Farming for Native Bees:

A Guide for Producers and Agricultural Professionals

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Contents:

Introduction:

Over the past 10 years, pollinator decline has emerged as a critical threat to long-term agricultural sustainability. Recent reports of declines in honeybees and wild bees across the globe are urging nations into action. New research and extension projects have made headway in developing and disseminating technologies that serve to attract and sustain wild bee pollinators as a crucial supplement, and perhaps eventually, as an alternative to honeybee crop pollination services. Installation of pollinator habitat is key among these, and various manuals and programs have been created that offer instruction on how to construct these habitats.

Considering the urgent nature of pollinator decline, particularly in the light of climate change, these manuals and programs are an important first step towards raising awareness and encouraging action to sustain pollinators and the crops that depend on them. However jumping into farming for pollinators can be a daunting experience, even with a plethora of resources and recommendations available. By providing science-based information on the processes of planning and implementing habitat, this toolkit serves an introductory resource for agricultural professionals.

This toolkit will help producers and other agricultural professionals:

1. Understand the importance of honey bee and native bee pollination to agriculture
2. Be aware of the threats facing these pollinators
3. Know of other farmers who have successfully implemented native bee habitat on their farms
4. Have better knowledge of bee plant relationships and how these can be used in habitat planning to better plan habitats for specific pollination needs
5. Be able to start a farm evaluation or know who to contact for help beginning one
6. Recognize native bee habitat will be adapted for different farm operations and pollination needs
7. Compile a list of additional resources to help in planning, implementation, and monitoring.

For a more comprehensive introduction to native bee farming, It is recommended that this toolkit be used in conjunction with the *Farming for Native Bees Video Series.* Furthermore, references in the Resource section provide even more additional in-depth information on specific recommendations for all stages of planning, implementing, and monitoring pollinator habitat.

Like all media resources, this guide will not replace the need for one-on-one interactions between conservation professionals and producers. Person-to-person interactions serve a vital function in implementing native bee habitat particularly in providing operation-specific technical assistance. This guide is intended to inspire producers to take steps toward implementing native bee habitat, which includes reaching out to agencies and agricultural professionals; help professionals and agency staff to support producers in implementation; and/or to be used as a planning tool during these interactions.

Hopefully, with broad distribution and continued refinement, the recommendations presented in this toolkit will significantly reinforce California's growing sustainable agriculture movement, particularly as it relates to integrating wildlife habitat management into the agricultural working lands matrix. Individual farmers and California agriculture as a whole have much to gain from this movement, from increased crop production and long-term crop security, to decreased costs related to crop pollination. Increased native bee habitat also promises to provide important refuges for dwindling native bee populations, particularly as they continue to suffer ongoing habitat loss.

Chapter 1: Importance of Bees to Agriculture

Everybody has heard about the drastic decline of honey bees – in recent years, it has been making headlines across the United States and Europe. According to the Congressional Research Service Report on bee health, "the value of insect pollination to U.S. agricultural production is estimated at $16 billion annually, of which about three-fourths is attributable to honey bees" (April 2014). Over 100 U.S. crops are bee-pollinated, representing two-thirds of food consumed (Allen-Wardell et al. 1998, NRC 2007). As such, our nation's economic stability and food security depend on healthy and accessible populations of bees.

California's almond economy provides a vivid example of the high economic stakes involved in crop pollination. California supplies almost 100% of the country's almonds and over 80% worldwide, with an annual crop value of over $4 billion dollars (California Almond Board). Almond flowers have a self-incompatible breeding system, requiring outcrossing between flowers of cross-compatible cultivars. In other words, they depend absolutely on bees for their reproduction. Approximately 1 million hives, nearly 60% of all managed colonies in the US, are transported to the Central Valley for almond pollination. While commercial beekeepers have managed to adapt to these changes thus far, ongoing declines may soon begin to impact production costs and threaten farmers with crop loss (SARE Handbook 11).

The causes behind honey bee decline are still poorly understood. Research points to stress factors like mechanized management, chemical treatments for Varroa mites, and a lack of diversity in their diets, which weakens honey bees' immune systems and makes them susceptible to pathogens, especially viruses. Since the outbreak of Colony Collapse Disorder a decade ago, honey bee populations have seen an average over winter hive loss of 30% per year. According to a preliminary analysis conducted by Bee Informed, this percentage has jumped in 2015 and 2016 to over 40%.

Bee Crop Pollination Services

- Annual Values:
  - Global: $217 billion
  - U.S.: $20 billion
  - CA: Over $4 billion
- Over 100 crops grown in the U.S. and Canada depend or benefit from the services of a bee pollinator. Includes: almonds, watermelon, cherries, and avocados.

Honey Bee Declines

- Since 1945, the number of managed hives in the U.S. has decreased from 5 million to 2.66 million.
- Colony Loss Data (Bee Informed 2016)
  Acceptable Winter Loss: 15-18%
  Winter Loss 2006-2016: 25-35%
  Annual Loss 2011-2016: 36-46%

The honey bee crisis has lead to a surge in honey bee health research, with new programs and initiatives dedicating entire funding streams towards curbing honey bee mortality factors (Pollinator Research Action Plan 2015). Extensive studies are underway at institutions across the nation to tackle the plight of the honey bee. These studies, however, do not address the underlying issue of dependence on one or two species for the majority of the nation's crop pollination needs.

The next chapter (section?) introduces alternative bee pollinators and their largely untapped potential to contribute to existing crop pollination systems.

Chapter 2: Native Bees & Agriculture

Honey bee declines have sparked new interest using in wild bees as a potential supplement or alternative to honey bee pollination services. The National Research Council (2007) points out the need for more native bee research and application, and the most recent Farm Bill (2014) reauthorized and expanded provisions in the 2008 Farm Bill for "the development of habitat for native and managed pollinators." Several species of wild bees have been extensively researched for their contributions to crop pollination, and many recommendations have been offered for their partial domestication and management. The USDA bee lab in Logan, Utah, the USDA-ARS lab in Beltsville, MD, and others have had notable success with select species, such as *Megachile rotundata*, *Osmia lignaria*, and *Nomia melanderi*, which are now actively managed for certain crops (Bosch et al. 2006; Johansen et al. 1978; Wichelns et al. 1992; Bosch and Blas 1994; Vicens and Bosch 2000; Maccagnani et al. 2003; Cane 2008).

Research is demonstrating that many native species are actually more effective pollinators than honey bees. When wild bees are diverse and abundant, they enhance the pollination efficiency of honey bees, provide services that honey bees are not adequately delivering, improve productivity of self-fertilizing crops that are not typically managed for pollination, and can even substitute managed honey bees (Garibaldi et al. 2013). **In fact, researchers estimate that 35-39% of the pollination services required by California crops, equivalent to $2 billion annually, are already provided by native bees visiting from nearby wild areas (Chaplin-Kramer, et al 2011).**

Why, then, isn't the use of native bees as crop pollinators widespread in California agriculture. The first reason may simply be that farmers have been using honey bees for decades, have long-standing relationships with beekeepers, and have structures and systems in place to manage crop pollination. Since native bees differ substantially from honey bees in their life cycles and habits, managing for them requires adopting new practices and systems, many of which are still being developed.

For example, while honey bees may not be the most efficient pollinators, they are *generalists*, which means they will visit just about any flower that offers nectar and/or pollen rewards. Native bees range widely in shape, size and structure – many are literally built to collect resources from specific flower types. Honey bees are also on the wing year round, while many native bee species have shorter life cycles, and are only present during certain months of the year.

Another important difference is that honey bees are *social* and live in hives that can easily be transported, while most native bees are *solitary*, building individual nests in the ground or in cavities, such as holes in trees, fence posts, and pithy stems. Transported from one crop/farm/state to the next, honey bees can get their pollen and nectar needs met throughout the year (although scientists are now finding that this kind of "crop-hopping" puts tremendous stress on honey bee colonies, and may be contributing to their decline).

Native bees, on the other hand, must be supplied with enough floral resources to sustain them throughout their lifecycle (Frankie et al 2014), which is often longer than the flowering period of any one particular crop. Hedgerows and wild flower mixes have been offered as one solution to this management issue. But more work needs to be done to determine how effective these habitats are, and whether they can bring in the right kinds of bees in large enough quantities to supplement or replace honey bee pollinators.

It can be hard to change one's approach and try something totally new when the current system seems to be working. For many farms, honey bee decline hasn't reached the point yet where it feels like a threat. Some researchers have called native bees a good "insurance policy" against honey bee decline, and it makes sense to plan ahead before a crisis hits so that new systems can be comfortably integrated and adapted. Research has also found that native bee pollination actually improves quality of product.

<u>Native Bee Basics</u>

- There are 4,000 bee species in the U.S. and Canada
- 1,600 of those species are native to California!
- 70% of native bees are solitary nesters (they do not live in a hive with a queen)
- 70% of native bees are ground nesters; 20% are cavity nesters; 10% of kleptoparasites
- Native bees pollination is valued at an estimated $2 billion a year in California alone!
- Native bees can be more efficient crop pollinators (e.g. 250 female Blue Orchard Bees can pollinate at the same rate as 30-60,000 honey bees)
- The presence of native bees can improve the efficiency of honey bee pollinators.

Chapter 3: Farming for Native Bees

In partnership with NRCS and WSARE, the UC Berkeley Urban Bee Lab has been addressing knowledge gaps related to bee habitats on small farms in California through *Farming for Native Bees.* Since 2009, the project has conducted extensive research on bee-flower relationships (Frankie et al. 2005, 2009a,b, 2014) to create high-quality native bee habitats that synchronize with specific crops and provide measurable increases in target native bee crop pollinators. Close collaborations between farmers, researchers and extension specialists have resulted in habitat designs that are based on sound biological information, and can be adapted to the unique needs of individual farm operations.

The overarching goals of *Farming for Native Bees* are to:

1. Provide a stable, cost-effective and sustainable supplement to honey bee pollination
2. Establish new habitats that will conserve and protect California's native bees
3. Partner with farmers to educate Californians about native bees and their critical importance agriculture

The project has produced exciting results: over 130 species have been recorded on habitat plants – a much higher number than have been found in similar agricultural projects to date – and key native bee pollinators have been recorded regularly visiting crop flowers (including *Bombus vosnesenskii, Bombus melanopygus, Xylocopa varipuncta, Ceratina* species, halictid spp., *Andrena* spp., and several *Osmia* spp.). With 6 years of data on local diversity and abundance of wild bee populations, the project is well on its way to shedding light on long-term local population trends – including the impacts of drought and climate change – that will shape strategies for native bee farming in the future.

Several of the *Farming* partners in Brentwood, Contra Costa Co., California are profiled in the following sections. To hear more about each farmer and their unique stories, watch the *Farming for Native Bees Modules Series: Module 3.* Information on other native bee farming projects can be found in the Resources section.

Case Study: Dwelley Farms

Patrick Johnston
Farmer/Managing Partner

"Farming is one of those business that there are a lot of unknowns…You don't know when it's going to come, so by being as well equipped as possible it allows you to sleep at night a little bit better."

***Crops Grown*:**

Row Crops:	Orchard Crops:
Eggplant	Apples
Green Beans	Apricots
Onions	Cherries
Peppers	Nectarines
Squash	Peaches
Sweet Corn	Pluots
Tomatoes	

Organic/Conventional: Both

Year Started Native Bee Farming: 2011

Habitat Design: Perennial habitat gardens & seeded annuals

Acres of Habitat Installed:

- 1 acre of habitat gardens; ~400 individual plants
- 2 acres of annual wildflowers; 5 different varieties

No. Bee Species at Start: 28

No. Bee Species as of 2016: 74

Case Study: Enos Family Farms

Ron Enos
Farmer/Owner

"The entire program that we started with, the hedgerows and the seed planting, over the last 5 years we've seen a big increase in the native pollinators that have shown up out here."

Crops Grown:

Row Crops:

Beans (multiple varieties)	Melons
Broccoli	Squash
Corn	Strawberries
Winter greens	Tomatoes

Orchard Crops:

Apricots

Organic/Conventional: Organic

Year Started Native Bee Farming: 2011

Habitat Design: Perennial habitat gardens & seeded annuals

Acres of Habitat Installed:

- 1 acre of habitat gardens; ~400 individual plants
- 1.5 acres of annual wildflowers; 5 different varieties

No. Bee Species at Start: 13

No. Bee Species as of 2016: 48

Case Study: Frog Hollow Farm

"Farmer Al" Courchesne
Farmer/Owner

"I think it is very cool to be enhancing nature, to be learning about nature and learning how nature helps us grow food."

Crops Grown:

Orchard Crops:

Apples	Olives
Apricots	Oranges
Asian Pears	Peaches
Cherries	Pears
Kumquats	Persimmons
Meyer lemons	Plums
Nectarines	Pluots

Organic/Conventional: Organic

Habitat Design: Perennial habitat gardens & seeded annuals

Year Started Native Bee Farming: 2010

Habitat Design: Perennial habitat gardens & seeded annuals

Acres of Habitat Installed:

- 1 acre of habitat gardens; ~400 individual plants
- 20 acres of annual wildflowers; 6 different varieties & pollinator mix

No. Bee Species at Start: 12

No. Bee Species as of 2016: 47

Chapter 4: Farm Evaluation & Habitat Prescription

Beginning the process of installing native bee habitat can seem daunting. Some producers may not know what opportunities are available for their operations or, on the contrary, may be overwhelmed by the amount of information and recommendations available. So how should one get started?

A good place to start is by identifying goals and objectives. Why add native bee habitat to an operation? Is the goal to enhance general on-farm pollinator populations? , or to increase pollinators for a specific crop(s)? Is a goal to provide habitat for other beneficial insects? For other wildlife? The goals will guide implementation and management so it is important to consider them from the outset. Goals can change over time, and habitat plans and management can be adapted as operation evolve.

Once a set of goals and objectives have been outlined, the next step is to contact a local USDA-NRCS Conservationist and UC Cooperative Extension Farm Advisor. They are excellent resources who can provide producers and agricultural professionals with information on both financial and technical support to plan and implement pollinator plantings on farms.

Producers should then evaluate their operations and the resources they will dedicate to installing native bee habitat. The following sections, outlined below, will give a breakdown of the different factors that will need to be considered to conduct a comprehensive evaluation.

USDA United States Department of Agriculture

Natural Resources Conservation Service

5 Steps to Assistance

How to Get Assistance from NRCS for Farms, Ranches and Forests

1 PLANNING: Visit your local NRCS field office to discuss your goals and work with staff on a conservation plan.

2 APPLICATION: With the help of NRCS, complete an application for financial assistance programs.

3 ELIGIBILITY: Find out if you're eligible for NRCS' variety of financial assistance programs.

4 RANKING: NRCS ranks applications according to local resource concerns.

5 IMPLEMENTING: Put conservation to work by signing a contract and implementing conservation practices.

Get Started with NRCS

Do you farm or ranch and want to make improvements to the land that you own or lease?

Natural Resources Conservation Service offers technical and financial assistance to help farmers, ranchers and forest landowners.

1 Planning **To get started with NRCS, we recommend you stop by your local NRCS field office. We'll discuss your vision for your land.**

NRCS provides landowners with free technical assistance, or advice, for their land. Common technical assistance includes: resource assessment, practice design and resource monitoring. Your conservation planner will help you determine if financial assistance is right for you.

2 Application **We'll walk you through the application process. To get started on applying for financial assistance, we'll work with you:**

- To fill out an AD 1026, which ensures a conservation plan is in place before lands with highly erodible soils are farmed. It also ensures that identified wetland areas are protected.
- To meet other eligibility certifications.

Once complete, we'll work with you on the application, or CPA 1200.

Applications for most programs are accepted on a continuous basis, but they're considered for funding in different ranking periods. Be sure to ask your local NRCS district conservationist about the deadline for the ranking period to ensure you turn in your application in time.

USDA is an equal opportunity provider and employer.

3 Eligibility **As part of the application process, we'll check to see if you are eligible. To do this, you'll need to bring:**

- An official tax ID (Social Security number or an employer ID)
- A property deed or lease agreement to show you have control of the property; and
- A farm tract number.

If you don't have a farm tract number, you can get one from USDA's Farm Service Agency. Typically, the local FSA office is located in the same building as the local NRCS office. You only need a farm tract number if you're interested in financial assistance.

4 Ranking **NRCS will take a look at the applications and rank them** according to local resource concerns, the amount of conservation benefits the work will provide and the needs of applicants.

5 Implementing **If you're selected, you can choose whether to sign the contract for the work to be done.**

Once you sign the contract, you'll be provided standards and specifications for completing the practice or practices, and then you will have a specified amount of time to implement. Once the work is implemented and inspected, you'll be paid the rate of compensation for the work if it meets NRCS standards and specifications.

To find out more, go to: **www.nrcs.usda.gov/GetStarted**

Farm Evaluation Outline:

1. ***Farm Operation Characteristics:*** Identify crops that depend on, or are enhanced by, bee pollination and evaluate existing on-farm conditions and surrounding land use. The crops will determine what bee groups should be targeted in habitat planning.
2. ***Target Bee Species:*** Identify the bee species or group of species known to provide the best pollination services for your crops.
3. ***Host Species*****:** Select combinations of host plants that will draw and sustain the best native bee pollinators for specific crop types. This section will consider crop and host plant flowering periods, as well as potential habitat requirements and constraints, such as irrigation.
4. ***Habitat Sites*****:** Identify potential habitat sites, such as hedgerows, spaces between crop rows and road margins, as well as opportunities for future sites as crops rotate, suffer mortality or as farm operations change.
5. ***Habitat Installation:*** Prepare for installation, including ground preparation, habitat design, and plant preparation.
6. ***Irrigation*****:** Evaluate **i**rrigation requirements and opportunities for shared irrigation with crops
7. ***Adaptive Management*****:** Plan ongoing management, such as rodent control, weeding, irrigation, among others.
8. ***Nesting Habitat:*** Identify nesting requirements of target bee species and what can be done to enhance nesting habitat.
9. ***Chemical Management*****:** Evaluate existing chemical applications, how these may impact native bees, and potential modifications that protect habitats.
10. ***Estimated Costs*****:** Estimate costs for installing native bee habitat including expenses for plants, seeds, and irrigation.

1. Farm Operation Characteristics

The first step in planning a habitat is identifying which crops need or benefit from the services of bee pollinators. Many crops, even self-pollinating ones, can greatly benefit from the presence of insect pollinators. The following table ranks common crops by their level of dependence on flower visitors, primarily bees, for production. The ranking is given according to production reduction rates without the presence of flower visitors. In other words, a crop with an Essential rating suffers a 90% or more reduction in production when there are no flower visitors to assist with pollination and a Little rating suffers less than 10% reduction.

Essential (90% or more reduction)	High (40-90% reduction)	Modest (10-40% reduction)	Little (<10% reduction)
Gourd	Apples	Beans: Broad, Fava, Field, Jack, Horse, Sword	Citrus
Marrow	Apricots	Eggplant	Beans: Black-eyed, Kidney, Haricot, Lima, Adzuki, Mungo, String, Congo
Melons	Avocados	Okra	Hog Plums
Pumpkins	Blueberries	Pomegranates	Peppers
Rowanberry	Cherries	Prickly pear	Persimmons
Squash	Cranberries	Soy bean	Tomatoes
Watermelon	Cucumbers	Strawberries	
Zucchini	Loquats	Tree strawberry	
	Nectarines/Peaches		
	Pears		
	Plums		
	Berries: Raspberry, Blackberry, Dewberry		
	Turnips		

Information from Klein et al. *Importance of pollinators in changing landscapes for world crops.* Proc. R. Soc. B 2007 274 303-313

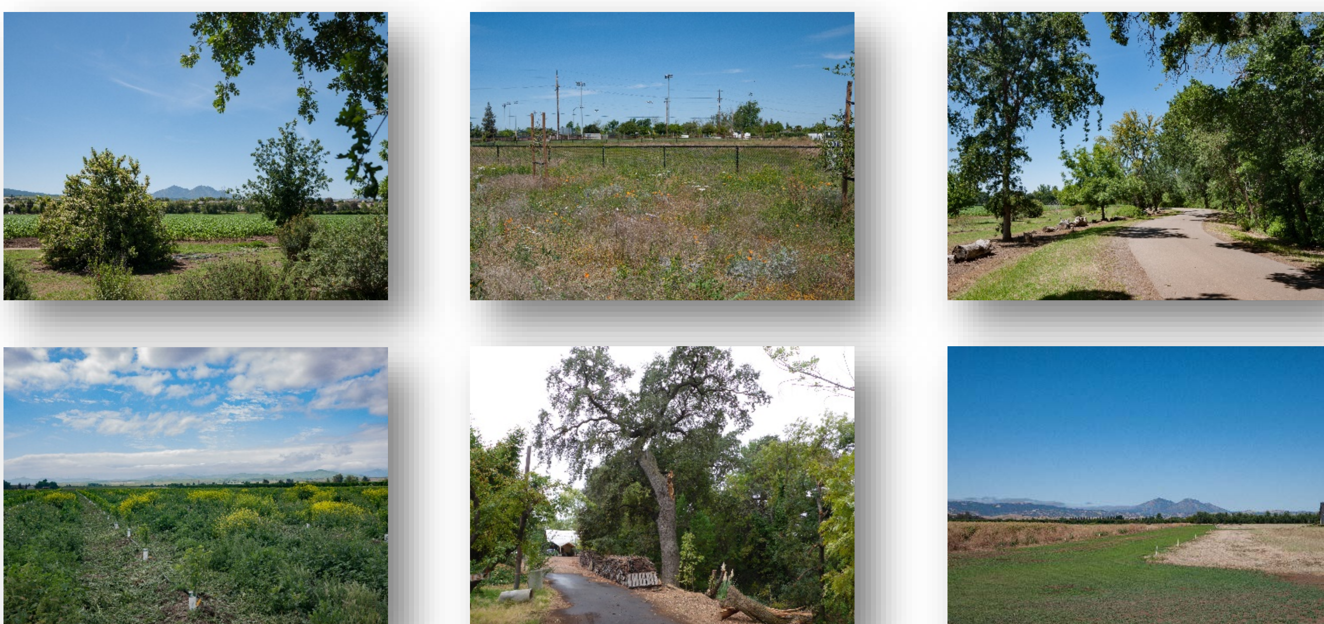
The land use patterns that surround a farm, as well as on-farm plant diversity (crop plants and weeds), have important impacts on native bee abundance and diversity. Farms surrounded by areas characterized by low plant diversity (e.g. monocultures) often attract lower number of native bees than farms in close proximity to diverse floral communities. In particular, farms with wild areas nearby often see higher rates of native bee visitors to their farms.

When planning habitat for a farm, the amount of existing habitat on-farm and in surrounding areas will determine how much additional habitat will be needed to benefit from pollination services For example, research has demonstrated that watermelon fields, where 40% or more of the landscape within a 2.4 km radius is wildland habitat, can achieve full pollination from wild pollinators. Therefore a farm under those conditions does not need additional on-farm habitat (Kremen et al 2004). However, farms with little existing habitat in the surrounding area will need to make a greater investment in habitat development to achieve the same benefits.

Producers interested in implementing native bee farming should evaluate the on-farm and surrounding land use for existing habitat. Common areas for existing habitat include:

- Fallow areas—often contain bee-attractive weeds such as wild mustards (Brassicaceae) and fiddleneck (*Amsinckia* spp.)
- Orchards—may contain bee-attractive weeds and dead trees with nesting habitat for cavity-nesting bees
- Cover crops—many existing cover cropping mixes include bee-attractive plants like clover and legumes
- Riparian areas (e.g. creeks and canals)—provide nesting habitat for cavity and ground nesting bees
- Suburban developments—home gardens and landscaping often have bee-attractive plants such as lavender (*Lavnadula* spp.) and sages (*Salvia* spp.)

Home gardens can serve as important refuges for wild pollinators. The Urban Bee Survey has recorded over 400 species of bees in urban gardens throughout California (Frankie et al 2014).



Examples of common landscapes near agricultural areas that provide floral and nesting habitat for pollinators: (1)existing plantings for natural enemies, (2 & 3) suburban landscaping, (4) weedy orchards, (5) riparian areas, and (6) fallow fields.

2. Target Bee Species

Different crops are pollinated by different native bee species. These differences are due to the differing flight seasons and floral preferences of diverse bee species. Many of California's native bees are highly seasonal: there are certain groups of bees that only fly in Spring, others in Summer, and some in Fall. When planning a crop-specific habitat, it is important to target the bee species that are flying during the crop bloom.

Bees also exhibit floral preferences. Some bees are specialists on one type of crop, such as the squash bee (*Peponapis pruinosa*) which pollinates crops within the Cucurbita genus. Bumble bees (*Bombus* species) are more general in their preferences and may pollinate several different crops within their flight season. *Farming for Native Bees* has identified a number of target native bee species for specific crops. These crop-specific, target pollinators, as well as some generalist pollinators, are listed below.

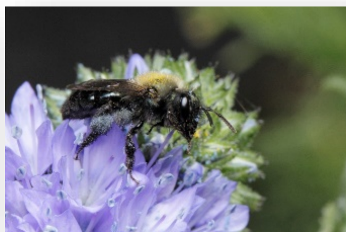
Generalist Wild Bee Pollinators:

Andrena spp.
Bombus vosnesenskii
Bombus melanopygus
Ceratina acantha
Ceratina nanula
Halictus ligatus
Halictus tripartitus
Lasioglossum incompletum
Lasioglossum kincaidii
Megachile apicalis
Megachile rotundata
Osmia spp.

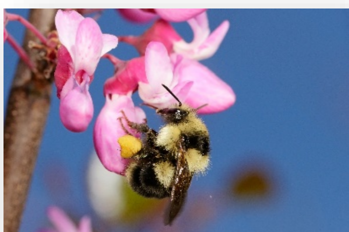
Crop-Specific Bee Pollinators:

Bee Species	Crop(s)
Agapostemon texanus	Blackberries
Andrena miserabilis	Apples Cherries
Bombus melanopygus	Apples Blackberries
Bombus vosnesenskii	Apples Blackberries Cherries
Ceratina acantha	Blackberries
Ceratina nanula	Blackberries
Halictus ligatus	Apples Blackberries
Halictus tripartitus	Apples Blackberries Cherries
Lasioglossum kincaidii	Blackberries
Osmia lignaria propinqua	Orchard trees
Xylocopa varipuncta	Blackberries Cherries

Agapostemon texanus
Ultra Green Sweat Bee

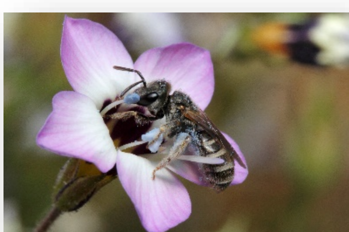


Andrena spp.
Mining Bees

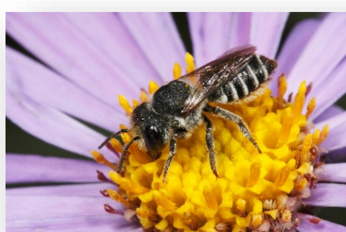


Bombus melanopygus
Black-tailed Bumble Bee

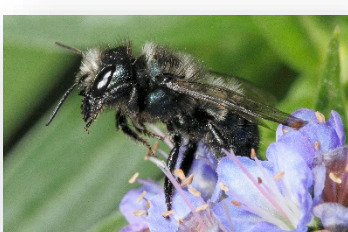
Ceratina nanula
Small Carpenter Bee



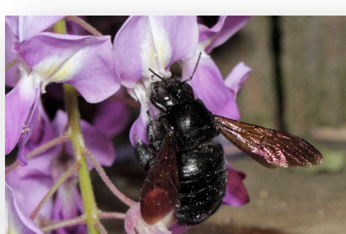
Halictus tripartitus
Sweat Bee



Megachile rotundata
Alfalfa Leafcutter Bee
(non-native but naturalized)



Osmia lignaria propinqua
Blue Orchard Bee



Xylocopa varipuncta
Large Carpenter Bee

Once target bee species for a particular crop have been identified, it is time to consider the characteristics of their lifestyles that will influence habitat design. The three most important characteristics are:

1. **Flight season:** Determines when floral resources are needed. A successful habitat will supply sufficient resources for target bee species to persist onsite throughout their entire flight season. Without sufficient resources, bees will leave in search of other floral hosts.
2. **Life history:** Considers differences in behaviors among social and solitary bee species in terms of foraging and interactions with other pollinators. Habitat management should be tailored to encourage target bee groups.
3. **Nesting requirements:** Identifies nesting requirements of target bee groups. Floral resources alone are usually not sufficient to encourage bee populations to persist on a farm.

Bee Profiles in the Resource Section provide the lifestyle characteristics for all identified target bee groups.

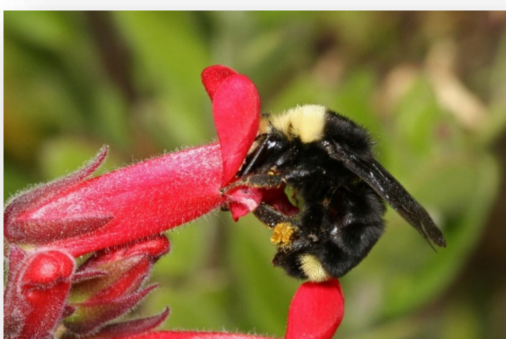
Example: *Andrena* spp. (Mining Bees)

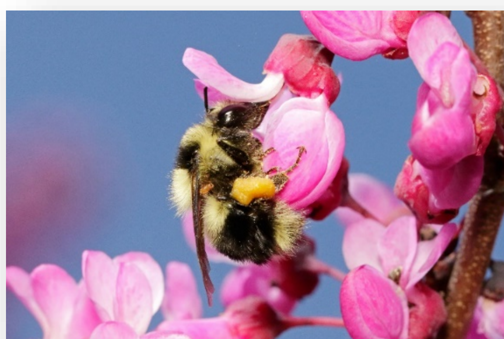
Flight Season: February-June. Peak activity March-May.

Lifestyle: Solitary.

Nesting Habitat: Nest in flat, bare ground. Nest entrances often surrounded by mounds of excavated soil.

Example: *Bombus* spp. (Bumble Bees)





Flight Season: Late winter to Fall.

Lifestyle: Social with annual colonies.

Nesting Habitat: Typically underground in abandoned rodent burrows and tufts of grass. *Bombus melanopygus* have been documented using abandoned bird houses.

3. Host Plants

Many of California's native bees are generalists but have distinct floral preferences. For 16 years, the UC Berkeley Urban Bee Lab has studied these preferences and has documented predictable patterns (Frankie et al 2005, 2009a, 2009b, 2014). In agricultural operations, this predictive information can be used to develop habitats designed to attract specific bee pollinators. Extensive plant lists for the bee pollinators presented in the previous section have been developed (see Prescriptive Treatment section) and can be referenced in the resource section.

Selecting plants can be one of the most overwhelming parts of planning a habitat. Plants lists are often extensive and it is difficult to know which plants are most suited for a particular site or crop. Here are a few starting tips:

1. The characteristics of each site will determine the habitat design and plants selected.

How much space is available and for how long? How much preparation will be required for planting, and how much effort will be required to maintain the site? Is irrigation easily accessible? Two common designs include: seeded annual wildflower patches and perennial habitat gardens. The benefits and drawbacks of each design are listed below to help determine which design, or if both, are appropriate for an operation.

Seeded Annuals:

Benefits:

- Short time commitment. Can be as short as 4 months from seeding to bloom.
- More opportunities for habitat to be in close proximity to crop plants (e.g. between orchard rows)
- Annual wildflowers can be incorporated into existing cover cropping systems.
- Relatively low establishment costs
- Low irrigation requirements
- Can reseed readily on their own
- Little to no maintenance required

Drawbacks:

- May not provide resources for entire flight season of target bee species. Most wildflowers have a short flowering time.
- May not bloom each year if rainfall is not sufficient.
- May require reseeding, at an additional cost, if the flowers are mowed or tilled prior to seed set.

Perennial Habitat Gardens:

Benefits:

- Greater diversity of perennial plants can provide floral resources for the entire flight seasons of most target bee species.
- Certain perennial plants also provide nesting habitat.
- Once established, perennial plants flower most years, providing consistent sources of pollen and nectar.
- Provides habitat for beneficial insects and other wildlife.
- Can provide other on farm benefits such as wind buffers and erosion control.

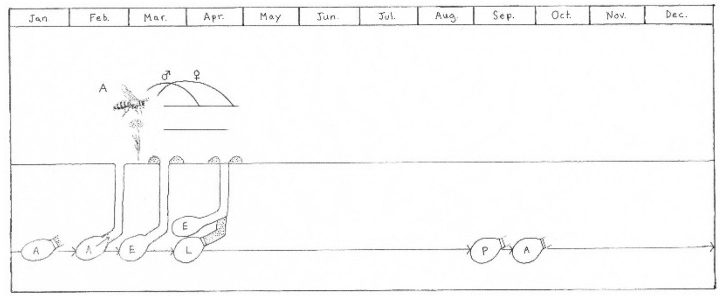
Drawbacks:

- Requires longer term commitment of land
- Higher irrigation requirements during establishment
- Greater establishment costs
- Requires ongoing maintenance

2. Provide sufficient pollen and nectar resources for the entire flight season for your target bee species.

Depending on the target bee species' life history, it may only be necessary to provide resources before and after the crop bloom, as is the case with mining bees (*Andrena*) which only fly during the spring. Resources may be needed for the majority of the year in the case of social bumble bees (*Bombus*) and multi-generational small carpenter bees (*Ceratina*).

It is also important to note that not all plants provide pollen and nectar. Some, like sages (*Salvia* spp.) and lavenders (*Lavandula* spp.), only provide nectar, others, such as California poppies (*Eschscholzia californica*) and California lilac (*Ceanothus* spp.), only pollen.



Annual life cycle of a mining bee species (*Andrena*). Seasonal bees, like *Andrena*, spend the majority of their lives developing underground. Adults fly for only a few weeks in the Spring. This short period is the only time they require floral resources. Life stages in brood chambers: A=Adult; E=Egg; L=Larva; P=Pupa

Detailed information on individual plants, including what resource they provide, can be found in the Plant Profiles.

Example Plant Profile

Ceanothus 'Dark Star' and 'Julia Phelps' California Lilac

Plant Form: Shrubby tree
Flower Color: Dark cobalt or indigo blue
Size at maturity: Up to 6 ft high and 6 ft wide
California Native?: Yes
Flowering Time: March-April
Annual/Perennial: Perennial
Floral Resource: Pollen
Maintenance: Gopher bag root ball before installation. Low maintenance. Prune for space management.
Water requirements: Regular watering for first 3 years of establishment. After first 3 years, requires little to no additional irrigation.
Common Bee Visitors: *Andrena* and *Bombus* species

3. It is ok to start small.

It is not necessary to take on a large habitat plan right away. Instead, begin by experimenting with a smaller habitat closer to crop plants to get a sense for how installation and management can best be integrated into the overall operation. It may be that all pollination needs can be met with just annual plants. It also may happen that some of the plants first selected are not compatible with current management regimes. Working out these kinks on a smaller scale will facilitate development of successful habitats without wasting time and resources. More habitat can be progressively installed as habitat implementation and management is adapted to a particular operation.

4. Habitat Sites

As mentioned in the previous section, the characteristics of a site will determine what habitat design, and therefore which plants, are appropriate for an operation. There are many opportunities within farms for both annual and perennial habitats that will not interfere with land in production. The characteristics of good sites for both habitat designs and examples of each are listed below.

Seeded Annuals:

Characteristics of a Good Site:

- Close to target crop plants (within 600 ft.)
- Undisturbed until after seed set (early-mid Summer)
- Require low levels of maintenance and preparation

Examples:

- Between orchard and crop rows
- Incorporated in crop rotations
- Bordering roadways or fields
- Dead tree stands in orchards

Perennial Habitat Gardens:

Characteristics of a Good Site:

- Will not take land out of production
- Have easy access to irrigation
- Have easy access for maintenance and monitoring

Examples

- Ends of orchard or crop roads
- Along irrigation pipes
- Inter-planted in crop rows
- Along field borders

Examples of good locations for annual and perennial habitat (1)between orchard rows, (2)along field borders, (3)bordering access roads, and (4)along irrigation ditches.

Tip from Farmer Al:

"There are acres and acres of ground between the trees in the tree rows. Certain times of the year during the winter months, we can actually plant cover crops broadcast throughout the whole orchard to cover the entire orchard floor…that will provide a huge habitat to attract bees here in the first place and then hopefully they'll find other reasons to stay here, other kinds of flowers, bushes, and trees to live in once that widely planted cover crop goes away. "

5. Habitat Installation

How plants are installed is crucial to the long-term success of a habitat. Installing during the peak of summer, when soil and air temperatures are highest, will stress new plants and require significant irrigation to see them through establishment. Certain habitat plants are susceptible to gophers and need protection during installation or they will eventually be damaged. If immature plants are installed too close together some may be crowded out or stunted from competition as they grow. Carefully considering these factors prior to installation will limit plant mortality and is the fastest way to a successful habitat.

The following sections break down the main factors that need consideration during installation.

Seeded Annual Wildflowers

Seeding Time:
Right before the start of winter rains; normally late October through November. Timing seed dispersal with the rains will limit or eliminate the need for additional irrigation in the spring. This will also protect seeds from birds, as the rains will push them into the soil.

Ground Preparation:
Ground preparation will vary depending on site characteristics, particularly weed pressure. Sites with few weeds may simple require a light discing. More aggressive methods may be needed where there are more weeds. Recommended methods include aggressive tillage and solarization.

Herbicides are not recommended, but, if thy are necessary, the following guidelines can prevent undue harm to bees:

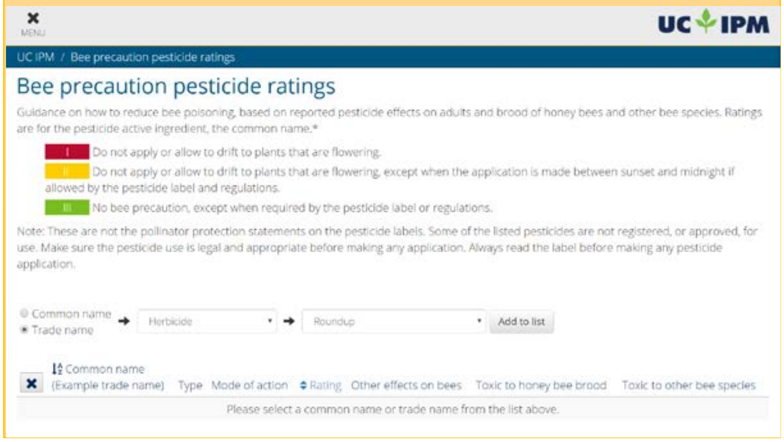
- Use a non-persistent herbicide, ideally one approved for organic operations
- Try to spray selectively with a backpack sprayer rather than widespread application
- Time sprays to minimize unnecessary exposure to bees and their floral hosts (e.g. in the evening, before the bloom, before harvest, after harvest)
- Avoid herbicides such as Paraquat and Gramoxone that are toxic to bees.
- See Managing Alternative Pollinators and Farming for Bees (Xerces Society 2010 and 2015) for more detailed recommendations

Seeding Method:
Broadcast seeding either by hand or machine is the most flexible and one of the least expensive methods. Other methods such as drill seeding and drop seeding can be used for larger areas but may involve a higher level of preparation and cost. Extensive recommendations can be found in *Managing Alternative Pollinators* and *Farming for Bees* (2015) and *Establishing Pollinator Meadows from Seed* (Xerces Society 2013).

Bee Precautious!

Before applying any agricultural chemicals in an future habitat area or where bee pollinators might be visiting, visit the **UC Integrated Pest Management Bee Precaution Website** to check the toxicity of the active ingredients to bee populations.

The ratings are categorized in three ways (outlined below). It is important to note that these ratings are not the pollinator protection statements found on chemical labels. Often the UC IPM ratings recommend more precautions than most labels and offer more protection to insect pollinators.

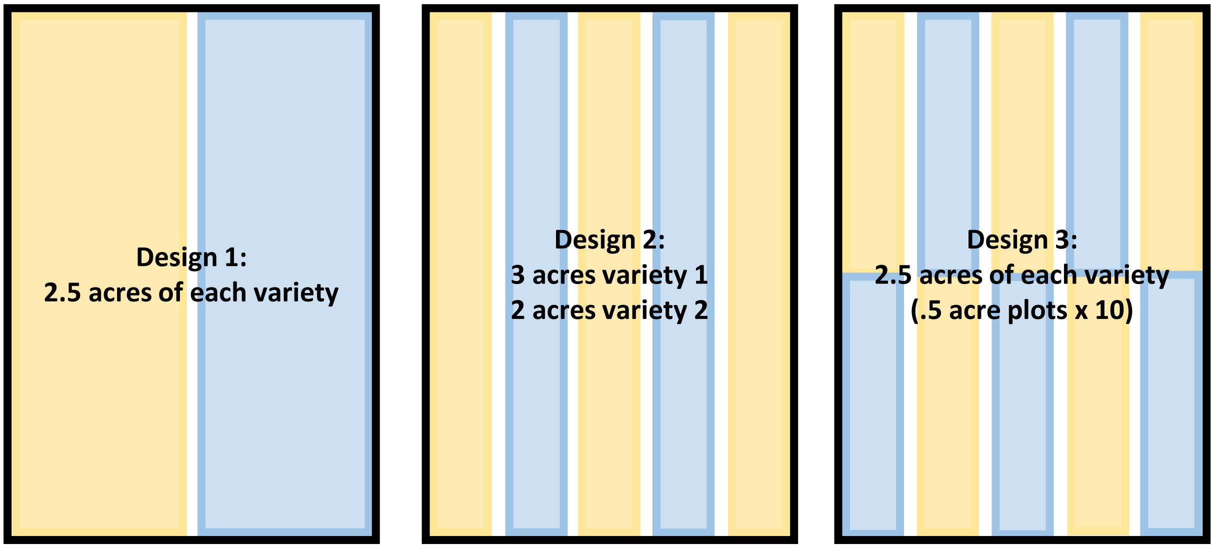


Habitat Design:
Wildflowers can either be seeded in areas of single species or mixed together.


Above: *Phacelia tanacetifolila* seeded along orchard borders. Habitat for native bees also provide resources for resident honey bee populations on this farm.

There are benefits to using both single species and mixes. Single species allows for more uniform growth of wildflowers and runs less risk of competition between different plant types (e.g. *Phacelia tanacetifolia* is tall growing and often outcompetes smaller, slower growing annuals). A major drawback of seeding in blocks of single species is that it limits diversity of floral resources and therefore diversity of pollinators attracted. Another drawback is the relatively short flowering season of individual wildflower species: a single species will only provide resources for a certain time period.

Using a seed mix will provide a diversity of resources for a longer period, but there may be uneven success among the different wildflowers used depending on their ability to deal with competition from other wildflowers and weeds.



Three sample seeding designs for 5 acre single species blocks. Yellow=plant variety 1; Blue=plant variety 2.


Comparison of two different seed types: *Phacelia tanaceitofila* (right) and *Lupinus bicolor* (left). Different sized seeds will require different amounts per acre for establishment.

Recommended lbs of seeds per acre:
Note that different seed types will require different amounts per acre.

- Eschscholzia californica: 6lbs/acre
- Gilia capitata: 3lbs/acre
- Lupinus nanus: 9 lbs/acre
- Phacelia cicutaria: 3 lbs/acre
- Phacelia tanacetifolia: 3lbs/acre

Initial Care:
Areas with seeded wildflowers should require no maintenance or irrigation after seeding. If seeding does not correspond with a rain event, minimal overhead watering from a sprinkler or tank will help with establishment and protection from birds.

Perennial Habitat Gardens

Planting Time:
Late fall through early Spring; right before, during, and after the rainy season. Timing installations with rain events or while soil moisture is high will ease the establishment of new plants.

Ground Preparation:
The two most important factors in preparing ground for perennial habitat are: clearing weeds and dampening the soil prior to planting.

Like ground preparation for seeded annuals, weed removal methods will be determined by weed pressure. Sites with fewer weeds, can be managed with a hoe or weed whacker. Where there are more weeds, more aggressive methods such as those listed in the previous section may be necessary.

Soil moisture at planting can greatly impact the establishment of new plants. If soils are particularly dry, consider irrigating a day before planting to ease the plants' transition. If pre-irrigation is not possible, be sure to give newly installed plants a large dose (at least 2.5 gallons) of water on the day of planting to help with establishment.

To encourage faster root development of immature plants, dig holes that are twice as large as the plant's container. For example, for a 5-gallon plant, dig a 10-gallon hole. This is particularly important in hard soils, where new roots will have difficulty penetrating the soil beyond the immediate hole.

Installed perennial habitat on a farm. Note the large patches of the same plants (e.g. the large area of dark purple *Lavandula stoechas*).

Examples of root health (right to left): under-developed, well-developed, and root-bound.

Mesh bags are placed around the root-crown (left) for quick and easy protection from gopher damage.

Habitat Design:
Recommended to plants large patches of the same type of plant. For example, plant several lavenders next to each other for dense flowering.

Recommended plants per 100 linear feet:
15-25 depending on the size of the plants

Plant Preparation:
It is important to select plants with well-established roots, as newly transplanted ones will have a much harder time getting established. If a plant is root-bound be sure to loosen and separate the roots to encourage more expansive root development.

1-gallon plants are recommended, and 5-gallons for slower growing plants. However, root development is critical to successful establishment, so smaller container sizes will also work as long as the roots are well developed.

Certain plants are more attractive to gophers than others. These plants should be planted with gopher screens to protect the root ball. Western Planting Solutions Gopher Baskets are a good option.

Be sure to leave enough space around each plant to grow to maturity. Insufficient space around immature plants may result in competition as they grow.

Initial Care:
Newly installed plants need water to establish. The amount of water will depend on soil moisture. For particularly dry soils, give at least 2.5 gallons. For wetter soil, use 0.5-1 gallon. Fertilizer and mulch can also be added at this time.

The best way to ensure a successful habitat is keep an eye on new plants to make sure they are not stressed from lack of water or nutrients. Obvious signs of stress are wilting leaves and flowers, browning foliage, and slow growth (will vary depending on plant, see Plant Profiles for details).

6. Irrigation

Ideally the sites and habitat designs selected will integrate with the existing irrigation regime. Good sites for seeded annuals can be watered via sprinkler and good sites for perennial gardens are on or near existing drip systems. Habitat designs in new areas without existing irrigation should be considered carefully so the plants selected will received sufficient water for success.

In general, seeded annuals should require little to no additional irrigation if they receive adequate rainfall. However, during times of water scarcity additional spring watering will help with germination.

Installed perennial habitat gardens will require irrigation, particularly during establishment. Many of the recommended plants are drought-tolerant. However, all plants, including California natives, require regular water for establishment. Water all plants at least once a week for the first 3 years during spring, summer, and fall. The amount of water per watering may vary depending on the time of year. During spring, only a half-hour of drip irrigation may be required, but may jump up to 2 hours in summer.

It is worth repeating that the best way to ensure successful establishment is to keep an eye on soil moisture and the plants for signs of stress. Water stressed plants produce fewer floral resources and therefore are less attractive to bees. A habitat of water stressed plants will not be very successful.

After the first 3 years, many plants will require little to no additional irrigation except during droughts and other periods of stress. Some plants, such as many *Ceanothus* species, actually dislike excessive watering, particularly during the summer. Others, such as the sages (*Salvia* species), will bloom more vigorously and for longer periods if given a little water. For the water preferences of individual plants, refer to the Plant Profiles in the Resource section.

7. Adaptive Management

Above: *Phacelia cicutaria* gone to seed.

In general, installed habitats, both seeded and perennial, will require little maintenance.

Seeded wildflowers in particular require no attention until after they have bloomed and set seed. It is best to leave these areas undisturbed until the fall when the flowers have dropped their seeds into the seed bank. If necessary, they can be tilled or mowed after they have gone to seed. If they are removed before seed set, those areas will have to be reseeded, at an additional cost, the following year.

Perennial gardens require little maintenance, but by providing a regular care, many plants will produce more floral resources for bees and therefore will be more successful in attracting pollinators.

Maintenance for an optimal pollinator habitat includes:

- Pruning for space management,
- Removing weeds around the base of plants (Using mulch around the base of plants can reduce the need for constant maintenance).
- Occasional applications of fertilizer,
- Deadheading spent flowers to encourage new or extending flowering. Deadheading certain plants can also have the extra benefit of creating nesting habitat for certain bee species that excavate pithy stems, such as the small carpenter bees (*Ceratina* spp.).

As with irrigation, the best way to determine maintenance requirements is to keep an eye on habitat plants throughout the year for signs of stress and damage and adjust accordingly. If plants continue to suffer damage from on farm activities, such as tractors turning at the end of habitat rows, a more intensive pruning schedule may be necessary. If many installed plants are showing signs of nutrient or water stress, consider incorporating regular applications of fertilizer or increasing the watering frequency.

Remember, water and nutrient stressed plants produce fewer floral resources and are therefore less successful in attracting bees!

Unpruned *Salvia brandegeei* (left) planted at the end of a cherry tree row. *Salvia* species are excellent choices for ends of orchard rows because they withstand heavy pruning (below left) and can survive some damage (below right).

Gaillardia aristata with spent, blooming, and new flowers.

Gaillardia aristata with spent flowers deadheaded but blooming and new flowers undisturbed.

8. Nesting Habitat

Providing floral resources may not be enough to encourage bee populations to persist and provide pollination services. Bees that have nesting sites closer to floral resources will be able to forage more frequently and future generations may persist to provide continual pollinations services. Providing onsite nesting habitat will encourage these populations to remain and provide those services.

The majority of California's native bee species (~70%) nest in the ground. In general, they prefer flat, bare soil. Currently, the best way to encourage ground-nesting is to leave bare areas of ground undisturbed (from tilling and other soil invasive activities) near floral habitat and crops. Do not use pesticides or herbicides in those areas, (this will be explained further in the following section). Good nesting sites for ground-nesting bees are along roadways or irrigation ditches, along berms, in storage areas, and around the base of perennial floral habitat.

Approximately 20% of native bees are cavity-nesters, either using pre-existing cavities or excavating pithy stems or soft wood. The most common way to encourage cavity-nesters is by providing artificial cavities and other nesting materials for excavation. There is a lot of existing information on how to create artificial nest habitat (many guides and recommendations are listed in the Resource section), but following are few ways to get started.

Commercial mason bee nests are available at nurseries and online (see Resource section for more information). These can also be created using 2"x4" pieces of wood, preferably Douglas fir or redwood, with various sized holes drilled approximately 4" deep. For bees that excavate pithy stems, bundles of dried stems from plants like *Rubus, Salvia, Perovksia, Agave,* and various mustards can be placed nearby floral habitat.

More detailed information regarding nesting requirements and habitat recommendations can be found in the Bee Profiles.

Artificial cavity nesting blocks installed in an orchard. Note the different sized holes and configurations.

Common Ground Nesting Bees in Agricultural Areas:

Agapostemon texanus

Andrena spp.

Bombus spp.

Halictus spp.

Lasioglossum spp.

Peponapis pruinosa

Common Cavity Nesting Bees in Agricultural Areas:

Ceratina spp.

Megachile spp.

Osmia lignaria propinqua

Osmia spp.

Xylocopa spp.

9. Chemical Management

Many agricultural chemicals have been identified as potential threats to pollinator populations. Even chemicals not targeted towards insects, such as fungicides and herbicides, can be harmful and reducing or eliminating their use whenever possible can play a large role in protecting those populations. If chemicals are used, it is important to be informed about their potential impacts and take precautions to minimize those impacts on bee populations. For comprehensive resources on agricultural chemicals and pollinator populations, refer to the Additional Readings in the Resource section.

Pesticides:

Many pesticides can be harmful to beneficial insects, including bee pollinators, and reducing and/or eliminating pesticide use will protect bee populations. Extensive recommendations for alternative pest management methods can be found on the UC Cooperative Extension Integrated Pest Management website.

If pesticides must be used, consider the following factors: .

1. What are the active ingredients and how toxic are they to bees? Certain active ingredients are highly toxic to bees, such as the neonicotinoids. Others, like *Bacillus thuringiensis* are considerably less toxic to bees.
2. Try to reduce drift as much as possible. Do not spray on windy days or in unfavorable conditions, or consider planting a buffer strip.
3. Time sprays during periods that will minimize unnecessary exposure. Never use pesticides on plants in bloom to protect foraging bees. Try to spray only when needed and ideally after the flight season of most bee pollinators. (Vaughan et al 2015).

For more detailed information and recommendations refer to Managing Alternative Pollinators and Farming for Bees (Mader et al 2010 and Vaughan et al 2015).

When purchasing plants for installation, it is important to remember that many plants come pretreated with systemic insecticides that are active for the first 2 years or more of the plant's life (e.g**.**, neonicotinoids). The pesticides persists in pollen and nectar and can cause harm to bees and other flower visitors. **When purchasing plants for bees, make sure they have not been pretreated with pesticides.**

Plant label for neonicotinoid treated plant.

Herbicides:

Not a lot is known about the impact of herbicides on native bees particularly on ground nesting bees. Try to manage weeds through non-chemical methods such as mechanical or hand removal, mulching or solarization.

Agricultural Weed	Common Bee Visitors
Brassicaceae (weedy mustards)	*Ceratina, Eucera, Halictus, Hylaeus, Megachile*
Centaurea solstitialis	*Halictus, Megachile, Melissodes*
Cirsium spp. (thistles)	*Bombus, Ceratina, Halictus, Lasioglossum, Megachile*
Convolulus arvensis	*Agapostemon texanus, Ceratina, Halictus, Lasioglossum*
Picris echioides	*Bombus, Ceratina, Halictus, Lasioglossum, Melissodes*
Verbesina encelioides	*Diadasia, Halictus, Melissodes*

If herbicides must be used, consider using the following guidelines:

1. Use a non-persistent herbicide, ideally one approved for organic operations
2. Spray selectively with a backpack sprayer rather than widespread application
3. Time sprays to minimize unnecessary exposure to bees and their floral hosts (e.g. in the evening, before the bloom, before harvest, after harvest)
4. Avoid herbicides such as Paraquat and Gramoxone that are toxic to bees. (Vaughan et al 2015).

Another option is to consider tolerating a few weeds or even managing weeds for on-farm benefits. Quite a few common weed species provide pollen and nectar for pollinators and other beneficial insects. *Picris echioides* and weedy mustards can attract great numbers of bees, particularly when other resources are not available.

10. Estimated Costs

Costs will vary according to the size, design, and composition of the habitat. It will also depend on the costs of plants and seeds in a given region. Contact a NRCS District Conservationist or UC Cooperative Extension Farm Advisor for nursery and seed source recommendations.

Although costs will vary, most establishment costs will fall within a certain range. The following tables present an example cost breakdown for seeding 5 acres of annual wildflowers and installing 100 perennial habitat plants based on average plant, seed, and irrigation prices.

Plant	Lbs Seed/Acre	Price/Pound	Price/Acre
Eschscholzia californica	6lbs	$14.00	$84.00
Gilia capitata	3lbs	$35.00	$105.00
Lupinus nanus	9lbs	$35.00	$315.00
Phacelia cicutaria	3lbs	$35.00	$105.00
Phacelia tanacetifolia	3lbs	$12.00	$36.00
		Total:	**$645.00**

Container Size	Qty	Average Price	Total
1 gallon	80	$6.50	$520.00
5 gallon	20	$20.00	$400.00
		Total:	**$920.00**

Equipment	Qty	Average Price	Total
1000’ ½ (16mm) Polyethylene Blank Drip Tubing	1	$100.00	$100.00
500’ 1/8 in Vinyl or Poly Micro Tubing	1	$20.00	$20.00
Emitters (25-pack)	4	$8.00	$32.00
Stakes (10-pack)	10	$2.00	$20.00
		Total:	**$172.00**

Total Seeded Annual Wildflower Costs: $645.00
Total Perennial Habitat Garden Costs: $1092.00

Total Habitat Installation Costs: $1737.00

Chapter 5: Habitat Prescription- Example

Using the guidelines presented in the previous chapter, this chapter illustrates the process of narrowing down and adapting each element of native bee farming to an actual farm operation.

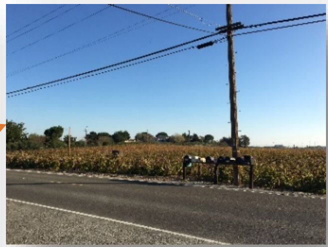
The habitat plan is crop-specific, using a prescription that targets key pollinators for blackberry varieties and hybrids. Prescriptions for different crops can be found in the Resource section. Research is ongoing and new prescriptions are currently being created. These will be published as they are completed. A general pollinator prescription for the most common bee species recorded visiting multiple crops has been developed and can be used for most crops for which a prescription has not yet been developed.

1. Characteristics of Farm Operation

Target Crop: Blackberries, including varieties and cultivars
Critical Pollination Time: March-May
Size of crop area: 5 acres
Conventional or Organic: Conventional
Surrounding Landscape: Suburban developments close by (within a half mile); agriculture (within a half mile); wild habitat (within a half mile); and fallow areas (within a half mile).

Nearby suburban developments may provide existing habitat for pollinators (e.g. home gardens)

Fallow areas often have weeds that attract pollinators. *Verbesina encelioides* (above) is a common agricultural weed that can attract a great number of bees.



Surrounding agricultural land use can facilitate pollinators moving through areas seeking new floral hosts.

Existing on farm agricultural practices can provide habitat. Cultivated herbs like rosemary (above) are attractive to pollinators and maybe included in habitat designs.

2. Target Bee Species

The most common bee species recorded regularly visiting blackberry flowers are:

<ins>*Ceratina acantha* and *C. nanula*</ins>

Flight Season: Spring-Fall; peaks between April-August

Lifestyle: Solitary nesters (usually). Multi-generational.

Nesting Habitat: Females excavate pithy or soft-core dead stems of plants like *Sambucus, Rubus, Brassica, Helianthus, Perovskia atriplicifolia,* and *Salvia mellifera.*

<ins>*Bombus vosnesenskii*</ins>

Flight Season: Late winter to Fall.

Lifestyle: Social with annual colonies.

Nesting Habitat: Typically under ground in abandoned rodent burrows and tufts of grass. *Bombus melanopygus* have been documented using bird houses.

<ins>*Halictus ligatus*</ins>

Flight Season: Spring through Fall. Females emerge in March and males in June.

Lifestyle: Primitively social with annual colonies.

Nesting Habitat: Nest in flat, bare ground. May be aggregated.

<ins>*Halictus tripartitus*</ins>

Flight Season: Spring through Fall. Females emerge in March and males in June.

Lifestyle: Primitively social with annual colonies.

Nesting Habitat: Nest in flat, bare ground. May be aggregated.

3. Host Plants

Below are comprehensive plant lists for each of the target bee species for blackberries. However, not all of these plants will be suitable for the sites selected on this farm (see below). For example, low-growing plants such as *Erigeron karvinskianus* and *Monardella villosa* would not do well at the ends of orchard rows or areas where they may be outcompeted by larger plants. Others, such as certain *Ceanothus* species and *Vitex agnus-castus*, grow to be large trees and would be too large for many areas. More details on plant types and their growth patterns can be found in the Plant Profiles.

Tips for Selecting Plants:

1. Must provide flowering for entire flight season of target bees.
2. Must provide pollen and nectar.
3. Site selection will determine what plants are appropriate
4. It is ok to start small!

BEE POLLINATORS	**PLANT RECOMMENDATIONS**			
	PLANT	FLR TIME	ANNUAL/ PERENNIAL	RESOURCE Pollen/Nectar
<u>*CERATINA* SPP.</u>	*Aster* x *frikartii*	June-Sept	P	P/N
C. acantha	*Calamintha nepeta* ssp. *nepeta*	June-Sept	P	N
C. nanula	*Coreopsis lanceolata* or *grandiflora*	May-Aug	P	P/N
	Erigeron glaucus	Jan-Aug	P	P/N
	Erigeron karvinskianus	Year-Round	P	P/N
	Eschscholzia californica	Apr-July	A	P
	Grindelia camporum, hirsutula, or *stricta*	Apr-Oct	P	P/N
	Lavandula stoechas	Mar-Aug	P	N
	Nepeta x *faassenii*	May-Sept	P	N
	Phacelia tanacetifolia	Mar-May	A	P/N
	Perovskia atriplicifolia	July-Oct	P	N
	Rosmarinus officinalis 'Lockwood de Forest' or 'Ken Taylor''	Aug-Jan	P	N
	Salvia brandegeei	Apr-May	P	N
	Salvia mellifera	Mar-July	P	N
	Salvia 'Dara's Choice'		P	N
Bombus vosnesenskii	*Ceanothus* spp.	Feb-May	P	P
	Echium candicans	Feb-June	P	P/N
	Erysimum 'Bowles Mauve'	Mar-Aug	P	P/N
	Eschscholzia californica	Apr-July	A	P
	Gaillardia x *grandiflora* 'Oranges & Lemons'	May-Aug	P	P/N
	Lavandula x *intermedia* 'Provence'	June-Aug	P	N
	Monardella villosa	June-Aug	P	N
	Nepeta x *faassenii*	May-Sept	P	N
	Perovskia atriplicifolia	June-Aug	P	N
	Phacelia cicutaria	Mar-May	A	P/N
	Phacelia tanacetifolia	Mar-May	A	P/N
	Salvia brandegeei	Apr-May	P	N
	Salvia chamaedryoides	May-Oct	P	N
	Salvia 'Dara's Choice'	Mar-July	P	N
	Salvia mellifera	Mar-July	P	N
	Salvia munzii	Mar-July	P	N
	Salvia uliginosa	May-Aug	P	N
	Vitex agnus-castus	July-Aug	P	P/N

Halictus ligatus	*Achillea* 'Moonshine'	Apr-Aug	P	P
	Coreopsis grandiflora	May-Aug	P	P/N
	Coreopsis verticillata	June-Sept	P	P/N
	Cosmos bipinnatus	June-Oct	A	P/N
	Encelia californica	Feb-June	P	P/N
	Erigeron glaucus	Jan-Aug	P	P/N
	Erigeron karvinskianus	Year-Round	P	P/N
	Gaillardia 'Oranges & Lemons'	May-Aug	P	P/N
	Grindelia camporum	Apr-Oct	P	P/N
	Helianthus annuus	June-Aug	A	P/N
	Mentha spp.	Mar-OCt	P	N
	Rudbeckia hirta	June-Sept	A/P	P/N
	Solidago velutina ssp. *californica*	June-Oct	P	P/N
Halictus tripartitus	*Ceanothus griseus* 'Yankee Point'	Feb-Apr	P	P/N
	Ceanothus 'Ray Hartman'	Feb-Apr	P	P/N
	Coreopsis grandiflora	May-Aug	P	P/N
	Erigeron karvinskianus	Year-round	P	P/N
	Eriogonum grande var rubescens	Apr-Oct	P	N
	Eschscholzia californica	Feb-Sept	A	P
	Gaillardia x *grandiflora* 'Oranges & Lemons'	May-Aug	P	P/N
	Grindelia stricta	Apr-Oct	P	P/N
	Helianthus annuus	June-Aug	A	P/N
	Heteromeles arbutifolia	June-Aug	P	P/N
	Phacelia cicutaria	Mar-May	A	P/N
	Phacelia tanacetifolia	Mar-May	A	P/N
	Rosmarinus officinalis	Aug-Jan	P	N
	Salvia brandegeei	Feb-Apr	P	N
	Salvia clevelandii	May-Aug	P	N
	Salvia uliginosa	May-Aug	P	N
	Solidago velutina ssp. *californica*	June-Oct	P	P/N
	Sphaeralcea ambigua	Feb-Aug	P	N
	Vitex agnus-castus	July-Aug	P	P/N

Initial Notes on Plant Selection:

1. All of the target bee species have long flight seasons, so plants selected must provide resources for most of the year.
2. Plants attractive to multiple target bee species:
   - *Ceanothus* spp.
   - *Coreopsis grandiflora*
   - *Erigeron glaucus*
   - *Eschscholzia californica*
   - *Grindelia camporum*
   - *Perovskia atriplicifolia*
   - *Phacelia cicutaria*
   - *Phacelia tanacetifolia*
   - *Rosmarinus officinalis*
   - *Salvia brandegeei*
   - *Salvia mellifera*

Bombus vosnesenskii visiting *Erigeron glaucus*

Halictus tripartitus visiting *Erigeron glaucus*

3. A large number of plants provide both pollen and nectar and are good choices for habitat.

4. Habitat Sites

To recap from Chapter 4, ideal seeding locations will:

1. Be as close to target crop plants as possible;
2. Be undisturbed until after key pollination times;
3. Require low levels of maintenance and preparation.

Ideal areas for perennial habitat gardens will:

1. Not take land out of production;
2. Have easy access to irrigation;
3. Have easy access for maintenance.

Keeping this information in mind, the areas highlighted on the map have been selected for habitat.

Phacelia tanacetifolia in full bloom between orchard rows.

Perennial habitat garden in bloom along an access road.

Seeded Areas:

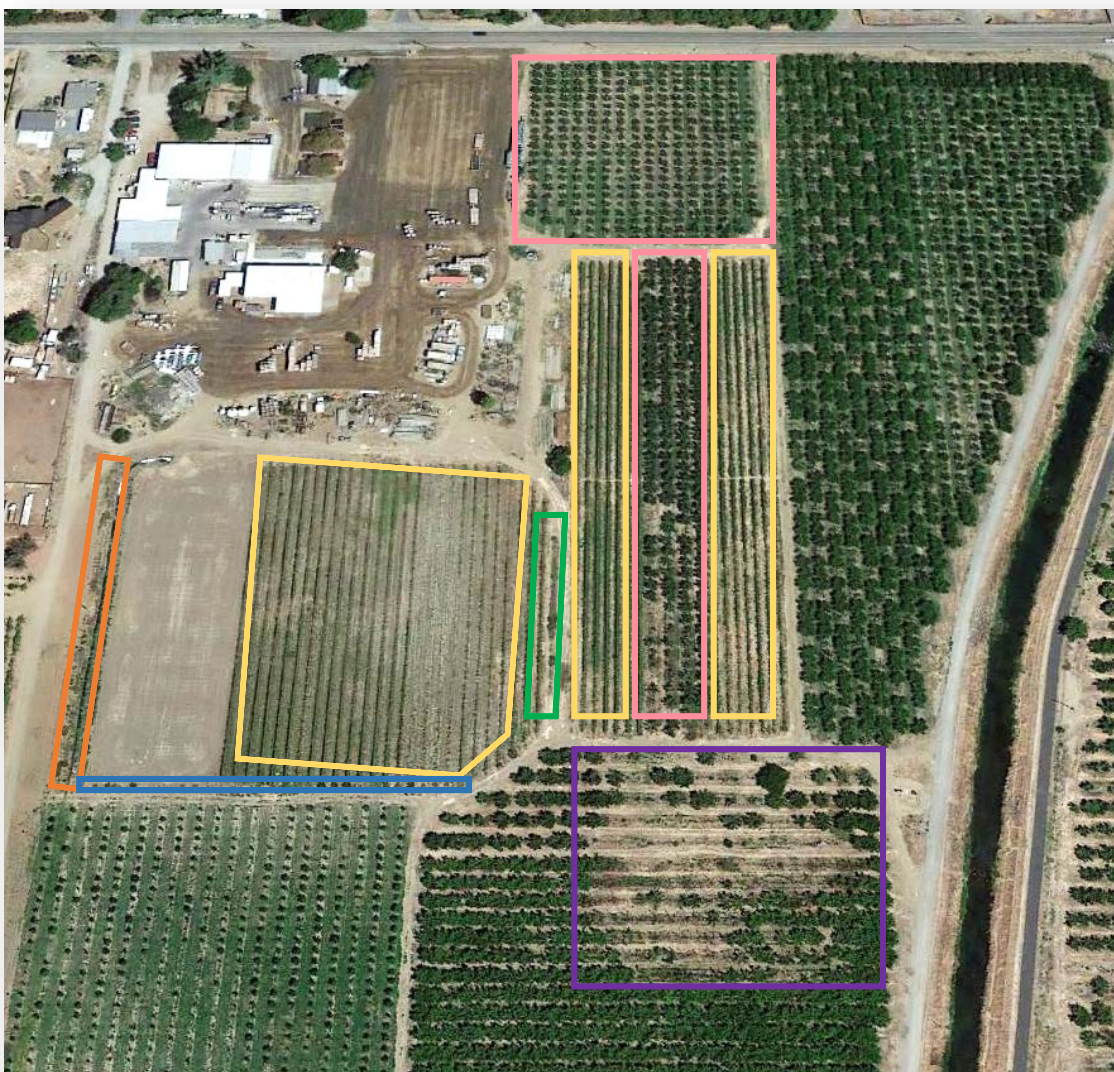
- Between berry rows
- Between orchard rows
- In dead tree stands

Total Area: 6.75 acres

Perennial Habitat Gardens:

- Area 1: west side of berries
- Area 2: east side of berries
- Area 3: south end of berry rows

Total Area: 1 acre



5. Habitat Installation

Seeded Annual Wildflowers

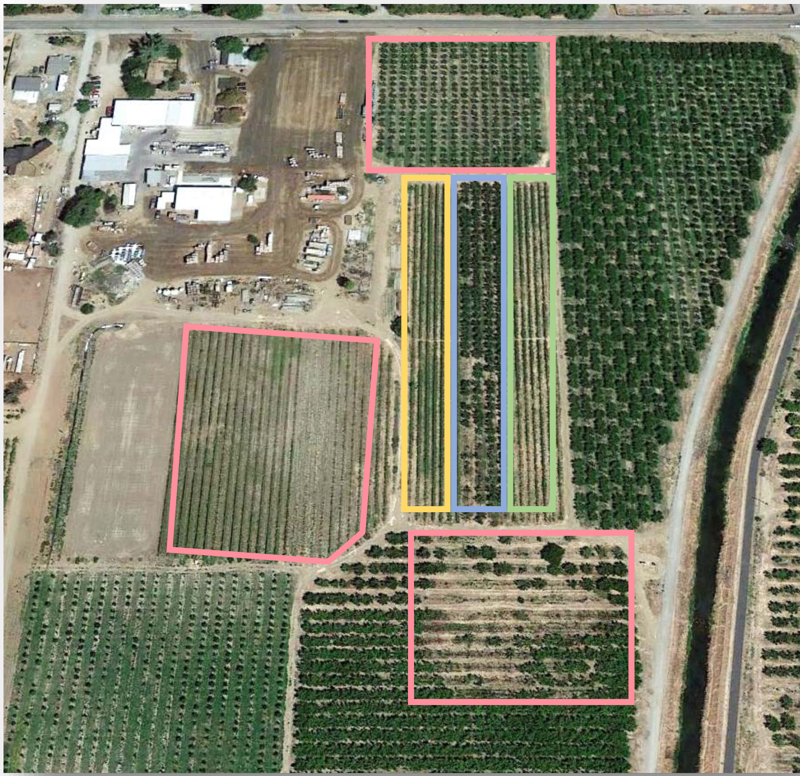
Seeding Time:
Mid-November

Ground Preparation:
Weed pressure is low in orchards and between berry rows because of active management (mechanical and chemical). Light discing should be sufficient.

Seeding Method:
Broadcast seeding (by machine in orchards and by hand in berry rows)

Habitat Design:
Single species and pollinator mix of all 3.

Acres	Plant	Lbs of Seed Needed
.85	Eschscholzia californica	5
.85	Phacelia cicutaria	3
.85	Phacelia tanacetifolia	3
4.2	Pollinator Mix	17



Initial Care:
Seeding is timed to correspond with rain events so the seeds will be pushed into the seed bank and protected from birds. If rain is insufficient, may employ a roller to cover seed with a thin layer of soil.

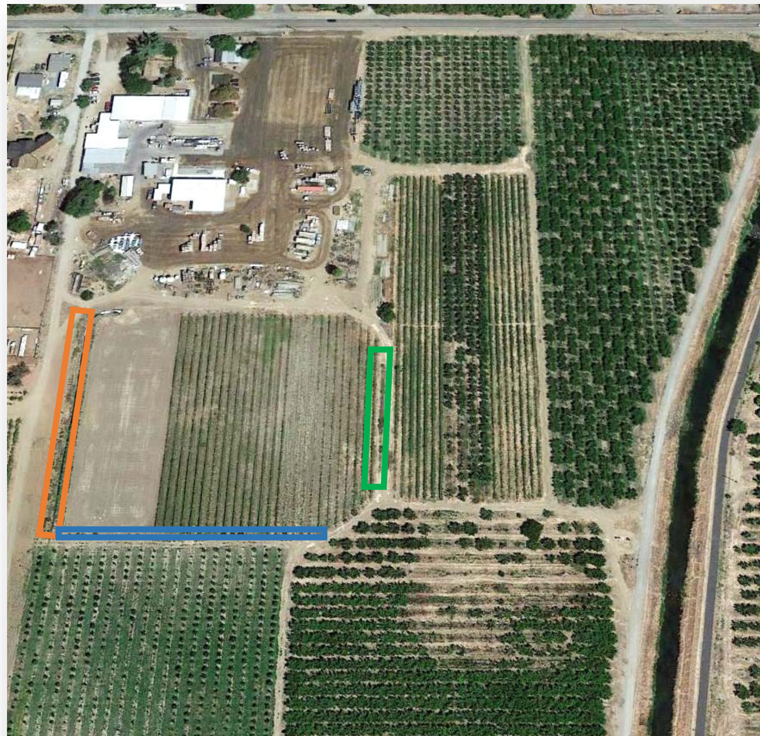
Perennial Habitat Gardens

Planting Time:
Mid-October

Ground Preparation:
There is low weed pressure in all 3 areas due to active management (mechanical and chemical). Some weed removal is necessary, and will be removed mechanically.

Area 1 (Orange): This area has sandy soil that dries out quickly. It will require either pre-irrigation or a large amount of water for each plant after installation.

Area 2 (Green) and 3 (Blue): These areas have hard soil, and will require pre-irrigation (for several hours the day before installation) to facilitate installation and establishment of new plants..



Habitat Design:
Area 1: The area is large – ~330 linear ft. – and has some spatial limitations but is relatively removed from other farm activities low-growing and large plants could be used here.

Quantity	Plant
4	*Salvia brandegeei*
4	*Salvia mellifera*
3	*Echium candicans*
5	*Encelia californica*
5	*Lavandula stoechas*
5	*Lavandula* 'Provence'
5	*Grindelia camporum* or *stricta*
5	Gaillardia 'Oranges & Lemons'
5	*Nepeta* x *faassennii*
5	*Erigeron glaucus*
5	*Eriogonum grande* var *rubescens*
5	*Coreopsis grandiflora* or *lanceolata*
5	*Solidago velutina* ssp. *californica*
5	*Perovskia atriplicifolia*
4	*Rosmarinus* 'Lockwood de Forest' or 'Ken Taylor'
5	*Salvia* 'Dara's Choice'
5	*Ceanothus* 'Julia Phelps' or 'Dark Star'

Area 2: This area is smaller, with ~150 linear ft., with some spatial limitations because it borders an access road.

Quantity	Plant
5	*Perovksia atriplicifolia*
6	*Lavandula stoechas*
6	*Nepeta* x *faassenii*
6	*Erigeron glaucus*
5	*Encelia californica*

Area 3: The ends of orchard rows will require hardy plants that can withstand occasional interference from farm activities (e.g. tractors). This area is also a good location for plants that will provide additional nesting materials.

Quantity	Plant
12	*Salvia brandegeei*
12	*Perovskia atriplicifolia*
12	*Salvia mellifera*

Newly installed perennial habitat garden. Note the dry, sandy soil. Each plant has a well formed around the base so they can be heavily watered to ease establishment.

Plant Preparation:

Container Size: Most new plants will be 1-gallon. Two slower-growing plants will be 5-gallon: *Cenaothus* 'Julia Phelps' and *Rosmarinus officinalis.*

Plants Needing Gopher Protection: *Encelia californica* and *Ceanothus* 'Julia Phelps'

Spacing: 4.5-5 ft in between plants in Areas 1 and 2

Initial Care:

Water: 4 gallons per plant in Area 1. 2 gallon per plant in Areas 2 and 3.

Other Applications: A small amount of fertilizer (~1/4 cup per gallon container or according to label) and organic or stone mulch around the base of most plants.

6. Irrigation

The seeded annuals should require no additional irrigation. However if they do need supplemental irrigation, the annuals seeded in most areas can receive water from the sprinklers used for orchard irrigation.

The perennial habitat gardens will use drip irrigation extended from the berry vines. They will be watered according to the following schedule.

Year 1
- Water once a week unless it is raining

Years 2 and 3
- Oct.-Apr.: Once every two weeks unless it is raining
- May-Sept: Once a week

Year 4 and Beyond
- Water once or twice a month depending on need.
- During summer months, watering may need to be increased, especially in Area 1 (sandy soil).

7. Adaptive Management

Seeded Annuals:
These areas will be left undisturbed until seed set, and then mowed. They cannot remain until Fall because access to those areas is needed for pruning and harvesting.

Weeding Schedule:
Once a month in Areas 1 and 2. Area 3 will be managed with the berry vines.

Pruning:
Areas 1 and 2: Most plants will be left to grow unmaintained, unless they develop dead spots or begin crowding out other plants.

Area 3: Plants will be pruned in late fall for space management so they do not interfere with access to the berry vines.

Special Notes: All *Perovskia* will be cut back to 10-12 inches in November. Leaving long dead stems will provide nesting habitat for *Ceratina.* Pruning *Salvia* species will also provide nesting habitat.

Water stressed *Salvia* 'Dara's Choice'. Note dry, brittle leaves are good indicators of insufficient water or nutrients.

Ceratina nest in pruned *Salvia mellifera* stem.

Coreopsis lanceolata with spent flowers.

Coreopsis lanceolata deadheaded.

Deadheading:
The following plants will be pruned at the end of flowering to encourage new growth:

- *Coreopsis grandiflora*
- *Encelia californica*
- *Lavandula* 'Provence'
- *Nepeta* x *faassenii*

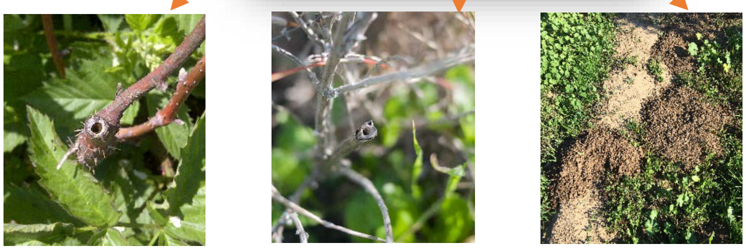
Amendments:
Fertilizer will be applied once per season.

8. Nesting Habitat

Recall from section 2 our target bee species:

Ceratina acantha and *C. nanula*	Excavate pithy stems
Bombus vosnesenskii	Have annual colonies that nest in abandoned rodent burrows and tussocks of grass
Halictus ligatus and *H. tripartitus*	Nest in flat, bare ground

Bombus vosnesenskii workers at entrance to underground nest.



Clockwise from top left: pruned berry vines left on guiding wires; storage area with flat bare ground; gopher holes in orchard; pruned *Perovskia* stem with *Ceratina* nest; and pruned blackberry stem with *Ceratina* nest.

Ceratina acantha* and *C. nanula:
Nesting habitat for *Ceratina* will be increased by:

1. Leaving pruned dead berry vines on the guiding wires
2. Bundling dried blackberry stems and attaching them to posts at the ends of berry rows;
3. Pruning habitat plants such as *Perovskia* and *Salvia* species

Bombus vosnesenskii:
There are plenty of gophers holes readily available for *Bombus vosnesenskii* colonies in most orchards. No additional work is necessary to increase habitat.

Halictus ligatus* and *H. tripartitus
At this location, there is plenty of bare, flat ground close to the habitat in the storage area. The area to the west of the berries also has significant flat, bare ground. No additional work is necessary to increase habitat.

Pictured:
1. Pruned blackberry vines left on guiding wires for *Ceratina* nesting habitat.
2. Flat, bare ground in storage area provides nesting habitat for *Halictus* spp.
3. *Ceratina* nest in pruned blackberry stem.
4. *Ceratina* nest in pruned *Pervoskia* stem.
5. Gopher holes in orchards provide nesting habitat for *Bombus* spp.

9. Chemical Management

Because this is a conventional farm, precautions must be taken to avoid unnecessary exposure of bee pollinators to potentially harmful chemicals. Ideally, pesticide use can be eliminated or reduced whenever possible. At this location both pesticides and herbicides will be used but they will be timed carefully to avoid exposure and will never be sprayed on or around installed habitat plants.

Pesticides will be applied according to the following schedule:
- Sprayed either early in the morning or late afternoon when bee activity is lowest.
- Single applications will be made before the crop bloom and after the harvest. No spraying will be done while crops are blooming to avoid exposure to bee populations.

Herbicides will be applied in the following manner:
- Sprayed only along berms of orchard rows.
- Single applications will be made before the crop bloom, after fruit set, and in late Fall.

Tips for Chemical Applications

Pesticides:
1. Use the UC IPM Bee Precaution website for impacts of individual ingredients on bee populations.
2. Try to reduce drift as much as possible.
3. Time sprays during periods that will minimize unnecessary exposure.

Herbicides:
1. Use a non-persistent herbicide, ideally one approved for organic operations.
2. Try to spray selectively with a backpack sprayer rather than widespread application.
3. Time sprays to minimize unnecessary exposure to bees and their floral hosts.
4. Avoid herbicides such as Paraquat and Gramoxone that are toxic to bees. (Xerces Society 2015).

10. Estimated Costs

The cost breakdown for installing this habitat comprised of 6.75 acres of seeded annual wildflowers and 144 perennial habitat plants is as follows.

Plant	Lbs Seed/Acre	Price/Pound	Price/Acre	Total
Eschscholzia californica	6lbs	$14.00	$84.00	$71.40
Phacelia cicutaria	3lbs	$35.00	$105.00	$89.25
Phacelia tanacetifolia	3lbs	$12.00	$36.00	$30.60
Pollinator Mix	3lbs (2 lbs of *E. californica*, 1 lb *P. cicutaria*, 1 lb *P. tanacetifolia*)	(see above)	$75.00	$315.00
			Total:	$506.25

Container Size	Qty	Average Price	Total
1 gallon	135	$6.50	$877.50
5 gallon	9	$20.00	$180.00
		Total:	$1057.50

Equipment	Qty	Average Price	Total
1000’ ½ (16mm) Polyethylene Blank Drip Tubing	1	$100.00	$100.00
500’ 1/8 in Vinyl or Poly Micro Tubing	1	$20.00	$20.00
Emitters (25-pack)	6	$8.00	$48.00
Stakes (10-pack)	15	$2.00	$30.00
		Total:	$198.00

Total Seeded Annual Wildflower Costs: $506.25
Total Perennial Habitat Garden Costs: $1255.50

Total Habitat Installation Costs: $1761.75

Chapter 6: Habitat and Bee Monitoring

So how does one evaluate a habitat's success? For most farmers, success will be measured by increased rates of bee visitations to crop flowers. Standard per-acre rates of managed pollinators, in the absence of native bees, have been estimated at:

- 1-2 honey bees hives (30-120,000 honey bee workers)
- 4 bumble bee hives (~800 bumble bee workers)
- 20,000 leaf-cutter bees
- Or 250 female mason bees (for fruit trees) (Vaughan 2015)

While per-acre rates for most native bees have not yet been determined, a lot can be gleaned about habitat success by observing native bees on habitat and crop flowers. Some questions to consider while observing bees are:

- Are bees other than honey bees visiting crop flowers?
- Are they visiting in large numbers?
- What resources are they collecting?
- How often are they visiting crop flowers?
- Are they visiting multiple flowers on a plant? Multiple flowers between plants? Only one flower on a single plant?
- What times of day are they visiting?
- Are honey bees visiting at the same time?
- Are the honey bees and native bees interacting?

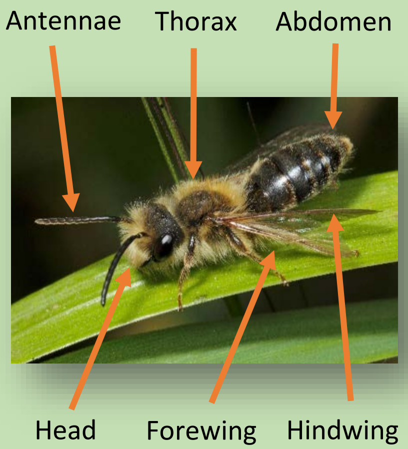
If bees other than honey bees are regularly observed visiting crop flowers, particularly visiting multiple flowers within and between trees**,** habitat can be considered a success. Being able to recognize different bee groups on habitat and crop flowers can be very useful for adaptive management. For example, if greater numbers of *Andrena* species are observed visiting orchard flowers after a habitat is installed, more habitat plants can be added to target those species.

In order to make informed observations, it is important to be knowledgeable about some of the general identifying characteristics of common bee pollinators. The following 3 characteristics are most useful:

1. Pollen collection method
2. Bee size and shape
3. Bee color

1. **Pollen Collection Method:** Bees collect pollen in 1 of 3 ways: on the legs, on the abdomen, or in the crop, where the bee ingests the pollen and regurgitates it back at the nests. The following are the most common bee groups in agricultural areas that use each of these methods.
    - **Legs:** *Andrena, Bombus, Ceratina*, *Halictus,* and *Lasioglossum*
    - **Abdomen:** *Megachile* and *Osmia*
    - **In the crop (ingestion and regurgitation):** *Hylaeus*

Anatomy of a Bee:



2. **Size and Shape:** Bees vary widely in size and shape, not only across groups but within groups. Some are large and stout like the large carpenter bees (*Xylocopa* spp.). Others are smaller than a grain of rice and are often confused as flies, such as the masked bees (*Hylaeus* spp.). Honey bees (see sample profile below) are a good reference for gauging the sizes of other bees for identification purposes.

3. **Color:** It may be surprising that not all bees are striped yellow and black. In fact, bees come in a wide variety of colors, ranging from metallic blue to gunmetal green to black. These bees are often mistaken for other insects, most commonly flies and wasps.

The Bee Profiles for each target bee species in the Resources section can help with general identifications.

"Wanna-Bee" Examples:

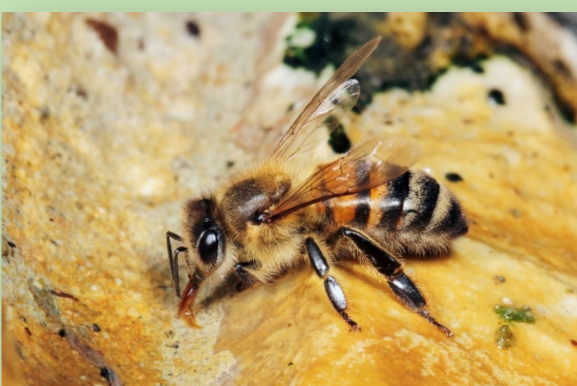
Osmia algaia
Mason Bee

Ornidia sp.
Metallic Hoverfly

Hylaeus punctatus
Masked Bee

Pisonopsis sp.
Wasp

Example: *Apis mellifera* (European Honey Bee)



Apis mellifera
European Honey Bee

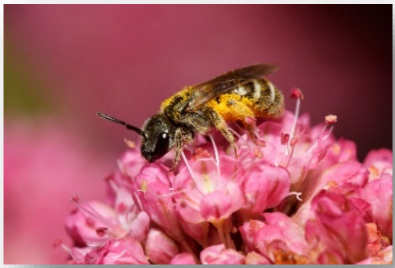
Pollen Transport: Transported as moistened pellets on hind legs.

Size and Shape: Medium-sized (~1/2 in long) and thick bodied

Color: Dark thorax and head with pale hair bands on abdomen.

But how can these characteristics be used to identify bees in the field? The following example will walk through the process of arriving at a general identification through process of elimination. The information presented can be found in the Bee Profiles.

General Bee Identification Example



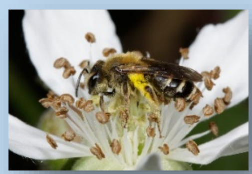
Group/Species: ?

Pollen Transport: On outer parts of hind legs to sides of thorax.

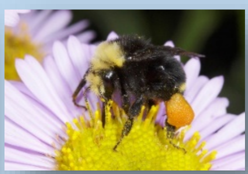
Size and Shape: Small (it is on an *Eriogonum grande* var *rubescens* flower for scale). Elongate body.

Color: Dark thorax and head with pale hair bands on abdomen.

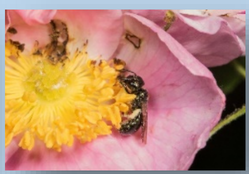
Step 1: Identify which bee groups collect pollen on legs.



***Andrena* spp.**
On outer part of hind legs to back side of thorax



***Bombus* spp.**
Transported as moistened pellets on hind legs

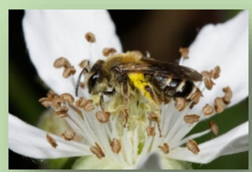


***Ceratina* spp.**
On outer part of hind legs

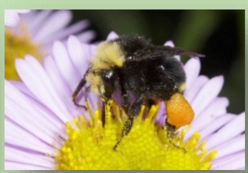
***Halictus* spp.**
On outer part of hind legs to side of thorax

Apis mellifera
Transported as moistened pellets on hind legs

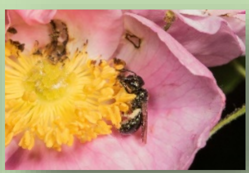
Step 2: Eliminate bee groups that are larger than ½ inch and have stout or robust bodies.



***Andrena* spp.**
Large to small. Elongate slender bodies.



***Bombus* spp.**
Medium to very large. Stout-bodied.



***Ceratina* spp.**
Small to tiny. Elongate bodies.

***Halictus* spp.**
Medium to small. Elongate bodies.

Apis mellifera
Medium. Thick-bodied.

Step 3: Eliminate bee groups that do not have stripes or dark thorax and abdomen.

***Andrena* spp.**
Pale thorax and pale stripes on abdomen.

***Ceratina* spp.**
Dark metallic gun-metal green.

***Halictus* spp.**
Dark bodies with pale stripes on abdomen.

Step 4: General identification.

***Halictus* spp.**
Sweat Bee

Pollen Transport: On outer parts of hind legs to sides of thorax. Rather messy collectors.

Size and Shape: Medium to small. Elongate bodies. Females are larger.

Color: Dark with pale hair bands on abdomen.

Chapter 7: Conclusions

There are many unknowns in farming that are only increasing in the face of changing environmental and market conditions. In recent years farmers have been facing a plethora of new challenges, including pollinator decline. Addressing these challenges by implementing and adapting new conservation technologies will help farmers continue fulfilling the vital agricultural needs of the world.

As unique as each individual farming operation is, there are many opportunities within most farming operations for native bee habitat. Successful native bee habitat will work to draw target native bee species for specific crops and will be adapted to existing systems and structures of individual operations. Starting with a farm evaluation, producers can identify existing habitat and identify opportunities for additional habitat. Reaching out to specialists at NRCS and other organizations will help producers develop operation-specific plans and gain access to in-depth resources.

Wild pollinators, such as native bees, play an important role in the resiliency and sustainability of California's agriculture. By implementing native bee habitat within farming operations, producers are taking important steps to ensure current and future generations enjoy the diversity and quality of food and life existing today.

Resources

Organizations for Technical and Financial Support

Xerces Society
An international, nonprofit organization dedicated to protecting invertebrate populations. Their organization has several programs, one of the most prominent being their Pollinator Conservation Program. Staff across the U.S. can provide technical assistance and resources to producers interested in implementing habitat for pollinators.
www.xerces.org

USDA Natural Resource Conservation Service (NRCS)
A branch of the US Department of Food and Agriculture dedicated to providing producers with financial and technical assistance to implement conservation practices.
www.nrcs.usda.gov

UC Cooperative Extension (UCCE)
A state-wide network part of the Division of Agriculture and Natural Resources (ANR) of the University of California. UCCE staff conduct and disseminate scientific knowledge to producers on a wide variety of agricultural topics.

Sustainable Agriculture Research and Education (SARE)--Western
A US Department of Food and Agriculture program that produces producer-oriented guidelines and recommendations through competitive grants conducted through partnerships by producers, researchers, and agricultural professionals.

Pollinator Management and Habitat Planning Guides and Resources

University of California, Urban Bee Lab
Farming for Native Bees Video Series
http://www.helpabee.org/farming-for-bees.html

Xerces Society
Pollinator Habitat Assessment Form and Guide
http://www.xerces.org/wp-content/uploads/2009/11/PollinatorHabitatAssessment.pdf

Pollinator Habitat Installation Guides
http://www.xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/

Attracting Native Pollinators. Protecting North America's Bees and Butterflies
Mader, E., M. Shepherd, M. Vaughan, S.H. Black, and G. LeBuhn. 2011. North Adams, MA: Storey Publishing. 320 pp.

Farming for Bees. Guidelines for Providing Native Bee Habitat on Farms.
Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S.H. Black. 2015. Xerces Society. 80 pp.

USDA Natural Resource Conservation Service (NRCS)
How Farmers Can Help Pollinators
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/pollinate/farmers/

Using 2014 Farm Bill Programs for Pollinator Conservation
http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=37370.wba

Sustainable Agriculture Research and Education (SARE)
How to manage the blue orchard bee. As an orchard pollinator.
Bosch, J. and W. Kemp. 2001. SARE Handbook 5. 88pp.

Managing Alternative Pollinators. A handbook for beekeepers, growers and conservationists.
Mader, E., M. Spivak and E. Evans. 2010. 162 pp. SARE Handbook 11.

The Integrated Crop Pollination Project
Tools for Growers
http://icpbees.org/tools-for-growers/

Pollinator Partnership
Ecoregional Planting Guides
http://www.pollinator.org/guides

Resources

Habitat and Bee Monitoring Guides and Resources

Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat
http://www.xerces.org/streamlined-bee-monitoring-protocol/

Guide for Bee Inventory Plots
http://online.sfsu.edu/~beeplot/

Sam's Very Handy Bee Manual
http://www.pwrc.usgs.gov/nativebees/Handy%20Bee%20Manual/Handy%20Bee%20Manual.pdf

Sam's How-To Videos
ftp://ftpext.usgs.gov/pub/er/md/laurel/Droege/How-to/

Bee Identification Resources

Bee Basics: An Introduction to Our Native Bees.
Moissett, B., and S. Buchmann. 2010. USDA. 40pp.

California Bees and Blooms: A Guide for Gardeners and Naturalists
Frankie, G.W., R.W. Thorp, R.E. Coville, and B. Erter. 2014. Heyday Books. 320pp.

Field Guide to the Common Bees of California: Including Bees of the Western United States
LeBuhn, G. 2013. California Natural History Guides. UC Press. 192pp.

The Bees in Your Backyard: A Guide to North America's Bees
Wilson, J.S., and O.J.M. Carril. 2015. Princeton Univ. Press. 288pp.

Bumble Bees of the Western United States
Kioch, J., J. Strange, and P. Williams. 2012. Pollinator Partnership. www.xerces.org/wp-content/uploads/2008/.../Western_BB_guide.pdf

Bumble Bees of North America: An Identification Guide
Williams, P.H., R.W. Thorp, L.L. Richardson, and S.R. Colla. 2014. Princeton Univ. Press. 208pp.

BugGuide
http://bugguide.net/node/view/8267/bgpage

Bee Flashcards
http://quizlet.com/64454746/flashcards

Bee Observer Cards
http://eol.org/info/disc_observer>http://eol.org/info/disc_observer

Discover Life Bee ID Guides
http://www.discoverlife.org/mp/20q?search=Apoidea

Additional Readings by Topic

Crop Pollination

Bee Pollination in Agricultural Ecosystems.
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Crop Pollination by Bees
Delaplane, K.S., and D.F. Mayer. 2000. CABI Publishing. 344pp.

Insect Pollination of Cultivated Crop Plants.
McGregor, S.E. 1976. USDA/ARS Agric. Handbook. No. 496. 411pp.

Agricultural Chemicals

Pollinator Protection: A Bee and Pesticide Handbook.
Johansen, C., and D. Mayer. 1990. Wicwas Press. 212pp.

How to Reduce Bee Poisoning from Pesticides
Johansen, E., L.A. Hooven, and R.R. Sagili. 2013. Oregon State Universtiy.

Are Neonicotinoids Killing Bees? A review of research into the effects of neonicotinoid insecticides on bees, with recommendations for action.
Hopwood, J., M. Vaughan, D. Biddinger, M. Shepherd, A. Code, E. Mader, S. Hoffman Black, and C. Mazzacano. 2014. Xerces Society. 70pp.

Benefits of Bee Farming

Flower Plantings Increase Wild Bee Abundance and the Pollination Services Provided to a Pollination-Dependent Crop
Blaauw, Brett R., and Rufus Isaacs. 2014. Journal of Applied Ecology. 51(4):890-898.

Hedgerows in an Agri-Natural Landscape: Potential Habitat Value for Native Bees
Hannon, L.E. and T.D. Sisk. 2009. Biological Conservation. 142(10):2140-2154.

Pest Control and Pollination Cost Benefit Analysis of Hedgerow Restoration in a Simplified Agricultural Landscape
Morandin, L.A., R.F. Long, and C. Kremen. 2016. Journal of Economic Entomology.

Wild Pollinators: Agriculture's Forgotten Partners
Wild Farm Alliance. 2007. 8pp.

General Pollinator Readings

The Forgotten Pollinators
Buchmann, S.L. and G.P. Nabhan. 1996. Island Press. 292pp.

Glossary of Bee and Plant Related Terms

Aggregated (Aggregations): Clustered together.

Annual Colonies: Colonies lasting only one year, initiated by an overwintered queen in spring, and ending by fall with the production of new males and females. After mating, females enter hibernation and the rest of the colony members die at the end of the season.

Annual: A plant that lives only one year.

Antennae: The elbowed feelers attached at the front of the face, usually about the middle.

Colony: The population of bees in a nest with a queen and her sterile female offspring (workers) cooperating in division of labor, and usually with some *drones*.

Deciduous: A plant that drops leaves in winter (or dry season), or dies to the ground.

Evergreen: A plant that bears leaves throughout the year.

Flower head: A tight cluster of flowers often resembling a single flower, especially in Asteraceae.

Generalist Foragers: Female bees that are not restricted to one or a few kinds of flowers, but collect pollen from many different flowering plants (*polyleges*).

Hive: The container or structure within which a colony of social bees resides.

Inflorescence: A term for the arrangement of flowers.

Larva (Larvae): The immature stages of a bee in which growth and development occur.

Lifecycle: The period of time from egg through the death of the adult individual.

Native: Occurring in an area prior to human activity (i.e., not introduced by humans either intentionally or unintentionally).

Perennial: A plant that lives several years.

Petal: One of a whorl of (usually) conspicuous, variously colored flower parts that (usually) serve as the primary attractors.

Pollen: Dust-like particles that contain the male *gametes* of flowers, produced by *anthers.*

Robust: Stout, heavy set, nearly as wide as long.

Social (Eusocial): A colony in which a queen overlaps with her adult offspring and cooperative division of labor occurs.

Solitary: Individual females that build their own nests without any cooperation from other females and without overlap or cooperation from their adult offspring.

Specialist Foragers: Female bees that restrict their pollen collection to flowers of one or a few closely related species of flowers.

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