Conservation and Management of NORTH AMERICAN MASON BEES

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EXECUTIVE SUMMARY

This document provides a brief overview of the diversity, natural history, conservation status, and management of North American mason bees. Mason bees are stingless, solitary bees. They are well known for being efficient pollinators, making them increasingly important components of our ecosystems in light of ongoing declines of honey bees and native pollinators. Although some species remain abundant and widespread, 27% of the 139 native species in North America are at risk, including 14 that have not been recorded for several decades. Threats to mason bees include habitat loss and degradation, diseases, pesticides, climate change, and their intrinsic vulnerability to declines caused by a low reproductive rate and, in many species, small range sizes.

Management and conservation recommendations center on protecting suitable nesting habitat where bees spend most of the year, as well as spring foraging habitat. Major recommendations are:

- Protect nesting habitat, including dead sticks and wood, and rocky and sandy areas.
- Ensure access to mud for nest construction.
- Avoid fires and mowing in potential nesting habitat, or alternate these management activities on an annual basis.
- Place wooden nest blocks in areas protected from the weather to promote breeding by cavity-nesting species.
- Ensure abundant and diverse spring-blooming plants, especially those in the heath, rose, and pea families.
- Avoid spraying pesticides on spring-blooming crops visited by mason bees, and avoid using systemic pesticides at any time of the year.
- Avoid introducing managed mason bees to regions where they are not native to prevent the spread of pathogens.
- Where feasible, establish inventory and monitoring programs to better understand the distribution and population trends of native mason bees.

Introduction

Mason bees are a large group of small, stingless bees that occur in many terrestrial regions primarily north of the equator (Rightmyer et al. 2013). All 342 described species are technically solitary in that each female builds and provisions her own larval nest, but some species will nest in aggregations. Mason bees are excellent pollinators, including for commercial crops. A few species have been introduced in Europe, the United States, and elsewhere for crop pollination. Interest in mason bees has increased in recent years due to their economic importance, which is poised to grow due to widespread declines of honey bees (*Apis mellifera*) and native pollinators (Burkle et al. 2013, Vanbergen et al. 2013). Mason bees diversify the range of pollinators in agricultural systems and thereby contribute to food security.

The best known of the economically important species in North America is *Osmia lignaria*, known as the blue orchard bee or orchard mason bee. This native species is important in pollinating spring-blooming crops. Dormant bees are sold in the winter to be placed in orchards for spring emergence and pollination. Advantages over honey bees include their non-aggressive, non-stinging behavior and greater efficiency at pollinating flowers of some crops.

Taxonomists currently place all North American mason bees in the genus *Osmia*. This large group is further subdivided into approximately nine subgenera. The mason bees, together with the leaf-cutter and resin bees (genus *Megachile*) and a few other genera, make up the family Megachilidae, the second largest family of bees in the world (Gonzalez et al. 2012). The family is united by a unique abdominal structure called a scopa that is used to carry pollen. Most other bees that gather pollen, including the familiar honey bee, carry pollen on their legs.

Diversity

About 139 species of mason bee are native to North America, or 41% of the global diversity of the group (ITIS 2008; see Appendix for complete list). An additional three species (*Osmia cornifrons* and *O. taurus* from Asia and *O. caerulescens* from Europe) have been introduced to the continent. Mason bees occur throughout North America except in the far northern regions of Canada and Alaska. The distribution of many species is incompletely known, and state or provincial lists are available for only a few jurisdictions. Diversity is much higher in the western than eastern United States. Mountainous states tend to have higher species richness than flatter states. California is the state with the highest documented diversity, with 88 species reported (Krombein et al. 1979). Colorado has 76 species (Scott et al. 2011) and Utah is reported to have more than 50 species, whereas most eastern states have 18-25 species (Ascher and Pickering 2014). States along the Gulf Coast from Louisiana to Florida have lower richness, 14-15 species each. Farther north, Vermont and the Canadian provinces of Quebec, New Brunswick, and Nova Scotia have 16-18 species each. At the northern tier of the continent, two species are recorded from Alaska, and 1-2 species each from Yukon, Northwest Territories, and Nunavut, Canada.

Natural History

Habitat.—Mason bees require habitats where they can find substrate for building their nests and flowers that bloom in the spring and early summer for foraging. These habitat features can be found in areas as varied as deserts, prairies, shrublands, deciduous forests, and coniferous forests. Species vary in their ability to adapt to disturbed habitats such as agricultural areas. Nesting sites vary (see below), but can include dry sticks, dead stems, soil, decaying wood, and rocks (Cane et al. 2007).

Annual Cycle.—Although the annual cycle has not been described for many species, we know enough to describe a general cycle for North American species (Parker 1984, Bosch et al. 2000, Bosch and Kemp 2001, Gordon 2003, Otto 2006, Sampson et al. 2009). Mason bees mostly have a single generation each year. Adult bees emerge from nests in the early spring, males before females, and promptly mate. Females then begin nest building. Nests typically contain clusters of several cells, each with a single egg. All eggs are laid by the same female. Females provision each cell with a pollen-nectar mixture for larval nutrition. Eggs hatch and larval development continues within the cells until early to mid-summer when larvae enter a prepupal aestivation (dormant period). After a few weeks or months (southern and low elevation populations tend to take longer), pupation occurs. Adults emerge about a month later in autumn. Adults remain dormant in their nest cell throughout the winter and emerge in the spring in response to warming temperatures. Thus mason bees spend most of their lives in their nest cell, becoming active as adults for only a short period in the spring and early summer.

Some variations to this pattern have been reported. In cold regions, the larval stage may last two years (Scott et al. 2011). Some larvae in a population may not pupate until the spring (e.g., *O. latisulcata*; Parker 1984). At least one British mason bee species is known to overwinter more than once before emerging (Packard 1870). More study may reveal that some western U.S. species can similarly spend more than a year in their nest cells, perhaps to avoid dry years as many desert insects do (Powell 1986, Powell 2001, Sandberg and Stewart 2004, Mader et al. 2010).

Nesting biology.—North American mason bees use a wide range of nesting substrates. Nests have been reported in abandoned tunnels bored by beetles into living trees, in abandoned nests built by other genera of solitary bees, under bark, in abandoned wasp nests, underground, in hollow reeds or other plant stems, under rocks, in mud, in sand or dunes, and in snail shells (Cane et al. 2007). In most cases, females chew leaf pulp and use the substance to form cells or compartments in their nests and to cap nest entrances. In some species, mud, sand or plant fibers are mixed with the pulp (Cane et al. 2007). Indeed, the use of construction materials for nests is the origin of their common name, "mason" bees. The shape of the head and jaws appears to be related to whether a species uses leaves or mud to build nests (Williams and Goodell 2000).

Most species have been reported to utilize only a single kind of substrate, although some are known to use several. Species that nest underground can require specific soil characteristics for their nesting sites (Otto 2006, Cane et al. 2007). The nesting habits of about half of the North American fauna remain unknown (Cane et al. 2007).

Many species will readily use artificial nest tubes drilled into blocks of wood. In fact, trapping with artificial nests is a method used to inventory mason bees in the field. However, species with subterranean nesting habits are typically not lured to these traps. Mason bees marketed for their pollination services are restricted to species that nest in wood, which facilitates transportation of bees to the crops where they are needed.

Foraging and nutrition.—Adult mason bees feed on flower nectar and collect pollen to provision nests. Often, but not always, bees will forage for pollen and nectar at different kinds of plants. The diversity of plant species from which mason bees collect nectar and pollen is mostly unknown, but many species are known to forage from plants of more than one genus or family. An example of a species that appears to prefer a single plant family for both pollen and nectar is *O. lanei*, from the western U.S., which collects pollen from plants in the pea family, such as clover (*Trifolium longipes*) (Otto 2006). The plant families reported as pollen sources for mason bees include (Krombein et al. 1979, Sampson et al. 2009, Haider et al. 2014):

- Asteraceae (aster family)
- Berberidaceae (barberry family)
- Ebenaceae (ebony family)
- Ericaceae (heath family)
- Fabaceae (pea family)
- Fagaceae (oak family)
- Grossulariaceae (currant family)
- Rhamnaceae (buckthorn family)
- Rosaceae (rose family)
- Scrophulariaceae (figwort family)

Mason bees can also be limited by flower morphology, pollen chemistry, or nectar availability. For example, some mason bees, such as *O. ribifloris*, have morphological and behavioral adaptations that allow them to forage effectively on flowers of particular shapes (Haider et al. 2014). Mason bees appear to forage for nectar from a broader range of plants than they do for pollen (Parker 1984, Gordon 2003, Otto 2006, Haider et al. 2014).

Pollination.—Studies of mason bee pollination have largely focused on the bees' ability to pollinate cultivated plants. Mason bees are considered efficient pollinators because visits to flowers result in a great deal of contact between pollen carried on the bee and the flower's stigmas, which enhances the chance of successful pollination (Monzón et al. 2004, Jauker et al. 2012). In fact, a single visit by a mason bee to an apple (*Malus domesticus*) flower is sufficient for normal fruit development, and females may visit more than 22,000 flowers over the course of a 15-day flowering season (Vicens and Bosch 2000). Also, mason bees readily switch among rows of trees in an orchard, promoting pollination in self-incompatible fruit trees (Sedivy and Dorn 2014). Mason bees forage at lower temperatures and during more hours of the day than honey bees (Sedivy and Dorn 2014). Consequently, fewer mason bees than honey bees are needed to pollinate a given crop. Furthermore, mason bees can pollinate plants grown in greenhouses whereas honey bees cannot (Sedivy and Dorn 2014).

Mason bees readily visit flowers of many spring-flowering crops, especially species or cultivars from native plant genera used by these bees. Examples are trees such as almond, plum, cherry, prune, apple and pear, and shrubs such as blackberries and raspberries (*Rubus* spp.), all members of the rose family. They also pollinate blueberries (*Vaccinium* spp.; heath family). Studies of pollinators visiting blueberry, apple, and raspberry crops in Michigan, Virginia, and Maine have found 8-14 species of mason bees, about a half to two-thirds of the known species in each of these states (Stubbs et al. 1997, Tuell et al. 2009, Adamson 2011). Species managed for crop pollination include *O. aglaia, O. lignaria, O. ribifloris*, and *O. cornuta* (Sedivy and Dorn 2014). Management procedures may be developed for more species in the future (Bosch and Kemp 2002, Sampson et al. 2009).

Mason bees are undoubtedly important pollinators of wild native plant species as well, although specific bee-plant pollination relationships are not well documented. As with other groups of pollinators, mason bee species likely vary from generalist to specialist pollinators. On the specialist end of the spectrum, members of the subgenus *Nothosmia* appear to be largely dependent on pollen and nectar from native beard-tongues (*Penstemon* spp.; Crosswhite and Crosswhite 1966). The common crop-pollinating species such as *O. lignaria* are generalist pollinators, visiting a variety of plant species.

Conservation Status

The mason bees as a group are not known to be threatened with extinction. However, for the last third of a century scientists have become increasingly concerned about populations of native bees and other pollinators (Tepedino 1979, Kearns et al. 1998, Potts et al. 2010, Burkle et al. 2013). Habitat loss and degradation, pathogens, and pesticides have been cited as contributors to these declines. Most native bee populations are not monitored regularly, so declines in many species could go undetected.

To determine the conservation status of North American mason bees, NatureServe assessed all species according to its standard assessment methodology. This approach, which uses ten factors that consider rarity, threats, and population trends, is widely used in North America to assess species, subspecies, varieties, and populations for extinction risk (Master et al. 2012).

The NatureServe conservation status assessment system ranks species on a seven-point scale: GX denotes extinct; GH, known only from historical records and possibly extinct; G1, critically imperiled; G2, imperiled; G3, vulnerable; G4, apparently secure; and G5, secure. Uncertainty about the exact status of a species is usually denoted by a range rank, with the range indicating the degree of uncertainty (e.g., G3G4 when G3 and G4 are roughly equally likely). However a "?" may also be used to denote that the rank is imprecise and may in fact be higher or lower (e.g., G2? when G2 is most likely, but G1 and G3 are possibilities). Species for which insufficient data are available to assign a rank receive a GU (for 'Unrankable'). The ranks of species for which the taxonomic validity has been questioned by taxonomists have a "Q" appended (e.g., G3Q).

Osmia lignaria / Rollin Coville

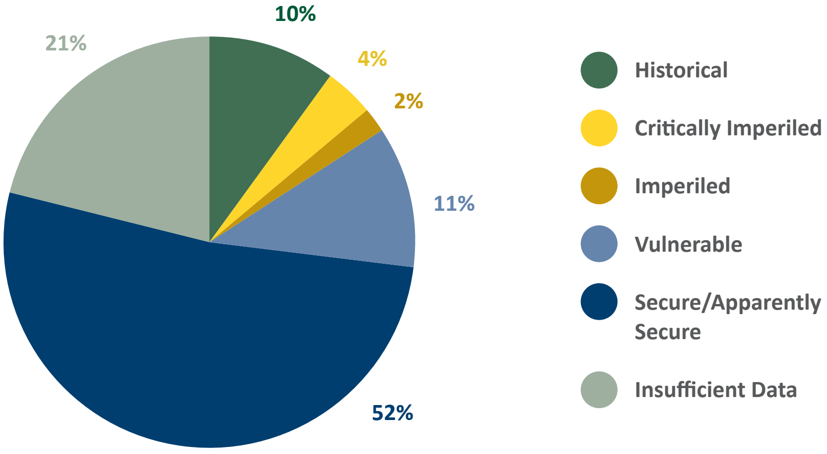

Figure 1. Proportion of the 139 native North American mason bee species that are at risk.

The conservation status of North American mason bees is summarized in Figure 1. Assessments for individual species are listed in the Appendix. Review of the conservation status information reveals six major conclusions:

1. Many mason bees are missing in action. A relatively large proportion of species, 10%, are known only from historical records and have not been recorded for at least several decades. Most are known from only a few scattered records or even just the type locality where the species was originally discovered (e.g., *O. ashmeadii, O. solitaria, O. tarsata, O. tokopahensis*). Ten of these species are from the western United States, one from Texas, one from the Great Lakes region, and two from maritime Canada. Some of these species may indeed be extinct whereas others may persist undetected in isolated areas or specialized habitats.

2. Many mason bees are at risk. Including the species only known historically, 27% of the North American mason bee fauna is at risk or missing (i.e., ranked GH, G1, G2, or G3). Besides the 10% of species that are historical, 11% are vulnerable and the remainder are imperiled or critically imperiled. An example of a critically imperiled species is *O. calaminthae*, which occurs in only four sites within a 40 km^2 area on the Lake Wales Ridge, Highlands County, Florida (Rightmyer et al. 2011).

3. More mason bees are at risk than most other North American insect groups. Mason bees have a higher percentage of at risk species than bumble bees (genus *Bombus*), the only other group of North American bees that has been comprehensively assessed for conservation status (Schweitzer et al. 2012). A higher percentage of mason bees are at risk than for numerous other insect groups that have been assessed, including butterflies, most moths, and dragonflies and damselflies (Figure 2).

4. No extinctions have been documented. There is not enough evidence at the present time to declare any species of North American mason bee extinct. However, mason bees are hard to census thoroughly enough to be confident that a particular species is extinct, especially those last seen long ago and for which little is known about their natural history.

5. More population and threat data are needed. One in five mason bee species is so poorly known that it is challenging to assign a rank other than GU. These species could be secure or critically imperiled – we simply do not know. Of the remainder, knowledge is still incomplete such that over two-thirds (69%) of the ranked species received either a range rank or a "?" rank. Much more work surveying for mason bees and enumerating the scope and severity of threats is clearly needed to better refine our knowledge

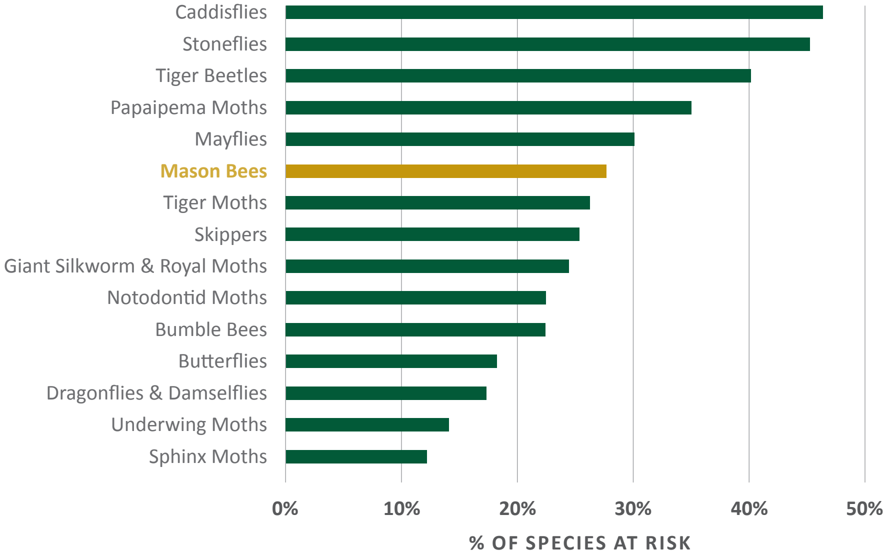

Figure 2. Comparison of mason bee threat status with that of other North American insect groups that have been comprehensively assessed. Vulnerable species are those with a conservation status rank of GX, GH, G1, G2, or G3. Source: NatureServe central databases, July 2015.

of the conservation status of North American mason bees. As more species are assessed, more threatened species may be identified.

6. Clarification of the taxonomic status of several species is needed. Although the last century has witnessed substantial clarification of mason bee taxonomy (Ungricht et al. 2008), four species (*Osmia novaescotiae, O. tarsata, O. exigua, O. granulosa*) were flagged as needing revision to verify whether they indeed represent distinct species. Considering the secretive nesting habits and restricted ranges of some species, additional mason bee species may yet be discovered in North American habitats. Undescribed species may have already been collected but await formal description by taxonomists.

Population trends.—Monitoring data are virtually nonexistent for most mason bees, but an indirect indication of their population trend can be discerned from the literature and records available online at Discover Life (www.discoverlife.org), where many professional entomologists, including those at the U.S. Department of Agriculture, Agriculture Research Service, Bee Biology and Systematics Laboratory, post collection records. Existing data are sufficient to estimate whether population trends are increasing, declining, or relatively stable for 66 native species of mason bees. Of these, the majority are stable (39 species), nine are possibly declining (although the evidence is not strong enough to rule out the possibility they are stable), and 17 are almost certainly declining. Only one species, *O. lignaria*, a common species used to pollinate crops, is thought to be increasing.

Unlike bumble bees, in which most declines are limited to species in two taxonomic subgenera, the trend data do not reveal an overall pattern to mason bee declines. One apparent trend, for example, is that the largely co-occurring *O. gabrielis* and *O. glauca* appear to be on different trajectories, with the former declining and the latter remaining stable, at least according to collection data. Because they both occur in California, collecting effort is likely to be roughly similar, pointing to real differences in trends. *O. bella* is another widespread species from western North America that is no longer recorded as frequently as in the past. The most dramatic decline is *O. illinoiensis*, which once ranged from North Dakota to Texas but has not been recorded anywhere in several decades.

Causes of Declines

Although a number of mason bees are in decline and possibly some are extinct, scientists have not identified any unusual threat acting on a group of species at a particular period of time. Rather, declines in mason bees have taken place over many decades and do not appear to have disproportionately affected any particular group of closely related species. More likely a range of factors, some working in concert with others in some situations, are contributing. Historic declines, particularly in western species, are mostly unexplained. A brief summary of the major potential causes of declines follows.

Habitat loss and degradation.—As with many native plant and animal species, habitat loss and degradation are likely important causes of mason bee declines. For example, the decline of *O. illinoensis* is likely attributable at least in part to the loss of native prairie habitat, a major ecosystem occurring across the historical range of the species. The two southeastern endemics *O. calaminthae* and *O. conjunctoides* have become very rare, presumably due to loss of habitat. Because individual bees range over relatively small areas and require generalized habitat features such as dead sticks or rocks and spring-blooming flowers, it is harder to attribute population declines to habitat loss. Bees could theoretically persist even in hedgerows between crops or suburban gardens. However, a study of other native bees indicated that crop pollination rates decrease substantially with agricultural intensification and pesticide use (Kremen et al. 2002).

Invasive alien plants are a widespread cause of habitat degradation in North America, and could potentially outcompete native plants that provide the nectar and pollen resources needed by mason bees. However, at least in eastern North America, some mason bees forage for nectar and perhaps pollen on non-native, spring blooming vetches and clovers (pea family). The effect of non-native plants, especially in prairies and Great Basin deserts where they are transforming ecosystems, on mason bees is unknown.

Bamboo Nest / Mace Vaughan, The Xerces Society

Diseases.—Little is known about the population-level effects of natural diseases on mason bees. Native insects, mites, and fungal pathogens are known to cause mortality in immature stages (Krombein et al. 1979). For example, the fungal pathogen *Ascosphaera torchioi* causes mummification of larvae in at least *O. lignaria* and *O. californica* (Youssef and McManus 2001). Diseases of honey bees and bumble bees have been cited as a threat to native wild pollinators (Fürst et al. 2014). In theory, moving mason bees outside their normal ranges or setting out non-local stock of native species risks the spread of pathogens that could negatively affect local native species. However, the impacts to native species from the few introduced mason bee species have not been well-investigated.

Pesticides.—Mason bees inhabiting agricultural areas are likely to come into contact with pesticides used for insect and weed control on crops. Because mason bees are active outside of nests only during the spring and early summer, they are unlikely to be directly affected by spraying that occurs at other times of the year. However, systemic pesticides sprayed at other times of year that become persistent in plants can still be transferred to bees via pollen or nectar. Negative impacts to bees from pesticides are a concern, although native bees were rarely used until recently to test the toxicity of pesticides. Besides direct mortality, behavioral impairment or reduced fecundity are important considerations with bees (Vaughan and Black 2007).

In addition, fungicide application in an orchard can temporarily disrupt mason bee foraging and nesting behavior (Ladurner et al. 2008). Sprays containing *Bacillus thuringiensis* (also known as *Bt* or *Btk*) are specific to gypsy moth or other spring caterpillars and are unlikely to impact mason bee adults or larvae.

Use of neonicotinoid pesticides is a growing area of concern because of their potential lethal and sublethal effects on honey bees, native pollinators, (Godfray et al. 2014, Rundlöf et al. 2015, van der Sluijs et al. 2015) and insects in general (van Lexmond et al. 2015). These pesticides are sprayed on raspberries and fruit trees where they can become systemic in plant tissues such as nectar and pollen. Mason bees encounter these pesticides when visiting flowers of treated crops. Dosages found in nectar and pollen are likely to cause neurological impairment affecting memory and such behaviors as foraging and navigation (Feltham et al. 2014), which in turn affects reproductive success (Kessler et al. 2015). In one study performed on mason bees, the neonicotinoids clothianidin and imidacloprid were highly toxic, whereas the non-neonicotinoids deltamethrin and spinosad were intermediate in toxicity, and novaluron was nontoxic in direct contact with *O. lignaria* (Scott-Dupree et al. 2009). When mixed with pollen, imidacloprid retarded larval development of the same species at intermediate and high doses, but clothianidin had no detectable effects (Abbott et al. 2008). This study did not evaluate neurological status of resulting adults. Due to their widespread use and subtle but significant effects on bees, neonicotinoid pesticides pose a threat to mason bees and have been recently shown to reduce or eliminate mason bee nesting under field conditions, possibly due to impaired navigation (Rundlöf et al. 2015, van der Sluijs et al. 2015). Solitary bees were found to be more affected than social species.

Climate change.—Climate change will undoubtedly affect some species. An increase in warm weather late in the year or during the winter, after adults develop, can increase pre-winter fat depletion and decrease fitness in spring (Bosch et al. 2000). This effect could be compensated for by longer pre-pupal aestivation—an adaptation already present in southern populations of many species—but the extent to which mason bees have this plasticity in developmental control is unknown. Some distributions are likely to shift as the insects track their favored climates, but the net effects will likely vary by species depending on factors such as how rapidly climates change and the availability of nesting habitat and flowers for foraging in novel, climate-compatible areas. An increase in prolonged droughts in western states will probably be detrimental to many species, although a major unknown is the extent, if any, to which they can remain in diapause through dry years.

Intrinsic vulnerability.—Mason bees have three factors that cause intrinsic vulnerability and therefore hinder their ability to recover from population declines. First, female mason bees lay relatively few eggs (less than 30 in a lifetime; Tepedino 1979, Mader et al. 2010). Second, they reproduce only once per year. These two characteristics limit their potential rate of population increase in the event of a catastrophic decline (e.g. caused by a severe weather event or biocide application; Tepedino and Boyce 1979). Furthermore, many mason bees have naturally small ranges that cause them to be vulnerable to localized threats such as severe weather.

Conservation and Management

Little research has been devoted to promoting mason bee diversity and populations in natural systems. Most available management advice focuses instead on maintaining common mason bee species as pollinators in gardens or commercial farms. The following discussion, drawing from the available literature on management and natural history, highlights some considerations for promoting the conservation and management of a diversity of native mason bees. Like other bees, the broad habitat needs for mason bees are for nesting and for foraging to obtain nectar and pollen.

Habitat needs for nesting.—Due to the variety of microhabitats where mason bees nest, habitat mosaics that include dead stems and fallen logs, embankments, sandy areas, and rocky areas may best promote diverse communities of these insects. Some species also require mud and leaf material for nest construction, although the specificity of the types of plants needed is not well understood.

Mason bees spend most of the year in their nests and thus protection from disturbance is important. Because many mason bees nest in dead plant materials, fire and mowing of brush should be avoided to prevent mortality of larval, pupal, and dormant life stages. If nesting habitats are known, disturbance to them should be minimized to the extent practical. For species nesting in dead plant stems a mower that simply cuts and drops the stems will cause less mortality than one that grinds and chops, especially after winter when many stems may have fallen naturally. In fire-adapted ecosystems, rotate burned areas to ensure availability of dead stems and wood for nesting.

Mason bee house / Matthew Shepherd, The Xerces Society

The use of artificial nest sites can benefit multiple species, especially those important in crop pollination. This strategy entails setting out blocks of wood with drilled holes, into each of which is inserted a piece of reed, bamboo, paper, or plastic tubing. Several tubes are placed in each block and these are usually stacked in a shelter to provide protection from weather and predators (e.g. ants, birds and rodents). Blocks should be aboveground and oriented to the morning sun (Mader et al. 2010, Sedivy and Dorn 2014, Vaughan et al. 2015).

Habitat needs for foraging.—Because most mason bees forage only in the spring and early summer, the options for the kinds of plants that can be used to provide foraging habitat are limited to those that bloom during that period. Maintaining abundant and diverse spring-blooming wild flowers, especially those in the families listed above under *Foraging and nutrition*, will help fulfill the nutritional needs of a diverse mason bee assemblage. Blueberries and spring flowering plants in the rose and pea families seem to be the most commonly used by mason bees.

Pesticide avoidance.—Due to toxic effects, pesticides, except those such as *Bt* that are proven to be harmless to mason bees, should not be sprayed in the spring when bees are foraging. Systemic pesticides should be avoided year-around due to their uptake in pollen and nectar that can be detrimental when consumed by mason bees.

Mason bee closing nest / Mace Vaughan, The Xerces Society

Disease prevention.—The introduction of non-native pathogens through the movement of mason bees is a major potential threat to native species. The "spillover" of pathogens (including parasites) acquired by native bumble bees that had been reared in Europe apparently caused severe declines in several species of bumble bee (Meeus et al. 2011). This example underlines the importance of strict quarantine measures before introducing managed mason bees to regions where they are not native or even of native species that were reared outside their normal ranges.

Research Needs.—Research will continue to be an important component of native bee conservation programs. Urgent research needs for mason bees include:

- Field inventory to clarify the status of missing species and to better document the distributions of less rare species
- Compilation of existing locality information to generate range maps that would allow for analysis of patterns of species richness as well as to identify concentrations of threatened and data deficient species.
- Population-level monitoring to provide more direct evidence of population trends.
- Natural history study to identify the nesting substrate for over half of the North American species, and to better understand nectar and pollen sources, especially for species of conservation concern.

Notes about Monitoring

More data from monitoring studies is clearly needed to better understand the status of mason bees in North America. Monitoring these insects, however, is challenging for several reasons. First, species-level identification of mason bees requires the assistance of a specialist. Second, because of the varied natural history of mason bees, no single method of monitoring is adequate to sample all species (Westphal et al. 2008). Transects (walking along a set line collecting bees that are encountered), pan traps (small plastic cups painted with UV-bright paint and filled with water and a drop of detergent), and nest traps (clusters of hollow reeds or wood blocks with drilled cavities) may all be necessary to record most of the species occurring at a site (Frankie et al. 1998, Westphal et al. 2008). Third, high variability in numbers of bees recorded in a sampling period can limit the ability to statistically detect a population trend (Lebuhn et al. 2012). Fourth, not knowing whether bees remain in diapause during unfavorable years complicates interpretation of population fluctuations.

Monitoring efforts may therefore require limiting objectives to be successful and sustainable. Although use of multiple sampling techniques would be most helpful to search for missing species, restricting a project to a single method may be more realistic to monitor trends in a reduced number of species that are detectable by the same method. The number of mason bee species that are possible to record in a site are somewhat limited—perhaps a dozen species in eastern U.S. states to up to three dozen or slightly more species in the west, with fewer species in Canada and in the lowlands of southeastern states—enabling researchers, with the help of a specialist, to rapidly learn to identify distinctive species and the characteristics of specimens that should be referred to the specialist to confirm identification. Replicating sampling schemes as much as possible will help increase the detectability of population trends (Lebuhn et al. 2012).

Osmia sp. / Rollin Coville

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Resources

Discover Life.—A useful resource for bee identification and information on the distribution of mason bees and other insects. (http://www.discoverlife.org/)

Farming for Bees.—Helpful guidelines for providing native bee habitat on farms. (http://www.xerces.org/wp-content/uploads/2008/11/farming_for_bees_guidelines_xerces_society.pdf)

Substrates and Materials Used for Nesting by North American Osmia *Bees*.—A compilation of the known nesting habits of North American mason bees. (Cane et al. 2007)

U.S. Department of Agriculture Agricultural Research Service.—Good information on the science of pollination. (http://www.ars.usda.gov/main/site_main.htm?modecode=20-80-05-00)

Catalog of Hymenoptera in America north of Mexico.—Although somewhat dated, this compendium provides valuable records of flower visitation by mason bees. (Krombein et al. 1979)

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Appendix: Conservation Status of North American Mason Bees

Species-level taxonomy follows ITIS (2008). Subgeneric status from Rightmyer et al. (2013) and Ascher and Pickering (2014). See the Conservation Status section, above, for a description of the NatureServe conservation ranking system.

Scientific Name	NatureServe Conservation Rank	Range
Subgenus *Cephalosmia*		
Osmia californica	G4G5	Western North America, east to South Dakota
Osmia grinnelli	G4?	Western U.S., south to Baja California
Osmia marginipennis	G4?	Western U.S., south to Baja California
Osmia montana	G4?	Western North America, plus Kansas and Texas
Osmia subaustralis	G4G5	Western North America, plus Ontario, Quebec and Michigan
Subgenus *Diceratosmia*		
Osmia conjuncta	G4	Eastern North America, plus California
Osmia conjunctoides	GU	Southeastern U.S.
Osmia botitena	GH	South central Texas to northeastern Mexico
Osmia subfasciata	G4G5	Eastern and southwestern U.S., northeastern Mexico
Subgenus *Euthosmia*		
Osmia glauca	G4	Western U.S.
Subgenus *Hapsidosmia*		
Osmia iridis	G3G4	Western U.S, plus British Columbia
Subgenus *Helicosmia*		
Osmia caerulescens	G5	Eurasia; introduced in Canada, the U.S., and New Zealand
Osmia chalybea	G4	Eastern North America
Osmia coloradensis	G5	Widespread in North America
Osmia georgica	G4G5	Eastern North America
Osmia texana	G4G5	Widespread in North America
Subgenus *Melanosmia*		
Osmia aglaia	G4	Oregon and California
Osmia albiventris	G3G5	Eastern North America
Osmia albolateralis	G4G5	Widespread in North America
Osmia alpestris	G3G4	Nevada and Utah
Osmia aquilonaria	G4G5	Northern North America, primarily Canada
Osmia ashmeadii	GH	Oregon
Osmia atriventris	G4G5	Northern and eastern North America
Osmia atrocyanea	G4?	Western North America
Osmia austromaritima	G2G4	Western North America
Osmia bella	GU	Western North America
Osmia brevis	G5	Western North America, east to Nebraska
Osmia bruneri	GU	Western North America, east to Nebraska
Osmia bucephala	G5	Widespread in North America, absent in southern plains

Scientific Name	NatureServe Conservation Rank	Range
Osmia cahuilla	GU	Western U.S.
Osmia calaminthae	G1	Florida
Osmia calcarata	GH	California and Colorado
Osmia calla	G4G5	Western North America
Osmia cara	G4?	Western North America
Osmia caulicola	GU	Colorado, Utah, Wyoming and Idaho
Osmia cerasi	G3G4	Wyoming and Utah south to Texas and Sonora, Mexico
Osmia clarescens	G4?	Western U.S. to Baja California
Osmia cobaltina	G4?	Western U.S.; absent from Great Basin
Osmia collinsiae	G4G5	Eastern North America
Osmia cordata	G3G4	Central and eastern U.S., and Baja California
Osmia crassa	G4G5	Southwestern U.S.
Osmia cyanella	G4G5	Western U.S east to South Dakota
Osmia cyaneonitens	G3G4	South Dakota to Nevada
Osmia cyanopoda	G3G5	Western U.S.
Osmia dakotensis	G4?	Western U.S. and Baja California
Osmia densa	G4G5	Western North America
Osmia distincta	G4G5	Central and eastern North America
Osmia dolerosa	G3G5	Western North America, east to South Dakota and north to Alaska
Osmia ednae	G3G5	Western U.S.
Osmia enixa	G1G3	California
Osmia exigua	GUQ	Western U.S., east to Nebraska
Osmia felti	G2G4	Upper midwest and northeastern North America
Osmia foxi	GU	Arizona, New Mexico, and northwestern Mexico
Osmia gabrielis	GU	Western U.S., south to Baja California
Osmia gaudiosa	G4G5	Central and western U.S, south to Baja California
Osmia giffardi	G2G4	Southwestern United States
Osmia giliarum	GU	Western North America
Osmia granulosa	GUQ	Western U.S., plus North Carolina (where possibly introduced)
Osmia grindeliae	G3G5	Western North America
Osmia hemera	G2G4	California
Osmia hendersoni	GU	Western North America
Osmia hesperos	GU	Oregon and California
Osmia illinoensis	GH	Central U.S.
Osmia inermis	G5	North America and Eurasia
Osmia inspergens	G3G5	Central and eastern North America, plus Alberta
Osmia integra	G5	Central and western North America, plus Maine
Osmia inurbana	G4?	Western North America
Osmia juxta	GU	Western North America

Scientific Name	NatureServe Conservation Rank	Range
Osmia kenoyeri	GU	Widespread in North America
Osmia kincaidii	G4?	Western North America, plus South Dakota
Osmia lacus	G1?	California and Oregon
Osmia laeta	G4?	Western U.S. south to Baja California
Osmia lanei	GU	Washington, Oregon, California
Osmia laticeps	G5	North America and Eurasia
Osmia liogastra	G4?	Southwestern U.S to Sonora, Mexico
Osmia longula	G4?	Western North America
Osmia lupinicola	GU	California to Baja California
Osmia malina	GU	Western North America
Osmia marginata	G4?	Southwestern U.S.
Osmia maritima	G5?	North America and Eurasia
Osmia melanopleura	G4	Western U.S.
Osmia mertensiae	GU	Colorado, Utah, and California
Osmia michiganensis	G2G4	Great Lakes
Osmia mixta	G1G3	California
Osmia morongana	G1?	California
Osmia nanula	GU	Western North America, east to South Dakota
Osmia nearctica	G4G5	Canada and Washington
Osmia nemoris	G4G5	Western North America
Osmia neocyanopoda	GH	California and Baja California
Osmia nifoata	G4?	Western North America
Osmia nigrifrons	G4?	Western North America, east to the Dakotas
Osmia nigriventris	G5	North America and Eurasia
Osmia nigrobarbata	GU	Western North America
Osmia novaescotiae	GHQ	Nova Scotia
Osmia obliqua	GU	Western North America
Osmia odontogaster	G2G3	Western North America
Osmia pagosa	GH	Western U.S.
Osmia palmula	G2G4	Southwestern U.S. to Sonora, Mexico
Osmia paradisica	G4G5	Western U.S. east to South Dakota
Osmia pentstemonis	G4G5	Western North America
Osmia phenax	G4G5	Southwestern U.S. and Baja California
Osmia pikei	G4?	Western North America
Osmia pingreeana	GU	Colorado
Osmia pinorum	GU	California
Osmia potentillae	G1?	California
Osmia proxima	G4G5	Widespread in North America, except for the central regions
Osmia prunorum	G3G4	Southwestern U.S. to Sonora, Mexico

Scientific Name	NatureServe Conservation Rank	Range
Osmia pulsatillae	GU	Western North America
Osmia pumila	G5	Central and eastern North America
Osmia pusilla	G4G5	Western North America, plus South Dakota
Osmia raritatis	G4?	Western U.S. to Baja California
Osmia rawlinsi	G4?	Western U.S.
Osmia regulina	G2G4	Western North America
Osmia rostrata	G1?	California
Osmia sanctaerosae	GU	California and Utah
Osmia sandhouseae	G4G5	Primarily southeastern U.S., with scattered records elsewhere
Osmia sanrafaelae	G3G4	Western U.S.
Osmia sculleni	G4?	Western North America, plus Manitoba and Minnesota
Osmia sedula	GU	Western North America
Osmia sequoiae	GH	California
Osmia simillima	G5	Widespread in North America, except Texas and the southeast
Osmia solitaria	GH	California
Osmia tanneri	G3G5	Western U.S., plus Yukon
Osmia tarsata	GHQ	Quebec
Osmia tersula	G5	Northern and western North America
Osmia thysanisca	GH	Western U.S.
Osmia tokopahensis	GH	California
Osmia trevoris	G5	Western North America, east to South Dakota
Osmia trifoliama	GH	Pacific Northwest (U.S.)
Osmia tristella	GU	Western North America, east to South Dakota
Osmia unca	G4G5	Western North America
Osmia vandykei	G2G4	Western U.S to Baja California
Osmia virga	G3G5	Northeastern U.S.
Osmia watsoni	G2G4	Southwestern U.S.
Osmia wyomingensis	GU	Wyoming
Osmia zephyros	GU	California and Wyoming
Subgenus *Osmia*		
Osmia cornifrons	G5	Asia; introduced in eastern U.S., Utah and Oregon
Osmia lignaria	G5	Widespread in North America
Osmia ribifloris	G4G5	Western U.S. to Texas and Mexico
Osmia taurus	G5	Asia; introduced in eastern North America
Subgenus *Trichinosmia*		
Osmia latisulcata	G3G5	Southwestern U.S.
Subgenus *uncertain*		
Osmia angustipes	GH	Colorado

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