TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE STATE OF COLORADO NATURAL RESOURCES CONSERVATION SERVICE

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Pollinator Biology and Habitat

This technical note provides information on how to plan for, protect, and create habitat for pollinators in agricultural settings. 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.

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. 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, and egg-laying or nesting sites. The NRCS can assist landowners with providing adequate pollinator habitat by, for example, suggesting locally appropriate plants and offering advice on how to provide nesting or egg-laying habitat.

Pollinator Conservation and Farm System Planning

A growing emphasis within the NRCS is to take a whole farm approach to conservation efforts. As projects are being considered, field conservation staff must constantly weigh the potential costs against the benefits of the practices they help implement.

Habitat enhancement for native pollinators 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 your 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.

This document provides a four-step approach to pollinator conservation: (1) advice on recognizing existing pollinator habitat, (2) steps to protect pollinators and existing habitat, (3) methods to further enhance or restore habitat for pollinators, and then (4) managing habitat for the benefit of a diverse pollinator community.

General native pollinator habitat requirements

Pollinator	**Food**	**Shelter**
Solitary bees Bumble bees	Nectar and pollen 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 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		
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
Hummingbirds	Nectar, insects, tree sap, spiders, caterpillars, aphids, insect eggs, and willow catkins Typically need red, deep-throated flowers, such as twin berry or penstemons	Trees, shrubs, and vines.

[Adapted from: Native Pollinators. Feb. 2006. Fish and Wildlife Habitat Management Leaflet. No. 34.]

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). Linear habitats along field margins such as field edges, hedgerows, and drainage ditches 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, marginal areas, less fit for crops, may be useful instead as pollinator habitat (Morandin and Winston 2006). Here we provide advice on recognizing specific habitat resources so that they can be factored into farm systems planning.

A. **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, etc. 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 letting some of the native or non-native forbs that are currently present on site to bloom prior to their crop bloom, mow them during crop bloom, then let them bloom again afterward. For example, dandelions, clover, and other non-native plants are often good pollinator plants (Free 1968, Mosquin 1971). Forbs can be mowed during crop bloom; however, one must weight benefits to crop pollination against potential negative effects on ground nesting wildlife. Forbs can be mowed during crop bloom; however, one must weight benefits to crop pollination against potential negative effects on ground nesting wildlife. Growers may also allow some 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).

Keep in mind that small bees may only fly a couple hundred yards, while large bees, such as bumble bees, easily forage a mile or more from their nest (Greenleaf et al. 2007). 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 a resident population of pollinators (Winfree et al. 2008).

B. **Nesting and Overwintering Sites**

Bees need nest sites. Indeed, to support 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). However, it is important that these two key habitat components are not too far apart (Westrich 1996).

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 black berry 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 sand 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 100s or 1000s 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). Bunch grasses tend to provide better nesting habitat than does sod- forming varieties.

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 or contact local experts (Appendix I. A) to find out about species' specific needs.

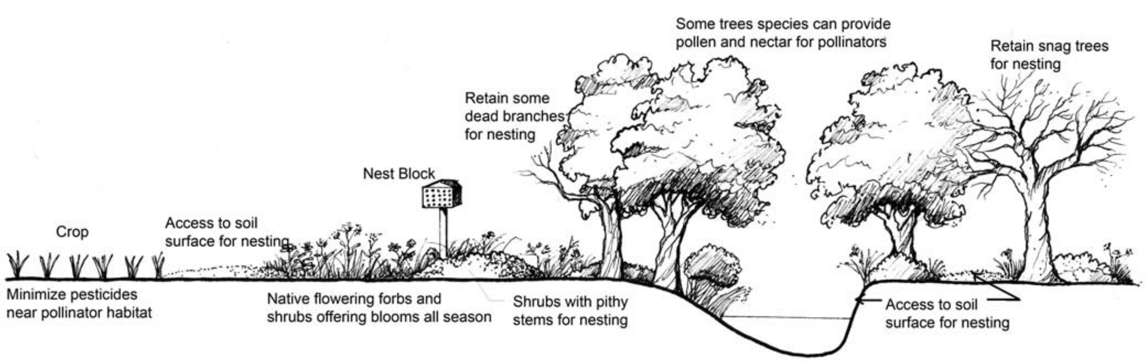

Figure 1. From: Agroforestry Note – 34: "Enhancing Nest Sites for Native Bee Crop Pollinators"

II. Protecting Pollinators and Their Habitat

When farmers and landowners recognize the potential pollinator habitat on their land, they can then work to protect these resources. In addition to conserving the food and nest sources of their resident pollinators, farmers can take an active role in reducing 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. **Minimizing Pesticide Use**

Pesticides are detrimental to a healthy community of native pollinators. 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).

Integrated Pest Management (IPM) can protect pollinators by combining Prevention, Avoidance, Monitoring and Suppression activities in a way that minimizes potential economic, health and environmental risks. IPM is a science based decision-making process that coordinates the use of pest biology, environmental information and available technology to prevent unacceptable levels of pest damage by the most economical means, while posing the least possible risk to people, property, resources and the environment, including pollinators (USFW 2006).

What are the benefits of IPM?

1. Reduce risks from pest management-related strategies to people, property, resources and the environment.
2. Save time and resources by understanding pest biology and eliminating conditions that favor the pest, thereby reducing the need to manage the pest.
3. Increase implementation of more effective pest management strategies by using a tiered decision - making process.
4. Increase management of pest species based on a proactive science based approach rather than managing pests on a calendar basis or waiting for a pest outbreak.
5. Increase coordination and partnerships for effective pest management.
6. Decrease or eliminate unnecessary pesticide use.
7. Decrease pest resistance from repetitive pesticide use.
8. Increase the use of best management practices for pesticides and other management tools. To

protect pollinators from pesticide exposure:

1. Do not apply insecticides to crops unless pests have exceeded the recommended action threshold.
2. Consider alternative control measures (e.g. early cutting in the case of alfalfa weevil).
3. If an insecticide treatment is necessary, make applications during early morning or late evening hours when bees are less likely to be foraging.
4. Avoid treating fields in which crop and or weeds are in bloom.
5. If a crop in bloom (especially alfalfa) is to be treated, notify local beekeepers so their bees can be moved or confined before the application.
6. Read, understand and follow all label instructions including environmental hazards.
7. Use insecticides that are relatively safe for bees (Peairs 2001).

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).

All pesticide labels include a statement of environmental hazards, which includes recommendations to protect bees, birds, mammals, fish and aquatic invertebrates. Always read and understand the pesticide label before using the product. 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. Local cooperative extension personnel can often assist with the selection of less toxic pesticides.

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 effecting 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.

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 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 worst 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 insecticide within the crop canopy where it is less likely to be carried by wind currents (Ozkan 2000).

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.

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).

B. **Minimizing 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), as well as other wildlife. 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) and no more than one-half of the field per year.

C. **Protecting Ground Nesting Bees**

In order to protect nest sites of ground-nesting bees, 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 should be avoided. 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 (Agrios 2005, Yeates et al. 1991).

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

D. **Protecting 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, so long as they do not pose a risk to property or people, and protecting shrubs with pithy or hollow stems, such as elderberry, raspberry, black berry, box elder, will go a long way towards supporting these solitary bees.

III. Enhancing and Developing New Pollinator Habitat

Landowners who want to take a more active role in increasing their population of resident pollinators can increase the available foraging habitat to 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 other similar efforts.

Where possible, locally, native plants are often preferred for their ease of establishment, greater wildlife value, and their mutually beneficial co-evolution 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, so 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 (including aspect and plant shade) 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, which are usually of little food value to pollinators, but may host nest sites for ground-nesting bees and bumble bees. 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. USING 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 (Carvell 2004).

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 one-half acre area in size, with two acres or more 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 reduce 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 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, might still benefit from pollinator habitat located some distance from the field (although even bumble bees prefer habitat as close to the crop as possible). 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 sites, or constructing new enhancement areas adjacent to them.

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 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 (Tillman et al. 2006). 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 *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 more even ideal for attracting pollinators and providing efficient foraging (Frankie et al. 2002).

4. INCLUSION OF 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 or shrubs 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 form 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. Planting in the fall, rather than spring, 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. 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. Similarly, 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 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 available and economical, native plants and seed should be procured from "local eco-type" providers (Aldrich 2002). 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). 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 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 during which they may need mulching and supplemental water to insure 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. Similarly 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 areas of low cost, temporary bee pasture 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 Section VI.

D. Creating 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, however, the precise conditions needed by most other ground-nesting bees are not well known. Some species nest in the ground at the base of plants, and others prefer smooth packed bare ground. Landowners can create conditions suitable to a variety of species by maximizing areas of undisturbed, untilled ground and/or 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, loamy sand 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.

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 (Vaughan et al 2007).

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. 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 richhabitat 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).

Similarly, no single area should be burned 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 planning permanent firebreaks using the NRCS Conservation Practice Standard 394, Firebreak, that separate the habitat into multiple sections.

Pollinator Habitat and NRCS Practices

The Natural Resources Conservation Service supports the use of native species in many of their conservation practices that involve seeding or transplanting. Selecting pollinator-friendly native 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, criteria or considerations for enhancing wildlife (including pollinators). However, an enhancement for wildlife should not compromise other intended functions 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 primary objective of stabilizing the waterway against erosion.

Some practices that could include pollinator friendly supplements include:

Conservation Practice Name	Code	Pollinator Notes (Units)
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 Crop Rotation	328	Can include rotation plantings that provide abundant (Ac.)

forage for pollinators forbs (e.g. various legumes, buckwheat (*Fagopyrum* 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.

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 (*Fagopyrum* 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 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 2 to 3 years and, ideally, on only 30 % or less of the overall site. This allows for recolonization from non- treated habitat. For example, mowing or burning 1/3 of the site every 2 or 3 years, on a 3-year cycle. When possible, disturbance should be implemented during late fall and winter when most pollinators are inactive.
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 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.
Forest Stand (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.
Pasture and Hay (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	595	Biological pest management can include plantings that

		attract beneficial insects that predate or parasitized crop 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	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	528	Can help maintain late successional habitat and its associated flowering plants. Can help provide for a stable base of pollinator plant species. 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 and 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.
Stream Habitat Improvement	395	Plants chosen for adjoining riparian areas can include
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.

and Management (Ac.)		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 in the field are extended over a longer period of time.
Tree/Shrub Establishment	612	Can include trees and shrubs especially chosen to provide pollen and nectar for pollinators, or host plants for butterflies
Use Exclusion (Ac.)	472	Used to keep humans and other animals out of a planting, thus protecting the site from related damage.
Wetland Creation (Ac.)	658	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 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 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.

Conversely, various pollinator requirements are supported by the following conservation practices:

Pollinator	Code and Conservation Practice Name (Units) Resource	
Forage (diverse sources of pollen and nectar that support pollinators from early in the spring to late in the fall)	327 Conservation Cover (Ac.) 328 Conservation Crop Rotation (Ac.) 340 Cover Crop (Ac.) 342 Critical Area Planting (Ac.) 386 Field Border (Ft.) 393 Filter Strip (Ac.) 512 Pasture and Hay Planting (Ac.) 595 Pest Management (Ac.) 409 Prescribed Forestry (Ac.) 528 Prescribed Grazing (Ac.) 550 Range Planting (Ac.) 643 Restoration and Management of Rare and Declining Habitats (Ac.) 391 Riparian Forest Buffer (Ac.) 390 Riparian Herbaceous Cover	395 Stream Habitat Improvement and Management (Ac.) 580 Streambank and Shoreline Protection (Ft.) 585 Stripcropping (Ac.) 612 Tree/Shrub Establishment (Ac.) 645 Upland Wildlife Habitat Management (Ac.) 472 Use Exclusion (Ac.) 658 Wetland Creation (Ac.) 659 Wetland Enhancement (Ac.) 657 Wetland Restoration (Ac.) 644 Wetland Wildlife Habitat Management (Ac.) 380 Windbreak/Shelterbelt Establishment (Ft.) 650 Windbreak/Shelterbelt Renovation (Ft.)

(Ac)		
Nest sites (stable ground, holes in wood, cavities for bumble bees, or overwintering sites for bumble bee queens)	342 Critical Area Planting (Ac.) 386 Field Border (Ft.) 409 Prescribed Forestry (Ac.) 329 Residue & Tillage Management, No-Till/Strip Till/Direct Seed (Ac.) 643 Restoration and Management of Rare and Declining Habitats (Ac.) 391 Riparian Forest Buffer (Ac.) 612 Tree/Shrub Establishment (Ac.)	645 Upland Wildlife Habitat Management (Ac.) 658 Wetland Creation (Ac.) 659 Wetland Enhancement (Ac.) 657 Wetland Restoration (Ac.) 644 Wetland Wildlife Habitat Management (Ac.) 380 Windbreak/Shelterbelt Establishment (Ft.) 650 Windbreak/Shelterbelt Renovation (Ft.)
Pesticide protection (refuge from spray, buffers to drift, etc.)	342 Critical Area Planting (Ac.) 391 Riparian Forest Buffer (Ac.)	657 Wetland Restoration (Ac.) 380 Windbreak/Shelterbelt Establishment (Ft.)
Site management for pollinators	647 Early Successional Habitat Development or Management (Ac.) 595 Pest Management (Ac.) 338 Prescribed Burning (Ac.) 409 Prescribed Forestry (Ac.) 528 Prescribed Grazing (Ac.)	643 Restoration and Management of Rare and Declining Habitats (Ac.) 645 Upland Wildlife Habitat Management (Ac.) 644 Wetland Wildlife Habitat Management (Ac.)

Plant Tables

Below are tables with information about native and non-native trees, shrubs, wildflowers, and grasses to consider for plantings to enhance pollinator habitat. 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 your Ecological Site Description, Soil Survey plant list, Colorado Plant Materials Technical Note #59, or other plant zone criteria. 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/).

These tables 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. Bloom times can vary depending on timing of rainfall or irrigation, whether or not the site is mowed or grazed, elevation, aspect, and other factors. For this technical note:
Early = April/May Mid = June/July
Late = August/September

I. 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, fertilizing) are calculated over the long-term, native plantings can ultimately 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).

A. Native Trees and Shrubs for Pollinator Enhancement

Tree and shrub plantings may be designed for a number of concurrent purposes, such as wildlife enhancement, streambank stabilization, windbreak, and/or pollinator enhancement (Henry et al. 1999). These are just some of the tree and shrub species that you might want to consider, paying close attention to overlapping bloom periods and the appropriate plant for the site conditions.

Common Name	***Scientific Name***	**Native or Introduced**		**Bloom Time**		
		Native	**Introduced**	**Early**	**Mid**	**Late**
American plum	*Prunus americana*	y		y		
Apple/crabapple	*Malus spp.*		y	y		
Aspen	*Populus tremuloides*	y		y		
Ball cactus	*Pediocactus simpsonii*	y			y	
Bitterbrush/Antelope brush	*Purshia tridentata*	y		y		
Boulder Raspberry	*Oreobatus deliciosus*	y			y	
Buckbrush	*Ceanothus spp.*	y			y	
Buffaloberry	*Shepherdia spp.*	y		y	y	
Butterfly bush	*Buddleia spp.*		y		y	y
Caryopteris	*Caryopteris spp.*		y			y
Cherry	*Prunus spp.*		y	y		
Chokecherry	*Padus (Prunus) virginiana*	y		y	y	
Cliff Fendler Bush	*Fendler rupicola*	y		y	y	
Cliffrose/Quininebush	*Cowania stansburiana*	y		y		
Cottonwood	*Populus spp.*					
Currant	*Ribes spp.*	y		y	y	
Elder	*Sambucus spp.*	y			y	
Firethorn	*Cotoneasater pyracantha*		y	y		
Gambel oak	*Quercus gambelii*	y		y		
Gooseberry	*Ribes inerme*	y			y	
Hackberry	*Celtis occidentalis*	y	y	y		
Hawthorn	*Crategus spp.*	y		y		
Hedgehog/claret cup cactus	*Echinocereus spp.*	y			y	
Highbush cranberry	*Viburnum edule*	y		y	y	
Holly/Oregon Grape	*Mahonia (Berberis) repens*	y		y		
Honeysuckle	*Lonicera spp.*	y		y	y	
Leadplant	*Amorpha fruticosa/canescens*	y			y	
Lilac	*Syringa vulgaris*		y	y	y	
Mock Orange	*Philadelphus microphyllus*	y		y		
Mountain ash	*Sorbus scopulina*	y		y	y	
Ninebark	*Physocarpus spp.*	y			y	
Pin Cherry	*Prunus pennsylvanica*	y		y		
Pincushion cactus	*Coryphantha/Escobaria spp.*	y			y	
Prickly pear	*Opuntia spp.*	y			y	
Rabbitbrush	*Ericameria nauseosus*	y				y
Raspberry	*Rubus idaeus*	y			y	

Redosier dogwood	*Swida/Cornus sericea*	y		y	y	
Sand Cherry	*Prunus besseyi*	y		y		
Serviceberry/Shadbush	*Amelanchier utahensis/alnifolia*	y		y		
Shrubby cinquefoil	*Pentaphylloides/Potentilla floribunda/fruticosa*	y		y		y
Siberian peashrub	*Caragana arborescens*		y	y	y	
Skunkbrush/Lemonadebush	*Rhus aromatica/trilobata*	y		y		
Snowball tree	*Viburnum opulus*		y	y		
Snowberry	*Symphoricarpos spp.*	y			y	
Spirea	*Holodiscus dumosus*	y			y	
Squaw apple	*Peraphyllum ramosissimum*	y		y	y	
Twinberry/bush honeysuckle	*Distegia/Lonicera involucrata*	y			y	
Twinflower	*Linnaea borealis*	y			y	
Wax Flower	*Jamesia americana*	y			y	
Willow	*Salix spp.*	y		y		
Woods/Wild Rose	*Rosa woodsii*	y		y	y	
Yucca	*Yucca glauca*	y		y		

B. Native Forbs (wildlflowers)

There is a vast array of native forbs to choose from in designing a 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, field border, filter strip, waterway or range planting to enhance conditions for pollinators. These are just 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.

Common Name	***Scientific Name***	**Origin**		**Bloom Time**		
		Native	**Introduced**	**Early**	**Mid**	**Late**
Alfalfa	*Medicago sativa*		y	y	y	y
Alsike clover	*Trifolium hybridum*		y	y	y	y
American vetch	*Vicia Americana*	y		y		
Arrowleaf Balsmroot	*Balsamorhiza sagittata*	y			y	
Aster	*Aster spp.*	y	y	y	y	y
Basil	*Ocimum basilicum*		y		y	
Beardtongue	*Penstemon spp.*	y		y	y	
Beebalm	*Monarda spp.*	y			y	y
Beeplant	*Cleome serrulata*	y			y	y
Birdsfoot trefoil	*Lotus corniculatus*		y	y	y	
Bittercress	*Cardamine cordifolia*	y			y	
Black-eyed susan	*Rudbeckia spp.*	y	y		y	y
Bladderpod	*Lesquerella spp.*	y			y	
Blanketflower	*Gaillardia aristata*	y			y	y
Blue flax	*Adenolinum/Linum lewisii*	y			y	
Butterfly Milkweed	*Asclepias tuberosa*	y			y	
Cardinal Flower	*Lobelia cardinalis*	y			y	
Catnip/cat mint	*Nepeta cataria*		y		y	y

Chiming bells	*Mertensia ciliata*	y		y	y	
Chyrsanthemum	*Chrysanthemum spp.*		y		y	y
Cicer milkvetch	*Astragalus cicer*		y	y	y	y
Cinquefoil	*Potentilla spp.*	y		y	y	y
Columbine	*Aquilegia caerulea*	y		y		
Coneflower	*Ratibida columnifera*	y			y	y
Cosmos	*Cosmos spp.*		y		y	y
Crown vetch	*Coronilla varia*		y	y	y	
Dill	*Anethum graveolens*		y	y		
Evening Primrose	*Oenothera spp.*	y		y	y	
False golden aster	*Heterotheca vilosa*	y			y	y
Fennel	*Foeniculum vulgare*		y		y	
Fireweed	*Chamerion angustifolium*	y			y	y
Flax	*Linum usitatissimum*		y		y	
Fleabane	*Erigeron spp.*	y				y
Four O'clock	*Mirabilis multiflora*	y		y	y	y
Gayfeather	*Liatris punctata*	y				y
Geranium	*Geranium spp.*	y		y	y	
Gilia	*Ipomoxis spp.*	y			y	
Globe Mallow	*Sphaeralcea spp.*	y		y	y	
Golden Banner	*Thermopsis rhombifolia/montana*	y		y		
Golden Smoke	*Corydalis aurea*	y			y	
Goldenrod	*Solidago spp.*	y	y		y	y
Harebell	*Campanula rotundifolia*	y		y	y	
Hollyhock	*Alcea rosea*		y		y	y
Hyssop	*Agastache spp.*		y		y	y
Iris	*Iris missouriensis*	y		y		
Larkspur	*Delphinium spp.*	y	y		y	
Lavender	*Lavandula spp.*		y		y	y
Lupine	*Lupinus argentus*	y			y	
Mariposa/sego lily	*Calochortus gunnisonii*	y		y		
Marjoram	*Origanum*		y		y	
Maximilian sunflower	*Helianthus maximiliani*	y				y
Mint	*Mentha arvensis*	y			y	
Paintbrush	*Castilleja spp.*	y		y	y	
Parsley	*Petroselinum crispum*		y			y
Penstemon	*Penstemon spp.*	y	y	y	y	
Phlox	*Phlox spp.*	y	y		y	
Poppy	*Papaver spp.*		y	y		
Poppymallow	*Callirhoe involucrate*	y		y	y	
Prairie clover	*Dalea spp.*	y				y
Prince's plume	*Stanleya pinnata*	y			y	
Puccoon	*Lithospermum incisum*	y		y	y	
Purple Coneflower	*Echinacea angustifolia*	y			y	y
Purple Fringe	*Phacelia sericea*	y			y	y
Red clover	*Trifolium pratense*		y	y	y	y
Rosemary	*Rosmarinus*		y			y
Russian sage	*Perovskia atriplicifolia*		y		y	y

Sage	*Salvia spp.*		y		y	
Sainfoin	*Onobrychis viciifolia*		y	y	y	y
Senecio	*Senecio spp.*	y	y		y	y
Showy Milkweed	*Asclepias speciosa*	y			y	
Skullcap	*Scutellaria brittonii/galericulata*	y		y	y	
Small Burnet	*Sanguisorba minor*		y	y	y	
Spring Beauty	*Claytonia lanceolata/rosea*	y		y		
Strawberry clover	*Trifolium fragiferum*		y	y	y	y
Sulfur Flower	*Eriogonum umbellatum*	y			y	
Sunflower	*Helianthus spp.*	y	y		y	y
Sweet pea	*Lathyrus spp.*		y		y	
Thyme	*Thymus vulgaris*		y		y	y
Utah sweetvetch	*Hedysarum boreale*	y		y	y	
Violet	*Viola spp.*	y		y		
Western Wallflower	*Erysimum capitatum/asperum*	y		y	y	
White clover	*Trifolium repens*		y	y	y	y
White sweetclover	*Melilotus alba*		y		y	y
Wild Strawberry	*Fragaria virginiana*	y		y		
Yarrow	*Achillea lanulosa*	y		y	y	
Yellow stonecrop	*Amerosedum lanceolatum*	y			y	
Yellow Sweetclover	*Melilotus officinale*		y		y	y
Zinnia	*Zinnia spp.*	y	y	y	y	y

C. Native Bunch Grasses

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).

In general warm season bunch grasses (which produce most of their leaf mass in the summer) are more favorable than cool season grasses that grow quickly in the spring, and thus potentially shade out developing forbs (Steinauer 2003). Anecdotal evidence also suggests that tall grasses crowd out forbs more easily than short grasses. Seeding rates for grasses should also not exceed seeding rates for forbs.

Common Name	*Scientific Name*	Native/Introduced	Season
Alkali sacaton	*Sporobolus airoides*	N	Warm
Arizona fescueArizArizon	*Festuca arizonica*	N	Cool
Basin wildrye	*Lymus cinereus*	N	Cool
Big bluegrass	*Poa ampla*	N	Cool
Blue grama	*Bouteloua gracilis*	N	Warm
Bluebunch wheatgrass	*Pseudorogneria spicata*	N	Cool
Bottlebrush Squirreltail	*Elymus elymoides*	N	Cool
Canada wild rye	*Elymus canadensis*	N	Cool
Columbia needlegrass	*Stipa columbiana*	N	Cool
Green needlegrass	*Nassella viridula*	N	Cool
Idaho fescue	*Festuca idahoensis*	N	Cool
Indian ricegrass	*Oryzopsis hymenoides*	N	Cool
Indiangrass	*Sorghastrum nutans*	N	Warm
Letterman needlegrass	*Stipa lettermani*	N	Cool
Little bluestem	*Schizachyrium scoparium*	N	Warm

Mammoth wildrye	*Leymus racenisa*	I	Cool
Mountain brome	*Bromus marginatus*	N	Cool
Mountain muhly	*Muhlenbergia montana*	N	Warm
Muttongrass	*Poa fendleriana*	N	Cool
Needle & thread	*Heterostipa comata*	N	Cool
Nodding/Porter brome	*Bromopsis porteri*	N	Cool
Orchardgrass	*Dactylis glomerata*	I	Cool
Parry oatgrass	*Danthonia parryi*	N	Cool
Pine dropseed	*Blepharoneuron tricholepis*	N	Cool
Russian wildrye	*Psathyrostachys juncea*	I	Cool
Sand dropseed	*Sporobolus cryptandrus*	N	Warm
Sandberg bluegrass	*Poa sandbergii*	N	Cool
Sheep fescue	*Festuca ovina*	I	Cool
Slender wheatgrass	*Elymus trachycaulus*	N	Cool
Switchgrass	*Panicum virgatum*	N	Warm
Tall dropseed	*Sporobolus asper*	N	Warm
Tall fescue	*Festuca arundinacea*	I	Cool
Tall wheatgrass	*Elytrigia elongatum*	I	Cool
Timothy	*Phleum pratense*	I	Cool
Tufted hairgrass	*Deschampsia caespitosa*	N	Cool

Appendix: Additional Information

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

I. 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

Shepherd, M., S. Buchmann, M. Vaughan, and S. Black. 2003. *Pollinator Conservation Handbook*. Portland, OR: The Xerces Society for Invertebrate Conservation. 145 pp.

ES EPA and USDA. 1991. *Applying Pesticides Correctly, A Guide for Private and Commercial Applicators*. USDA Agriculture Extension Service.

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USDA, NRCS and FS, M. Vaughan and S.H. Black. 2006. Agroforestry Note – 33*: Improving Forage for Native Bee Crop Pollinators*. USDA National Agroforestry Center. http://www.unl.edu/nac/agroforestrynotes/an33g07.pdf

USDA, NRCS and FS, M. Vaughan and S.H. Black. 2006. Agroforestry Note – 34: *Enhancing Nest Sites for Native Bee Crop Pollinators*. USDA National Agroforestry Center. http://www.unl.edu/nac/agroforestrynotes/an34g08.pdf

USDA, NRCS and FS, M. Vaughan and S.H. Black. 2006. Agroforestry Note – 35: *Pesticide Considerations for Native Bees in Agroforestry*. USDA National Agroforestry Center. http://www.unl.edu/nac/agroforestrynotes/an35g09.pdf

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

USDA, NRCS. 2001. *Creating Native Landscapes in the Northern Great Plains and Rocky Mountains* 16pp. http://www.mt.nrcs.usda.gov/technical/ecs/plants/xeriscp/

USDI, BLM. 2003. Technical Reference 1730-3. *Landscaping with Native Plants of the Intermountain Region*. 47pp.

Vaughan, M., M. Shepherd, C. Kremen, and S. Black. 2007. *Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms. 2nd Ed.* Portland, OR: Xerces Society for Invertebrate Conservation. 44 pp. *http://www.xerces.org/Pollinator_Insect_Conservation/Farming_for_Bees_2nd_edition.pdf*

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

II. Web-Sites

1. POLLINATOR INFORMATION

- The Xerces Society Pollinator Conservation 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

2. HABITAT RESTORATION WITH NATIVE PLANTS

- 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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