

**There's no place like home: investigating the ideal
nesting site requirements of Megachilidae bees in the
Rocky Mountains of Colorado.**

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ABSTRACT

Solitary mason bees in the family Megachilidae are known to be important pollinators worldwide. They are important pollinators of natural ecosystems and also are widely used for the commercial pollination of crop plants such as almonds, cherries, peaches, plums, and apples. Given that they are such important pollinators, there is still little known about their nesting biology. The goal of this study was to determine which specific site characteristics Megachilids look for when choosing a nest. Eleven sub-alpine meadows around the Rocky Mountain Biological Laboratory in Gothic, Colorado were selected, and ten artificial trap-nests were placed on trees within each meadow. Site-specific characteristics such as floral resources and quantity of nesting material, along with the nest-specific criteria of nest height and aspect were recorded and compared to nesting within each trap-nest and site as a whole. We found that floral resources within a site do not play a role in Megachilidae nesting, but the amount of nesting material is positively correlated to the amount of bees nesting at a given site. This information can be applied towards both habitat restoration and land management in that emphasis should be given to the availability of nesting material to foster healthy populations of these pollinators.

INTRODUCTION

Pollinators are key components of every ecosystem as they provide the means for sexual reproduction in 87.5% of all flowering plants (Ollerton *et al.* 2011). The diverse set of organisms regarded as pollinators include hummingbirds, butterflies, beetles, flies, and most importantly, bees. Despite the fact that pollinators represent a broad and diverse group of organisms, pollinator populations across the globe are at risk due to rapid anthropogenic disturbance including habitat destruction and alteration, invasion by non-native species, rapid climate change, and species extinctions (Kearns *et al.* 1998). These changes can result in a loss of habitat and food supply, which has the potential to stress pollinator populations and cause a pollination crisis (Kearns *et al.* 1998). Williams *et al.* (2010) showed that this danger of stressing pollinator populations is serious: bee abundance decreases as a result of anthropogenic disturbances. Additionally, in Europe there is significant concern for pollinator populations given that up to 52% of European bee species are at risk of extinction (Mohra *et al.* 2004). Despite these threats to pollinator populations, there still remain large gaps in our knowledge of basic pollination ecology and importantly, life history biology of our pollinators such as bees.

Bees (Hymenoptera; Apidea) are one of the most important pollinators in the majority of ecosystems worldwide (Nabhan & Buchmann 1997; Kearns *et al.* 1998). Across the globe there are more than 20,000 bee species representing 11 families found in nearly all ecosystems (O'Toole & Raw 2004). In exchange for pollination, bees feed on floral nectar, and collect pollen as the primary food resource for their larvae (O'Toole & Raw 2004; Potts *et al.* 2003). The most well-known bees are honey bees and bumblebees, both of which are social to some degree. The vast majority of bee species, however, are not social but solitary. Solitary bees live in individual nests that can be made from pre-existing holes in ground or wood, or, holes that they have excavated themselves (O'Toole & Raw 2004).

One such family of solitary bees is the Megachilidae family. Megachilids are mason bees that take advantage of already existing holes in dead wood to build their nests (O'Toole & Raw

2004). Although this family of bees is regarded as important pollinators, almost nothing is known about their life history, nesting biology or habitat requirements. Megachilids are likely to be significantly impacted by anthropogenic environmental disturbances. They are primarily obligate wood nesters and a decrease in habitat caused by intensive agriculture, fire, or land development can reduce their available nesting material and subsequently their overall abundance (Winfrey *et al.* 2006; Williams *et al.* 2010). A study by Gathmann and Tscharrntke (2002) found that Megachilids have a limited foraging range that has an upper range limit of 200-600 meters from their nests, depending on the species, and that foraging range is also positively correlated to body size. So in addition to populations being potentially limited by nesting habitat, populations could also decrease in areas where there are limited floral resources. Megachilids are an important study subject because they are found worldwide, are important crop pollinators, and are one of the primary pollinators in the Rocky Mountains of Colorado, where this study was conducted at the Rocky Mountain Biological Laboratory (RMBL).

The objective of this study was to determine what local site factors and characteristics are associated with Megachilidae nesting success in the RMBL area using artificial trap-nesting boxes. Our primary hypothesis was that an ideal nesting site would be associated with abundance of both floral resources and nesting material in order to minimize the energy spent foraging for nectar and pollen while provisioning nest cells. This is supported in part by Potts *et al.* (2005) who found that while floral community composition accounts largely for nest site choice, at least 5% of bee diversity is explained by the available nesting material. However, this work focused on ground nesting bees where nesting habitat may be more abundant in any given area; thus, for cavity nesting bees, nesting material may play a much stronger role due to its limited local availability. We predicted that most bees would be found nesting at sites with high floral abundance and suitable nesting material. Alternatively, other factors may play a role in Megachilid nesting site suitability. Such factors that may influence nest site preference include: height of the nest box off the ground and nest box aspect. This information provides us with a better understanding of the habitat requirements for Megachilidae bees in Colorado, as well as provides insight to the nesting requirements of many other bees across the globe. This is especially important if we are to predict the responses of important pollinators to habitat destruction and other anthropogenic disturbances that are only likely to increase in all areas across the globe in coming years.

METHODS

STUDY SITE & SYSTEM:

We had 11 study sites set up throughout the RMBL area. These sites could be characterized as sub-alpine meadows at ca. 9500 ft in elevation that range in size from approximately 75 m² to 150 m². The sites were spread across a linear distance of approximately 4 km, all within the RMBL area. Within each site, there were 10 artificial trap-nest bee boxes (except for two sites: Martina's Meadow, 8 boxes, and Forrest Meadow, 20 boxes). These boxes mimicked natural nesting material, but enabled nests and nesting activity to be easily monitored via the nest holes that have been drilled into the box. The bee boxes were visually aged by burning to better mimic the appearance of dead wood. The boxes were non-destructively attached to aspens along the edge of each meadow. All boxes were oriented approximately southerly, but within the aspect of 50° to 270°.

HYPOTHESIS 1: *Megachilidae bees prefer nesting sites with both ample floral resources and nesting material.*

Megachilid adults use nectar as their primary energy source and collect pollen to provision their young. Therefore an ideal nesting site should presumably have floral resources close at hand. Additionally, Megachilids nest in pre-existing holes in dead wood. A preferred nesting site should consequently contain a large amount of nesting material near an abundance of floral resources. These factors, alone or together, minimize energy spent foraging. Taken together, these are both likely to be critical factors in predicting nesting at sites in our study system.

HYPOTHESIS 2: *The ideal Megachilidae nesting site may also be affected by relatively minor factors within the nesting environment including: height of nest box off the ground, nest box aspect, average amount of sunlight reaching the boxes, and the distance of the meadow to the nearest water source.*

Each meadow has different characteristics, which create microenvironments and may affect the bees' preference for nesting in an area. These characteristics include nest height and nest aspect.

SPECIFIC METHODOLOGIES:

Site selection and nesting blocks:

To address HYPOTHESES 1 and 2, 11 test sites were set up throughout the RMBL area. These sites ranged from Judd Falls Parking Lot area to the Avalanche Cabin area representing variation in the plant communities around RMBL. Ten artificial trap-nesting boxes were set up at each meadow (except for one site which had 20 boxes and another with 8). The boxes were placed near or on woody materials (e.g., rotting stumps or aspen trees) and affixed non-destructively. The boxes consisted of blocks of wood 30 x 15 x 12 cm in size, with 30 holes 10.5 cm in depth. In each box there are equal numbers of three hole sizes that are 6 mm, 8mm, and 9.5 mm in diameter in order to attract a range of Megachilidae bees based on varying body size between species (J. Forrest, J. Cane and P. CaraDonna, *personal communication*). These artificial nesting blocks mimic the nesting materials used by the Megachilidae. The boxes were monitored bi-weekly for Megachilidae nest activity using flashlights and were scored according to bee activity: bee sighted within box, nest construction in progress, or nest construction completed. The completed nest, quantified by a mud or leaf plug at the end of the nest hole, was considered a successful nest. The number of nests constructed at each site were compared between sites to determine overall site preference.

Quantifying floral resources and nesting material.

To address HYPOTHESIS 1, a 100 x 0.5 m transect was set up at each site. All open flowers were counted along the transect once per week. This information was used to estimate floral resource abundance and diversity of each meadow during the collection period of the May to August.

To estimate the relative amount of nesting material in each site, all dead wood (potential nesting material) within a 5 m radius of each box was quantified. Only wood that had a minimum diameter of 10 cm was scored based on two characteristics, size and quality. Nesting material was scored on a qualitative scale of 1-5 for size and 0-3 for nest material quality. The size was

graded according to table 1 (Appendix I). In terms of nesting material quality, a 0 represents a dead tree that has no cracks or holes, but could still be used for nesting. A 1 was considered wood that had few cracks or holes. A 2 had moderate cracks with a combination of holes, and a 3 had many holes and large cracks and ample nesting options throughout the entire specimen. Both scores for an individual wood sample were then multiplied to obtain the wood score. All wood scores for a box and within a site were then added together to determine the relative amount of nesting material around each box or at each site. This quantifies both the amount of wood available and the approximate nesting potential of each dead wood specimen. If a sample of dead wood was not completely enclosed within the surveying circle, it was entirely scored and included in the survey.

Measuring microenvironment site/nesting box factors.

To address HYPOTHESIS 2, other minor factors that may affect Megachilidae nest site preference were measured. The height of the nesting box off the ground was measured from the bottom edge of the box to the ground. The aspect of each box was measured via compass.

Data Analysis:

Data was analyzed by performing separate linear regressions with each environmental variable as an independent variable and the number of nests as the dependent variable in order to determine which factors best predict bee nesting at each site. The data collected from the site known as the “Bench Forest” was found to be an outlier and was removed from the data analyzed for all tests. Analyses were done at both the site level and box-specific level. Site level data was analyzed as the total number of nests made or attempted at each site compared with the total amount of dead wood in a site and the total number of flowers observed at the site for the duration of the summer. Box-specific data was analyzed as the total number of nests made in each box compared with the amount of nesting material around that box, the height of the box, and the aspect of the box. All analyses were performed using the software R.

RESULTS

Summary of bee data

Through the duration of the sampling period (May – August) a total of 244 nests were counted across all sites, along with 12,701 flowers. The average nests per box per site varied between sites in a range from 0.8 nests/box to 4.4 nests/box (Fig. 1).

Impact of Floral Resources on Site Habitation

The floral abundance at a given site had no impact on the number of nests observed at each site ($R^2=0.051$, $P=0.529$; Table 2).

Effects of Nesting Material on Site Habitation

There was a positive relationship between the number of nests at a given site and the amount of nesting material ($R^2=0.411$, $P=0.045$; Fig. 2). The site with the lowest number of bee nests at 8

also had one of the lowest wood scores at 53. Conversely, the site with the greatest amount of nests at 44 had one of the highest wood scores at 115.

Effects of nest height and nest aspect on number of nests constructed

There was little to no effect observed between the height of the nest and the number of nests built, and for the aspect of the nest and the number of nests built. ($R^2 = 0.05$, and $R^2 = 0.013$, respectively).

Tables and Figures

Figure 1: The average number of nests constructed at each site.

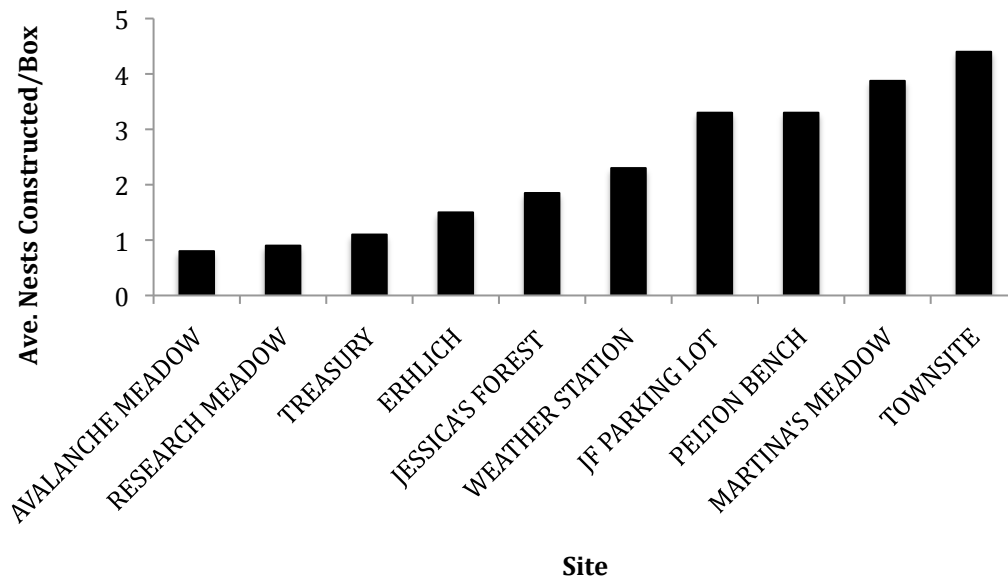


FIGURE 1: The average number of nests constructed per box for a given site differed between sites. The average number of nests ranged from 0.8 per box for the Avalanche meadow and 4.4 nests per box for the Townsite.

Figure 1: Nesting material is positively correlated to the amount of nests built at a site

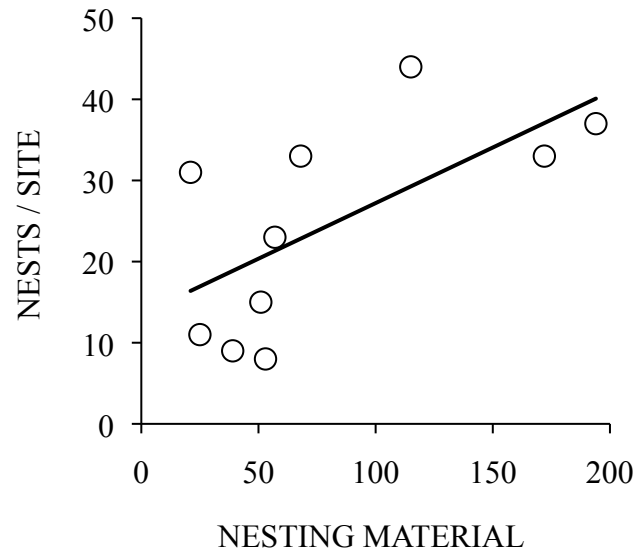


FIGURE 2: The relationship between the amount of nesting material at a site and the number of nests at a site. ($R^2 = 0.411$, $P = 0.045$)

Table 2: Floral abundance, nest height, and nest aspect all proved to have little to no effect on the bees' preference to nest at a certain site or a certain box.

Factor	R^2
Ave. Floral Abundance	0.051
Height (cm)	0.05
Aspect (°)	0.013

DISCUSSION

Variation was seen in the amount of nesting bees at each site (Fig. 1). This suggests that there are differences between sites that are affecting the desirability of a particular site. The difference in desirability is partially explained by the amount of available nesting material. We found that when choosing a nesting site, mason bees in the Megachilidae family will preferentially nest in sites that have the greatest abundance of nesting material (Fig. 2). The floral resources at the site, however, play little to no role in making a site more desirable (Table 2). Taken together, our results are partially consistent with hypothesis 1, which states that bees will nest in sites that have both the most nesting material and floral resources. These results, however, are inconsistent with the findings of Potts *et al.* (2005) who found that floral abundance played a significant role in the desirability of a particular site to the local bee community. This may be explained by the fact that Potts *et al.* was studying ground-nesting bees. For these bees, nesting material may not be a limiting resource, so they may choose a site based on the next limiting resource, floral food abundance. For mason bees, nesting material could greatly limit their habitat options as a paucity

of decayed trees in for example, farm fields or a young regenerating forest, would result in an inability to nest. Additionally, this was an exceptionally dry season. There was low floral abundance at every site, and phenology was accelerated an average of four weeks for flower species (D. Inouye, *personal communication*). This unusual summer may have been too aberrant for bees to appropriately adapt and use floral resources as a nest site guide. Also, as the bees have a maximum foraging range between 200-600 m (Gathmann & Tschardt 2002), they may have found sufficient floral abundance through foraging in meadows adjacent to the study sites. The low floral abundance may also have caused the variation in abundance between sites to not be great enough to affect nesting. Floral abundance likely plays some role in bee nesting preference, but the unusual growing season could have obscured a potential trend.

The factors tested in hypothesis 2, height and aspect, were found to have little to no effect on the bees' preference for a given nest (Table 2). However, the project was not developed with these particular questions in mind. As a result, there is a limitation to the amount of variation in factors related to each box. For example, box heights ranged from 23-160 cm, which does not provide a full picture of bees potential nesting heights as bees were seen searching for nests up to 3m above the ground (V. Milici & P. CaraDonna, *personal observation*). Additionally, the boxes were arranged approximately southwest in order to increase daily exposure to daylight and warmer temperatures. This resulted in a nest aspect range from 50-270°, instead of the 0-360° possible. If the height and aspect range were expanded to their full potential, a preference to a certain aspect range could potentially be observed.

Much of the variation between sites is still yet to be explained as the amount of nesting material only accounted for 40% of the variation in nesting (Fig. 2). There is still 60% of the variation left unexplained. Future research should attempt to account for the remaining 60% of variation. Aspect and height may still play an important role in nest preference. If the trap-nest ranges for both of these variables are expanded, this may provide enough contrast to indicate a preference to these variables. There is also the possibility that other variables, as of yet unexplored, could play a significant role in the unraveling of the ideal nesting site.

This study provides key information into the nesting biology of bees in the Megachilidae family and potentially mason bees in other families. We now know that Megachilids will preferentially nest in meadows that have an abundance of dead wood nesting material and that the flowers in a particular meadow aren't a predictor of bee abundance. Additionally, we know that trap-nests placed within the height and aspect parameters used by the trap-nests in this study are within an acceptable range for Megachilids. Although more research needs to be done to fully understand the nesting biology of Megachilidae bees, the information provided by this study can be applied to restoration, land management, and agriculture. Those involved in the management of these lands should ascribe more importance to the availability of nesting materials over the abundance of flowers in a given meadow. This will enable a higher rate of Megachilid nesting to be observed at these sites. It's incredibly important that there are healthy and sustainable populations of Megachilidae and other pollinators to maintain healthy and diverse ecosystems.

Works Cited

- Bosch, J., W.P. Kemp, and S.S. Peterson. 2000. Management of *Osmia lignaria* (Hymenoptera: Megachilidae) populations for almond population: Methods to advance bee emergence. *Physiological and Chemical Ecology* 29:874-883.
- Gathmann, A., and T. Tschardt. 2002. Foraging ranges of solitary bees. *Journal of Animal Ecology* 71:757-764.
- Kearns, C.A., D.W. Inouye, and N.M. Waser. 1998. Endangered mutualisms: The conservation of plant-pollinator interactions. *Annual review of ecology and systematics* 29:83-112.
- Mohra, C., M. Fellendorf, and R.J. Paxton. 2004. The population dynamics and genetics of solitary bees: a European case study, *Andrena vaga* (Hymenoptera, andrenidae). Pp 85-95 in B.M. Freitas and J.O.P. Pereira, editors. *Solitary bees: conservation, rearing and management for pollination*. University Federal do Ceara, Ceara, Brazil.
- Nabhan, G.P., and S.L. Buchmann. 1997. Services provided by pollinators. Pp 133-150 in G.C. Daily, editor. *Nature's services: Societal dependence on natural ecosystems*. Island Press, Washington, D.C.
- Ollerton J., R. Winfree, and S. Tarrant. 2011. How many flowering plants are pollinated by animals? *Oikos*, 120(3):321-326.
- O'Toole, C., and A. Raw. 2004. *Bees of the World*. Facts on File, Inc, New York, New York. Pp. 22-27.
- Potts, S.G., B. Vulliamy, A. Dafni, G. Ne'eman, and P. Willmer. 2003. Linking bees and flowers: How do floral communities structure pollinator communities? *Ecology*, 84(10): 2628-2642.
- Potts, S.G., B. Vulliamy, S. Roberts, C. O'Toole, A. Dafni, G. Ne'eman, and P. Wilmer. 2005. Role of nesting resources in organizing diverse bee communities in a Mediterranean landscape. *Ecological Entomology*, 30: 78-85.
- Williams, N.M., E.E. Crone, T.H. Roulston, R.L. Minckley, L. Packer, and S.G. Potts. 2010. Ecological and life-history traits predict bee species responses to environmental disturbances. *Biological Conservation*, 143: 2280-2291.
- Winfree, R., T. Griswold, and C. Kremen. 2007. Effect of human disturbance on bee communities in a forested ecosystem. *Conservation Biology*, 21:213-223.

APPENDIX I

Table 1: Diameter and length requirements of each size rating in the dead wood quantification scale.

Size	Diameter (min)	Length
1	10 cm	0-3m
2	20 cm	3-5 m
3	30 cm	5-7 m
4	50 cm	7-9 m
5	80 cm	9+ m