrad the transverse carina) with submedian teeth closer to each other than to lateral teeth, or distances subequal (Fig. 21A) .... *Megachile* (*Litomegachile*) *snowi* Mitchell
9'. Apical margin of T6 (ventrad the transverse carina) with submedian teeth closer to lateral teeth than to each other (Fig. 21B) 10

10(9'). Scutum and tergites with white and black intermixed pubescence .... *Megachile* (*Litomegachile*) *texana* Cresson
10'. Scutum and tergites with mostly white pubescence .... *Megachile* (*Litomegachile*) *lippiae* Cockerell

11(5') T4-5 somewhat dull, with punctures ~1 pd apart .... *Megachile* (*Litomegachile*) *gentilis* Cresson

11'. T4-5 polished and shiny, with punctures 2-4 pd apart ....
....*Megachile* (*Litomegachile*) *mendica* Cresson

12(2'). S4 not visible, retracted...13
12'. S4 visible 14

13(12). Front coxa covered with dense, plumose setae obscuring small coxal spine; vertex of head with large, sparse punctation (~4 punctures between lateral ocelli and posterior margin of vertex) ....*Megachile* (*Chelostomoides*) *campanulae* (Robertson)
13'. Front coxa with short setae not obscuring small coxal spine; vertex of head with small and dense punctation (~9 punctures between lateral ocelli and posterior margin of vertex) ....
....*Megachile* (*Chelostomoides*) *angelarum* Cockerell

14(12'). Front coxal spine present, may be reduced to a small nub and covered with dense orange setae 15
14'. Front coxal spine absent 18

15(14). Front coxal spine prominent, longer than wide..16
15'. Front coxal spine nub-like, wider than long and covered with dense orange setae 17

16(15). Ocelloccipital distance greater than ocellocular distance (Fig. 18A); T2-4 strongly depressed basally and apically (Fig. 23A)............ *Megachile (Megachiloides) dakotensis* Mitchell
16'. Ocelloccipital distance less than ocellocular distance (Fig. 18C); T2-4 moderately depressed basally but not depressed apically (Fig. 23B)..
....*Megachile* (*Litomegachile*) *onobrychidis* Cockerell

17(15'). Mandibular teeth unevenly spaced, 2nd tooth closer to apical tooth; ocelloccipital distance longer than ocellocular distance (Fig. 18A); body size 11-16 mm long ....
....*Megachile* (*Megachile*) *inermis* Provancher
17'. Mandibular teeth evenly spaced from one another; ocelloccipital distance approximately subequal to ocellocular distance (Fig. 18B); body size 9-11mm long ....
.... *Megachile* (*Megachile*) *montivaga* Cresson

18(14'). Clypeal margin with small triangular median tubercle...
.... *Megachile* (*Megachile*) *lapponica* Thomson and *Megachile* (*Megachile*) *relativa* Cresson

[Note: The males of *M. lapponica* and *M. relativa* cannot be reliably separated in Montana based on morphology.]

18'. Clypeal margin without median tubercle...
....*Megachile* (*Megachile*) *centuncularis* (Linnaeus)

19(1'). Middle basitarsus with smooth, setae-less protuberance ventrally; middle tibia without apical spur (Figs. 15A-B) 20
19'. Middle basitarsus without protuberance ventrally; middle tibia with apical spur (Fig. 15C) 22

20(19). Ventral mesepisternum (from ventral view of mesosoma, directly anterior to middle coxa) with small spine ....*Megachile* (*Xanthosarus*) *dentitarsus* Sladen
20'. Ventral mesepisternum (from ventral view of mesosoma, directly anterior to middle coxa) with smooth, spineless carina 21

21(20'). Middle basitarsus from anterior view with narrow, fin-shaped protuberance basally (Fig. 15B) ....*Megachile* (*Xanthosarus*) *perihirta* Cockerell
21'. Middle basitarsus from anterior view with quadrate protuberance basally (Fig. 15A) ....*Megachile* (*Xanthosarus*) *latimanus* Say

22(19'). Mandibles 4-toothed 23
22'. Mandibles 3-toothed 25

23(22). Front femur with two brown stripes ventrally...... *Megachile* (*Xanthosarus*) *frigida* Smith
23'. Front femur without two brown stripes ventrally (often one stripe occurs on *M. circumcincta*) 24

24(23'). Front tibia with dark small spine on apical rim…*Megachile* (*Xanthosarus*) *gemula* Cresson

[Note: *Megachile* (*Xanthosarus*) *circumcincta* (Kirby) also keys out at 24. This species has not been recorded from Montana but could potentially occur in the state. *Megachile circumcincta* has an apical setal band on T5, a pale front tibial spine (*Megachile gemula* has a dark front tibial spine), and often has one brown stripe on the front femur, ventrally.]

24'. Front tibia with rounded, flattened, pale tubercle on apical rim....................................... ....*Megachile* (*Xanthosarus*) *melanophaea* Smith

25(22'). Front coxal spine thin and narrowly pointed (Fig. 17A) 26
25'. Front coxal spine wide and spatulate (Fig. 17B) 28

26(25). T5 without white apical setal band; front tarsi distinctly yellow ....*Megachile* (*Sayapis*) *mellitarsis* Cresson
26'. T5 with white apical setal band; front tarsi white or pale yellow to dark brown 27

27(26'). Scoop-shaped dilation of front basitarsus with dark setae along 1/3 of anterior margin.... .... *Megachile* (*Sayapis*) *pugnata* Say

27'. Scoop-shaped dilation of front basitarsus with dark setae along entire anterior margin.... ....*Megachile* (*Sayapis*) *fidelis* Cresson

[Note: *Megachile* (*Sayapis*) *inimica* Cresson also keys out at 27'. This species has not been recorded from Montana but could potentially occur in the state. *Megachile inimica* has a patch of short, suberect setae at the base of the front coxal spine (setae shorter than flagellomere 1), while *M. fidelis* has a few long, erect setae (setae longer than flagellomere 1) at the base of the front coxal spine.]

28(25'). Genal margin directly posterior to the ventral mandibular attachment with tooth as-long-as or longer-than-wide (the forelegs may need to be repositioned to see this character) (Fig. 25A) 29

28'. Genal margin directly posterior to the ventral mandibular attachment without obvious tooth, often with a tuft of setae (Fig. 25B) 31

29(28). Front coxal spine with short, suberect setae in patch at base (Fig. 17B) ....*Megachile* (*Megachiloides*) *nevadensis* Cresson

[Note: *Megachile nevadensis* has not been recorded in Montana since 1937 when Mitchell published an occurrance record from Bozeman (Mitchell 1937a). We could not locate this specimen to verify the accuracy of this record.]

29'. Front coxal spine without patch of setae at base 30

30(29'). Ventral mesepisternum (from ventral view of mesosoma, directly posterior to the front coxal spine) with smooth, rounded carina, not protruding; hind tarsomeres triangular from lateral view (Fig. 16A)....................*Megachile* (*Megachiloides*) *manifesta* Cresson

30'. Ventral mesepisternum (from ventral view of mesosoma, directly posterior to the front coxal spine) with protruding triangular carina; hind tarsomeres quadrate from lateral view (Fig. 16B)...*Megachile* (*Megachiloides*) *wheeleri* Mitchell

31(28'). Pubescence on mid and hind legs mostly black .... *Megachile* (*Megachiloides*) *subnigra* Cresson

31'. Pubescence on mid and hind legs mostly pale 32

32(31'). Clypeal margin emarginate medially and laterally (Figs. 22A-B)..................................33

32'. Clypeal margin mostly straight, with slight emargination medially (Fig. 22C)................. ....*Megachile* (*Megachiloides*) *casadae* Cockerell

33(32). T5 with white apical setal band; clypeal margin with deep U-shaped median emargination (as deep as wide) (Fig. 22A); S5 narrowly rimmed apicomedially with dark brown setae (Fig. 24A); hind femur with hint of light fovea dorsally ....*Megachile* (*Megachiloides*) *pascoensis* Mitchell

33’. T5 without white apical setal band; clypeal margin with wide, shallow median emargination (2-3 times as wide as deep) (Fig. 22B); S5 with black apicomedial setal patch (Fig. 24B); hind femur with distinct, elongate, brown fovea dorsally ....*Megachile (Megachiloides) anograe* Cockerell

[Note: *Megachile (Callomegachile) sculpturalis* Smith also keys out at 33’. This species has not been recorded from Montana but is an introduced species that could potentially occur in the state. *Megachile sculpturalis* has extremely large, unevenly-spaced punctures on T2-3, T2-4 basally depressed, T2-5 without white apical setal bands, a carinate genal margin, and a body size >20 mm long. It does not have dorsal fovea on the hind femur as in *M. anograe*.]

<u>Key to *Megachile* species of Montana: female specimens</u>.

1. Sterna with white apical setal bands between scopal setae (Fig. 26); T2 with lateral, ovate fovea 2
1’. Sterna without white apical setal bands between scopal setae; T2 without lateral, ovate fovea.. 3

2(1). S5 scopal setae black; clypeal margin with small median tubercle (Fig. 28A); T3 with lateral, ovate fovea...*Megachile* (*Eutricharaea*) *apicalis* Spinola
2’. S5 scopal setae white, sometimes half-black; clypeal margin without median tubercle, essentially straight; T3 without lateral, ovate fovea .... *Megachile* (*Eutricharaea*) *rotundata* (Fabricius)

[Note: *Megachile* (*Eutricharaea*) *concinna* Smith also keys out at 2’. This species has not been recorded from Montana but is an introduced species that could potentially occur in the state. *Megachile concinna* has black setae laterally on T5-6 at most, while *M. rotundata* has black setae laterally on T2-6.]

3(1’). Metasoma in dorsal view rounded, T2-3 widest, then narrowing from T4-6 (Fig. 27A) 4
3’. Metasoma in dorsal view subparallel, T2-4 subequal in width (Fig. 27B) 32

4(3). Terga without white apical setal bands; T1-2 covered in light yellow to white pubescence contrasting dark pubescence on T3-5 5
4’. Most terga with white apical setal bands; T1-2 sometimes with light pubescence, but T3-5 without entirely black pubescence...7

5(4). S2-6 scopal setae orange; T6 usually with pale appressed setae... ....*Megachile* (*Xanthosarus*) *melanophaea* Smith

[Note: *Megachile* (*Xanthosarus*) *circumcincata* (Kirby) also keys out at 5. This species has not been recorded from Montana but could potentially occur in the state. *Megachile circumcincta* has entirely pale pubescence on the ventral mesosoma and coxae, a median impunctate line on the clypeus, and no excision on the inner mandibular tooth.]

5’. S2-6 scopal setae reddish-brown to black; T6 usually with dark appressed setae 6

6(5). Fourth tooth truncate (Fig. 30E); mandible from lateral view square basally, with parallel sides for a distance as long as wide, then tapering apically (Fig. 29B); S2-6 scopal setae reddish-brown to black .... *Megachile* (*Xanthosarus*) *gemula* Cresson
6’. Fourth tooth pointed (Fig. 30B); mandible from lateral view gradually tapering in width towards apex (Fig. 29A); S2-6 scopal setae entirely black ....
.... *Megachile* (*Megachiloides*) *subnigra* Cresson (part)

7(4’). S2-4 scopal setae entirely black .... *Megachile* (*Megachiloides*) *subnigra* Cresson (part)

[Note: There is a pale form of *M. subnigra* that has not been recorded from Montana but could potentially occur in the state. This form has all white scopal setae.]
[Note: Rare, melanistic forms of *Megachile (Megachiloides) anograe* Cockerell (S2-6 scopal setae black) also key out at 7 but have 3-toothed mandibles. This form has not been recorded from Montana.]

7’. S2-4 scopal setae usually white, yellow, or orange 8

8 (7’). Mandible 3-toothed (Fig. 30A) 9
8’. Mandible 4- (Figs. 30B-E) or 5-toothed (Figs. 30F-H) 10

9 (8). T6 smooth and shiny, with punctures 3-5 pd apart ....
.... *Megachile* (*Megachiloides*) *anograe* Cockerell
9’. T6 pitted and dull, with punctures ≤ 1 pd apart ....
.... *Megachile* (*Megachiloides*) *pascoensis* Mitchell

10(8’). Mandibles without cutting edge beneath (ventrad) the tooth plane; 5-toothed; elevated ridge running diagonally across surface of mandible from apex of 2nd tooth to mandibular acetabulum (Fig. 30H)............... *Megachile* (*Megachile*) *montivaga* Cresson
10’. Mandibles with cutting edge beneath (ventrad) the tooth plane, sometimes only present as small angled edge (Figs. 30B-G); 4- or 5-toothed; mandible surface without elevated ridge 11

11(10’). Mandibles 4-toothed (Figs. 30B-E) 12
11’. Mandibles 5-toothed (Figs. 30F-G) 27

12(11). Mandibles with extra protuberance between 3rd and 4th tooth, appearing as a weak additional tooth (i.e., approaching 5-toothed) (Fig. 30D) 13
12’. Mandibles distinctly 4-toothed (Figs. 30B-C, 30E) 15

13(12). S2-4 scopal setae ivory; T6 weakly concave (Fig. 31A).. .... *Megachile* (*Litomegachile*) *gentilis* Cresson
13'. S2-4 scopal setae yellow to orange; T6 straight (Fig. 31B) 14

14(13'). T6 with brown appressed setae ....*Megachile* (*Litomegachile*) *mendica* Cresson
14'. T6 with pale appressed setae ....*Megachile* (*Litomegachile*) *snowi* Mitchell

15(12'). Clypeus shiny and sparsely punctate medially (punctures 2-3 pd apart), becoming more densely punctate laterally ....*Megachile* (*Megachiloides*) *casadae* Cockerell
15'. Clypeus with dense punctation medially and laterally (punctures ≤ 1 pd apart)............16

16(15'). Mandibles with asymmetrical emargination between tips of 3rd and 4th tooth, emargination deepest closer to 4th tooth (Fig. 30C) AND mandible from lateral view gradually tapering in width towards apex (Fig. 29A)...17
16'. Mandibles with semicircular, symmetrical emargination between tips of 3rd and 4th tooth (Fig. 30B) AND mandible from lateral view square basally, with parallel sides for a distance slightly shorter than wide, then tapering apically (Fig. 29C) 21

17(16). Fourth tooth truncate (Fig. 30E)........................... *Megachile* (*Xanthosarus*) *frigida* Smith
17'. Fourth tooth pointed (Fig. 30B-C)..18

18(17'). T3-5 strongly concave medially between surrounding apical and basal grooves, when viewed from lateral profile (Fig. 32); ocellocular distance shorter than ocelloccipital distance (Fig. 18A) ....*Megachile* (*Megachiloides*) *dakotensis* Mitchell
18'. T3-5 continuous from lateral profile, without deep basal and apical grooves; ocellocular distance longer than ocelloccipital distance (Fig. 18C)..19

19(18'). T5 with punctures 2-4 pd apart medially, surface polished and shiny................................ ....*Megachile* (*Megachiloides*) *wheeleri* Mitchell
19'. T5 with punctures ≤ 1 pd apart medially, surface matte to shiny.................................20

20(19'). S5 scopal setae all white; area directly posterior of scutum center with variable punctation 1-2 pd apart ....*Megachile* (*Megachiloides*) *nevadensis* Cresson

[Note: *Megachile nevadensis* has not been recorded in Montana since 1937 when Mitchell published an occurance record from Bozeman (Mitchell 1937a). We could not locate this specimen to verify the accuracy of this record.]

20'. S5 scopal setae at least partly black; area directly posterior of scutum center with consistently spaced punctures almost touching ......*Megachile* (*Megachiloides*) *manifesta* Cresson

21(16'). S6 scopal setae mostly light, ivory to orange (can be half black)...................................22
21'. S6 scopal setae mostly black 24

22(21). Clypeal margin with two broadly incurved emarginations (Fig. 28B); tarsi reddish brown, contrasting black tibia ....*Megachile* (*Sayapis*) *mellitarsis* Cresson (part)
22'. Clypeal margin straight and even; tarsi brown to black, not contrasting tibia 23

23(22'). S6 upcurved at the tip, extending beyond T6 (Fig. 31D); T6 straight in lateral profile with light, velvety, appressed setae (Fig. 31D) .. *Megachile* (*Argyropile*) *parallela* Smith
23' S6 not upcurved, not extending beyond T6; T6 convex basally and concave apically in a "pinched shape" in lateral profile (Fig. 31C); T6 with suberect, light setae .... *Megachile* (*Litomegachile*) *brevis* Say

24(21'). T2-3 in dorsal view with lateral, erect black setae... ....*Megachile* (*Litomegachile*) *texana* Cresson
24'. T2-3 in dorsal view without lateral, erect black setae 25

25(24'). T6 strongly convex basally and concave apically in a "pinched shape" in lateral profile (Fig. 31C) ....*Megachile (Litomegachile) onobrychidis* Cockerell
25'. T6 concave apically in lateral profile (Figs. 31E-F)...26

26(25'). T6 with suberect pale setae and erect black setae; T6 concave apically in lateral profile (Fig. 31F); apical margin of clypeus with short median carina 2x as long as diameter of median ocellus (Fig 28C) .... *Megachile* (*Litomegachile*) *lippiae* Cockerell
26'. T6 with suberect and erect brown to black setae (sometimes with suberect pale setae in small patches laterally); T6 slightly to moderately concave apically in lateral profile (Fig 31E); apical margin of clypeus with long carina 4x as long as diameter of median ocellus (Fig 28D) .... *Megachile* (*Litomegachile*) *coquilletti* Cockerell

27(11'). Mandibles with deepest emargination between tips of 3rd and 4th tooth, emargination strongly angled towards 4th tooth (Fig. 30F) 28
27'. Mandibles with emarginations between teeth similar in depth (Fig. 30G) 29

28(27). T3-5 with apical setal bands consistently wide, as wide medially as laterally (Fig 34A); T1-2 usually covered in white pubescence; T6 with appressed pale setae......................... ....*Megachile* (*Xanthosarus*) *dentitarsus* Sladen
28'. T3-5 with apical setal bands narrower (or missing) medially, often incomplete (Fig 34B); T1-2 usually covered in yellow to orange pubescence; T6 with appressed yellow to orange setae .... *Megachile* (*Xanthosarus*) *latimanus* Say and *Megachile* (*Xanthosarus*) *perihirta* Cockerell

[Note: The females of *M. latimanus* and *M. perihirta* cannot be reliably separated in Montana based on morphology.]

29(27'). Body size 17-20 mm long; clypeus shiny and sparsely punctate medially (punctures 1-3 pd apart); clypeal margin with four tubercles *Megachile* (*Megachile*) *inermis* Provancher
29'. Body size 9-12 mm long; clypeus densely punctate medially (punctures ≤1 pd apart); clypeal margin variable but without four prominent tubercles 30

30(29'). S6 scopal setae black ....*Megachile* (*Megachile*) *lapponica* Thomson
30'. S6 scopal setae mostly yellow to orange 31

31(30'). T6 with black setae ....*Megachile* (*Megachile*) *centuncularis* (Linnaeus)
31'. T6 with golden setae..*Megachile* (*Megachile*) *relativa* Cresson

32(3'). Genal margin with pronounced tooth posteriorly (Fig. 33); clypeal margin with one medial and two lateral tubercles .... *Megachile* (*Sayapis*) *pugnata* Say
32'. Genal margin without tooth posteriorly; clypeal margin variable....................................33

33(32). Mandibles without cutting edge between 2nd and 3rd tooth, beneath (ventrad) the tooth plane 34
33'. Mandibles with cutting edge between 2nd and 3rd tooth, beneath (ventrad) the tooth plane 35

34(33). T5 with a white apical setal band ....*Megachile* (*Chelostomoides*) *angelarum* Cockerell
34'. T5 without a white apical setal band ....*Megachile* (*Chelostomoides*) *campanulae* (Robertson)

[Note: *Megachile (Callomegachile) sculpturalis* Smith keys out at 34'. This species has not been recorded from Montana but could potentially occur in the state. *Megachile sculpturalis* has yellow pubescence on T1 with a white apical setal band, black apical setal bands on T2-5, T2-6 are depressed basally and coarsely pitted apically, and a large body size (21-25 mm).]

35(33'). Clypeal margin with two broadly incurved emarginations (Fig. 28B) ....*Megachile* (*Sayapis*) *mellitarsis* Cresson (part)

[Note: *Megachile* (*Sayapis*) *inimica* Cresson also keys out at 35. This species has not been recorded from Montana but could potentially occur in the state. *Megachile inimica* has all red or all black legs, while *Megachile mellitarsis* has red tarsi contrasting with the black tibia.]

35'. Clypeal margin with two prominent, wide, lateral tubercles (at least as long as wide), surrounding median triangular tubercle....................*Megachile* (*Sayapis*) *fidelis* Cresson

Synonymical Tables of Montana *Megachile* Species

The following synonymical tables are not exhaustive and represent literature records for Montana and relevant nomenclatural acts important to understanding our usage, including usage in papers cited in the text. Species are arranged alphabetically, irrespective of subgenus, for ease of locating. We followed the classification of Hurd (1979), modified by Michener (2000), with placements validated by Raw (2002) and incorporated by Michener (2007).

***Megachile* (*Chelostomoides*) *angelarum* Cockerell, 1902**

Megachile angelarum Cockerell, 1902: 70. Burkle *et al*. 2020: 7.
Megachile (*Chelostomoides*) *angelarum*; Mitchell 1937d: 386; 1956: 131. Sheffield *et al*. 2011: 26. Kuhlman and Burrows 2017: 12. Reese *et al*. 2018: 21. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 69.
Chalicodoma (*Chelostomoides*) *angelarum* (Cockerell); Butler 1965: 15. Hurd 1979: 2073.

***Megachile* (*Megachiloides*) *anograe* Cockerell, 1908**

Megachile anograe Cockerell, 1908: 261. Adhikari *et al*. 2019: Supplementary Table S4.
Megachile (*Derotropis*) *anograe*; Mitchell 1936: 158; 1944: 142. Hurd 1979: 2062. Ivanochko 1979: 257.
Megachile (*Megachiloides*) *anograe*; Raw 2002: 16. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 52. Delphia *et al*. 2019a: 25.
Megachile (*Derotropis*) *laurita* Mitchell, 1927: 115; 1936: 160.
Megachile (*Megachiloides*) *laurita*: Raw 2002: 18.
Megachile (*Xeromegachile*) *alamosana* Mitchell, 1934: 329.
Megachile (*Derotropis*) *alamosana*; Mitchell 1936: 158; 1937a: 330; 1944: 142.
Megachile (*Megachiloides*) *alamosana*; Raw 2002: 16. Scott *et al*. 2011: 55.

***Megachile* (*Eutricharaea*) *apicalis* Spinola, 1808**

Megachile apicalis Spinola, 1808: 259.
Megachile (*Eutricharaea*) *apicalis*; Mitchell 1962: 120. Hurd 1979: 2057. Cooper 1984: 225. Sheffield *et al*. 2011: 29. Kuhlman and Burrows 2017: 12. Reese *et al*. 2018: 21. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 69.
Megachile virginiana Mitchell, 1926: 113.

***Megachile* (*Litomegachile*) *brevis* Say, 1837**

Megachile brevis Say, 1837: 407. O'Neill and Seibert 1996: 321. Pearce 2008: 51, 107. Drons 2012: 58. Pearce *et al*. 2012: 101. Adhikari *et al*. 2019: Supplementary Table S4.
Megachile (*Litomegachile*) *brevis*; Mitchell 1935a: 13; 1962: 114. Butler 1965: 2. Hurd 1979: 2051. Ivanochko 1979: 78. Fultz 2005: 134. Gonzalez 2008: 35. Scott *et al*. 2011: 55.

Sheffield *et al*. 2011: 33. Bzdyk 2012: 37. Kuhlman and Burrows 2017: 12. Reese *et al*. 2018: 21. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 70. Engel 2020: 11.
Megachile brevis var. *nupta*; Mitchell 1935a: 13.

***Megachile* (*Chelostomoides*) *campanulae* (Robertson, 1903)**
Oligotropus campanulae Robertson, 1903: 171.
Megachile (*Chelostomoides*) *campanulae*; Mitchell 1934: 301; 1937d: 389; 1956: 136; 1962: 182. Raw 2002: 7. Gonzalez 2008: 37. Scott *et al*. 2011: 54. Sheffield *et al*. 2011: 28. Drons 2012: 58. Reese *et al*. 2018: 21. Delphia *et al*. 2019a: 24.
Chalicodoma (*Chelostomoides*) *campanulae*; Hurd 1979: 2073.
Megachile campanulae; Burkle *et al*. 2020: 7.
Chelosomoides (*Chelosomoides*) *campanulae*; Engel 2020: 11.
Oligotropus wilmingtoni Mitchell, 1924: 156.

***Megachile* (*Megachiloides*) *casadae* Cockerell, 1898**
Megachile casadae Cockerell, 1898: 127. Drons 2012: 58.
Megachile (*Xeromegachile*) *casadae* Cockerell; Mitchell 1934: 302; 1937a: 348; 1944: 136. Butler 1965: 7. Hurd 1979: 2063.
Megachile (*Megachiloides*) *casadae* Cockerell; Raw 2002: 17. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 54.
Megachile austinensis Mitchell, 1927a: 105.

***Megachile* (*Megachile*) *centuncularis* (Linnaeus, 1758)**
Apis centuncularis Linnaeus, 1758: 575.
Megachile (*Athemois*) *centuncularis*; Mitchell 1935b.
Megachile (*Megachile*) *centuncularis*; Mitchell 1962: 124; 1980: 25. Butler 1965: 5. Hurd 1979: 2055. Ivanochko 1979: 145. Gonzalez 2008: 35. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 44. Sheffield and Heron 2019: 70.

***Megachile* (*Litomegachile*) *coquilletti* Cockerell, 1915**
Megachile mendica coquilletti Cockerell, 1915: 535.
Megachile (*Litomegachile*) *coquilletti*; Mitchell 1935a: 21. Butler 1965: 2. Hurd 1979: 2052. Ivanochko 1979: 93. Sheffield *et al*. 2011: 35. Bzdyk 2012: 41. Kuhlman and Burrows 2017: 12. Sheffield and Heron 2019: 70.

***Megachile* (*Megachiloides*) *dakotensis* Mitchell, 1926**
Megachile dakotensis Mitchell, 1926: 164.
Megachile (*Xeromegachile*) *dakotensis*; Mitchell 1937a: 335; 1944: 136; 1962: 145. Hurd 1979: 2063.
Megachile (*Megachiloides*) *dakotensis*; Raw 2002: 17.

***Megachile* (*Xanthosarus*) *dentitarsus* Sladen, 1919**
Megachile dentitarsus Sladen, 1919: 85. Drons 2012: 58. Adhikari *et al*. 2019: Supplementary Table S4.

Megachile (*Xanthosarus*) *dentitarsus*; Mitchell 1936: 127. Butler 1965: 11. Hurd 1979: 2067. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 73.

***Megachile* (*Sayapis*) *fidelis* Cresson, 1878**
Megachile fidelis Cresson, 1878: 120. Drons 2012: 58.
Megachile (*Sayapis*) *fidelis*; Mitchell 1937c: 180. Butler 1965: 12. Hurd 1979: 2070. Ivanochko 1979: 325. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 64. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 22. Sheffield and Heron 2019: 70. Engel 2020: 11.

***Megachile* (*Xanthosarus*) *frigida* Smith, 1853**
Megachile frigida Smith, 1853: 193. Drons 2012: 58.
Megachile (*Delomegachile*) *frigida*; Mitchell 1942: 116; 1944: 135; 1962: 133. Butler 1965: 6. Hurd 1979: 2059. Ivanochko 1979: 195.
Megachile (*Xanthosarus*) *frigida*; Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 76. Reese *et al*. 2018: 22. Delphia *et al*. 2019a: 25. Delphia *et al*. 2019b: 649. Sheffield and Heron 2019: 70. Fultz 2005: 134. (*Megachile vidua*, not Smith, 1853, misidentification).
Megachile (*Delomegachile*) *frigida appalachensis* Mitchell, 1962: 134.
Megachile (*Delomegachile*) *vidua* var. *appalachensis* Mitchell, 1935b: 205.

***Megachile* (*Xanthosarus*) *gemula* Cresson, 1878**
Megachile gemula Cresson, 1878: 118. Mitchell 1927b: 178. Drons 2012: 58.
Megachile (*Delomegachile*) *gemula* Cresson; Mitchell 1935b: 181; 1936: 185; 1962: 134. Butler 1965: 6. Hurd 1979: 2059. Ivanochko 1979: 186.
Megachile (*Xanthosarus*) *gemula*; Raw 2002: 36. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 78. Reese *et al*. 2018: 23. Delphia *et al*. 2019b: 649. Sheffield and Heron 2019: 70.

***Megachile* (*Litomegachile*) *gentilis* Cresson, 1872**
Megachile gentilis Cresson, 1872: 267.
Megachile (*Litomegachile*) *gentilis*; Mitchell 1935a: 23. Butler 1965: 3. Hurd 1979: 2053. Gonzalez 2008: 35. Sheffield *et al*. 2011: 36. Bzdyk 2012: 44. Sheffield and Heron 2019: 70.

***Megachile* (*Megachile*) *inermis* Provancher, 1888**
Megachile inermis Provancher, 1888: 323. Drons 2012: 58.
Megachile (*Anthemois*) *inermis*; Mitchell 1935b: 171.
Megachile (*Megachile*) *inermis*; Mitchell 1962: 126. Hurd 1979: 2055. Ivanochko 1979: 133. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 45. Sheffield and Heron 2019: 70.

***Megachile* (*Megachile*) *lapponica* Thomson, 1872**
Megachile lapponica Thomson, 1872: 227.
Megachile (*Megachile*) *lapponica*; Sheffield *et al*. 2011: 47. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 22. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 70.
Megachile nivalis Friese, 1903: 246.
Megachile (*Anthemois*) *santiamensis* Mitchell, 1934: 311.

Megachile (*Anthemois*) *nivalis*; Mitchell 1935b: 174; 1942: 115.
Megachile (*Megachile*) *nivalis*; Mitchell 1962: 129. Hurd 1979: 2056. Ivanochko 1979: 170. Sheffield and Westby 2007: 178. Scott *et al*. 2011: 55.

***Megachile* (*Xanthosarus*) *latimanus* Say, 1823**
Megachile latimanus Say, 1823: 81.
Megachile (*Xanthosarus*) *latimanus*; Mitchell 1936: 130; 1962: 157. Hurd 1979: 2067. Ivanochko 1979: 268. Fultz 2005: 134. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 79. Reese *et al*. 2018: 23. Delphia *et al*. 2019a: 25. Engel 2020: 11.
Megachile (*Delomegachile*) *vidua* Smith, 1853: 192. Mitchell 1935b: 200.
Megachile latimanus/perihirta; Pearce 2008: 57.

***Megachile* (*Litomegachile*) *lippiae* Cockerell, 1900**
Megachile cleomis var. *lippiae* Cockerell, 1900: 15.
Megachile texana var. *lippiae* Cockerell, 1900: 223. Mitchell 1935a: 37.
Megachile lippiae; Pearce 2008: 51. Pearce *et al*. 2012: 101.
Megachile (*Litomegachile*) *lippiae*; Butler 1965: 3. Hurd 1979: 2053. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 38. Bzdyk 2012: 46. Kuhlman and Burrows 2017: 12. Sheffield and Heron 2019: 70. Engel 2020: 11.
Megachile concinna, not Smith, 1879 (misidentification); Pearce 2008: 107.

***Megachile* (*Megachiloides*) *manifesta* Cresson, 1878**
Megachile manifesta Cresson, 1878: 122. Drons 2012: 58.
Megachile (*Xeromegachile*) *manifesta*; Mitchell 1937a: 352. Butler 1965: 8. Hurd 1979: 2064.
Megachile (*Megachiloides*) *manifesta*; Raw 2002: 18. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 55.

***Megachile* (*Xanthosarus*) *melanophaea* Smith, 1853**
Megachile melanophaea Smith, 1853: 191. Drons 2012: 58. Burkle *et al*. 2020: 7.
Megachile (*Delomegachile*) *melanophaea*; Mitchell 1935b: 190; 1962: 138. Butler 1965: 6. Hurd 1979: 2060. Ivanochko 1979: 215. Fultz 2005: 134.
Megachile (*Xanthosarus*) *melanophaea*; Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 81. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 23. Delphia *et al*. 2019a: 25. Sheffield and Heron 2019: 70.
Megachile melanophaea wootoni; Mitchell 1935b: 190.

***Megachile* (*Sayapis*) *mellitarsis* Cresson, 1878**
Megachile mellitarsis Cresson, 1878: 121.
Megachile (*Sayapis*) *mellitarsis*; Mitchell 1937c: 194. Hurd 1979: 2071. Ivanochko 1979: 328. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 66. Sheffield and Heron 2019: 70.

***Megachile* (*Litomegachile*) *mendica* Cresson, 1878**
Megachile mendica Cresson, 1878: 126. Drons 2012: 58.

Megachile (*Litomegachile*) *mendica*; Mitchell 1935a: 26; 1962: 117. Butler 1965: 3. Hurd 1979: 2053. Ivanochko 1979: 96. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 39. Bzdyk 2012: 47. Sheffield and Heron 2019: 70. Engel 2020: 11.

***Megachile* (*Megachile*) *montivaga* Cresson, 1878**
Megachile montivaga Cresson, 1878: 124. Drons 2012: 58.
Megachile (*Anthemois*) *montivaga*; Mitchell 1935b: 167.
Megachile (*Megachile*) *montivaga*; Mitchell 1962: 127. Butler 1965: 5. Hurd 1979: 2056. Ivanochko 1979: 127. Gonzalez 2008: 35. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 49. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 22. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 70. Engel 2020: 11.

***Megachile* (*Megachiloides*) *nevadensis* Cresson, 1879**
Megachile nevadensis Cresson, 1879: 209.
Megachile (*Xeromegachile*) *nevadensis*; Mitchell 1937a: 359. Hurd 1979: 2064.
Megachile (*Megachiloides*) *nevadensis*; Raw 2002: 19. Scott *et al*. 2011: 56.

***Megachile* (*Litomegachile*) *onobrychidis* Cockerell, 1908**
Megachile onobrychidis Cockerell, 1908: 266.
Megachile (*Litomegachile*) *brevis onobrychidis*; Butler 1965: 2. Hurd 1979: 2052. Scott et al. 2011: 55.
Megachile (*Litomegachile*) *onobrychidis*; Ivanochko 1979: 90. Sheffield *et al*. 2011: 41. Bzdyk 2012: 50. Kuhlman and Burrows 2017: 12. Reese *et al*. 2018: 22. Sheffield and Heron 2019: 70. Engel 2020: 11.

***Megachile* (*Argyropile*) *parallela* Smith, 1853**
Megachile parallela Smith, 1853: 191. Pearce 2008: 51. Drons 2012: 58. Pearce *et al*. 2012: 101.
Megachile (*Argyropile*) *parallela*; Mitchell 1937b: 48. Mitchell 1943: 12; 1944: 132; 1962: 159. Butler 1965: 10. Hurd 1979: 2066. Ivanochko 1979: 303. Gonzalez and Griswold 2007: 3. Gonzalez 2008: 161. Scott *et al*. 2011: 54. Sheffield *et al*. 2011: 23. Kuhlman and Burrows 2017: 12. Reese *et al*. 2018: 21. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 69. Engel 2020: 11.
Megachile (*Argyropile*) *asterae* Mitchell, 1943: 13.

***Megachile* (*Megachiloides*) *pascoensis* Mitchell, 1934**
Megachile (*Xeromegachile*) *pascoensis* Mitchell, 1934: 320.
Megachile (*Derotropis*) *pascoensis*; Mitchell 1944: 142. Hurd 1979: 2062.
Megachile (*Megachiloides*) *pascoensis*; Kuhlman and Burrows 2017: 13.
Megachile gabrielensis Michell, 1934: 346; 1936: 159.

***Megachile* (*Xanthosarus*) *perihirta* Cockerell, 1898**
Megachile perihirta Cockerell, 1898: 126. Drons 2012: 58. Adhikari *et al*. 2019: Supplementary Table S4.

Megachile (*Xanthosarus*) *perihirta*; Mitchell 1936: 136. Butler 1965: 11. Hurd 1979: 2067. Fultz 2005: 134. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 83. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 23. Delphia *et al*. 2019a: 25. Sheffield and Heron 2019: 70. Engel 2020: 11.

Megachile circumcincta, not Kirby, 1802 (misidentification); Adhikari *et al*. 2019: Supplementary Table S4.

***Megachile* (*Sayapis*) *pugnata* Say, 1837**

Megachile pugnatus Say, 1837: 408.

Megachile (*Sayapis*) *pugnata*; Mitchell 1937c: 201; 1962: 179. Butler 1965: 14. Hurd 1979: 2072. Ivanochko 1979: 316. Fultz 2005: 134. Gonzalez 2008: 36. Scott *et al*. 2011: 56. Sheffield *et al*. 2011: 67. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 22. Delphia *et al*. 2019a: 25. Sheffield and Heron 2019: 70. Engel 2020: 11.

Eumegachile (*Sayapis*) *pugnata* (Say); Mitchell 1980: 51.

Megachile pugnata; Drons 2012: 58.

Megachile inimica, not Cresson, 1872 (misidentification); Pearce 2008: 51. Pearce *et al*. 2012: 101.

***Megachile* (*Megachile*) *relativa* Cresson, 1878**

Megachile relativa Cresson, 1878: 126. Mitchell 1927b: 179. Jensen 2003: 195. Fultz 2005: 82. Drons 2012: 59.

Megachile (*Anthemois*) *relativa*; Mitchell 1935b: 162.

Megachile (*Megachile*) *relativa*; Mitchell 1962: 129. Butler 1965: 5. Hurd 1979: 2056. Ivanochko 1979: 153. Sheffield and Westby 2007: 178. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 51. Kuhlman and Burrows 2017: 13. Reese *et al*. 2018: 22. Delphia *et al*. 2019a: 25. Sheffield and Heron 2019: 70. Engel 2020: 11.

Megachile aspera Mitchell, 1924: 158.

***Megachile* (*Eutricharaea*) *rotundata* (Fabricius, 1793)**

Apis rotundata Fabricius, 1793: 332.

Megachile rotundata; Gerber and Akre 1969: 1. Jensen 2003: 195. O'Neill and O'Neill 2003: 447; 2011: 223. O'Neill *et al*. 2004: 619. Pearce 2008: 51. O'Neill *et al*. 2010: 775. O'Neill *et al*. 2011: 917. Delphia and O'Neill 2012: 380. Drons 2012: 59. Pearce *et al*. 2012: 97. O'Neill *et al*. 2014. O'Neill *et al*. 2015: 1. Soltani *et al*. 2017: 827. Donahoo *et al*. 2021: 444.

Megachile (*Eutricharaea*) *rotundata* (Fabricius). Mitchell 1962: 122. Ivanochko 1979: 113. Cooper 1984: 225. Gonzalez 2008: 35. Scott *et al*. 2011: 54. Sheffield *et al*. 2011: 31. Kuhlman and Burrows 2017: 12. Reese *et al*. 2018: 21. Delphia *et al*. 2019a: 24. Sheffield and Heron 2019: 69. Engel 2020: 11.

Apis pacifica Panzer 1798: 16.

Megachile (*Eutricharaea*) *pacifica*; Hurd 1979: 2057.

***Megachile* (*Litomegachile*) *snowi* Mitchell, 1927**

Megachile mendica snowi Mitchell, 1927: 113.

Megachile (*Litomegachile*) *mendica snowi*; Mitchell 1935a: 31. Butler 1965: 4. Scott *et al*. 2011: 55.

Megachile (*Litomegachile*) *snowi*; Bzdyk 2012: 55. Sheffield and Heron 2019: 70.

***Megachile* (*Megachiloides*) *subnigra* Cresson, 1879**

Megachile subnigra Cresson, 1879: 208.

Megachile (*Xeromegachile*) *subnigra*; Mitchell 1937a: 364; 1944: 138. Hurd 1979: 2065. Ivanochko 1979: 252.

Megachile (*Megachiloides*) *subnigra*; Raw 2002: 21. Scott *et al*. 2011: 56. Sheffield *et al*. 2011. Reese *et al*. 2018: 22. Delphia *et al*. 2019a: 25. Sheffield and Heron 2019: 70.

Megachile (*Xeromegachile*) *angelica* Mitchell, 1934: 318.

Megachile (*Xeromegachile*) *blaisdelli* Mitchell, 1934: 336.

Megachile (*Xeromegachile*) *moschata* Mitchell, 1934: 338.

***Megachile* (*Litomegachile*) *texana* Cresson, 1878**

Megachile texana Cresson, 1878: 125. Drons 2012: 59.

Megachile (*Litomegachile*) *texana;* Mitchell 1935a: 32; 1962: 118. Butler 1965: 4. Hurd 1979: 2054. Ivanochko 1979: 103. Scott *et al*. 2011: 55. Sheffield *et al*. 2011: 42. Bzdyk 2012: 56. Reese *et al*. 2018: 22. Sheffield and Heron 2019: 70. Engel 2020: 11.

Megachile texana var. *cleomis*; Mitchell 1935a: 32.

***Megachile* (*Megachiloides*) *wheeleri* Mitchell, 1927**

Megachile wheeleri Mitchell, 1927: 107.

Megachile (*Xeromegachile*) *wheeleri* Mitchell. Butler 1965: 9. Hurd 1979: 2066. Ivanochko 1979: 244. Mitchell 1937a: 355

Megachile (*Megachiloides*) *wheeleri* Mitchell. Raw 2002: 21. Scott et al. 2011: 56. Sheffield *et al*. 2011: 61. Reese *et al*. 2018: 22. Sheffield and Heron 2019: 70.

Megachile spokanensis Mitchell, 1927: 109.

Discussion

Bringing together the historical records of Montana *Megachile* and new records from targeted collecting provides a more complete picture of the diversity and distribution of the 35 *Megachile* species in the state. Some *Megachile* species were quite widespread and commonly collected, whereas others were found in only limited regions of Montana. *Megachile perihirta* was collected in the greatest number of counties, 44, with 1,150 records (Figs. 1ab, 12). Two species, *M. nevadensis* and *M. snowi*, are singletons, having only one record in Montana, and there were four doubletons (Fig. 12): *M. dakotensis*, *M. mellitarsis*, *M. mendica*, and *M.*

pascoensis. *Megachile dakotensis*, *M. mendica* and *M. snowi* were all collected only in eastern Montana (Figs. 1i, 1v, 1af). *Megachile pascoensis* is only known from northwest Montana (Fig. 1aa), and *M. mellitarsis* is known from southern Montana, in Beaverhead and Carbon Counties (Fig. 1u).

With new collections from this project and the loans from other collections, we observed that *Megachile* are less commonly collected than other priority genera, especially *Bombus*. In this study, we compiled data from 4,968 Montana *Megachile* specimens, while the previous WBMT project on the *Bombus* of Montana (Dolan *et al*. 2017) compiled data from 12,067 specimens, even though *Bombus* has fewer species in Montana. This discrepancy may stem from the ease of sighting and collecting *Bombus* in the field compared to *Megachile* and their attractiveness to collectors.

As the Chao1 mean estimator of species richness was 35.2 species (95% CI from 35.01 to 39.08, Fig. 9) and the species accumulation curve approaches an asymptote at 35 species, we documented the Chao1 mean predicted diversity in the state, but more species are possible. Chao1 is a lower bound estimate, which means that it is an estimator of minimum species richness and will usually underestimate the true total (Chao 1984). As the 95% CI for the Chao1 mean ranges up to 39 species, this analysis indicates that more *Megachile* species are possible in Montana. Range data of other *Megachile* species known in nearby states similarly suggests that several additional species are predicted to occur in Montana (See Unrecorded *Megachile* Potentially in Montana below).

Future faunistic bee studies should emphasize eastern and xeric regions of Montana, areas historically under-collected. Two new state records (*M. mendica* and *M. snowi*) were recorded in the southeast parts of Montana and many of the predicted *Megachile* species are hypothesized to occur in southern and eastern Montana (Figs. 1v, 1af). Michener (1979) ranks warm temperate xeric zones as highest for bee biodiversity and abundance, followed by temperate mesic, with temperate prairie and steppe ranked as moderately biodiverse out of all climatic regions. Warm xeric habitats are predicted to harbor higher bee diversity (Michener 1979, Orr *et al*. 2021), in part because of ephemeral floral resources and appropriate ground nesting habitat favoring solitary bees (Danforth *et al*. 2019). The arid landscapes and lack of prior research highlight the importance of future faunistic bee studies in southeast Montana.

With baseline faunistic data, further scientific questions may be asked of the bee populations in Montana. However, there are several limitations to a complete faunistic treatment of the bee species of Montana. First is the sheer size of the state and distance from research centers with the resulting lack of prior bee collecting statewide, plus the extensive time and labor involved in collecting and specimen preparation, and the taxonomic challenges (including need for revisions).

Another issue in faunistic projects is existing biodiversity data without voucher specimens. Online resources such as Discover Life and traditional publications present records of species without vouchers deposited in a collection, and these are problematic for future research as they cannot be traced or replicated. Suspicious records with corresponding vouchers, in contrast, are able to be corrected or verified, advancing understanding of species ranges with accurate data. In this project, we attempted to verify several such suspicious records of Montana *Megachile* species.

For example, *Megachile policaris* Say, a species found mainly in the central to southern United States (Discover Life 2021), was recorded on Discover Life from Haugan, MT (KSEM506871, Discover Life 15 May 2021). We worked with the SEMC to locate the specimen, which indeed was misidentified. The specimen was reidentified by Victor Gonzalez as *Megachile fidelis* Cresson (*in lit*. 13 Jan 2021). The record is still (27 June 2021) on Discover Life as *M. policaris* but has been updated on the online SEMC database (SEMC 2021).

A single specimen of *Megachile circumcincta* Linnaeus was recorded by Adhikari *et al*. (2019) from Chouteau County, Montana (MTEC035028). However, the specimen was reexamined and reidentified as a male *M. perihirta* and is included under that name in our dataset. It is possible that the range of *M. circumcincta* could extend into Montana (see Unrecorded *Megachile* Species Potentially in Montana below), but as of now, this species is not recorded in the state.

A Montana record of *Megachile inimica* Cresson was published by Pearce *et al*. (2012). The specimen (MTEC57005) was reexamined and reidentified as *M. pugnata*. There is a record on Discover Life as a state centroid for *M. inimica* (Discover Life 27 June 2021), but it is unknown whether that record is representative of the Pearce *et al*. (2012) literature record. We predict this species could eventually be found to occur in Montana (see Unrecorded *Megachile* Species Potentially in Montana below).

Megachile fortis Cresson was originally included in the provisional list of Montana *Megachile* based on Sheffield *et al*.'s (2011) Map 33, showing a range reaching along the northern border of the USA (including all of Montana), from Manitoba to British Columbia. With verified records of the species in eastern Colorado and South Dakota (Mitchell 1936, Hurd

1979, Scott *et al*. 2011) and Montana squarely in-between, this large and obvious species seemed certain to be in the state. However, the British Columbia record, based on Ivanochko (1979), was dropped as incorrect by Sheffield and Heron (2019), even though the Alberta, Saskatchewan, and Manitoba records were maintained on the Bees of Canada website (Sheffield 2021). These records for Alberta, Saskatchewan, and Manitoba made it onto Discover Life (2021) as centroid records. However, no Alberta or Saskatchewan specimens were cited anywhere.

Our failure to find this very distinctive species in Montana made us investigate this situation further. An inquiry was made to Sheffield, and the following answer was received (Cory Sheffield, *in lit*., 07 April 2021): "Sheffield *et al*. used shade maps which gave an inaccurate representation of its distribution in Canada based on the actual data. Thus the only "good" data point is the occurance from Manitoba." Thus, *M. fortis* is in fact not known from Alberta or Saskatchewan and therefore is now not expected in Montana. With the exception of the Manitoba record, there are no verified specimen records north of 44°N (Mitchell 1936, Hurd 1979, Discover Life 2021). The sole actual Canada record is in the Canadian National Collection of Insects (Ottawa)—a single specimen from Awame, Manitoba, east of 100°W— and has been located, reexamined, and verified by Sheffied (*in lit*., 16 June 2021). Our original expectation was thus due to the misleading nature of using distribution polygons simply encircling the furthest flung data points, as they then enter the literature as records without corresponding specimens.

In a similar situation is *Megachile sublaurita* Mitchell. As a species recorded from Utah (Mitchell 1936), Colorado and the southwest United States (Discover Life 30 May 2021), and from Hays, the southern prairies of Alberta (Ivanochko 1979, Sheffield *et al*. 2011), it was expected to be widespread in eastern Montana, but no specimens were found. Specimen-verified records of this species are all south of 40°N, with the northern-most available record being from Mesa, Colorado (39.104N, 108.456W, BOLD record BEECD299-09 at York University). No one has apparently examined the Alberta specimen since Ivanochko's (1979) Master's degree thesis, and no further specimens were found from Canada (Sheffield *et al*. 2011). Combined with the lack of Montana specimens, this suggests a misidentification is involved. The whereabouts of the specimen was not reported, and it is not in any of the collections Sheffield *et al.* (2011) examined, which included all the major Canadian repositories. We tentatively consider the Alberta record incorrect based on the known distribution of the species. As such, it is not suspected from Montana.

Fultz (2005) recorded several *Megachile* species in her thesis, and those specimens were reexamined for this project. One specimen, recorded as *Megachile vidua* Smith, was reexamined and updated as *Megachile frigida* Smith. Another species included by Fultz was *Megachile integra* Cresson, which was recorded in her thesis with a question mark. When reexamining this material, we did not come across any specimens with this label information, did not identify any of the material as *M. integra*, and do not expect *M. integra* to occur in Montana based on its range (primarily eastern U.S. to Kansas). Therefore, in Table 1, we do not include *M. integra* or *M. vidua* under Fultz (2005).

Last, taxonomic literature and resources for *Megachile* and other bee genera are in need of updates. As more researchers aim to identify bees with limited regional keys available, the available keys may be misleading in the scope of possible species or the possible intraspecific morphological variation regionally. In this project, we supplemented key use with reference specimens for all the species we deemed potential Montana *Megachile*. We found unreported morphological variation in our reference specimens and also our Montana material that we incorporated in our key to attempt to improve this situation.

Taxonomic Challenges

Megachile latimanus/Megachile perihirta females. Mitchell (1936) considered females of *M. perihirta* and *M. latimanus* so similar morphologically that it is "nearly impossible to separate by anything other than geographic location". *Megachile perihirta* is considered to generally occur west of the 100th meridian, whereas *M. latimanus* is usually found east of the 100th meridian, an arbitrary boundary between "eastern" and "western" North America (Sheffield *et al*. 2011). Similarly, Mitchell (1936) describes *M. perihirta* occurring from the west coast to Montana, Alberta, Wyoming, Colorado, and Texas, and *M. latimanus* occurring east of Montana, from North Carolina to Nova Scotia, west to Alberta, Wyoming, and Colorado. Therefore, Mitchell suggests that in areas where their ranges overlap, which includes Montana, only male determinations should be used to identify these two species until there is more known on the species distributions along the continental divide. Based on our identifications of male specimens, both *M. perihirta* and *M. latimanus* occur across the state, although *M. latimanus* males (6 specimens) were much less abundant than *M. perihirta* males (263 specimens). Stretching from the eastern to western borders of the state (Fig. 4ab), *M. perihirta* is known from all the counties where *M. latimanus* males are known (Fig. 4q), and *M. latimanus* reaches to near the Idaho border in the west. Therefore, we cannot use geography to identify female specimens to species in Montana.

Among the Montana specimens examined of this species pair, we were unable to morphologically distinguish females into two forms. Alongside geography, Mitchell (1936) used the size of the patch of black pubescence on the scutum and scutellum to identify female specimens to species, with *M. perihirta* having a larger patch of black pubescence that often extends into the scutellum compared to *M. latimanus*, which displays a smaller patch. However, Mitchell (1936) adds that "individual variations destroy the value of this character as a means of identification". In the Montana specimens examined, the size of the black pubescence patch was intermediate (usually a medium amount of black pubescence was present on the scutum) such that we could not reliably identify these specimens to species. Sheffield *et al*. (2011) pointed to pale pubescence on T6 of *M. latimanus*, versus intermixed black and white pubescence on T6 of *M. perihirta*, which again was not distinct in our series. With the lack of consistently distinct morphological characters and the overlap of geographic ranges, we identified all female specimens as "*M. latimanus*/*M. perihirta*" and considered all female specimens to be the more abundant *M. perihirta* for the purposes of analyses.

<u>*Megachile gentilis* females</u>. Montana specimens that we identified as female *M. gentilis* varied slightly from the descriptions of Mitchell (1935a) and Sheffield *et al*. (2011). Both earlier works describe completely black scopal setae on S6, whereas many of our Montana specimens displayed a few light setae among the black setae. We consider this simply unreported intraspecific variation.

<u>*Megachile brevis* Say females</u>. Some Montana specimens that we identified as female *M. brevis* varied somewhat from the descriptions of Mitchell (1935a) and Sheffield *et al*. (2011). Both earlier works describe the scopal setae of S6 as being mostly light, whereas 16 of our

specimens (out of 427 females examined) displayed black scopal setae on the apical half and light scopal setae on the basal half of S6. Again, we consider this unreported intraspecific variation.

Megachile lippiae Cockerell/*Megachile coquilletti* Cockerell females. *Megachile lippiae* female specimens are difficult to discern from *M. coquilletti*. Characters used to separate these species include T6 of *M. lippiae* having light-colored appressed setae and intermixed erect black setae and the profile of T6 being distinctly concave in lateral view (Mitchell 1935a [as *M. texana* var. *lippiae*], Sheffield *et al*. 2011 [as *M. lippiae*]). In contrast, *M. coquilletti* has appressed black setae on T6, which is "just perceptibly concave" in lateral profile (Mitchell 1935a).

The light-colored appressed setae on T6 of *M. lippiae* can be quite difficult to see. They are most easily viewed from a lateral profile of T6 while tilting the specimen back and forth to see the sheen of these appressed lighter setae. Adding complexity, additional plumose light setae are often found in small patches on the T6 lateral margins of *M. lippiae*. We did not consider these few lateral plumose setae as appressed setae that would distinguish a specimen as *M. lippiae*. We instead relied on an overall sheen of appressed pale setae on T6 as diagnostic for *M. lippiae*.

The T6 concavity was also a problematic character because many of our specimens that we identified as *M. lippiae* and *M. coquilletti* exhibited a more intermediate state that we could not easily characterize as either distinctly concave or just perceptibly concave. Therefore, to distinguish these species we use both the T6 concavity and the pale appressed setae characters in our key, with the addition of a previously unused character, a carina on the apical clypeal margin.

<u>*Megachile manifesta* Cresson/*Megachile nevadensis* Cresson/*Megachile wheeleri* Mitchell females</u>. The one report of *M. nevadensis* in Montana comes from a literature record (Mitchell 1937a). The voucher specimen was not found, although we suspect it may be at the National Museum of Natural History, whose collections have been unavailable during this study (F. Shockley, *pers. com.*). Given that the record is from Bozeman, home to the MTEC and the largest number of *Megachile* records, this is suspicious, but since the determination was made by the revisor of the genus, it cannot be lightly dismissed. Verified specimens are known from nearby Sheridan, WY (BBSL519179), making it a plausible member of the Montana fauna. However, we did not collect any specimens of this species during our study, so we did not have any Montana material to examine for preparation of our key and we therefore relied on borrowed material (2 specimens) from California and Utah as well as descriptions by Mitchell (1937a).

Mitchell (1937a) advises that females of *M. nevadensis* are difficult to discern from those of *M. manifesta* and *M. wheeleri*, both of which were collected in Montana during this study. *Megachile nevadensis* is typically "larger and much more ochraceous pubescent than the other two species" (Mitchell 1937a), but as color and size can vary, the punctation of T5 alongside the coloration of setae on S5 are important characters to distinguish these three species. *Megachile wheeleri* has a polished, sparsely punctate T5, and black scopal setae, at least apically, on S5 (Mitchell 1937a). *Megachile nevadensis* also has a polished, sparsely punctate T5, but light-colored scopal setae on S5 (Mitchell 1937a). *Megachile manifesta* has close punctures on T5 and black scopal setae apically on S5 (Mitchell 1937a, Sheffield *et al.* 2011).

Based on Mitchell's key to *Xeromegachile* (1937a), we used the distinctively widely spaced punctures (2-4 pd [puncture diameter] apart) on a polished and shiny T5 to distinguish *M.*

wheeleri from *M. nevadensis*, which had a moderately shiny T5 with punctures spaced ≤1 pd apart in our reference specimens (seemingly closer together than Mitchell [1937a] describes). This character also distinguishes *M. wheeleri* from *M. manifesta*, which similarly displayed close punctures, ≤1 pd apart, on T5.

Also based on Mitchell (1937a), we used the presence of black scopal setae (which varied from ca. ¼ to 1/3) on S5 to distinguish *M. manifesta* from *M. nevadensis*, which has all pale scopal setae on S5. Additionally, for our specimens identified as *M. manifesta*, the area posteriad the central scutum exhibited evenly spaced, dense punctures that were almost touching, whereas in *M. nevadensis* the punctures in this area were variable and spaced 1–2 pd apart.

One specimen that we identified as *M. manifesta* (specimen MTEC046014) presented difficulty and should be examined if *M. manifesta* is revisited in any future revision. This specimen exhibited black scopal setae on the apical half and white scopal setae on the basal half of S6, making it not quite fit into couplet 14 of the *Xeromegachile* key (Mitchell 1937a), which separates specimens that have entirely pale scopal setae on S6 (except a darker tuft apically) from specimens that have entirely black scopal setae on S6. Due to the apparent variation in this character, we chose not to use this character in our key.

Megachile anograe Cockerell females. *Megachile anograe* females are generally characterized by pale scopae on S2–4 (Mitchell 1936), and this was consistent with all our Montana specimens, but some rare extra-limital specimens are reported to be melanistic and have completely black scopae on S2–6 (Sheffield *et al*. 2011; also specimens MCZ15711, from Umatilla, Oregon, and MCZ15712, from Utah, *in lit*., C. Meier, 3/22/2021). The melanistic form could lead to species misidentifications if this variant was to be found in Montana in the future. We have accounted for this possible variation in our key.

Megachile anograe males. Among our Montana specimens of *M. anograe*, we found intraspecific variation that should be examined in future revisions of *Megachile* or the subgenus *Megachiloides*. The characters used to identify *M. anograe* males (= *Megachile alamosana* Mitchell; Mitchell 1934, 1936, 1937a) include the lack of a white apical setal band on T5, a shallow median emargination of the clypeal margin, and sparse T5 punctures (Mitchell 1937a). Three male *M. anograe* specimens (MTEC050668, MTEC050667, and MTEC042258) exhibited variation in the clypeal margin and some indication of the presence of a T5 apical setal band. Specimen MTEC050668 had some white setae along the apical margin of T5 suggesting the presence of an apical setal band and a shallow median emargination of the clypeal margin, MTEC050667 had a T5 apical setal band and a clypeal margin with a bevelled edge, and MTEC042258 lacked a T5 apical setal band (as in Mitchell's species description) and had a lumpy, minutely-denticulate-multi-tuberculate median emargination of the clypeal margin.

Without any reference material of male *M. anograe* for comparison with our specimens, this variation was concerning during the determination process. However, additional characters were suggested (Mitchell 1936 as *M. alamosana* and Terry Griswold, *in lit*., 21 April 2021), including presence of a small patch of black setae apicomedially on S5 and the presence of an elongate fovea on the dorsal hind femur. All of the specimens we identified to *M. anograe* exhibited both of these characters, which we also included in our key.

Megachile subnigra Cresson females. Female specimens from Montana that we identified as *M. subnigra* exhibited white apical setal bands on T2–T6 (though sometimes appearing reduced). In some cases, where specimens were somewhat bedraggled, the setal bands appeared to be absent, such that the pubescence on the tergites resembled that of *Megachile gemula* Cresson, with no white apical setal bands and overall white pubescence on T1 and T2. Because of this, and because *M. gemula* can also have black scopal setae on S2–6, occasional specimens of these two species could easily be confused. Our key accounts for those *M. subnigra* specimens with visible white apical setal bands on the tergites as well as those where the white apical setal bands are reduced or difficult to see due to specimen condition, and therefore the species keys out twice. Additionally, there is a pale form of *M. subnigra* (Sheffield *et al*. 2011) occurring in the Western U.S. (Sheffield *in lit*. 12 June 2020) that we did not see in Montana material, but is a possible variant that could present difficulty in identification.

Megachile lippiae Cresson/*Megachile texana* Cresson males. Males of *M. lippiae* and *M. texana* are very similar to one another morphologically and their distributions overlap in Montana. Mitchell (1935a) considered *M. lippiae* to be a subspecies of *M. texana*, which he distinguished from *M. texana* based on the amount of black pubescence (little to none) on the scutum, scutellum, and T1 of *M. lippiae*. Sheffield *et al*. (2011) raised *M. lippiae* to a species based on CO1 data (divergence levels of 2.59%) and the morphological characters used by Mitchell (1935a). Similarly, according to Bzdyk (2012), male *M. lippiae* have no black pubescence, except on the vertex of the head, whereas *M. texana* have black pubescence on the vertex of the head and the scutum.

Our Montana specimens exhibited varying amounts of dark setae mixed with light setae on the scutum and dorsal surface of the tergites, making it difficult to determine if there was "enough" black setae to identify a specimen as *M. texana*. We determined specimens with more than ca. 75% black pubescence on the scutum and significant bands of black pubescence on the dorsal surface of the tergites to be *M. texana*, and specimens with less than ~10% black pubescence on the scutum and mostly light pubescence on the dorsal tergites to be *M. lippiae*.

<u>*Megachile lapponica*/*Megachile relativa* males</u>. *Megachile lapponica* and *M. relativa* males are morphologically similar but *M. lapponica* is most common in northwestern North America, and *M. relativa* is widespread in the U.S. and Canada (Sheffield and Westby 2007). This geographic distinction is not useful to us, as their ranges overlap in Montana.

The male of *M. lapponica* was described for the first time by Sheffield and Westby (2007), as *Megachile nivalis* Friese, and later synonymized with *M. lapponica* based on CO1 and morphological characters by Sheffield *et al*. (2011). Characters used to separate males of *M. lapponica* and *M. relativa* include the shape of the hypostomal cavity, the size of the hypostomal tubercle, the comparative length of the r and Rs wing veins, and comparisons of various genital structures (Sheffield and Westby 2007). *Megachile relativa* is described as having a shallow hypostomal cavity, short hypostomal tubercle, and subequal lengths of veins r and Rs along the marginal cell of the forewing. *Megachile lapponica* is described as having a deep hypostomal cavity, a long hypostomal tubercle, and shorter r compared to Rs vein along the marginal cell of the forewing. However, Sheffield *et al*. (2011) also states that "the male of *M. lapponica* can only be distinguished with certainty from *M. relativa* by examining the genitalia". The gonocoxite's dorsal lobe in *M. relativa* is short, subequal in length to the width of the gonobase, and not reaching the gonoforceps base. In *M. lapponica*, the gonocoxite's dorsal lobe is longer than the width of the gonobase and reaches the base of the gonoforceps (Sheffield and Westby 2007).

Among our Montana specimens, we could not see any clear differences in the hypostomal cavity or tubercle to separate species with confidence-although most seemed to have shallow cavities and short tubercles, which would suggest *M. relativa*. The forewing r and Rs veins were not reliable characters in our specimens. We also found no clear differences in the genitalia of specimens previously identified as *M. lapponica* compared to those identified as *M. relativa* (identifications by Z.A. Pritchard and C.M. Delphia, December 2020) based on the hypostomal cavities and tubercles.

Parallel to our approach with female *M. perihirta* and *M. latimanus*, given the lack of distinct morphological characteristics to separate the males of these two species, we identified male specimens in our dataset and key as *M. lapponica/relativa*. In our analyses, male *M. lapponica/relativa* specimens were counted as *M. relativa* based on the greater abundance of *M. relativa* females in Montana.

Unrecorded *Megachile* Potentially in Montana

Several species of *Megachile* are recorded in literature and databases occurring close to or in continuous landscapes with Montana but have not yet been recorded in the state. These potential species are predicted to possibly occur in Montana and may be uncovered through further faunistic work.

Megachile (*Xanthosarus*) *circumcincta* is a boreal species ranging from Alaska through British Columbia and Alberta into northern Saskatchewan (Mitchell 1935b, Sheffield *et al.* 2011, Sheffield 2021). It has also been recorded from the mountains of Colorado (Mitchell 1935b, Scott *et al*. 2011 = *Megachile giliae* Cockerell). With records both north and south of Montana, this species would be predicted to occur widely in Montana.

Megachile (*Megachiloides*) *hookeri* Cockerell, which Mitchell states may be a color variation of *M. nevadensis* (Mitchell 1937a), was collected 200 km away from Montana in Pavillion, Wyoming (BBSL518981). It is also recorded in Lehi, Utah (Mitchell 1937a) and Colorado (Scott *et al*. 2011). From the Wyoming record, we predict that *M. hookeri* may be found in the south-central badlands region of Montana near Bridger.

Discover Life shows an unvouchered Montana centroid record for *Megachile* (*Sayapis*) *inimica* (Discover Life 05 May 2021). There is a specimen record near Montana from Moran, Wyoming (AMNH UID653582), the identification of which was verified by Corey Smith (*pers. com*., 24 Mar 2021). As this species is also recorded close to the Wasatch Range in Willard, Utah (BBSL519969), we would predict *M. inimica* may occur in southwest Montana, especially in the Centennial Valley (Beaverhead Co.) and surrounding area.

Megachile (*Megachiloides) latita* Mitchell was recorded in badland habitats in Worland, Wyoming and Maybell, Colorado (Mitchell 1934). As Worland is near the Montana border, we predict that this species may occur in south-central Montana in the contiguous xeric area south of Bridger, Montana.

Megachile (Leptorachis) petulans Cresson has been recorded to occur widely in the eastern, southern, and central U.S. but has fewer western records (Discover Life 01 June 2021, Mitchell 1937b). As it has been recorded in Jamestown, North Dakota (Mitchell 1937b), a prairie pothole region, it would possibly be expected in the prairie pothole region of northeast Montana near Plentywood and Caldera, approaching the North Dakota and Canada borders.

Megachile (*Megachiloides*) *umatillensis* Mitchell was recorded from Cornish, Utah near the Wasatch Range (University of Kansas Snow Entomology Collection, SEMC416330, Discover Life, 05 May 2021), in southern British Columbia (Sheffield *et al*. 2011, Sheffield and Heron 2019), in Santa Clara, Utah, in Roggen, Colorado, and in Washington (Mitchell 1936). With records north, west, and south of Montana, we would predict this species is likely to occur at least along the western or southern borders of Montana, but so far we have not detected it.

Megachile (Megachiloides) wyomingensis Mitchell was also recorded in Worland, Wyoming badlands (Mitchell 1937a). It is also recorded from Sweetwater Co., Wyoming (University of Kansas Snow Entomological Museum Collection SEMC498031) and Leota, Utah (USDA-ARS Pollinating Insects Research Unit, BBSL519311) on Discover Life (01 June 2021). From these records, *M. wyomingensis* is predicted to possibly occur in the same area of south-central Montana, specifically south of Bridger, Montana in the xeric landscape.

Further afield, but worth considering, specimens of *Megachile* (*Chelostomoides*) *subexilis* Cockerell are known from Fossil Butte National Monument, Wyoming (USGS_DRO314013), Timpanogos Cave National Monument, Utah (AMNH_BEE00079322), Provo, Utah (AMNH_BEE0007931), and Badlands National Park, South Dakota (USGS_DRO246767). This distribution suggests that this species is somewhat likely to occur in the badlands of south-central Montana near Bridger, the Black Hills region of Carter Co., and in the southwest corner of the state in or near the Centennial Valley (Beaverhead Co.).

Invasive species that may reach Montana. *Megachile* (*Eutricharaea*) *concinna* Smith is an invasive species originally from the Mediterranean region (Ghazi-Soltani *et al.* 2017) that is expanding its range in the U.S., including the west (Discover Life 01 June 2021) with the closest records being in Otero and Yuma Counties of Colorado (Scott *et al*. 2011) and in Timpanogos, Utah (AMNH_BEE00010214). Although not currently known from the state, *M. concinna* could feasibly reach Montana as its range expands in the future.

One last invasive species to watch for is *Megachile* (*Callomegachile*) *sculpturalis* (Smith). This native of eastern Asia is spreading from the eastern U.S., and now is established in most states east of the Mississippi River (Stevens *et al*. 2019). The predicted range of this species includes far western Montana with a lower probability along the Yellowstone River Valley (*loc. cit*.).

The Importance of Vouchers

Voucher specimens are very important in creating reproduceable research (Turney *et al.* 2015). We mention specific specimens that presented taxonomic challenges so that future researchers can reference and examine these specimens if more work is needed. Without vouchers in a museum, the results of our study would not be verifiable or reproduceable. When there were incorrect records published or posted online (as in *M. policaris* and *M. circumcincta*) we were able to identify the specimens ourselves or entail the help of curators to trace the specimens in question and correct the identifications and range distributions of these species. For mysteries such a *M. nevadensis* and *M. sublaurita*, in the absence of a voucher, we are left to speculate.

Searching for Mitchell's Montana Species

Megachile dakotensis was recorded to occur in Montana with no further locality by Mitchell (1937a), but no specimens had been recorded from the state since. A 1921 record of the species in Marmarth, North Dakota at the American Museum of Natural History shows a record ca. 10 km from the Montana border (AMNH_BEE00019636). From this information, we predicted that the species could be found in a similar dry badland landscape in southeastern Montana. We focused sampling efforts on the eastern border of Montana in 2019 and 2020 and collected one male and one female *M. dakotensis* in Carter County, at Medicine Rocks State Park in bee bowls on 20 July 2020 (Fig. 1i).

Megachile nevadensis was recorded from Bozeman, Montana by Mitchell (1937a), but has not been recorded from Montana since. Other nearby records include Crow Heart Butte, Wyoming (Mitchell 1936), 13 mi southwest of Dubois Wyoming (BBSL519101), and Sheridan, Wyoming (BBSL519179). In Montana, this species would be predicted to occur widely, but collecting efforts did not recover any specimens.

For the missing Mitchell vouchers of *M. nevadensis* and *M. dakotensis*, we contacted specific collection managers of collections found to hold Montana material of *Bombus* (Dolan *et al*. 2017), the home institution of Mitchell at North Carolina State University, and the major bee collections in North America, but these specimens were not found. All checked their collections and reported these specimens were not present. We also put out a general call via the Entomological Collection Network and Beemonitoring listservs to search for these Montana specimens.

The Mitchell specimens of neither species were located for this project. The *M. dakotensis* record has been repeated and the importance of the voucher therefore diminished somewhat, but the important *M. nevadensis* voucher, supposedly from the most extensively sampled bee locality in the state, remains at large. We have included it as a valid record and included it in the specimen and species counts and key, given the credibility of the determiner (Mitchell himself), but it remains uncertain if this species actually occurs in Montana.

Notes on *Megachile* (*Eutricharaea*) *rotundata* and Introduced *Megachile* Species

Megachile rotundata, or the alfalfa leafcutting bee, is native to Eurasia and detected in the United States in the 1930's after being accidentally introduced (Pitts-Singer and Cane 2011). Soon after, it was propagated across the western U.S. for alfalfa seed pollination, being first noted in Montana in 1969 (Gerber and Akre 1969). It is managed for alfalfa seed pollination widely, including in Montana. Today, its economic value is second only to honey bees in crop pollination (Pitts-Singer and Cane 2011).

Although *M. rotundata* are usually thought of as managed in agricultural fields, feral populations also exist in the wild (Jensen 2001, O'Neill *et al*. 2010). *Megachile rotundata* accepts a diversity of nest materials and nesting sites (MacIvor and Moore 2013, Sheffield 2017). In the Wolf Mountains of Montana, a wild nesting aggregation was found in holes in sandstone cliffs far from alfalfa fields (ZAP pers. obs., 2019).

Stem nesting behavior in *Megachile* makes them more likely to be accidently transported to new regions, as they readily nest in human-made substrates and can be transported in materials like irrigation tubing or drilled holes in wood or metal (Russo 2016, Poulsen and Rasmussen 2020). These introductions could be an issue for native species as one study in California suggested that invasive *Megachile* could potentially compete with native *Megachile* for nesting sites (Cane 2003).

Megachile (*Eutricharaea*) *apicalis* Spinola is an accidentally introduced species that is now established in the U.S. (Cooper 1984, Russo 2016) and found in Montana. This species was first recorded from Montana by Kuhlman and Burrows (2017) in Missoula County, and we record specimens from 11 counties in Montana starting in 2013 (Figs. 1c, 13c). It is already documented in much of the western U.S., and is associated with an invasive weed of rangelands, *Centaurea solstitialis* L., Asteraceae (Barthell *et al*. 2001, McIver *et al*. 2009, Sheffield *et al*. 2011). In Montana, Kuhlman and Burrows (2017) suggest that *M. apicalis* may be using *Centaurea stoebe* L., Asteraceae, a Montana weed that is a relative of *C. solstitialis*.

Conclusion

Several lessons have been learned and highlight work that remains. Collecting of *Megachile* in Montana has historically been geographically biased and remains extremely uneven statewide even after our efforts to remedy this problem. Future bee collecting should focus on the under-sampled regions of eastern and central Montana, easily visible as gaps in Figure 2. This especially represents regions that would be predicted to have high bee diversity (Orr *et al*. 2021), including Makoshika State Park, Medicine Rocks State Park, the prairie regions, the xeric regions (such as the region south of Bridger MT), and those with affinities to the Great Plains. There are also remaining gaps in western Montana: the high alpine, the Bob Marshall Wilderness Complex, the Big Hole, the Purcell-Cabinet Wilderness, and the northern Bitteroot Range.

Megachile specimens are less collected than some other bee taxa, like *Bombus*, and historical and museum data remain sparse for Montana *Megachile*. Extensive collecting is required throughout the state to better document diversity even in moderately well-collected areas. Further collecting of *Megachile* may reveal more species in Montana, as our Chao1 range indicates. Bee collecting efforts in Montana should keep watch for potential new state records of the introduced species *M. concinna* and *M. sculpturalis*, and the predicted native species *M. circumcincta*, *M. hookeri*, *M. inimica*, *M. latita*, *M. petulans, M. subexilis*, *M. umatillensis*, and *M. wyomingensis*.

The voucher specimen of Mitchell's *M. nevadensis* (1936) would be informative for confirming the species' occurance or absence in Montana. Further efforts to locate this specimen are needed.

More taxonomic work is needed in order to clarify relationships of the *Megachile*, especially the taxonomic challenges discussed herein. Revision of the subgenera that have not been recently revised should be a priority, but in fact a comprehensive revision of North American *Megachile* is needed, to allow better regional keys, and to aid in identifying species ranges and possible conservation concerns. With several taxonomic challenges just in the *Megachile* fauna of Montana, revisional work alongside support of taxonomists is needed to advance our understanding of this group and the other bee genera of Montana.

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Table 1. Publications and theses recording Montana *Megachile* species. First published state records are indicated in bold text. Thesis records repeated in publications are not included.

Publication	Species Recorded from Montana
Mitchell, T. B. (1934)	***M. pascoensis***
Mitchell, T. B. (1935a)	***M. brevis*, M. *brevis* var. *nupta, M. texana*, *M. texana* var. *cleomis*, *M. texana* var. *lippiae***
Mitchell, T. B. (1935b)	***M. gemula*, *M. inermis*, *M. melanophaea*, *M. melanophaea wootoni*, *M. montivaga*, *M. relativa*, *M. vidua* (= *latimanus*)**
Mitchell, T. B. (1936)	***M. anograe*, *M. dentitarsus*, *M. perihirta***
Mitchell, T. B. (1937a)	***M. dakotensis*, *M. manifesta*, *M. nevadensis*, *M. subnigra*, *M. wheeleri***
Mitchell, T. B. (1937b)	***M. parallela***
Mitchell, T. B. (1937c)	***M. fidelis*, *M. pugnata***
Mitchell, T. B. (1942)	***M. nivalis* (= *lapponica*)**
Mitchell, T. B. (1944)	*M. anograe*
Butler, G. D. (1965)	*M. dentitarsus, M. fidelis, M. lippiae, M. manifesta*
Gerber and Akre (1969)	***M. rotundata***
Hurd (1979)	*M. anograe*, *M. dakotensis*, *M. dentitarsus*, *M. fidelis*, *M. manifesta*, *M. melanophaea wootoni, M. nevadensis*, *M. pascoensis*, *M. subnigra*
O'Neill and Seibert (1996)	*M. brevis*
Jensen *et al*. (2003)	*M. relativa*, *M. rotundata*
O'Neill and O'Neill (2003)	*M. rotundata*
O'Neill *et al*. (2004)	*M. rotundata*
Fultz 2005	*M. brevis*, *M. latimanus*, *M. melanophaea*, *M. perihirta*, *M. pugnata*, *M. relativa*
Sheffield and Westby (2007)	*M. lapponica* (=*nivalis*)
O'Neill *et al*. (2010)	*M. rotundata*
O'Neill and O'Neill (2011)	*M. rotundata*
O'Neill *et al*. (2011)	*M. rotundata*
Delphia and O'Neill (2012)	*M. rotundata*
Pearce *et al*. (2012)	*M. brevis, M. inimica*[1]*, M. lippiae, M. parallela, M. rotundata*
O'Neill *et al*. (2014)	*M. rotundata*
O'Neill *et al*. (2015)	*M. rotundata*

[1] Misidentification of *M. inimica*, this specimen, housed in the Montana Entomology Collection (MTEC057005) was later identified as *M. pugnata*.

[2] Misidentification of *M. circumcincta*, this specimen, housed in the Montana Entomology Collection (MTEC035028), was later identified as *M. perihirta*.

Table 1 Continued. Publications and theses recording Montana *Megachile* species. First published state records are indicated in bold text. Thesis records repeated in publications are not included.

Publication	Species Recorded from Montana
Kuhlman and Burrows (2017)	***M. angelarum***, ***M. apicalis***, *M. brevis*, ***M. coquilletti***, *M. lapponica*, *M. lippiae*, *M. melanophaea*, *M. montivaga*, ***M. onobrychidis***, *M. pascoensis*, *M. perihirta*, *M. pugnata*, *M. relativa*, *M. rotundata*
Reese *et al*. (2018)	*M. angelarum*, *M. apicalis*, *M. brevis*, ***M. campanulae***, ***M. frigida***, *M. gemula*, *M. lapponica*, *M. latimanus*, *M. melanophaea*, *M. montivaga*, *M. onobrychidis*, *M. parallela*, *M. perihirta*, *M. pugnata*, *M. relativa*, *M. rotundata*, *M. subnigra*, *M. texana*, *M. wheeleri*
Delphia *et al*. (2019a)	*M. angelarum*, *M. anograe*, *M. apicalis*, *M. brevis*, *M. campanulae*, *M. frigida*, *M. lapponica*, *M. latimanus*, *M. melanophaea*, *M. montivaga*, *M. parallela, M. perihirta*, *M. pugnata*, *M. relativa*, *M. rotundata*, *M. subnigra*
Delphia *et al***.** (2019b)	*M. frigida*, *M. gemula*
Adhikari *et al*. (2019)	*M. anograe*, *M. brevis*, ***M. circumcincta***[2], *M. dentitarsus*, *M. perihirta*
Burkle *et al*. (2020)	*M. angelarum*, *M. campanulae*, *M. melanophaea*
LaManna *et al*. (2020)	*M. angelarum*, *M. apicalis, M. brevis*, *M. campanulae*, *M. fidelis*, *M. frigida*, *M. gemula*, *M. lapponica*, *M. melanophaea*, *M. montivaga*, *M. onobrychidis*, *M. parallela*, *M. perihirta*, *M. pugnata*, *M. relativa*, *M. rotundata*, *M. wheeleri*
Donahoo *et al*. (2021)	*M. rotundata*

[1] Misidentification of *M. inimica*, this specimen, housed in the Montana Entomology Collection (MTEC057005) was later identified as *M. pugnata*.

[2] Misidentification of *M. circumcincta*, this specimen, housed in the Montana Entomology Collection (MTEC035028), was later identified as *M. perihirta*.

Table 2. Labs, institutions, and individuals that contributed Montana *Megachile* specimens. "Specimen" refers to physical bee specimens with unique identifying codes that we examined on loan.

Lab, Institution, or Individual	Number of Specimens Examined and Included in Dataset
Alex Morphew, USDA-ARS, Sidney, MT	4
American Museum of Natural History, New York, NY (AMNH)	22
California Academy of Sciences Collection, San Francisco, CA (CAS-ENT)	21
Catherine E. Seibert Personal Collection, Belgrade, MT (CESC)	562
Casey M. Delphia Personal Collection, Bozeman, MT (CMDC)	135
Essig Museum of Entomology, University of California, Berkely, CA (EMEC)	1
William F. Barr Entomological Collection, University of Idaho, Moscow, ID (WFBM)	19
Illinois Natural History Survey Insect Collection, University of Illinois Urbana-Champaign, Champaign, IL	7
Montana Entomology Collection, Montana State University, Bozeman, MT (MTEC)	1,617
Kevin M. O'Neill Lab Collection, Montana State University, Bozeman, MT (KMOC)	605
C.A. Triplehorn Insect Collection, The Ohio State University, Columbus, OH (OSUC)	3
Snow Entomological Museum Collection, University of Kansas, Lawrence, KS (SEMC)	156
Texas A&M University Insect Collection, College Station, TX, (TAMUIC)	11
University of Colorado Museum of Natural History, Boulder, CO (UCMC)	27

Table 3. Labs, institutions, individuals, and publications that contributed Montana *Megachile* records. "Record" refers to data corresponding to a specimen with a unique identifying code. Records were included in our dataset if they were not a new county record or were identified by a trusted identifier.

Lab, Institution, Individual, or Publication	Number of Records Included in Dataset
Adhikari *et al*. (2019)	17
American Museum of Natural History, New York, NY (AMNH)	1
Ann Rodman, Yellowstone National Park, WY	15
Bethann Bruninga-Socolar, University of Minnesota, St. Paul, MN	3
Bohart Museum of Entomology, University of California Davis, Davis, CA (BMEC)	1
Cornell University Insect Collection, Ithaca, NY (CUIC)	2
Delphia *et al*. (2019a)	243
Illinois Natural History Survey Insect Collection, University of Illinois Urbana-Champaign, Champaign, IL (INHS)	1
Kuhlman and Burrows (2017)	1010
LaManna *et al*. (2020)	378
Marirose Kuhlman, MPG Ranch, Missoula, MT	4
Museum of Southwestern Biology, University of New Mexico, Albuquerque, NM (MSBA)	1
Reese *et al*. (2018)	3 (Records not included in LaManna *et al*. 2020)
Sam Droege, USGS Patuxent Wildlife Research Center, Laurel, MD	4
Severin-McDaniel Insect Research Collection, South Dakota State University, Brookings, SD (SDSU)	7
Snow Entomological Museum Collection, University of Kansas, Lawrence, KS (SEMC)	23
University of California, Riverside, CA (UCRC)	1
University of Texas El Paso Entomology Collection, El Paso, TX (UTEP)	4
U.S. National Pollinating Insects Collection (BBSL) housed in the USDA-ARS Pollinating Insects Collection at Logan, Utah	76

Table 4. *Megachile* species, earliest date of record, first published record, county records, and number of specimens recorded from Montana. Recorded counts of specimens include a count of one for each county record of a species by Mitchell. “Earliest recorded specimen” refers to the earliest date of collection for a specimen in our dataset with a unique identifying code.

Species (Alphabetical order)	Earliest recorded specimen (Year)	First published record for Montana	Total N County records	Total N Montana specimens[1]
Megachile (*Chelostomoides*) *angelarum* Cockerell, 1902	2005	Kuhlman and Burrows (2017)	11	32
Megachile (*Megachiloides*) *anograe* Cockerell, 1908	1916	Mitchell (1936)	11	33
Megachile (*Eutricharaea*) *apicalis* Spinola, 1808	2013	Kuhlman and Burrows (2017)	11	253
Megachile (*Litomegachile*) *brevis* Say, 1837	1949	Mitchell (1935a)	38	525
Megachile (*Chelostomoides*) *campanulae* (Robertson, 1903)	2000	Reese *et al*. (2018)	3	9
Megachile (*Megachiloides*) *casadae* Cockerell, 1898	1989	New state record	7	11

[1] Mitchell county records are counted as one specimen each.

[2] Female specimens identified as *Megachile latimanus*/*Megachile perihirta* are combined as *M. perihirta* because they are not morphologically distinguishable in Montana and because males of *M. perihirta* were more abundant than *M. latimanus*.

[3] Male specimens identified as *Megachile lapponica*/*M. relative* are combined as *M. relativa* because they are not morphologically distinguishable in Montana and because females of *M. relativa* were more abundant than *M. lapponica*.

Table 4 Continued. *Megachile* species, earliest date of record, first published record, county records, and number of specimens recorded from Montana. Recorded counts of specimens include a count of one for each county record of a species by Mitchell. "Earliest recorded specimen" refers to the earliest date of collection for a specimen in our dataset with a unique identifying code.

Species (alphabetical order)	Earliest recorded specimen (Year)	First published record for Montana	Total N County records	Total N Montana specimens[1]
Megachile (*Megachile*) *centuncularis* (Linnaeus, 1758)	1940	New state record	2	6
Megachile (*Litomegachile*) *coquilletti* Cockerell, 1915	1902	Kuhlman and Burrows (2017)	11	105
Megachile (*Megachiloides*) *dakotensis* Mitchell, 1926	2020	Mitchell (1937a)	1	2
Megachile (*Xanthosarus*) *dentitarsus* Sladen, 1919	1914	Mitchell (1936)	17	117
Megachile (*Sayapis*) *fidelis* Cresson, 1878	1917	Mitchell (1937c)	10	43
Megachile (*Xanthosarus*) *frigida* Smith, 1853	1904	Reese *et al*. (2018)	24	227
Megachile (*Xanthosarus*) *gemula* Cresson, 1878	1904	Mitchell (1935b)	19	54

[1] Mitchell county records are counted as one specimen each.
[2] Female specimens identified as *Megachile latimanus*/*Megachile perihirta* are combined as *M. perihirta* because they are not morphologically distinguishable in Montana and because males of *M. perihirta* were more abundant than *M. latimanus*.
[3] Male specimens identified as *Megachile lapponica*/*M. relative* are combined as *M. relativa* because they are not morphologically distinguishable in Montana and because females of *M. relativa* were more abundant than *M. lapponica*.

Table 4 Continued. *Megachile* species, earliest date of record, first published record, county records, and number of specimens recorded from Montana. Recorded counts of specimens include a count of one for each county record of a species by Mitchell. "Earliest recorded specimen" refers to the earliest date of collection for a specimen in our dataset with a unique identifying code.

Species (alphabetical order)	Earliest recorded specimen (Year)	First published record for Montana	Total N County records	Total N Montana specimens[1]
Megachile (*Litomegachile*) *gentilis* Cresson, 1872	1936	New state record	4	7
Megachile (*Megachile*) *inermis* Provancher, 1888	1920	Mitchell (1935b)	10	32
Megachile (*Megachile*) *lapponica* Thomson, 1872	1931	Mitchell (1942)	7	41
Megachile (*Xanthosarus*) *latimanus* Say, 1823	1946	Mitchell (1935b)	6	8
Megachile (*Litomegachile*) *lippiae* Cockerell, 1900	1972	Mitchell (1935a)	13	37
Megachile (*Megachiloides*) *manifesta* Cresson, 1878	1917	Mitchell (1937a)	8	12
Megachile (*Xanthosarus*) *melanophaea* Smith, 1853	1902	Mitchell (1935b)	35	377

[1] Mitchell county records are counted as one specimen each.
[2] Female specimens identified as *Megachile latimanus*/*Megachile perihirta* are combined as *M. perihirta* because they are not morphologically distinguishable in Montana and because males of *M. perihirta* were more abundant than *M. latimanus*.
[3] Male specimens identified as *Megachile lapponica*/*M. relative* are combined as *M. relativa* because they are not morphologically distinguishable in Montana and because females of *M. relativa* were more abundant than *M. lapponica*.

Table 4 Continued. *Megachile* species, earliest date of record, first published record, county records, and number of specimens recorded from Montana. Recorded counts of specimens include a count of one for each county record of a species by Mitchell. "Earliest recorded specimen" refers to the earliest date of collection for a specimen in our dataset with a unique identifying code.

Species (alphabetical order)	Earliest recorded specimen (Year)	First published record for Montana	Total N County records	Total N Montana specimens[1]
Megachile (*Sayapis*) *mellitarsis* Cresson, 1878	2018	New state record	2	2
Megachile (*Litomegachile*) *mendica* Cresson, 1878	2015	New state record	2	2
Megachile (*Megachile*) *montivaga* Cresson, 1878	1931	Mitchell (1935b)	22	126
Megachile (*Megachiloides*) *nevadensis* Cresson, 1879	--Only literature records--	Mitchell (1937a)	1	1
Megachile (*Litomegachile*) *onobrychidis* Cockerell, 1908	1931	Kuhlman and Burrows (2017)	19	388
Megachile (*Argyropile*) *parallela* Smith, 1853	1913	Mitchell (1937b)	20	125

[1] Mitchell county records are counted as one specimen each.

[2] Female specimens identified as *Megachile latimanus*/*Megachile perihirta* are combined as *M. perihirta* because they are not morphologically distinguishable in Montana and because males of *M. perihirta* were more abundant than *M. latimanus*.

[3] Male specimens identified as *Megachile lapponica*/*M. relative* are combined as *M. relativa* because they are not morphologically distinguishable in Montana and because females of *M. relativa* were more abundant than *M. lapponica*.

Table 4 Continued. *Megachile* species, earliest date of record, first published record, county records, and number of specimens recorded from Montana. Recorded counts of specimens include a count of one for each county record of a species by Mitchell. "Earliest recorded specimen" refers to the earliest date of collection for a specimen in our dataset with a unique identifying code.

Species (alphabetical order)	Earliest recorded specimen (Year)	First published record for Montana	Total N County records	Total N Montana specimens[1]
Megachile (*Megachiloides*) *pascoensis* Mitchell, 1934	2015	Mitchell (1934)	2	3
Megachile (*Xanthosarus*) *perihirta* Cockerell, 1898[2]	1899	Mitchell (1936)	44	1157
Megachile (*Sayapis*) *pugnata* Say, 1837	1904	Mitchell (1937c)	25	211
Megachile (*Megachile*) *relativa* Cresson, 1878[3]	1904	Mitchell (1935b)	30	534
Megachile (*Eutricharaea*) *rotundata* (Fabricius, 1793)	1963	Gerber and Akre (1969)	33	392
Megachile (*Litomegachile*) *snowi* Mitchell, 1927	2019	New state record	1	1

[1] Mitchell county records are counted as one specimen each.
[2] Female specimens identified as *Megachile latimanus*/*Megachile perihirta* are combined as *M. perihirta* because they are not morphologically distinguishable in Montana and because males of *M. perihirta* were more abundant than *M. latimanus*.
[3] Male specimens identified as *Megachile lapponica*/*M. relative* are combined as *M. relativa* because they are not morphologically distinguishable in Montana and because females of *M. relativa* were more abundant than *M. lapponica*.

Table 4 Continued. *Megachile* species, earliest date of record, first published record, county records, and number of specimens recorded from Montana. Recorded counts of specimens include a count of one for each county record of a species by Mitchell. "Earliest recorded specimen" refers to the earliest date of collection for a specimen in our dataset with a unique identifying code.

Species (alphabetical order)	Earliest recorded specimen (Year)	First published record for Montana	Total N County records	Total N Montana specimens[1]
Megachile (*Megachiloides*) *subnigra* Cresson, 1879	2012	Mitchell (1937a)	8	19
Megachile (*Litomegachile*) *texana* Cresson, 1878	1926	Mitchell (1935a)	13	30
Megachile (*Megachiloides*) *wheeleri* Mitchell, 1927	1904	Mitchell (1937a)	15	72

[1] Mitchell county records are counted as one specimen each.
[2] Female specimens identified as *Megachile latimanus*/*Megachile perihirta* are combined as *M. perihirta* because they are not morphologically distinguishable in Montana and because males of *M. perihirta* were more abundant than *M. latimanus*.
[3] Male specimens identified as *Megachile lapponica*/*M. relative* are combined as *M. relativa* because they are not morphologically distinguishable in Montana and because females of *M. relativa* were more abundant than *M. lapponica*.

Table 5. Montana *Megachile* specimens by collecting method (N = 2,348). “Pan trap” refers to data entered as: “Bee bowl”, “Bowl”, “Bowl trap”, “Pan”, and “Pan trap” and where no color was associated with the trap. “Blue pan trap” refers to data entered as: “Blue pan trap”, “Blue bowl”, and “Blue cup”. “Yellow pan trap” refers to data entered as: “Yellow pan”, “Yellow pan trap”, “Yellow bowl”, and “Yellow cup”. “White pan trap” refers to data entered as: “White bowl”, “White pan trap”, and “White cup”. “Bee Bucket” refers to data entered as: “Bee bucket”, “Yellow bucket”, “Bucket trap”, and “Yellow bucket trap”. “Pitfall trap” refers to data entered as: “Pit trap”, “Pitfall trap”, and “Pitfall”.

Collection Method	*Megachile* specimens
Pan Traps	Total = 1,060
Pan trap	766
Blue pan trap	10
White pan trap	11
Yellow pan trap	273
Net	673
Sweep net	6
Trap nest	432
Bee bucket	27
Pitfall trap	16
Vane trap	6
Blue vane trap	2
Yellow vane trap	55
Japanese beetle trap	44
Lindgren funnel	19
Malaise trap	7

Figure 1. County-level distribution of each *Megachile* species in Montana. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell county records are included in maps but not in specimen counts. Two specimens did not have county-level localities and are not included in maps but are included in specimen counts.

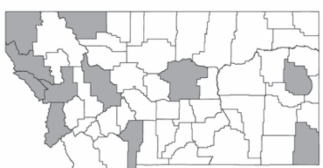


Figure 1a. *Megachile* (*Chelostomoides*) *angelarum* in MT, 32 specimens in 11 counties.

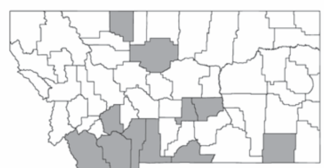


Figure 1b. *Megachile* (*Megachiloides*) *anograe* in MT, 31 specimens in 11 counties.

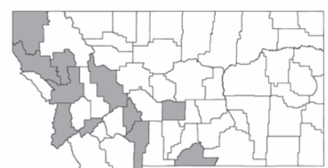


Figure 1c. *Megachile* (*Eutricharaea*) *apicalis* in MT, 253 specimens in 11 counties.

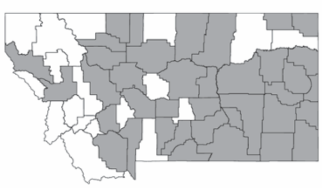


Figure 1d. *Megachile* (*Litomegachile*) *brevis* in MT, 525 specimens in 38 counties.

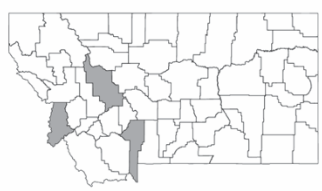


Figure 1e. *Megachile* (*Chelostomoides*) *campanulae* in MT, 9 specimens in 3 counties.

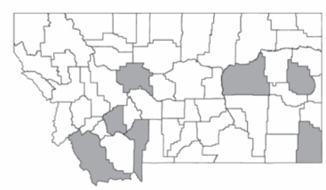


Figure 1f. *Megachile* (*Megachiloides*) *casadae* in MT, 11 specimens in 7 counties.

Figure 1g. *Megachile* (*Megachile*) *centuncularis* in MT, 6 specimens in 2 counties.

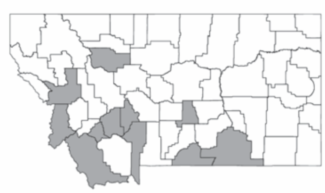


Figure 1h. *Megachile* (*Litomegachile*) *coquilletti* in MT, 105 specimens in 11 counties.

Figure 1i. *Megachile* (*Megachiloides*) *dakotensis* in MT, 2 specimens in 1 county.

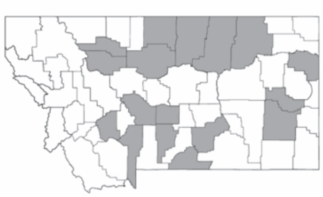


Figure 1j. *Megachile* (*Xanthosarus*) *dentitarsus* in MT, 114 specimens in 17 counties.

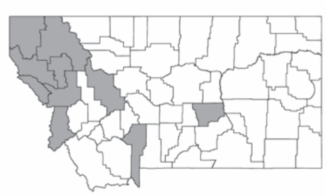


Figure 1k. *Megachile* (*Sayapis*) *fidelis* in MT, 43 specimens in 10 counties.

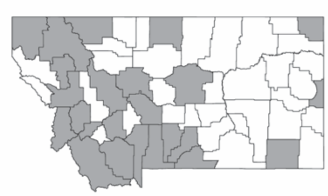


Figure 1l. *Megachile* (*Xanthosarus*) *frigida* in MT, 227 specimens in 24 counties.

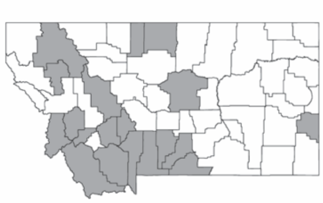


Figure 1m. *Megachile* (*Xanthosarus*) *gemula* in MT, 53 specimens in 19 counties.

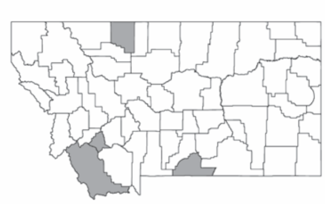


Figure 1n. *Megachile* (*Litomegachile*) *gentilis* in MT, 7 specimens in 4 counties.

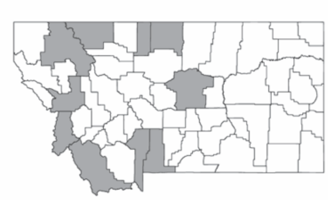


Figure 1o. *Megachile* (*Megachile*) *inermis* in MT, 31 specimens in 10 counties.

Figure 1 Continued. County-level distribution of each *Megachile* species in Montana. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell county records are included in maps but not in specimen counts. Two specimens did not have county-level localities and are not included in maps but are included in specimen counts.

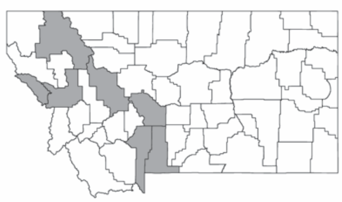


Figure 1p. *Megachile* (*Megachile*) *lapponica* in MT, 41 specimens in 7 counties.

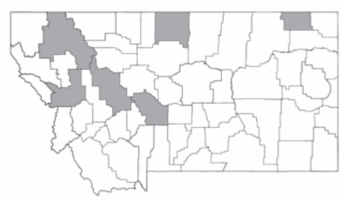


Figure 1q. *Megachile* (*Xanthosarus*) *latimanus* in MT, 6 specimens in 6 counties.

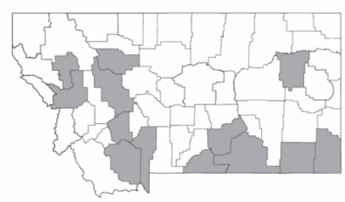


Figure 1r. *Megachile* (*Litomegachile*) *lippiae* in MT, 36 specimens in 13 counties.

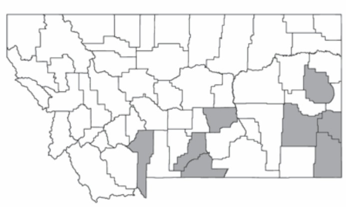


Figure 1s. *Megachile* (*Megachiloides*) *manifesta* in MT, 9 specimens in 8 counties.

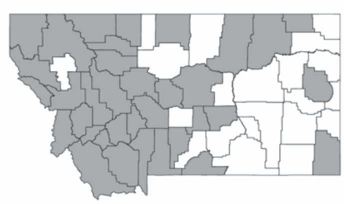


Figure 1t. *Megachile* (*Xanthosarus*) *melanophaea* in MT, 371 specimens in 35 counties.

Figure 1u. *Megachile* (*Sayapis*) *mellitarsis* in MT, 2 specimens in 2 counties.

Figure 1v. *Megachile* (*Litomegachile*) *mendica* in MT, 2 specimens in 2 counties.

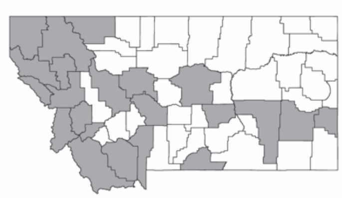


Figure 1w. *Megachile* (*Megachile*) *montivaga* in MT, 125 specimens in 22 counties.

Figure 1x. *Megachile* (*Megachiloides*) *nevadensis* in MT, 0 specimens, literature record in 1 county.

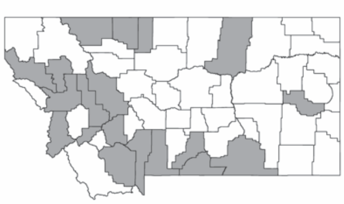


Figure 1y. *Megachile* (*Litomegachile*) *onobrychidis* in MT, 388 specimens in 19 counties.

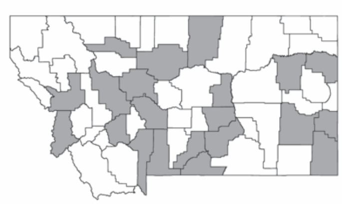


Figure 1z. *Megachile* (*Argyropile*) *parallela* in MT, 122 specimens in 20 counties.

Figure 1aa. *Megachile* (*Megachiloides*) *pascoensis* in MT, 2 specimens in 2 counties.

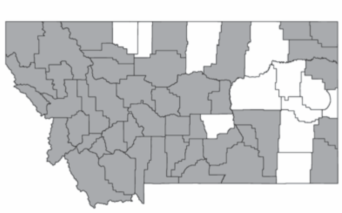


Figure 1ab. *Megachile* (*Xanthosarus*) *perihirta* in MT, 1150 specimens in 44 counties.

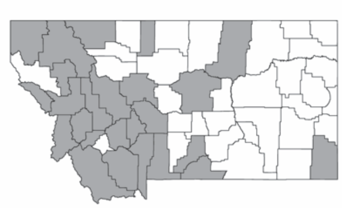


Figure 1ac. *Megachile* (*Sayapis*) *pugnata* in MT, 209 specimens in 25 counties.

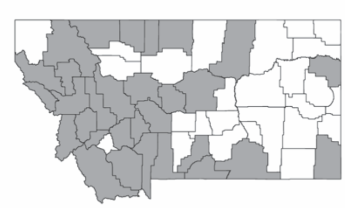


Figure 1ad. *Megachile* (*Megachile*) *relativa* in MT, 533 specimens in 30 counties.

Figure 1 Continued. County-level distribution of each *Megachile* species in Montana. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell county records are included in maps but not in specimen counts. Two specimens did not have county-level localities and are not included in maps but are included in specimen counts.

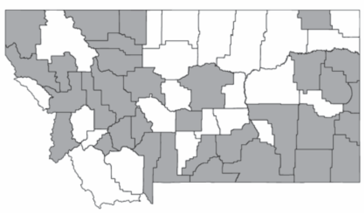


Figure 1ae. *Megachile* (*Eutricharaea*) *rotundata* in MT, 392 specimens in 33 counties.

Figure 1af. *Megachile* (*Litomegachile*) *snowi* in MT, 1 specimen in 1 county.

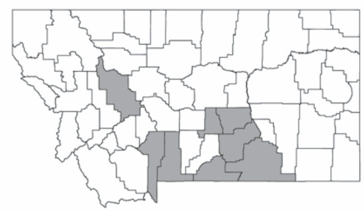


Figure 1ag. *Megachile* (*Megachiloides*) *subnigra* in MT, 18 specimens in 8 counties.

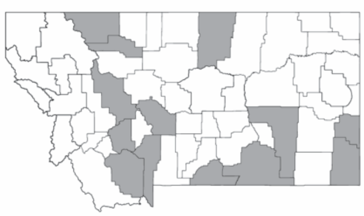


Figure 1ah. *Megachile* (*Litomegachile*) *texana* in MT, 28 specimens in 13 counties.

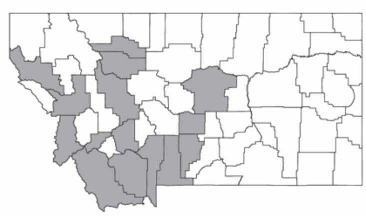


Figure 1ai. *Megachile* (*Megachiloides*) *wheeleri* in MT, 68 specimens in 15 counties.

Figure 2. All localities of Montana *Megachile* specimens. Mitchell literature records are not included in the map.

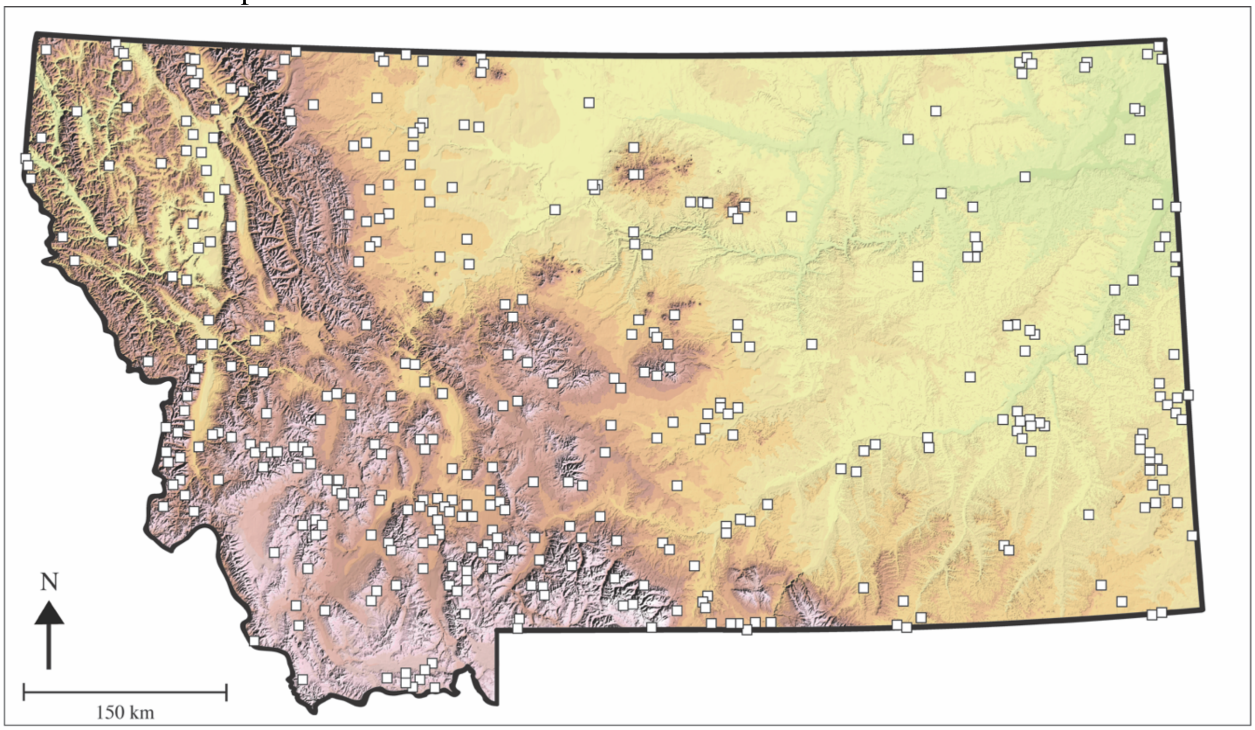


Figure 3. Number of *Megachile* specimens in each Montana county in 2014 (A) and 2020 (B).

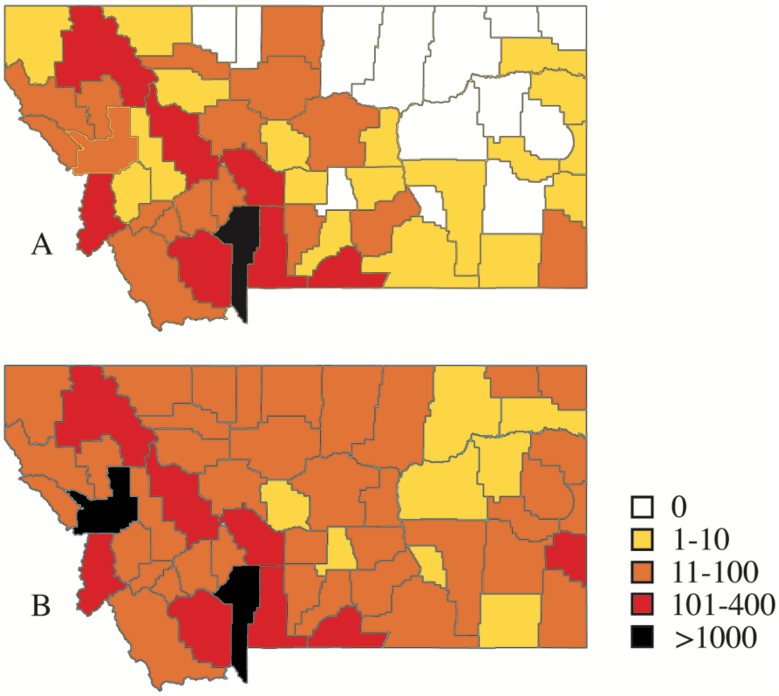


Figure 4. Number of *Megachile* species in each Montana county in 2014 (A) and 2020 (B).

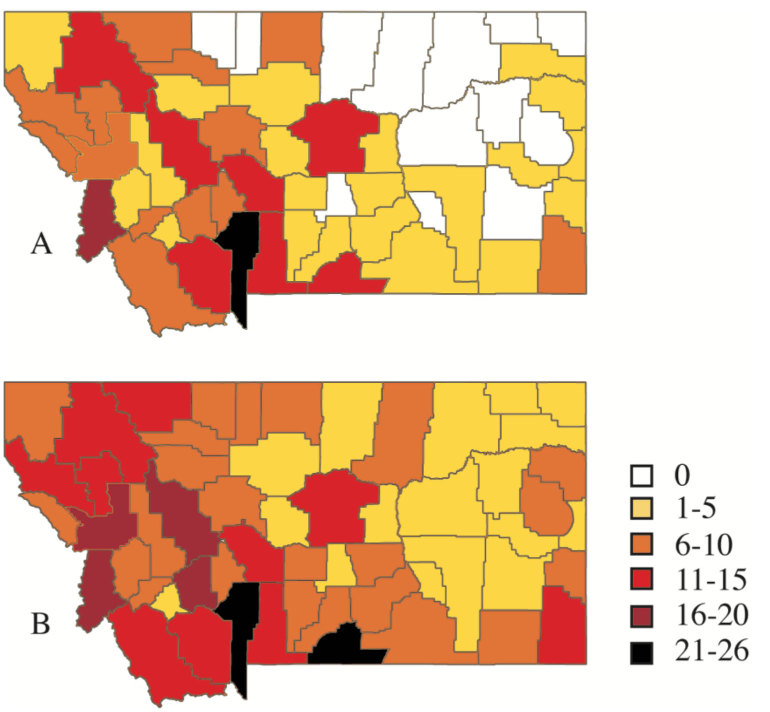


Figure 5. Accumulation of Montana *Megachile* specimens by county and year. Gallatin and Missoula counties are presented separately due to the much higher abundance of specimens. Two specimens without localities, Mitchell literature records, and five specimens without dates were not included in this graph.

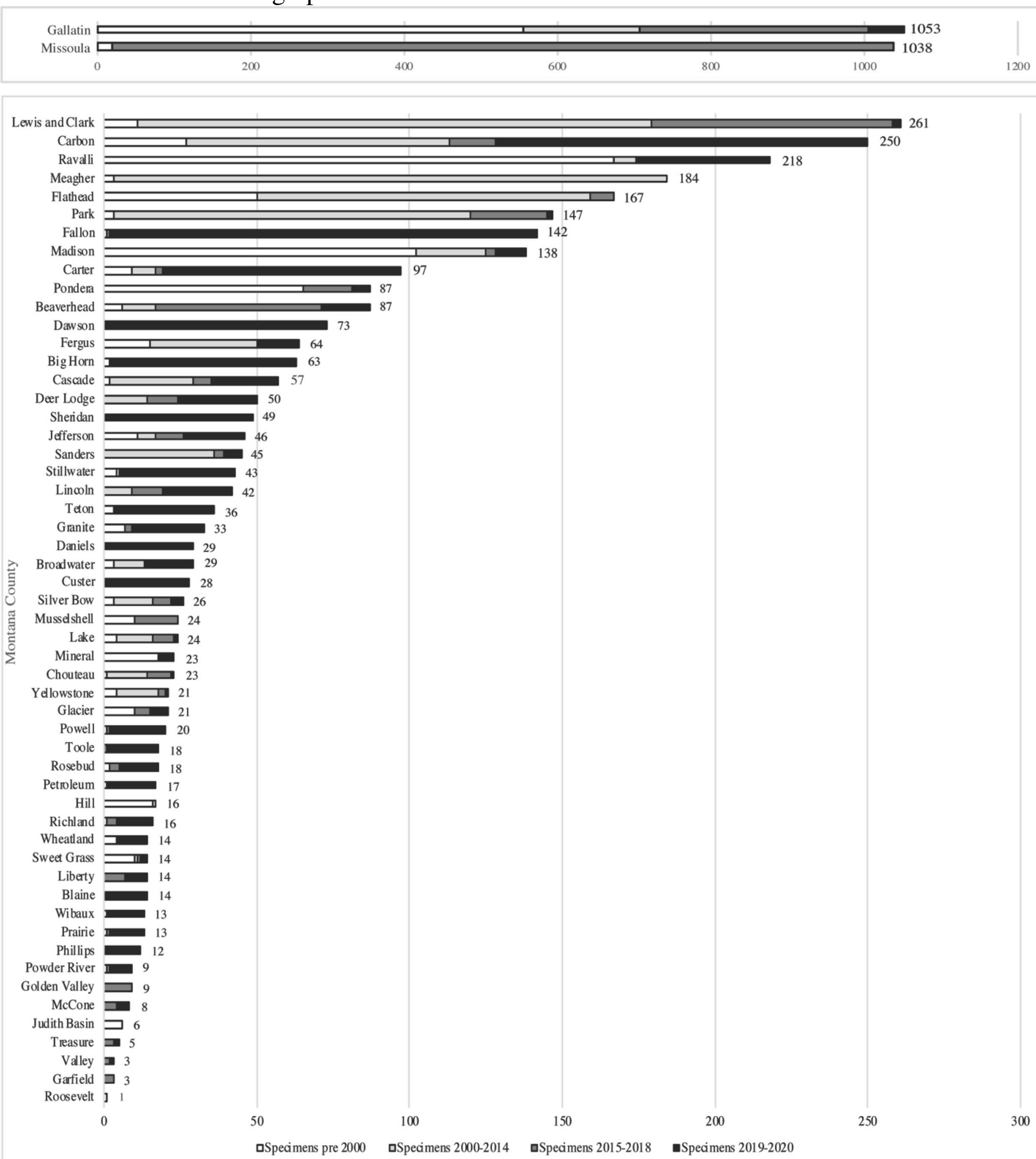


Figure 6. Accumulation of Montana *Megachile* species by county and year. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature records, two specimens without localities, and five specimens without dates are not included in this graph.

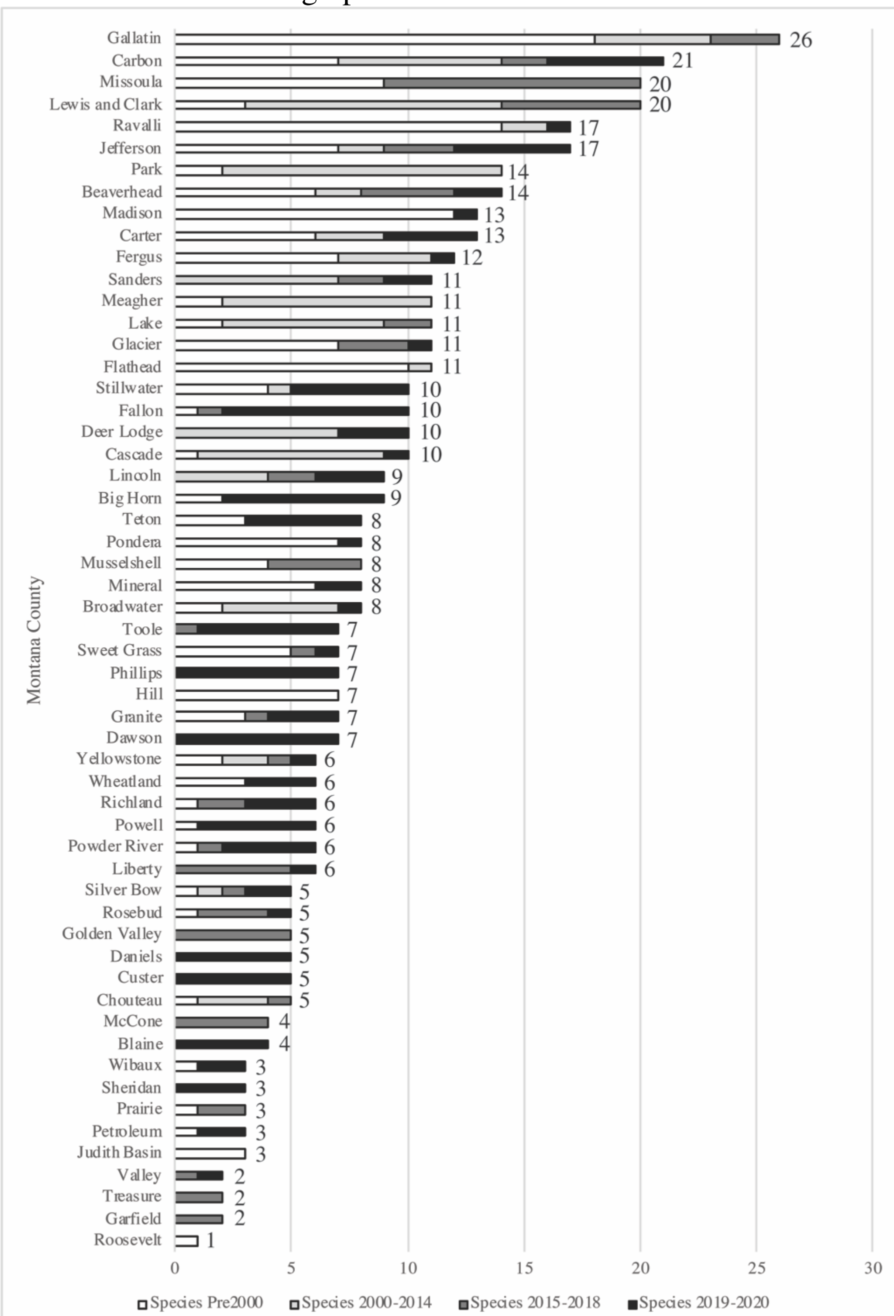


Figure 7. Montana *Megachile* species and specimens by county. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature records and two specimens without localities are not included.

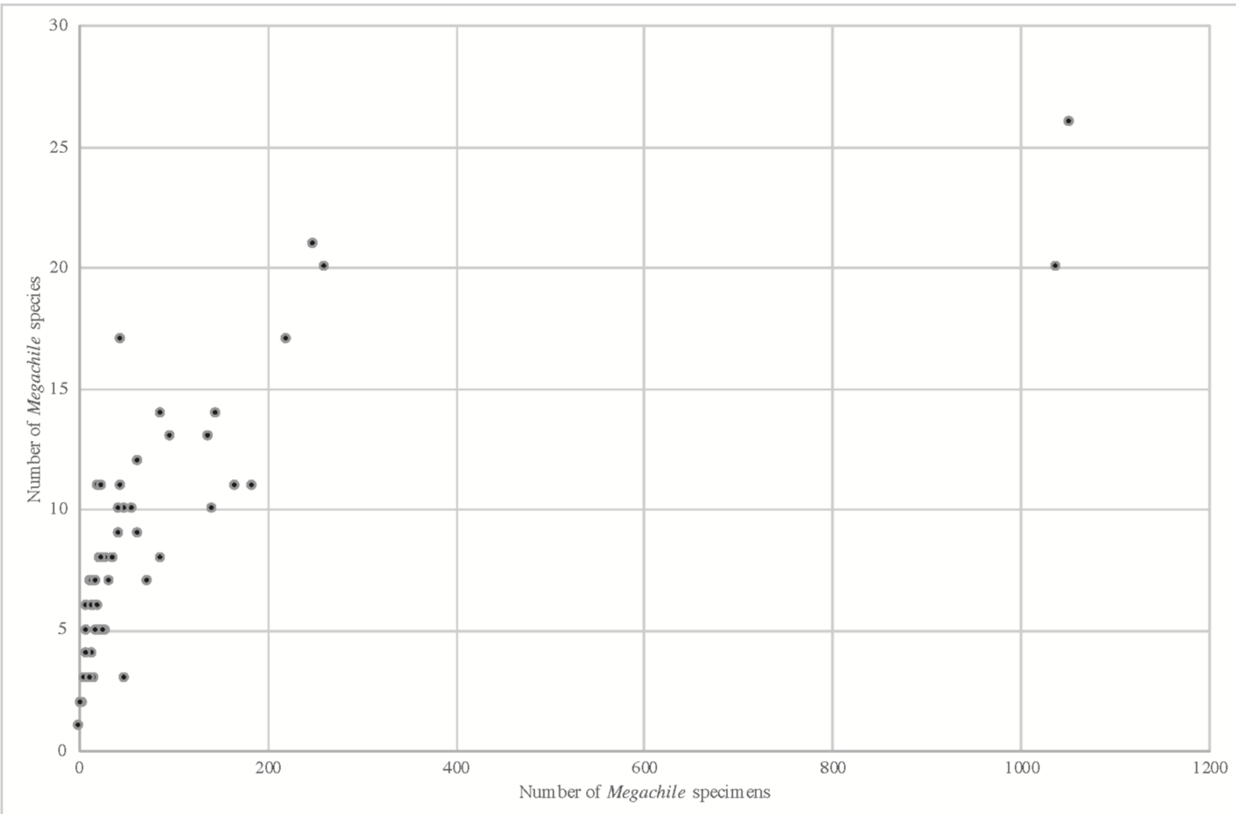


Figure 8. Accumulation of Montana *Megachile* specimens by year. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature records and five specimens without dates are not included in this graph.

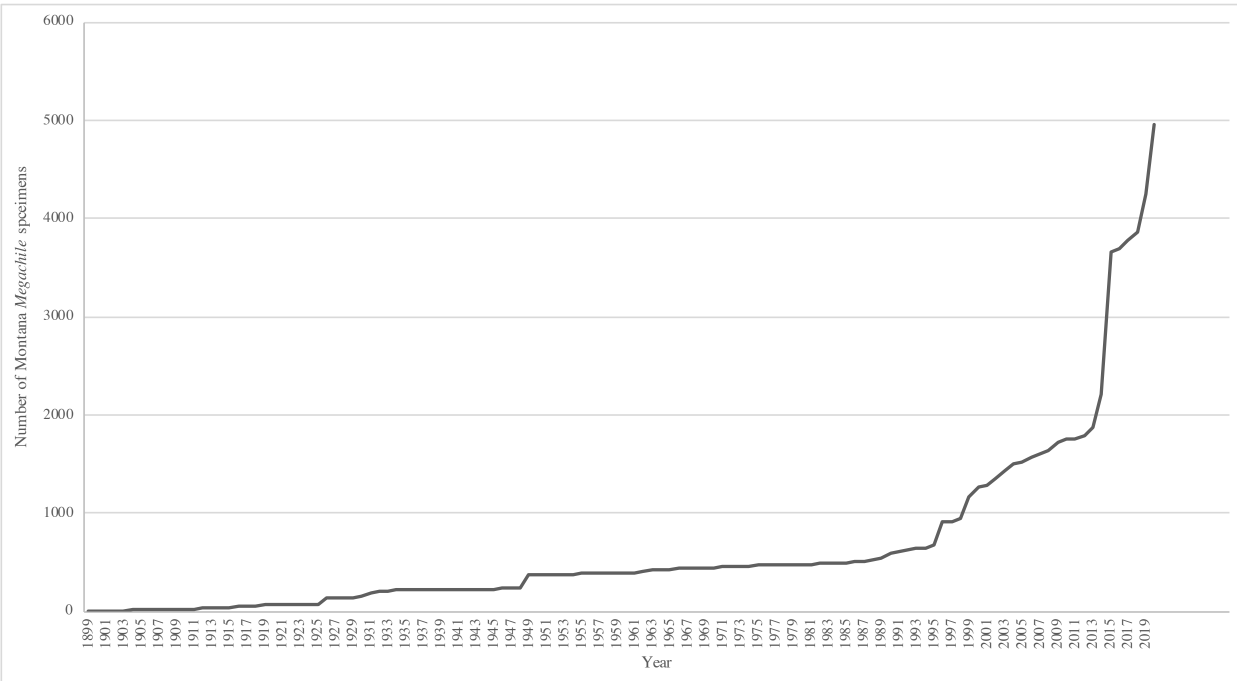


Figure 9. Montana *Megachile* species accumulation curve. Each county was counted as a sample and the data were randomized 100 times in EstimateS (Colwell 2013). Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature records are not included, except a single record of *M. nevadensis* that comprises the only record in Montana.

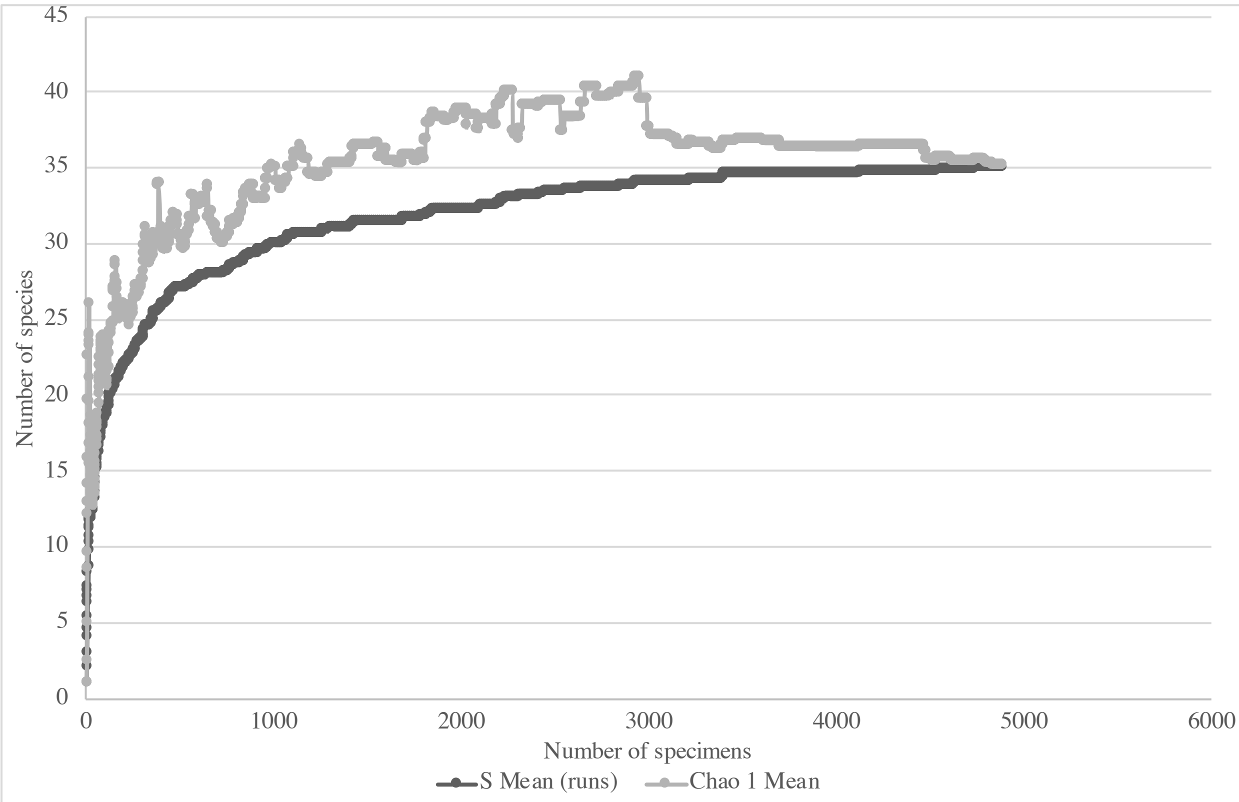


Figure 10. Accumulation of Montana *Megachile* species by year. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature records and five specimens without dates are not included in this graph.

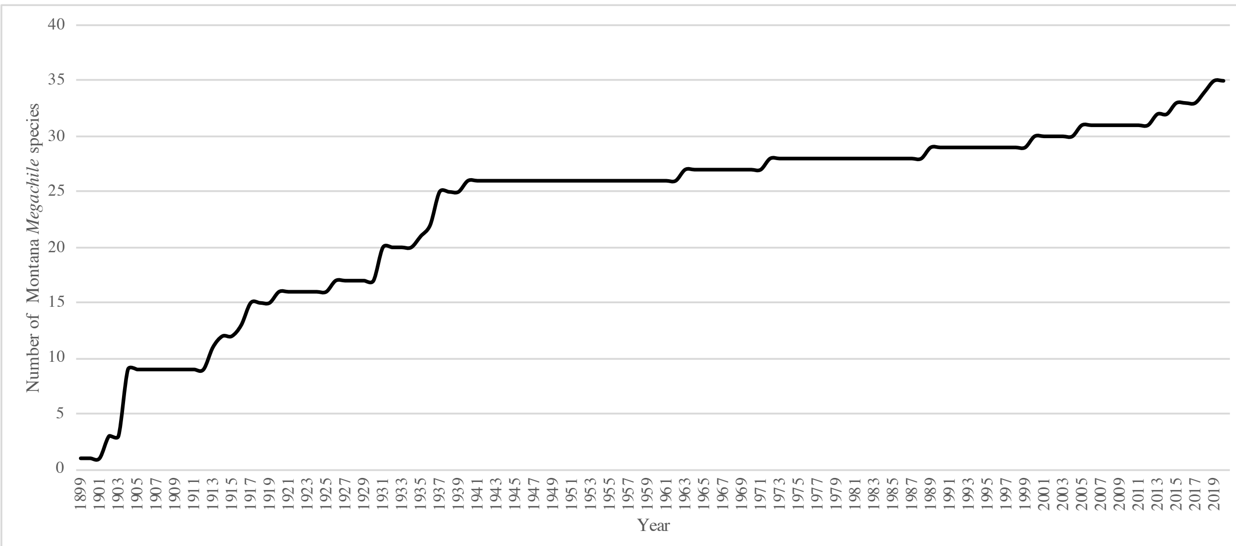


Figure 11. Accumulation of new *Megachile* county records by year (i.e., the first year a *Megachile* species was recorded in a Montana county). Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted as *M. relativa* as they are not distinguishable from one another in Montana. These data include county records from specimens and Mitchell literature records. Two county records from other databases were excluded because the specimens were not examined and the determiners were unknown (SEMC469014, *M. parallela* from Ravalli Co. and BBSL988318, *M. dentitarsus* from Cascade Co.). Two specimens without localities and five specimens without dates are not included.

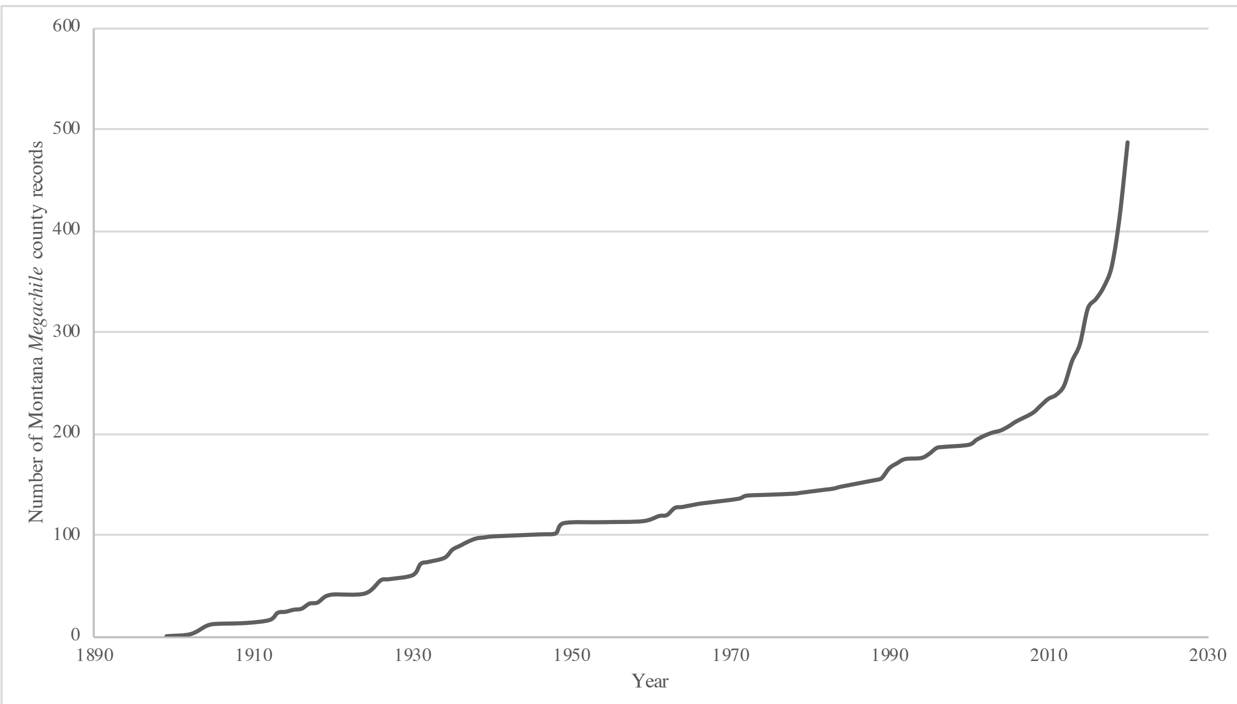


Figure 12. Number of specimens for each species of *Megachile* in Montana. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature records are not included, except a single record of *M. nevadensis* that comprises the only record in Montana.

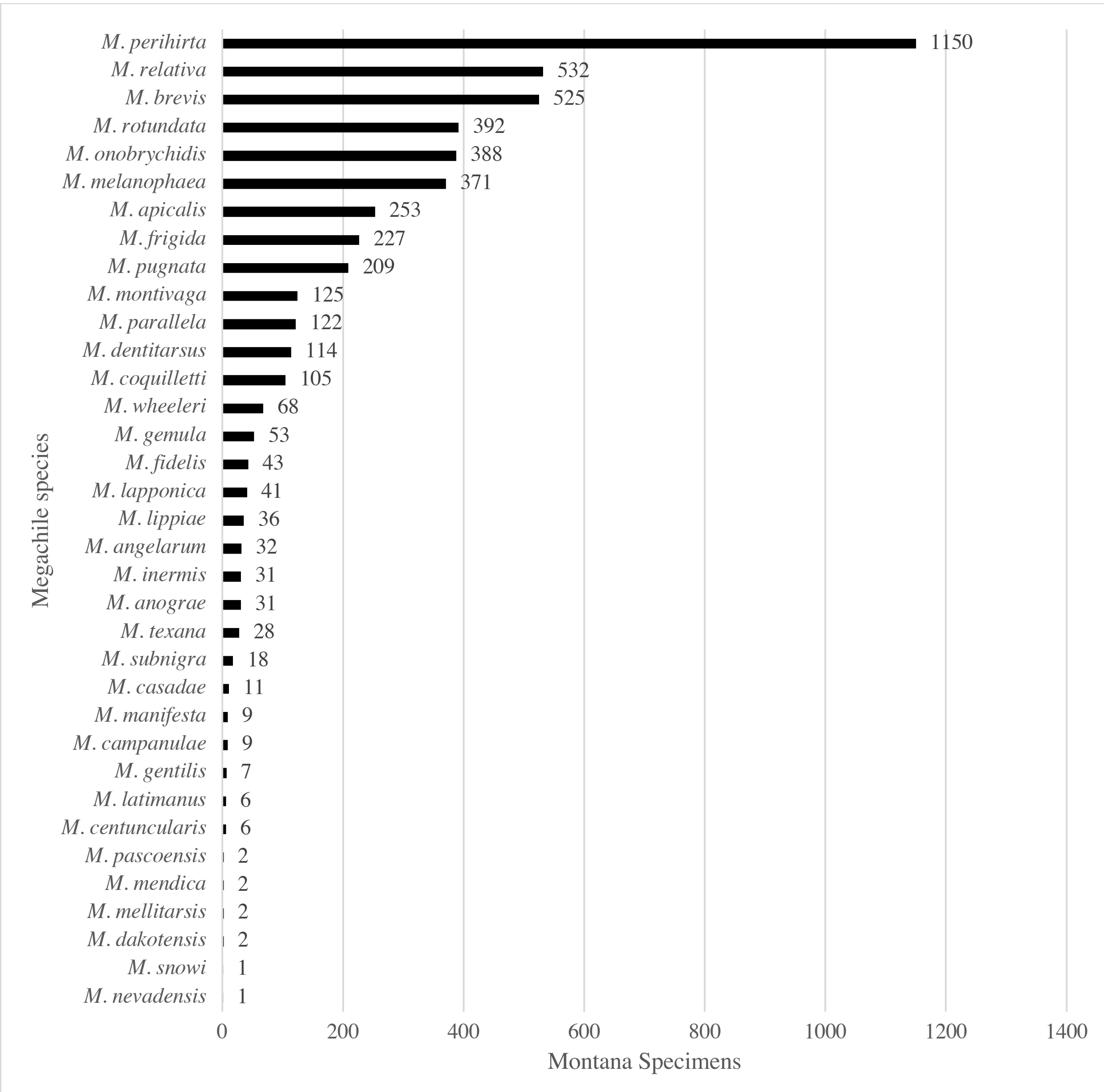


Figure 13. Specimen accumulation for each of the 35 Montana *Megachile* species by year. The y-axes differ based on total specimen count. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature record and five specimens without dates are not included in this graph.

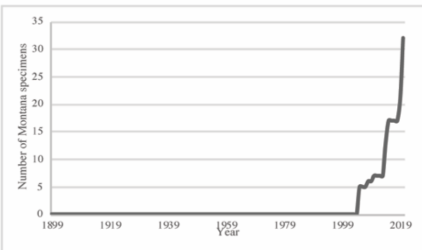


Figure 13a. Accumulation of *Megachile angelarum*.

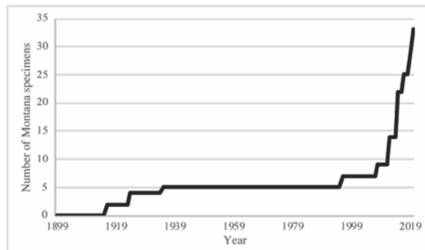


Figure 13b. Accumulation of *Megachile anograe*.

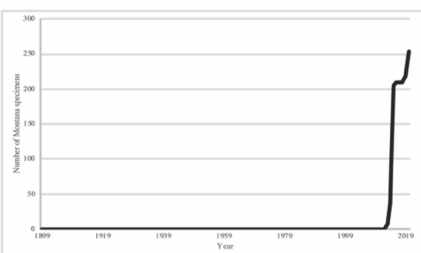


Figure 13c. Accumulation of *Megachile apicalis*.

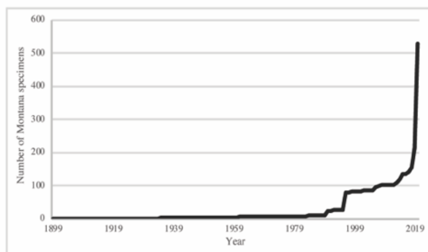


Figure 13d. Accumulation of *Megachile brevis*.

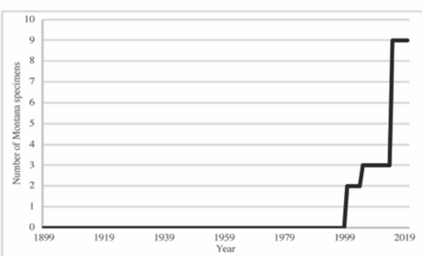


Figure 13e. Accumulation of *Megachile campanulae*.

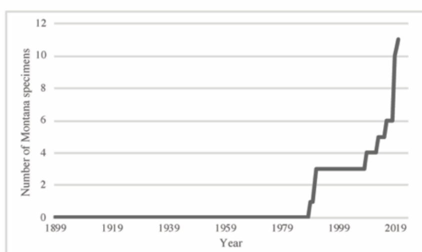


Figure 13f. Accumulation of *Megachile casadae*.

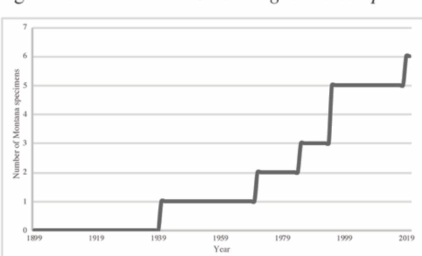


Figure 13g. Accumulation of *Megachile centuncularis*.

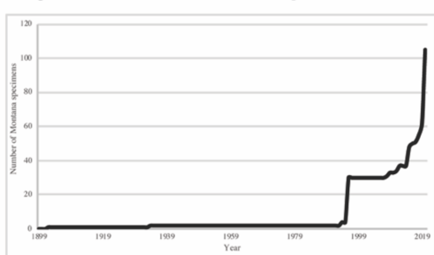


Figure 13h. Accumulation of *Megachile coquilletti*.

Figure 13 Continued. Specimen accumulation for each of the 35 Montana *Megachile* species by year. The y-axes differ based on total specimen count. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature record and five specimens without dates are not included in this graph.

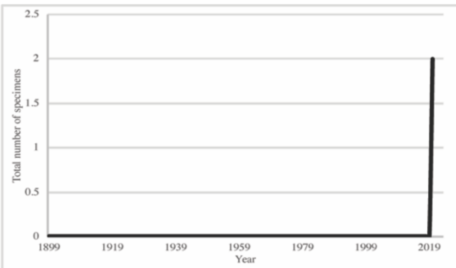


Figure 13i. Accumulation of *Megachile dakotensis*.

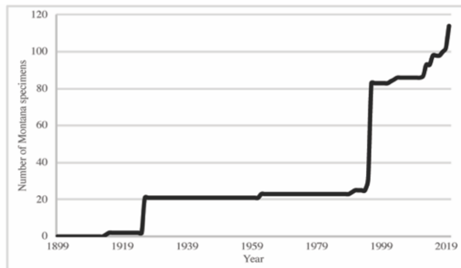


Figure 13j. Accumulation of *Megachile dentitarsus*.

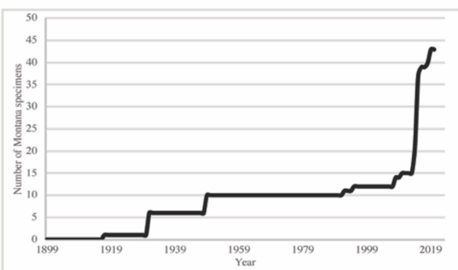


Figure 13k. Accumulation of *Megachile fidelis*.

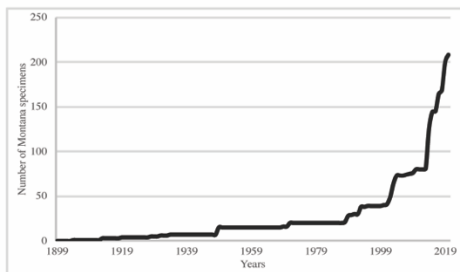


Figure 13l. Accumulation of *Megachile frigida*.

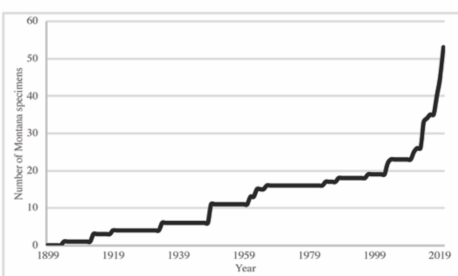


Figure 13m. Accumulation of *Megachile gemula*.

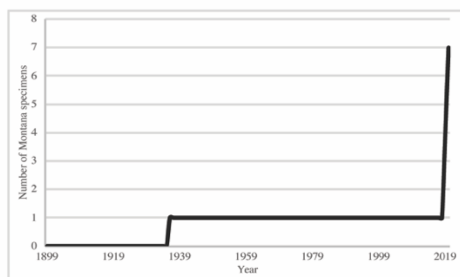


Figure 13n. Accumulation of *Megachile gentilis*.

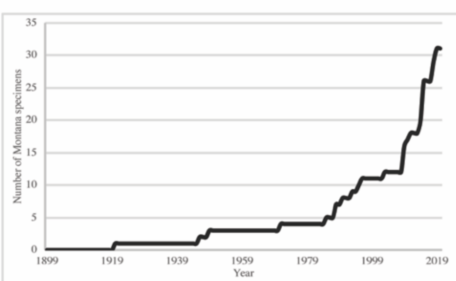


Figure 13o. Accumulation of *Megachile inermis*.

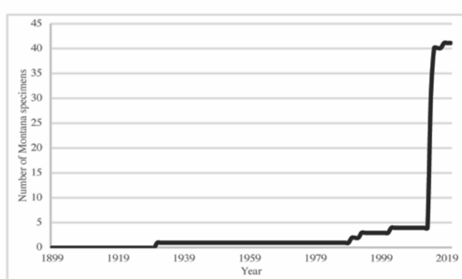


Figure 13p. Accumulation of *Megachile lapponica*.

Figure 13 Continued. Specimen accumulation for each of the 35 Montana *Megachile* species by year. The y-axes differ based on total specimen count. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature record and five specimens without dates are not included in this graph.

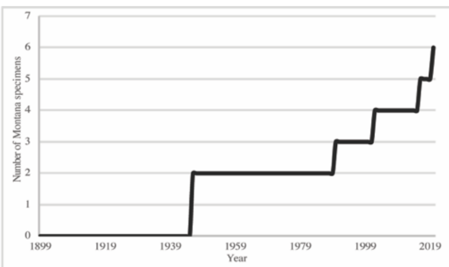


Figure 13q. Accumulation of *Megachile latimanus*.

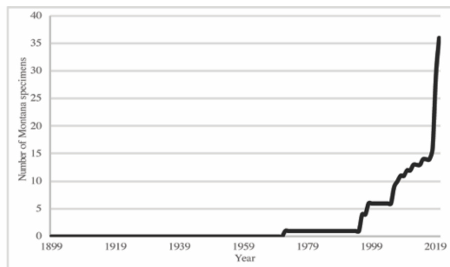


Figure 13r. Accumulation of *Megachile lippiae*.

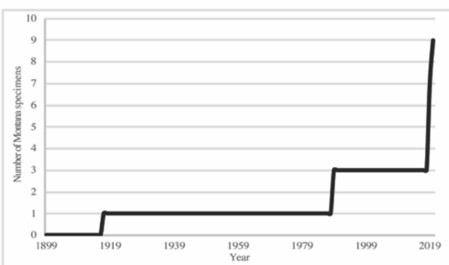


Figure 13s. Accumulation of *Megachile manifesta*.

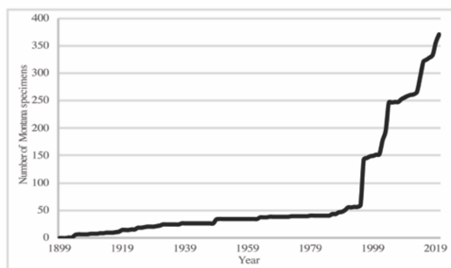


Figure 13t. Accumulation of *Megachile melanophaea*.

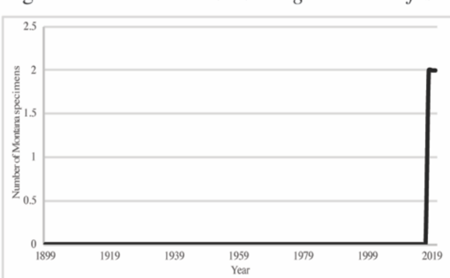


Figure 13u. Accumulation of *Megachile mellitarsis*.

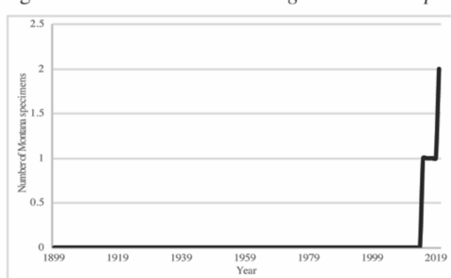


Figure 13v. Accumulation of *Megachile mendica*.

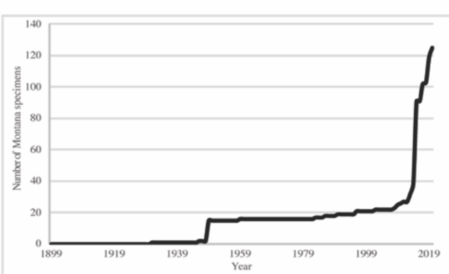


Figure 13w. Accumulation of *Megachile montivaga*.

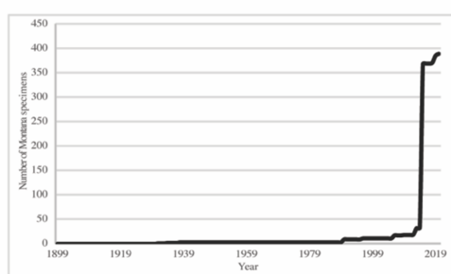


Figure 13x. Accumulation of *Megachile onobrychidis*.

Figure 13 Continued. Specimen accumulation for each of the 35 Montana *Megachile* species by year. The y-axes differ based on total specimen count. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature record and five specimens without dates are not included in this graph.

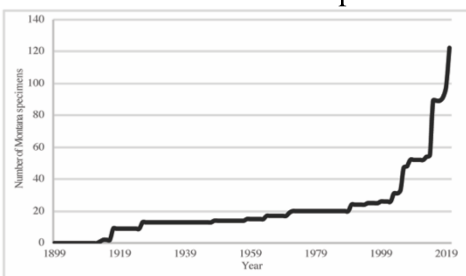


Figure 13y. Accumulation of *Megachile parallela*.

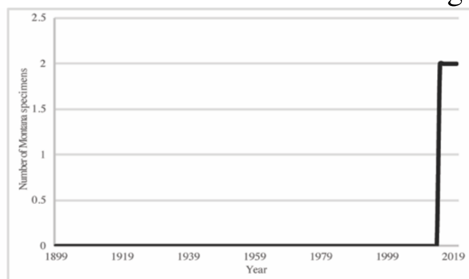


Figure 13z. Accumulation of *Megachile pascoensis*.

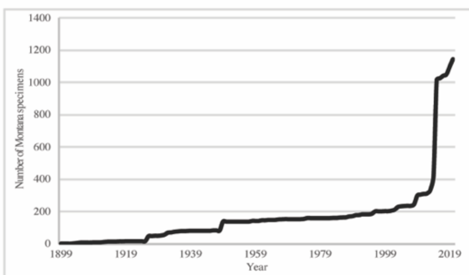


Figure 13aa. Accumulation of *Megachile perihirta*.

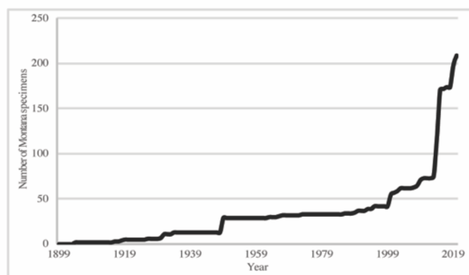


Figure 13ab. Accumulation of *Megachile pugnata*.

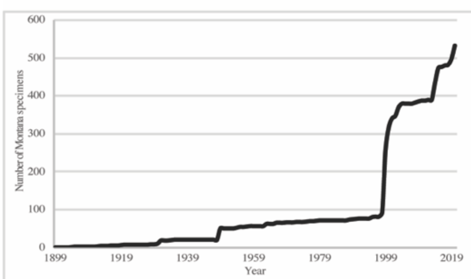


Figure 13ac. Accumulation of *Megachile relativa*.

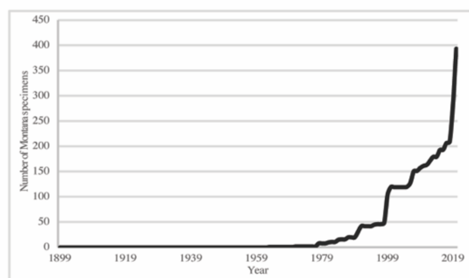


Figure 13ad. Accumulation of *Megachile rotundata*.

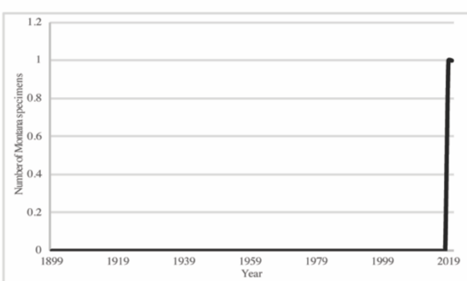


Figure 13ae. Accumulation of *Megachile snowi*.

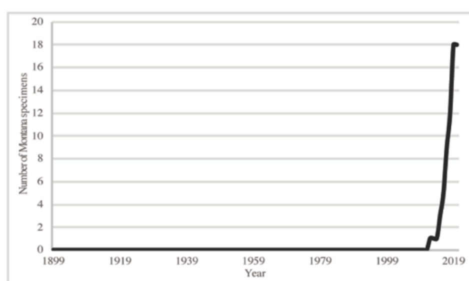


Figure 13af. Accumulation of *Megachile subnigra*.

Figure 13 Continued. Specimen accumulation for each of the 35 Montana *Megachile* species by year. The y-axes differ based on total specimen count. Females identified as *Megachile latimanus*/*Megachile perihirta* (and data without recorded specimen sexes) are counted here as *M. perihirta* as they are not distinguishable from one another in Montana. Males identified as *Megachile lapponica*/*Megachile relativa* (and data without recorded specimen sexes) are counted here as *M. relativa* as they are not distinguishable from one another in Montana. Mitchell literature record and five specimens without dates are not included in this graph.

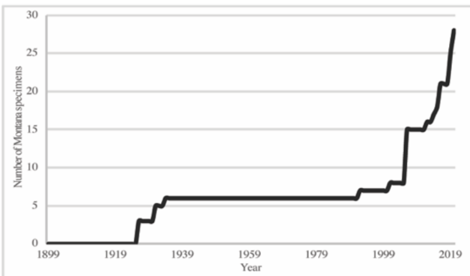


Figure 13ag. Accumulation of *Megachile texana*.

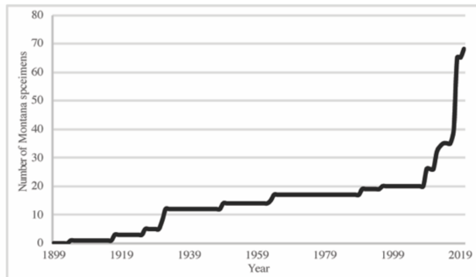
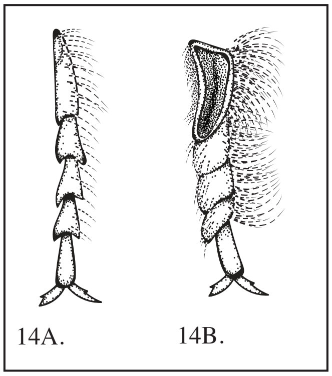
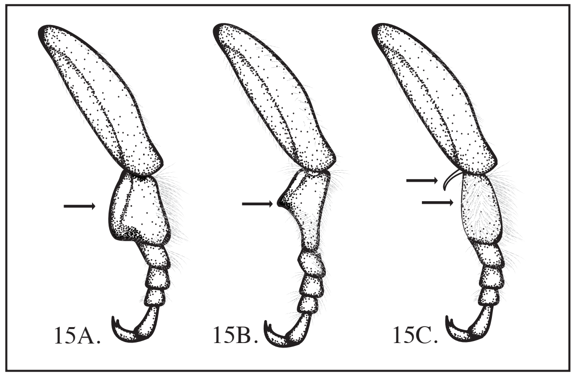
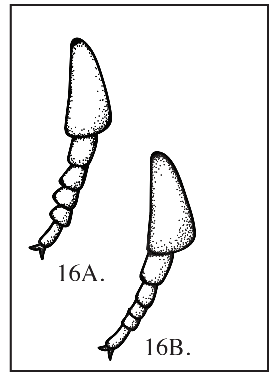
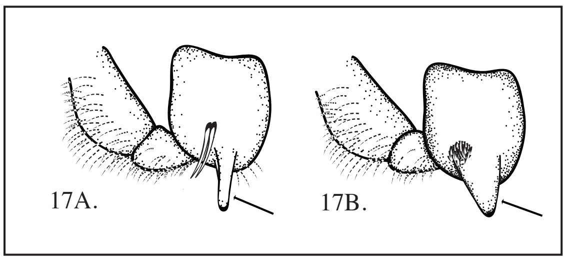


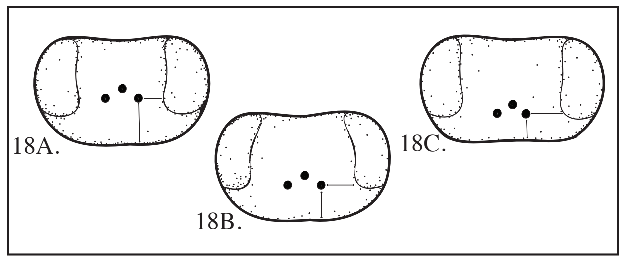
Figure 13ah. Accumulation of *Megachile wheeleri*.

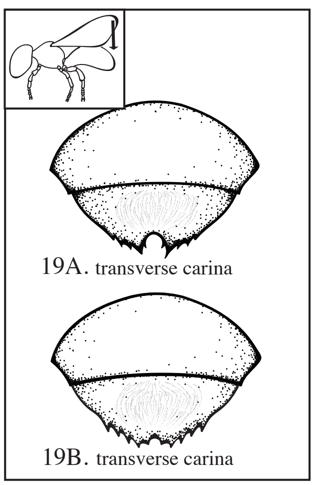

14A.
14B.

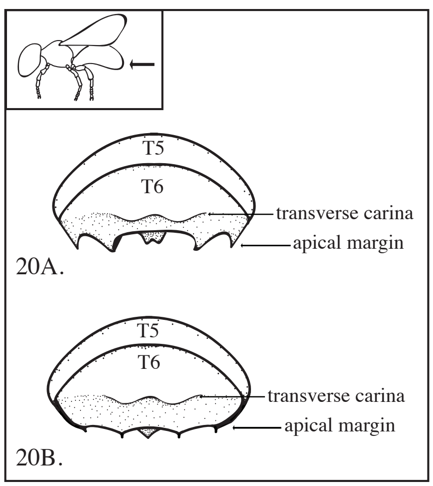

15A.
15B.
15C.

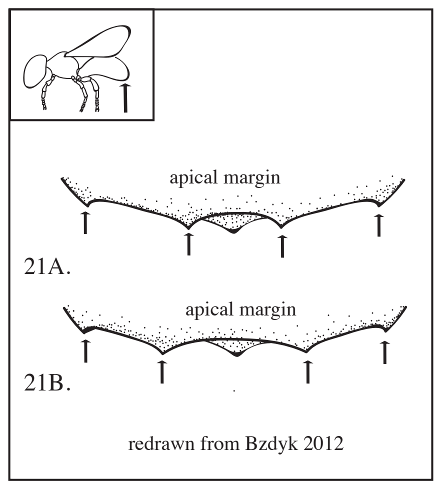

16A.
16B.

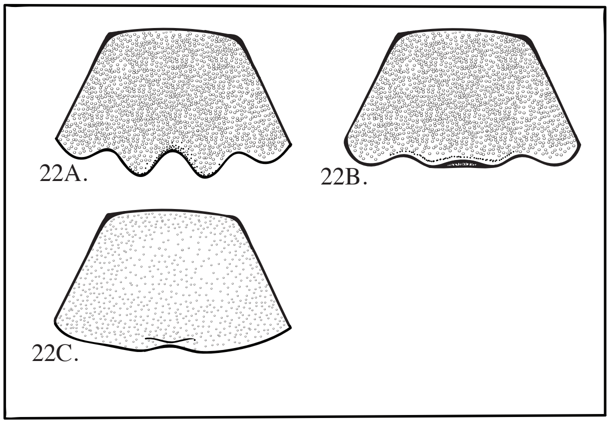

17A.
17B.

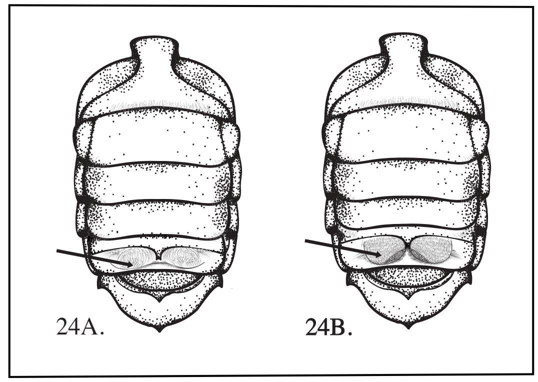

18A.
18B.
18C.

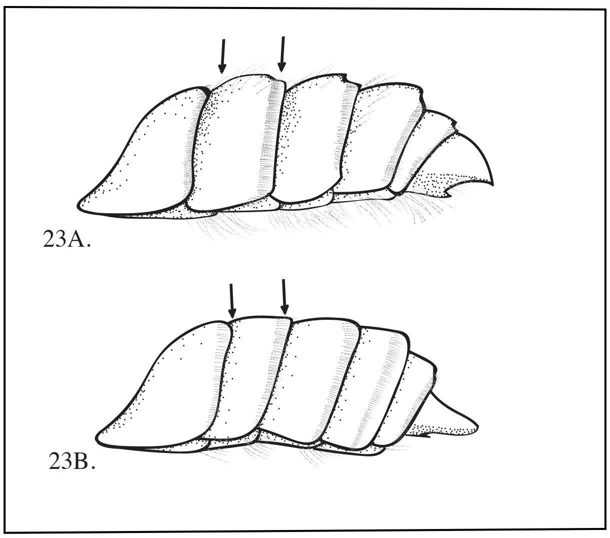

19A. transverse carina
19B. transverse carina

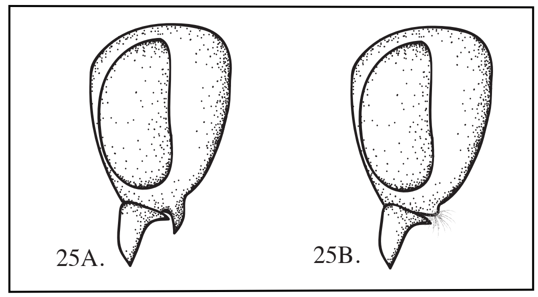

T5
T6
transverse carina
apical margin
20A.
T5
T6
transverse carina
apical margin
20B.

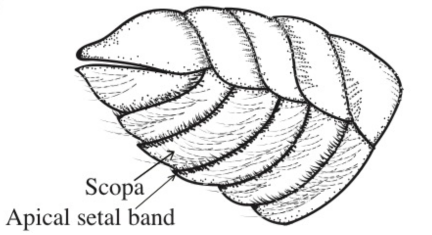

apical margin
21A.
apical margin
21B.
redrawn from Bzdyk 2012


22A.
22B.
22C.

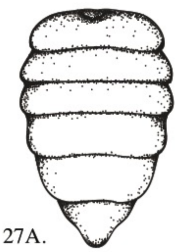

24A.
24B.


23A.
23B.

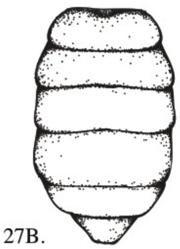

25A.
25B.



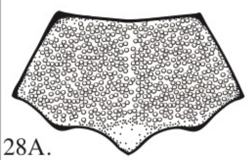
26.



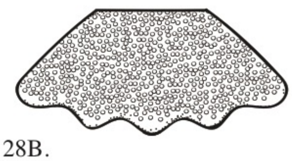
27A. redrawn from Sheffield 2011



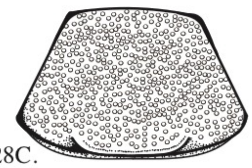
27B. redrawn from Sheffield 2011



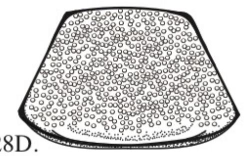
28A.



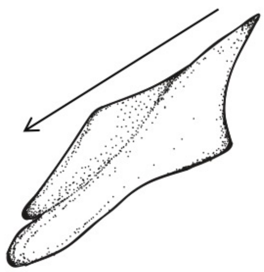
28B.



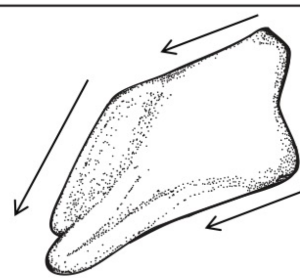
28C.



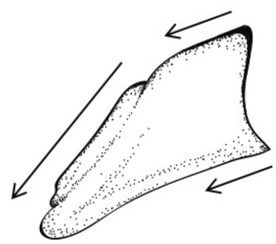
28D.



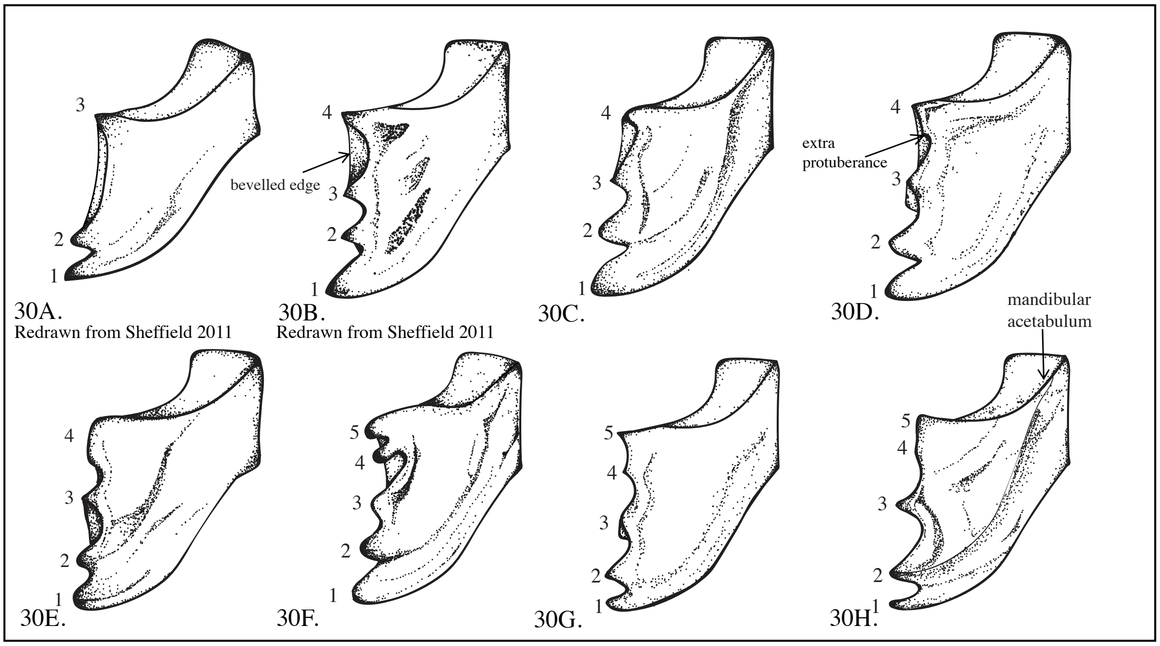
29A. Redrawn from Sheffield 2011.



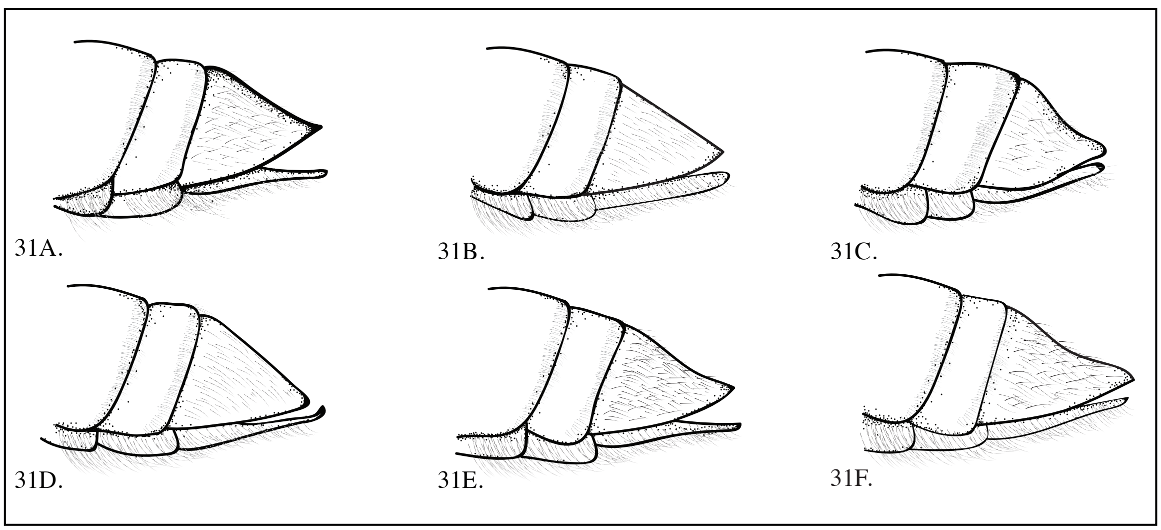
29B Redrawn from Sheffield 2011.



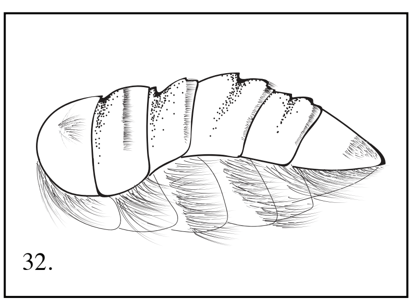
29C.



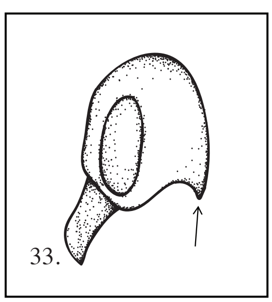
30A.
Redrawn from Sheffield 2011
30B.
Redrawn from Sheffield 2011
30C.
30D.
30E.
30F.
30G.
30H.



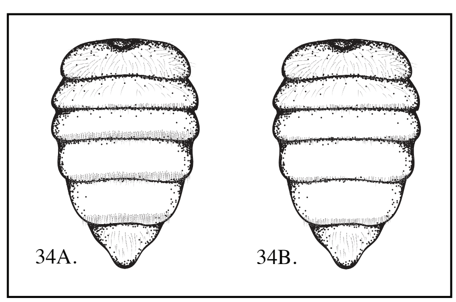
31A.
31B.
31C.
31D.
31E.
31F.



32.



33.



34A.
34B.

CHAPTER TWO

CHECKLIST OF BEES (HYMENOPTERA: APOIDEA) FROM THE SOUTHERN WOLF MOUNTAINS, MONTANA AND WYOMING

Introduction

Wild bees are important pollinators of a variety of flowering plants, including agricultural crops (Klein *et al*. 2003, Winfree *et al*. 2008, Garibaldi *et al*. 2013) and native trees, shrubs and forbs (Tepedino *et al*. 1997, Tepedino 2000, Fowler 2016). It is estimated that over 3,600 species of wild bees occur in the United States (U.S.) and Canada (Engel 2020), but there is limited understanding of their distributions, biology, and ecology. Recent research has documented declines in some wild bee populations (Colla and Packer 2008, Grixti *et al*. 2009, Potts *et al*. 2010, Goulson *et al*. 2015), causing conservation concern and a call for increased native bee monitoring (Woodard *et al*. 2020). However, to understand the status of wild bee populations, more work is needed to first document which native bee species occur in North America and where they occur, particularly in understudied areas.

Faunistic studies of wild bees are important for characterizing regional biodiversity and documenting wild bee species ranges. The diversity of wild bees has been documented at local and regional scales in various checklists and inventories in some parts of the western U.S., including Colorado (Scott *et al*. 2011), Wyoming (Lavigne and Tepedino 1976), Grand Staircase-Escalante National Monument in Utah (Carril *et al*. 2018), the San Francisco Peaks in Arizona (McCabe *et al*. 2020), and the Black Hills in South Dakota (Drons 2012), among others.

Though such research is expanding, much of the wild bee fauna remains little-studied in the western U.S., including Montana.

Montana is predicted to host a diverse bee fauna, based on its large area and diversity of habitats (Lesica 2012). A recent state-wide bumble bee inventory (*Bombus* Latreille spp.) resulted in documentation of 28 species in Montana, including new state records, a range expansion, and overlapping species pairs, suggesting there is much yet to be discovered in this region (Dolan *et al.* 2017). Previous research on bees in Montana has focused on western Montana, especially Chouteau, Flathead, Gallatin, Lewis and Clark, Meagher, Missoula, and Park Counties (Fultz 2005, Kuhlman and Burrows 2017, Reese *et al.* 2018, Adhikari *et al.* 2019, Delphia *et al.* 2019a, LaManna *et al.* 2020), and has provided important information on the bee fauna from these areas as well as contributed to the beginning of a state species list. However, there has been little prior bee collecting or research in the eastern half of the state. Due to the vastly different climates, habitats, and plant species in the eastern versus western parts of Montana, the bee species present are expected to vary considerably. Western Montana contains montane, alpine and subalpine zones, coniferous forests, aspen forests, sagebrush steppe, meadows, wetland and riparian areas, whereas Eastern Montana hosts riparian woodlands, riparian wetlands, sagebrush steppe, grasslands, and coniferous forests (Lesica 2012).

One area of particular interest is the Wolf Mountain Range in southcentral Montana which, to our knowledge, has not been previously surveyed for insect diversity. Records of all bee genera known to occur in Montana from Discover Life (DiscoverLife.org), an online source for insect diversity data particularly strong in bee records, show no bee specimens at all from the Wolf Mountains (Fig. 35). This indicates a lack of prior collecting, and a "black hole" of faunal bee data. This region is a dry plains region, which is predicted to contain moderate bee diversity when compared to all landscape types worldwide (Michener 1979). The Wolf Mountains are located east of Lodge Grass in Big Horn County, on the southeast border of the Crow Reservation, and extend from Montana into northern Wyoming, near Sheridan. The area is managed by several entities including the Crow Tribe, private owners, ranchers, and the State of Montana. The mountain range is ca. 56 km long, with a maximum elevation of 1,477 m (Topozone 2021). The Wolf Mountains are characterized as mesic dissected plains, or a dry region divided by steep valleys (Woods *et al*. 2002). The area contains sagebrush steppe, grassland habitats, and coniferous forests (Lesica 2012). Creeks within the range drain into Rosebud Creek in the east and the Little Bighorn River in the west (Google Earth®). The area has a mean annual high temperature of 15.5° C, mean annual low temperature of -3.6° C, and mean annual precipitation of 304 mm based on data from Decker, Montana (8.3 km northwest of the closest point we sampled) (Western Regional Climate Center 2021). In 2019 and 2020, as part of an ongoing project to inventory the wild bees of Montana, we surveyed bees in the Wolf Mountains in Big Horn County, Montana and Sheridan County, Wyoming at Padlock Ranch and in Big Horn County, Montana at Rosebud Battlefield State Park (Fig. 36). Here we report a list of bee species identified from these efforts, which contributes to creating a comprehensive Montana state list and filling gaps in our understanding of the bee fauna in this region.

Material and Methods

Study Sites

We collected bees at 37 localities within the Padlock Ranch in Big Horn County, Montana and Sheridan County, Wyoming and at 3 localities in Rosebud Battlefield State Park, Big Horn County, Montana (Fig. 36). Padlock Ranch is a private ranch engaged in cow-calf grazing, feedlot operations, and farming alfalfa, grass hay, corn silage, and hay barley (Padlock Ranch 2020). Though the ranch property spans 192,226 ha in both Sheridan County, Wyoming and Big Horn County, Montana (Environmental Stewardship 2021), our sampling was mostly conducted in the Montana portion of the ranch, northwest of Decker, Montana.

Rosebud Battlefield State Park, 15 km south of Kirby, Montana off Highway 314, is a National Historic Landmark of the 1876 Battle of the Rosebud. The park spans 1,235 ha and is at an elevation of 1,311 m (Montana Fish Wildlife and Parks 2021).

Collecting Specimens

We collected bees 31 May–2 June 2019, 15–18 July 2019, and 18–19 May 2020 using a combination of pan trapping and opportunistic netting (mostly from flowers). At pan-trap localities, we set 15 pan traps (7 yellow, 6 blue, and 2 white 20 oz. plastic bowls) partially filled with soapy water at ground level for 24 hours before retrieving samples and storing them in 70% EtOH (Droege 2015). We transported these samples to the Montana Entomology Collection (MTEC), where we processed specimens.

Processing Specimens and Deposition

We pinned bees netted in the field on the same day. For bees collected from pan traps, we first washed and blow dried them following Droege (2015), then pinned or point mounted specimens. We labeled mounted specimens with locality information and a unique identifier label (barcode). We recorded locality data and unique identifiers in an Excel spreadsheet, and archived the specimens in the MTEC. Upon publication of this work we will deposit the data in Hymenoptera Online (HOL), a publicly accessible database operated by Ohio State University.

Voucher specimens from this study are deposited in the MTEC at Montana State University, Bozeman, MT.

Classification and Species Identification

Our list follows the classification of Michener (2007) and some later modifications (Onuferko *et al*. 2021). We identified bees to genus using Michener *et al*. (1994) and when available, used published keys to species (Mitchell 1934, 1935a, 1935b, 1936, 1937, 1960; Hurd and Linsley 1951; Timberlake 1951, 1969; Stephen 1954; Mitchell 1960; Roberts 1972, 1973; Brooks 1983; McGinley 1986, 2003; Coelho 2004; Sheffield *et al*. 2011; Gonzalez and Griswold 2013; Williams *et al*. 2014; Dolan *et al*. 2017; Burrows *et al*. 2020; Ascher and Pickering 2021; Onuferko *et al*. 2021). We compared tentatively identified bees with reference specimens in the MTEC and the U.S. National Pollinating Insects Collection (BBSL) housed in the USDA-ARS Pollinating Insects Collection in Logan, Utah. When we were not able to identify specimens to species, we denoted morphospecies for specimens that appeared distinct from one another and applied unique numeric identifiers, using “M” for males and “F” for females (e.g., sp. F1, sp. F2, etc.). Where it was not possible to separate specimens by morphospecies [e.g., genera *Sphecodes* Latreille, and *Nomada* Scopoli, or subgenera *Lasioglossum* (*Dialictus*) Robertson, *Lasioglossum* (*Evylaeus*) Robertson] specimens are pooled together as “spp.’ in the checklist.

Several genera were identified by taxonomic experts: Skyler Burrows for *Andrena* Fabricius, *Colletes* Latreille, and *Habropoda* Smith; Karen Wright for *Melissodes* Latreille; and Terry Griswold for *Ashmeadiella* Cockerell, *Dioxys* Lepeletier and Serville, *Heridaes* Spinola, *Hoplitis* Klug, and *Osmia* Panzer. Some of these identifications are modified by qualifiers like “?”, “cf.”, and “nr.”. Skyler Burrows used ““nr.” and “?” if the identification was closest to a given species based on the reference material and species description, but not a perfect match. The qualifier “cf.” (Latin: *confer/conferatur*, both meaning "compare"), designated lack of reference specimens for comparison in the identification.

Analysis

We counted the total number of distinct species for analysis by summing the identified species and morphospecies. If a taxon was only identified to genus (i.e., *Nomada* spp.), that counted as one. When unassociated morphospecies consisting of males or females of the same genus occurred, we counted only the largest number of males or females in our species tally, to avoid over-counting. We tallied specimens that were not distinguished between two species (i.e., *Agapostemon angelicus* Cockerell and *Agapostemon texanus* Cresson females) as one “morphospecies”.

We used the program EstimateS (Colwell 2013) to estimate the Chao1 species richness predictor. We ran 100 randomizations of the sample using the “individual-based abundance sample” and used the output to create a species richness curve.

New State Records

We determined new state records by searching relevant literature, including taxonomic revisions (Mitchell 1960, Roberts 1972), published catalogues (Hurd 1979), and literature that included the Montana bee fauna (e.g., Dolan *et al*. 2017, Kuhlman and Burrows 2017, Reese *et al*. 2018, Adhikari *et al*. 2019, Delphia *et al*. 2019a) for Montana records.

Results

We collected 4,996 bees representing 138 species (including morphospecies and pooled species) of 28 genera and five families. The total number of genera, species, and specimens collected in each family are: Colletidae: 2 genera, 5 species, 15 specimens; Andrenidae: 1 genus, 34 species, 335 specimens; Halictidae: 6 genera, 20 species, 3,917 specimens; Megachilidae: 8 genera, 47 species, 255 specimens; Apidae: 11 genera, 30 species, 431 specimens.

Among these, *Augochloropsis metallica* (Fabricius, 1793) (new genus and species record) and *Agapostemon coloradinus* (Vachal, 1903) (new species record) were recorded from Montana for the first time, and two non-native species were found, both feral populations of managed species (Russo 2016): (*Megachile rotundata* [Fabricius, 1787], *Apis mellifera* Linnaeus, 1758). Not all possible new state records were exhaustively checked, and more may be found among this list.

Analysis with EstimateS (Colwell 2013) predicted a Chao1 mean of 189 species (Fig. 37), predicting an additional 51 species to occur beyond those we documented (Supplemental File C contains the EstimateS input file). The species accumulation curve does not approach an asymptote, clearly showing that more sampling is required to document the full bee species diversity in the region (Fig. 37).

List of Bee Species of the Southern Wolf Mountains

Colletidae
Colletinae
Colletini
Colletes fulgidus Swenk, 1904
Colletes brevicornis Robertson, 1897
Colletes consors or *robertsonii* group
Colletes ?eulophi Robertson, 1891

Hylaeinae

Hylaeus sp. F1

Andrenidae

Andreninae

Andrenini

Andrena (*Andrena*) ?*buckelli* Viereck, 1924
Andrena (*Andrena*) *thaspii* Graenicher, 1903
Andrena (*Diandrena*) *nothocalaidis* (Cockerell, 1905)
Andrena (*Euandrena*) *astragali* Viereck and Cockerell, 1914
Andrena (*Euandrena*) *lawrencei* Viereck and Cockerell, 1914
Andrena (*Euandrena*) *nigrocaerulea* Cockerell, 1897
Andrena (*Holandrena*) *cressonii* Robertson, 1891
Andrena (*Iomelissa*) *violae* Robertson, 1891
Andrena (*Larandrena*) *miserabilis* Cresson, 1872
Andrena (*Melandrena*) *commoda* Smith, 1879
Andrena (*Melandrena*) *lupinorum* Cockerell, 1906
Andrena (*Melandrena*) *nivalis* Smith, 1853
Andrena (*Melandrena*) cf. *regularis* Malloch, 1917
Andrena (*Micrandrena*) *illinoiensis* Robertson, 1891
Andrena (*Micrandrena*) *microchlora* Cockerell, 1922
Andrena (*Micrandrena*) *piperi* Viereck, 1904
Andrena (*Plastandrena*) *crataegi* Robertson, 1893
Andrena (*Plastandrena*) *prunorum* Cockerell, 1896
Andrena (*Scaphandrena*) *merriami* Cockerell, 1901
Andrena (*Scaphandrena*) *scurra* Viereck, 1904
Andrena (*Scrapteropsis*) *imitatrix* Cresson, 1872
Andrena (*Simandrena*) *nasonii* Robertson, 1895
Andrena (*Simandrena*) *pallidifovea* (Viereck, 1904)
Andrena (*Simandrena*) *wheeleri* Mitchell, 1927
Andrena (*Thysandrena*) *medionitens* Cockerell, 1902
Andrena (*Thysandrena*) *vierecki* Cockerell, 1904
Andrena (*Trachandrena*) *amphibola* Viereck, 1904
Andrena (*Trachandrena*) nr. *salicifloris* Cockerell, 1897
Andrena (*Tylandrena*) *erythrogaster* (Ashmead, 1890)
Andrena (*Tylandrena*) *subtilis* Smith, 1879
Andrena (*Tylandrena*) nr. *wilmattae* Cockerell, 1906
Andrena sp. F1
Andrena sp. F2
Andrena sp. M1
Andrena sp. M2
Andrena sp. M3

Halictidae

Halictinae

Halictini

Agapostemon (*Agapostemon*) *coloradinus* (Vachal, 1903)

New species record for Montana

Agapostemon (*Agapostemon*) *melliventris* Cresson, 1874

Agapostemon (*Agapostemon*) *texanus* Cresson, 1872/*Agapostemon (Agapostemon) angelicus* Cockerell, 1924

Agapostemon (*Agapostemon*) *virescens* (Fabricius, 1775)

Halictus (*Nealictus*) *farinosus* Smith, 1853

Halictus (*Odontalictus*) *ligatus* Say, 1837

Halictus (*Protohalictus*) *rubicundus* (Christ, 1791)

Halictus (*Seladonia*) *confusus* Smith, 1853

Halictus (*Seladonia*) *tripartitus* Cockerell, 1895

Lasioglossum (*Dialictus*) spp.

Lasioglossum (*Evylaeus*) spp.

Lasioglossum (*Lasioglossum*) *paraforbesii* McGinley, 1986

Lasioglossum (*Lasioglossum*) *sisymbrii* (Cockerell, 1895)

Lasioglossum (*Lasioglossum*) spp.

Lasioglossum (*Sphecodogastra*) *abberans* (Crawford, 1903)

Lasioglossum (*Sphecodogastra*) *lusorium* (Cresson, 1872)

Lasioglossum (*Sphecodogastra*) *texanum* (Cresson, 1872)

Sphecodes spp.

Augochlorini

Augochlorella (*Augochlorella*) *aurata* (Smith, 1853)

Augochloropsis (*Paraugochloropsis*) *metallica* (Fabricius, 1793)

New species and genus record for Montana

Megachilidae

Megachilinae

Osmiini

Ashmeadiella (*Ashmeadiella*) *cactorum* (Cockerell, 1879)

Heriades (*Neotrypetes*) *carinata* Cresson, 1864

Heriades (*Neotrypetes*) *variolosa* (Cresson, 1872)

Hoplitis (*Alcidamea*) *albifrons* (Cresson, 1864)

Hoplitis (*Alcidamea*) *hypocrita* (Cockerell, 1906)

Hoplitis (*Alcidamea*) *pilosifrons* (Cresson, 1864)

Hoplitis (*Alcidamea*) *producta* (Cresson, 1864)
Hoplitis (*Alcidamea*) *spoliata* (Provancher, 1888)

Osmia (*Acanthosmioides*) *giliarum* Cockerell, 1906
Osmia (*Acanthosmioides*) *integra* Cresson, 1878
Osmia (*Melanosmia*) *albolateralis* Cockerell, 1906
Osmia (*Melanosmia*) *atrocyanea* Cockerell, 1897
Osmia (*Melanosmia*) *austromaritima* Michener, 1936
Osmia (*Melanosmia*) *bella* Cresson, 1878
Osmia (*Melanosmia*) *brevis* Cresson, 1864
Osmia (*Melanosmia*) *bruneri* Cockerell, 1897
Osmia (*Melanosmia*) *cordata* Robertson, 1902
Osmia (*Melanosmia*) *densa* Cresson, 1864
Osmia (*Melanosmia*) *dolerosa* Sandhouse, 1939
Osmia (*Melanosmia*) *ednae* Cockerell, 1907
Osmia (*Melanosmia*) *iridis* Cockerell and Titus, 1902
Osmia (*Melanosmia*) *kincaidii* Cockerell, 1897
Osmia (*Melanosmia*) *melanopleura* Cockerell, 1916
Osmia (*Melanosmia*) *pusilla* Cresson, 1864
Osmia (*Melanosmia*) *simillima* Smith, 1853
Osmia (*Melanosmia*) sp. M1
Osmia (*Melanosmia*) *trevoris* Cockerell, 1897
Osmia (*Melanosmia*) *unca* Michener, 1937
Osmia (*Osmia*) *lignaria* Say, 1837
Osmia spp.

Anthidiini

Anthidium (*Anthidium*) *clypeodentatum* Swenk, 1914
Anthidium (*Anthidium*) *emarginatum* (Say, 1824)
Anthidium (*Anthidium*) *mormonum* Cresson, 1878
Anthidium (*Anthidium*) *utahense* Swenk, 1914
Anthidium (*Callanthidium*) *formosum* Cresson, 1878

Dianthidium spp.

Dioxyini

Dioxys pacificus pacificus Cockerell, 1916
Dioxys pomonae pomonae Cockerell, 1910
Dioxys productus productus (Cresson, 1879)

Megachilini

Megachile (*Eutricharaea*) *rotundata* (Fabricius, 1793)
Megachile (*Litomegachile*) *brevis* Say, 1837
Megachile (*Litomegachile*) *lippiae* Cockerell, 1900

Megachile (*Litomegachile*) *onobrychidis* Cockerell, 1905
Megachile (*Litomegachile*) *texana* Cresson, 1878
Megachile (*Megachile*) *relativa* Cresson, 1878
Megachile (*Megachiloides*) *subnigra* Cresson, 1879
Megachile (*Xanthosarus*) *perihirta* Cockerell, 1898

Apidae
Xylocopinae
Ceratinini
Ceratina sp. F1

Nomadinae
Nomadini
Nomada spp.

Epeolini
Triepeolus sp. M1

Apinae
Emphorini
Diadasia spp.

Eucerini
Eucera (*Synhalonia*) *actuosa* (Cresson, 1878)
Eucera (*Synhalonia*) *hamata* (Bradley, 1942)
Eucera spp.

Melissodes (*Callimelissodes*) *plumosus* LaBerge, 1961
Melissodes (*Eumelissodes*) *coreopsis* Robertson, 1905
Melissodes (*Eumelissodes*) *gelidus* LaBerge, 1961
Melissodes (*Melissodes*) *communis* Cresson, 1878

Anthophorini
Anthophora (*Lophanthophora*) *affabilis* Cresson, 1878
Anthophora (*Lophanthophora*) *pacifica* Cresson, 1878
Anthophora (*Lophanthophora*) *porterae* Cockerell, 1900
Anthophora (*Lophanthophora*) *ursina* Cresson, 1869
Anthophora (*Melea*) *bomboides* Kirby, 1838
Anthophora (*Melea*) *occidentalis* Cresson, 1869

Habropoda cineraria (Smith, 1879)

Melectini
Brachymelecta californica (Cresson, 1878)

Bombini

Bombus (*Bombias*) *nevadensis* Cresson, 1874
Bombus (*Cullumanobombus*) *griseocollis* (De Geer, 1773)
Bombus (*Cullumanobombus*) *rufocinctus* Cresson, 1863
Bombus (*Psithyrus*) *insularis* (Smith, 1861)
Bombus (*Pyrobombus*) *centralis* Cresson, 1864 /*Bombus* (*Pyrobombus*) *flavifrons* Cresson, 1863
Bombus (*Pyrobombus*) *flavifrons* Cresson, 1863
Bombus (*Pyrobombus*) *huntii* Greene, 1860
Bombus (*Pyrobombus*) *huntii* Green, 1860/(*Pyrobombus*) *ternarius* Say, 1837
Bombus (*Pyrobombus*) *sylvicola* Kirby, 1837
Bombus (*Subterraneobombus*) *appositus* Cresson, 1878
Bombus (*Thoracobombus*) *californicus* Smith, 1854
Bombus (*Thoracobombus*) *fervidus* (Fabricius, 1798)

Apini

Apis mellifera Linnaeus, 1758

Discussion

Though this study adds faunistic bee data to a previously undocumented region in southcentral Montana, there is still need for more collecting in this area. We were only able to collect in some regions within the study area and visited the area only during short trips in May, June, and July. Due to road conditions in the earlier season and fire hazards on later visits, higher elevations were never visited. The species accumulation curve (Fig. 37) does not approach an asymptote, showing that more specimens are needed to calculate a more robust estimate of species richness. With the specimens in our study, the Chao1 mean prediction of total species richness is 189, similarly indicating that we did not collect the full range of species possible.

The data used in this Chao1 analysis also underestimates the diversity present in the material collected. Our species data include 46 singletons and 18 doubletons, with many more likely once pooled groups are split into actual species.

The specimens of certain genera (e.g., *Nomada*, *Diadasia*, *Sphecodes*, and *Lasioglossum*) were pooled under "spp." and counted as one "species," which obviously underrepresents the actual species count. This pooling of multiple specimens under a single "species" can influence the Chao estimate negatively. The Chao1 analysis uses the numbers of singletons and doubletons to calculate how many more species would be predicted in a sample, and these pools reduce the number of singletons, possibly significantly.

Greater capacity for species-level identifications would contribute to better documenting the bee diversity present in the Wolf Mountains. We identified *Sphecodes*, *Nomada*, and *Diadasia* to genus only. Only some *Lasioglossum* in the subgenus *Lasioglossum* were identified to species. *Lasioglossum* (*Dialictus*) and *Lasioglossum* (*Evylaeus*) were not identified past subgenus. In particular, the subgenus *Dialictus* presented a major challenge. *Lasioglossum* (*Dialictus*) included 2,204 specimens, or 44% of the total bee specimens. There are no keys or revisions for most western *L.* (*Dialictus*), and they remain quite difficult to separate, let alone identify to species (but see Gardner and Gibbs 2020).

Although first reported here from Montana, *A.coloradinus* and *A. metallica* were expected to occur in Montana based on their previously known ranges; *A. coloradinus* has been collected in other parts of Montana in other ongoing surveys, though *A. metallica* has not. Roberts (1972) writes that *A. coloradinus* is the rarest North American *Agapostemon* species, with a limited range including South Dakota, Nebraska, Kansas, Colorado, and Wyoming. Other published records of *A. coloradinus* include several counties in Colorado (Scott *et al*. 2011) and two eastern Wyoming localities (Lavigne and Tepedino 1976). Specimen data taken from Discover Life (19 June 2021) document *A. coloradinus* in Salt Lake City, Utah (University of Kansas Snow Entomological Museum Collection KSEM495229), Logan, Utah (KSEM495230), and Bloomington Canyon, Idaho (USDA Bee Biology and Systematics Lab collection BBSL81457).

Augochloropsis metallica, a new genus and species record for Montana, would also be predicted to occur in the state based on existing range data. *Augochloropsis metallica* generally occurs further south and east in the U.S. relative to Montana, and the closest records include the Black Hills of South Dakota (Mitchell 1960, Drons 2012) and Colorado (Scott *et al*. 2011).

The non-native species *A. mellifera* and *M. rotundata* are both economically important species for agriculture in the U.S. *Megachile rotundata*, a species commonly managed for alfalfa seed production (*Medicago sativa* L., Pitts-Singer and Cane 2011), is also known to occur in feral populations in Montana (O'Neill *et al*. 2010) and was present in wild nesting aggregations in sandstone formations on Padlock Ranch. *Apis mellifera* is a widely managed pollinator that was present in high numbers at the Rosebud Battlefield location, which was near commercial hives alongside Highway 314 north of Rosebud Battlefield (ZAP pers. obs., 18 July 2019). No managed bees were kept on Padlock Ranch (Trey Patterson *pers. com*.), yet honey bees were found extensively on the ranch, more than 10 km from known human-managed hives, and possibly representing a feral population (see Beekman and Ratnieks 2000). Non-native bee species are predicted to potentially impact native species negatively (Goulson 2015), but we do not know the impact of *A. mellifera* or *M. rotundata* on native bee species in this region.

Conclusion

This study provides bee biodiversity data for a previously unstudied region in Montana and Wyoming and adds new Montana state records for two species and one genus, contributing to the growing list of wild bee species found in the state. This research also highlights the need for updated taxonomic revisions and taxonomic expertise to support such faunistic work, based on the lack of western keys to several genera found in our collecting. Clearly, more sampling in the Wolf Mountains will uncover additional species. Extensions of this project could include visiting higher elevation springs and forests, among other regions in the Wolf Mountains range that we did not visit during our study, and working with experts to identify challenging bee genera to species. More faunistic work like this will be important to catalogue the bee diversity of Montana.

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Figure 35. Existing records of all bee genera from Discover Life (accessed 21 June 2021) in the region including the Wolf Mountains (Wolf Mountains indicated by red rectangle).

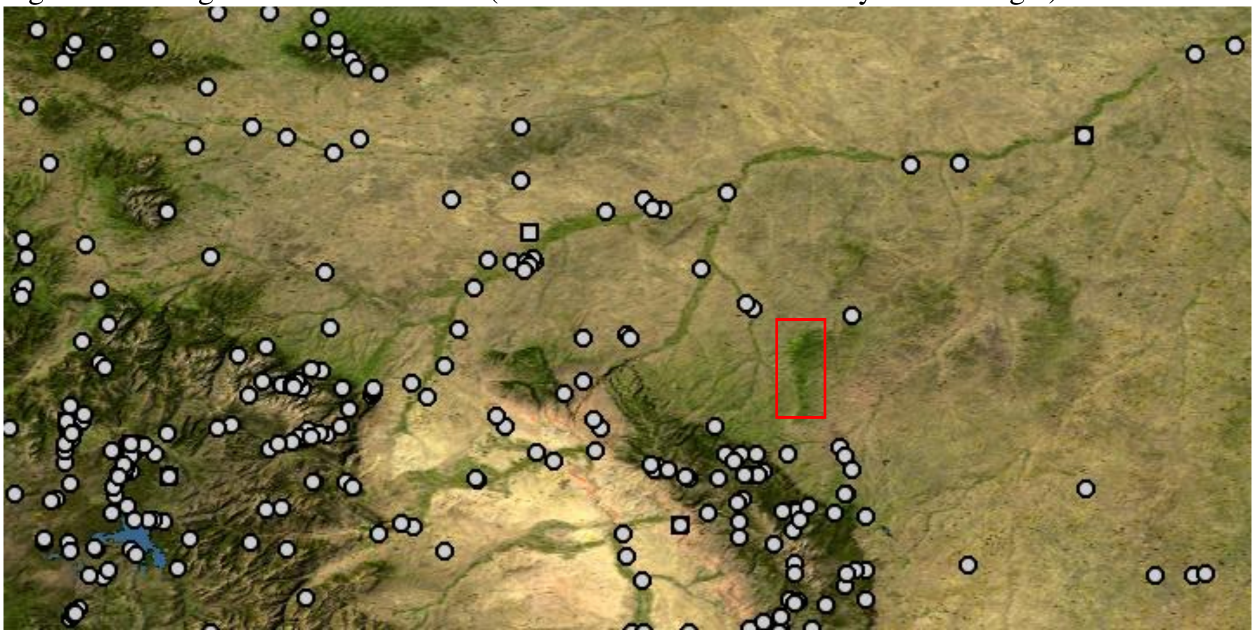


Figure 36. Collecting sites in the Wolf Mountains, Montana and Wyoming.

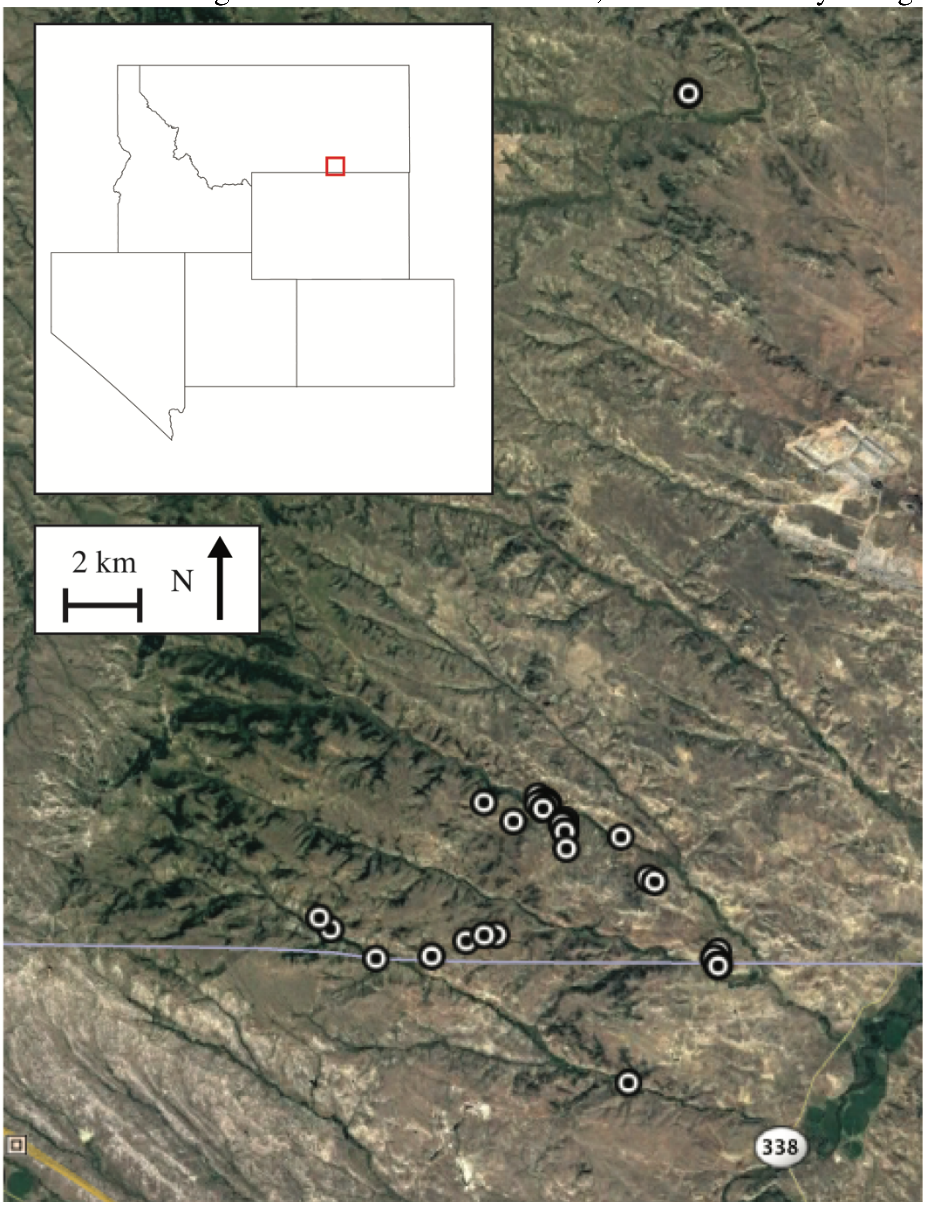
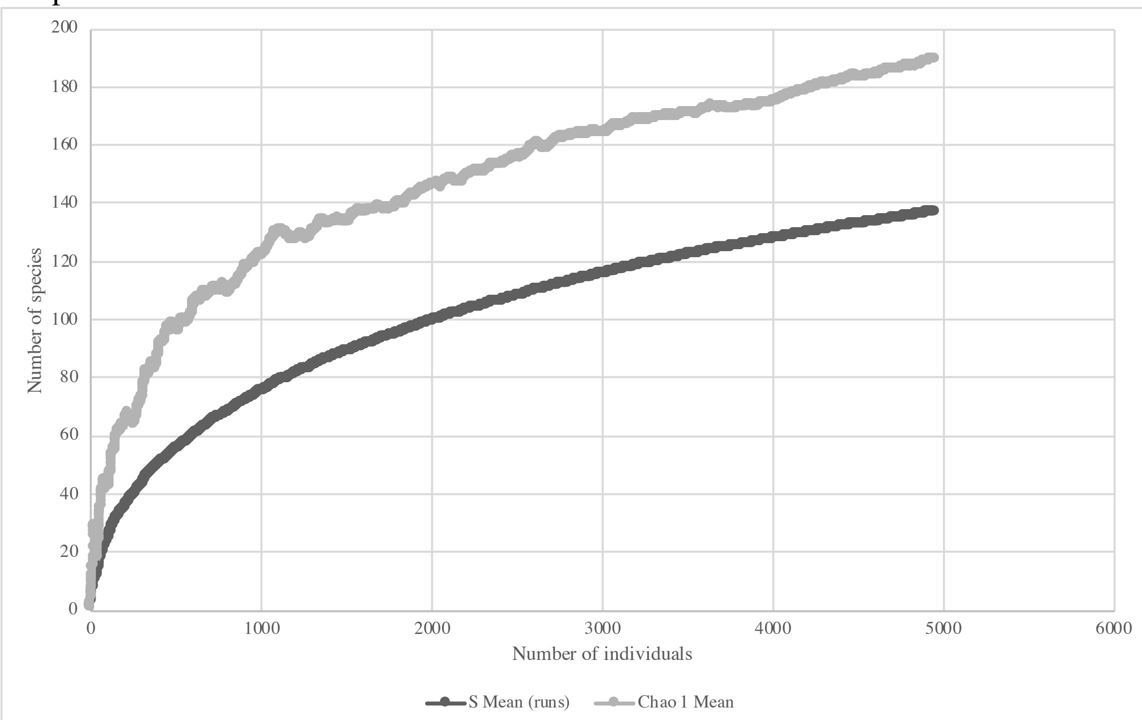


Figure 37. Wolf Mountains bee species accumulation curve. This figure was generated using EstimateS (Colwell 2013). Data were entered as one individual-based abundance sample. The sample was randomized 100 times to create the Chao1 mean curve.



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