TECHNICAL NOTES

U.S. Department of Agriculture **Natural Resources Conservation Service**

TN – BIOLOGY – CA-19 April 2009

Pollinator Biology and Habitat in California

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Bumble bee on California poppy (Photo by Mace Vaughn)

Sweat bees on Gumplant (Photo by John Anderson)

This technical note provides information on how to plan for, protect, create and manage habitat for pollinators, particularly native bees, but also including honey bees and other native pollinators in agricultural settings using riparian buffers, windbreaks, hedgerows, alley cropping, field borders, filter strips, waterways, range plantings and other NRCS practices.

Pollinators are an integral part of our environment and our agricultural systems; they are important in 35% of global crop production (Klein et al. 2007). Animal pollinators include bees, butterflies, moths, wasps, flies, beetles, ants, bats and hummingbirds. This technical note focuses on native bees, the most important pollinators in temperate North America, but also addresses the habitat needs of butterflies and, to a lesser degree, other beneficial insects. We welcome your comments for improving any of the content of this publication for future editions. Please contact Thomas Moore at thomas.moore@ca.usda.gov to improve this publication.

Worldwide, there are an estimated 20,000 species of bees (Michener 2000), with approximately 4,000 species native to the United States (Winfree et al. 2007a). The non-native European honey bee (*Apis mellifera*) is the most important crop pollinator in the United States. Honey bees pollinate an estimated $15 billion in commercial crops in the U.S. However, the number of honey bee colonies is in decline because of disease and other factors (National Research Council 2007), making native pollinators even more important to the future of agriculture. Native bees provide free pollination services, and are often specialized for foraging on particular flowers, such as squash, berries, or orchard crops (e.g. Tepedino 1981, Bosch & Kemp 2001, Javorek et al. 2002). This specialization results in more efficient pollination and the production of larger and more abundant fruit from certain crops (Greenleaf & Kremen 2006, Klein et al. 2007). Native bees contribute an estimated $3 billion worth of crop pollination annually to the U.S. economy (Losey & Vaughan 2006).

Undeveloped areas on and close to farms can serve as long-term refugia for native wild pollinators. Protecting, enhancing or providing habitat is the best way to conserve native pollinators (Kremen et al. 2007) and, at the same time, provide pollen and nectar resources that support local honey bees. On farms with sufficient natural habitat, native pollinators can provide all of the pollination for some crops (Kremen et al. 2002, Kremen et al. 2004, Winfree et al 2007b).

Pollinators have two basic habitat needs: a diversity of flowering native or naturalized plants for forage, and egg-laying or nesting sites. The NRCS can assist landowners with providing adequate pollinator habitat by, for example, suggesting locally appropriate plants for forage and offering advice on how to provide nesting or egg-laying habitat.

Habitat enhancement for native pollinators and honey bees on farms, especially with native plants, provides multiple benefits. In addition to supporting pollinators, native plant habitat will attract beneficial insects that predate on crop pests and lessen the need for pesticides on the farm (Barbosa 1998, Landis et al. 2000, Nicholls et al. 2000, Lee et al. 2001, Van Emden 2003, Olsen & Wackers 2007). Pollinator habitat can also provide habitat for other wildlife, such as birds (Belfrage et al. 2005), serve as windbreaks, help stabilize the soil, and improve water quality.

Considerations for Honey Bees

With a social lifecycle consisting of a single queen, her daughter-workers, and male drones whose only purpose is to mate, honey bees represent what most people think of when bees are discussed. Their habit of producing useful products like excess honey and wax has inspired people to keep them in man-made hives since at least 900 BC.

While not native to North America, the European honey bee (*Apis mellifera*) remains a crucial agricultural pollinator. Upon its introduction to North America in 1622, the honey bee initially thrived, with feral colonies rapidly spreading across the continent by swarming from managed hives (the process by which an overgrown colony divides with half the colony flying away to find a new nest).

Unfortunately the subsequent accidental introduction of several major parasitic mites and bee diseases has slowly devastated both feral and managed honey bees in the U.S. In addition, the same habitat degradation and pesticide issues that have affected native bees have also taken a dramatic toll on honey bee populations. The result is that with the exception of feral Africanized honey bees, which escaped from a research facility in Brazil in 1957 and slowly moved north from the southwestern U.S., few feral honey bees exist in North America. Similarly, the number of managed honey bee hives in the U.S. has declined by 50% since 1945, while the amount of crop acreage requiring bee pollination continues to rise.

Beekeepers have also suffered in recent years due to declining honey prices; the result of low-cost imported honey. As a result, many commercial beekeepers have increasingly turned to a pollination-for-hire business model, making much of their income by renting bees to growers who need their crops pollinated. The advantage of honey bees to growers is they can be transported long distances, and because of their perennial nature, they can rapidly be deployed in large numbers at any time of year.

Solutions to the many parasite and disease problems facing honey bees will require additional research and new management practices. The issue of habitat degradation, however, can be addressed now. The same habitat enhancement guidelines outlined here that promote native bee populations, also promote honey bee populations and honey bee health. The critical factor for all bees is the presence of abundant pollen and nectar sources throughout spring, summer, and fall.

One habitat requirement for honey bees that is generally not as critical for native bees is access to water. Honey bees require water (which they carry back to the hive in their stomach) to cool their hives through evaporation and dilute honey to feed to their brood. Preferred water sources are shallow and calm with low approaches where bees can stand while they drink. It is imperative that water sources be clean and free of pesticides.

NRCS 9-Step Conservation Planning Process

This document addresses the resource concerns associated with pollinators by following the steps in the NRCS three-phase, nine-step planning process.

- Phase I - planners work with interested landowners to better understand pollinator conservation problems and identify existing opportunities to improve pollinator habitat.
- Phase II – focuses on the alternatives / site specific measures that protect existing pollinators and their habitats, while recommending appropriate management practices to develop additional areas as suitable pollinator habitat.
- Phase III - lays out approaches to implement enhancement, restoration, and management practices identified in the conservation plan, and then monitor the response of pollinators to the management practices implemented.

PLANNING PHASE I

Recognizing Existing Pollinator Habitat

Many growers may already have an abundance of habitat for native pollinators on or near their land. Having semi-natural or natural habitat available significantly increases pollinator populations (Kremen et al. 2004, Williams & Kremen 2007). Marginal lands such as field edges, hedgerows, sub-irrigated areas, and drainage ditches mimic natural early successional habitat and can offer both nesting and foraging sites (Carvell 2004). Woodlots, conservation areas, utility easements, farm roads, and other untilled areas may also contain good habitat. Often, poor quality soils, unfit for crops, may be useful instead as pollinator habitat (Morandin and Winston 2006). Here we provide information on habitat preferences so that planners may better recognize specific habitat resources that can be factored into whole farm systems planning.

Existing Plant Composition

When assessing pollen and nectar resources, it is important to look at all of the potential plant resources on and around a landowner or farmer's property, and which plants are heavily visited by bees and other pollinators. These plants include insect-pollinated crops, as well as the flowers – even "weeds" – in buffer areas, forest edges, hedgerows, roadsides, natural areas, fallowed fields and other vegetated areas. Insect-pollinated crops may supply abundant forage for short periods of time, and such flowering crops should be factored into an overall farm plan if a grower is interested in supporting wild pollinators (Banaszak 1992). However, for pollinators to be most productive, nectar and pollen resources are needed outside the period of crop bloom.

As long as a plant is not a noxious weed species that should be removed or controlled, producers might consider allowing some of the native or non-native forbs that are currently present onsite to bloom prior to their crop bloom, mow them during crop bloom, and then let them bloom again afterward. For example, dandelions, clover, and other non-native plants are often good pollinator plants (Free 1968, Mosquin 1971). Growers may also allow some unharvested salad and cabbage crops to bolt. In addition to pollinators, the predators and parasitoids of pests are attracted to the flowers of arugula, chervil, chicory, mustards and other greens, supporting pest management.

When evaluating existing plant communities on the margins of cropland, a special effort should be made to conserve very early and very late blooming plants. Early flowering plants provide an important food source for bees emerging from hibernation, and late flowering plants help bumble bees build up their energy reserves before entering winter dormancy (Pywell et al. 2005).

Nesting and Overwintering Sites

Bees need nest sites. When supporting populations of native bees, protecting or providing nest sites is as important, if not more important, as providing flowers (Tscharntke et al. 1998, Cane 2001, Potts et al. 2005). Similarly, caterpillar host plants are necessary for strong butterfly populations, if that is a management goal (Feber et al. 1996).

The ideal is to have nesting and forage resources in the same habitat patch, but bees are able to adapt to landscapes in which nesting and forage resources are separated (Cane 2001). It is important that these two key habitat components are not too far apart (Westrich 1996). The distance a bee can fly between nest site and forage area is related to its size (Greenleaf et al. 2007), and for many species may be no more than 200-300 meters (Gathmann & Tschamtke 2002). For larger bee species, such as bumble bees, foraging distances can be up to a couple of miles from the nest site. Therefore, taken together, a diversity of flowering crops, wild plants on field margins, and plants up to a half mile away on adjacent land can provide the sequentially blooming supply of flowers necessary to support resident populations of pollinators (Winfree et al. 2008)

Native bees often nest in inconspicuous locations. For example, many excavate tunnels in bare soil, others occupy tree cavities, and a few even chew out the soft pith of the stems of plants like elderberry or blackberry to make nests (O'Toole & Raw 1999, Michener 2000). It is important to retain as many naturally occurring sites as possible and to create new ones where appropriate.

Most of North America's native bee species (about 70 percent or very roughly 2,800 species) are ground nesters. These bees usually need direct access to the soil surface (Potts et al. 2005) to excavate and access their nests. Ground-nesting bees seldom nest in rich soils, so poor quality sandy or loamy soils may provide fine sites. The great majority of ground-nesting bees are solitary, though some will share the nest entrance or cooperate to excavate and supply the nest (Michener 2000). Still other species will nest independently, but in large aggregations with hundreds or thousands of bees excavating nests in the same area.

Approximately 30 percent (around 1,200 species) of bees in North America are wood nesters. These are almost exclusively solitary. Generally, these bees nest in abandoned beetle tunnels in logs, stumps, and snags. A few can chew out the centers of woody plant stems and twigs (Michener 2000), such as elderberry, sumac, and in the case of the large carpenter bee, agave or even soft pines. Dead limbs, logs, or snags should be preserved wherever possible. Some wood-nesters also use materials such as mud, leaf pieces, or tree resin to construct brood cells in their nests (O'Toole & Raw 1999).

Bumble bees are the native species usually considered to be social. There are about 45 species in North America (Kearns & Thomson 2001). They nest in small cavities, such as abandoned rodent nests under grass tussocks or in the ground (Kearns & Thompson 2001). Leaving patches of rough undisturbed grass in which rodents can nest will create future nest sites for bumble bees (McFrederick & LeBuhn 2006).

A secondary benefit of flower-rich foraging habitats is the provision of egg-laying sites for butterflies and moths. They lay their eggs on the plant on which their larva will feed once it hatches (Croxton et al. 2005, Feber et al. 1996, Ries et al. 2001). Some butterflies may rely on plants of a single species or genus for host-plants (the monarch is an example, feeding only on species of milkweed, *Asclepias* sp.), whereas others may exploit a wide range of plants, such as some swallowtails (*Papilio* sp.), whose larvae can eat a range of trees, shrubs, and forbs (Scott 1986). In order to provide egg-laying habitat for the highest number of butterflies and moths, growers should first provide plants that can be used by a number of species. Later those plants can be supplemented with host-plants for more specialized species. Consult a book on your region's butterfly fauna to find out about species' specific needs.

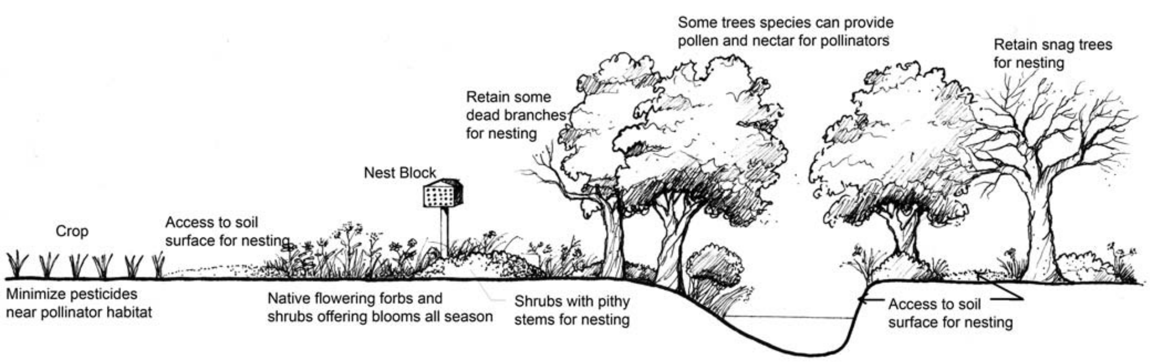

Figure 1. From: Agroforestry Note – 34: "Enhancing Nest Sites for Native Bee Crop Pollinators"

Table 1. General Native Pollinator Habitat Requirements [Adapted from: Native Pollinators. Feb. 2006. NRCS Fish and Wildlife Habitat Management Leaflet. No. 34.

Pollinator	Food	Shelter
Solitary bees	Nectar and pollen	Most nest in bare or partially vegetated, well-drained soil; many others nest in narrow tunnels in dead standing trees, or excavate nests within the pith of stems and twigs; some construct domed nests of mud, plant resins, saps, or gums on the surface of rocks or trees
Bumble bees	Nectar and pollen	Most nest in small cavities (approx. softball size), often underground in abandoned rodent nests or under clumps of grass, but can be in hollow trees, bird nests, or walls
Honey Bees	Nectar and pollen	Hollow trees for feral colonies
Butterflies and Moths – egg	Non-feeding stage	Usually on or near larval host plant
Butterflies and Moths – caterpillar	Leaves of larval host plants	Larval host plants
Butterflies and Moths - pupa	Non-feeding stage	Protected site such as a bush, tall grass, a pile of leaves or sticks or, in the case of some moths, underground
Butterflies and Moths – adult	Nectar; some males obtain nutrients, minerals, and salt from rotting fruit, tree sap, animal dung and urine, carrion, clay deposits, and mud puddles	Protected site such as a tree, bush, tall grass, or a pile of leaves, sticks or rocks

PLANNING PHASE II

Development of Alternative Management Practices that Protect Pollinators and their Habitat

When farmers and landowners recognize the potential pollinator habitat on their land, they can then work to develop site specific measures to protect these resources for pollinators and their habitats. Of highest priority, is the development of management practices that provide guidance for the implementation of recommended practices. Upland Wildlife Habitat Management (645), or Restoration and Management of Rare or Declining Habitats (643) are the best management practices to guide restoration, enhancement, and maintenance activities of suitable pollinator habitat. These management practices have the greatest potential to effect long term sustainability of the habitat requirements for pollinators. When needed to achieve the landowner's objectives the planner may recommend implementing "accelerating" practices to directly improve resource conditions when changes in management cannot achieve the resource management goals. These vegetative or structural practices act as a catalyst to overcome some impediment to achieving the desired condition. Lastly, planners may recommend additional practices identified as facilitating practices. The goal of facilitating practices is to enhance the land managers' ability to properly manage the land under the current land use.

These alternative management practices consist of conserving the food and nest sources for resident pollinators, as well as actively reducing direct mortality of the pollinators themselves. While insecticides are an obvious threat to beneficial insects like bees, other farm operations or disturbance, such as burning and tilling, can also be lethal to pollinators (Kim et al. 2006).

A. Minimize Pesticide Use

Pesticides, including insecticides and herbicides, are detrimental to a healthy community of native pollinators and honey bees. Insecticides not only kill pollinators (Johansen 1977), but sub-lethal doses can affect their foraging and nesting behaviors (Thompson 2003, Decourtye et al. 2004, Desneux et al. 2007), often preventing pollination. Herbicides can kill plants that pollinators depend on when crops are not in bloom, thus reducing the amount of foraging and egg-laying resources available (Kremen 2002, Tscharntke et al. 2005).

If pesticides cannot be avoided, they should be applied directly on target plants to prevent drift, and broad-spectrum chemicals should be avoided if at all possible (Zhong et al. 2004). Similarly, crops should not be sprayed while in bloom and fields should be kept weed free (or mowed just prior to insecticide applications) to discourage pollinators from venturing into the crop if it needs to be sprayed outside of the bloom period. Nighttime spraying, when bees are not foraging, is one way to reduce bee mortality (Riedl et al. 2006, Tew 1997, Johansen & Mayer 1990). Periods of low temperatures may also be good for spraying since many bees are less active. However, the residual toxicity of many pesticides tends to last longer in cool temperatures. For example, dewy nights may cause an insecticide to remain wet on the foliage and be more toxic to bees the following morning, so exercise caution (Vaughan et al. 2007, Tew 1997, Johansen & Mayer 1990).

In general, while pesticide labels may list hazards to honey bees, potential dangers to native bees are often not listed. For example, many native bees are much smaller in size than honey bees and affected by lower doses. Also, honey bee colonies may be covered or moved from a field, whereas wild natives will continue to forage and nest in spray areas.

The use of selective insecticides that target a narrow range of insects, such as *Bacillus thuringiensis* (*Bt*) for moth caterpillars, is one way to reduce or prevent harm to beneficial insects like bees. Generally dusts and fine powders that may become trapped in the pollen collecting hairs of bees and consequently fed to developing larvae are more dangerous than liquid formulations (Riedl et al. 2006). Alternatives to insecticides are also available for some pests, such as pheromones for mating disruption, and kaolin clay barriers for fruit crops. Additional information is available at University of California Integrated Pest Management (UC IPM) Program http://www.ipm.ucdavis.edu/NEWS/index.html

Landowners who encourage native plants for pollinator habitat will inevitably be providing habitat that also will host many beneficial insects that help control pests naturally, and may come to depend less on pesticides.

In addition to providing pollinator habitat, windbreaks, hedgerows, and conservation headlands can be effective barriers to reduce pesticide drift from adjacent fields (Ucar & Hall 2001, Longley & Sotherton 1997). Spray drift can occur either as spray droplets or vapors—as happens when a volatile liquid changes to a gas. Factors affecting drift include weather, application method, equipment settings, and spray formulation (Ozkan 2000). Weather related drift increases with temperature, wind velocity, convection air currents, and during temperature inversions. Regardless of the chemical or type of application equipment used, sprayers should be properly calibrated to ensure that excess amounts of pesticide are not applied.

Wind related drift can be minimized by spraying during early morning or in the evening when wind velocity is often lower. However even a light wind can cause considerable drift. Pesticide labels will occasionally provide specific guidelines on acceptable wind velocities for spraying a particular product (Ozkan 2000).

Midday spraying is also less desirable because as the ground warms, rising air can lift the spray particles in vertical convection currents. These droplets may remain aloft for some time, and can travel many miles. Similarly, during temperature inversions spray droplets become trapped in a cool lower air mass and move laterally above the ground. Inversions often occur when cool night temperatures follow high day temperatures, and are usually worse in early morning before the ground warms. Low humidity and high temperature conditions also promote drift through the evaporation of spray droplets and the corresponding reduction of particle size. Optimal spray conditions for reducing drift occur when the air is slightly unstable with a very mild steady wind (Ozkan 2000).

Spray application methods and equipment settings also strongly influence the potential for drift. Since small droplets are most likely to drift long distances, aerial applications and mist blowers should be avoided whenever possible. Standard boom sprayers should be operated at the lowest effective pressure and with the nozzles set as low as possible. For example, drop nozzles can be used to deliver insecticides within the crop canopy where it is less likely to be carried by wind currents (Ozkan 2000).

Nozzle type also has a great influence on the amount of drift a sprayer produces. Turbo jet, raindrop, and air-induction nozzles produce less drift than conventional nozzles. Standard flat fan or hollow cone nozzles are generally poor choices. Select nozzles capable of operating at low pressures (15 to 30 psi) to produce larger, heavier droplets (Ozkan 2000).

Finally, oil-based chemical carriers produce smaller, lighter, droplets than water carriers and should also be avoided when possible. Consider using thickening agents if they are compatible with your pesticide (Ozkan 2000).

If pest control is necessary, use bee-safe insecticides if possible. If you are uncertain about the toxicity of a product to bees refer to the tables in the Northwestern extension publication 591 “How to Reduce Bee Poisoning from Pesticides (available on line at http:/extension.oregonstate.edu/catalog/pdf/pnw/pnw591.pdf.). Where herbicides are needed for spot weed control, use carefully to preserve pollinator plants. Another source is the UC

IPM program information on relative toxicity of pesticide use in cucurbits to natural enemies and honey bees at http://www.ipm.ucdavis.edu/PMG/r116900311.html .

B. Minimize the Impact of Mowing, Haying, Burning, or Grazing

Only a portion of pollinator habitat should be burned, mowed, grazed, or hayed at any one time in order to protect overwintering pollinators and foraging larvae and adults (Black et al 2008). This will allow for recolonization of the disturbed area from nearby undisturbed refugia, an important factor in the recovery of pollinator populations after disturbance (Hartley et al. 2007). In order to maximize foraging and egg-laying opportunities, maintenance activities should be avoided while plants are in flower (Smallidge & Leopold 1997). Ideally, mowing or haying should be done only in the fall or winter (Munguira & Thomas 1992).

C. Protect Ground Nesting Bees

In order to protect nest sites of ground-nesting bees, avoid tilling (Shuler et al. 2005) and flood-irrigating (Vaughan et al. 2007) areas of bare, or partially bare ground that may be occupied by nesting bees. Grazing such areas can also disturb ground nests (Gess & Gess 1993, Vinson et al. 1993). Similarly, using fumigants like Chloropicrin for the control of soilborne crop pathogens (such as *Verticillium* wilt), or covering large areas with plastic mulch could be detrimental to beneficial ground nesting insects like bees.

Weed control alternatives to tillage include the use of selective crop herbicides, flame weeders, and hooded sprayers for between row herbicide applications.

Entrances to these ground nesting nests resemble ant hills but have larger entrances

Pollinator habitat along edges of riparian zone (photo by John Anderson)

D. Protect Tunnel-Nesting Bees

Tunnel-nesting bees will make their homes in the abandoned tunnels of wood-boring beetles and the pithy centers of many woody plant stems. Allowing snags and dead trees to stand, as long as they do not pose a risk to property or people, and protecting shrubs with pithy or hollow stems, such as elderberry, blackberry, and box elder, will go a long way towards supporting these solitary bees.

Enhance and Develop New Pollinator Habitat

Landowners intending to increase their pollinator populations may need to implement more than the management practices that minimize negative impacts to pollinators or protect existing foraging or nesting sites. High quality foraging habitat may be limited. Accelerating or facilitating practices can be implemented to increase the available foraging habitat, that include a range of plants that bloom and provide abundant sources of pollen and nectar throughout spring, summer, and fall. Such habitat can take the form of designated pollinator meadows ("bee pastures"), demonstration gardens, orchard understory plantings, hedgerows and windbreaks with flowering trees and shrubs, riparian and rangeland re-vegetation efforts, flowering cover crops and green manures, and countless other similar efforts.

Where possible, planting local native plants is often preferred for their ease of establishment, greater wildlife value, and their evolutionary mutualism with native pollinators (Kearns et al. 1998). Non-native plants may be suitable, however on disturbed sites, for specialty uses such as cover cropping, and where native plants are not available. Mixtures of native and non-native plants are also possible, as long as non-native species are naturalized and not invasive.

A. Site Selection

Site selection for installing new pollinator-enhancement habitat should begin with a thorough assessment of exposure and soil conditions, but also must take into account land use and available resources.

1. ASPECT: In general, areas of level ground, with full sun throughout the day, and good air circulation offer the most flexibility. East and south-facing slopes may also be acceptable as long as erosion is controlled during the installation process. Unless the site is located near a large body of water, west-facing slopes in many climates are often subjected to hot afternoon sunlight, and drying winds. Under such conditions west-facing slopes tend to be naturally dominated by grasses, with limited benefits to pollinators. North-facing slopes are often cooler and tend to be dominated by trees.

2. SUN EXPOSURE: Since some plants require full sun or shaded conditions to thrive, the planting design should allow for sun-loving plants to remain in full sun as the habitat matures. Plantings can also be installed in several phases, for example, allowing trees and shrubs to develop an over-story prior to planting shade-loving herbaceous plants below. Generally, plants will flower more, and thus provide greater amounts of nectar and pollen, when they receive more sunlight than when they are fully shaded.

3. SOIL CHARACTERISTICS: Soil type is also an important consideration when selecting a site, with some plants favoring particular soil textures such as sand, silt, clay, or loam. Drainage, salinity, pH, organic content, bulk density, and compaction are some of the other factors that will influence plant establishment. Many of these factors can be determined from local soil surveys, and the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/). Planning should emphasize those plants that will be adapted for the particular soil conditions faced.

Fertility, soil pathogens, the presence of rhizobium bacteria, and previous herbicide use should also be considered during the planning process (Packard 1997). Soil fertility will be most critical during early plant establishment, especially on previously cropped land. As the habitat matures, few if any inputs should be required, especially if native plants are selected. Similarly, previously cropped land may harbor soilborne pathogens that may inhibit plant development. Where such conditions exist, pathogen-resistant plant species should be considered. Conversely some soil microorganisms, such as rhizobium bacteria, are essential for the successful establishment of certain types of plants, legumes for example. If rhizobium bacteria are absent in the soil, specially inoculated seed is often available. Finally, herbicides like atrazine and trifluralin can inhibit seed germination (Packard 1997). These chemicals, soil pathogens, beneficial microorganisms, and soil fertility can all be tested for by state, and extension soil laboratories.

4. ADJACENT LAND USE: Along with exposure and soil conditions, adjacent plant communities and existing land use activities should be considered. For example, even if weeds are eliminated prior to planting, the presence of invasive plants adjacent to the restored habitat may result in a persistent problem that requires ongoing management (Steinauer 2003). Adjacent cropland can also present a challenge unless the enhancement site is protected from herbicide drift.

5. USE MARGINAL LAND: Some otherwise marginal land, such as septic fields and mound systems, can be perfectly suited for pollinator plantings. While trees may be problematic on such sites, forbs will generally not penetrate pipes or clog systems. As an added benefit, plants on these sites may help absorb excess nutrients from wastewater. Ditches, field buffer strips, and waterways can also be planted with pollinator-friendly plants rather than turf grass.

6. SIZE AND SHAPE: The larger the planting area, the greater the potential benefit to pollinator species. An area considered for enhancement should be at least at least 0.05 acre area in size, with a minimum size of two acres providing even greater benefits (Morandin & Winston 2006, Kremen et al. 2004). With herbaceous plantings, large, square planting blocks will minimize the edge around the enhancement site and thus susceptibility to invasion by weeds surrounding the perimeter. However, linear corridor plantings (e.g. along a stream or a hedgerow, or a crop border) will often be more practical. NOTE: consider requiring 1 or 2 acres for every 25 acres of cropped field.

B. Habitat Design

When designing a pollinator planting, first consider the overall landscape and how the new habitat will function with adjacent crops. From there, focus on the specifics of the planting, such as species diversity, bloom time, plant density, and the inclusion of grasses for weed control and soil stabilization.

1. LANDSCAPE CONSIDERATIONS: The first step in habitat design should be a consideration of how the area can work with adjacent landscape features.

For example, is the new habitat area located close enough to crops requiring pollination to be of significant value? Remember that flight distances of small native bees might be as little as 500 feet, while larger bumble bees may forage up to a mile away from their nest. Thus, crops that depend heavily upon bumble bees for pollination, such as cranberries or blueberries, can have pollinator habitat located some distance from the field. This sort of arrangement would minimize the encroachment into the crop by unwanted pollinator plants while still supporting a strong local population of bees.

Similarly, is the new habitat located near existing pollinator populations that can “seed” the new area?   For example, fallow areas, existing wildlands, or unmanaged landscapes can all make a good starting place for habitat enhancement. In some cases these areas may already have abundant nest sites, such as fallen trees or stable ground, but lack the floral resources to support a large pollinator population. Be aware of these existing habitats and consider improving them with additional pollinator plants or nesting habitat.

2. DIVERSE PLANTINGS: Diversity is a critical factor in the design of pollinator enhancement areas. Flowers should be available throughout the entire growing season, or at least whenever adjacent crops needing pollination are not in bloom. It is desirable to include a diversity of plants with different flower colors, sizes and shapes as well as varying plant heights and growth habits to encourage the greatest numbers and diversity of pollinators (Frankie et al. 2002, Potts et al. 2003, Ghazoul 2006). Most bee species are generalists, feeding on a range of plants throughout their life cycle. Many others, including some important crop pollinators, only forage on a single family or even genus of plants.

Butterflies have a long tongue that can probe tubular flowers. Therefore, choose plants with a variety of flower shapes in order to attract a diversity of pollinators. Color is another consideration. Bees typically visit flowers that are purple, violet, yellow, white, and blue (Proctor et al. 1996). Butterflies visit a similarly wide range of colors, including red (Procter et al. 1996), whereas flies are primarily attracted to white and yellow flowers (Stubbs & Chandler 1978). Thus, by having several plant species flowering at once, and a sequence of plants flowering through spring, summer, and fall, habitat enhancements can support a wide range of pollinator species that fly at different times of the season (Feber et al. 1996, Tscharntke et al. 1998, Potts et al. 2003).

Diverse plantings that resemble natural native plant communities are also the most likely to resist pest, disease, and weed epidemics and thus will confer the most pollinator benefits over time. Species found in association with each other in local natural areas are likely to have the same light, moisture, and nutrient needs such that when these species are put into plantings they are more likely to thrive together (Biondini 2007).

The level of plant community diversity can be measured in several ways. One system used in managed woody plant ecosystems is the the*10-20-30 Rule*. This rule states that a stable managed plant community (i.e. one able to resist insect and disease epidemics) should contain no more than 10% of a single plant species, no more than 20% of a single genera, and no more than 30% of a single family (Santamour 1990).

3. PLANT DENSITY AND BLOOM TIME: Plant diversity should also be measured by the number of plants flowering at any given time. Researchers in California have found that when eight or more species of plants with different bloom times are grouped together at a single site, they tend to attract a significantly greater abundance and diversity of bee species (Frankie et al. 2002). Therefore, at least three different pollinator plants within each of three blooming periods are recommended (i.e. early, mid or late season - refer to the tables in Section VI for more information). Under this plan at least nine blooming plants should be established in pollinator enhancement sites, although in some studies bee diversity continues to rise with increasing plant diversity and only starts to level out when twenty or more different flower species occur at a single site (Tscharntke et al. 1998, Carvell 2002, Frankie et al 2002).

It is especially important to include plants that flower early in the season. Many native bees, such as bumble bees and some sweat bees, produce multiple generations each year. More forage available early in the season will lead to greater reproduction and more bees in the middle and end of the year. Early forage may also encourage bumble bee queens that are emerging from hibernation to start their nests nearby, or simply increase the success rate of nearby nests (Carvell et al. 2007). Conversely, it is also important to include plants that flower late in the season to ensure that queen bumble bees are strong and numerous going into winter hibernation (Hines and Hendrix 2005, Pywell et al. 2005).

Plant clusters of a single species when possible. Research suggests that clump-plantings of at least three foot by three foot blocks of an individual species (that form a solid block of color when in flower) are more attractive to pollinators than when a species is widely and randomly dispersed in smaller clumps. Even larger single-species clumps (e.g. a single species cluster of perennials or shrubs more than 25 square feet in size) may be even more ideal for attracting pollinators and providing efficient foraging (Frankie et al. 2002).

4. INCLUDE GRASSES: Herbaceous plantings should include at least one native bunch grass or sedge adapted to the site in addition to the three or more forbs from each of the three bloom-periods (i.e. spring, summer, and fall - refer to the tables in Section VI). This scenario results in a minimum of 10 plant species per planting. Strive for an herbaceous plant community that mimics a local native ecosystem assemblage of plant density and diversity (generally with a greater diversity of forbs) to maximize pollinator habitat. Most native plant communities generally contain at least one dominant grass or sedge in their compositions. These grasses and sedges often provide forage resources for beneficial insects (including larval growth stages of native butterflies), potential nesting sites for colonies of bumble bees, and possible overwintering sites for beneficial insects, such as predaceous ground beetles (Kearns & Thompson 2001, Purtauf et al. 2005, Collins et al. 2003). The combination of grasses and forbs also forms a tight living mass that will resist weed colonization (Vance et al. 2006). Grasses are also essential to produce conditions suitable for burning, if that is part of the long-term management plan.

Care should be taken however that grasses do not take over pollinator sites. Anecdotal evidence suggests that tall grasses crowd out forbs more easily than short grasses, and that cool season grasses are more competitive against many forbs than warm season grasses. Seeding rates for grasses should also not exceed seeding rates for forbs. Fall (rather than spring) planting will also favor forb development over grasses.

C. Plant Selection and Seed Sources

Choose plants with soil and sunlight requirements that are compatible with the site where they will be planted. The plant tables in Section VI provide a starting point for selecting widely distributed and regionally appropriate pollinator plants. If these plants are not available, other closely related species might serve as suitable replacements.

1. NATIVE PLANTS: Native plants are adapted to the local climate and soil conditions where they naturally occur (Williams & Kremen 2007). Native pollinators are generally adapted to the native plants found in their habitats. Conversely, some common horticultural plants do not provide sufficient pollen or nectar rewards to support large pollinator populations. Non-native plants may become invasive and colonize new regions at the expense of diverse native plant communities.

Native plants are advantageous because they generally: (1) do not require fertilizers and require fewer pesticides for maintenance; (2) require less water than other non-native plantings; (3) provide permanent shelter and food for wildlife; (4) are less likely to become invasive than non-native plants; and (5) promote local native biological diversity (Summerville et al. 2007, Tinsley et. al 2006, Waltz & Covington, 2004).

Using native plants in multiple projects will help provide connectivity for native plant populations, particularly in regions with fragmented habitats. By providing connectivity of plant species across the landscape, the potential is increased for these species to move in the landscape in relation to probable future climatic shifts.

2. SEED SOURCES: Where possible, native plants and seed should be procured from "local eco-type" providers. Local eco-type refers to seed and plant stock harvested from a local source (often within a few hundred miles). Plants selected from local sources will generally establish and grow well because they are adapted to the local climatic conditions (Lippit et al. 1994 and Aldrich 2002). Depending on the location, state or local regulations may also govern the transfer of plant materials beyond a certain distance (sometimes called *Seed Transfer Zones*). Similarly, where possible, commercially procured seed should be certified by the state Crop Improvement Agency. Seed certification guarantees a number of quality standards, including proper species, germination rate, and a minimum of weed seed or inert material.

3. TRANSPLANTS: In addition to seed, enhancement sites can be planted with plugs, or in the case of woody plants, container grown, containerized, bare-root, or balled and burlaped materials.

Herbaceous plants purchased as plugs have the advantage over planting seed, because of rapid establishment and earlier flowering, although the cost of using plugs can be prohibitive in large plantings. Transplanted forbs also typically undergo a period of shock, after transplanting, during which they may need mulching and supplemental water to ensure survival (Packard 1997).

Woody plants may also undergo a period of transplant shock and need similar care. In general, container grown and balled and burlaped woody plants have a higher survival rate and are available in larger sizes. They are also generally more expensive than bare-root or containerized plants. Containerized trees and shrubs are plants that were either hand-dug from the ground in a nursery setting, or were harvested as bare-root seedlings, then placed in a container. Although the cost of containerized plants is typically low, they should be examined for sufficient root mass before purchase to ensure successful establishment (Shigo 1991).

4. AVOID NUISANCE PLANTS: When selecting plants, avoid ones that act as alternate or intermediate hosts for crop pests and diseases. For example, many rust fungi require two unrelated plant species to complete their life cycle. Similar economically important agricultural plants (or closely related species) are generally a poor choice for enhancement areas, because without intensive management, they may serve as a host reservoir for insect pests and crop diseases.

5. APPLICATIONS FOR NON-NATIVE PLANT MATERIALS: While in most cases native plants are preferred, non-native ones may be suitable for some applications, such as annual cover crops, buffers between crop fields and adjacent native plantings, or short-term low cost insectary plantings that also attract beneficial insects which predate or parasitize crop pests (Potin et. al. 2006). For more information on suitable non-native plants for pollinators, see the table in Appendix 1.

D. Management of New Pollinator Habitat

Habitat plantings for pollinators should remain undisturbed to the greatest extent possible throughout the growing season so that insects can utilize flower pollen and nectar resources (for adult stages) and vegetative parts of plants for food and cover resources (for immature/larval stages). If site maintenance must occur during the growing season in order to maintain the open, species rich habitat preferred by pollinators, establish a system for managing a small percentage (30% or less) of the site each year on a three to five year rotation. This will allow for re-colonization of disturbed habitat from the surrounding area (Black et al. 2008).

Controlled, rotational grazing may also be a viable option for managing the plant community. Grazing should generally occur during the pollinator dormant season and at light intensity, or at least with a long rest-rotation schedule of grazing (Carvell 2002).

E. Create Artificial Nest Sites

There are many successful ways to provide nesting sites for different kinds of native bees, from drilled wooden blocks to bundles of reeds to bare ground or adobe bricks. The Xerces Society's *Pollinator Conservation Handbook* (Shepherd et al. 2003) provides detailed information on how to build artificial nest sites. Generally, increasing nesting opportunities will result in at least a short-term increase in bee numbers (Steffan-Dewenter & Schiele 2008).

Most native bees nest in the ground. The requirements of one species, the alkali bee (*Nomia melanderi*) are so well understood that artificial nesting sites are created commercially to provide reliable crop pollination for alfalfa in eastern Washington and Idaho.

Unlike the alkali bee, the precise conditions needed by most other ground-nesting bees are not well known. However, landowners can create conditions suitable to a variety of species by constructing designated areas of semi-bare ground, or piles of soil stabilized with bunch grasses and wildflowers. Such soil piles might be constructed with soil excavated from drainage ditches or silt traps. Different species of bees prefer different soil conditions, although research shows that many ground nesting bees prefer sandy or sandy loam soils.

In general these constructed ground nest sites should receive direct sunlight, and dense vegetation should be removed regularly, making sure that some patches of bare ground are accessible. Once constructed, these nest locations should be protected from digging and compaction.

Colonization of these nest sites will depend upon which bees are already present in the area, their successful reproduction and population growth, and the suitability of other nearby sites. Ground-nesting bee activity can be difficult to observe because there is often little above ground evidence of the nests. Tunnel entrances usually resemble small ant mounds, and can range in size from less than 1/8 inch in diameter to almost ½ inch in diameter, depending on the species.

In contrast to ground-nesting bees, other species such as leafcutter and mason bees naturally nest in beetle tunnels and similar holes in dead trees. Artificial nests for these species can be created by drilling a series of holes into wooden blocks. A range of hole diameters with encourage a diversity of species, providing pollination services over a longer period of time.

Such blocks should be constructed of preservative-free lumber, and the hole depth should be at least 4 inches (up to 6 inches is even better). Holes should not be drilled all the way through the block, and should also be spaced at least ¾ inch apart so that bees returning to the block from foraging can easily find their own nest tunnel (Vaughan et al. 2007).

Nest blocks should be hung in a protected location where they receive strong indirect sunlight and are protected from rain. Large blocks tend to be more appealing to bees than small ones, and colonization is often more successful when blocks are attached to a large visible landmark (such as a building), rather than hanging from fence posts or trees.

In addition to wooden blocks, artificial nests can be constructed with bundles of paper straws, cardboard tubes, or sections of reed or bamboo cut so that a natural node forms the inner wall of the tunnel.

Extensive information constructing these types of nests is widely available. In order to be sustainable, artificial nests will need routine management, and regular cleaning to prevent the build-up of bee parasites and diseases (Bosch & Kemp 2001).

IV. Pollinator Habitat and NRCS Practices

The Natural Resources Conservation Service supports the use of native plant species in many conservation practices that involve seeding or transplanting. Selecting pollinator-friendly native plant species for these practices can provide added conservation benefits. Many conservation practices also can support the inclusion or management of nest sites for native bees.

Many of these practices have a purpose or consideration for enhancing wildlife (that can include pollinators). However, the enhancement for wildlife should not compromise the intended function of the practice. For example, plants attractive to pollinators could be used in a grassed waterway practice, but the planting should not interfere with the hydraulic function of the practice and objective of stabilizing the waterway against erosion.

Some practices that could include pollinator friendly supplements include:

Table 2. NRCS Conservation Practices that enhance, restore or manage pollinator habitat

Conservation Practice Name (Units)	Code	Pollinator Notes
Alley Cropping (Ac.)	311	Can include native trees or shrubs or row covers (e.g. various legumes) that provide nectar or pollen (see USDA National Agroforestry Center *Agroforestry Note 33*).
Channel Bank Vegetation (Ac.)	322	Can include diverse flowering trees, shrubs, and forbs. Channel banks provide a unique opportunity to supply early-flowering willow and, in dry areas, late flowering native forbs (e.g. goldenrod (*Solidago* spp.).
Conservation Cover (Ac.)	327	Can include diverse forbs (e.g. various legumes) to increase plant diversity and ensure flowers are in bloom for as long as possible, providing nectar and pollen throughout the season.

Conservation Practice Name (Units)	Code	Pollinator Notes
Conservation Crop Rotation (Ac.)	328	Can include rotation plantings that provide abundant forage for pollinators with forbs (e.g. various legumes, buckwheat (*Eriogonum* spp.), phacelia (*Phacelia* spp.), etc.). Moving insect-pollinated crops no more than 250 meters (750 feet) during the rotation may help maintain local populations of native bees that have grown because of a specific crop or conservation cover. Growers may want to consider crop rotations that include a juxtaposition of diverse crops with bloom timing that overlaps through the season to support pollinator populations. Growers might also consider eliminating, minimizing insecticides and/or using bee-friendly insecticides in cover crop rotations.
Contour Buffer Strips (Ac.)	332	Can include diverse legumes or other forbs that provide pollen and nectar for native bees. In addition, the recommendation to mow only every two or three years to benefit wildlife also will benefit nesting bumble bees. To protect bumble bee nests, mowing should occur in the late fall when colonies have died for the year and queens are overwintering.
Cover Crop (Ac.)	340	Can include diverse legumes or other forbs that provide pollen and nectar for native bees. Look for a diverse mix of plant species that overlap in bloom timing to support pollinators throughout the year. Some examples of cover crops that are utilized by bees include clover (*Trifolium* spp.), phacelia (*Phacelia* spp.), and buckwheat (*Eriogonum* spp.). Many “beneficial insect” cover crop blends include plant species that will also provide forage for pollinators.
Critical Area Planting (Ac.)	342	Can include plant species that provide abundant pollen and nectar for native bees and other pollinators.
Early Successional Habitat Development/Management (Ac.)	647	This management practice is important for maintaining prime open and sunny habitat for pollinators. Note: To minimize damage to pollinator populations, disturbance practices should be implemented only every two to three years and, ideally, on only 30 percent or less of the overall site. This allows for recolonization from non-treated habitat. For example, mowing or burning one-third of the site every two or three years, on a three-year cycle. In addition, when possible, disturbance practices should be implemented when most pollinators are inactive, such as in late fall or winter.
Field Border (Ft.)	386	Can include diverse legumes or other forbs that provide pollen and nectar for native bees. Strive for a mix of forbs and shrubs that come into bloom at different times throughout the year. Site management (for example, mowing) should occur in the fall to

Conservation Practice Name (Units)	Code	Pollinator Notes
		minimize impacts on pollen and nectar sources used by pollinators. If a goal is to create potential nesting habitat for bees, mowing, combined with no tillage, can maintain access to the soil surface that may provide nesting habitat for ground-nesting solitary bees. Alternatively, allowing field borders to become overgrown (e.g. with native bunch grasses) may provide nesting habitat for bumble bees.
Filter Strip (Ac.)	393	Can include legumes or other forbs that provide pollen and nectar for native bees. Look for a diverse mix of plant species that come into bloom at different times throughout the year. Site management (for example, mowing or burning) should occur in the fall to minimize impacts on pollinators.
Forest Stand Improvement (Ac.)	666	Can help maintain open understory and forest gaps that support diverse forbs and shrubs that provide pollen and nectar for pollinators. Standing dead trees may be kept or drilled with smooth 3- to 6-inch deep holes to provide nesting sites for bees.
Grassed Waterway (Ac.)	412	Can include diverse legumes or other forbs that provide pollen and nectar for native bees. In dry regions, these sites may be able to support flowering forbs with higher water requirements and thus provide bloom later in the summer.
Hedgerow Planting (Ft.)	422	Can include forbs and shrubs that provide pollen and nectar for native bees. Look for a diverse mix of plant species that come into bloom at different times throughout the year. Bee nesting sites also may be incorporated, including semi-bare ground or wooden block nests. Including strips of unmowed grasses and forbs along the edge of the hedgerow may provide nesting opportunities for bumble bees. This practice also can help reduce drift of pesticides onto areas of pollinator habitat.
Herbaceous Wind Barriers (Ft.)	603	Can include diverse forbs and shrubs that provide pollen and nectar for native bees. Look for a diverse mix of plant species that come into bloom at different times throughout the year.
Multi-Story Cropping (Ac.)	379	Woody plants may be chosen that supply pollen and nectar for pollinators. Look for mixes of plants that flower at different times throughout the growing season and support pollinator populations over time.
Pasture and Hay Planting (Ac.)	512	Can include diverse legumes (e.g. alfalfa, clovers) or other forbs that, when in bloom, provide pollen and nectar for native bees.
Pest Management (Ac.)	595	Biological pest management can include plantings that attract beneficial insects that predate or parasitize crop

Conservation Practice Name (Units)	**Code**	**Pollinator Notes**
		pests. These plantings can also benefit pollinator species. Plants commonly used for pest management that also benefit bees include: yarrow (*Achillea* spp.), phacelia (*Phacelia* spp.), and sunflowers (*Helianthus* spp.). Can include legumes or other forbs that provide pollen and nectar for native bees. Look for a diverse mix of plant species that come into bloom at different times throughout the year.
Prescribed Burning (Ac.)	338	Can greatly benefit pollinators by maintaining open, early successional habitat. Note: It is best if (a) only 30% or less of a site is burned at any one time to allow for recolonization by pollinators from adjacent habitat and (b) if burning occurs when pollinators are least active, such as when most plants have senesced or in the fall.
Prescribed Grazing (Ac.)	528	Can help maintain late successional habitat and its associated flowering plants. Can help provide for a stable base of pollinator plant species. Note: Properly managed grazing can sustain and improve all pollinator forage (pollen and nectar sources) and potential nesting sites for ground-nesting and cavity-nesting bees. Provide rest-rotation in pastures/fields during spring and summer when pollinators are most active.
Range Planting (Ac.)	550	Can include diverse legumes, other forbs, or shrubs that provide pollen and nectar for native bees.
Residue and Tillage Management, No-Till/Strip Till/Direct Seed (Ac.)	329	Leaving standing crop residue can protect bees that are nesting in the ground at the base of the plants they pollinate. Tillage digs up these nests (located 0.5 to 3 feet underground) or blocks emergence of new adult bees the proceeding year.
Restoration and Management of Rare or Declining Habitats (Ac.)	643	Can be used to provide diverse locally grown native forage (forbs, shrubs, and trees) and nesting resources for pollinators. Many specialist pollinators that are closely tied to rare plants or habitats may significantly benefit from efforts to protect rare habitat. In addition, certain rare plants require pollinators to reproduce. Note: Pollinator plants should only be planted if they were part of the rare ecosystem you are trying to restore.
Riparian Forest Buffer (Ac.)	391	Can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators. This practice also can help reduce drift of pesticides onto areas of pollinator habitat.
Riparian Herbaceous Cover (Ac.)	390	Can include diverse forbs that provide pollen and nectar for native bees. In drier parts of the U.S., many of these forbs flower in the late summer and fall, when forage is needed most.

Conservation Practice Name (Units)	**Code**	**Pollinator Notes**
Silvopasture Establishment (Ac.)	381	If grazing intensity is low enough to allow for plants to flower, this practice can include legumes and other forbs that provide pollen and nectar for native bees. Trees and shrubs that provide pollen and nectar also can be planted.
Stream Habitat Improvement and Management (Ac.)	395	Plants chosen for adjoining riparian areas can include trees, shrubs, and forbs that provide pollen and nectar for pollinators. Maximizing plant diversity along riparian corridors will result in more pollinators and other terrestrial insects to feed fish in the streams.
Streambank and Shoreline Protection (Ft.)	580	If vegetation is used for streambank protection, plants can include trees, shrubs, and forbs (for example, willow (*Salix* spp.), dogwood, (*Cornus* spp.) and goldenrod (*Solidago* spp.)) especially chosen to provide pollen and nectar for pollinators.
Stripcropping (Ac.)	585	Can include diverse legumes or other forbs that provide pollen and nectar for native bees. Also, if insect pollinated crops are grown, plants used in adjacent strips of vegetative cover may be carefully chosen to provide a complementary bloom period to the crop, such that the flowers available at the field are extended over a longer period of time.
Tree/Shrub Establishment (Ac.)	612	Can include trees and shrubs especially chosen to provide pollen and nectar for pollinators, or host plants for butterflies.
Upland Wildlife Habitat Management (Ac.)	645	Can include managing for pollinator forage or pollinator nest sites, such as nest blocks or snags for cavity nesting bees, or overgrown grass cover for bumble bees.
Vegetative Barriers (Ft.)	601	Can include plants that provide pollen and nectar for pollinators as long as they are of a stiff, upright stature for impeding surface water flow.
Vegetated Treatment Area (Ac.)	635	Can include plants that provide pollen and nectar for pollinators.
Wetland Enhancement (Ac.)	659	Wetland and adjacent upland can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators. Snags can be protected or nest blocks for bees erected. Some forbs used for enhancement will require pollinators to reproduce.
Wetland Restoration (Ac.)	657	Wetland and adjacent upland can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators. Snags can be protected or nest blocks for bees erected. Some forbs used for restoration will require pollinators to reproduce.
Wetland Wildlife Habitat Management (Ac.)	644	Wetland and adjacent upland can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators. Snags can be protected or nest

Conservation Practice Name (Units)	Code	Pollinator Notes
		blocks for bees erected.
Windbreak/Shelterbelt Establishment (Ft.)	380	Can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators. Can also be a site to place nesting structures for native bees. Windbreaks and shelter belts also will help reduce drift of insecticides on to a site.
Windbreak/Shelterbelt Renovation (Ft.)	650	Can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators. If appropriate, dead trees and snags may be kept or drilled with holes to provide nesting sites for bees.

Presented another way, various pollinator requirements are supported by the following conservation practices:

Table 3. NRCS Practices that provide pollinator requirements

Pollinator Resource	Code and Conservation Practice Name (Units)
Forage (diverse sources of pollen and nectar that support pollinators from early in the spring to late in the fall)	311 - Alley Cropping (Acres) 322 - Channel Bank Vegetation (Acres) 327 - Conservation Cover (Acres) 328 - Conservation Crop Rotation (Acres) 332 - Contour Buffer Strips (Acres) 340 - Cover Crop (Acres) 342 - Critical Area Planting (Acres) 386 - Field Border (Feet) 393 - Filter Strip (Acres) 412 - Grassed Waterway (Acres) 422 - Hedgerow Planting (Feet) 603 - Herbaceous Wind Barriers (Feet) 379 - Multi-Story Cropping (Acres) 512 - Pasture and Hay Planting (Acres) 595 - Pest Management (Acres) 409 - Prescribed Forestry (Acres) 528 - Prescribed Grazing (Acres) 550 - Range Planting (Acres) 643 - Restoration and Management of Rare or Declining Habitats (Acres) 391 - Riparian Forest Buffer (Acres) 390 - Riparian Herbaceous Cover (Acres) 381 - Silvopasture Establishment (Acres) 395 - Stream Habitat Improvement and Management (Acres) 580 - Streambank and Shoreline Protection (Feet) 585 - Stripcropping (Acres) 612 - Tree/Shrub Establishment (Acres) 645 - Upland Wildlife Habitat Management (Acres) 601 - Vegetative Barriers (Feet) 659 - Wetland Enhancement (Acres) 657 - Wetland Restoration (Acres) 644 - Wetland Wildlife Habitat Management (Acres)

	380 - Windbreak/Shelterbelt Establishment (Feet) 650 - Windbreak/Shelterbelt Renovation (Feet)
Nest sites (stable ground, holes in wood, cavities for bumble bees, or overwinter sites for bumble bee queens)	322 - Channel Bank Vegetation (Acres) 656 - Constructed Wetland (Acres) 332 - Contour Buffer Strips (Acres) 342 - Critical Area Planting (Acres) 386 - Field Border (Feet) 422 - Hedgerow Planting (Feet) 409 - Prescribed Forestry (Acres) 329 - Residue & Tillage Management, No-Till/Strip Till/Direct Seed (Ac.) 643 - Restoration and Management of Rare or Declining Habitats (Acres) 391 - Riparian Forest Buffer (Acres) 612 - Tree/Shrub Establishment (Acres) 645 - Upland Wildlife Habitat Management (Acres) 659 - Wetland Enhancement (Acres) 657 - Wetland Restoration (Acres) 644 - Wetland Wildlife Habitat Management (Acres) 380 - Windbreak/Shelterbelt Establishment (Feet) 650 - Windbreak/Shelterbelt Renovation (Feet)
Pesticide protection (refuge from spray, buffers to drift, etc.)	322 - Channel Bank Vegetation (Acres) 656 - Constructed Wetland (Acres) 342 - Critical Area Planting (Acres) 422 - Hedgerow Planting (Feet) 595 – Pest Management (Acres) 391 - Riparian Forest Buffer (Acres) 657 - Wetland Restoration (Acres) 380 - Windbreak/Shelterbelt Establishment (Feet)
Site management for pollinators	647 - Early Successional Habitat Development or Management (Acres) 595 - Pest Management (Acres) 338 - Prescribed Burning (Acres) 409 - Prescribed Forestry (Acres) 528 - Prescribed Grazing (Acres) 643 - Restoration and Management of Rare or Declining Habitats (Acres) 645 - Upland Wildlife Habitat Management (Acres) 644 - Wetland Wildlife Habitat Management (Acres) 395 - Stream Habitat Management and Improvement (Acres) 472 - Access Control (Acres)

V. Financial Resources

NRCS provides financial assistance through farm bill programs for implementation of conservation practices, including those for pollinator habitat. Information can be found at http://www.ca.nrcs.usda.gov/

VI. Plant Tables

See Appendix I in this technical note for recommended native trees and shrubs for Major Land Resource Areas (MLRAs) in California. The tables contain information about native and non-native trees, shrubs, wildflowers, and grasses to consider for plantings to enhance pollinator habitat. These tables include brief information on bloom timing and the basic cultural needs of the plants. The information provided is a starting point for determining plants to use for a particular project.

To find species that are available and/or hardy for a specific location, consult the electronic California Vegetative Guide and Calflora data base both of which are accessible at http://www.calflora.org/app/npb?page=home. Additional lists for the remaining MRLAs are currently in development. Additional information such as the geographic distribution and cultural requirements for various plants is available from species fact sheets like those found at the USDA PLANTS database (http://plants.usda.gov/java/factSheet).

The tables in Appendix 1 are not exhaustive; many other plants are good for bees. These lists were limited to those plants thought to require insect pollination and to be relatively widespread and commonly found in the public marketplace as seed or nursery stock.

A. Native Plant Species

The cost of native plants may appear to be more expensive than non-native alternatives when comparing costs at the nursery, but when the costs of maintenance (e.g. weeding, watering, and fertilizing) are calculated over the long-term, native plantings can eventually be more cost-efficient for pollinator enhancement. Native plantings also give the added benefit of enhancing native biological diversity (e.g. plant and wildlife diversity) and are the logical choice to enhance native pollinators (Frankie et al. 2002, Samways 2007).

1. NATIVE TREES AND SHRUBS FOR POLLINATOR ENHANCEMENT

Tree and shrub plantings may be designed for a number of concurrent purposes, such as wildlife enhancement, stream stabilization, windbreak, and/or pollinator enhancement (Henry et al. 1999). Appendix 1 lists some of the tree and shrub species that you might consider, paying close attention to overlapping bloom periods and plant suitability based on site constraints.

2. NATIVE FORBS (WILDLFLOWERS)

There is a vast array of native forbs to choose from when designing pollinator enhancement. These are species that you might consider using in a hedgerow “bottom” (at the base of one or both sides of a hedgerow), riparian buffer, windbreaks, alley cropping, field border, filter strip, waterway or range planting to enhance conditions for pollinators. Appendix 1 suggests some of the plant options that you might want to consider, paying close attention to overlapping bloom periods and the appropriate plant for the site conditions.

3. NATIVE BUNCH GRASSES AND SEDGES TO INCLUDE IN AN HERBACEOUS MIXTURE OF NATIVE FORBS

Herbaceous plantings should include at least one native bunch grass or clump-forming sedge adapted to the site in addition to the forbs that will be planted. Including a grass or sedge in the planting mixture will help keep weeds out of the planting area, stabilize the soil, provide overwintering habitat for beneficial insects, forage resources for larval growth stages of some butterflies, and nest sites for bumble bees (Svensson et al. 2000, Kells and Goulson 2003).

Anecdotal evidence suggests that tall grasses crowd out forbs more easily than short grasses. Many of our bunch grasses are taller grass species. Planting specific areas with higher rates of forbs interspersed within grass planting areas will reduce the competitive edge of grasses. Seeding rates for grasses should also not exceed seeding rates for forbs.

B. Non-Native Plant Species for Cover Crops, Green Manures, Livestock Forage and Insectary Plantings

A number of non-native plants used for cover crops, insectaries, green manure, or short-term plantings are productive forage sources for pollinators. Some of these species could become weedy (e.g. able to reproduce and spread) so you will want to choose appropriate species for your needs and monitor their development on your site.

Cover crops are generally established for seasonal vegetative cover and soil conservation. They reduce erosion and weed competition, and improve soil organic material and tilth (Lu et al. 2000). They may be part of a rotation as a harvested crop or they may be inter-planted between rows (e.g. vineyards) to enhance soil organic matter and nutrients. Nitrogen-fixing legumes are often used in cover crop mixtures to increase soil fertility. Broadleaf cover crops (i.e. forbs) may also provide good pollen or nectar sources for bees and other beneficial insects.

Insectary plantings may be placed as a block inside of a crop, along the borders or just outside of a crop to attract beneficial insects to the crop for biological control (i.e. predators or parasitoids) of crop pests (Colley & Luna 2000). Beneficial insects can be significantly more abundant in insectary plantings than where such habitat is absent. Some of these plants can also provide good pollen or nectar sources for bees. These may be annual plantings or more permanent plantings along the outer rows within the field or outside but adjacent to the crop field. The principles of enhancement for pollinators also generally apply to insectary plantings, such as including a diversity of flowers that bloom through the entire growing season to provide a steady supply of nectar.

The species suggested in Appendix 1 are known to be used commonly in farm practices and presumed to be widely available in the marketplace. These plants will generally do best in a full sun location and may require supplemental summer watering. Fertility requirements can vary widely.

C. Garden Plants

This type of planting will generally be a more permanent planting outside but adjacent to cropland. The pollinator habitat enhancement principles will also apply—such as including a diversity of flowers that bloom through the entire growing season to provide a steady supply of nectar and pollen. Also, when selecting plant varieties, keep in mind that the simple-flowered cultivars generally provide greater nectar and pollen rewards than multi-petaled (e.g. double petal) varieties.

The plants suggested in Appendix 1 are all commonly available garden plants. These species will generally do best in a full sun location and may require supplemental irrigation and fertilization. Establishment of perennial plants may take a few years, but they will often last for an extended period of time. One strategy is to plant annual and perennial garden plants together, with the annual plants providing immediate benefits the first year, while the perennial plants become established (Szalai 2001).

D. Noxious Weed Species

A plant that is well suited to one region may become a weed when transported outside of its native range. When developing pollinator enhancement sites, it is important that weedy species are not intentionally planted, and that noxious species already present in the local environment are controlled.

PLANNING PHASE III

Site Preparation, Planting and Ongoing Maintenance of New Pollinator Habitat

Developing new pollinator habitat through implementation of conservation practices requires some basic horticultural knowledge. The following section describes the fundamental techniques of site preparation, planting, and initial maintenance. Standard agricultural equipment, with some modifications, can be used in many cases, however some planting techniques (for example, drill seeding native plants) may require specialized field implements which can often be rented or borrowed from local cooperatives, hardware stores, or conservation groups.

A. Site Preparation

Site preparation is one of the most important and often inadequately addressed components for project success. It is also a process that may require several seasons of effort reducing competition from invasives, noxious or undesirable non-native plants prior planting. Regardless of whether the objective is to establish herbaceous or woody vegetation, more effort and time spent eradicating undesirable plants will result in higher success rates of establishing targeted plant community.

Weed removal can be performed in four basic ways: (1) without cultivation by smothering or the use of broad-spectrum herbicides; (2) without cultivation through use of targeted herbicide directed towards broadleafs or selected families of plant species; (3) with cultivation through aggressive tillage or sod removal; or (4) a combination of tillage and herbicides. The appropriate method to use will depend on the farm operation (e.g. whether or not it is conventional or organic), equipment availability, and the existing weed pressure. All applications of selected herbicides should follow the label, when applying herbicides near water or crops that may be sensitive to the active ingredients or surfactants.

1. SITE PREPARATION FOR WOODY PLANTS: In general, hedgerows or plantings of woody species require significantly less site preparation than herbaceous plants. Once invasives and noxious weeds are eradicated or under control, efforts can focus on the removal of undesirable existing woody species with weed wrenches, machetes, chainsaws, and branch loppers. Even after cutting back to ground level, many undesirable woody plant species will continue to re-sprout new trunks. For permanent removal, these sprouts will require repeated cutting (until the stored energy reserves in the root system are depleted), or the stumps will need to be treated with an herbicide. A number of woody plant herbicides are commercially available, most containing a broad spectrum, non-selective herbicide. They are usually applied as a spray, or a paste that is painted on freshly cut stump surfaces. Several broad spectrum, non-selective herbicide products are also available for wetland-emergent woody plants. Best approaches to treating targeted weed species can be found through various websites or references

2. SITE PREPARATION FOR HERBACEOUS PLANTS: Site preparation for herbaceous plants can be significantly more complex. Generally the site should be free of existing weeds, weed seed that has not yet germinated, and debris that will inhibit planting operations. Perennial weed seed and rhizomes in particular need to be killed. Annual and biennial weed seed may still be present, but with several years of proper management forb plantings can be largely free of these weeds.

Repeated weed removal can be performed in three basic ways: (1) without cultivation by smothering or the use of broad-spectrum herbicides; (2) with cultivation through aggressive tillage or sod removal; or (3) a combination of tillage and herbicides. The appropriate method to use will depend on the farm operation (e.g. whether or not it is conventional or organic), equipment availability, and the existing weed pressure.

Site Preparation without cultivation: Smothering existing vegetation with black plastic is an option on small areas. Often the plastic will need to be left in place for at least a year before all the vegetation under it is dead. Clear plastic can also be used, however black plastic may result in greater soil heating, and more successful destruction of weeds and weed seed.

Existing vegetation can also be killed with non-persistent broad spectrum, non-selective herbicides. This is a low cost approach that can be extremely effective, even on large areas, with minimal labor (Scott & Gerry 1995). For maximum efficiency, these treatments should be applied when weeds are actively growing. To insure good contact, first burn the area you intend to plant, or mow the site as low as possible then rake off the debris. Do this in the early spring. Then, as the weeds begin actively re-growing, make the first herbicide application. Follow up with additional treatments every month and a half throughout the growing season (Steinauer 2003).

It is important that applications begin early in the season when cool weather weed species are actively growing. Later in the summer when these weed species are dormant, the herbicide will not be transported to the root system. Similarly early season applications will not kill warm weather weeds that are actively growing in the summer (Steinauer 2003). Repeated herbicide treatments are essential. In all cases, applications should be made following the instructions on the product label.

If mechanical drill seeding is planned for no-till sites, the area may be rolled with a cultipacker prior to planting if there is a significant amount of stubble. Planting can be done right after broad spectrum, non-selective herbicide applications.

Site preparation without cultivation is advantageous because the costs are relatively low, soil erosion is controlled, dormant weed seeds in the soil are not brought to the surface where they may germinate, and complex tillage equipment is not required. This approach may not be possible in areas that have a soil compaction problem. The primary disadvantage of site preparation without cultivation is that planting with desirable replacement species can only be performed by hand with plugs, or with drill seeders that may not be widely available.

Site Preparation with Cultivation: Existing vegetation can be removed with aggressive, repeated tillage performed to a depth of several inches every other week for an entire growing season. This site preparation method works best on previously cropped land, or land without a history of aggressive perennial weed problems. This approach can be labor intensive, take more than one year, and only reduce, but not eliminate all weed seeds in the seed bank.

Frequent follow up is essential as some weeds may be uprooted and carried through the blades of a rototiller only to be replanted. Also, since some weeds spread by rhizomes, repeated chopping of these root sections into multiple pieces may result in creating more weeds that are then spread throughout the planting area. Finally for every weed plowed under, several dormant weed seeds may be brought to the surface where they will germinate. With aggressive repeated tillage however, the perennial weed “seed bank” will be depleted, leaving mostly annual weed seed to contend with during the planting process (Steinauer 2003).

Mechanical removal of turf or low-growing rhizomatous weeds, like Bermuda or Johnson grass can be performed with walk-behind sod cutters on small areas or by scraping with the bucket of a skid steer loader. Repeated passes with a heavy duty box scraper may also be suitable in areas with weakly rooted existing vegetation. This approach is expensive when planting acreages of any size. Planting of natives plants should only be implemented once these rhizomatous weedy species are fully eradicated.

After the existing vegetation is gone, cultivated soils will need to be smoothed, lightly packed, and free of stubble prior to planting (Kurtz 2001). Large straight toothed harrows can be used to break up large soil clods, and excess plant litter can be smoothed with a shallow disking.

Site preparation with only cultivation may be preferred by certified organic growers, by growers with extensive tillage equipment, and in areas where drill seeders are not locally available. Site preparation with only cultivation is limited to areas with minimal perennial weed pressure, and is a time consuming and labor intensive process.

Site Preparation with a combination of tillage and herbicides: Ongoing cultivation can be alternated with herbicide applications for an entire growing season. At the end of the season the smoothed and prepared seedbed can be treated with a final herbicide application one week prior to planting.

B. Planting and Initial Establishment

Planting methods vary depending on the type of enhancement being created (e.g. woody versus herbaceous plants), and the planting conditions (e.g. an untilled stubble field versus a cultivated seedbed).

1. WOODY PLANTS: Trees and shrubs can be planted whenever the nursery stock is available and the soil can be worked (although planting during dry seasons may require more careful follow-up care). Planting depth is critical. Woody plants should be planted at or slightly above the depth they were grown in at the nursery. This will allow for settling, prevent the formation of stem-girdling roots, and improve oxygen availability to the roots. Remove rocks from the hole and do not line the bottom of the hole with gravel to improve drainage unless it is connected to a drain tile system (Gillman & Johnson 1999, Shigo 1991).

Prepare the hole to a depth of almost 2/3 the height of the plant's root mass or soil ball, and 1-2 feet wider than the size of the root system. The sides of the hole should be roughened in heavy clay soils. Small holes can be hand dug, for larger field transplants or balled and burlaped nursery stock, a mechanical tree spade may be more convenient. Prior to digging any large hole, especially near roads, buildings, railroad right-of-ways, or utility easements, the local utility companies should be contacted to prevent accidentally cutting underground wires or gas lines.

Regardless of the type of nursery stock, care should be taken not to damage the roots of woody plants during the installation process. Balled and burlaped and containerized plants should only be moved by the container or soil ball, never by the stem. After placing them in the planting hole, backfill balled and burlaped plants to almost 1/3 the height of the soil ball, tamping the soil to remove air pockets. Next with a knife and a wire cutter remove as much of the wire cage, burlap, and twine as possible without allowing the soil ball to fall apart. Finish filling in the hole, again tamping the soil in the process. The same planting method can be employed for containerized trees, placing the entire container in the hole, and cutting away the plastic with a utility knife.

Bare-root plants should be installed immediately to prevent drying of the roots. When placing the plant in the hole, the roots should be straightened and spread out evenly before backfilling. As the soil is tamped during the backfilling process, the stem can be gently raised and lowered several times to eliminate air pockets.

Container grown trees should be removed from their pot completely before planting, and any rootbound condition (roots growing in a spiral around the soil ball) should be returned to the nursery. For those container plants that were not planted upon delivery from the nursery corrective measures should be applied to the roots. Rootbound plants can be treated by making several shallow vertical cuts along the sides of the rootmass. Encircling roots that are not corrected may continue to expand in size over time and eventually girdle the trunk (Johnson and Hauer 2000). Following root correction, container grown stock can be planted in the same way as balled and burlaped plants.

Adding mulch around the base of trees and shrubs helps maintain soil moisture and suppresses competing weeds. Wood chips are a good mulch material and can be applied in a 3-6 inch layer radiating 3-6 feet from the base of the plant. The mulch should not directly contact the base of the trunk.

Most newly planted trees and shrubs do best without staking. Trunk movement caused by wind helps develop proper trunk taper and resilient root systems (Shigo 1991). If stakes must be used (i.e. the plant cannot stand on its own), loose webbing or thick, non-abrasive straps should hold the trunk loosely to the stake, still allowing for some movement. The stakes and bracing materials should be removed as soon as possible to prevent girdling.

Animal browsing can be a problem for small woody plants. Where this occurs, trunks can be protected with plastic trunk guards, or hardware cloth cylinders. Small woody plants can be planted inside plastic grow tubes. Some newer tubes are manufactured from plastic that is intended to breakdown in sunlight over several seasons.

2. PLUGS AND CONTAINER PLANTS: Most native herbaceous plants can be installed throughout the growing season, even when the plant is dormant. Ideally, the best time to plant plugs and containerized plants is from October through January. Plugs dry out quickly in their containers and should be watered often and stored out of the wind and direct sunlight if they cannot be planted immediately. To plant, dig a hole the same depth as the container, remove the plant from the container, and position the base slightly below the surrounding soil surface. Fill the hole surrounding the plant making sure to cover the potting mix completely with the native soil (to prevent moisture from wicking out of the potting mixture). First year transplants may benefit from a 3-inch thick layer of straw or leaf mulch after going dormant in the fall (Packard 1997).

3. SEEDING A CULTIVATED SEEDBED: For flowering forbs, fall planting is best. Many plant seeds require exposure to cold temperatures and damp conditions before germination can occur. Additionally, winter precipitation will help the seeds settle into the soil.

The exact seeding rate for native forbs is usually based on the California Vegetative Guide, or eVegGuide recommendations. Where there are no recommended pure live seed seeding rates in the eVegGuide refer to the seed vendor's recommendation, which is usually based on weight (how many pounds of a single species are needed to plant a certain area size). In general, broadcast planting will require twice the amount of seed as drill or slit seeding. Seed mix recommendations are available at NRCS California's Vegetative Guide at http://www.calflora.org/app/npb?page=home . The login ID is Bennett and the password is SCS1935. See plant tables for examples of seeding mix with recommended seeding rates.

Broadcast seeding can be performed by hand on small areas with a belly grinder or similar seed spreader apparatus. For even distribution, it can be mixed with a slightly damp inert material such as sawdust, peat moss, or vermiculite.

For seeding larger areas, an ATV mounted seed spreader, or tractor-mounted Brillion double box drop seeder is preferred. The latter are typically used for alfalfa and grass mixtures, and may require replacing the standard wire agitators in the front box with native seed bristle agitators. Again, depending on the agitators and the seedmix, an inert material may need to be added for proper seed distribution. Follow the equipment manufacturer's instructions on this process (Steinauer 2003).

For most, broadcast seeding plantings (either mechanically or by hand), the seed should be mixed together into a single mix. When the seed drill has two compartments there may be an advantage to placing forb seeds of larger size in one compartment and smaller sized seeds in the other. This will reduce the chance of the smaller sized seeds from being dispersed as soon as the seeder is started; therefore drilling or broadcasting the larger sized seeds once the smaller seeds have been planted.

Seeding with large Brillion seeders equipped with heavy wheels that press the seed into the soil help ensure good contact. For other broadcast seeders, the soil should be lightly raked and pressed with cultipackers, corrugated cast-iron field rollers, or the wheels of a truck or tractor (Steinauer 2003).

Whatever method you use, newly planted bare soil should be protected as necessary with an inch thick layer of weed-free straw, or hydro-mulch to reduce erosion and rill formation (Packard 1997). For seeded areas we recommend 1 – 1.5 tons straw to the acre. One should be able to see bare ground through the mulch to allow for germination.

4. DRILL SEEDING A NO-TILL SEEDBED: No-till seed drills and slit seeders allow planting on rough soil, which is advantageous in areas with a large amount of dormant weed seed that may germinate when brought to the surface by cultivation. Seed drills also provide ideal planting depth and spacing, and require half the amount of seed that broadcast seeding requires for the same area. Even though cultivation is not necessary when using a seed drill, growers should cultipack the soil before planting if there is a significant amount of stubble (Steinauer 2003, Packard 1997). As with planting in a cultivated seedbed, drill seeding in the fall is best, and consistently produces the best pollinator habitat by favoring the development of flowering forbs over grasses.

The drawback of this planting method is equipment availability. Standard agricultural seed drills will not work. Instead, special native plant seed drills, such as those manufactured by Tye or Truax are often required (Steinauer 2003). Fortunately these seed drills are becoming more widely available, as private conservation groups (often hunting organizations) are purchasing them for their local chapters. Often these groups make their planters available to non-members on a rental basis.

C. Ongoing Management

One of the great advantages of using native plants for pollinator habitat enhancement projects is that once the native plants are established the routine maintenance is often minimal when compared to non-native or horticultural plants. In fact, frequent disturbance of pollinator habitat can be detrimental to insect populations. The most time consuming maintenance task—watering newly installed plantings—tapers off quickly as the habitat matures. Natural nutrient cycling in native plant ecosystems eliminates the need for supplemental fertilizers, and typically the only maintenance necessary will be the occasional monitoring for, and removal of weed species.

1. WATERING NEW PLANTINGS: Once established, native plants usually do not need supplemental irrigation. However, depending on the species, newly transplanted trees, shrubs and forbs may require routine watering, with the exact amount depending on the species, location, precipitation, and time of year. The original plant vendor or a local nursery can often provide the necessary guidance on such water requirements.

Seed germination and seedling survival (for native species) may also benefit from regular irrigation during the first two months after planting. Non-native plants, such as cover crops, may require greater amounts of water, sometimes throughout the entire growing season. Irrigation is most effective in the early morning, allowing for soil infiltration before rising temperatures increase the rate of evaporation. Irrigation in the evening can result in wet overnight conditions that promote fungal disease development. Over-irrigating can also be as harmful to plants as under-irrigating.

Excluding drought conditions, native plants in their natural habitat should not require ongoing irrigation once they are established. With or without supplemental water however, many native perennial seeds germinate slowly, and may even take several seasons to germinate. Although this seems like a drawback, it allows for the identification (and removal) of faster growing weeds in the seedbed (Packard 1997).

2. WEED CONTROL: If they are properly mulched, woody plants and transplanted forbs are usually well protected from weed encroachment during early establishment.

Seeded areas of native perennials need more protection, especially from annual and biennial weeds during establishment (all perennial weeds should have been destroyed prior to planting). The best way to control these weeds is by mowing the seedbed down to a height of about 6 inches several times during the first growing season. The number of times mowing will be required is dependent on the particular weed species present, and how quickly they grow (often dependent on precipitation). Plan on mowing every time the vegetation reaches a height of 12 inches. This will prevent most weeds from flowering, while leaving the slower growing native forbs untouched (Steinauer 2003). The exception to that occurs when mowing yellow star-thistle too early. When mowed too early yellow star-thistle will resprout when mowed when six inches in height.

For small areas, a walk-behind sickle bar mower is often better than a standard lawn mower (which is likely to bog down in thick vegetation). Sickle bar mowers can be rented at many hardware stores. For large areas, a tractor mounted flail mower is ideal because it shreds the cut weeds into small pieces, thus not smothering desirable plants with debris. Weeds can also be spot treated with a selective or broad spectrum herbicide using a backpack sprayer, or brushed with an herbicide wick. This is particularly useful against low growing weeds that might be missed by the mower. Weeds should not be pulled if at all possible, especially during the first year when the surrounding seedlings are still developing their root systems.

In the early spring of the second year, before plant emergence, the previous season's debris should be mowed and raked away. If perennial weeds were destroyed prior to planting, and annual weeds mowed during the first year of growth, the majority of the remaining weeds should be biennial species. These plants develop a thick taproot during their first year, and then flower during the second year before dying. The main control tactic should again be mowing. However, rather than mowing at regular intervals, growers can wait until most of the biennial weeds are about to flower, then mow only as necessary. On small areas, the flower stalks of these plants can be destroyed with a string trimmer, or again with broad spectrum, non-selective herbicide. It is essential to prevent them from producing seed.

3. LONG TERM MAINTENANCE: Many native plants require several seasons before their initial flowering. As they mature, bees, butterflies, and other pollinators like hummingbirds will become increasingly common.

At this point the primary maintenance activity will be the periodic removal of undesirable woody plants and herbaceous weeds. This is often performed through mowing or burning in the early spring prior to the emergence of desirable pollinator plants.

To protect dormant insects such as butterfly pupae, you should only mow or burn part of the planting in a single season (Panzer 2002, Black et al. 2008). This should ideally be only one third or one-forth of the overall area. No single area should be burned or mowed more frequently than every two years. To facilitate these limited burns, temporary firebreaks can be created as needed, or they can be designed into the planting from the beginning by creating strips of turf grass that separate the habitat into multiple sections.

For detailed information on long-term site maintenance for pollinator habitat, that addresses techniques for minimizing the impact of herbicide, fire, grazing, mowing and other management activities, download a copy of:
Pollinators in Natural Areas: A Primer on Habitat Management.
http://www.xerces.org/Pollinator_Insect_Conservation/Managing_Habitat_for_Pollinators.pdf.

Appendix II contains a concise description of the Management Guidelines for Pollinator Conservation. Using a farm management plan that protects existing native bee habitats and minimizes the negative effects of certain farm management practices will allow both crops and native bees to thrive.

Monitoring

Assessing impacts of implementing practices to meet a management objective is best done through some form of monitoring the response of the target species. When the target species or guild is pollinators, monitoring the newly managed, restored or enhanced areas can provide some information as to the success of the landowner's efforts. Monitoring native pollinators nesting sites and the available forage sources of pollen and nectar throughout spring, summer, and fall can provide some information on the preferences of the native pollinators for that area of the state. More accurate assessments are derived by professionals or researchers. Monitoring by individuals with less rigorous training and experience is providing useful information for other guilds and classes of species such as the effort to assess abundance and diversity of birds through Christmas counts, breeding bird surveys, and eBird, a checklist program developed in 2002 by the Cornell Lab of Ornithology and National Audubon Society

Professional monitoring

To monitor native bee abundance and diversity, scientists utilize two main techniques: netting at flowers and pan-trapping to monitor native bee abundance and diversity. To determine the amount of forage available and estimate potential nesting sites, they conduct floral surveys that include a measure of bare ground (potential nest sites for ground-nesting bees) and nesting substrate (for tunnel nesting bees).

Citizen scientist monitoring

The Xerces Society and UC Berkeley developed a protocol and training materials for a citizen scientist monitoring program where citizen scientists are trained in how to observe and identify native bee groups. To be clear, the protocol does not require participants to determine which species they observe. Rather the goal is to teach observers how to recognize broad groups of bees (e.g. bumble bees, small sweat bees, large hairy leg bees, etc.). Early results from Xerces Society/UCB pilot tests suggest that the citizen monitoring technique tracks overall bee diversity and abundance. Ultimately, this monitoring tool will allow NRCS staff to monitor native bees on a given property, help growers recognize the native bees visiting their crops, and produce a standardized measure of the native bees on their land.

Additional Information

In addition to this document, information on pollinator habitat conservation is available through a number of other publications, websites, and organizations.

Publications

Black, S.H., N. Hodges, M. Vaughan and M. Shepherd. 2008. Pollinators in Natural Areas:A Primer on Habitat Management http://www.xerces.org/pubs_merch/Managing_Habitat_for_Pollinators.htm

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USDA-NRCS. Conservation Security Program Job Sheet: "Nectar Corridors," Plant Management EPL 41. *www.wv.nrcs.usda.gov/programs/csp/06csp/JobSheets/nectarCorridorsEL41.pdf*

USDA, NRCS, Idaho Plant Material Technical Note #2, "Plants for Pollinators in the Intermountain West" ftp://ftp-fc.sc.egov.usda.gov/ID/programs/technotes/pollinators07.pdf

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See "Native Pollinators", "Butterflies", "Bats", and "Ruby-throated Hummingbird" Fish and Wildlife Habitat Management Leaflet Numbers 34, 15, 5, and 14 respectively. http://www.whmi.nrcs.usda.gov/technical/leaflet.htm

Web-Sites

1. POLLINATOR INFORMATION

- The Xerces Society Pollinator Program http://www.xerces.org/Pollinator_Insect_Conservation
- USDA ARS Logan Bee Lab www.loganbeelab.usu.edu
- Logan Bee Lab – list of plants attractive to native bees http://www.ars.usda.gov/Main/docs.htm?docid=12052
- The Pollinator partnership http://www.pollinator.org/
- U.S. Forest Service Pollinator Information http://www.fs.fed.us/wildflowers/pollinators/index.shtml
- U.S. Fish & Wildlife Service Information http://www.fws.gov/pollinators/Index.html
- Pollinator friendly practices http://www.nappc.org/PollinatorFriendlyPractices.pdf
- Urban bee gardens http://nature.berkeley.edu/urbanbeegardens/index.html
- The Great Sunflower Project http://www.greatsunflower.org

2. HABITAT RESTORATION WITH NATIVE PLANTS

- California eVeg Guide http://www.calflora.org/app/npb?page=home [Login ID: Bennett, Password :1935]
- Considerations in choosing native plant materials http://www.fs.fed.us/wildflowers/nativeplantmaterials/index.shtml
- Selecting Native Plant Materials for Restoration http://extension.oregonstate.edu/catalog/pdf/em/em8885-e.pdf
- Native Seed Network http://www.nativeseednetwork.org/ has good species lists by ecological region and plant communities
- Prairie Plains Resource Institute has extensive guidelines for native plant establishment using agricultural field implements and methods http://www.prairieplains.org/restoration_.htm

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Acknowledgements

Financial support to the Xerces Society for the development of this technical note was provided by the NRCS Agricultural Wildlife Conservation Center, NRCS California, the CS Fund, the Turner Foundation, the Columbia Foundation, the Dudley Foundation, the Bullitt Foundation, the Disney Wildlife Conservation Fund, the Richard and Rhoda Goldman Foundation, the Panta Rhea Foundation, the Gaia Fund, the Billy Healy Foundation, the Bradshaw-Knight Foundation, the Wildwood Foundation, and Xerces Society Members.

APPENDIX I

Native California Forbs for Pollinators

Common Name	Scientific Name	MLRA's in which species occurs	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Annual, Perennial, or Biennial	Notes
Early Blooming Plants											
Imbricae phacelia	*Phacelia imbricata*	5, 14, 15, 16, 17, 18, 19, 20, 22A, 30	white	1	sun	moderate	7	8	moderate	P	
Purple Chinese houses	*Collinsia heterophylla*	14, 15, 16, 17, 18, 19, 20, 22A, 30	purple	3	shade	low	5	6	low	A	
California phacelia	*Phacelia californica*	4B, 5, 14, 15, 29	purple	3	sun	moderate	6	8	moderate	P	
Desert bluebells	*Phacelia campanularia*	17, 20, 30	blue	1	sun	high	6	8	moderate	A	
Large flower phacelia	*Phacelia grandiflora*	15, 19, 30	purple	3	sun to part shade	moderate	6	8	moderate	A	
California gilia	*Gilia achilleifolia*	14, 15, 16, 17, 19, 20	purple	2	sun	low	6	7.5	low	A	
Globe gilia	*Gilia capitata*	5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B	blue	3	sun	low	6	7	low	P	
Rigid hedgenettle	*Stachys ajugoides*	14, 15, 16, 17, 18, 19, 20, 22A, 30	pink	2	part shade	low	5	8	low	P	
Tansy phacelia	*Phacelia tanacetifolia*	5, 14, 15, 16, 17, 18, 20, 22A, 30	purple	1	sun	high	6	7.5	moderate	A	
California bee plant	*Scrophularia californica*	14, 15, 16, 17, 18, 19, 20, 22A, 29, 30	red	4	sun to shade	low	5	7	low	P	Host plant for Chalcedon Checkerspot butterfly
Five Spot	*Nemophila maculata*	17, 18, 22A	white	0.5	sun - prt shade	low	6.5	7.9	low	A	
Baby Blue Eyes	*Nemophila menziesii*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B, 30	Blue	0.5	sun - prt shade	low	6.5	7.9	low	A	

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Early to Mid-Season Blooming Plants											
Ithurieal's spear	*Triteleia laxa*	4B, 5, 14, 15, 16, 17, 18, 22A, 22B	purple	3	sun	moderate	6	8	low	P	
Bull Clover	*Trifolium fucatum*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 30	white, yellow, or red	1	sun to part shade	low	6	7.5	low	A	
Creek Clover	*Trifolium obtusiflorum*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B, 30	pink	1	sun to part shade	low	6	7.5	low	A	
Yellow bee plant	*Cleome lutea*	29	yellow	2.5	sun	high	6	8.5	moderate	P	
Rocky Mountain bee plant	*Cleome serrulata*	5, 22A, 26	pink	3	sun to shade	low	6	7.5	moderate	A	
California hedgenettle	*Stachys bullata*	14, 15, 16, 20	pink	2	part shade	low	5	8	low	P	
Lupine	*Lupinus* spp.	5, 14, 15, 16, 17, 18, 19, 20	blue	3	sun	low	6	8	low	A, P	Both annual and perennial species
Penstemon	*Penstemon* spp.	5, 14, 15, 16, 17, 18, 19, 20, 22A	purple	3	sun to shade	moderate	6	8	high	P	Numerous species available, depending on location.
salt heliotrope	*Heliotropium curassavicum*	14, 15, 16, 17, 18, 19, 20, 22A, 30, 31	white	0.5	sun	high	6	8	high	P	
Turkey tangle fogfruit	*Phyla nodiflora*	14, 15, 16, 17, 18, 19, 20, 22A	pink	0.5	sun	low	5.5	8.5	low	P	Can become weedy
California poppy	*Eschscholzia californica*	14, 15, 16, 17, 18, 19, 20, 22A, 29, 30	orange	2	sun	moderate	5	8	moderate	P	
Mid-Season Blooming Plants											
Deer Weed	*Lotus scoparius*	5, 14, 15, 16, 17, 18, 20, 22A, 30	yellow	3	sun	moderate	7	8	moderate	P	
Elegant clarkia	*Clarkia unguiculata*	5, 14, 15, 16, 17, 18, 20, 22A, 30	yellow	3	sun	moderate	7	8	moderate	P	

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Common Name	Scientific Name	MLRA's in which species occurs	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Annual, Perennial, or Biennial	Notes
Mid-Season Blooming Plants											
American licorice	*Glycyrrhiza lepidota*	4B, 5, 14, 15, 16, 17, 18, 22A, 22B	purple	3	sun	moderate	6	8	low	P	
Sneezeweed	*Helenium puberulum*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B	red	2	sun to shade	moderate	6	8	low	A	
Elegant madia	*Madia elegans*	5, 14, 15, 16, 17, 18, 20, 22A, 29, 30, 31	white	3	sun	low	5.5	8	moderate	P	
Evening primrose	*Oenothera elata*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A	yellow	3	sun	low	5	8	low	P	
Bird's eyes	*Gilia tricolor*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B, 30	yellow	3	part shade	moderate	6	8	moderate	P	
Buckwheat	*Eriogonum spp.*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 26	white, yellow, red	.5 - 4	sun to part shade	moderate	5.5	8	moderate	P	
Point Reyes horkelia	*Horkelia marinensis*	5, 14, 15, 16, 17, 18, 19, 20	purple	0.5	sun	high	6	8	moderate	A	
Common yarrow	*Achillea millefolium*	15, 19, 30	white	2	sun	moderate	5	7.5	moderate	P	
Coyote mint	*Monardella villosa*	4B, 5, 14, 15	white	1	sun	moderate	6	7.5	low	P	
Turkey mullein	*Eremocarpus setigerus*	14, 15, 16, 17, 18, 22A	purple	2	sun to shade	low	6	8	moderate	P	
Mid - Late Season Blooming Plants											
Spanish clover	*Lotus purshianus*	14, 15, 17, 18, 19, 20, 22A, 30	white	2	sun	low	5	8	high	P	
Fireweed	*Chamerion angustifolium*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 21, 22A, 22B, 26, 29, 30	pink	1	sun - shade	moderate	5.5	8	low	A	Can become weedy
California horkelia	*Horkelia californica*	14, 15, 16, 17, 18, 19, 20, 22A, 30	white	1	sun	moderate	5.5	7.5	moderate	A	

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Common Name	Scientific Name	MLRA's in which species occurs	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Annual, Perennial, or Biennial	Notes
Late Season Blooming Plants											
Blazing Star	*Mentzelia laevicaulis*	5, 14, 15, 17, 19, 20, 21, 22A, 22B, 26, 29, 30	yellow	3	sun	low	7	8	moderate	A	
Vinegar weed	*Trichostema lanceolatum*	5, 14, 15, 16, 17, 18, 19. 20, 22A, 22B, 30	blue	3	sun	low	6.8	7.8	moderate	A	
Gumplant	*Grindelia camporum*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B	yellow	3	sun	high	6	8	high	P	
Small flower western rosinweed	*Calycadenia pauciflora*	14, 15	white	3	sun	moderate	6	7.5	low	A	
Sunflower	*Helianthus* spp.	15, 16, 17, 18, 19, 20, 21, 22A, 23, 29, 30, 31	yellow	3	sun	moderate	5.5	8	moderate	A	
California goldenrod	*Solidago californica*	14, 15, 17, 18, 19, 20, 22A, 30	yellow	3	sun	low	5.5	7	low	P	
Western Goldentop	*Euthemia occidentalis*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B, 29, 30	yellow	3	sun	low	5.5	8	high	P	
Hayfield tarweed	*Hemizonia congesta*	5, 14, 15, 16, 17	white	3	sun	low	6	7	low	A	
Rod wirelettuce	*Stephanomeria virgata*	14, 15, 16, 17, 18, 19, 20, 22A, 30	white, purple	6	sun	moderate	6	7	low	P	easily hybridizes with other *Stephanomeria* species
Aster	*Aster spp.*	4B, 5, 14, 15, 16, 17, 18, 20, 22A, 22B, 29, 30	white, blue, purple	3	sun	moderate	5	7	moderate	P	
Hummingbird trumpet	*Epilobium canum*	15, 19, 20, 30	red	2	sun	high	5.5	6.5	moderate	P	attracts hummingbirds

* Heights and tolerances may differ between populations, races, or ecotypes of the same species.

APPENDIX I

California Garden Plants for Pollinators

Common Name	Scientific Name	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Annual, Perennial, or Biennial	Notes
Early Blooming Plants										
Borage	*Borago officinalis*	blue	2	sun	low	6	7.5	moderate	A	
Pride of Madeira	*Echium candicans*	blue	6	sun	high				P	
Chamomile	*Matricaria recutita*	white	0.5	sun	moderate	5.5	7.5		A	
Tansy phacelia	*Phacelia tanacetifolia*	purple	1	sun	high	6	7.5	moderate	A	
Early to Mid-Season Blooming Plants										
Horehound	*Marrunbium vulgare*	white	3	sun	low	6	8	low	P	Can become weedy
Penstemon	*Penstemon* spp.	purple	3	sun to shade	moderate	6	9	high	P	
Lavender	*Lavandula* spp.	purple	3	sun	moderate	6.5	7.5	moderate	P	
Cape mallow	*Anisodontea* spp.	pink	6	sun	high				P	
Mid-Season Blooming Plants										
Pincushion flower	*Scabiosa atropurpurea*	purple	3	sun	moderate	6.5	8		P	
Basil	*Ocimum* spp.	white	2	sun	moderate	4	8	low	A	
Sea holly	*Eryngium* spp.	blue	2	sun	moderate	6.5	8	low	P	
Korean hummingbird mint	*Agastache rugosa*	purple	4	sun - part shade	low	6	8	low	P	
Anise hyssop	*Agastache rupestris*	purple	4	sun - part shade	low	6	8	moderate	P	
Catmint	*Nepeta* spp.	white or blue	1	sun - part shade	moderate	6	8	low	P	
Russian sage	*Perovskia atriplicifolia*	blue	5	sun	moderate	6	7.5	high	P	
Oregano	*Origanum* spp.	pink	1	sun	high	6.5	8	moderate	P	
Toadflax	*Linaria purpurea*	purple	3	sun		6	8	low	P	
Spearmint	*Mentha spicata*	white or pink	1	sun	low	6.5	7	low	P	
Thyme	*Thymus* spp.	pink	1	sun	moderate	6.5	8	moderate	P	

APPENDIX I

California Garden Plants for Pollinators

Common Name	Scientific Name	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Annual, Perennial, or Biennial	Notes
Mid to Late Season Blooming Plants										
Globe thistle	*Echinops ritro*	blue	5	sun	high	5	6		P	
Mexican sunflower	*Tithonia rotundifolia*	orange	6	sun	moderate	6	8	moderate	A	
Calliopsis	*Coreopsis tinctoria*	yellow	3	sun	high	6	7.5	low	A,B,P	
Cosmos	*Cosmos bipinnatus*	variable	5	sun	high	6.5	8.5	moderate	A	
Salvia	*Salvia* spp.	blue	5	sun to part shade	moderate	5.5	7.5		P	
Late Season Blooming Plants										
Rosemary	*Rosemarinus officinalis*	blue	3	sun	high	6.5	7.5	moderate	P	
Blue mist	*Caryopteris x clandonensis*	blue	2	sun - part shade	moderate	6	7.5	low	P	
Sunflower	*Helianthus* spp.	yellow	3	sun	moderate	5.5	8	moderate	A	
Monch Aster	*Aster* spp.	blue	2	sun - part shade	moderate	6.5	7.5		P	

* Heights and tolerances may differ between populations, races, or ecotypes of the same species.

APPENDIX I

Native California Bunch Grasses for Pollinators

Common Name	Scientific Name	MLRA's in which species occurs	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Notes
Tufted hair grass	*Deschampsia caespitosa*	4B, 5, 14, 15, 16, 17, 18, 20, 22A, 26	2	sun	low	5	7	low	
Purple needle grass	*Nassella pulchra*	14, 15, 17, 19, 20	2	sun	high	5	8	moderate	
California meadow barley	*Hordeum brachyantherum*	14, 15, 16, 17, 18, 19, 10, 22A, 26, 30	0.5	sun	low	5	7	low	
Blue wildrye	*Elymus glaucus*	15, 17, 18, 19, 20, 22A, 30	2	part shade	moderate	5	9	low	
Pacific reed grass	*Calamagrostis nutkaensis*	4B, 5, 14, 15	4	sun	low	5.5	7.5	moderate	
San Diego sedge	*Carex spissa*	15, 19, 20	6	sun	low	5	7.5	moderate	
California fescue	*Festuca californica*	4B, 5, 14, 15, 16, 17, 18, 20, 22A	3	part shade	low	6	7.5	low	
Idaho fescue	*Festuca idahoensis*	4B, 5, 14, 15, 17, 18, 22A, 22B, 26	1	sun	moderate	6	8	moderate	Host plant for Lindsey Skipper butterfly
Deergrass	*Muhlenbergia rigens*	5, 15, 17, 18, 19, 20, 22A, 30	3	sun	moderate	5	8		
Desert needle grass	*Stipa speciosa*	15, 17, 18, 19, 20, 30	1	sun	high	7	8	moderate	
Basin wildrye	*Elymus cinereus*	21, 22A, 26, 29, 30	2	sun	high	6	9	high	
Bifid Sedge	*Carex serratodens*	5, 14, 15, 16, 17, 18, 22A	5	sun	low	5	8	low	
Cane Bluestem	*Andropogon barbinodis*	19, 20, 30	5	sun	moderate	7	10	low	
Various nerved sedge	*Carex heteroneura*	22A, 22B, 26, 30	2	sun	low	4	7	low	

* Heights and tolerances may differ between populations, races, or ecotypes of the same species.

APPENDIX I

Insectary and Pollinator Friendly Cover Crops for California

Common Name	Scientific Name	Bloom Period	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Annual, Perennial, or Biennial	Notes
Early Blooming Plants											
Hairy vetch	*Vicia villosa*	early	blue	1	sun to part shade	low	5.5	6.5	moderate	A	
Canola	*Brassica napus*	early	yellow	1	sun	low	5.5	7	moderate	A	
Crimson clover	*Trifolium incarnatum*	early	red	1	sun to part shade	low	6	7	low	A	
Phacelia	*Phacelia tanacetifolia*	early	purple	3	sun to shade	moderate	6	9	high	A	
Borage	*Borage officinalis*	early	blue	1.5	sun	low	6	7.5	moderate	A	
Early to Mid-Season Blooming Plants											
White Lupine	*Lupinus alba*	early to mid	blue or white	3	sun	low	5	8	low	A	
Purple vetch	*Vicia atropurpurea*	early to mid	purple	1.5	sun to part shade	low	5.5	6.5	moderate	A	
Daikon radish	*Raphanus sativus*	early to mid	white	2	sun	moderate	6.5	7.5	low	B	
Fava bean	*Vicia faba*	early to mid	white	4	sun	low	5	8	low	A	
Mid-Season Blooming Plants											
Alfalfa	*Medicago sativa*	mid	purple	1.5	sun	moderate	6.5	7	moderate	P, A	perennial and annual varieties
New Zealand clover	*Trifolium repens*	mid	white		sun to part shade	low	6	7	low	P	
Mid to Late Season Blooming Plants											
Buckwheat	*Fagopyrum esculentum*	mid to late	white	1.5	sun	moderate	5.5	6.5	moderate	A	

* Heights and tolerances may differ between populations, races, or ecotypes of the same species.

APPENDIX I

Native California Trees and Shrubs for Pollinators

Common Name	Scientific Name	MLRA's in which species occurs	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Notes
Very Early Blooming Plants										
Whiteleaf Manzanita	*Arctostaphylos Manzanita*	4B, 5, 22A, 22B	white	10	sun	high	5	7	low	
Sticky Whiteleaf Manzanita	*Arctostaphylos viscida*	4B, 5, 17, 18, 21, 22A, 22B	pink	12	sun	high	5	7	low	
Bigberry Manzanita	*Arctostaphylos glauca*	14, 15, 17, 19, 20, 30, 31	white	12	sun	high	5.9	7	low	
Pinemat Manzanita	*Arctostaphylos nevadensis*	4B, 5, 17, 18, 21, 22B, 22A, 23, 30	white	2	sun - part shade	high	6	8.4	low	
Greenleaf Manzanita	*Arctostaphylos patula*	4B, 5, 19, 20, 21, 22A, 22B, 26, 29, 30, 31	white	6	sun	high	5.5	7.6	low	
Willow	*Salix* spp.	4B, 5, 14, 15, 16, 17, 18, 19, 20, 21, 22A, 22B, 29, 30, 31	yellow	20	sun	low	5	8	low	separate male and female plants
Early Blooming Plants										
Western Redbud	*Cercis occidentalis*	5, 14, 15, 16, 17, 18, 20, 21, 22A, 22B 30	red	15	sun - shade	moderate	5.5	8	low	
Oregon Grape	*Mahonia aquifolium*	5, 14, 15, 17, 18, 19, 20, 21, 22A, 22B, 23, 30, 31	yellow	8	sun - shade	moderate	5	8	low	
Buckbrush	*Ceanothus cuneatus*	15, 17, 18, 19, 20, 30	white	8	sun	high	6	8	moderate	
Blueblossom Ceanothus	*Ceanothus thyrsiflorus*	4B, 5, 14, 15, 19, 20, 21, 22A, 22B, 30, 31	blue	12	sun - part shade	high	5	8	moderate	

APPENDIX I

Native California Trees and Shrubs for Pollinators

Common Name	Scientific Name	MLRA's in which species occurs	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Notes
Early Blooming Plants										
Woolyleaf Ceanothus	*Ceanothus tomentosus*	4B, 5, 18, 19, 20, 22A, 22B, 30, 31	blue / white	8	sun - prt shade	high	5	8	moderate	
Ocean Spray	*Holodiscus discolor*	14, 15, 16, 17, 18, 19, 20, 221A, 26, 30	white	5	sun to shade	low	6	8	moderate	
False white indigobush	*Amorpha fruticosa*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A	white	10	sun	moderate	6	8	high	
Hollyleaf cherry	*Prunus ilicifolia*	15, 17, 18, 19, 20, 30	white	25	sun	low	5	8	low	
Early to Mid-Season Blooming Plants										
Mule Fat	*Baccharis salicifolia*	15, 16, 17, 18, 19, 20, 30	white	8	sun	low	6	8.5	moderate	separate male and female plants
Deerbrush	*Ceanothus integerrimus*	4B, 5, 15, 17, 18, 19, 20, 21, 22A, 30, 31	white / pink	12	sun - part shade	moderate	7	8.5	low	
Yerba Santa	*Eriodictyon californicum*	5, 14, 15, 16, 17, 18, 22A, 30	pink	5	sun	moderate	5	8	moderate	
Mock Orange	*Philadelphus lewisii*	4B, 5, 17, 18, 22A, 22B,	white	8	sun	moderate	7	8	low	
Flannel Bush	*Fremontodendron californicum*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 22B, 30	yellow	10	sun - part shade	high	6	8	moderate	

APPENDIX I

Native California Trees and Shrubs for Pollinators

Common Name	Scientific Name	MLRA's in which species occurs	Flower Color	*Height Mature (feet)	Light Needs	*Drought Tolerance	*pH Min.	*pH Max.	*Salinity Tolerance	Notes
Mid-Season Blooming Plants										
Toyon	*Heteromeles arbutifolia*	14, 15, 16, 17, 18, 19, 20	white	4	sun - part shade	high	5	8	moderate	
California Buckwheat	*Eriogonum fasciculatum*	14, 15, 16, 17, 18, 19, 20, 22A, 30, 31	white	5	sun	high	6	8	moderate	
Naked Buckwheat	*Eriogonum nudum*	4B, 5, 14, 15, 16, 17, 18, 19, 20, 22A, 26, 30, 31	white	6	sun	high	6	8	moderate	
California Wild Rose	*Rosa californica*	14, 15, 16, 17, 18, 19, 20, 22A	pink	6	sun - shade	moderate	5	8	low	
Chamise	*Adenostoma fasciculatum*	15, 19, 20, 30	white	10	sun	high	5	8	high	
Western dogwood	*Cornus sericea*	5, 14, 15, 16, 17, 18, 20, 22A, 30	white	4	sun to shade	low	5	7	low	
California coffeeberry	*Rhamnus californica (Frangula californica)*	15, 17, 18, 19, 20, 30	white	15	part shade	moderate	6	6	moderate	
Late Season Blooming Plants										
Button bush	*Cephalanthus occidentalis*	15, 17, 18	white	6	sun	low	5	8.5	high	
Rabbitbrush	*Chrysothamus viscidiflorus*	4B, 5, 17, 18, 20, 21, 22A, 22B, 30, 31	yellow	3	sun	high	7	8.5	low	
Sulphur Flower	*Eriogonum umbellatum*	4B, 5, 16, 17, 18, 20, 21, 22A, 22B, 23, 26, 29, 30, 31	yellow	4	sun	high	6	8	high	
Coyotebrush	*Baccharis pilularis*	14, 15, 16, 17, 18, 19, 20	white	8	sun	moderate	5	8	moderate	separate male and female plants

* Heights and tolerances may differ between populations, races, or ecotypes of the same species.

APPENDIX II

Farm Management Guidelines for Pollinator Conservation

There are approximately 1,500 species of native bees in California. These bees contribute substantially to the agriculture of the state and are increasingly important as honey bee numbers continue to decline. The annual value of the pollination service that these native bees provide to the U.S. economy is believed to be worth $3 billion worth, and new research conducted in California suggests that interactions between native bees and managed honey bees results in more effective overall crop pollination.

The habitat requirements of our native bees vary. Most need a diversity of plants that provide pollen and nectar throughout the growing season. Similarly, depending on the species, these bees might nest in the ground, in hollow twigs and abandoned beetle burrows in trees, in clumps of lodged grass, or even in abandoned rodent burrows.

Using a farm management plan that protects existing native bee habitat and minimizes the negative effects of certain farm management practices will allow both crops and native bees to thrive.

Whole Farm Practices

Even when prolifically blooming crops are available, bees and other pollinators have additional needs. For example the bloom period of most crops is shorter than the lifespan of many bees. Without additional food sources, bees will leave an area and their long-term population will decline. Similarly, pollinators need refuge areas free of pesticides, and undisturbed areas for reproduction and nesting.

These needs should be incorporated into the entire farm where possible, including field margins, riparian areas, uncultivated land around buildings and equipment parking areas.

Reduce Pesticide Use
Create pesticide buffer zones between crops and natural areas or conservation plantings.
Protect Native Bee Nest Sites
Conserve known native bee nest sites such as wood piles, dead timber, patches of bare ground, and habitat patches with abandoned rodent burrows.
Conserve Alternative Forage Sources
Allow native plants and non-invasive weeds outside of crop areas to bloom, unless the bloom time is the same as crops requiring pollination.
Land Planning
Consider transitioning unproductive fields into natural habitat areas.

Crop Management Guidelines

Some crop management practices promote bee abundance while others are detrimental. Weed and pest control make it difficult to follow all of these recommendations, but any effort where possible should be attempted.

Protection of Pollinators from Pesticides
Use the least toxic pesticide formulation available.
Do not spray insecticides to blooming crops or to adjacent flowering weeds.
Apply pesticides at night if possible when bees are not active.
Control spray drift and over-application drift, through equipment calibration, proper nozzle and pressure settings, and by spraying under appropriate weather conditions.
Establish an Integrated Pest Management (IPM) program, including practices like using multiple pest control practices, crop scouting, and establishing economic thresholds before resorting to chemical controls.
Conservation of Ground-Nesting Bees
Use shallow or no-till practices to conserve ground nesting bees (alternative practices include flame weeding, hooded row sprayers, and selective herbicides).
Minimize the use of plastic mulch.
Avoid flood irrigation.
Do not use soil fumigants such as chloropicrin.
Providing Alternative Bee Forage
Grow a diversity of crops, stagger planting times to maximize bloom period, and allow un-harvested crops to bolt.
Plant flowering cover crops in fallow fields.
Plant flowering bee pasture strips between crop rows.

Managing Pollinator Habitat Enhancement Sites

Pollinator conservation areas can be used in agricultural landscapes to encourage crop-pollinating native bees.

With minimal maintenance, restored native plants will prosper, and your resident bee population will continue to grow. An effective management plan balances the needs of the pollinators with the maintenance requirements of the area.

These guidelines apply *after the initial installation and weed control phase is complete*, a process that may require several years.

Protection of Pollinators
Avoid mowing, tilling, burning, and/or applying herbicides in restored areas during the growing season.
Do not apply pesticides within restored areas.
Establish a buffer zone around pollinator enhancement sites to reduce the potential for pesticide and herbicide drift.

Management of Native Bee Nest Sites
Reduce tillage near or in enhancement areas to protect ground-nesting bees.
Avoid off-road driving in pollinator areas, regardless of time of year.
Perform maintenance activities on only small sections of restored areas, at infrequent intervals (e.g. only burn or mow 1/3 to 1/4 of the area at 2 or 3 year intervals).
Phase out and replace bee blocks every few years.
Landscape Operations
Control invasive weeds.
Replace species that die-out or do not thrive to ensure season-long blooms.
Irrigate and protect new transplants as necessary.

Technical and Financial Assistance
USDA Natural Resources Conservation Service (NRCS)
For questions about habitat restoration, native plant establishment, or conservation efforts, and for financial assistance in implementing conservation practices contact your local NRCS or conservation district office (http://www.ca.nrcs.usda.gov/ and http://carcd.org/directory.php)

Pesticide Information
How to Reduce Bee Poisoning from Pesticides
This Oregon State University Extension Service publication contains an extensive list of agricultural chemicals and their relative toxicity to multiple bee species. The chemicals on the list are common throughout much of the U.S. and the multi-species approach makes the list a useful supplement to product labels which typically only reference honey bee toxicity. http://extension.oregonstate.edu/catalog/pdf/pnw/pnw591.pdf. Another site is the IPM program information on relative toxicity of pesticide use in cucurbits to natural enemies and honey bees at http://www.ipm.ucdavis.edu/PMG/r116900311.html .

Additional Pollinator Conservation Information
The Xerces Society for Invertebrate Conservation
http://www.xerces.org
The Xerces Society is a member-supported, nonprofit organization dedicated to preserving wildlife habitat and biodiversity through the conservation of invertebrates. Through its pollinator Conservation Program (www.xerces.org/Pollinator_Insect_Conservation), the Society offers practical advice on habitat management for native pollinator insects.

USDA-Agriculture Research Service, Pollinating Insect-Biology, Management, and Systematics Research Lab
http://www.ars.usda.gov/main/site_main.htm?modecode=54280500
The scientists working at this lab conduct research on native bees as crop pollinators. Their web site provides information on identifying bees, bee plants and enhancing nesting habitat.