2015 Project Abstract
For the Period Ending June 30, 2021

PROJECT TITLE: Minnesota Native Bee Atlas
PROJECT MANAGER: Robert B. Blair
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 03g as extended by M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 19 as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

APPROPRIATION AMOUNT: $790,000
AMOUNT SPENT: $790,000
AMOUNT REMAINING: $0

Sound bite of Project Outcomes and Results
The Minnesota Bee Atlas relied on volunteers to collect data on native bee distribution and diversity as well as previously unstudied nesting phenology. This data supplements existing information from the Minnesota DNR and UMN Insect Collection and can inform land management and policy decisions.

Overall Project Outcome and Results

Although the plight of bees and other pollinators has been highlighted recently, the question of how bees are doing is complicated. There is still much to be known about which bees live where in Minnesota and their population status. From 2015 through 2019, volunteers documented over 25,000 bees in Minnesota as a part of the Minnesota Bee Atlas. They did this by submitting photos of bees to iNaturalist, adopting roadside survey routes to capture, identify and release bumble bees, and monitoring nesting blocks for stem-nesting bees.

Through this work, five species were documented that had previously not been recorded in Minnesota. While it's difficult to know if they are new arrivals or just newly documented, Minnesota is at the northern end of the range for 3 of those species and could be evidence of shifting ranges.
Non-lethal bumble bee sampling led to documentation of additional populations of the federally endangered rusty patched bumble bee (*Bombus affinis*). This data informs the US Fish and Wildlife Service species recovery plan.

The Bee Atlas documented nest structures and nest activity for stem-nesting bees that had not previously been recorded. This information may inform management decisions that would impact the amount of forage or nesting habitat available for bees as changes could be made at times when bees are less active.

Finally, the Bee Atlas engaged members of the public beyond volunteer participants when volunteers became active in their own communities. Volunteers shared their knowledge of bees and pollinator conservation with youth scout groups, 4-H youth, Master Gardeners, Master Naturalists, and countless friends and neighbors.

Project Results Use and Dissemination
1. *All records from the Bee Atlas can be found in publicly accessible databases, namely iNaturalist.org and the Minnesota Biodiversity Atlas, found at http://bellatlas.umn.edu. Additionally, species-specific information such as seasonality, floral associations, and identification for bumble bees and stem-nesting bees can be*

accessed through the University of Minnesota Extension, http://z.umn.edu/beeatlas. All volunteer training documents are also found on this page.

2. *BONUS: Publications*
   -- Record of Anthophora (Clisodon) terminalis in a wooden trap-nesting block and comparison to available nesting information (Hymenoptera: Apidae) Journal of Melittology
   -- Minnesota State Records for Osmia georgica, Megachile inimica, and Megachile frugalis (Hymenoptera, Megachilidae), Including a New Nest Description for Megachile frugalis Compared with Other Species in the Subgenus Sayapis The Great Lakes Entomologist

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2015 Work Plan Final Report

Date of Report: October 13, 2021

Final report

Date of Work Plan Approval: June 11, 2015

Project Completion Date: June 30, 2021

PROJECT TITLE: Minnesota Native Bee Atlas

Project Manager: Robert B. Blair

Organization: University of Minnesota

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Location: Statewide.

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$790,000**
	Amount Spent:	**$790,000**
	Balance:	**$0**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03g as extended by M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 19 as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

Appropriation Language:
$790,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to supplement and enhance existing bee survey efforts by engaging citizens in helping to document the distribution and phenology of wild Minnesota bees and integrating data from all related bee survey efforts into a single publicly accessible, online tool and repository. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

M.L. 2019 - Carryforward; Extension (a) The availability of the appropriations for the following projects is extended to June 30, 2020:(2) Laws 2015, chapter 76, section 2, subdivision 3, paragraph (g), Minnesota Native Bee Atlas;

I. PROJECT TITLE: Minnesota Native Bee Atlas

II. PROJECT STATEMENT:
The Minnesota Native Bee Atlas will engage citizens in documenting the distribution and phenology of native Minnesota bees. It will complement (not duplicate) other, on-going, pollinator surveys by sampling tunnel-nesting and bumble bees in all of the ecological provinces, sections, and subsections of the state. It will also integrate bee distribution data from several other sources to create a publicly accessible, user friendly database on all bee distributions in the state.

Need. Wild bees are a vital part of our state's ecosystems. However, we know very little about their distribution, abundance, and seasonal activity. The only statewide checklist of Minnesota bees was published in 1919 and contained 88 species, far fewer than the approximately 400 species that are suspected of living here. Additionally, little is published about the phenology of individual bee species: when they become active after winter, when they lay eggs, and when the adults emerge. The Minnesota Wild Bee Atlas will document the distributions throughout the state of tunnel-nesting bees, which comprise ~30% of Minnesota's bee species. Their nesting habits allow the use of standardized nesting blocks, which trained citizen scientists can easily deploy. The project also focuses on bumble bees because of the straightforward visual identification of most Minnesota bumble bees and their high public interest.

This project will complement and build upon two LCCMR-funded projects that are documenting bee distributions in Minnesota and one that is recommended for funding. "Wild Bee Pollinator Surveys in Prairie-Grassland Habitats", managed by Gerda Nordquist MN-DNR, will intensively sample wild bees in up to 90 random sites in the prairie portions of the state. "Enhancing Pollinator Landscapes", managed by Marla Spivak UMN, will intensively survey three areas in southeastern Minnesota to compare historic records to current ones. "Effects of Grazing Versus Fire for Prairie Management" managed by Karen Oberhauser is a project recommended for funding that will study the effects of grazing and fire on tallgrass prairie plants and pollinators in 75 prairie sites in Minnesota. Though the focus of this project is not bee distributions, the data collected on bee distributions will be archived in the Minnesota Wild Bee Atlas.

All of these projects address one facet of bee distributions in the state but none has a statewide geographic focus and most of the sites that will be sampled are located in the western third of the state that was formerly dominated by tallgrass prairie. The "Minnesota Wild Bee Atlas" will expand the geographic focus of wild bee surveys to all portions of the state, but concentrate on the tunnel-nesting and bumble bees because of the involvement of trained, but not expert, citizen scientists.

Using citizen scientists will add the extensive sampling power of citizen science to other survey efforts by enabling much broader geographic coverage. It will involve hundreds of volunteer citizen scientists systematically documenting wild bee distributions and phenology at hundreds of sites throughout the state. It will also make the data of all three projects easily accessible to researchers and the public through its digital portal.

Goals and Outcomes. The goal of Minnesota Wild Bee Atlas is to promote the conservation of Minnesota native pollinators. The direct outcomes of the project are to:
1) determine the distribution of tunnel-nesting and bumble bees throughout Minnesota;
2) document the phenology of these bees to aid in their management and conservation;
3) promote an understanding of native bees among Minnesota citizens by engaging them in documenting bee distribution and phenology; and

4) combine this information with that from other LCCMR-funded pollinator surveys in a digital atlas to make this information widely available to researchers and the public.

Process. The project will occur in three steps:
1) The first step in building the Minnesota Native Bee Atlas will be to refine existing sampling protocols for use in Minnesota, create a comprehensive web site and database that will be used to enter and retrieve data, and develop training materials and workshops for the citizen scientists who will be collecting the data.
2) The second step will be to train citizen scientists to survey bees across the state. The project will have three tiers of sampling and rigor: incidental observation of all bees, targeted observation of bumble bees, and systematic sampling of tunnel-nesting bees. Casual participants will be able to report bees that they encounter outdoors. Those who are more passionate will be able to adopt specific sampling locations and either conduct targeted observation of bumble bees or deploy wood nesting blocks to sample tunnel-nesting bees.
3) The third, and final, step will be to cross-validate the data submitted by the citizen-scientists and to make them available in a database that can be queried by the citizen scientists, researchers, and the general public.

Significance. The project will 1) provide the first ***systematic statewide assessment*** of the distribution of tunnel-nesting and bumble bees; 2) provide ***phenologies for individual bee species***, which can guide management practices such as timing of herbicide use, prescribed burns, mowing, and other management actions; 3) develop a ***statewide cohort of citizen scientists*** that is knowledgeable about native bees; and 4) link with the Global Biodiversity Information Facility (www.gbif.org), an international clearinghouse on biodiversity data. The long-term strategy for the project is to provide data that will aid in the conservation of Minnesota's wild bees.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2016: Work in the fall of 2015 focused on researching data submission platforms, developing research protocols, creating print and electronic materials to recruit volunteers, and sourcing nesting blocks. A pilot volunteer build day was held at Afton State Park as a part of National Public Lands Day where five volunteers were able to partially construct 60 bee nesting blocks. We learned that building the blocks requires access to tools not commonly available and have contracted with a woodworker to complete the blocks needed for the 2016 field season.

Project Status as of July 1, 2016: In the spring of 2016, all scientific protocols and data submission websites were completed. The nesting blocks were completed by ATH Enterprises, LLC and mounted in 128 different locations across the state. Block monitors include nature centers, individuals, volunteers and employees at county and regional parks, DNR staff, DNR Scientific and Natural Area volunteer stewards, homeschool families, and native plant nurseries. Workshops were held at 10 different locations, reaching 184 participants. Additionally, 199 volunteers participated by submitting photos to the website and smart phone app iNaturalist or on our Facebook page.

Amendment Request as of September 22, 2016: We request a no-cost budget adjustment in two areas: 1. Graphic design needs for Activity 2 can partially be met by in-house production with personnel at the University of Minnesota, so $4000 of the money allocated to contracts needs to be reallocated to the "Personnel" and $600 to the "Equipment/Tools/Supplies" categories from the "Professional/Technical/Service Contract" category, and 2. Curatorial supplies to process the bees correctly for the University of Minnesota Entomology Collection in Activity 3 were not considered in the original grant proposal and we would like to reallocate $7500 of the "Travel expenses in Minnesota" money for the entomologist on the project to "Equipment/Tools/Supplies" in order to purchase curatorial supplies.

Project Status as of January 1, 2017: The 2016 field season was completed in the fall of 2016. Volunteers returned nesting blocks to University of Minnesota Extension offices and submitted final observations of nesting

blocks and bumble bee survey routes. The nesting blocks are currently in cold storage to simulate a Minnesota winter and will be warmed in early March to complete the bees' development so adult bees can be identified to species. In total, 120 volunteers monitored nesting blocks, 12 surveyed bumble routes, and 512 photo observations were submitted to the website and mobile app iNaturalist. The Bee Atlas Facebook page has 189 followers.

Project Status as of July 1, 2017: The 2017 field season has begun with 130 bee blocks placed across the state, 25 volunteers monitoring bumble bee routes, and 855 observations on iNaturalist. Of note, 11/12 volunteers who surveyed bumble bee routes in 2016 returned to continue monitoring in 2017. All new volunteers have gone through in-person or online training.

Data from the 2016 field season continues to be analyzed. Bee blocks were held in cold storage through March 2017 and then warmed for adult emergence. Approximately 3000 specimens were collected from the bee blocks, not all of them bees, and the specimens are still in the process of being pinned and identified in the lab.

Project Status as of January 1, 2018: The 2017 field season was completed in October. Bee blocks were returned to St. Paul campus to be placed in cold storage for the bee larvae to go through diapause and complete their development. Bumble bee routes were completed, resulting in 1259 observations that represented 15 different species of bumble bee. Volunteers submitted 1932 observations on iNaturalist.org. The Bee Atlas Facebook page has 310 followers.

Specimens from 2016 have been identified and results sent to volunteers and land managers.

Project Status as of July 1, 2018: The 2018 field season is underway with 135 bee blocks distributed across the state, 30 claimed bumble bee routes, and continued observations on iNaturalist.org. Workshops to train volunteers have been completed for the season and public events and social media engagement continues.

Bees from 2017 bee blocks have been reared and are in the process of being pinned and identified. There are nearly 3000 bee specimens, 1500 wasps, and additional non-target organisms such as beetles, ants, and flies.

Amendment Request I as of August 8, 2018: We request a retroactive amendment to the project. Specifically, we wish to reduce the target number of nesting blocks from 250 to 125 per year. In the Spring of 2016, after writing protocols for processing nesting blocks, we decided that this number would be more appropriate. This number is based on the amount of work required to rear the collected larvae, identify them to the species level, and prepare them for the University of Minnesota Insect Collection. In order to insure that this change in protocol would not decrease the scope of the project, we also decided to recruit new bee block volunteers each year to maintain the geographic extent of the original proposal. This tactic has been successful in that we have 385 unique locations covered. **Amendment Approved by LCCMR 8/21/2018**

Amendment Request II as of August 8, 2018: We request a no-cost extension of the project until June 30, 2020. When we conceived of this project, we planned for the deployment of nesting blocks, collection of nesting blocks, rearing of larvae, pinning of adults, and identification of adults to be completed within a single 12-month period. We have found that it takes 20-months to complete this research cycle for the approximately 5000 bees we collect annually. For example, the bees that nested in the blocks that were deployed in April of 2016 were not completely identified and catalogued until January of 2018. Consequently, we don't expect to completely identify and catalogue the bees that nest in this year's (2018) blocks until January 2020. In order to not lose an entire year's worth of data, we respectfully request that we be allowed to continue this project through June 30, 2020 through a no-cost extension of the grant period. All three outcomes of Activity 3 would be extended a year from their original due dates. **Amendment Request signed into law 5/31/19.**

Project Status as of January 1, 2019: The 2018 field season was completed in October. Bee blocks were returned to St. Paul campus to be placed in cold storage for the bee larvae to go through diapause and complete their development. Bumble bee routes were completed, resulting in 1541 observations that represented 16 different species of bumble bee, including the federally endangered *Bombus affinis*, the rusty-patched bumble bee. Observers submitted 4943 observations on iNaturalist.org from 123 species. The Bee Atlas Facebook page has 468 followers.

Specimens from 2017 have been identified and results sent to volunteers and land managers.

Project Status as of July 1, 2019: The 2019 field season is underway with a number of changes from previous years. Due to the time required to rear, pin, identify, and process specimens, bee blocks were not distributed this year to ensure all work was complete before June 30, 2020. However, ten nests made from native plant stems were sent to high performing volunteers in areas with high bee diversity to learn more about bee preferences for nesting materials. Volunteers adopted twenty-four bumble bee routes. Workshops to train volunteers have been completed for the season and public events and social media engagement continues.

Bees from 2018 bee blocks have been reared and are in the process of being pinned and identified. Volunteers have been trained to help pin to complete the task earlier in the summer. There are nearly 3000 bee specimens, 1500 wasps, and additional non-target organisms such as beetles, ants, and flies.

Amendment Request as of September 22, 2019:
We are requesting that funds be shifted between several categories due to the year-long no-cost extension that we received. The changes will allow us to complete processing the bee samples, curating the collections properly, and making the information available to researchers and the public.
• The Personnel budget would be increased $39,761 to $628,386.
The Personnel budget change is requested to cover additional time required to identify and curate the bees that have been collected during the project.
• The Professional/Technical/Service Contracts budget would be decreased $11,752 to $79,248.
The Professional/Technical/Service Contracts budget change is requested because less graphic design of materials is needed as we adopted a web-based means of communication with the participants.
• The Equipment/Tools/Supplies would be increased $11,520 to $49,395.
The Equipment/Tools/Supplies budget change is requested to purchase additional curation supplies; in particular, storage units for the long-term conservation of specimens.
• The Printing budget would be decreased by $10,925 to $6,575.
The Printing budget change is requested because we required less printing of hard materials as we adopted a web-based means of communication with the participants.
• The Travel Expenses in MN budget would be decreased $17,791 to $10,209.
The Travel Expenses in MN budget change is requested because we managed to offer our workshops with two staff members instead of three.
• The Other budget would be decreased $12,764 to $14,236.
The Other budget change is requested because we did not have to purchase Cloud Storage for the Bee Atlas because we combined efforts with the Minnesota Biodiversity Atlas, which will be the digital repository for the project. **Amendment Approved by LCCMR 10/10/2019**

Project Status as of January 1, 2020: The 2019 field season was completed in October. Stem bundles were returned to St. Paul campus to be placed in cold storage for the bee larvae to go through diapause and complete their development. Bumble bee routes were completed, resulting in 2304 observations that represented 16 different species of bumble bee, including the federally endangered *Bombus affinis*, the rusty-patched bumble

bee. Over the course of the project, observers submitted 9910 observations on iNaturalist.org from 142 species. The Bee Atlas Facebook page has 644 followers.

Specimens from 2018 bee blocks have been identified and results sent to volunteers and land managers.

Project extended to June 30, 2021 by LCCMR 6/18/20 as a result of M.L. 2020, First Special Session, Chp. 4, Sec. 2, legislative extension criteria being met.

Amendment Request as of June 29, 2020:
We are requesting that funds be shifted between several categories due to the year-long no-cost extension that we received. The changes will allow us to complete making the information available to researchers and the public.
• The Personnel budget would be increased $18,004 to $646,390.
The Personnel budget change is requested to cover additional time required to upload final data to the Minnesota Biodiversity Atlas.
• The Equipment/Tools/Supplies would be decreased $17,546 to $31,849.
The Equipment/Tools/Supplies budget change was decreased because the entomology collection had no more room for storage units for the long-term conservation of specimens.
• The Printing budget would be increased by $63 to $6,638.
The Printing budget change is requested because we ran two more seminars on bumblebee identification than anticipated, which required printing of handouts.
• The Travel Expenses in MN for the entomologist budget would be decreased $521 to $1,500 because of one less trip due to Covid-19 travel restrictions.

Amendment Approved by LCCMR 7/7/2020.

Project Status as of January 1, 2021:
The project completed its goals by August 2021. Over 24890 occurrences of 60 species of stem nesting and bumble bees were obtained by citizen science volunteers, raised by Bee Atlas staff, and identified by the project entomologist. Bumble bee routes were completed, resulting in 2304 observations that represented 16 different species of bumble bee, including the federally endangered *Bombus affinis*, the rusty-patched bumble bee. Over the course of the project, observers submitted 9910 observations on iNaturalist.org from 142 species. The Bee Atlas Facebook page has 644 followers.

Project Status as of July 1, 2021:
Nothing to add.

Overall Project Outcomes and Results:
Although the plight of bees and other pollinators has been highlighted recently, the question of how bees are doing is complicated. There is still much to be known about which bees live where in Minnesota and their population status. From 2015 through 2019, volunteers documented over 25,000 bees in Minnesota as a part of the Minnesota Bee Atlas. They did this by submitting photos of bees to iNaturalist, adopting roadside survey routes to capture, identify and release bumble bees, and monitoring nesting blocks for stem-nesting bees.

Through this work, five species were documented that had previously not been recorded in Minnesota. While it's difficult to know if they are new arrivals or just newly documented, Minnesota is at the northern end of the range for 3 of those species and could be evidence of shifting ranges.

Non-lethal bumble bee sampling led to documentation of additional populations of the federally endangered rusty patched bumble bee (*Bombus affinis*). This data informs the US Fish and Wildlife Service species recovery plan.

The Bee Atlas documented nest structures and nest activity for stem-nesting bees that had not previously been recorded. This information may inform management decisions that would impact the amount of forage or nesting habitat available for bees as changes could be made at times when bees are less active.

Finally, the Bee Atlas engaged members of the public beyond volunteer participants when volunteers became active in their own communities. Volunteers shared their knowledge of bees and pollinator conservation with youth scout groups, 4-H youth, Master Gardeners, Master Naturalists, and countless friends and neighbors.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Develop citizen science sampling protocols, training, and digital database.
Description: Activity 1 will occur from July 2015 through January 2016; the first seven months of the project.

The sampling protocol for tunnel-nesting bees will be based on citizen-science projects in Florida (UFL's Native Buzz) and Colorado (UC's The Bees' Needs). The University of Florida's Native Buzz was initiated in 2012. They offer web-based resources on how to build tunnel nests and how to identify tunnel-nesting bees. They do not offer in-person training nor guide participants to sampling locations. The University of Colorado's Bees Needs provides standardized sampling blocks and requests that participants sample bees in their backyards. Both programs have web-based data submission. The Minnesota Wild Bee Atlas will use the knowledge gained in developing these programs to create a consistent bee sampling protocol that is appropriate for Minnesota but will direct participants to sample specific locations throughout the state. The training materials that we develop for in-person training will be derived from the materials developed by these programs.

The sampling protocol for bumble bees will be based on the Twin Cities-based Bumble Bee Survey. Elaine Evans, a doctoral candidate at the University of Minnesota and a member of the Minnesota Wild Bee Atlas team, has developed and implemented this survey in 2011. This project and Elaine were influential in developing the recently debuted Xerces Society Bumble Bee Watch, which is an effort to involve citizen scientists in mapping the distribution of bumble bees across North America.

In addition to strategic sampling of the tunnel-nesting and bumble bees in Minnesota, we will also allow citizen scientists to report when they encounter any bee species. The reporting of incidental observation of all bee species will follow the protocols of the National Biological Information Infrastructure's (NBII) DiscoverLife.

Once the sampling protocols are established, we will develop training manuals and training workshops for participants. These workshops will be 6 – 8 hours long, cover the basics of bee biology, and appropriate bee sampling protocols. The format will be based on that used by the Minnesota Master Naturalist program for informal adult science education. All manuals will be peer reviewed by national experts in bee biology and adult science education.

The Atlas' website and database will be adapted from the Monarch Larva Monitoring Project. The website will allow citizen scientists to adopt areas (blocks) across Minnesota in which they will survey the tunnel-nesting and bumble bees and then enter their site-specific data. It will also allow citizen scientists to report and upload photographs of observations of all bee species for verification. The website will be vital in training participants, providing resources for interested citizens, and managing the data gathered by the citizens.

The database function of the web site will be important in sharing the data broadly with the citizens that participate in the program, the public, and researchers. In developing the database, we coordinate with National Biological Information Infrastructure's (NBII) DiscoverLife the Global Biodiversity Information Facility (www.gbif.org) programs to insure that records are shared accurately and without duplication of specimen records. Additionally, we will coordinate with the Bell Museum-based project "Integrating Minnesota's Biodiversity Data: a Comprehensive, Dynamic Atlas" which was recommended for funding by the LCCMR. This project does not include information on insects as they are outside of the current purview of the Bell Museum.

Summary Budget Information for Activity 1:

ENRTF Budget: $82,111
Amount Spent: $82,111
Balance: $0

Outcome	Completion Date
1. Develop tunnel-nesting, bumble, & observed bee survey protocols & training materials.	1/1/16
2. Develop website to support recruitment, training, data submission, and quality review	1/1/16

Activity 1 Status as of January 1, 2016: Protocol outlines have been written for tunnel-nesting bees, bumble bees, and casual bee observations. Relationships have been formed with nature centers across the state to host nesting blocks. We have received a research permit from the Minnesota Department of Natural Resources to place blocks in Scientific and Natural Areas (SNAs) and ask volunteer SNA stewards to monitor the blocks. This will allow us to distribute blocks evenly and represent all habitat types in the state. Structured bumble bee observations will be done along the routes developed for the Breeding Bird Survey. Volunteers will be able to choose a route to observe three times during the summer. Casual bee observations will be submitted to iNaturalist.org, a citizen website with an accompanying mobile app designed to develop a network of observers and document global biodiversity.

Development of experimental protocols was delayed by the hiring of a qualified entomologist. Between the time of this grant proposal and the dispersal of funds, the anticipated entomologist accepted another position and it was necessary to open the position to others at the University of Minnesota.

Website and database design have been contracted to Witty Web Design and will be completed following University of Minnesota branding requirements.

Activity 1 Status as of July 1, 2016: Protocols have been completed for monitoring tunnel-nesting bees in trap nests as well as for monitoring bumble bees by adopting a route to survey three times during the summer. Volunteers participating at either level have received handbooks containing detailed protocols and data sheets. Custom websites for data submission and resulting databases were created by Witty Web Design, allowing for easier data entry and a streamlined process for volunteers.

The majority of volunteers are expected to participate by submitting photos to the website and mobile app iNaturalist. This website allows participants to share photos of bees with or without identification; community experts will add details as are possible.

Activity 1 Status as of January 1, 2017: Volunteers followed protocols to monitor nesting blocks, conduct surveys to capture and release bumble bees, and share photos of bees. Observations for both the bee blocks and bumble bee survey routes were submitted using a custom-designed database and web entry portal while bee photos were shared on the website and mobile app iNaturalist, an existing platform studying global biodiversity.

Activity 1 Status as of July 1, 2017: Activity is completed. Volunteers continue to collect data using the developed protocols.

Activity 1 Status as of January 1, 2018: Activity is completed. Volunteers continue to collect data using the developed protocols.

Activity 1 Status as of July 1, 2018: Activity is completed. Volunteers continue to collect data using the developed protocols.

Activity 1 Status as of January 1, 2019: Activity is completed. Volunteers continue to collect data using the developed protocols.

Activity 1 Status as of July 1, 2019: Activity is completed. Volunteers continue to collect data using the developed protocols. Protocols from bee block observations have been adapted to reflect the changes in nesting materials for summer 2019.

Activity 1 Status as of January 1, 2020: Activity is completed. Volunteers continued to collected data using the developed protocols through the end of the 2019 field season.

Activity 1 Status as of July 1, 2020: Activity is completed. Volunteers continued to collected data using the developed protocols through the end of the 2019 field season.

Activity 1 Status as of January 1, 2021: Activity is completed. Volunteers continued to collected data using the developed protocols through the end of the 2019 field season

Final Report Summary: Activity is completed. Volunteers continued to collected data using the developed protocols through the end of the 2019 field season.

ACTIVITY 2: Train citizen scientists and conduct survey of native bee fauna.
Description: Activity 2 will occur between January of 2016 and October of 2018; roughly the middle three years of the project.

Citizen scientists will be recruited and trained through both online and in-person methods. We expect that many volunteers will be Minnesota Master Naturalists, Master Gardeners, participants in the LCCMR-funded Breeding Bird Atlas, and regular DNR volunteers. We will also broaden participation to youth groups and their leaders.

The in-person training will involve 25 one-day training sessions offered across the state – tentatively in the Twin Cities, Morris, Crookston, Lamberton, Duluth, Rochester, and Bemidji – with projected average attendance of 30 individuals. The majority of these training events will occur between January and June of 2016, with additional trainings occurring through June of 2017.

Sampling for the project will start in May of 2016. Each participant will deploy three tunnel-nesting blocks in a county determined in conjunction with program staff and at locations in specific habitat types expected to gain the widest diversity of bees within the region. At the end of the sampling season in October, participants will mail a subsample of the bees and blocks for verification of species identification to the University of Minnesota's bee lab. The participants will deploy blocks in the same locations again for the summer if 2017 and 2018 because bee populations are cyclical and adequate sampling typically requires three years of effort at a single site. However, to encourage wider participation and because of attrition that occurs in long-term citizen science projects, we will allow some participants to join the program in 2017 and conduct two years of sampling.

Finally, we will also coordinate training and sampling with "Driven to Discover: Citizen Science Inspires Classroom Investigation" which is a project to train classroom teachers to use citizen science projects in their educational efforts. This project, headed by MN Wild Bee Atlas members Karen Oberhauser and Rob Blair, was recently funded by the National Science Foundation. Coordination with this project will allow the Bee Atlas to reach Minnesota's science educators and youth.

Summary Budget Information for Activity 2:

ENRTF Budget: $446,868
Amount Spent: $446,868
Balance: $0

Outcome	Completion Date
1. Recruit and train ~750 citizen scientists for all three tiers of bee survey protocols.	6/1/17
2. Deploy ~250 citizen scientists with appropriate materials to conduct surveys of tunneling bees at sites across the state that they have adopted for 3 annual cycles. ~ 250 will similarly survey bumble bees at adopted sites. ~250 will conduct incidental observations of all bees.	10/31/18
3. Monitor incoming data, identify sources of reporting error, refine training and website.	6/31/20

Activity 2 Status as of January 1, 2016: Twenty-five nature center participants were recruited by presenting at the Minnesota Naturalists Association Conference on November 15. Individual participants have been recruited by advertising in the University of Minnesota Department of Fisheries, Wildlife, and Conservation Biology alumni blog and Facebook. Future participant pools will include SNA site stewards and Minnesota Master Naturalist volunteers.

Activity 2 Status as of July 1, 2016: Nesting blocks have been distributed at 128 sites across the state. Host sites include nature centers, individuals, county and regional parks or other public landowners, colleges and universities, DNR Scientific and Natural Areas, homeschool families, and native plant nurseries. After writing protocols for processing nesting blocks in the fall, the decision was made to reduce the target number of nesting blocks from 250 to 125. This number is more reasonable based on the amount of work required to rear the collected larvae, identify to the species level, and prepare for the University of Minnesota Insect Collection. This decision will be revisited after the blocks from the 2016 field season have been fully processed.

As volunteer monitors are spread across Minnesota, a series of training videos was created to describe the monitoring protocols. The titles of the four videos are Minnesota Bee Atlas, Collecting Data from a Bee Block: A Behind the Scenes Tour, How to Make and Submit Observations, and Mounting Your Wild Bee Nesting Block.

Workshops covering content wild bees were held in West Saint Paul, Henderson, Bloomington, Faribault, Brainerd, and Ely. An additional session was presented at the Gathering Partners Conference in Winona. These workshops reached 147 participants. Participants have a greater understanding of the role wild bees play in Minnesota, basic bee identification skills, strategies to promote healthy bee habitats in their homes and yards, and protocols to submit anecdotal observations of wild bees to the Bee Atlas. Workshops on species-level bumble bee identification were held in Grand Marais, Maplewood, and Winona and reached 36 participants. These participants will adopt survey routes based on the Breeding Bird Survey and conduct three surveys from late June 2016 to August 2016. These protocols are more rigorous than initially proposed and will provide important data on seasonal fluctuations of bumble bees but may attract fewer volunteers than expected.

Additionally, the Bee Atlas Project on iNaturalist.org has 49 members and the Bee Atlas Facebook page has 151 "likes" from volunteers following the project.

Activity 2 Status as of January 1, 2017: Over the summer of 2016, 120 volunteers participated in monitoring nesting blocks and 12 volunteers adopted bumble bee survey routes to visit three times between June and August. Volunteers monitoring blocks observed the dates new nests were built, the size hole used for each nest, and the materials used to build each nest. These details will be used to help identify the bees to the species level. Volunteers surveying for bumble bees caught and identified common species and photographed rare species for expert identification before releasing bees caught along the survey route. Volunteers observed 800 individual bumble bees, representing 12 different species. 512 observations were submitted to iNaturalist by 87 volunteers.

A workshop was held at the Minnesota Naturalists Association Conference on November 12 to teach nature center staff to lead a photo bioblitz to involve the public in a large-scale event to photograph bees to submit to iNaturalist. The conference session was attended by 25 participants.

The Bee Atlas was invited to participate in several public outreach events by hosting an exhibitor table. Through these events, the Bee Atlas reached an estimated 800 people to provide resources on native bee biology and protocols to participate in Bee Atlas research next field season.

Activity 2 Status as of July 1, 2017: 10 workshops were help from April to June in locations across the state. These events reached 232 people. Volunteers were recruited to observe 130 nesting blocks across the state, and 27 bumble bee survey routes. Additionally, 855 observations have been recorded on the website and mobile app iNaturalist. The Bee Atlas continues to participate in public outreach events by staffing exhibitor tables.

Activity 2 Status as of January 1, 2018: The Bee Atlas sent 130 nesting blocks in 2017 and 126 were returned. This represented 45 counties. The blocks were returned to St. Paul campus and are currently in cold storage to replicate outdoor conditions.

Volunteers monitored 22 bumble bee routes in 2017 and recorded 1249 bumble bees. The most commonly observed species were *Bombus vagans*, *Bombus bimaculatus*, and *Bombus ternarius*.

Volunteers submitted 1932 photos of bees to the website iNaturalist.org. The most commonly observed species was *Bombus impatiens*, the common eastern bumble bee.

2 additional workshops were held in the second half of 2017 with 29 participants. The Bee Atlas also reached 300 people through public outreach events during the second half of the year.

Activity 2 Status as of July 1, 2018: Bee Atlas staff presented eight workshops in the months from March to May and introduced new formats including a level II bumble bee identification workshop, a webinar held in partnership with University of Minnesota Extension, and a workshop held in cooperation with the University of Minnesota Bee Lab.

To date, Bee Atlas staff have reached 339 participants through workshops on native bees and 229 participants through workshops focused on bumble bees for a total of 568 participants. In 2018, 2 workshops and 1 webinar on native bees reached 53 people. Bumble bee-specific workshops were held in five locations, reaching 90 people. Although many workshop participants go on to monitor bee blocks, survey bumble bee routes, or submit photos to iNaturalist, many also attend just to learn more about Minnesota bees. As the protocols for

bumble bee surveys are more rigorous than initially planned, potential volunteers often end up submitting photos of bumble bees to iNaturalist or Bumble Bee Watch instead of adopting a bumble bee survey route. Volunteers who are not able to attend an in-person workshop may prepare for the field season by watching online video tutorials, viewing presentation slides on the Bee Atlas website, and practicing identification using online flashcards.

The total number of participants in the survey efforts is extensive and they break down into three categories:
1) Volunteers who monitor bee blocks. Bee blocks were mailed in March and volunteers are observing 135 blocks across the state bringing the total of bee blocks deployed during the entire project to 385.
2) Volunteers who survey bumble routes. Due to the late spring, bumble bee monitoring did not begin until the end of June but 26 volunteers are surveying 30 routes. Each 'route' consists of a 10-mile long transect along roads with a stop every two-miles. Consequently, a single route includes 6 sites that are monitored for a total of 180 sites this year and a total of 64 routes and 384 sites over the course of the project.
3) Volunteers who submit data via iNaturalist. Volunteers have submitted 2384 observations on iNaturalist.org. Many of the 349 users on the website have participated in a Bee Atlas workshop but as data on iNaturalist is publicly accessible, some of the observations that meet the criteria to be included in the project were made by users who may be unfamiliar with the Bee Atlas. We do not have a count of the number of new users over the past year.

Activity 2 Status as of January 1, 2019: The Bee Atlas sent 135 nesting blocks in 2018 and replaced an additional 5 blocks mid-season to account for early emerging bee species like *Megachile relativa*. All but 2 of the blocks were returned to St. Paul campus and are currently in cold storage to replicate outdoor conditions.

Volunteers monitored 27 bumble bee routes in 2018 and recorded 1541 bumble bees. The most commonly observed species were *Bombus impatiens* and *Bombus ternarius*.

Due to changes to the online platform, the Bee Atlas project on iNaturalist.org was changed to an "umbrella project," meaning any observations of bees in Minnesota submitted to the website would automatically be included in the Bee Atlas. This resulted in 642 observers, 4943 observations, and 123 species. The most commonly observed species were *Apis mellifera,* honey bees, *Bombus impatiens*, the common eastern bumble bee, and *Bombus griseocollis*, the brown-belted bumble bee.

2 additional public events were held in the second half of 2018, reaching 130 participants.

Activity 2 Status as of July 1, 2019: Bee Atlas staff presented five workshops in the months from March to May focused on bumble bee identification to prepare volunteers for the field season.

To date, Bee Atlas staff have reached 359 participants through workshops on native bees and 302 participants through workshops focused on bumble bees for a total of 661 participants. Although some participants continue to monitor bee blocks or survey for bumble bees after completing a workshop, many attend to learn more about native bees and current conservation efforts.

In the final field season, ten volunteers are observing nests made from native plant stems, 24 will complete roadside surveys for bumble bees, and efforts to encourage observations to iNaturalist will continue. iNaturalist is an open platform so any user may participate regardless of training and 6313 observations have been catalogued to date from 787 observers.

Activity 2 Status as of January 1, 2020: The Bee Atlas sent 10 nesting stem bundles in 2019. All were returned to St. Paul campus and are currently in cold storage to replicate outdoor conditions.

Volunteers monitored 25 bumble bee routes in 2019 and recorded 2304 bees. The most commonly observed species were *Bombus ternarius* and *Bombus vagans.*

The Bee Atlas project on iNaturalist grew quickly. To date, the project has 1245 observers, 9910 observations, and 143 species. The most commonly observed species were *Bombus impatiens*, the common eastern bumble bee, *Apis mellifera*, honey bees, and *Bombus griseocollis,* the brown-belted bumble bee.

Two additional public events were held in the second half of 2019, reaching 204 participants.

Activity 2 Status as of July 1, 2020: In March and April of 2020, bee atlas staff hatched specimens from 10 bundles submitted by volunteers. This was a small test case beyond the scope of the original Bee Atlas to see if stem bundles resulted in different species of bees than the nesting block used for the project.

Activity 2 Status as of January 1, 2021: Activity is completed.

Final Report Summary: Over the course of the project, the Bee Atlas involved more than 150 volunteers who set out 453 bee nesting blocks and 10 stem-nesting bundles. We had volunteers conducting bumble bee surveys on 103 route observations. Over 2,315 observers submitted 19,360 observations of bees on iNaturalist.

ACTIVITY 3: Validate data, combine with other surveys, and create digital atlas.
Description: Activity 3 will occur concurrently with Activity 2 (1/2016 to 10/2019) with an additional eight months to process the data, finalize the atlas, and complete the project (11/2018 to 6/2020).

To ensure validity and usefulness of the data, the staff entomologist will collect subsamples of nesting blocks and raise larvae for identification. This will involve volunteers mailing subsamples of the nesting blocks at the end of each nesting season to UMN, raising the larvae through the spring of the next year, and identifying the adults that emerge.

We will combine all data from this project with that generated by the LCCMR-sponsored projects: "Wild Bee Pollinator Surveys in Prairie-Grassland Habitat"; "Enhancing Pollinator Landscapes", and "Effects of Grazing Versus Fire for Prairie Management" so that citizen scientists, researchers, and the general public can explore the distributions of Minnesota's bees. This data will be shared with appropriate state, national, and international biodiversity databases (see details above). The final atlas will be both a site where researchers can research the occurrence and phenology of wild bees in Minnesota, as well as an educational resource for citizens who want to know more about Minnesota's wild bees.

Summary Budget Information for Activity 3:

ENRTF Budget: $261,021
Amount Spent: $261,021
Balance: $0

Outcome	Completion Date
1. Collect samples of 250 bee-nesting blocks per year for three years (subsamples each year from the 3 blocks allotted to each citizen scientist), hatch larvae, identify bees.	10/30/19
2. Apply quality control measures to subsamples to cross-validate data.	4/31/20
3. Supplement website to make all known bee data from multiple surveys available through online query to researchers and public.	6/31/20

Activity 3 Status as of January 1, 2016: Conversations have begun with the Minnesota Biodiversity Atlas and the University of Minnesota Insect Collection to integrate databases by using similar fields and software.

Activity 3 Status as of July 1, 2016: We contracted with Witty Web Design to create a custom database for volunteers to submit observations as well as for staff to add identifications based on rearing the larvae from nesting blocks. A subset of blocks has been deployed in cooperation with Three Rivers Park District to verify appropriateness of protocols and accuracy of volunteer observations.

Activity 3 Status as of January 1, 2017: The nesting blocks monitored by volunteers were collected in October and November and a volunteer work night was held to prepare the blocks for cold storage. 10 volunteers helped cap the holes in the blocks and all 120 blocks are now resting at 5 degrees Celsius in a growth chamber on the St. Paul campus of the University of Minnesota. Starting at the beginning of March, the temperature will be raised and the adult bees will begin to emerge. At that point, species level identification will begin.

Activity 3 Status as of July 1, 2017: Work continues to pin and identify specimens collected from the 2016 nesting blocks. Temperatures were raised in March and all adult bees have emerged from the nesting blocks.

All bumble bee photos contributed by volunteers have been reviewed and assigned species-level identification.

Activity 3 Status as of January 1, 2018: Species-level identification of bees from 2016 bee blocks has been completed and results sent to volunteers and land managers. Data currently resides on the UMN server but will be transferred to the Minnesota Biodiversity Atlas. The nesting blocks monitored by volunteers in 2017 were collected in October and November and a volunteer work night was held to prepare the blocks for cold storage. 10 volunteers helped cap the holes in the blocks and all 126 blocks are now resting at 5 degrees Celsius in a growth chamber on the St. Paul campus of the University of Minnesota. Starting at the beginning of March, the temperature will be raised and the adult bees will begin to emerge. At that point, species level identification will begin.

Activity 3 Status as of July 1, 2018: Bees have been reared from the 2017 bee blocks and are in the process of being pinned and identified. Specimen numbers were almost doubled from 2016, resulting in over 5000 bees, wasps, and other invertebrates. Work is underway to begin displaying 2016 bee block data through the Minnesota Biodiversity Atlas at the Bell Museum of Natural History. Although the Biodiversity Atlas does not have the capability to display additional information about individual species at this time, we are creating temporary pages on the Bee Atlas website hosted by the University of Minnesota Extension to share information about nesting materials, flight seasons, etc until the Biodiversity Atlas platform is complete.

Of the 135 bee blocks deployed in 2018, 5 have been replaced mid-summer to capture data from multivoltine bees, those with multiple generations in one season. These blocks were in far Western MN, central MN, and NE MN, representing prairie, deciduous forest, and boreal forest habitats.

Activity 3 Status as of January 1, 2019: Species-level identification of bees from 2017 bee blocks has been completed and results sent to volunteers and land managers. Data currently resides on the UMN server but will be transferred to the Minnesota Biodiversity Atlas. Maps of species distribution and block-level results as well as profiles of species commonly found in bee blocks can be found on the Bee Atlas website.

The nesting blocks monitored by volunteers in 2018 were collected in September and October. Volunteer work events were held to prepare the blocks for cold storage. At that time, volunteers helped cap the holes in the blocks and blocks are now resting at 5 degrees Celsius in a growth chamber on the St. Paul campus of the University of Minnesota. Starting at the beginning of March, the temperature will be raised and the adult bees will begin to emerge. At that point, species level identification will begin.

Activity 3 Status as of July 1, 2019: Bees have been reared from the 2018 bee blocks and are in the process of being pinned and identified. Specimen numbers are comparable to 2017, resulting in over 5000 bees, wasps, and other invertebrates. Data from 2016 and 2017 bee blocks has been submitted to the Minnesota Biodiversity Atlas. Although the Biodiversity Atlas does not have the capability to display additional information about individual species at this time, we have created pages on the Bee Atlas website hosted by the University of Minnesota Extension to share information about nesting materials, flight seasons, etc until the Biodiversity Atlas platform is complete.

Activity 3 status as of January 1, 2020: Species-level identification of bees from 2018 bee blocks has been completed and the results sent to volunteers and land managers. Data currently resides on the UMN server but will be transferred to the Minnesota Biodiversity Atlas. Maps of species distribution and block-level results as well as profiles of species found in bee blocks can be found on the Bee Atlas website.

The stem bundles monitored by volunteers in 2019 were collected in September. Currently, the bundles are resting at 5 degrees Celsius in a growth chamber on the St. Paul campus of the University of Minnesota. At the beginning of March, the temperature will be raised and the adult bees will begin to emerge. At that point, species level identification will begin.

Activity 3 Status as of July 1, 2020: Species-level identification of bees from 2019 bee blocks has been completed and the results sent to volunteers and land managers. Maps of species distribution and block-level results as well as profiles of species found in bee blocks can be found on the Bee Atlas website.

Activity 3 Status as of January 1, 2021: Data that resided on the UMN server was verified and transferred to the Minnesota Biodiversity Atlas. The Bird Atlas confirmed location and identity of more than 24,890 specimens of 60 species of bees in Minnesota. Activity is completed.

Final Report Summary: The Bird Atlas project staff confirmed location and identity of more than 24,890 specimens of 60 species of bees across Minnesota.

V. DISSEMINATION:

Description: Dissemination of information developed during the project will occur through three major outlets: 1) print and web materials developed to train the citizen scientists in face-to-face workshops, 2) print and web materials for citizen scientists who want to participate by providing casual (non-systematic) observations of bees, and 3) a web-based interface to the database on bee distributions and their phenologies, which is the final outcome of the project. The digital portal for the Minnesota Wild Bee Atlas will contain data from this project as well as two other LCCMR pollinator distribution projects. It will be linked to the National Biological Information Infrastructure's (NBII) DiscoverLife database as well with the Global Biodiversity Information Facility (www.gbif.org), an international clearinghouse on biodiversity data. The portal and database will be permanently housed by the Bell Museum of Natural History.

Status as of January 1, 2016: A Facebook page was created, Minnesota Native Bee Atlas, and will primarily be used to communicate with volunteers to share information on bees/pollinators and provide reminders of the monitoring schedule.

Status as of July 1, 2016:

The Facebook page has been supplemented. Additionally, we have created several training videos that are now available on the University of Minnesota Extension's Citizen Science YouTube channel.

Status as of January 1, 2017: The Bee Atlas Facebook page has 189 followers and is a main source of information for volunteers and others interested in the project. Project updates are shared as possible and volunteers contribute photos and questions based on their own experiences. The Bee Atlas also tabled at local outreach events such as the Minneapolis Pollinator Party and PolliNATION, organized by the Pollinator Friendly Alliance to share information about native bees and the Bee Atlas with the public.

Status as of July 1, 2017: The Bee Atlas led 10 public workshops, including a new partnership with the Minnesota Landscape Arboretum for an Earth Day event as well as the UMN Extension Gathering Partners conference. These workshops reached 232 participants.

The Bee Atlas continues to maintain a Facebook page with 255 followers as well as an Instagram account to share bee photos.

Status as of January 1, 2018: The Bee Atlas led 22 workshops and public events, reaching 899 participants in 2017. The Bee Atlas maintains a Facebook page with 310 followers and an account on Instagram with 51 followers. Through these formats, the Bee Atlas is able to share information about the natural history of native bees, upcoming events, and answer questions for volunteers and interested members of the public.

Status as of July 1, 2018: The Bee Atlas presented at twelve workshops and other public events, reaching 591 participants. Social media engagement continues to grow and the Bee Atlas Facebook page has 398 followers while the Instagram account has 125 followers. These avenues allow us to quickly share information with volunteers as well as the general public.

Status as of January 1, 2019: Throughout 2018, the Bee Atlas presented at 14 workshops and other public events, reaching 721 participants. The Bee Atlas maintains a Facebook page with 468 followers and an account on Instagram with 194 followers. Although many followers are volunteers, the majority of accounts are from the interested public or other natural history organizations.

Status as of July 1, 2019: The Bee Atlas presented at fifteen workshops and other public events from January to June, reaching 360 participants. Social media engagement continues to grow and the Bee Atlas Facebook page has 587 followers while the Instagram account has 302 followers. These avenues allow us to quickly share information with volunteers and the general public as well as recruit new volunteers for short-term or one-time opportunities like working in the lab during rearing season or pinning specimens.

Status as of January 1, 2020: Throughout 2019, the Bee Atlas presented at 18 workshops and other public events, reaching 589 participants. The Bee Atlas maintains a Facebook page with 644 followers and an Instagram account with 377 followers. Although many followers are volunteers, the majority of accounts are from the interested public or other natural history organizations.

Status as of July 1, 2020: No additional workshops occurred in 2020 because of the COVID-19 Pandemic

Status as of January 1, 2021: In addition to workshops and making the data and distributions available on the Minnesota Biodiversity Atlas, the Bee atlas now has the following scientific publications:

Satyshur, C. D., & Orr, M. C. (2020). Record of Anthophora (Clisodon) terminalis in a wooden trap-nesting block and comparison to available nesting information (Hymenoptera: Apidae). *Journal of Melittology*, (99), 1–6. https://doi.org/10.17161/jom.vi99.13315

Satyshur, Colleen D.; Evans, Thea A.; Forsberg, Britt M.; and Blair, Robert B. 2020. "Minnesota State Records for Osmia georgica, Megachile inimica, and Megachile frugalis (Hymenoptera, Megachilidae), Including a New Nest Description for Megachile frugalis Compared with Other Species in the Subgenus Sayapis," *The Great Lakes Entomologist*, vol 53 (2)
Available at: https://scholar.valpo.edu/tgle/vol53/iss2/6

Final Report Summary: Throughout the project, the Bee Atlas presented at 79 workshops and other public events, reaching 3392 participants. The Bee Atlas maintains a Facebook page with 961 followers and an Instagram account with 787 followers. Although many followers are volunteers, the majority of accounts are from the interested public or other natural history organizations. The project has resulted in 2 scientific publications and two more are in development.

Finally, we have a strong online presence:

Facebook:
https://www.facebook.com/MNBeeAtlas
Instagram:
https://www.instagram.com/minnesotabeeatlas/
iNaturalist:
https://www.inaturalist.org/observations?project_id=5845
University of Minnesota Extension:
https://extension.umn.edu/natural-resources-volunteers/minnesota-bee-atlas
Minnesota Bee Atlas: Comprehensive site of all data including maps and bee identification guide
http://apps.extension.umn.edu/environment/citizen-science/bee-atlas/bee-blocks/Results/
Minnesota Biodiversity Atlas:
https://bellatlas.umn.edu/collections/index.php

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$628,386	•Robert Blair, Project Director (75% salary, 25% benefits); 8.3% FTE for 4 years •Karen Oberhauser, Training and Database Construction (75% salary, 25% benefits); 8.3% FTE for 4 years •Kevin Williams, Volunteer Training (75% salary, 25% benefits); 12.5% FTE for 4 years •Elaine Evans, Bumble Bee Survey Coordinator (81% salary, 29% benefits); 16.6% FTE for 4 years •Joel Gardner, Entomologist and Database Manager (83% salary, 17% benefits); 100% FTE for 4 years •Project Coordinator (75% salary, 25% benefits); 100% FTE for 4 years
Professional/Technical/Service Contracts:	$79,248	•Witty Design to build website and database in Year 1 ($25,000), to refine in Years 2&3 ($10,000/yr), to expand Year 4 ($20,000) (Witty Design is the desired contractor as they will adapt the existing Monarch Larvae Monitoring Project web site which they developed and manage. Witty design was competitively selected for the original MLMP web site.)

Budget Category	$ Amount	Overview Explanation
		•Graphic design of educational materials (instruction handbooks, web site, recruiting/informational brochures). (To be determined by competitive bid.)
Equipment/Tools/Supplies:	$49,395	•2500 Bee nesting blocks -- 3 per each of 250 initial volunteers so that volunteers may deploy nesting blocks at three locations in the first year of sampling (750 Total), 1500 additional for replacements so that these volunteers may replace the initial blocks and send them to St Paul for verification of identifications annually for two additional years, plus 250 for broader distribution to the interested public who wish to join the program after the initial year. •Postage to ship nesting blocks (Necessary for initial distribution and for validation, $12.35 per box of 2) •Boxes for Shipping
Printing:	$6,575	• Educational materials (1000 handbooks, 3000 brochures, signage)
Travel Expenses in MN:	$10,209	•$18,000 for travel for 3 staff members to offer 25 one-day training sessions in Twin Cities, Morris, Crookston, Lamberton, Duluth, Rochester, and Bemidji. Each workshop will take 3 days and 2 nights of staff time. Each workshop is budgeted at an average of 200 miles of travel at $0.55 per mile, 2 hotel rooms for 2 nights at $83 per room per night, and two days of food per diem per staff person at $46 per person per day (6 person-days total). •$10,000 for travel for staff entomologist. $2,500 is budgeted for each year of the project to check placement of traps and to cross-validate identifications in the field.
Other:	$14,236	•$15,000 in workshop Materials ($20 per volunteer trained in 25 workshops with expected attendance of 30 per workshop). Includes Xerces Society bee identification guide ($17) and hand lens ($2) for each participant. Also general workshop delivery materials including items such as post its, markers, and easel paper. •$12,000 in cloud storage for database. Budgeted at $2,500 per year.
TOTAL ENRTF BUDGET:	**$790,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 9.8

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 1.0

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota	$17,748	$	Rob Blair 4% FTE per yr
University of Minnesota	$4,790		Karen Oberhauser 1% FTE per yr
Citizen Scientists	$300,000		Collective volunteer effort.
State			
DNR	$8,148	$	Megan Benage 60 hrs per year for 4 years
TOTAL OTHER FUNDS:	**$330,686**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners: This project is a collaboration of entities with strengths in bee sampling and surveys (**UMN Bee Lab, MNDNR**); citizen science (**Monarch Larva Monitoring Project**); volunteer recruitment and training (**Minnesota Master Naturalist**); outreach (**UMN Extension, Bell Museum**), and natural history data management (**Bell Museum, MNDNR**).

This project will be managed by University of Minnesota Extension and formally housed in the Bell Museum of Natural History. Volunteers will be recruited heavily from the Minnesota Master Naturalist Program as well as other insect-oriented citizen groups. Technical support will be from Dr. Marla Spivak's Bee Lab. We will coordinate efforts and share data with the DNR and the LCCMR-funded *Wild Bee Pollinator Surveys in Prairie-Grassland Habitats* managed by Gerda Nordquist and the survey portions of the resampling efforts of the LCCMR-funded *Enhancing Pollinator Landscapes* managed by Dr. Marla Spivak.

B. Project Impact and Long-term Strategy:

This project will use citizen science to 1) determine the distribution of tunnel-nesting and bumble- bees *throughout* Minnesota, 2) document the *phenology* of these bees to aid in their management and conservation; 3) promote an understanding of native bees among Minnesota citizens by engaging them in research on wild bees, and 4) combine this information with data from other LCCMR-funded pollinator surveys to make this information in a *digital atlas* widely available to researchers, land managers, and the public. The final product is the atlas. The project will sunset at the end of the grant period. The completed digital atlas will become part of the collections of the Bell Museum of Natural History.

C. Funding History: N/A

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A

IX. VISUAL COMPONENT

Creating the Minnesota Native Bee Atlas

Step 1 Train Citizen Scientists in Three Bee Survey Protocols

All Bees

Bumble Bees

Tunnel-Nesting Bees

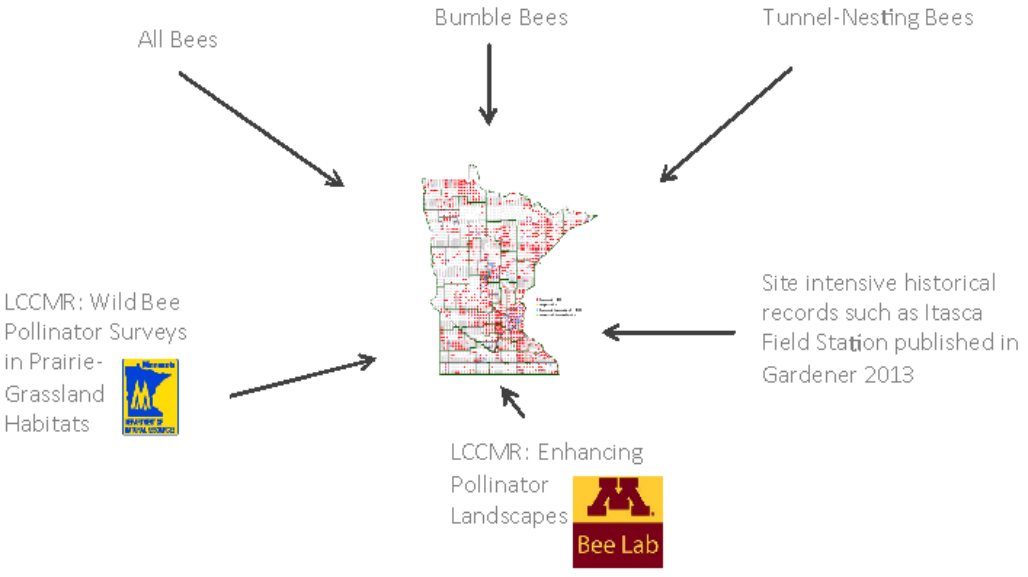
Step 2 Implement Three Protocols for Three Years

Casual Observation of All Bees

Structured Observation of Bumblebees

Stratified Sampling using Bee Blocks

Step 3 Build Digital Atlas with Data from Multiple Sources



X. RESEARCH ADDENDUM: N/A

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than July 1, 2016, January 1, 2017, July 1, 2017, January 1, 2018, July 1, 2018, January 1, 2019, July 1, 2019, January 1, 2020, July 1, 2020 and January 1, 2021. A final report and associated products will be submitted between June 30 and August 15, 2021.

Environment and Natural Resources Trust Fund
M.L. 2015 FINAL Budget

Project Title: Minnesota Native Bee Atlas
Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03g
Project Manager: Robert B. Blair
Organization: University of Minnesota
M.L. 2015 ENRTF Appropriation: $790,000
Project Length and Completion Date: *6* Years, June 30, 2021
Date of Report: 10-13-21

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Revised Acitivity 1 Budget 10/10/2019	Amount Spent	Activity 1 Balance	Revised Activity 2 Budget 6/29/20	Amount Spent	Activity 2 Balance	Revised Activity 3 Budget 6/29/20	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM											
Personnel (Wages and Benefits) Overall	$57,475	$57,475	$0	$367,914	$367,914	$0	$221,001	$221,001	$0	$646,390	$0
Robert Blair, Project Director (75% salary, 25% benefits); 8.3% FTE for 4 years. Estimated Total $52,719											
Karen Oberhauser, Training and Database Construction (75% salary, 25% benefits); 8.3% FTE for 4 years. Estimated Total $55,902											
Kevin Williams, Volunteer Training (75% salary, 25% benefits); 12.5% FTE for 4 years. Estimated Total $44,477											
Elaine Evans, Bumble Bee Survey Coordinator (81% salary, 29% benefits); 16.6% FTE for 4 years. Estimated Total $16,637											
C. Satyshur, Entomologist and Database Manager (83% salary, 17% benefits); 100% FTE for 4 years. Estimated Total $167,743											
Project Coordinator (75% salary, 25% benefits); 100% FTE for 4 years. Estimated Total $252,084											
(09/22/2016) Graphic Designer/Video Production (Hourly $4000)											
Professional/Technical/Service Contracts											
Witty Design to adapt Monarch Larva Monitoring Project website and database in Year 1 ($25,000), to refine in Years 2&3 ($10,000/yr), to expand Year 4 ($20,000). Witty Design was competitively selected to build the original MLMP website and database	$24,636	$24,636	$0	$20,000	$20,000	$0	$34,612	$34,612	$0	$79,248	$0
Graphic design of educational materials (instruction handbooks, web site, recruiting/informational brochures).				$1,951	$1,951	$0	$0	$0	$0	$1,951	$0
Equipment/Tools/Supplies				$27,733	$27,733	$0	$4,116	$4,116	$0	$31,849	$0

2500 Bee nesting blocks -- 3 per each of 250 initial volunteers (750 initially) so that volunteers may deploy nesting blocks at three locations in the first year of sampling, replacements for two additional years (1500 for replacements), plus 250 for broader distribution to the interested public who wish to join the program after the initial year				$22,500	$22,500	$0				$22,500	$0
(09/22/2016) Curatorial supplies for bees collected for UMN Entomology Collection including pins, boxes, cabinet, bags etc.							$4,116	$4,116	$0	$4,116	$0
Postage to ship nesting blocks (Necessary for initial distribution and for validation, $12.35 per box of 2)				$4,633	$4,633	$0				$4,633	$0
Supplies for graphic design of web-based training materials in addition to brochures and signage.				$600	$600	$0				$600	$0
Boxes for Shipping				$0	$0	$0				$0	$0
Printing						$0				$0	$0
Educational materials (1000 handbooks, 3000 brochures, signage)				$6,325	$6,325	$0	$313	$313	$0	$6,638	$0
Travel expenses in Minnesota											
Travel for 3 staff members to offer 25 one-day training sessions in Twin Cities, Morris, Crookston, Lamberton, Duluth, Rochester, and Bemidji. Each takes 3 days and 2 nights of staff time.Budgetd at 200 miles of travel at $0.55 per mile, 2 hotel rooms for 2 nights at $83 per room per night, andsix person-days of food per diem at $46 per person per day				$8,010	$8,010	$0			$0	$8,010	$0
Travel for entomologist to check field placement and cross validate traps. $2500 per year of project budgeted.				$699	$699	$0	$979	$979	$0	$1,678	$0
Other											
Workshop Materials ($20 per volunteer trained in 25 workshops with expected attendance of 30 per workshop). Includes Xerces Society bee identification guide ($17) and hand lens($2) for each participant. Also general workshop delivery materials including items such as post its, markers and easel paper				$14,236	$14,236	$0			$0	$14,236	$0
Cloud storage for database			$0	$0	$0	$0		$0	$0	$0	$0
COLUMN TOTAL	**$82,111**	**$82,111**	**$0**	**$446,868**	**$446,868**	**$0**	**$261,021**	**$261,021**	**$0**	**$790,000**	**$0**

Journal *of* Melittology
Bee Biology, Ecology, Evolution, & Systematics *The latest buzz in bee biology*
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BRIEF COMMUNICATION

Record of *Anthophora* (*Clisodon*) *terminalis* in a wooden trap-nesting block and comparison to available nesting information (Hymenoptera: Apidae)

Colleen D. Satyshur[1] & Michael C. Orr[2]

Abstract. Bee nesting substrate choice can influence habitat use, conservation effort efficacy, and population or landscape-use modeling, but information on nesting sites are often scattered in the literature. Here we bring together the available information on nests of a widespread bee, *Anthophora* (*Clisodon*) *terminalis* Cresson, and describe an unusual new nesting substrate use for this species.

INTRODUCTION

Nesting habits in the genus *Anthophora* Latreille are fairly broad. Many species nest in the ground (Michener, 2007), but some may use preexisting cavities instead of excavating them (Torchio, 1971; Orr *et al*., 2016). Wood nesting is rarer, reported only for species in the subgenus *Clisodon* Patton as well as for *Anthophora* (*Anthophoroides*) *signata* Brooks, although this is not likely its sole potential substrate (Brooks, 1988). The subgenus *Clisodon* contains five species that inhabit generally boreal habitats throughout Eurasia (Ascher & Pickering, 2019). Only one of them (*A. terminalis* Cresson) also occurs in North America. Records of *A. terminalis* nests (Table 1) include the use of dead or rotting wood, where the bee has been recorded to partly or fully excavate its own burrows and use the sawdust to line cells and form cell partitions (Cockerell, 1903; Sladen, 1919; Medler, 1964; Stephen *et al*., 1969; Brooks, 1988). Other materials in which nests have been found include trap nests made from sumac stems (Medler, 1964) and cardboard tubes mounted in insulation boards housed within PVC

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tubing (MacIvor & Packer, 2015). Based on 60 nests found in sumac trap nests in Wisconsin, Medler (1964) found "1/4–5/16 in. (6.25–7.8 mm) holes most suitable though bees did excavate walls to their desired size." Depending on the substrate, this species may also nest in large aggregations. Stephen *et al*. (1969) reported *A. terminalis*, *Megachile inermis* Provancher, and *Osmia* sp. "using a communal burrow excavated by a beetle in an aspen log." Dead logs may provide enough substrate for *A. terminalis* to appear as active as, "a strong colony of bumble-bees" (Sladen, 1919).

This species appears to be univoltine in North America (Cockerell, 1903; Medler, 1964), with records of nest construction in mid-late summer (Cockerell, 1903: August in New Mexico; Medler, 1964: August–September in Wisconsin). Young overwinter as a prepupa, which do not spin a cocoon (Medler, 1964). Despite obtaining 60 nests of *A. terminalis*, Medler (1964) did not find any parasitism. As in many species of *Anthophora*, food provisions are reported to be sour smelling and of a more liquid consistency (Cockerell, 1903; Medler, 1964).

Here we document a nest that was discovered as part of the Minnesota Bee Atlas, a multi-year citizen science project using bee nest blocks to study the presence and distribution of species in Minnesota (https://z.umn.edu/beeatlas). We also summarize the nesting records of this widespread bee.

TRAP METHODS AND NEST DESCRIPTION

The nest block that yielded *A. terminalis* was located in Washington County, Minnesota, near the city of Afton (44.9255°N, -92.8002°W). It was mounted within the Belwin Conservancy on the edge of a pond at a height of 183 cm (72 in.), facing east. The immediately surrounding area was primarily mixed conifer/deciduous woodland (the Conservancy also contains areas of restored grassland of tallgrass prairie). Blocks were made from untreated pine or Douglas fir, with a roof of cedar shingling. Each block measured approximately 8.9 × 14 × 27.9 cm (3.5 × 5.5 × 11 in.) and contained five tunnels each of six different diameters: 3.18 mm, 4.76 mm, 6.35 mm, 7.94 mm, 9.53 mm, and 11.11 mm. Tunnels were approximately 11.43 cm (4.5 in.) deep and spaced 2.54 cm (1 in.) away from other tunnels or the block edge.

In March 2016, a total of 116 nest blocks were sent to volunteers across the state of Minnesota who had been selected to hang and monitor a block in a semi-natural habitat. Recommended block placement was 0.9–1.5 meters high facing south or east in a semi-sunny location, allowing volunteers to accommodate mounting sites available at their specific locations. Volunteers were asked to record mounting conditions of their block and report evidence of nest plugs every 2–3 weeks during the growing season. Blocks were returned to the University of Minnesota in late fall, where they were surveyed by otoscope, overwintered and reared to emergence in a growth chamber the following year. Warming was accomplished with constant temperature steps, rather than by tracking local daily fluctuations, therefore the emergence dates suggest relative seasonality rather than actual emergence in field conditions. For rearing, each tunnel entrance was covered with a plastic test-tube cap with a hole cut out of the end and a replaceable test tube. Emerged bees in test tubes were removed daily and new tubes placed on tunnels.

During the 2016 flight season, a nest was made in a 6.25 mm diameter tunnel that later yielded a male and a female of *A. terminalis*. This nest would have remained undiscovered if all nest tunnels had not been prepared for emergence, as it was not visibly plugged. The block volunteer reported on nest tunnel status seven times be-

Figures 1–2. The nest of *Anthophora* (*Clisodon*) *terminalis* Cresson, entrance on the right. **1.** Showing full nest tunnel. Red marks indicate approximate call partition locations. **2.** Close up of occupied portion of tunnel. The inner end of the nest, on the left, still contained a disc of agglutinated wood and possibly mud. The tunnel walls can be seen to be slightly excavated and are lined with wood pulp, making the inner surface smooth. Three cells appear visible, though only two adults emerged, and no failed cell parts were evidenced upon opening. Photos courtesy of Thea Evans.

tween 8 May and 16 September 2016 and did not report any plug or bee activity for this tunnel. No plug was visible during the end of season otoscope survey of nest tunnels in the lab. This lack of detection is not uncommon in cases such as this, where nest construction ceased well below the front of the tunnel (the evidence of nest occupation extended 56 mm from the rear of the 113 mm tunnel).

Warming the growth chamber to break diapause began on 21 March 2017. The bees emerged on 17 and 18 April 2017, the female unexpectedly emerging before the male (most *Anthophora* are protandrous). When these bees emerged, material that resembled sawdust and pulverized mud was found in the tubes with them. Bee identification was done by C. Satyshur using the DiscoverLife *Anthophora* key and verified by S. Droege. Specimens are deposited in the University of Minnesota Insect Collection.

After the emergence season, this nest tunnel was opened using a chop saw, hammer and chisel (Fig. 1). The nest appears to have had three cells, though only two adults emerged, and no failed cell parts were evidenced upon opening. The tunnel walls were slightly excavated for each cell. At the innermost end of the tunnel, before the first cell, there was a disc of agglutinated wood and possibly mud still present. The first cell measured 10.8 mm long, 7 mm wide, with an upper partition of 2.3 mm thick, approximately. The second cell was 9.7 mm long, 7.3 mm wide, with the upper partition 2.3 mm thick, approximately. The third cell was 9.8 mm long and 7 mm wide, with an upper partition 2.1 mm thick, approximately. The partitions were no longer present, but left scars of wood fragments oriented outward into the tunnel space, whereas the walls of the cells themselves were lined with smooth agglutinated wood pulp, which was darker than the unused portion of the tunnel. In front of the cells there was evidence of a vestibule or incomplete 4th cell, with some wall area darker stained and fully plastered with wood pulp, and some unstained, unlined wall below a partition scar of pale wood pulp.

DISCUSSION

Our record of *A. terminalis* nesting fits fairly well with previous descriptions of nest architecture describing sawdust as a nest cell partitioning material (Table 1), such

Table 1. Compilation of records of *Anthophora* (*Clisodon*) *terminalis* Cresson nesting. "—" indicates that a particular aspect was not addressed in a particular source.

Location	Date	Substrate	# Nests	# Cells	Nest length (cm)	Excavation	Reference
Beulah, NM, USA	August 1902	Dead fallen pine	"a number" 1+ opened	3–4	~10.2	Yes	Cockerell (1903)
Hull (Gatineau), QC, Canada	16 August 1913	Decayed but hard stump	"riddled with the burrows"	—	—	Yes	Salden (1919)
WI, USA, wild nest: Bayfield Co.	1952–1962; wild nest: 23 July 1952	sumac stem nest traps, "poplar log"	60 in sumac stems; 1 wild nest	Sumac: 5.8 av. Wild: 11	< 20.3 in sumac, cells 11mm	Yes, to different degrees	Medler (1964) R.E. Fye
—	—	"communal burrow excavated by a beetle in an aspen log"	1	—	—	No	Stephen *et al.* (1969)
Mad River Beach, Humboldt Co., CA, USA	—	"driftwood among sand dunes"	—	—	—	—	Brooks (1988)
Toronto, Canada	2013, part of 3-year study	cardboard tubes in PVC trap nests	—	—	<15	—	MacIvor & Packer (2015)
Cannibal Island, near Eureka, CA, USA	5 July 2014	thoroughly investigating driftwood	—	—	—	—	Orr (unpubl. data)
Near Afton, MN, USA	2016	pine/Douglas fir wooden nesting block	1	3	5.6	Slight widening of tunnel	This work

as the description in Medler (1964) that, "cells were composed of finely chewed sawdust. A more coarsely chewed sawdust was used to construct the partitions and terminal plugs. The latter plugs were made both in the tunnel and in an enlarged "cell" which was only partially filled with sawdust. This nest found in nature was essentially the same as those made in the trap-nests." The tunnel diameter in our record is within the range documented by Medler (1964), who stated that 1/4 or 5/16 in. (6.25 or 7.8 mm) holes were best but exact diameter was not necessary as the bees excavated the sides of the tunnels. The cell dimensions in our nest are also similar though slightly shorter. Medler (1964) states that cells were 7 mm wide and 11 mm long. Both Medler (1964) and Cockerell (1903) mentioned a smooth lining to the inside walls of the cells, which we also observed. However, extending beyond prior observations, the use of a fresh, solid wood nesting block in our study broadens our view of this species' nesting behavior, as other records show primarily nesting in softer, often rotting wood materials. This species appears to be an excavator, at least to some degree, maybe to get sawdust for nest partitions, similar to the obligate-excavator species in the genus *Ceratina* Latreille that use chewed pith to partition their nest cells (*e.g.*, Rehan & Richards, 2010; Vickruck *et al*., 2011). Medler (1964) reported that some *A. terminalis* even excavated their nests in the un-drilled fully pithy ends of the stem traps. We did observe some, though not much, bee-engineered change in the diameter of our pre-existing tunnel. The fact that *A. terminalis* has been recorded in trap nests twice suggests some adaptability in nest substrate use, a characteristic not often enough considered when discussing bee nesting.

Review of the available information and our new record suggests that *A. terminalis* may not be well-represented in surveys using solid wood nesting blocks or hard-sided tubes, which are commonly used for "wood-nesting" bees. We only obtained one nest of *A. terminalis*, despite having over 380 nest blocks deployed over three years across the state. This does not seem necessarily due to rarity, as the species is distributed across 24 counties in Minnesota in the University of Minnesota insect collection (as of September 2019). Development of variations in "nest trap" designs (*e.g.*, Sheffield *et al*., 2015) and rearing methods (*e.g.*, Graham *et al*., 2015; Leonard & Harmon-Threatt, 2019) may lead to alternate nest trapping methods for bees with atypical nesting substrate use, such as *A. terminalis*.

ACKNOWLEDGEMENTS

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Article 6

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Minnesota State Records for Osmia georgica, Megachile inimica, and Megachile frugalis (Hymenoptera, Megachilidae), Including a New Nest Description for Megachile frugalis Compared with Other Species in the Subgenus Sayapis

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Minnesota State Records for Osmia georgica, Megachile inimica, and Megachile frugalis (Hymenoptera, Megachilidae), Including a New Nest Description for Megachile frugalis Compared with Other Species in the Subgenus Sayapis

Cover Page Footnote

We are grateful to Jim Cane and Sam Droege for editing suggestions. Many thanks to Minnesota Bee Atlas volunteers who hosted these nest blocks: Ken Schauland, Rebecca Lofgren, Heidi Hansen, Kelly Hanson. Thank you to Jason Gibbs for reviewing specimen identification photographs. Editor Kristi Bugajski and two anonymous reviewers are thanked for their improvements. Funding for the Minnesota Bee Atlas project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR) (Legal Citation M.L. 2015, Chp. 76, Sec. 2, Subd. 03g). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources.

Minnesota State Records for *Osmia georgica, Megachile inimica,* and *Megachile frugalis* (Hymenoptera, Megachilidae), Including a New Nest Description for *Megachile frugalis* Compared with Other Species in the Subgenus *Sayapis*

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Abstract

In this article, we report the first Minnesota state records of *Osmia (Helicosmia) georgica* Cresson 1878, *Megachile (Sayapis) inimica* Cresson 1872, and *Megachile (Sayapis) frugalis* Cresson 1872, which were collected in 2018. We also provide the first description of the nest structure of *M. frugalis*. All three species typically have more southern distributions. The nest of *M. frugalis* shows similar structure to other species in the subgenus *Sayapis* Titus, such as *M. inimica* and *M. pugnata* Say, particularly in that the longitudinal nest cell walls lack a lining of leaf pieces, and the cell partitions are made from a layer of leaf pieces followed by a layer of masticated vegetation and soil particles.

Keywords: *Megachile inimica*, *Megachile frugalis*, *Sayapis*, *Osmia georgica*, natural history, cavity-nesting, trap nest, solitary bees, nest architecture

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In this paper, we report the first records of *Osmia georgica* Cresson, *Megachile inimica* Cresson, and *Megachile frugalis* Cresson in the state of Minnesota. Prior to this, *O. georgica* has shown a predominantly southeastern distribution in the United States of America, with digitized records showing it present along the entire eastern coast and west through Michigan, Nebraska and Texas. Both *Megachile* Latreille species have been recorded across the southern USA, extending northwards into southern Wisconsin, Michigan, New England and south into Mexico and central America (Medler and Lussenhop 1968, Gibbs et al. 2017, GBIF.org 2020). These new records for Minnesota add to the 18 species of *Osmia* Panzer and 22 species of *Megachile* currently known from the state (MNDNR 2019). In the United States as a whole there are 140 species of *Osmia* and 138 species of Megachile (Ascher and Pickering 2020). Bees in the genera *Osmia* and *Megachile* are solitary-nesting bees that typically use vegetative matter or mud to construct nest cells, although some species do use resin (Cane et al. 2007, Michener 2007, Sheffield et al. 2011).

The two new Megachile species reported here both belong to the subgenus *Sayapis* Titus. Prior to this, Minnesota has had only a single representative of the subgenus: *Megachile pugnata* Say. Species in the subgenus *Sayapis* have unusual nest structure compared with other congeners. Among the (*Sayapis*) species found in the United States, nests have been described for *M. pugnata*, *M. inimica*, *Megachile policaris* Say, and *Megachile zaptlana* Cresson (Table 1; Mitchel 1937, Medler 1964, Krombein 1967, Medler and Lussenhop 1968, Frohlich and Parker 1983, Raw 1984, MacIvor 2016, dos Santos et al. 2020). Two others, *Megachile fidelis* Cresson and *Megachile newberryae* Cockerell, have been recorded nesting in stems or wood, but their nest structure information is lacking (Mitchell 1937, Butler 1965, Barthell et al. 1998, Frankie et al. 1998). We know of no references of nests of *Megachile mellitarsis* Cresson or *M. frugalis*.

In addition to details of these new state records, we also provide the first description of the nest structure of *M. frugalis* in comparison with *M. inimica* and published nest descriptions of other species within the

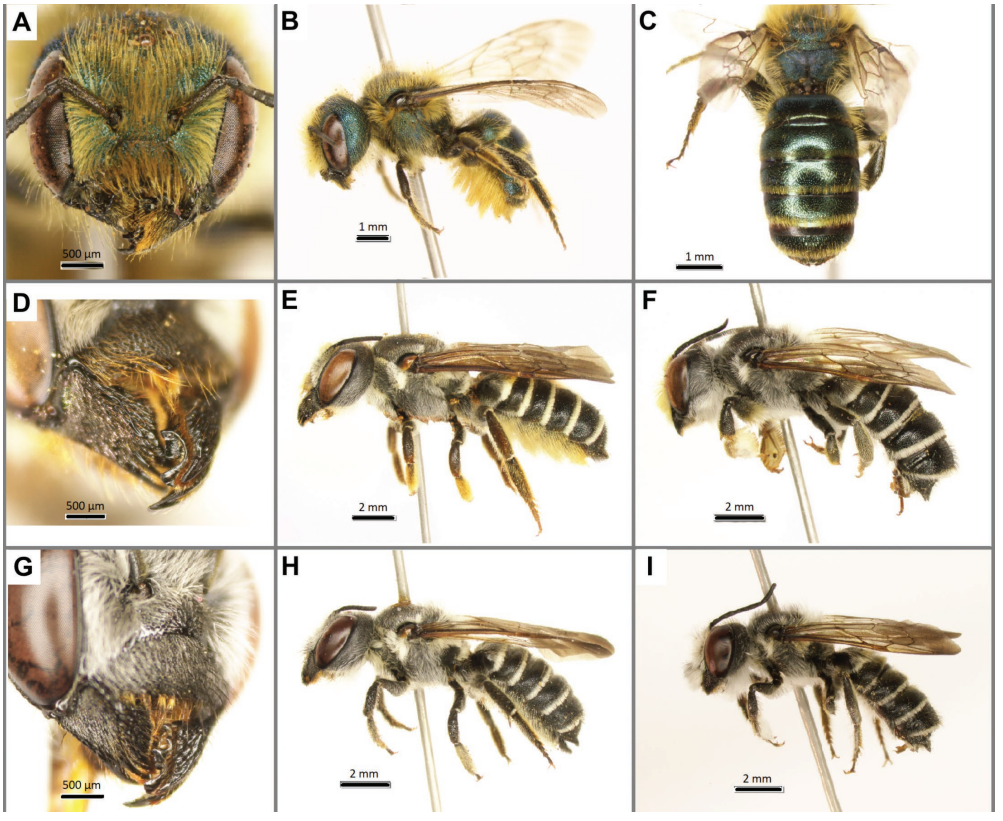

Figure 1: A) Female *O. georgica* mandible. B) *O. georgica* female side, note projection on mandible and yellow scopa. C) *O. georgica* male abdomen, note propodeal slit and T6 notch. D) *M. inimica* female mandible, note central point on clypeus. E) *M. inimica* female side. F) *M. inimica* male side, note lack of black brush on expanded forebasitarsis. G) *M. frugalis* female mandible, note black hair on clypeus. H) *M. frugalis* female side I) *M. frugalis* male side. (Photos courtesy of Thea Evans).

subgenus *Sayapis* which inhabit the United States.

Methods and Materials

Bees were collected with nest blocks as part of the citizen science project "Minnesota Bee Atlas" (https://z.umn.edu/beeatlas). Blocks were made from untreated pine or Douglas fir, with a roof of cedar shingling. Each block measured approximately 8.9 × 14 × 27.9 cm (3.5 × 5.5 × 11 in.) and contained five tunnels each of six different diameters: 3.18 mm, 4.76 mm, 6.35 mm, 7.94 mm, 9.53 mm, and 11.11 mm. Tunnels were approximately 11.43 cm (4.5 in.) deep and spaced 2.54 cm (1 in.) away from other tunnels or the block edge. Each block was identified by a unique number, and tunnels within blocks by unique letter-number combinations.

Volunteers across the state of Minnesota were selected to hang and monitor a nest block in a semi-natural habitat. In March 2018, a total of 140 nest blocks were sent out. Recommended block placement was 0.9–1.5 meters high facing south or east in a semi-sunny location. Volunteers were asked to record specific mounting conditions of their block and report every 2–3 weeks on evidence of nesting. All records discussed in this paper come from southern Minnesota. The nest block that yielded *O. georgica*, number 502, was placed in Winona County, Minnesota, southeast of the town of Lewiston (43.94986°N, –91.82164°W). According to volunteer observation, it was mounted next to several acres of Conservation Reserve Program (CRP) land containing trees, grasses, and native wildflowers, at a height of 1.22 m, facing southeast. The five *M. inimica* nests were distributed between two blocks. One block, number 453, was located near Revere in Cottonwood County (44.13895°N, –95.3601°W), and hung 1.2–1.4 m high,

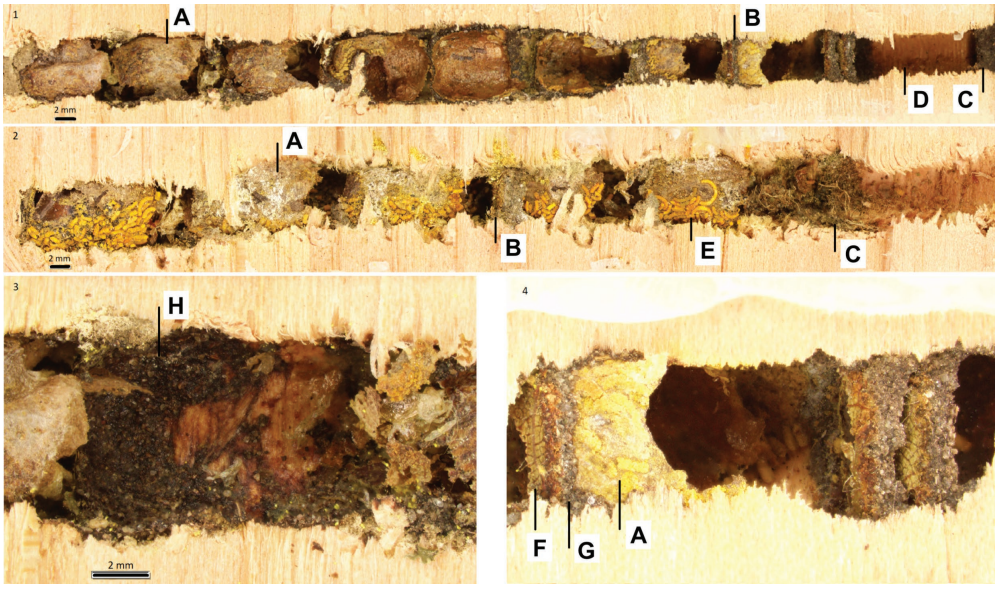

Figure 2. Nests of *M. frugalis* (top) and *M. inimica* (middle), with entrances to right, A=cocoon, B=cell partition, C=final nest plug, D=vestibule, E=frass. Bottom left: close up of 2nd cell of *M. frugalis* nest with cocoon removed - note partial lining of cell walls (H) with chewed vegetation. Bottom right: Close up of 8th cell of *M. frugalis* nest showing partition construction in more detail, F=leaf piece, G=chewed vegetation and soil particles. (Photos courtesy of Thea Evans).

facing southeast. The other block, 467, was located on the edge of Dover in Olmstead County (43.96863°N, –92.1343°W), and hung four feet high, facing south. The block was situated in a lawn with hostas, a highbush cranberry and arborvitae, very close to farmland and grassland. The block containing the *M. frugalis* nest, number 472, was located near Bingham Lake in Cottonwood County, (43.92406°N, –95.0407°W), and hung 1.37 m high, facing south. The volunteer described the location as bordering Conservation Reserve Program land with abundant flowers and near a lake.

In the late fall, blocks were returned to the University of Minnesota where they were surveyed by otoscope, overwintered and reared to emergence in a growth chamber the following year. Warming for emergence was conducted with constant temperature steps, rather than by tracking local daily fluctuations, therefore bee emergence dates suggest relative seasonality rather than actual emergence in field conditions. To capture emerging bees, a hollowed-out plastic test-tube cap was glued over each tunnel entrance and a replaceable test tube was inserted in the cap. Emerged bees in test tubes were removed daily and new tubes placed on tunnels. Bee identification was done by C. D. Satyshur using Mitchell (1962), Sandhouse (1939), and Discover Life keys (Andrus et al. 2020, Griswold et al. 2020, Nelson and Droege 2020a,b). Specimens were compared to materials in the University of Minnesota Insect Collection, which were available for all but *M. frugalis* females, and specimen photographs were reviewed by Jason Gibbs. Bees are deposited in the University of Minnesota Insect Collection; photographs are included in Fig. 1 and within the Minnesota Bee Atlas Species Guide (University of Minnesota Extension 2020).

After the emergence season, the *M. frugalis* and *M. inimica* nest tunnels were split open. Nests were photographed and measured using digital calipers and the Olympus cellSense Standard program. Composite photographs of the nests were created using the Olympus cellSense Standard, CombineZP, and Paint programs. A voucher nest for each species is housed in University of Minnesota insect collection. The *O. georgica* nest tunnel was not opened, because these bees were not identified until after block disposal. Nest descriptions for *O. georgica* can be found in the literature (*e.g.* Hartman et al. 1944, Krombein 1967, Hawkins 1975).

Table 1: Summaries of nesting records of Megachile (Sayapis) which inhabit the United States, encompassing the varying levels of information available.

Species	Location	Substrate	Materials and construction	Reference
M. fidelis	Sequoia Natl. Park, CA, USA	"small log"	1 nest.	Mitchell 1937
M. fidelis	Central Valley, CA, USA	pine trap nests	25 nests, 6.5–8.0 mm diameter.	Barthell et al. 1998
M. fidelis	San Joaquin Valley, CA, USA	Wooden trap nests	NA	Frankie et al. 1998
M. frugalis	Near Bingham Lake, MN, USA	pine/ Douglas fir wooden nesting block	1 nest, 7.94 mm diameter. Eight cells av. 10.1 mm long. Partitions made from leaf circles covered with masticated vegetation, which was also plastered on lower walls. Plug single layer of soil particles and masticated vegetation. Vestibule present.	This work
M. inimica inimica	San Antonio, TX, USA	"worm holes in mesquite trees or fenceposts."	Unknown number of nests. "Lined with circles cut from leaves of *Monisia pallida* Planch." (Probably *Celits pallida* Planch).	Mitchell 1937, H.B. Parks pers com.
M. inimica sayi	Sioux City, IA, USA	"mine in apple wood"	NA	Mitchell 1937, p 193
M. inimica inimica	Sand scrub in Florida, USA	Traps made from borings into wood	1 nest, 6.4 mm diameter. Cells 22–31 mm long. Partition before cells, cells unlined by leaf pieces, partitions "consisting of 1 or 2 circular leaf cuttings on the inner surface and 3-4 mm of agglutinated sand which also formed the base of the next cell." Vestibule 8 mm long, plug "17 mm thick of loosely arranged, more or less circular leaf cuttings."	Krombein 1967
M. inimica sayi	Desert floor, Arizona, USA	Traps made from borings into wood	2 nests, 6.4 mm diameter. Cells 17–25 mm long. Partition before cells. Partitions 1.5 or 2-3 mm thick, "had several leaf cuttings at the inner end then a layer of fine pebbles and leaf pulp". Vestibule 17 mm long. Plug 5 mm thick with leaf cuttings, pebbles and leaf pulp "which hardened into a firm plug."	Krombein 1967
M. inimica sayi	Ipswich, southern Wisconsin, USA	Sumac stem Traps	2 nests. Built against pith at tunnel bottom. "Not enclosed in pieces of leaf…but consisted only of the partitions formed of chewed leaf material."	Medler and Lussenhop 1968
M. inimica	Near Revere and Dover, MN, USA	pine/ Douglas fir wooden nesting block	5 nests, 6.35-9.53 mm diameter. Cells av. 12.8 mm long. Partitions made from one cut leaf piece, followed by a thin layer of soil particles, sometimes covered with chewed vegetation. Sometimes vegetation plastered on lower cell walls. Plug made of two layers of partitions with grass or wood pressed into it. No vestibule.	This work
M. newberryae	Arizona, USA	holes in *Prosopis*	Cutting leaves of *Celits*.	Butler 1965

Species	Location	Substrate	Materials and construction	Reference
M. pugnata	Wisconsin, USA	sumac stick trap-nests	20 nests, 6.25, 7.8 mm diameter, cells av. 15.27 mm long. "Cells were made with basal and apical partitions consisting of leaf discs, chewed leaf materials and soil." Vestibule present. Plug of layered partitions.	Medler 1964
M. pugnata	Captive rearing, Utah, USA	tunnels in elderberry, or glass tubes	Many nests. 8–9 mm diameter, some excavation. *Oenothera hookeri* for building material. Partitions made by masticating vegetation and smearing it on back and sides to make a rim. Leaf pieces attached to the rim, filling tunnel diameter. Another layer of masticated vegetation placed in a rim, smeared to the middle, and with soil particles pressed into it. Then "female laid on her back and groomed the posterior portion of the abdomen and again passed a droplet of liquid to the middle and fore-legs. This time the secretion was placed between the mandibles and chewed vigorously. The female then chewed and licked the outer surface of the partition." Almost all had vestibules.	Frohlich and Parker 1983
M. pugnata	Toronto, ON, Canada	Cardboard tube traps in PVC housing	45 nests. "Mud and chewed leaves to line its brood cells, and makes partitions between adjacent cells using circular pieces of leaves laid one over the other."	MacIvor 2016
M. policaris	Arizona and Florida, USA	Traps made from borings into wood	8 nests, 6.4 or 12.7 mm diameter. Single-larvae cells:13-30 mm long, communal brood cells: 17–78 mm long. "gummy leaf pulp" before cells, cells unlined by leaf material. Many large communal brood cells with multiple pollen balls or a long pollen ball. Partitions "2 layers of small compressed leaflets 2–9 mm long separated by thin septa of hardened, gummy leaf pulp. Occasionally several alternating layers . . . Closing plugs . . . were constructed of the same material in alternating layers." Vestibular cell frequently lacking. Leaf pieces from "*Prosopis* (mesquite), *Mimosa biuncifera* (cat claw acacia), *Eysenhardtia polystachya* (kidneywood)" and an unidentified shrub. Arizona bees used small whole leaflets vs circles.	Krombein 1967, W. Niles
M. zaptlana	Southern and coastal plains, Jamaica	"old beetle burrows in fence posts"	129 nests, cells av. 9.8 mm diameter. Cells av. 19.9 mm long. Base of the first cell lined with pieces of leaves and intercellular partitions constructed but longitudinal walls of cells unlined.	Raw 1984
M. zaptlana	Iguarassu, Pombos, PE, Brazil	Cardboard tubes in wooden traps, and wooden and clear plastic traps	157 nests, 6 mm diameter. Cells av. 6–9.3 mm long. Cells unlined by leaf pieces. Partitions between cells made of a rim of chewed leaves, followed by larger leaf pieces which were covered with chewed vegetation and sand. Most nests had 1 vestibule, some had up to 4. The final plug consisted of 2–5 juxtaposed partitions.	dos Santos et al. 2020

Table 2: Nests of new species records for Minnesota from 2018 season, with emergence dates of males (m) and females (f) listed in the timeline column.

Bee species	Minnesota County	Nest ID and tunnel diameter	Offspring	Emergence timeline
O. georgica	Winona Co.	502(F3) 4.76 mm (3/16 in.)	7	10-Mar-19: 2m 11-Mar-19: 4m 13-Mar-19: 1f
M. inimica	Cottonwood Co.	453(G2) 7.94 mm (5/16 in.)	4	1-May-19: 1m 7-May-19: 3f 9-May-19: 1f
M. inimica	Cottonwood Co.	453(H2) 7.94 mm (5/16 in.)	5	4-May-19: 2m 7-May-19: 3f
M. inimica	Olmstead Co.	467(D1) 9.53 mm (3/8 in.)	6	4-May-19: 6f
M. inimica	Olmstead Co.	467(E1) 9.53 mm (3/8 in.)	3	6-May-19: 2f 7-May-19: 1f
M. inimica	Olmstead Co.	467(E2) 6.35 mm (1/4 in.)	4	28-Apr-19: 1m 4-May-19: 1f Upon opening: 2f dead
M. frugalis	Cottonwood Co.	472(F2) 7.94 mm (5/16 in.)	8	15-Apr-19: 3m,1f 16-Apr-19: 4f

Results

Warming for emergence began on 4 March 2019 (Table 2). Six males and one female *O. georgica* emerged from a single nest between 10–13 March (Fig. 1). Three males and five female *M. frugalis* emerged from a single nest between 15–16 April 2019. Bees emerged from the five *M. inimica* nests between 28 April–7 May 2019. A total of *22 M. inimica* were collected, four males and 18 females, with an average of 4.4 bees/nest. In all cases above, males emerged before females within nests and there were no other organisms that emerged from these tunnels.

The *O. georgica* nest was in the 4.76 mm diameter tunnel F3 in block 502. The volunteer reported partial plugs of "mud/sand" on 2 June and 24 June 2018, and a full plug of the same material on 25 July 2018. Upon return to the University of Minnesota, we used the otoscope to record a complete outer nest plug of masticated vegetation, rather than mud/sand, which was a common misinterpretation among reporters. Despite frequent volunteer reports and helpful pictures of the five *M. inimica* nest blocks, nesting phenology information is sparse, possibly because these nests were plugged well inside tunnel entrances, making them difficult to see. Volunteer reports include grass material in 467(E1) on 7 July 2018, and a full plug of unknown material in 467(E2) on 28 September 2018. Upon return to the University of Minnesota, we recorded the following plug materials in the five tunnels that later produced *M. inimica:* three complete grass plugs, one complete plug of leaf/petal pieces, and one complete mud/sand plug. Variation in otoscope-recorded plug materials within a species can indicate incomplete nests, or that a species adds extra material to the final plug, or that another species has built a second nest in the tunnel, closer to the opening. Evidence from opening nest tunnels suggests the first two situations are likely for these nests as no evidence of other species' nests were seen. The *M. frugalis* nest was made in block 472(F2). The volunteer submitted six observations, with no activity in this tunnel. However, volunteer photographs show a full plug on 10 August 2018, which was absent on 22 July 2018, indicating the nest was completed between those dates. Upon return to University of Minnesota, we observed a full plug of masticated vegetation in the tunnel.

All five *M. inimica* nests were opened and a composite photograph of nest 453(H2) was created (Fig. 2). Four of the five nests were complete and measured on average 81.8 mm long, with final plugs recessed on average 26.2 mm from the tunnel entrance.

Three complete nests had five cells, one had six, and the incomplete nest had four cells. The average cell length was 12.8 mm (range: 8.3–17.6 mm). However, the cell lengths were longer in narrower diameter tunnels and shorter in wider diameter tunnels. The average cell length was 10.1 mm in the two 9.53 mm diameter tunnels, 14.0 mm long in the two 7.94 mm diameter tunnels and 15.7 mm long in the 6.35 mm diameter tunnel. In one nest, the innermost cell failed early, leaving a mass of pollen stores. In two other nests, there was a cell that did not produce an emerging adult, but these must have failed after cocoons were spun, as all cells contained evidence of cocoons. There was no evidence that the nests were parasitized, and no dead pupae or adults were found. Emerging bees can chew through dead offspring or adults, sometimes pushing debris out of the tunnel as they go and leaving little evidence behind. The average thickness of partitions between cells across all nests was 1.9 mm. The partitions were made from one whole leaf piece, followed by a thin layer of soil particles, in some cases with chewed vegetation on top. Cell walls were generally unlined by any leaf or soil material, although sometimes mud or masticated vegetation was spread part way up the sides of cells from the lower partition. The bees' cocoons were clearly evident, made of parchment-like material with yellowish orange frass distributed over the outside. No complete nest contained a vestibule. Despite the otoscope records of grass nest plugs, all final plugs consisted primarily of two consecutive partitions, of similar construction to cell partitions, with grass or wood fibers only pressed into the outermost surface of some. Plugs averaged 7.4 mm thick (range 6.6–8.3 mm).

The *M. frugalis* tunnel 472(F2) was opened and a composite photograph of the nest was created (Fig. 2). The nest had eight cells, corresponding to eight emerged adults. The nest occupied the full length of the 106.7 mm tunnel. Mud and possibly masticated vegetation were plastered on the innermost end of the nest, measuring 2.4 mm thick. The average nest cell length was 10.1 mm (range 9.6–10.7 mm) and partition thickness was 0.8 mm (range 0.3–1.1 mm). Each cell had a thin layer of masticated vegetation plastered on the inner 1/3–1/2 of the wall length, while the remaining wall area was covered with a shiny material over the bare wooden tunnel wall (Fig. 2). The bees' cocoons were clearly evident, made of parchment-like material with a small amount of brown frass, primarily on the outer ends. The upper partition of the last cell was made of two layers instead of one and measured 3.2 mm. All partitions were made of a single layer of leaf pieces, followed by a thin layer of masticated vegetation and sand. The nest contained a 13.1 mm long vestibule between the last cell and the final plug. The final plug was located at the tunnel entrance and composed of a single layer of soil particles mixed with masticated vegetation that was 2.3 mm thick.

Discussion

Our understanding of all three species' distributions is expanded somewhat northward by these new records for Minnesota. Among digitized bee records, the closest prior records for *O. georgica* are found in northern Indiana, Illinois, Kansas, and Missouri (GBIF.org 2020). It's also reported from nine counties in the Lower Peninsula of Michigan (Gibbs et al. 2017). *Megachile inimica* has been recorded in southern Wisconsin (Medler and Lussenhop 1968) and in Kalamazoo county in the Lower Peninsula of Michigan (Gibbs et al. 2017). The nearest digitized records are in Nebraska and Illinois (GBIF.org 2020). *Megachile frugalis* has also been recorded from eight counties in southern Michigan (Gibbs et al 2017) and there are also digitized records from Missouri and Kansas (GBIF.org 2020). Whether the northern records reported here are due to a change in the species' ranges or increased sampling effort is difficult to say from these data.

Our available nesting and emergence phenology point to mid or late summer nesting by *M. inimica* and *M. frugalis*. *Megachile frugalis* had clear nest plug data for late July to early August. The sparse nesting information for *M. inimica* nests came in July and September, somewhat corresponding to the flight period reported for southern Wisconsin of 4 July to 2 September (Medler and Lussenhop 1968). *Megachile inimica* also emerged at the very end of rearing, later than the rest of the bees. As we rear at fixed temperatures, and bee and wasp species emerge in a predictable order each year, the greater degree-days before emergence of *M. inimica* could point to a possible mechanism for the species primarily being found in areas with longer growing seasons. It also could point to a mechanism for a possible northward expansion of the species' distribution, as the freeze-free season in southern Minnesota has lengthened by 16 days from 1951–2012 (GLISA 2020).

Similarly, the full plug date for *O. georgica* reported by the volunteer (between 24 June and 25 July) would be late compared to other *Osmia* species seen in this project, which often complete nest building by early to mid-June. However, the partial plug noted by the volunteer in early June may actually represent the nest completion date, and the offspring emerged in the growth chamber in

the same timeframe as other small *Osmia*. Hawkins (1975) reports *O. georgica* completed nests between the end of May and the end of June in Tennessee.

With the addition of the *M. frugalis* nest in this work, seven of the eight (*Sayapis*) species in the US now have at least one record of a nesting substrate, or the material in which a nest is made (Table 1). Natural nests have been documented in wood substrates for *M. fidelis, M. inimica inimica* Cresson, *M. inimica sayi* Cresson, *M. newberryae* and *M. zaptlana* (Mitchell 1937, Butler 1965, Raw 1984). Others are only known from trap nests, which, while suggestive and in some cases well documented, does not necessarily fully encompass their nesting biology. For example, one predominantly ground nesting bee species, *Megachile wheeleri* Mitchell, has been caught in trap nests (Gordon 2000). O*smia lignaria* Say, which is managed using trap nests, can also nest in the ground (Rau 1937, Linsley and MacSwain 1941, Levin 1966). Other species may show flexibility in the use of nest substrate, such as *Megachile brevis* Say. This bee species can be found in trap nests, but also has been found in standing dead stems, in a termite hole in a garage door, among leaves — both alive and dead, in prostrate corn stalks, under cow chips and mats of prairie grass, among small rocks on the ground, and in holes actually in the ground (Michener 1953).

To date, internal nest architecture appears to be fairly conserved within the subgenus *Sayapis* in the United States. There is now information of varying detail for five of the eight species (Table 1). All available information indicates they construct nest cells that are unlined by leaf pieces, in contrast with most other *Megachile* which fully line the longitudinal walls of their nest cells with cut leaf pieces. Partitions between cells are also similar for these five (*Sayapis*) species, consisting of a layer of leaf pieces on the inner side covered with a mix of soil particles and masticated vegetation.

There are some differences between species. All United States (*Sayapis),* in contrast with many other *Megachile,* make use of soil particles in nest building to some degree. However, nest accounts indicate that the ratio of soil to masticated vegetation may differ between species in the subgenus. For example, we recorded final nest plugs of *M. inimica* covered with soil particles with grass or wood pressed into it, while the *M. frugalis* plug was primarily masticated vegetation. The *M. frugalis* nest also had masticated vegetation plastered on the lower walls of cells (Fig. 2), which is more wall lining than reported for *M. inimica* or *M. pugnata.* The *M. frugalis* nest contained a vestibule, similar to reports for *M. pugnata* and *M. inimica* (Medler 1964, Krombein 1967). In contrast, we did not see vestibules in our *M. inimica* nests. The most unusual nest structure in United States (*Sayapis*) is reported for *M. policaris.* This species can construct atypically large, multi-offspring cells (Krombein 1967, Michener 2007), unlike the more common single-offspring cells of *M. inimica, M. frugalis, M. pugnata and M. zaptlana (*Table 1; Medler 1964, Krombein 1967, Medler and Lussenhop 1968, Frohlich and Parker 1983, Raw 1984, MacIvor 2016, dos Santos et al. 2020). It is unknown to what degree nest architecture may naturally vary within a species or may differ between nests in trap nests compared to natural substrates.

It would be interesting to see how nest construction of other members of this subgenus compare to the five United States species that have been described. The nests of *M. fidelis* should be attainable from trap nests, and perhaps those of *M. newberryae* also. The final species, *M. mellitarsis*, has two intriguing synonyms (*M. terrestris_homonym* Cockerell 1908a and *M. geophila* Cockerell 1908b), which suggest affiliation for the ground, possibly indicating that it breaks from the other members of the subgenus and nests below-ground. However, Cockerell's (1908a) original description does not mention nesting, simply noting that the bee was flying close to the ground when caught. Future research could focus on nests of *M. mellitarsis,* as well as filling out nest architecture and natural substrate information for the other US (*Sayapis)* species. The results presented in this work add to foundational data on both bee distribution and nesting biology, addressing the lack of nesting information for bee species in the United States (Harmon-Threatt 2020).

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