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Habitat Planting for Pollinators

Pacific Islands Area

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Habitat Planting for Pollinators

Pacific Islands Area

Introduction

The geographic scope of this technical note coincides with the NRCS Pacific Islands Area (PIA), which includes the Hawaiian Islands, Guam, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia, the Marshall Islands, and American Samoa. The purpose of this technical note is to provide guidance to NRCS and partner agency staff when protecting, designing, and installing habitat for pollinators on or near farms. This technical note focuses on the biology and habitat needs of pollinators native to the PIA, but the habitat needs of honey bees and other beneficial insects are briefly discussed.

Pollination in the Pacific Islands Area

Pollination, which is movement of pollen from the male to the female part of a flower, is required for the reproduction of most terrestrial plants. For some plants (such as grasses) and crops (such as rice and corn) pollination is achieved by wind movement of pollen. For almost all other plants, including a third of crop species, pollination is facilitated by animals. More specifically, animals visit flowers to collect food for themselves and their offspring. In the process of visiting flowers, animal pollinators inadvertently move pollen between the male and female parts of the flower. Pollination is important because it enables plants to reproduce (e.g., create viable seed) and persist in the ecosystem. Pollination also enables plants to produce foods (such as fruits, vegetables, and some nuts) which support human and other animal populations. Providing habitat for pollinators is the focus of this technical note. Appendix A gives examples of commonly cultivated plants in the PIA, along with the degree these crops require animal-assisted pollination.

Pollinators of the Pacific Islands Area

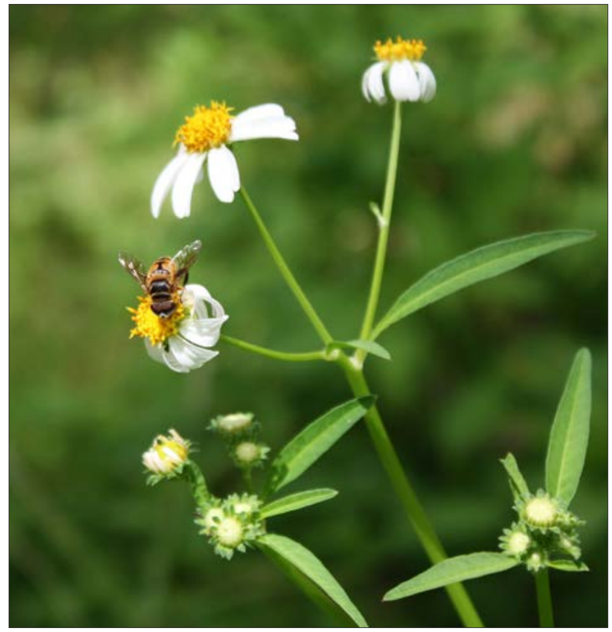
The PIA has a diversity of native animal pollinators, some of which are endemic to a single island. Unfortunately, native pollinator diversity in the PIA has decreased over the last 200 years, with many species becoming extinct, due to habitat degradation/destruction and the negative impacts of introduced plants, animals, and pathogens. Knowledge about life history of most native PIA pollinators is greatly lacking compared to knowledge about pollinators in the continental United States. However, this technical note aims to provide the most current status on PIA pollinators, which include the following:

- Fruit bats (also known as flying foxes)—There are a handful of fruit bat species, belonging to the genus *Pteropus*, in the PIA. These species provide important pollination and seed dispersal services to a wide range of plants. Appendix B gives more details, including a link to the NRCS Pacific Region bat technical note.
- Honeyeaters, Honeycreepers, and White-eyes—These are the three main groups of pollinating birds found in the PIA. Appendix C gives more details.
- Native bees—Some of the best-known and best-researched native pollinators in the PIA are the yellow-faced bees of Hawaii, which belong to the genus *Hylaeus*. There are also other species of native bees living in the PIA. Appendix D gives more details about PIA's native bees, while Appendix E focuses on information about the yellow-faced bees of the Hawaiian Islands.
- Introduced bees—The European honey bee (*Apis mellifera*) is the most widespread introduced bee in the PIA. There are also other non-native bees, such as carpenter bees and leafcutter bees, which live in the PIA. Appendix D gives more information about these introduced species of bees.
- Butterflies & moths—Butterflies and moths serve vital roles in ecosystems throughout the PIA, including pollination and indications of ecosystem health. Plus, butterflies and moths are attractive to the public and can enhance ecotourism. Appendix F gives more details about the butterflies and moths of the PIA.

Conservation Biocontrol

Pollinating insects are considered *beneficial insects* because of the services they provide to plants, the ecosystem, and to society. Predators and parasitoids of crop pests are also beneficial (as are spiders and some mite species). These predator and parasitoid insects help suppress pest populations, reducing crop damage and the need for insecticides. The practice of providing habitat for predators and parasitoids is referred to as *conservation biological control*, or simply *conservation biocontrol*. Conservation biocontrol may appeal to clients seeking to reduce their dependence on chemical insecticides. However, it is important to note that the presence of beneficial insects alone may not solve all pest problems. For general information and strategies about conservation biocontrol, see the technical note *Beneficial Insect Habitat Planning: Providing habitat for predators and parasitoids of crop pests* written by the Xerces Society for Invertebrate Conservation. For comprehensive pest management guidance, the client should consult with appropriate local Extension personnel, Integrated Pest Management (IPM) specialists, Certified Crop Consultants, or other pest management experts. Conservation biocontrol can be supported through multiple conservation practices. These same installed practices, when designed with predators and parasitoids in mind, can also support pollinators and other wildlife such as birds. Appendix G contains a table listing examples of predator and parasitoid insects, their common prey, and general conservation strategies.

Figure 1 A syrphid fly foraging on *Bidens* in an understory planting of an American Samoa banana plantation. Beneficial insects, such as this syrphid fly, can help control pests on cropland.



(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

Note that there are other approaches to controlling pests using predatory or parasitoid insects, including strategies known as *classical biological control* and *augmentative biological control*. These other strategies promote the intentional release of commercially-raised predator or parasitoid insects into an area where they are not already present. In many cases these intentionally-released predators and parasitoids are not native to the area where they are released, and the impacts on local ecosystems cannot be predicted. For example, a recent study in Hawaii revealed that 83 percent of parasitoids found attacking native moths were non-native species that had originally been introduced for pest control. Because of such risks, conservation biological control represents an ecologically safer approach for farmers who want to increase pest control by beneficial insects.

Habitat Needs of Pollinators in the Pacific Islands Area

Pollinators have three basic habitat needs. These include 1) food (in the form of pollen and nectar for adults, and sometimes plant material for nesting), 2) egg-laying, nesting, and maturing sites, and 3) protection from harmful land management activities, such as insecticide use. Having a diversity of flowering plants with overlapping blooming times provides pollinators with food throughout the year. Pollinators also need places to nest, lay eggs, and mature. For butterflies and moths this means providing suitable host plants for their caterpillars to eat. Most bee species are solitary and nest in underground tunnels, or in narrow crevices and holes found in dead trees or hollow plant stems. Whether underground or in wood, most bee species spend a portion of the year maturing in their nest (brood) cells. In these cells, they are vulnerable to mechanical nest disturbance such as soil tillage or tree removal. Finally, pollinators need protection from potentially harmful activities such as insecticide use. Broad spectrum insecticides are particularly harmful to many types of insects. Furthermore, indiscriminate herbicide use can remove many of the flowers that pollinators need for food.

Pollinators and Conservation Planning

Fragmentation, destruction, and alteration of habitat are major causes of pollinator population declines worldwide. Therefore, it is essential to understand the habitat needs of pollinators in order to provide for long-term ecosystem health in the PIA. The Natural Resources Conservation Service (NRCS) can assist farmers and land managers with providing adequate pollinator habitat by recommending locally appropriate pollen and nectar plants and offering advice on how to best manage pollinator habitat.

As projects are being considered, conservation planners must weigh the potential costs against the benefits of the practices they recommend. Habitat enhancement for pollinators on farms, especially with native plants, provides multiple benefits. In addition to supporting pollinators, native plant habitat will attract beneficial insects that prey on crop pests and may reduce the need for insecticides. Pollinator habitat can also provide habitat for other wildlife, help stabilize the soil, and improve water quality. The following section gives a four step approach to pollinator habitat.

Figure 2 Many of the cultivated plants in American Samoa have multiple uses. For example, multiple species from the plant genus *Syzygium* grow in cultivated and natural forest areas. The flowers and fruits of these species provide great food for pollinators. Pollen and nectar is available for pollinating insects and the fruits provide food for bats and birds. In addition, humans eat the fruits and use multiple parts of the plant for medicinal purposes. Thus, *Syzygium* plants are a valuable component of agroforests for multiple reasons.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

Four Step Approach to Pollinator Habitat

1 Recognize Existing Pollinator Habitat

Many farmers may already have an abundance of habitat for pollinators on or near their land. This is important because having semi-natural or natural habitat available significantly increases pollinator populations. Linear habitats along field margins such as field edges, hedgerows, and drainage ditches offer both nesting and foraging locations for a variety of pollinators. Woodlots, conservation areas, utility easements, farm roads, or other untilled areas may also contain valuable habitat. Here we provide advice on recognizing specific habitat resources so that they can be factored into farm planning.

Food Resources

When assessing pollen and nectar resources, it is useful to look at all of the potential plant resources on and around a farm. These plants may include insect-pollinated crops, as well as the vegetation in buffer areas, agroforestry plots, forest edges, hedgerows, roadsides, natural areas, and fallow fields. 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 farmer is interested in supporting pollinators. 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 or state-listed invasive weed species that should be removed or controlled, farmers might consider allowing some of the native and non-native plants that are currently present on the property to bloom prior to their crop bloom, mow them during crop bloom, then let them bloom again afterward. For example *Ageratum* and *Desmodium*, and other non-native plants may often serve as good forage plants for honey bees. These types of plants could be mowed while an adjacent crop blooms in order to continue to provide nectar and pollen resources without interruption. As an example for vegetable producers, some portions of those types of crops could be allowed to bolt to continue to provide resources outside and beyond the bloom period. Some crops are secondarily beneficial. In addition to providing pollinator resources, the predators and parasitoids of pests are attracted to the flowers of brassicas, and other greens and, therefore, support pest management.

When evaluating existing plant communities on the margins of cropland, a special effort should be made to have plants which bloom throughout the year. Keep in mind that small-bodied pollinators may only fly a couple hundred yards, while honey bees easily forage a mile or more from their nest. 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.

Figure 3 A *Badamia exclamationis* (Brown awl skipper) caterpillar feeding on its host plant *Terminalia* in an American Samoa agroforestry plantation.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

Figure 4 *Acacia koa* provides both forage and nesting substrate for native *Hylaeus* bees and other PIA pollinators.

(Photograph by Gregory Koob, Hawaii NRCS.)

Nesting, Egg Laying, and Maturing Sites

Pollinators need nesting and egg-laying sites and safe places to mature in order to be productive and increase populations. Indeed, to support populations of pollinators, protecting and providing these sites is as important as providing floral resources. It is ideal to have nesting and forage resources in the same habitat patch, but most pollinators are able to adapt to landscapes in which nesting and forage resources are separated. However, it is important that these two key habitat components are not located too far apart.

Wild bees often nest in inconspicuous locations. Some excavate tunnels in the soil, others occupy tree cavities, and others such as the native Hawaiian *Hylaeus* may use the soft pith of plant stems to make nests. It is important to retain or encourage as many naturally occurring sites as possible or create new ones where appropriate.

A second benefit of flower-rich foraging habitat is the provision of egg-laying sites for butterflies and moths. Butterflies and moths lay their eggs on plants on which their larva will feed. Some butterflies may rely on plants of a single species or a closely-related group of plants (genus) for host-plants. The Kamehameha butterfly is an example of a species that relies on a single species of plant, the mamaki (*Pipturus albidus*), whereas others may exploit a wide range of plants. The Blackburn's sphinx moth (*Manduca blackburni*), for example, uses several species of *Solanaceae* as larval hosts.

2 Protecting Pollinators and their Habitat

When farmers recognize the potential pollinator habitat on their land, they can then work to protect these resources. In addition to conserving the food and nesting sources of their resident pollinators, they can take an active role in reducing mortality of the pollinators themselves. While insecticides are an obvious threat to beneficial insects, other common farm operations or disturbances, such as mowing or tilling, can also be lethal to pollinators.

Minimize Pesticide Use

Pesticides may be detrimental to a healthy community of pollinators. Insecticides not only kill pollinators, but sub-lethal doses can affect their foraging and nesting behaviors, often preventing pollinators from reproducing and from pollinating plants. 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.

Broad-spectrum chemicals should be avoided if at all possible. If pesticide use cannot be avoided, they should be applied directly to target plants to prevent drift. Crops should not be sprayed while in bloom and fields should be kept weed free or mowed just prior to insecticide applications. This discourages pollinators from venturing into the crop if sprayed outside of the bloom period. Night-time spraying, when most pollinators are not foraging, is one way to reduce mortality. Periods of low temperatures may also be beneficial for spraying because many pollinators are less active in cooler conditions. However, the residual toxicity of many pesticides tends to last longer in cool temperatures. Dewy nights may cause an insecticide to remain wet on the foliage and be more toxic to pollinators the following morning.

In general, while pesticide labels may list hazards to honey bees, the potential dangers to other bees and other pollinators are often not listed. Many native bees such as *Hylaeus* are much smaller in size than honey bees and may be affected by lower doses of chemicals. Also, honey bee colonies may be covered or moved from a field, whereas wild bees will continue to forage and nest in areas that have been sprayed.

The use of selective pesticides that target a narrow range of insects, such as *Bacillus thuringiensis* (Bt) for

Figure 5 Insecticides can cause significant damage to pollinator populations, either by directly killing individuals or by compromising their ability to navigate and find food. Herbicides can kill plants essential to pollinator health. Properly calibrating equipment, carefully choosing when to spray, and using targeted backpack sprayers can help limit exposure and drift to undesirable species.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

moth caterpillars, is one way to reduce or prevent harm to beneficial insects like bees. (Note: Bt is toxic to non-pest butterfly and moth larvae and should be used carefully where this is a concern). Generally, dusts and fine powders are more dangerous than liquid formulations. This is partly because the dust and fine particles of the pesticide become trapped in the pollen-collecting hairs of bees, and the chemicals are consequently fed to developing larvae. Alternatives to insecticides are also available for some pests, such as kaolin clay barriers for fruit crops. Farmers who encourage native plants for pollinator habitat will inevitably be providing habitat that will also host many beneficial insects that help control pest insects naturally. This may result in less dependency on pesticides.

Reduce Pesticide Drift

Windbreaks, hedgerows, and conservation buffers can be effective barriers to reduce pesticide drift from adjacent fields, but it is important that these pesticide barriers are not attractive to pollinators. Spray drift can occur as either spray droplets or vapors. Factors effecting drift include weather, method of application, equipment settings, and spray formulations. Weather related drift increases with temperature, wind velocity, convection air currents, and during temperature inversions. Pesticide labels will occasionally provide specific guidelines on acceptable wind velocities for spraying a particular product. Always check and follow those recommendations when present.

Spray equipment methods and equipment settings also strongly influence the potential for drift. Small droplets are more likely to drift the longest distances, so mist blowers should be avoided where feasible. Standard boom sprayers should be operated at the lowest effective pressure and with the nozzles set as low as possible. Drop nozzles should be used to deliver insecticide within the crop canopy where it is less likely to be carried by wind currents. 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 for drift reduction. Select only nozzles capable of operating at low pressures (15–30 psi) to produce larger, heavier droplets. 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 the pesticides.

If pesticide use is an integral part of the farm operation and it is not practical to eliminate from the operation, farmers should be provided risk assessments using NRCS protocols such as a pesticide screening tool (i.e., Win-PST).

Minimize the Impacts of Mowing, Grazing, and Cultivation

Disturbance in a farm setting is often frequent and abrupt and can occur as tilling, mowing, or grazing. When developing disturbance strategies with pollinators in mind, it is important to consider the timing, amount, and intensity of the disturbance. A general rule is that only 25%–33% of pollinator habitat should be disturbed by mowing or grazing at any one time in order to minimize impacts on pollinators, as well as other wildlife. The area disturbed should not totally eliminate a resource critical to pollinator habitat such as the only area providing pollen and nectar resources during a given period. This will allow for re-colonization of the disturbed area from nearby undisturbed refugia, an important factor in the recovery of pollinator populations after disturbance. In order to minimize negative impacts on foraging and egg-laying opportunities, maintenance activities should be avoided while plants are in flower.

Protect Ground Nesting Bees

In order to protect nest sites for ground-nesting bees, tilling or other disturbance of bare or partially bare ground that may be occupied by nesting bees should be avoided. Grazing such areas may also disturb ground nests. Similarly, using fumigants like chloropicrin for the control of soil-borne crop pathogens (such as *Verticillium* wilt) or covering large areas with plastic mulch could be detrimental to beneficial ground nesting insects. Weed control alternatives to tillage include the use of selective crop herbicides and hooded sprayers for between-row herbicide applications.

Protecting Wood Nesting Bees

Wood 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 plants with pithy or hollow stems, such as koa and ohia species, will provide nesting opportunities for these solitary bees.

Supporting Managed Honey Bees

While not indigenous to the Pacific Islands Area, the European honey bee (*Apis mellifera*) remains an important agricultural pollinator. Unfortunately, habitat degradation, inappropriate pesticide use, parasitic mites, and diseases have taken a dramatic toll on honey bee populations in many parts of the world. Solutions to 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 that promote native pollinators also promote managed honey bee populations and honey bee health.

The critical factors for all bees is an abundance of pollen and nectar throughout the year and protection from harmful chemicals.

One habitat requirement for honey bees that is generally not as critical for native bees is access to water. Honey bees require water to cool their hives through evaporation. They carry the water back to the hive in their stomachs. 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 and other chemicals.

Nesting Blocks

One option for enhancing nesting sites for bees is through the creation of nesting blocks. Bees which naturally nest in beetle tunnels and similar holes in dead trees will sometimes use homemade or commercially-available nesting blocks. A nest block consists of a wood block (usually 4 x 4 untreated lumber) drilled with a series of dead-end holes (approximately ¼–⅝ inch diameter and 3–6 inch depth to attract a variety of native bees) and hung or mounted in a protected location. An alternative is to simply drill holes into a log and stand it up like a fence post to simulate a beetle-tunneled snag.

Figure 6 Pollinators need suitable sites to lay eggs, nest, and roost. To conserve pollinators in PIA, it is important to protect and plant those plants which are used by bats and birds to nest and roost and by pollinating insects to lay eggs. Native bees build their nests in the soil or in wood, depending on the species. Farm practices which reduce the disturbance of soils, such as leaving residue as a mulch instead of tilling the soil, can help protect ground-nesting bees. At the restoration site on the left, cocoa transplants were planted directly in the residue instead of tilling the soil. At the restoration site on the right, plants which are known to be used by pollinators for laying eggs and nesting are being marked so they can be easily recognized and conserved.

(Photographs by Jolie Goldenetz-Dollar, American Samoa Community College.)

3 Enhancing and Developing New Pollinator Habitat

Farmers who want to take a more active role in increasing the 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 the year. Such habitat can take the form of flowering cover crops, agroforestry plantings, windbreaks with flowering trees and shrubs, and similar practices. Locally native plants are preferred over non-native plants due to their adaptations to local soil and climatic conditions, greater wildlife value, and their mutually beneficial co-evolution with native pollinators. However, non-native plants could be suitable on disturbed sites and for specialty uses such as cover cropping. Mixtures of native and non-native plants may also work, so long as non-native species are naturalized and not invasive and the native species are the dominant component.

Site Selection

Sites 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.

Sun Exposure

Some plants require full sun or shaded conditions to thrive, so the planting design should allow for sun-loving plants to remain in full sun as the habitat matures. Plantings may also be installed in several phases. For example, if trees and shrubs are concurrently planned or utilized, they should be allowed to completely develop an over-story prior to planting shade-loving herbaceous plants in the understory.

Soil Characteristics

Soil type is an important consideration when selecting a site. Some plants grow, reproduce, and flower better in specific soil textures (i.e., sands, silts, clays, or loams). Drainage, pH, organic content, and compaction are some of the other factors that will influence plant establishment and productivity. Most of these factors can be determined from local soil surveys and the NRCS Web Soil Survey (available at: http://websoilsurvey.nrcs.usda.gov/app/). Planning should emphasize those plants that will be adapted for the particular soil conditions and moisture regimes anticipated. Fertility, soil pathogens, the presence of symbiotic fungi and bacteria, and previous herbicide use should also be considered during the planning process. Soil fertility will be most critical during early plant establishment, especially on previously cleared or deforested lands. As the habitat matures, few, if any, inputs should be required, especially if native plants are selected. Similarly, some previously cropped areas may harbor soil-borne pathogens that could inhibit plant development. Where such conditions are known to exist, pathogen-resistant plant species should be considered. Finally, pesticide residues or herbicides like atrazine and trifluralin can inhibit seed germination. These chemicals, soil pathogens, beneficial microorganisms, and soil fertility can usually be tested for by a local University soil laboratory. At a minimum, a soil test is recommended to determine fertility prior to establishment, and then periodically (2–5 years) after establishment.

Adjacent Land Use

Adjacent plant communities and existing land use on neighboring lands must also be considered. Even if weeds are eliminated prior to planting, the presence of invasive plants adjacent to a restored habitat may result in a persistent problem requiring continuous maintenance and management. Adjacent cropland may also present a challenge unless the enhancement site is protected from pesticide drift. Adjacent crops may change, so it is important to consider the timing of floral resources and coordinate resources accordingly.

Marginal Land

Some otherwise marginal land, such as drainage ways, waterways, and buffer systems may be suited for pollinator plantings. While trees may be problematic on such sites, herbaceous plants will not prevent future maintenance, and these sites may actually help absorb excess nutrients from wastewater. Ditches, field buffer strips and borders, and even grassed waterways can be planted with pollinator-friendly plants rather than or in conjunction with grasses. Legumes such as *Vigna marina* and native plants in the *Canavalia* or *Mucuna* genus along with grasses could be utilized in these types of situations.

Size and Shape

Although there is no required minimum, the larger the planting area, the greater the potential benefit for pollinator species. With herbaceous plantings, such as cover crops, large 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 crop border) will often be more practical. Where these linear plantings are installed, a minimum width of 10 feet should be considered. However, certain conservation practice standards require different widths for specific purposes. Planners should refer to the criteria outlined within NRCS practice standards to determine the proper widths of linear plantings.

Habitat Design

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

Landscape Considerations

The first step in good habitat design is the consideration of how the area functions with the adjacent landscape. Crops which require animal-assisted pollination will most likely benefit from pollinator habitat located adjacent to the crop field. Flight distances of small bees might be as little as 500 feet, while honey bees may forage up to five miles away from their hive. This may require some general understanding of the types of bees or other pollinators currently within the local area. Thus, crops that depend heavily on honey bees for pollination, such as macadamia nut or cucurbits, might still benefit from pollinator habitat located some distance from the field. It should be noted however, that even honey bees prefer habitat as close to the crop as possible. This sort of arrangement would minimize the encroachment of unwanted pollinator plants into crops while still supporting a strong local population of bees. Fallow or natural areas, existing abandoned fields, 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 bare ground, and only lack the floral resources to support a larger pollinator population. Be aware of these existing habitats and consider improving them with additional pollinator plants and protecting them from livestock.

Figure 7 The fruit yields of carambola significantly benefit from animal pollination, and a large tree, such as the one shown here, can provide many insects with pollen and nectar. Adjacent to this tree is an agroforestry plot with many crops which also require animal-assisted pollination, such as cucumber and cocoa. Therefore, this carambola tree is valuable for multiple reasons: it provides delicious fruits as well as valuable pollen and nectar to pollinators when other crops are not in bloom. This one tree is a valuable resource for pollinators in the area, especially since it appears to have year-round flowering.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College..)

Diverse Plantings

Diversity is an important factor in the design of new pollinator habitat. 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, varying plant heights and growth habits to encourage and benefit the greatest numbers and diversity of pollinators. Most bee species are generalists, which means that they feed on a range of plants throughout their life cycle. Many other pollinators, including some native species, only forage on a single family or even a single genus of plants. Choose plants with a variety of flower shapes in order to attract a diversity of pollinators. Some flowers appear almost closed which require bees to crawl inside the petals to obtain nectar rewards. Other species are long and tubular-shaped requiring insects like butterflies that have long tongues to obtain the resources. Color is another important consideration. Bees typically visit flowers that are purple, violet, yellow, white, and blue. Butterflies visit a similarly wide range of colors including red, whereas flies are primarily attracted to white and yellow flowers. Thus, by having several plant species flowering at once, and a sequence of plants flowering throughout the growing season, habitat enhancements are able to support a wide range of pollinating insects.

Plant Density and Bloom Time

Plant diversity should also be measured by the number of plants flowering at any given time. Research has 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. 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. Clusters of single species should be planted where possible. Herbaceous or woody shrub single species clump-plantings of at least three feet by three feet blocks are more attractive to pollinators than widely scattered species or randomly dispersed small clumps. The goal is for the established blocks to form a solid block of color when in flower. Larger single-species clumps such as a cluster of perennials or shrubs more than twenty-five square feet in size can be ideal for attracting pollinators and providing efficient foraging resources.

Plant Selection and Seed Sources

First, choose plants with soil and sunlight requirements that are compatible with the site where they will be planted. The plant tables located in Appendix I 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.

Figure 8 The forestry extension greenhouse at American Samoa Community College. This greenhouse provides native plants for habitat restoration practices.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

Contact the State Biologist, Plant Materials Specialist, or NRCS Forester to determine other suitable species. Also, please refer to the list of Pacific Island nurseries, *USDA-NRCS Plant Materials Tech Note 6* (available at: http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1262766&ext=pdf).

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. Some common horticultural plants do not provide sufficient pollen or nectar rewards to support larger pollinator populations. Just because a certain species of horticultural variety of plants produces a large visually attractive flower does not necessarily mean that the plant produces nectar or pollen in necessary quantities to sustain pollinators. In addition, some non-native plants have the ability to invade and colonize new regions at the expense of existing native plant communities. Often native plants have co-evolved with the pollinators that frequent them and are uniquely adapted to be most efficiently pollinated by those native insects.

Native perennial plants are advantageous because they generally:

1. require less fertilizer and do not usually require pesticides for maintenance;
2. may 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 biological diversity.

Using native plants will help provide connectivity to existing native plant populations particularly in regions with fragmented habitats. Providing connectivity on a landscape level increases the ability for species to move in response to environmental shifts and increases the genetic variability potential. Native plantings also give the added benefit of enhancing native biological diversity and are the logical choice to enhance native pollinators.

Seed Sources

The term local eco-type refers to seed and plant stocks harvested from local sources often within the same elevation and rainfall on the same island. Where available and economical, native plants and seed should be procured from local eco-type providers. Plants selected from local sources will generally establish and grow well because they are adapted to the local conditions.

Transplants

In addition to seed, enhancement sites could be planted with plugs, container grown, containerized, bare-root stock, or live stakes. Refer to conservation practice Tree and Shrub Establishment (612) or other appropriate standards for more information. Herbaceous plants purchased as plugs have the advantage of rapid establishment and earlier flowering, although the cost and feasibility of using plugs can be prohibitive for large plantings. Transplanted plants also typically undergo a period of shock during which they may need mulching and supplemental water to ensure survival. Similarly, woody plants may also require mulching and supplemental water after planting.

Figure 9 Many plants in the tropics (such as this native hibiscus in American Samoa) can be easily reproduced by planting stem cuttings.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

Avoid Nuisance Plants

When selecting plants, avoid ones that act as alternate or intermediate hosts for crop pests and diseases. 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. For example, commercial tomato growers may prefer not to see native Solanaceae used in adjacent conservation plantings for wildlife because the plants are likely to harbor various insect pests and disease spores. It is prudent to be familiar with the crops and their commonly associated diseases within the local area of consideration.

Non-Native Plant Material

While in most cases native plants are preferred, non-native ones may actually be more appropriate for some applications. These include practices that involve cover crops, temporary bee pasture plantings, or agroforestry understory plantings. Often it is necessary to include non-native or introduced species to fill in gaps of bloom times, or when native plants are not available. These low-cost plantings can also attract beneficial insects, some of which may predate or parasitize crop pests. For more information on suitable non-native plants for pollinators refer to the Plant Tables in Appendix I. The tables provide a list of non-natives that are non-invasive and could be used in conjunction with native species in mixes or established as individual stands. Any other non-native species utilized should not be invasive or established at the expense of native plant species. This is not a complete list and there are certainly other species that could be used. Consult with technical specialists to determine the suitability of those species.

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4 Management and Maintenance of Pollinator Habitat

Habitat plantings for pollinators should remain undisturbed to the greatest extent possible throughout the growing season so that pollinators 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 main growing season, establish a system for managing a small percentage (33% or less) of the site each year on a three to five year rotation. This will also allow for necessary invasive plant management on disturbed sites.

Weed Suppression During the Establishment Period

Competition control remains the most important part of pollinator habitat establishment for up to three years after planting. Weed control during the establishment period is usually achieved by mechanical (mowing or disking) or chemical methods (if absolutely necessary).

Control of Invasive Plants and Cattle Exclusion

Invasion by non-native (and sometimes native) plants is a common and major issue in the PIA. Pollinator habitat should be regularly surveyed for invasive plants, and when invasive plants are identified, they need to be controlled efficiently and effectively through mechanical and/ or chemical control. Likewise, the ecological impacts of grazing animals can be severe, if not managed appropriately. Harmful effects of grazing on pollinator habitat include the destruction of potential foraging and nesting sites, destruction of existing nests, and direct trampling of pollinators. Local extension agents and NRCS personnel can help farmers determine control options for invasive plants and grazing animals for specific sites.

Pollinator Habitat and NRCS Practices

Most NRCS practices can be designed to support pollinators by including high value pollen and nectar plants (especially flowering trees, shrubs, and herbaceous flowers, as opposed to grasses which have pollen of relatively low nutritional value for insects). In many instances, simply incorporating native flowering plants into conservation practices intended to meet other goals will also benefit pollinators. For example, when selecting tree species for a forested riparian buffer, the inclusion of multiple species with diverse flowering times can support pollinators while still meeting the original goal of protecting the water quality. Selecting pollinator-friendly native species for these practices should not compromise other intended functions of a practice. Again, using the example above, plants attractive to pollinators could be used in a riparian zone, but the plants selected should not interfere with the hydraulic function of the practice and the primary objective of stabilizing erosion.

Appendix H is a quick reference to NRCS practice standards to aid in planning the appropriate practices for pollinators. Some practices have specific pollinator jobsheets while others have had existing jobsheets modified to include pollinators. This list will likely change as other standards are revised. Planners should look closely at the "Considerations" and the "Criteria" portions of the practice standards to identify recommendations that could benefit pollinators.

Sample Scenarios for Improving Pollinator Habitat

Many NRCS practices can be used to support pollinator conservation. The following scenarios represent just a few of many options for planners to consider.

Scenario 1. Multi-Story Cropping (379)

Using this practice standard, existing or planted stands of trees and shrubs are managed as an overstory with an understory of woody and/ or non-woody plants that are grown for a variety of products. Overstory tree-to-tree distance is wide enough to let sufficient light through to understory or groundcover plants. "Forest farming" is a form of multistory cropping. Many native species are suitable components of multi-story forest overstory and understory layers.

Multi-Story Cropping may be associated with other practices such as Tree/ Shrub Pruning (660), Tree/ Shrub Site Preparation (490), Woody Residue Treatment (384), Mulching (484), and Access Control (472).

An example multi-story cropping system that could benefit pollinators might include an overstory of pollinator-attractive trees such as macadamia, avocado, neem, Ohi'a lehua, or mango, and an understory of shade-tolerant pollinator-attractive plants such as coffee, cacao, vanilla, or cardamom. In such combination plantings, the diversity of species provides extended bloom periods for pollinators, as well as more complex vegetative structures for nesting by leafcutter bees, carpenter bees, and other insects.

Figure 10 A typical agroforestry plot in American Samoa consists of coconuts, citrus, breadfruits, bananas, papaya, taro, edible hibiscus and other vegetables, and vetiver grass. Incorporating additional native flowering plants either as overstory or understory components will attract beneficial insects, which, in turn, aid in pest control and crop pollination.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

Because multiple-levels of the plant canopy are farmed at the same time, such systems may enhance farm profit potential and product diversification. One example system is highlighted in the report, *Shade-Grown Coffee for Hawaii: Results of a twelve farm study in Kona* (available at: www.agroforestry.org/images/pdfs/Hawaii_shade_coffee.pdf).

Scenario 2. Cover Crops (340)

Cover crops are used to control erosion, add fertility and organic matter to the soil, improve soil tilth, and increase infiltration and aeration of the soil. Depending on the plant species used, cover crops may also suppress pests, such as nematodes through root exudates, and they can prevent the encroachment of weeds on fallow cropland. Example uses of cover crops may include their use in rotation with short-term row crops (e.g., seed corn and tomatoes), or as understory plantings in agroforestry systems (e.g., below coffee or koa crops).

The use of flowering cover crops, such as sunn hemp, buckwheat, and cowpea, can increase pollen and nectar resources for bees and other beneficial insects (including those that prey upon crop pests). To increase pollinator benefits, multi-species cover crops can be used to provide longer bloom periods, and diverse flower shapes that support more insect species. Similarly, the inclusion of grass cover crops, such as oats, in a multi-species cover crop may enhance insect diversity by providing greater cover and vegetative structure for some beneficial insect groups.

Cover crop systems for the PIA are being researched and improved on an ongoing basis, and fact sheets are available from many regional colleges, universities, and agencies. For some current findings, see the *Adoption of Cover Crop Technology* website (http://oahurcd.org/resources/cover-crop-guidelines/) maintained by O'ahu Resource Conservation and Development Council, and *Cover Crops and Green Manures for Hawaii* (http://www.ctahr.Hawaii.edu/sustainag/Database.asp), a website maintained by the University of Hawaii's Sustainable and Organic Agriculture Program.

Figure 11 This understory planting of sunn hemp provides valuable forage resources for pollinators and other beneficial insects.

(Photograph by Eric Lee-Mäder, The Xerces Society.)

Scenario 3. Windbreak/Shelterbelt Establishment (380)

Windbreaks consist of one or more rows of closely spaced trees and/or shrubs planted in linear configurations. The wind shadow areas created to the leeward side of these barriers provide protected growing conditions for crops, as well as homes and farm structures. A single windbreak may consist of one to many rows of trees/ shrubs to ensure adequate canopy density. Example uses of windbreaks in the PIA include the protection of plants, animals, structures and people from wind, enhanced wildlife habitat, and reducing soil erosion by wind, irrigation losses, and air borne particulate matter (e.g., chemicals, odor, dust).

To incorporate pollinator benefits into a windbreak design, select tree and shrub species that have pollinator-attractive flowers such as gliricidia, avocado, dwarf banana, kou (*Cordia*), milo, mango, hibiscus (tree-like varieties), coconut, and others. (NOTE: Where possible, locally native windbreak species should be prioritized.) The inclusion of multiple tree and shrub species in windbreak designs will provide more continuous floral resources, enhanced nesting and shelter resources for pollinators, and may increase windbreak effectiveness by improving canopy density.

Several valuable resources for windbreak design are available, including the Molokai Plant Materials Center presentation, *Windbreaks for Agroforestry* (available at: http://www.plant-materials.nrcs.usda.gov/pubs/hipmssy6712.pdf), and the University of Hawaii Extension publication, *Trees and Shrubs for Windbreaks in Hawaii* (available at: http://www.ctahr.Hawaii.edu/oc/freepubs/pdf/C1-447.pdf).

Figure 12 This coastal hedge of beach cabbage (*Scaevola taccada*) protects adjacent crops and other plants from sea-spray, and the flowers provide honey bees and other pollinating insects with nectar and pollen.

(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)

List of Appendices

Appendices Key

Location: AS = American Samoa; CNMI = the Commonwealth of the Northern Marianas Islands; FSM = the Federated States of Micronesia; Gu = Guam; HI = Hawaiian Islands; MI = the Marshall Islands; RP = the Republic of Palau

Native Status: A= Adventive; E = Endemic; I = Indigenous

Note: Adventive secies are exotic plants that are introduced and naturalized; endemic species are native and only found in their specified locations (and do not occur elsewhere); indigenous species are native, but may also be found in other parts of the world, not specified in the table.

Appendix A: Pacific Islands Area Crop Pollination

Level of need for animal-assisted pollination for crops grown in the Pacific Islands Area, evidenced by increased fruit or seed set, weight, and/ or quality. The primary flower visitor(s) are also listed next to each crop.

Animal Pollination Requirement	Fruits	Vegetables & Pulses	Roots & Tubers	Oils, Spices, & Stimulants
Essential	Cantaloupe: bee Custard apple: beetle Passion fruit: bee Watermelon: bee	Pumpkin: bee Squash: bee Gourd: bee Zucchini: bee		Cocoa: bee/ midge Macadamia nut: bee/ wasp/ butterfly Vanilla: human/ bee
Significant	Avocado: bee/ fly/ moth Starfruit: bees Durian: bee/ bat/ bird Loquat: bee Mango: bee/ fly/ wasp	Cucumber: bee		Allspice: bee Cardamon: bee Nutmeg: beetle
Moderate		Eggplant: bee Okra: bee Lablab: bee		Coconut: bee Coffee: bee Sunflower: bee
Low	Breadfruit: bee Litchi: bee/ fly Longan: bee Papaya: bee/ thrips/ butterfly/ moth Rambutan: bee/ fly Star apple: bat/ bee/ fly Tamarind: bee	Sweet & hot pepper: bee/ fly Green bean: bee/ thrips Pigeon pea: bee		Oil palm: weevil/ thrips Peanut: bee/ fly/ butterfly
Pollination only required for breeding purposes (e.g., seed production)	Banana & Plantain Pineapple	Broccoli Cabbages Mustards Cauliflower Celery Lettuce Spinach Green onion	Carrot Cassava Garlic Jicama Bulb onion Potato Radish Sweet Potato Taro Yam	
None	Mangosteen	Bamboo shoots Corn Watercress Green pea	Ginger	Date palm Kava Sugar cane Tea Black pepper
Variable (depends on cultivar)	Citrus: bee	Tomato: bee		
Unknown	Jackfruit: bee/ fly/ moth	Chayote: bee/ fly/ moth Velvet bean: bat Winged bean: bee		

Appendix B: Fruit Bat and Flying Fox Pollinators

Fruit bat/ flying fox pollinators found in the Pacific Islands Area. (See Appendices Key on p.18 for abbreviations.)

	PIA Occurrences*							
Fruit Bats or Flying Foxes	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments**
***Pteopodidae* (Old World fruit bats)**								
Pteropus insularis (Chuuk flying fox)			E					Listed as critically endangered
Pteropus mariannus (Fanihi, Mariana fruit bat)		E		E				Listed as endangered
Pteropus molossinus (Caroline flying fox)			E					Listed as vulnerable
Pteropus pelewensis (Pelew flying fox)							E	Listed as near threatened
Pteropus samoensis (Pe'a Samoan flying fox)	I							Listed as near threatened
Pteropus tonganus (Pe'a Pacific flying fox)	I							
Pteropus ualanus (Kosrae flying fox)			E					Listed as vulnerable
Pteropus yapensis (Yap flying fox)			E					Listed as vulnerable

Additional Comments:

- For more information, please see the USDA-NRCS *Biology Technical Note 20: Bats of the U.S. Pacific Islands* (available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_036705.pdf).
- A number of species of fruit bats have become extinct as a result of overharvesting for human consumption. In Guam and the Northern Mariana Islands the meat is considered a delicacy, which led to a large commercial trade. The commerce in fruit bats continues either illegally or because of inadequate restrictions. Local farmers may also kill the bats because they feed in their plantations.
- The Hawaiian hoary bat or Opeapea (family *Vespertilionidae*) is endemic to the Hawaiian Islands. The species is not considered a pollinator because it feeds primarily on insects. This species is listed as endangered, and the U.S. Fish and Wildlife Service has approved a formal recovery plan.

Figure 13 Fruit bats and birds live on many islands of the PIA and play a key role in pollinating native trees and some crops. These pollinating animals are very important to both the healthy and persistence of natural areas and cropping systems.

(Photographs courtesy of the National Park of American Samoa.)

Appendix C: Bird Pollinators

Bird pollinators found in the Pacific Islands Area. (See Appendices Key on p.18 for abbreviations.)

	PIA Occurrences*							
Birds	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments**
Fringillidae: Drepanidinae **(Honeycreeper subfamily)**								
Hemignathus flavus (Amakihi)					E			Listed as vulnerable, endemic to Oahu
Hemignathus kauaiensis (Amakihi)					E			Listed as vulnerable
Hemignathus lucidus (Nuku puu)					E			Listed as critically endangered
Hemignathus procerus (Kauai akialoa)					E			Listed as endangered
Hemignathus virens (Common Amakihi)					E			Found on the islands of Hawaii and Maui
Himatione sanguinea (Apapane)					E			Found on the island of Hawaii
Loxops coccineus (Akepa)					E			Listed as endangered
Palmeria dolei (Akohekohe)					E			Listed as critically endangered, endemic to Maui
Paroreomyza montana (Maui Alauahio)					E			Listed as endangered
Vestiaria coccinae (Iiwi)					E			Listed as vulnerable
Meliphagidae **(Honeyeaters and Australian chats)**								
Foulehaio carunculatus (Wattled honeyeater)	I							
Myzomela cardinalis (Cardinal honeyeater)	I							
Myzomela rubratra (Micronesian myzomela)		I	I	I			I	Likely extinct on Guam
Psittaculidae								
Vini australis (Blue-crowned lorikeet)	I							
Zosteropidae **(White-eyes)**								
Zosterops cinereus (Grey-brown white-eye)			E				E	
Zosterops conspicillatus (Guam bridled white-eye)		E		E				Listed as endangered
Zosterops finschii (Dusky white-eye)							E	
Zosterops hypolais (Plain white-eye)			E					
Zosterops oleagineus (Olive-colored white-eye)			E					
Zosterops rotensis (Rota bridled white-eye)		E		E				Listed as critically endangered

Additional Comments:

- The extinction or near-extinction of a number of pollinating birds in Guam (due to predation by brown tree snakes) has affected the ecosystem in multiple ways.
- Many of the above genera have a highly developed brush-tipped tongue which is frayed and fringed with bristles to soak up nectar.
- In addition to nectar, nearly all honeyeaters also eat insects or other small creatures.
- The wide range of bill sizes and shapes in these groups of birds has arisen through adaptive radiation, where an ancestral finch has evolved to fill a large number of ecological niches.
- Approximately 20 species of Hawaiian honeycreepers have become extinct in the recent past, and many more in earlier times, due to introduced species, such as rats and pigs, and habitat destruction.
- The preferred habitat for most of the Hawaiian honeycreeper species is wet forest with *Metrosideros polymorpha* and *Acacia koa*. Other preferred species include *Rubus hawaiensis* and *Sophora chrysophylla*.

Appendix D: Bees in the Pacific Islands Area

Bees found in the Pacific Islands Area. (See Appendices Key on p.18 for abbreviations.)

	PIA Occurrences*							
Bees	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments**
Apidae								
Apis mellifera (European honey bee)	A		A	A	A		A	
Ceratina arizonensis					A			
Ceratina dentipes					A			
Ceratina mariannensis		E						
Ceratina palauensis							E	
Ceratina smaragdula					A			
Tetragonula clypearis							I	
Tetragonula fuscobalteata							I	
Tetragonula sapiens			I					
Xylocopa sonorina		A		A	A			
Colletidae								
Hylaeus in Hawaii					E			See Appendix E for details
Hylaeus guamensis				E				
Hylaeus hirticaudus							E	
Hylaeus leptocephalus					A			Current status and distribution is uncertain
Hylaeus rotensis		E						
Hylaeus strenuus					A			Associated with *Erythrina* and *Scaevola* spp.
Hylaeus yapensis			E					
Halictidae								
Lasioglossum aurigrum			E					
Lasioglossum extraordinarium	E							
Lasioglossum imbrex					A			
Lasioglossum impavidum					A			
Lasioglossum kumejimense		E						
Lasioglossum latro	E							
Lasioglossum mackieae	E							
Lasioglossum niveifrons	E							syn. *Halictus mesocyaneus*
Lasioglossum microlepoides					A			
Lasioglossum nummatum			E					
Lasioglossum palaonicum							E	
Lasioglossum perpessicium	E							
Lasioglossum rotaense		E						
Lasioglossum saffordi				E				
Lasioglossum samoae	E							
Lasioglossum semicyaneum	E							

	PIA Occurrences*							
Bees	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments**
Halictidae cont.								
Lasioglossum stevensoni	E							
Lasioglossum swezeyi		I		I				
Lasioglossum upoluense	E							
Lasioglossum vexator		E						
Lasioglossum yapense			I				I	
Lasioglossum zachiorus	E							
Nomioides klausi					A			
Megachilidae								
Heriades paganensis					E			
Heriades plumosa							E	
Lithurgus bractipes	E							
Lithurgus scabrosus	A		A	A	A		A	
Megachile armstrongi	E							
Megachile buxtoni	E							
Megachile calens	E							
Megachile chlorura					A			
Megachile diligens	I		I		I	I		
Megachile fullawayi			A	A	A	A		
Megachile gentilis					A			
Megachile lanata					A			
Megachile laticeps		A	A	A			A	
Megachile palaonica							E	
Megachile scutellata	E							
Megachile similis	E							
Megachile timberlakei					A			
Megachile tutuilae	E							
Megachile umbripennis		E			A			
Megachile wilmattae	E							

Additional Comments:

- Beekeeping in Hawaii dates back to 1857, when the first hive from California was successfully established. Where the honey bee has not yet been introduced in the Pacific, an assessment of its impact on the native ecosystem should be considered prior to implementation of beekeeping activities.
- Leafcutter bees (*Megachilidae*) tend to nest in small cavities, hollow stems, and previously existing holes in wood. Many of them found their way to Hawaii and other PIA islands because immature stages were transported in these cavities (e.g., inside reed and bamboo).
- Most Halictids nest in the ground (though a few nest in wood), and they provision their young with a mass of pollen and nectar inside a waterproof cell.

Appendix E: *Hylaeus* bees in the Hawaiian Islands

Checklist and distribution of native *Hylaeus* bees in the Hawaiian Islands. Light grey boxes mean that the species was collected before, but not after, 1918, indicating that the species is very rare or extinct. Green boxes indicate that the species has been recently collected (after 1918). (See Appendices Key on p.18 for abbreviations.)

	Hawaii Occurrences										
***Hylaeus* in Hawaii**	**Nihoa**	**Lehua**	**Nihau**	**Kauai**	**Oahu**	**Molokai**	**Lanai**	**Maui**	**Kahoolawe**	**Hawaii**	**Comments**
H. akoko											All collections from *Chamaesyce olowaluana*
H. andrenoides											
H. angustulus											
H. anomalus											Not recorded since the 1970s
*H. anthracinus**											Prefers native coastal strand vegetation
*H. assimulans**											Frequently collected on *Sida fallax*
H. chlorostictus											
H. coniceps											
H. connectens											
H. crabronoides											
H. difficilis											Recent collections on *Chamaesyce olowaluana*
H. dimidiatus											
H. dumetorum											
*H. facilis**											
H. filicum											
H. finitimus											
H. flavifrons											
H. flavipes											
H. fuscipennis											
H. gliddenae											Not collected since 1934
H. haleakalae											
*H. hilaris**											
H. hirsutulus											
H. hostilis											
H. hula											
H. inquiline											
H. kauaiensis											
H. kokeensis											
H. kona											
*H. kuakea**											Only known from two collections in Waianae Mountains
H. kukui											
H. laetus											
*H. longiceps**											

	Hawaii Occurrences										
***Hylaeus* in Hawaii**	**Nihoa**	**Lehua**	**Nihau**	**Kauai**	**Oahu**	**Molokai**	**Lanai**	**Maui**	**Kahoolawe**	**Hawaii**	**Comments**
*H. mana**											Only known to occur in Koolau Mountains
H. mauiensis											
H. melanothrix											
H. mimicus											
H. muranus											
H. mutatus											
H. nalo											
H. niloticus											
H. nivicola											
H. ombrias											
H. paradoxicus											
H. pele											
H. perkinsianus											
H. perspicuus											
H. psammobius											
H. pubescens											
H. rugulosus											
H. satelles											
H. setosifrons											
H. simplex											
H. solaris											
H. specularis											Identification tentative for Maui
H. sphecodoides											
H. takumiae											
H. unicus											
H. volatilis											
H. volcanicus											
H. spp. A											Undescribed species

*In Sept. 2011 the U.S. Fish and Wildlife Service determined that listing for these seven species as endangered throughout their range was warranted, and the seven species were placed on the candidate species list.

Additional Comments:

- *Hylaeus* carry pollen in their crop (stomach), rather than externally like many other bees, and regurgitate it into a cell where it will be used as larval food. The liquid provisions are sealed inside a membranous cellophane-like cell lining. Nests are typically in dead twigs or plant stems, or other similarly small natural cavities.
- Hawaiian *Hylaeus* can be found in a variety of habitats throughout the Hawaiian islands, including coasts, dry forests and shrublands, mesic and wet forests, and subalpine shrublands. All the species strongly depend on an intact community of native plants and are mostly absent from habitats dominated by non-native plant species.
- The Xerces Society for Invertebrate Conservation has profiles of Hawaii's most at-risk *Hylaeus* spp. at: http://www.xerces.org/bees/, under "yellow faced bees."

Appendix F: Butterflies in the Pacific Islands Area

Checklist of butterflies found in the Pacific Islands Area. The list of moth species in the PIA is long and there are probably many more species which have yet to be identified. Therefore, this list only includes butterflies, but there are some interesting facts about moths included in the Additional Comments section below. (See Appendices Key on p.18 for abbreviations.)

	PIA Occurrences*							
Butterflies	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments (hp = host plant)**
Hesperiidae								
Badamia exclamationis (Brown awl)	I			I		I	I	hp = *Terminalia* spp.
Erionota thrax (Banana skipper)		A		A	A			Accidentally introduced; hp = monocots
Hasora chromus (Common banded awl)				I			I	hp = *Pongamia pinnata*
Hylephila phyleus (Fiery skipper)					A			
Parnara naso (Straight swift)							I	hp = rice, sugar cane, bamboo, taro, corn
Taractrocera ziclea (Grassdart)				A				hp = grasses or sedges
Lycaenidae								
Acytolepis puspa (Common hedge blue)			I				I	
Bindahara phocides (Plane)			I				I	hp = *Salacia prinoides*, larva feed on fruit
Brephidium exilis (Western pygmy blue)					A			hp = Pickleweed
Catochrysops taitensis pepe	I							
Chilades pandava (Plains cupid)		A						hp = *Cycas revoluta*
Deudorix doris	I							
Euchrysops cnejus (Cupid)			I				I	hp = *Phaseolus, Vigna*, and *Crotolaria* spp.
Euchrysops cnejus samoa	I							
Everes lacturnus (Tailed cupid)			I				I	hp = *Fabaceae*
Famegana alsulus (Black-spotted grass blue)							I	hp = legumes
Famegana alsulus lulu	I							
Jamides argentina	I							
Jamides bochus (Cerulean)			I				I	hp = *Crotolaria, Derris,* and *Vigna* spp.
Lampides boeticus (Long-tailed pea blue)		A	A	A	A		A	hp = various kinds of *Fabaceae*
Leptotes plinius (Zebra blue)							I	hp = Plumbago flowers
Megisba strongyle (Malayan)			I				I	hp = *Sapindaceae* spp.
Nacaduba dyopa dyopa	I							
Nacaduba kurava (White lineblue)			I				I	hp = *Maesa* and *Rapanea* spp.
Petrelaea dana (Dana blue)							I	
Petrelaea tombugensis	I							
Strymon bazochii (Lantana scrub hairstreak)					A			Intentionally introduced to control lantana
Tmolus echion (Red-spotted hairstreak)					A			Intentionally introduced to control Lantana

	PIA Occurrences*							
Butterflies	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments (hp = host plant)**
Udara blackburni (Blackburn's bluet)					E			hp = Koa
Lycaenidae cont.								
Zizula hylax (Tiny grass blue)		I	I	I				hp = Lantana, *Oxalis* spp.
Zizina otis (Lesser grass blue)			I	I				hp = *Mimosa pudica, Alysicarpus vaginalis*
Zizina otis labradus (Lesser grass blue)	I				A			
Nymphalidae								
Agraulis vanillae (Gulf fritillary)					A			hp = Lilikoi (*Passiflora* spp.)
Danaus affinis (Black and white tiger)			I				I	hp = *Apocynaceae*
Danaus plexippus (Monarch)	A	I	I	I	A	I	I	hp = Crownflower, *Asclepias* spp.
Doleschallia tongana vomana	A							
Euploea abjecta (Sickle-spotted brown crow)							I	
Euploea eleutho (Marianas brown crow)		E		E				Not collected since 1946, possibly extinct
Euploea eunice (Blue-branded king crow)		I	I				I	hp = *Ficus* spp.
Euploea lewinii bourkei	I							
Hypolimnas anomala (Guardian eggfly)		I	I	I			I	hp = *Pipturus argenteus*
Hypolimnas antilope lutescens	I							
Hypolimnas bolina (Blue moon eggfly)		I	I	I		I		Considered most variable butterfly in world
Hypolimnas bolina pallescens	I							
Hypolimnas misippus (Danaid eggfly)							I	hp = primarily *Portulcaca oleracea*
Hypolimnas octocula (Forest flicker)		I		I			I	hp = *Procris pedunculata* & *Elatostema calcareum*
Hypolimnas octocula marianensis (Mariana eight-spot)		E		E				hp = *Procris pedunculata* & *Elatostema calcareum*
Hypolimnas pithoeka (Dark eggfly)			I					
Junonia hedonia (Chocolate soldier)							I	
Junonia villida (Meadow argus)	I		I			I	I	Feed at night and spend the day in debris
Melanitis leda (Evening brown)		I		I				hp = various species of grasses
Melanitis leda hopkinsi	I							
Tirumala hamata tutuilae	I							
Vagrans egista (Vagrant)							I	hp = *Flacourtia, Xylosma,* and *Homalium* spp.
Vagrans egistina (Marianas rusty)		E		E				hp = *Celastraceae*
Vagrans egista bowdenia	I							hp = *Flacourtia rukam*
Vanessa atalanta (Red admiral)					A			hp = Mamaki
Vanessa cardui (Painted lady)					A			hp = Cocklebur
Vanessa indica (Indian red admiral)							I	
Vanessa tameamea (Kamehameha butterfly)					E			hp = *Pipturus albidus* (Mamaki)
Vanessa virginiensis (American painted lady)					A			hp = thistle weed (*Cirsium* spp.)

(*Butterflies in the PIA* cont. on next page.)

	PIA Occurrences*							
Butterflies	**AS**	**CNMI**	**FSM**	**Gu**	**HI**	**MI**	**RP**	**Comments (hp = host plant)**
Pieridae								
Appias ada (Rare albatross)			I				I	
Pieridae cont.								
Appias athama manaia	I							
Appias paulina (Common albatross)				I			I	hp = *Capparis* spp.
Belenois java schmeltzi	I							
Catopsilia pomona (Lemon migrant)		I	I	I			I	hp = *Cassia* spp.
Catopsilia pyranthe (Mottled emigrant)			I				I	hp = *Cassia* spp.
Eurema blanda (Large grass yellow)		I	I	I			I	hp = leguminous trees and shrubs
Eurema brigitta (No-brand grass yellow)							I	hp = *Cassia* spp.
Eurema hecabe (Common grass yellow)			I				I	hp = leguminous trees and shrubs
Pieris rapae (Cabbage white)					A			hp = Brassicas and *Capparis sandwichiana*
Phoebis agarithe (Large orange sulfur)					A			hp = Opiuma
Papilionidae								
Graphium agamemnon (Tailed jay)							I	hp = include *Annonaceae*
Papilio godeffroyi	E							hp = *Micromelum minutum*
Papilio polytes (Black citrus swallowtail)		I	I	I			I	hp = citrus and other *Rutaceae*
Papilio xuthus (Chinese yellow swallowtail)		I	I	I	A			hp = *Rutaceae*, possibly extinct

Additional Comments:

- Some butterfly species can fly thousands of kilometers and have the ability to migrate and colonize the vast (and sometimes very isolated) islands of the Pacific Ocean.
- Butterflies and moths have a four-stage life cycle of egg, larvae/ caterpillar, pupae/ chrysalis, and adult butterfly. The timing of these stages may relate to the prevailing conditions of their local environment, allowing butterflies to live in what might otherwise be inhospitable locations. Successful conservation of butterflies and moths requires special attention to the ecological requirements of each stage of the life cycle.
- The life spans of butterflies vary from two to twenty-one days after they emerge from their pupae, although some species can live for up to seven months.
- The greatest threats to butterflies and moths are habitat loss and degradation due to conversion for agriculture, logging, grazing, soil disturbance by a suite of non-native ungulates, and introduction of non-native plants and animals.
- Hawaii supports 995 native species of moths, including the endangered Blackburn's sphinx moth. These native moths are very small, with most only having a wingspan of once centimeter or less, and little information is known about most of them. For example, approximately 350 species of native moths are in the genus *Hyposmocoma*, and twice as many are likely undescribed.
- The great majority of moths are herbivorous, feeding on plants, plant debris, and lichens. However, in 2005, a new species (*Hyposmocoma molluscivora*) was discovered on Maui, with the larva feeding on snails. Less than one percent of the world's known moths and butterflies are carnivorous.

Appendix G: Conservation Biological Control

Examples of beneficial insects (including spiders and mites), common prey or hosts, and basic conservation strategies.

Beneficial Arthropod	Common Prey or Hosts	Conservation Strategies
Spiders (e.g., wolf spiders, jumping spiders, orb weaver spiders, sheet-weaving spiders)	Beetles, caterpillars, leafhoppers, and aphids	Provide natural areas and/ or permanent field borders near crop fields. Maintain cover crops and leave crop residue.
Predatory mites	Spider mites, thrips, mealybugs, psocids, whiteflies, small caterpillars, and fungus gnats	Cover crops, ground covers, and/ or permanent plantings should be maintained.
Ground beetles and rove beetles	Small insects, including caterpillars, beetle larvae, aphids, fly larvae, snails, and slugs	Create beetle banks, which are earthen ridges within fields planted with bunch grasses. Mulch, animal manure, and compost can also be beneficial.
Lady beetles, lady bugs, ladybird beetles	Specialize on aphids and scales, but may also consume whiteflies, mites, thrips, and insect eggs	Maintain non-crop areas or plantings within fields that support pollen and nectar producing plants.
Flower flies, hover flies, syrphid flies	Aphids, scales, mealybugs, spider mites, thrips	Protect flowering plants, gardens, field borders, and cover crop plantings within crop fields. Showy, open flowers (such as plants in the sunflower and carrot families) are especially attractive to flower flies.
Hemiptera (e.g., assassin bugs, minute pirate bugs)	Thrips, mites, scales, aphids, plant lice, leaf hoppers, leaf beetles, grasshoppers, small caterpillars, various insect eggs	Maintain permanent native habitat within or near crops. Flowers that attract these insect include plants in the bean, sunflower, and carrot families, as well as buckwheat.
Mantids	Wide variety of insects	Maintain native plant buffers.
Green and brown lacewings	Aphids, small caterpillars, beetles, thrips, mites, whiteflies, mealybugs	Plant a diversity of flowers within or near crops.
Tachinid flies	Larval stage of certain butterflies, moths, beetles, sawflies, true bugs, grasshoppers	Provide consecutively blooming wildflowers, particularly plants from the following families: carrot, sunflower, and milkweed.
Parasitoid wasps	Aphids, whiteflies, scales, caterpillars, flies, beetles, leafhoppers	Provide forest edges near fields as well as nectar sources. Increase crop diversity.
Predatory wasps	Caterpillars, beetles, flies, true bugs	Provide shallow flowers such as milkweeds and members of the sunflower, and carrot families.

Appendix H: NRCS Practices for Pollinators

NRCS practices which can benefit pollinators.

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 and pollen.
Brush Management (Ac.)	314	Reduction of noxious woody plants can be used to help maintain pollinator-friendly early successional habitat.
Channel Bank Vegetation (Ac.)	322	Can include diverse flowering trees, shrubs, and forbs.
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 (Ac.)	328	Can include rotation plantings of forbs that provide abundant forage for pollinators (e.g., sunn hemp, buckwheat). Moving insect-pollinated crops no more than 250 meters (820 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 blooming 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.
Constructed Wetland (Ac.)	656	Constructed wetlands can include plants that provide pollen and nectar for native bees and other pollinators. Look for appropriate obligate or facultative wetland plants for your island.
Contour Buffer Strips (Ac.)	332	Can include diverse legumes or other forbs that provide pollen and nectar
Contour Orchard and Other Perennial Crops (Ac.)	331	This practice has been revised to include consideration for pollinators. When establishing contours, utilize the areas between the contours to provide forage for pollinators. Select species that provide multiple benefits to insects and augment the period of crop bloom.
Cover Crop (Ac.)	340	Can include diverse legumes or other forbs that provide pollen and nectar for pollinators. Look for a diverse mix of plant species that overlap in bloom timing to support pollinators throughout the year. Many "beneficial insect" cover crop blends include plant species that will also provide forage for pollinators.
Critical Area Planting (Ac.)	342	Can include plan species that provide abundant pollen and nectar for native bees and other pollinators.
Field Border (Ac.)	386	This practice may provide nesting, foraging, and other forms of habitat along edges of fields. It provides early successional habitat by planting pollinator species a minimum of 20 feet wide to plants that provide resources throughout the year.
Filter Strip (Ac.)	393	Filter strips can be used to provide supplemental pollinator resources within crop fields; especially in areas where the landscape is somewhat homogenous. However, the primary purpose of the filter strips should not be compromised. Increasing the flow length (10 feet) on the downstream side of the filter strip and including legumes or other forbs that provide pollen and nectar is a good secondary resource.
Forest Stand Improvement (Ac.)	666	This practice has had a consideration added that can help maintain open understory and forest gaps that support diverse forbs and shrubs that provide pollen and nectar for pollinators.

Conservation Practice Name (Units)	Code	Pollinator Notes
Hedgerow Planting (Ft.)	422	Include trees and shrubs that provide pollen and nectar during the entire growing season Consider integrating shrubs that provide nesting cover for tunnel nesting bees or provide artificial nesting blocks. This practice also can help reduce drift of pesticides onto areas of pollinator habitat as well.
Herbaceous Weed Control (Ac.)	315	This practice is to be utilized to reduce or eliminate noxious herbaceous plants in order to maintain or restore a native plant community or maintain an established plant community that supports pollinators. Where possible, establish replacement species prior to removal to provide pollinator resources when noxious species are suspected of providing the principle source of pollinator habitat. In addition, apply herbicides in wildlife friendly methods to prevent harm to native pollinators and their food sources.
Herbaceous Wind Barriers (Ft.)	603	Can include tall flowering plants such as sunn hemp that provide pollen and nectar for native bees.
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 year and can support populations of pollinators over time.
Restoration and Management of Rare and Declining Habitats (Ac.)	643	A consideration was added to this practice. It could be used to provide diverse locally grown native forage (forbs, shrubs, and trees) and nesting resources for pollinators. Many specialist pollinators are closely tied to rare plants or habitats and these rare plants may significantly benefit from efforts to restore and/ or manage rare habitat. However, pollinator plants should only be planted if they were part of the rare ecosystem you are trying to restore.
Riparian Forest Buffer (Ac.)	391	Includes trees, shrubs, and forbs especially chosen to provide pollen and nectar during the entire year for pollinators. This practice also can help reduce drift of pesticides to areas of pollinator habitat.
Silvopasture Establishment (Ac.)	381	If grazing intensity is low enough to allow for plants to flower, this practice can include 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	A consideration was added to this standard to select plants for adjoining riparian areas. These can include trees, shrubs, and forbs that provide pollen and nectar for pollinators.
Streambank and Shoreline Protection (Ft.)	580	If vegetation is used for streambank protection, plants can include trees, shrubs, and forbs especially chosen to provide pollen and nectar for pollinators.
Stripcropping (Ac.)	585	The standard contains criteria to establish at least three species (with different bloom lengths) that provide supplemental forage before, during and after the primary crop bloom. There are also considerations to include diverse forbs that provide pollen and nectar for pollinators. If insect pollinated crops are grown, plants used in adjacent strips may be carefully chosen to provide complementary bloom periods prior to and after the crop.
Tree/ Shrub Establishment (Ac.)	612	Include trees and shrubs especially chosen to provide pollen and nectar for pollinators, or host plants for butterflies, and nesting habitat for tunnel nesting bees.
Upland Wildlife Habitat Management (Ac.)	645	Can include managing for pollinator forage or pollinator nest sites, such as nest blocks, snags for cavity nesting bees.
Vegetative Barriers (Ft.)	601	Can include plants that provide pollen and nectar for pollinators as long as they are a stiff, upright stature for impeding surface water flow.

Conservation Practice Name (Units)	Code	Pollinator Notes
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 wood-nesting bees. Windbreaks and shelter belts will also 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.

Figure 14 NRCS conservation practices can provide valuable forage and nesting habitat for pollinators including the Pea blue butterfly and Carpenter bees.

(Photographs by Glenn Sakamoto, Hoolehua Plant Materials Center.)

Additional NRCS conservation practices that can support pollinators.

Pollinator Resources	Code	Conservation Practice Name (Units)	Code	Conservation Practice Name (Units)
Forage (diverse sources of pollen and nectar that support pollinators throughout the year)	311	Alley Cropping (Ac.)	528	Prescribed Grazing (Ac.)
	322	Channel Bank Vegetation (Ac.)	643	Restoration and Management of Rare and Declining Habitats (Ac.)
	327	Conservation Cover (Ac.)	391	Riparian Forest Buffer (Ac.)
	328	Conservation Crop Rotation (Ac.)	390	Riparian Herbaceous Cover (Ac.)
	656	Constructed Wetland (Ac.)	381	Silvopasture Establishment (Ac.)
	332	Contour Buffer Strips (Ac.)	395	Stream Habitat Improvement and Management (Ac.)
	340	Cover Crop (Ac.)	580	Streambank and Shoreline Protection (Ft.)
	342	Critical Area Planting (Ac.)	585	Stripcropping (Ac.)
	386	Field Border (Ac.)	612	Tree/ Shrub Establishment (Ac.)
	393	Filter Strip (Ac.)	645	Upland Wildlife Habitat Management (Ac.)
	412	Grassed Waterway (Ac.)	601	Vegetative Barriers (Ft.)
	422	Hedgerow Planting (Ft.)	659	Wetland Enhancement (Ac.)
	603	Herbaceous Wind Barriers (Ft.)	657	Wetland Restoration (Ac.)
	379	Multi-story Cropping (Ac.)	644	Wetland Wildlife Habitat Management (Ac.)
	512	Pasture and Hay Planting (Ac.)	380	Windbreak/ Shelterbelt Establishment (Ft.)
	595	Pest Management (Ac.)	650	Windbreak/ Shelterbelt Renovation (Ft.)
	409	Prescribed Forestry (Ac.)		
Nest sites (stable ground, holes in wood)	322	Channel Bank Vegetation (Ac.)	391	Riparian Forest Buffer (Ac.)
	656	Constructed Wetland (Ac.)	612	Tree/ Shrub Establishment (Ac.)
	332	Contour Buffer Strips (Ac.)	645	Upland Wildlife Habitat Management (Ac.)
	342	Critical Area Planting (Ac.)	659	Wetland Enhancement (Ac.)
	386	Field Border (Ac.)	657	Wetland Restoration (Ac.)
	422	Hedgerow Planting (Ft.)	644	Wetland Wildlife Habitat Management (Ac.)
	409	Prescribed Forestry (Ac.)	380	Windbreak/ Shelterbelt Establishment (Ft.)
	329	Residue & Tillage Management, No-Till/ Strip Till/ Direct Seed (Ac.)	650	Windbreak/ Shelterbelt Renovation (Ft.)
	643	Restoration and Management of Rare and Declining Habitats (Ac.)		
Pesticide protection (refuge from spray, buffers to drift, etc.)	322	Channel Bank Vegetation (Ac.)	422	Hedgerow Planting (Ft.)
	656	Constructed Wetland (Ac.)	391	Riparian Forest Buffer (Ac.)
	342	Critical Area Planting (Ac.)	657	Wetland Restoration (Ac.)
	386	Field Border (Ac.)	380	Windbreak/ Shelterbelt Establishment (Ft.)
Site management for pollinators	314	Brush Management (Ac.)	643	Restoration and Management of Rare and Declining Habitats (Ac.)
	595	Pest Management (Ac.)	645	Upland Wildlife Habitat Management (Ac.)
	409	Prescribed Forestry (Ac.)	644	Wetland Wildlife Habitat Management (Ac.)
	528	Prescribed Grazing (Ac.)		

Appendix I: Pollinator Plants in the Pacific Islands Area

Potentially important plants for pollinators in the Pacific Islands Area. Please see USDA-NRCS's Vegetation Guide for more details, including native status and bloom period.

*At least one variety or subspecies listed as threatened or endangered.

Table 1: Hawaii

Commercially available food plants important to pollinators.

Trees & Shrubs

Acacia koa (Koa)
Acacia koaia (Koaia)
Achyranthes splendens var. *splendens* (Ewa hinahina)
Alphitonia ponderosa (Kauila)
Columbrina asiatica (Anapanapa)
Cordia subcordata (Kou)
Dodonaea viscosa (Kumakani, Aalii)
Gossypium tomentosum (Mao)
Hibiscus arnottianus spp. *arnottianus*
Hibiscus arnottianus spp. *punaluuensis*
Ilex anomala (Kawau)
Metrosideros polymorpha (Ohia)
Myoporum sandwicense (Naio)
Myrsine lessertiana (Kolea)
Myrsine sandwicensis (Kolea)
Nototrichium sandwicense (Hawaii rockwort, Kului)
Osteomeles anthyllidifolia (Ulei)
Pipturus albidus (Mamake, Waimea pipturus)
Pisonia brunoniana (Papala kepau)
Polyscias hawaiensis (Ohe mauka)
Polyscias racemosa (Pokalakala)*
Polyscias sandwicensis (Ohe makai)
Polyscias oahuensis (Ohe mauka)
Pritchardia spp. (Loulu)*
Psychotria spp. (Kopiko)
Psydrax odorata (Alahee)
Rubus hawaiensis (Kala, Akala)
Rhus sandwicensis (Nene leau)
Santalum ellipticum (Sandalwood, Iliahi)
Santalum freycinetianum (Sandalwood, Iliahi)
Santalum haleakalae (Sandalwood, Iliahi)*
Santalum paniculatum (Sandalwood, Iliahi)
Sapindus oahuensis (Lonomea)
Sapindus saponaria (Ae)
Scaevola tacadda (Naupaka)
Scaevola coriacea (Naupaka)*
Scaevola gaudichaudiana (Naupaka)
Scaevola procera (Naupaka)
Schiedea globosa (Globe schiedea)
Senna gaudichaudii (Kalamona)
Sesbania tomentosa (Ohai)*
Sida fallax (Ilima)
Sophora chrysophylla (Mamane)
Thespesia populnea (Milo)
Vaccinium calycinum (Ohelo kau laau)
Vaccinium reticulatum (Ohelo)
Vitex rotundifolia (Pohinahina)
Waltheria indica (Uhaloa)
Wikstroemia oahuensis var. *oahuensis* (Akia)

Herbaceous Plants & Vines

Bacopa monnieri (Aeae)
Bidens spp. (Koo-koolau)
Boerhavia glabrata (Alena)
Boerhavia repens (Alena)
Ipomoea indica (Koaliawa)
Jacquemontia sandwicensis (Pauohiiaka)
Sesuvium portulacastrum (Akulikuli)
Smilax melastomifolia (Hoi kuahiwi)
Tribulus cistoides (Nohu)
Vigna marina (Nanea)

Figure 15 Trees & Shrubs which are potential pollinator food plants and commecially available in Hawaii. Left to right: *Columbrina asiatica, Myoporum sandwicense,* and *Santalum paniculatum.*

(Photographs by Gregory Koob, Hawaii NRCS.)

Non-Native Cover Crops

Crotalaria juncea (Sunn hemp)
Fagopyrum esculentum (Buckwheat)
Melilotus spp. (Sweetclover)

Commercially available nesting and egg-laying plants important to pollinators.

Nesting Substrate for *Hylaeus* Bees

Acacia koa (Koa)
Boehmeria grandis (Akolea)
Broussaisia arguta (Kanawao)
Clermontia grandiflora (Blog clermontia)
Metrosideros polymorpha (Ohia)
Myrsine lessertiana (Kolea)
Pipturus albidus (Mamake)
Polyscias oahuensis (Ohe mauka)
Psychotria fauriei (Koolau Range wild coffee)
Psychotria hawaiiensis (Kopiko)
Psychotria mariniana (Kopiko)
Psychotria mauiensis (Opiko)
Rubus hawaiensis (Akala)
Smilax melastomifolia (Ulehihi)
Sophora chrysophylla (Mamane)

Caterpillar Host Plants

Acacia koa (Koa)
Pipturus albidus (Mamake)

Food plants important to pollinators with limited commercial availability.

Trees & Shrubs

Achyranthes splendens var. *rotundata* (Ahinahina)*
Antidesma platyphyllum (Haamaile)
Cheirodendron trigynum (Ehu)
Claoxylon sandwicense (Luakea)
Coprosma montana (Hupilo)
Dubautia ciliolata (Kupaoa)
Euphorbia celastroides (Kokomalei)
Euphorbia degeneri (Kokomalei)
Euphorbia multiformis (Akoko)
Euphorbia olowaluana (Kokomalei)
Geranium cuneatum (Hinahina)
Geranium tomentosum (Huluhulu)
Kadua affinis (Manono)
Leptocophylla tameiameiae (Kanehoa)
Lipochaeta lobata (Shrubland nehe)*
Melicope adscendens (Alani)*
Melicope anisata (Alani)
Melicope balloui (Alani)*
Melicope barbigera (Alani)
Melicope christophersenii (Alani)*
Melicope cinerea (Manena)*
Melicope clusiifolia (Kukaemoa)
Melicope cruciata (Cross-bearing pelea)*
Melicope degeneri (Kokee stream melicope)*
Melicope elliptica (Leiohiiaka)
Melicope feddei (Hiiaka)
Melicope haleakalae (Haleakala melicope)*
Melicope haupuensis (Haupa mountain melicope)*
Melicope hawaiensis (Mokihana kukae moa)*
Melicope hiiakae (Koolau Range melicope)*
Melicope hosakae (Honolulu melicope)
Melicope kaalaensis (Kaala melicope)*
Melicope kavaiensis (Kauai melicope)
Melicope knudsenii (Olokele Valley melicope)*
Melicope lydgatei (Koolau Range melicope)*
Melicope macropus (Kaholuamanu melicope)*
Melicope makahae (Alani)*
Melicope molokaiensis (Molokai melicope)
Melicope mucronulata (Alani)*
Sapindus saponaria (Manele)

Herbaceous Plants & Vines

Argemone glauca (Kala)
Argyroxiphium sandwicense (Silversword)*
Canavalia galeata (Puakauhi)
Portulaca lutea (Ihi)
Portulaca villosa (Ihi)

Figure 16 *Bacopa monnieri*, a herbacious food plant for pollinators.

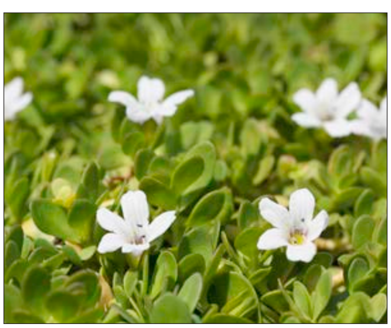

Figure 17 *Broussaisia arguta* and *Metrosideros polymorpha*, two commercially available potential nesting and egg-laying pollinator plants in Hawaii.

(Photographs by Gregory Koob, Hawaii NRCS.)

Table 2: American Samoa

Potentially important plants for pollinators. Note that the following plants are deemed beneficial to pollinators through personal observations (e.g., pollinators are seen using plants) and/ or because they are closely related to plants known to be beneficial to pollinators. Very little to no experimental testing for pollinator attractiveness has occured for many of these plants.

Trees & Shrubs

Barringtonia asiatica (Futu)
Calophyllum inophyllum (Fetau)
Calophyllum neo-ebudicum (Tamanu)
Cerbera manghas (Leva)
Clerodendrum inerme (Aloalo tai)
Decaspermum fruticosum (Nuanua)
Dendrolobium umbellatum (Lala)
Erythrina subumbrans (Gatae palagi)
Erythrina variegata orientalis (Gatae Samoa)
Eugenia reinwardtiana (Unuoi)
Flueggea flexuosa (Poumuli)
Gossypium hirsutum (Vavae)
Grewia crenata (Fau ui)
Guettarda speciosa (Puapua)
Hibiscus tiliaceus (Fau)
Intsia bijuga (Ifilele)
Kleinhovia hospita (Fuafua)
Metrosideros collina
Micromelum minutum (Talafalu) - host plant
Neisosperma oppositifolium (Fao)
Morinda citrifolia (Nonu)
Neonauclea forsteri (Afa)
Pisonia grandis (Pua vai)
Premna serratifolia (Aloalo)
Rhus taitensis (Tavai)
Scaevola taccada (Toitoi)
Sophora tomentosa
Syzygium spp. (Asi)
Terminalia catappa (Talie)
Terminalia samoensis (Talie)
Thespesia populnea (Milo)
Tournefortia argentea (Tausuni)
Trichospermum richii (Mao ui)
Vitex trifolia (Namulega)

Herbaceous Plants & Vines

Bidens spp.
Boerhavia repens (Ufiatuli)
Boerhavia tetrandra
Canavalia cathartica
Canavalia rosea (Fue fai vaa)
Canavalia sericea
Mucuna gigantea (Tupe)
Portulaca lutea (Tamole)
Portulaca samoensis (Tamole)
Sesuvium portulacastrum
Wollastonia biflora (Ateate)
Vigna marina (Fue sina)

Non-Native Cover Crops

Crotalaria juncea (Sunn hemp)
Fagopyrum esculentum (Buckwheat)
Melilotus spp. (Sweetclover)

Figure 18 Potential pollinator plants in American Samoa. Top row, left to right: *Barringtonia asiatica*, *Canavalia cathartica,* and *Bidens cosmoides.* Bottom row, left to right: *Crotalaria juncea, Erythrina variegata* var. *orientalis,* and *Scaevola taccada.*

(Photographs by Gregory Koob, Hawaii NRCS.)

Table 3: Guam and the Northern Mariana Islands

Potentially important plants for pollinators. Note that the following plants are deemed beneficial to pollinators through personal observations (e.g., pollinators are seen using plants) and/ or because they are closely related to plants known to be beneficial to pollinators. Very little to no experimental testing for pollinator attractiveness has occured for many of these plants.

Trees & Shrubs

Barringtonia asiatica (Puteng)
Calophyllum inophyllum (Daok)
Cerbera spp.
Clerodendrum inerme (Lodigao)
Dendrolobium umbellatum (Palaga hilitai)
Erythrina variegata (Gaogao)
Guettarda speciosa (Panao)
Heritiera littoralis (Ufa)
Hibiscus tiliaceus (Pago)
Morinda citrifolia
Moringa oleifera
Neisosperma oppositifolia (Fago)
Pisonia grandis (Omunu)
Psychotria mariana
Scaevola taccada (Nanasu)
Sophora spp.
Terminalia catappa (Talisai)
Terminalia samoensis (Talisai ganu)
Thespesia populnea (Banalu)
Tournefortia argentea (Hunek)
Vitex parviflora
Wikstroemia elliptica

Herbaceous Plants & Vines

Canavalia cathartica (Lodosong tasi)
Canavalia rosea (Akankang tasi)
Mucuna gigantea (Bayogon dikike)
Passiflora spp.
Sesuvium portulacastrum
Vigna marina (Akankang manulasa)
Wollastonia biflora (Masiksik)

Non-Native Cover Crops

Crotalaria juncea (Sunn hemp)
Fagopyrum esculentum (Buckwheat)
Melilotus spp. (Sweetclover)

Figure 19 Potential pollinator plants in Guam and the Northern Mariana Islands. Top row, left to right: *Cerbera dilatata*, *Guettarda speciosa,* and *Calopyllum inophyllum.* Bottom row, left to right: *Mucuna gigantea, Neisosperma oppositifolia,* and *Psychotria mariniana.*

(Photographs by Gregory Koob, Hawaii NRCS.)

Table 4: the Republic of Palau, the Federal States of Micronesia, and the Marshall Islands

Potentially important plants for pollinators. Note that the following plants are deemed beneficial to pollinators through personal observations (e.g., pollinators are seen using plants) and/ or because they are closely related to plants known to be beneficial to pollinators. Very little to no experimental testing for pollinator attractiveness has occured for many of these plants.

Trees & Shrubs

Barringtonia asiatica (Wop, Bduul)
Calophyllum inophyllum (Lukwej, Jiro)
Cerbera manghas (Toto, Vasa, Emeridech)
Clerodendrum inerme (Wulej)
Guettarda speciosa (Utilomar, Belau)
Heritiera littoralis (Ebibech)
Hibiscus tiliaceus (Lo, Ermall)
Lumnitzera littorea (Kimeme, Ngemool, Mekekad)
Neisosperma oppositifolia (Kojbar, Uaoch)
Pisonia grandis (Kanal, Mesbesibech, Emoi)
Scaevola taccada (Konnat, Gorai)
Sida fallax (Kio)
Sophora tomentosa (Kille, Dudurs)
Terminalia catappa (Kotol, Miich)
Terminalia samoensis (Ekkon, Esemiich)
Thespesia populnea
Tournefortia argentea (Kiden)
Vitex trifolia (Utkonamnam)

Herbaceous Plants & Vines

Boerhavia repens (Dapijdeka)
Boerhavia tetrandra (Dapijdeka, Torura)
Canavalia cathartica (Marlap, Keldellel)
Canavalia rosea (Marlap)
Canavalia sericea (Marlap)
Portulaca lutea (Aturi, Pokea, Patapata)
Sesuvium portulacastrum
Tribulus cistoides (Caltrops)
Vigna marina (Markinenjojo, Keldellel)
Wollastonia biflora (Marjaj)

Non-Native Cover Crops

Crotalaria juncea (Sunn hemp)
Fagopyrum esculentum (Buckwheat)
Melilotus spp. (Sweetclover)

Figure 20 Potential pollinator plants in Republic of Palau, the Federal States of Micronesia, and the Marshall Islands. Top row, left to right: *Boerhavia repens, Hibiscus tiliaceus,* and *Sesuvium portulacastrum.* Bottom row, left to right: *Sida fallax, Thespesia populnea,* and *Tournefortia argentea.*

(Photographs by Gregory Koob, Hawaii NRCS.)

Table 5: Multipurpose Agroforestry Species

Examples of multipurpose agroforestry species which may benefit pollinators. Note that species may not be native to all locations. Contact a Plant Materials Specialist for local suitability and/ or invasive potential.

Acacia koa (Koa)
Acacia koaia (Koaia)
Adonidia merrillii (Manila palm)
Albizia lebbeck (Albizia, Siris tree)
Albizia saman (Monkeypod)
Alphitonia zizyphoides (Hoop pine)
Azadarichta indica (Neem)
Bruguiera gymnorrhiza (Oriental mangrove)
Cajanus cajan (Pigeon pea)
Calliandra calothyrsus (Calliandra)
Calophyllum inophyllum (Portia tree)
Carica papaya (Papaya)
Cassia fistula
Cassia javanica
Cassia spectabilis (Cassia)
Citrus spp. (Citrus)
Cocos nucifera (Coconut)
Delonix regia
Elaeocarpus joga (Yoga, Blue marble tree)
Eucalyptus citriodora (Lemon-scented gum)
Eucalyptus crebra (Narrowleaf red ironbark)
Eucalyptus deglupta (Mindanao gum)
Eucalyptus saligna (Flooded gum)
Eucalyptus tereticornis (Forest red gum)
Gliricidia sepium (Madre de cacao)
Litchi sinensis (Lychee)
Mangifera indica (Mango)
Moringa oleifera
Pimenta dioica (Allspice)
Pritchardia spp. (Palm)
Rhizophora spp. (Red mangrove)
Senna siamea
Sesbania sesban (Sesban)
Tamarindus indica (Tamarind)

Figure 21 Potential Multipurpose Agroforestry Species of plants which may benefit pollinators. Clockwise from top left: *Mangifer indica, Acacia koa, Acacia koaia,* and *Moringa oleifera.*

(Photographs by Gregory Koob, Hawaii NRCS.)

Appendix J: Additional Resources

Agroforestry Guides for Pacific Islands

http://agroforestry.org/free-publications/agroforestry-guides
Offers free resources in tropical Pacific Island agroforestry, for extension agents and practitioners.

Butterfly Society of Hawaii

http://butterflysocietyofhawaii.org/
The Butterfly Society of Hawaii is dedicated to creating and expanding the network of butterfly habitats in Hawaii and to increasing awareness of butterflies' ecological importance and inspirational beauty.

Hawaiian Native Plant Propagation Database

http://www.ctahr.hawaii.edu/hawnprop/
This is a website hosted by the College of Tropical Agriculture and Human Resources at University of Hawaii at Mãnoa. It provides information on propagation techniques for indigenous and endemic plants. You can browse by scientific or common name.

Hawaii Beekeepers Association

http://www.hawaiibeekeepers.org/
The Hawaii Beekeepers Association's mission is to assist and educate beekeepers, to maintain beekeeper's individual rights, to encourage beekeeping as a hobby and an industry, to promote natural beekeeping methods, and to create a positive public image of beekeeping and bees.

Native Plants Hawaii

http://nativeplants.hawaii.edu/index/
NPH is a comprehensive and searchable knowledgebase that seeks to promote the understanding and use of native Hawaiian plants.

Pacific Islands Vegetative Guide

http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/hipmstn14436.pdf
The Pacific Islands Vegetative Guide is produced by the USDA Natural Resources Conservation Service Plant Materials Center in Hawaii. The guide is regularly updated and gives specifications for using plants for certain NRCS conservation practices.

The Xerces Society for Invertebrate Conservation

http://www.xerces.org/
The Xerces Society is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. The Society has been at the forefront of invertebrate protection worldwide, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs.

United States Department of Agriculture – Natural Resources Conservation Service – Pacific Islands Area

http://www.nrcs.usda.gov/wps/portal/nrcs/site/pia/home/

The NRCS partners with Conservation Districts and others to provide technical and some cost-share assistance to private farmers. Their main goal is to protect, enhance, and preserve our soil, water, air, plants, and animals using sound science and expertise.

University of Hawaii, College of Tropical Agriculture and Human Resources (CTAHR) Cooperative Extension Service

http://www.ctahr.hawaii.edu/Site/Extprograms.aspx

CTAHR Cooperative Extension Service is the third major component of land grant universities. It is a partnership between federal, state, and local governments and has responsibility for providing science-based information and educational programs in agriculture, natural resources, and human resources.

University of Hawaii Honeybee Project

http://www.uhbeeproject.com/

The UH Honeybee Project is interested in developing practical treatment options for local beekeepers and establishing a sound research program that focuses on maintenance and improvement of the Hawaiian honeybees.

U.S. Fish & Wildlife Service Pacific Islands

http://www.fws.gov/pacificislands/

The Pacific Islands Fish and Wildlife Office is an Ecological Services office headquartered in Honolulu. The office is divided into three major sections: Endangered Species, Habitat Conservation, and Invasive Species/ Marianas Terrestrial. Employees use the best available science and sound managerial techniques to further the Service's mission to conserve, protect, and enhance wildlife and their habitats for the continuing benefit of the American people.

Western IPM Center

http://www.westernipm.org/

The Western Integrated Pest Management Center is one of four regional centers funded by the USDA to promote IPM practices. It serves as the hub of a multi-state partnership and a communication network linking a diverse audience that includes researchers, growers, extension educators, commodity organizations, regulators, environmental groups, pest control professionals, government agencies, and others. From its office, headquartered at University of California, Davis, the Western IPM Center serves 14 Western states and territories stretching from the Northern Mariana Islands to Colorado.

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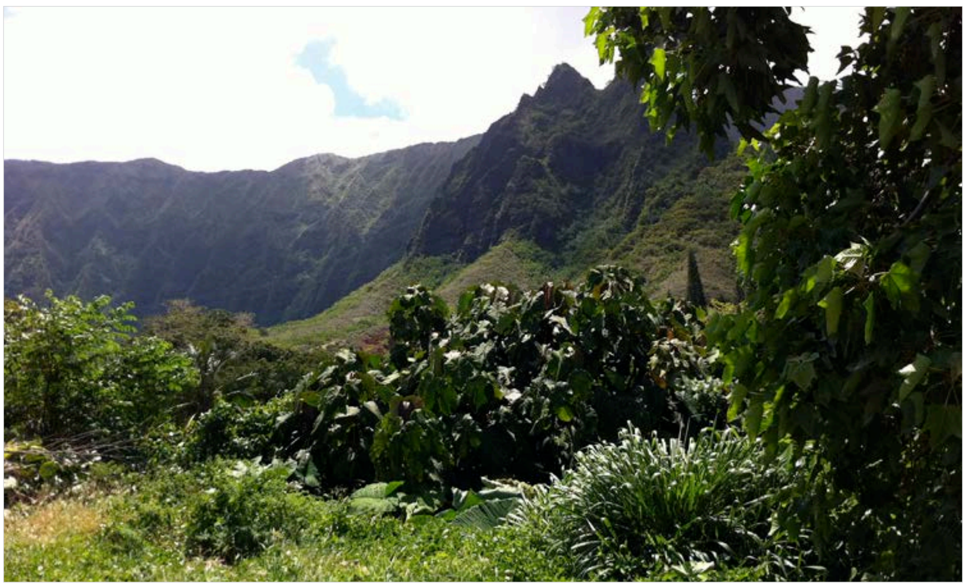
Figure 22 The majority of cropping systems in the Pacific Islands Area are multi-story agroforestry systems used by families for subsistence or for local markets. Incorporating plants that provide high quality food and nesting resources for pollinator populations can help farmers access pollination for their crops as well as attract other beneficial insects (predators and parasitoids) that could aid in pest management.



(Photograph by Jolie Goldenetz-Dollar, American Samoa Community College.)