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Modification of a Community Garden to Attract Native Bee Pollinators in Urban San Luis Obispo, California

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Abstract

Gardens have become increasingly important places for growing nutritional food, for conserving biodiversity, for biological and ecological research and education, and for community gathering. Gardens can also be designed with the goal of attracting specific wildlife, like birds and butterflies, but pollinators, like bees, can also be drawn to specially planned and modified gardens. A community garden in San Luis Obispo, California provided the setting for modification with the goal of attracting native bee pollinators by planting known bee-attractive plants. The local gardeners participated in a survey questionnaire and focused interviews to provide their input and interest in such a project. Presentations on our work with native bees in urban environments and gardening to attract bees were also given to interested gardeners. Work of this type also benefited from a lead gardener who managed donated bee plants and kept up momentum of the project. Modification of the garden and monitoring of native bees started in 2007 and continued through the growing season of 2009. Diversity of collected and observed native bees has increased each year since 2007. To date, 40 species in 17 genera of mostly native bees has been recorded from the garden, and this number is expected to increase through time.

Keywords

Native bees; urban gardening; community gardens; pollination; urban ecosystems; environmental education; bee pollinators.

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INTRODUCTION

In recent years the popularity of gardening has increased. More people are growing their own food as a means of increasing personal access to more affordable, better-tasting, and healthier produce (Marsh 1998; Ferris et al. 2001; Lawson 2005; NGA 2009; MacVean 2009). In 2008, 36 million households grew vegetables, fruits, and herbs in residential gardens; this number is expected to grow 19% in 2009 (NGA 2009). Community gardens are an ever-increasing means of providing sustenance when lacking private access to land (Lawson 2005; MacVean 2009). An estimated one million households utilize community garden plots; an additional five million households have expressed interest in constructing local community plots (NGA 2009).

The benefits of gardens range from recreation to community activism to conservation of biodiversity (Martin and Mardsen 1999; Lawson 2005; Hunter and Hunter 2008; Tallamy 2009). Gardens, especially in urban areas where green spaces are becoming fewer and far between, can provide places where one can get back to nature and observe ecological processes and natural systems (Lawson 2005; Flores 2006). School gardens are also becoming more commonplace, and states like California have developed programs to encourage them (Lawson 2005). These then become places where children can learn about where their food comes from, how it comes to be there by learning about ecology and pollination, and learning about general nutrition (Flores 2006). Gardens also become venues for environmental education of local residents, places for biological and ecological research, and can improve neighborhoods by bringing people together and providing a sense of community (Martin and Mardsen 1999; Armstrong 2000; Lawson 2005; Matteson et al. 2008).

Until recently, little scientific study was given to the ecology of urban areas (Niemela 1999; Collins et al. 2000). Urban areas, in green spaces, gardens, and parks, can provide islands of habitat for native fauna, including small mammals, birds, and especially invertebrates (Frankie and Ehler 1978; Savard et al. 2000; Fetridge et al. 2008; Tallamy 2009). Increasingly, people are taking an interest in conserving native species by practicing habitat gardening for wildlife (Owen 1991; the Xerces Society 1998; Buchanan 1999; Frey 2001; Grissell 2001; Tait 2006; Frey 2009). With careful planning, urban residents can attract a large diversity of native species to their gardens (Owen 1991; Tommasi et al. 2004; Tait 2006; Fetridge et al. 2008; Matteson et al. 2008; Tallamy 2009), and thus can contribute to conservation of local fauna, especially when utilizing native plant species (Frey 2001; Grissell 2001; McIntyre and Hostetler 2001; McKinney 2002; Lowry 2007).

We propose that urban areas, with their diverse floral resources, can simultaneously provide food and habitat for a diversity of native bees, which are important garden visitors. Gardens can be designed and managed to successfully attract native bee species that will not only forage for pollen and nectar from flowers, but will also find spaces to nest, either in the ground or in existing cavities (Fetridge et al. 2008; Frankie et al. 2005, 2009a). In California there are over 1,600 native bee species (R.W. Thorp Pers. Comm.), and almost 250 bee species (~15%) have been found to date in surveyed urban areas throughout the state (Frankie et al. 2009a). Further, existing gardens have the potential to be modified to become more pollinator-friendly. We tested this proposal in a community garden at Emerson Park in the city of San Luis Obispo, San Luis Obispo Co., California.

Our goal at Emerson Park was to diversify existing floral resources to make the garden more attractive to native bee species. We also wanted to record gardeners' responses to the modifications and assess their interest in learning how to garden for bees. We brought known bee attractive plants to the garden starting in 2007 and monitored them continually for growth, flowering, and attracted bees. We also monitored responses from local gardeners through personal communication, a questionnaire measuring interest in conserving native bee pollinators, and a focused interview.

MATERIALS AND METHODS

Site Description

The Emerson Park Community Garden is located in San Luis Obispo, San Luis Obispo Co., California, which is almost halfway between San Francisco and Los Angeles. San Luis Obispo is slightly inland from the coast, but is still subject to coastal influences. The garden is located on the corner of Nipomo and Pismo Streets on land owned and managed by the Parks and Recreation Department of San Luis Obispo. The entire block is known as Emerson Park, which also includes an outside gym, playground, basketball court, large grassy field, and a Parks and Recreation building. The park is located in a residential neighborhood less than 2.4 km NE of Laguna Lake Park and Natural Reserve and 0.8 km E of Cerro San Luis Natural Reserve. The ~4,000 m^2 garden includes 29 plots which are managed and maintained by members of the local community (see Figure 1 for a picture of one gardener's plot).

The community garden began in 1997-98 on land that previously housed the Emerson School K-3. The school district managed it until the school closed in the early 1980's. In 1994 the city of San Luis Obispo purchased the property and began construction on the current Parks and Recreation building in 1996. The land lay fallow between when the school closed and when the Parks and Recreation building was constructed. The garden was constructed in the exact location of the old school building. Although the garden started in 1997, by 2002 there were still only a small number of plots in use. From 2003 onward the garden received care and management of all the current 29 plots.

The garden plots are a combination of 17 large (~4.5m x 6m) and 12 small (~2m x 3m) plots. Prior to our addition of bee attracting plants the garden was utilized to grow vegetables, herbs, and a few ornamental flowers. In the early garden years (1997-2002) only a few plots were managed and most remained weedy for several years. Since 2003 the garden has been intensively managed and all plots have been in use. There were few weedy areas, and gardeners must work to keep their plots weed free to secure them for the entire year, or else they are given to someone else. As of the end of 2008, the three community gardens of San Luis Obispo had a waiting list of over 120 people.

Typical vegetables planted by most gardeners included tomatoes, lettuce, green beans, collared greens, Jerusalem artichokes, and corn. Ornamental flowers and herbs planted include rosemary, lavender, thyme, daffodils, nasturtium, sunflowers (*Helianthus annuus* vars.), Mexican sunflower, hollyhocks, and cosmos (Table 1). It is important to note that these plants were very sparse (~1 or 2 plants of each), and patch sizes were small (<0.5m^2), except sunflowers (*Helianthus annuus*), Mexican sunflower (*Tithonia rotundifolia*), and cosmos (*Cosmos bipinnatus*). One of the most attractive summer blooming flowers, cosmos, had been planted since the garden started in 1997.

Figure 1. Main garden cooperator Barbara Smith's plot showing vegetables growing towards the back and patches of bee attracting plants, like *Penstemon heterophyllus* and *Coreopsis grandiflora*, growing towards the front of her plot

Garden Modification

At the onset of the project in early-mid 2007, an assessment was made of existing plants in the garden that were known to attract bees (see lists in Frankie et al. 2005; http://nature.berkeley.edu/urbanbeegardens). Purpose of assessment was to determine the kinds of extant bees and if any plants could be used immediately to monitor bees, using the frequency count method described in Frankie et al. (2005). The evaluation indicated that only a few plants could be used to record bee diversity and abundance (Table 1). Of the pre-existing plants, the following are known to be consistently attractive to some native bees: rosemary (*Rosmarinus* sp.), lavender (*Lavandula* sp.), sunflowers (*Helianthus* spp.), Mexican sunflower (*Tithonia rotundifolia*), and cosmos (*Cosmos bipinnatus*). The two main criteria used to judge a plant's suitability were patch size and flower vigor. Plants also had to have consistent bee visitors, even if the numbers of visits were low. The garden was again surveyed in late summer and early fall of 2007 and records were made of additional floral resources in bloom and types of bees visiting them.

Table 1. Existing and added plant species to Emerson Park Garden from 2007-2009.
Early Spr. = March-April, Lt. Spr.= April-May, Sum.=June-Aug., Fall=Sept.-Oct. cvs=cultivars
Floral Resource: P=Pollen, N=Nectar

Scientific Name and Family	Flower Phenology	Floral Resource	Existing Plants	Added 2007	Added 2008	Added 2009
APIACEAE						
Foeniculum vulgare	Sum.-Fall	P/N	X			
ASTERACEAE						
Achillea millefolium[1]	Sum.	P	X			X
Aster chilensis cvs.[1]	Sum.-Fall	P/N		X		
Aster x *frikartii*	Sum.-Fall	P/N		X	X	
Bidens ferulifolia	Spr.-Fall	P/N		X		
Calendula sp.	Sum.-Fall	P/N	X			
Centarea cineraria	Sum.	P/N	X			
Coreopsis grandiflora cvs.	Sum.-Fall	P/N		X	X	X
Coreopsis lanceolata	Sum.	P/N		X		
Cosmos bipinnatus[2]	Sum.-Fall	P/N	X			
Cosmos sulphureus	Sum.-Fall	P/N		X		
Echinacea purpurea	Sum.-Fall	P/N	X			
Encelia californica[1]	Early Spr.-Sum.	P/N			X	
Erigeron glaucus cvs.[1]	Lt. Spr.-Sum., Oct.	P/N		X	X	X
Erigeron karvinskianus	Lt. Spr.-Sum.	P/N	X			
Gaillardia x *grandiflora* cvs.	Lt. Spr.-Fall	P/N	X	X		X
Gaillardia 'Oranges & Lemons'	Lt. Spr.-Fall	P/N			X	X
Grindelia hirsutula[1]	Sum.-Fall	P/N		X	X	
Grindelia stricta[1]	Sum.	P/N			X	
Helianthus annuus[1,2]	Sum.-Fall	P/N	X			X
Helenium 'Mardi Gras'	Sum.-Fall	P/N			X	X
Helianthus tuberosus[2]	Sum.-Fall	P/N	X			
Leucanthemum x *superbum*	Sum.	P/N	X			

Table 1. Continued.

Scientific Name and Family	Flower Phenology	Floral Resource	Existing Plants	Added 2007	Added 2008	Added 2009
ASTERACEAE – CON'T						
Picris echioides	Lt. Spr.-Sum.	P/N	X			
Rudbeckia 'Gloriousa Daisy'	Died	P/N		X		
Rudbeckia hirta	Sum.	P/N	X		X	X
Solidago californica[1]	Sum.-Fall	P/N		X	X	
Tithonia rotundifolia[2]	Lt. Spr.-Sum	P/N	X			
BORAGINACEAE						
Borago officinalis	Sum.	N	X			
Echium candicans	Early Spr.-Lt.-Spr.	P/N	X			
BRASSICACEAE						
Lobularia maritima	Lt. Spr.-Fall	P	X			
CONVOLVULACEAE						
Ipomoea tricolor	Sum.	N	X			
CUCURBITACEAE						
Cucurbita sp.	Sum.	P/N	X			
DIPSACACEAE						
Scabiosa atropurpurea	Sum.-Fall	P/N		X		
Scabiosa columbaria 'Black Knight'	Lt. Spr.-Sum.	P/N		X		
FABACEAE						
Psoralea pinnata	Early Spr.-Lt. Spr.	N			X	
HYDROPHYLLACEAE						
Phacelia californica[1]	Early Spr.-Sum.	P/N		X		
Phacelia tanacetifolia[1]	Lt. Spr.	P/N			X	X
LAMIACEAE						
Agastache 'Blue Fortune'	Sum.	N			X	
Calamintha nepetoides	Sum.-Fall	N				X
Caryopteris 'Hint of Gold'	Sum.-Fall	P/N				X
Caryopteris x *clandonensis* 'Summer Sorbet'	Sum.-Fall	P/N				X
Lavandula dentata var. *candicans*	Lt. Spr.-Fall	N			X	
Lavandula sp.[2]	Lt. Spr.-Fall	N	X			
Mentha sp.	Sum.-Fall	N	X			
Nepeta x *faassenii*	Lt. Spr.-Sum.	N		X		
Origanum sp.	Sum.-Fall	N	X			
Perovskia atriplicifolia	Sum.-Fall	N		X	X	
Rosmarinus sp.	Fall-Early Spr.	N	X			
Rosmarinus officinalis 'De Force'	Early Spr.-Sum.	N		X		

Table 1. Continued.

Scientific Name and Family	Flower Phenology	Floral Resource	Existing Plants	Added 2007	Added 2008	Added 2009
LAMIACEAE – CON'T						
Salvia brandegeei[1]	Early Spr., Sum.-Fall	N			X	
Salvia chamaedryoides	Sum.-Fall	N	X			X
Salvia 'Dara's Choice'[1]	Lt. Spr.-Sum.	N			X	X
Salvia microphylla 'Hot Lips'	Sum.-Fall	N	X			
Salvia 'Indigo Spires'	Sum.-Fall	N		X	X	
Salvia leucantha	Fall	N	X			
Salvia uliginosa	Sum.-Fall	P/N		X		
Stachys byzantina	Sum.	N	X			
Teucrium chamaedrys	Sum.	N	?			X
Thymus sp.	Sum.-Fall	N	X			
MALVACEAE						
Alcea rosea	Sum.-Fall	N	X			
PAPAVERACEAE						
Eschscholzia californica[1]	Early Spr.-Lt. Spr.	P			X	X
POLYGONACEAE						
Eriogonum grande var. *rubescens*[1]	Sum.-Fall	N				X
ROSACEAE						
Fragaria chiloensis[1]	Early Spr.-Lt. Spr.	P/N	X			
Rubus discolor	Lt. Spr.-Sum.	P/N	X			
SCROPHULARIACEAE						
Linaria purpurea	Sum.-Fall	N		X	X	X
Penstemon heterophyllus cvs.[1]	Lt. Spr.-Sum., Oct.	N		X	X	X
VERBENACEAE						
Aloysia triphylla	Sum.	N	X			
Vitex agnus-castus	Sum.-Fall	P/N				X
Species totals: 69			**32**	**21**	**21**	**20**

[1] Plants native to California

[2] Existing plants with large enough patches for sampling in 2007

In spring of 2007 we began bringing bee attractive plants, including natives, non-natives, annuals, and perennials, to Emerson Community Garden. This site was added in 2007 to a California statewide survey currently being conducted by our labs at University of California, Berkeley and Davis (Frankie et al. 2009a). Previously, only the California Polytechnic State University Arboretum (Cal Poly) and a few residential gardens were monitored for native bees in San Luis Obispo, but this mainly provided spring/early summer information as it contained mostly California native plants, which have their greatest flowering at this time of year. Emerson Garden was selected as an additional site because it provided summer/fall opportunities for monitoring and sampling bees on non-native plant species (as well as a few

natives). The statewide survey monitors 31 target plant types at 9 urban sites distributed widely from northern to southern California (Frankie et al. 2009a).

Since spring of 2007 we have brought 41 plant types, including cultivars, hybrids, and varieties, of which 19 are on the "target" plant list for the statewide survey. The remaining plant species were planted to generally increase diversity of bee attractive plants to the garden (Table 1). Based on results from the statewide survey, we have found that the more diverse gardens, with respect to plant material, also have the most diverse bees visiting them (Frankie et al. 2009a,b). Our findings indicate that predictive relationships exist between certain bee groups and certain plant types, and that this information can then be used to plan gardens. For example, California poppy (*Eschscholzia californica*) can expect to attract bumble bees (*Bombus* spp.), honey bees (*Apis mellifera*), and at least three species of sweat bees (*Halictus* spp.) throughout the state.

Seasonality was also considered when planning the bee garden. Bees need sources of nectar and/or pollen during the season in which they are foraging and provisioning nests (Tommasi et al. 2004; Wojcik et al. 2008; Frey 2009). With this in mind we selected plants that would successively bloom throughout the year (March-October) to provide these resources. Prior to our plant additions most of Emerson's plants bloomed from early summer to fall, so we incorporated spring flowers that would provide resources to early season bees.

A total of ~345 individual plants were brought to the garden during 2007-2009 with a survival rate of ~90%. Most were planted by our main cooperator in the garden, Barbara Smith, with our help and direction (Table 1). Plants were grouped in patches (~1.0m x 1.5m) in plots that had enough space to accommodate them. Large patches, rather than individual plants, are important because they offer more resources for bees (Isaacs et al. 2009). This allows them to forage longer in one place, which also allows for opportunity to observe and monitor them more easily. Gardeners with larger plots were more likely and willing to accept donations of bee plants, whereas some gardeners with smaller plots did not have extra room to spare, as the bee plants would have taken away from their limited space for growing vegetables. To date, 19 of 29 plots have welcomed the addition of bee plants.

Plant Additions from 2007-2009

After initial assessment in mid 2007 we began bringing known bee attractive plants to the garden and incorporating them into plots where space was available. Some of the first plants brought to the garden in June 2007 included: *Linaria purpurea*, *Penstemon heterophyllus*, *Coreopsis grandiflora* cultivars, *Aster chilensis* 'Purple Haze', *Aster* x *frikartii*, *Bidens ferulifolia*, and *Perovskia atriplicifolia* (see Table 1 for complete list of plants). *Gaillardia* x *grandiflora* was already in the garden, but more plants were incorporated to increase patch size. Plants were sourced from local nurseries in the San Francisco Bay Area and San Luis Obispo, and were in either four-inch pots or one-gallon containers. A total of 129 individual plants representing 20 different types, including hybrids, cultivars, and varieties, were brought to the garden in 2007. Many of the plants, 13 of 20 types, were on the target plant list (Frankie et al. 2009a). Observations were made on flowering condition as they began to mature, as well as types of bees that began to visit them.

In 2008 we brought plants to the garden in January and continued through October. To diversify floral resources for early season bees we incorporated native spring flowering plants such as: *Encelia californica, Eschscholzia californica, Phacelia tanacetifolia*, and *Salvia brandegeei* (Table 1). We also added more plants of existing species to enhance patches or to replace plants that had not survived. Ten of

18 plant types introduced to the garden in 2008 were on the target list (Frankie et al. 2009a). In total ~125 individual plants were brought and planted in the garden in 2008.

In 2009, 17 plant types (~105 individual plants) were planted in the garden beginning in early spring, and most were incorporated into previous patches to increase patch size. Almost all of these had already been added to the garden previously, but there were a few new additions such as *Teucrium chamaedrys, Caryopteris clandonensis* 'Summer Sorbet', and *Vitex agnus-castus* (Table 1). Ten of 17 plant types brought to the garden were on the target list.

Bee Monitoring and Data Collection from 2007-2009

In Emerson Park, bee data was collected through "frequency counts" as well as aerial netting, which was consistent with our methods for the statewide survey. Frequency counts are conducted by observing a patch of flowers, approximately 1.0-1.5m^2, then counting the number of bees that make visits to the reproductive parts of the flowers within a period of three minutes (see methodology in Frankie et al. 2005, 2009a). Bees are identified to genera, and whenever possible to species, and counted as they enter and visit flowers within a given patch. After numerous replicated counts, usually on different patches over one or more growing seasons, a relative measure of attraction is established. We also record type of resource bees receive from the flower, either nectar, pollen, or both. Once counts are completed, collections of representative bee species are made. Collections are also made from non-target flowers that attract bees. Bees are transported to our lab at University of California, Berkeley, curated, labeled, and brought to R. Thorp at the University of California, Davis for identification.

Bee observations in the Emerson Garden began in late July of 2007, and frequency counts were performed on two plants at that time, *Cosmos bipinnatus* and *Helianthus annuus*, both of which were found in large enough patches for monitoring. Observations continued monthly through November of 2007, and frequency counts were performed again on the same plants in August and October. We chose to make limited collections of bees in 2007 to avoid depleting populations of bees that may have begun colonizing the garden.

In 2008 the garden was sampled for bees beginning in July and continued monthly through October. Bee collections and frequency counts (on nine plant types) began on plants in full flower and in large enough patches (1.0-1.5m^2), and included many that had been incorporated into the garden in either 2007 or earlier in 2008. Native spring flowers of 2008 had not yet developed to the point where bee counts or collections could be made. The garden was sampled 13 times between the dates of 21 July and 14 October.

In 2009 the garden was surveyed for bees (collections and frequency counts) beginning in May when many spring plants were in flower. Poor weather conditions contributed to the garden not being sampled earlier in the season. The garden was monitored at least twice monthly through the end of the growing season (late October).

Educational Outreach & Survey of Gardeners

During our visits to monitor plants and bees we regularly provided information to gardeners about conserving native bee pollinators and how to garden for them. We found that many people were unfamiliar with the different types of bees that occur in their gardens, and we were often able to show them diverse bees visiting their own flowers. One of us (GWF) gave an informal talk to about 10 gardeners in late August of 2007, which provided an overview of native bee ecology and our work to date on the California statewide survey.

Our main cooperator, Barbara Smith, took a strong interest in learning about bee gardening. She spread her knowledge to other curious gardeners at their monthly potluck dinners and encouraged them to donate parts of their plots to bee attracting flowers. She also directed them to our website (http://nature.berkeley.edu/urbanbeegardens), which is constantly being updated with new information about bees and preferred host plants.

To evaluate the environmental education aspect of our garden modification we distributed a questionnaire survey to all members of the community garden in January/February 2009 (see Appendix A). Our goal was to find out how much interest gardeners had in learning about native bees and if they wanted to learn more about gardening to attract them. A pre-test was done prior to distribution. The survey was sent by email to those who had access to computers and internet, with hard copies sent to the rest (see Appendix A). It included questions about how much time gardeners work in their plots, their main purpose for gardening, were they familiar with our project, and if they had donated space in their plots for bee plants. We also asked if they had visited our website, if they had noticed an increase in amount and diversity of bees in the garden, and if they would like to hear a presentation that would explain more about bees in their garden and how to attract and conserve them. All responses were received by the end of February.

Based on responses from the gardeners we followed up with a presentation in early March 2009 and asked the 13 gardeners present to participate in a focused interview in order to assess the presented information. We fielded questions from the gardeners that ranged from how bees find flowers to the cues that tell bees when to emerge from their nests. We then asked them a series of questions to find out if anyone had noticed an increase in bee activity in the garden; if they would like to join us on a walk through the garden to identify bees; if they would like signage in the garden to document our project; and if they thought the garden should have a mission statement that would acknowledge the project and newly added goals of the garden.

RESULTS

Existing Garden Plants: Attraction to Bees

Only five plant types met the selection criteria in the first garden assessment for plant and bee monitoring (see Table 1). Four of these, *Cosmos bipinnatus*, *Helianthus annuus*, *H. tuberosa*, and *Tithonia rotundifolia* had medium-large patches of vigorous flowers and were commonly (> 5 visits per 3 min. observation) attracting *Melissodes robustior* and honey bees on occasion (<3 visits per 3 min. observation). The fifth plant, *Lavandula* species, attracted honey bees and rarely (~1 visit per 4-5 observations) *Anthophora urbana* (Table 1). All other potentially attractive bee plants were either in very small patches (< 0.5m^2), were small single specimens, or had poor flower quality. A few of these such as *Borago officinalis*, *Echinacea purpurea*, and oregano attracted honey bees on occasion. *Mentha* species attracted some honey bees and very few small bees, such as halictids and megachilids.

Other flowers that received visits by native bees were *Cosmos sulphureus*, *Salvia leucantha*, and *Gaillardia* x *grandiflora* cvs, though these were not found in large enough patch sizes or with enough vigorous flowering for monitoring. Bees observed visiting these flowers included the common *Melissodes robustior* and honey bee, as well as occasional to rare visits by *Anthophora urbana*, *Xylocopa tabaniformis orpifex*, and *Halictus* spp. Overall, the community garden of 29 plots in 2007 was considered largely unattractive to diverse bee species, especially natives, and this in turn was related to a lack of diverse and abundant floral resources (Frankie et al. 2005, 2009a).

Plant Additions from 2007-2009: Attraction to Bees

The following added plants flowered in the first year, but were slightly attractive to honey bees only: *Bidens ferulifolia, Aster chilensis, Salvia* 'Indigo Spires', *Grindelia hirsutula, and Perovskia atriplicifolia.* However, *Solidago californica* was attractive to small bees, such as halictids, and rarely to honey bees. *Linaria purpurea* also began flowering the first year and was commonly observed drawing in *Anthophora urbana* and honey bees. *Salvia uliginosa* also flowered and attracted *Melissodes robustior, Xylocopa tabaniformis orpifex*, and honey bees.

In 2008 plants that received increased and measurable visitation by diverse native bees included *Bidens ferulifolia*, *Gaillardia* x *grandiflora*, *Salvia uliginosa*, *Linaria purpurea* and *Aster* x *frikartii*. For example, nine species of native bees were collected from *Aster* x *frikartii*, and five species were collected from *Gaillardia* x *grandiflora*. Other plants in the garden received increased levels of visitation, like *Cosmos bipinnatus* and *Lavandula* spp., but these had not been added to the garden because they were already established.

Two native spring flowering plants that attracted new bees to the garden in 2009 were *Phacelia tanacetifolia* and *Salvia brandegeei*. Other plants found to be attractive to spring bees included *Coreopsis grandiflora, Grindelia hirsutula, Salvia uliginosa, Bidens ferulifolia*, and *Lavandula* spp. These flowers had been planted previously and are now established.

Bee Monitoring from 2007-2009

Numbers of bee taxa collected from original and added plant types from 2007 through 2009 are presented in Table 2. The most abundant bee in the garden in July was a long-horned bee (*Melissodes robustior*), which was frequently observed on *Cosmos bipinnatus, Helianthus annuus,* and *Tithonia rotundifolia*. Other native bees observed in the garden at this time were sweat bees (*Halictus* spp.), leaf cutting bees (*Megachile* spp.), and mining bees (*Anthophora* spp.), but all of these were rare and much less abundant than *M. robustior* and were found on *Lavandula* sp. and *Thymus* sp. Honey bees were also common in the garden and observed on *Echinacea purpurea, Lavandula* spp., *Borago officinalis*, and *Mentha* sp. Overall, bee diversity and abundance in the garden was low, with the exception of *M. robustior* and *A. mellifera*. The only new native bees observed later in the season were a very few carpenter bees (*Xylocopa* sp.), which were seen foraging on *Salvia leucantha, S. uliginosa*, and *S.* 'Indigo Spires'. *Melissodes robustior* remained the most common visitor in the garden until November (Table 2).

In 2008 we collected 21 bee species on 12 original and 10 added plant types from 2007/2008. One species, *Xylocopa tabaniformis orpifex,* was not collected, but was recorded, because it could be easily identified to species by all observers. Addition of this bee brought the total number of species to 22. Some bee species such as *Anthophora urbana, Apis mellifera* (honey bee), *Melissodes robustior*, and *Halictus tripartitus* had been collected/observed during the assessment phase in spring 2007, however, the vast majority of collected bee species in 2008 were considered new records to the garden. These four bee species are among the most common bees found throughout the state of California (Frankie et al. 2009a).

The most abundant bees in the garden, based on collections in 2008, were a long-horned bee (*Melissodes robustior*) and a sweat bee (*Halictus tripartitus*) (Table 2). *Melissodes robustior* was collected from 10 different plant species, seven of which were target plants, and *Halictus tripartitus* was collected on 14 plant species, nine of which were target plants. These two species along with a miner bee, *Anthophora urbana*, were present and collected each month from July to October. The honey bee, *Apis mellifera*, was also abundant in the garden and was a common and main visitor on many plants (Table 3), but not always collected, as it was easily identified and recorded.

Other bees collected and observed represent a diverse assortment of bees and include three species of cuckoo bees (*Triepeolus heururus*, *Xeromelecta californica*, and *Sphecodes* sp.) (Table 2). Cuckoo bees parasitize nests of other bees and thus rely on their hosts gathered floral resources for reproduction, as they do not build or provision their own nests. The squash bee, *Peponapis pruinosa*, a specialist on plants in the Cucurbitaceae family, was also present in the garden and frequently visited squash and pumpkin flowers.

Table 2. Number of bee taxa collected from added and original plant types, 2007 – 2009. The first number represents total number of bees collected and the numbers in parenthesis reflect the number of bees collected from added and original plants, respectively. Greater sampling effort in 2008-2009 compared to 2007.

Bee Species	2007	2008	2009
ANDRENIDAE			
Andrena cerasifolii			1 (0,1)
Andrena anguistitarsata			1 (1,0)
APIDAE			
Anthophora curta			7 (1,0)
Anthophora urbana	4 (0,1)	12 (5,2)	3 (2,1)
Apis mellifera †	Several Observed	2 (0,2)	4 (4,0)
Bombus crotchii			1 (1,0)
Bombus melanopygus			1 (1,0)
Bombus vosnesenskii		1 (0,1)	6 (6,0)
Ceratina acantha		7 (2,1)	6 (3,2)
Ceratina nanula		1 (0,1)	
Melissodes robustior	7 (0,2)	33 (6,4)	14 (5,0)
Peponapis pruinosa		4 (0,2)	
Triepeolus heururus *		1 (0,1)	
Xeromelecta californica *		1 (0,0)	1 (1,0)
Xylocopa tabaniformis orpifex			4 (2,1)
COLLETIDAE			
Colletes hyalinus gaudialis			1 (1,0)
Hylaeus mesillae		4 (2,2)	
Hylaeus polifolii			3 (1,0)
Hylaeus punctatus †		2 (1,0)	4 (1,0)
Hylaeus rudbeckiae		1 (1,0)	12 (6,0)
HALICTIDAE			
Halictus farinosus			1 (1,0)
Halictus ligatus		2 (0,0)	
Halictus tripartitus	1 (0,1)	43 (8,6)	13 (4,1)
Lasioglossum incompletum			3 (2,0)
Lasioglossum sisymbrii			2 (1,0)
Lasioglossum tegulariforme		1 (1,0)	
Lasioglossum (Dialictus) sp. 3			1 (1,0)
Lasioglossum (Evylaeus) sp. 3			1 (1,0)
Sphecodes sp. *		1 (0,1)	

Table 2. Continued

Bee Species	2007	2008	2009
MEGACHILIDAE			
Megachile angelarum	2 (0,1)		2 (1,1)
Megachile concinna †		1 (1,0)	2 (2,0)
Megachile fidelis			1 (1,0)
Megachile frugalis			1 (1,0)
Megachile gentilis		1 (1,0)	
Megachile montivaga		2 (0,1)	2 (1,1)
Megachile perihirta		1 (0,1)	
Megachile rotundata †		5 (2,0)	2 (1,0)
Osmia californica			1 (1,0)
Osmia coloradensis			6 (3,0)
Osmia cyanella			1 (1,0)
Total species collected	**5**	**21**	**31**
Total genera collected	**5**	**13**	**14**

(0,0) = No Host Label; †Non-native bee species; *Cuckoo Bee;.
Total no. of species collected in garden = 40 (17 genera)

Our previous sampling in greater San Luis Obispo, through 2007, revealed a total of 58 species in the area. Sampling from the Emerson Park garden in 2008 added eight new species to the area total. Sampling in the Cal Poly Arboretum also added eight new species, bringing the new total for San Luis Obispo to 74 for 2008.

The total number of collected bee species in 2009 was 31 (Table 2); four were new records for the San Luis Obispo area. Of those, 19 were new records for the garden and were attracted to six original and 13 added plant types from 2007-2009. Further, in contrast to the host plant associations of 2008, a higher percentage of bee species were collected from added plant types, which had been continually diversifying the garden over three years.

The increase in bee species from 2008 to 2009 is most likely the result of adding new diverse plant types to the garden (Frankie et al. 2009a) along with increased sampling effort in 2008 and 2009 compared to 2007. New genera (5) were also added to the list, which is another indication of increasing bee diversity (Table 2). Examples of notable increases include two *Andrena* species and three *Osmia* species that were recorded for the first time. These two genera are characteristic spring bees and are known to appear as California gardens mature with bee-attractive flowering plants (Frankie et al. 2005; Wojcik et al. 2008; Hernandez et al. 2009; Frankie and Pawelek unpub.). Three apid species, *Anthophora curta* and two spring *Bombus* species were recorded for the first time in 2009. Prior to 2009, *Bombus* were extremely rare in the garden, although in the nearby arboretum of California Polytechnic State University *Bombus melanopygus* and *B. vosnesenskii* were common on native plant species. Finally, numbers of small bees in the genera *Hylaeus* and *Lasioglossum* increased noticeably in 2009. From the total of 31 collected bee species in 2009, 24 were collected from added plant types only; seven from original types. Of the 19 bee species recorded for the first time in 2009, 16 were collected from added plants only (Table 2).

Table 3. Numbers of bee species visiting original and added plants and the main bee groups that visit.

Original plant types[1]	Total number bee species collected/ counted[3]	Main bee groups[4]
Lavandula spp.	7	Hb, Aurb, Meg
Cosmos bipinnatus	4	Mel, Hb
Borago officinalis	4	Hb, Hal, B
Helianthus annuus[2]	3	Mel, Hb
Salvia 'Hot Lips'	3	Xylo, Hal, sb
Tithonia rotundifolia	3	Mel, Hb, Hal
Foeniculum vulgare	3	Hal, Hyl, Hb
Calendula sp.	2	Hal
Added plant types[1]		
Gaillardia x *grandiflora* cvs	11	Hb, Mel, sb
Salvia uliginosa	11	Hal, Xylo, Hb, B
Aster x *frikartii*	9	sb, Mel, Meg
Bidens ferulifolia	9	Mel, Hal, sb
Coreopsis grandiflora cvs	8	Mel, Osm, sb
Phacelia tanacetifolia[2]	7	B, sb, Hb
Solidago californica[2]	6	Hal, sb, Hb
Grindelia stricta[2]	5	Mel, Hb, Hal
Grindelia hirsutula[2]	4	Mel, Hal, sb
Linaria purpurea	4	Aurb, Meg, Hb

[1]Includes cultivars
[2]Plants native to California
[3]From aerial netting and frequency counts, 2007-2009
[4]Left to right: highest to lowest bee frequency on plant types.
Main Bee Group Codes: Aurb=*Anthophora urbana;* B=*Bombus*; Hal=*Halictus*; Hb=Honey bee; Hyl=*Hylaeus*; Meg=*Megachile*; Mel=*Melissodes*; Osm=*Osmia*; sb=small bee; Xylo=*Xylocopa*

Plants that received the highest diversity in bee visitation, from collections and frequency counts, are shown in Table 3. Eight of the added plant types were more attractive than the originals, that is, being visited by more bee species, except for *Lavandula* spp., which had the most diversity with seven species. In its first year of flowering, *Phacelia tanacetifolia,* which is known to attract a wide diversity of bees (Frankie et al. 2009a), was visited by seven species. Of the original plant types, *Foeniculum vulgare* and *Calendula* sp. are considered weedy, but are still attractive to a variety of small bees. Overall and consistently, most added plant types had noticeably higher bee species diversity than established original plants in the garden (Table 3).

The total number of bee species recorded in the garden since the modification began in 2007 stands at 40 species in 17 genera. Total numbers of bee taxa recorded to date in all of San Luis Obispo are 78 species in 30 genera, 5 families.

Survey Results

We received completed surveys from 18 gardeners, seven through email and 11 hard copies. Almost 95% (17 out of 18) wanted to hear a presentation on our work so we made another, more formal, presentation to all interested gardeners during the first week of March 2009. Half the gardeners had visited our website before receiving the survey and had found the information presented useful. Only two

of 18 people did not make their plot available to the bee plant project, and all but one liked the concept of adding selected flowers to attract native bee pollinators.

Only three people had noticed increased bee activity in the garden, although others said they just started to become aware after looking at our website. Everyone was in agreement that a walk through the garden with us would be helpful so that they could see and learn to identify some of the bees visiting their flowers. They also thought the idea of an educational sign and a new mission statement for the garden would be helpful in promoting it as a pollinator friendly vegetable garden. In July of 2009 the gardeners met and developed a mission statement that reflected their participation in our project. Their mission statement is as follows: "The Emerson Community Organic Gardeners in collaboration with Dr. Gordon Frankie at the University of California, Berkeley are participating in a native bee study by establishing native bee attractive plants and habitat to conserve and increase (or restore) native bees and other pollinators." They have also come to a consensus that they will not do any excessive tilling or use any pesticides or herbicides that may damage native bee populations in the garden. Several gardeners have started planting their own bee plants in their plots since hearing the presentation and visiting the website (B. Smith Pers. Comm.).

DISCUSSION

Design or modification of a garden to attract bees is possible if correct plants are chosen and managed throughout the growing season. Bee-attractive plant materials were incorporated in patches in the Emerson garden through time to provide seasonal resources of nectar and pollen. Increased diversity of plant materials added to the garden is believed to have contributed to increased diversity of native bee species observed and collected in the garden from 2007 to 2009.

Our findings from the statewide survey suggest that there are predictable relationships; that is, certain flowers will attract mostly the same types of bees no matter where they are found in the state (Frankie et al. 2009a,b). Thus, by adding more plants having predictable relationships, this should increase bee diversity and eventually abundance. Our 2009 bee-plant findings at Emerson provide support for this hypothesis. The general pattern of increasing plant diversity of known bee plants has allowed for early stage development of bee habitat gardening at Emerson (see relevant 15 year garden study by Owen 1991).

The number of bee species collected in the Emerson garden has increased each year since 2007, along with increased sampling effort, and we expect this number to further increase as the study continues in 2010 and beyond. It is probable that the most common bee species (*Melissodes robustior*, *Halictus tripartitus*, and *Anthophora urbana*) were already established in the garden because some of their host plants were found in the garden before modification. Honey bees came from outside the garden, as Emerson does not have any established colonies. Presence of cuckoo bees in the garden indicates that a food web is beginning to form and that more complex relationships are developing. The three species of cuckoo bees (Table 2) recorded in the garden are most likely associated with the three most common bees in the garden, but specific host records are not known for some of the species collected so only generalizations can be made (R.W. Thorp Pers. Comm.). The garden added 12 new species to our list of bees in San Luis Obispo, which is encouraging, because this site is located ~ 4.8 kilometers from our other study site at the Cal Poly Arboretum, which has a diverse inventory of flowering plants from California and other parts of the world.

The diversity of bee species could have been higher if we had used additional collecting methods such as pan traps (Wojcik et al. 2008; Hernandez 2009) and other interception devices. These methods, however, would not have provided floral host information for collected bees, which were needed to meet our goals.

The ongoing drought in California (2007 to present, http://www.water.ca.gov/drought/) may have also affected diversity and abundance levels of bees at Emerson garden as these conditions are believed to impact bee development and emergence. Less than optimal climatic conditions are known to cause some bee species to hold over in their nests for more than a year (R. Thorp and G. Frankie, unpub). Bee numbers are expected to increase when the drought breaks and conditions become more favorable for their reproduction and survival.

If bee-attracting plants in the garden are managed and encouraged each year, overall diversity and abundance of native bees is likely to continue to increase. We have observed this trend in our experimental bee garden in Berkeley, California (Wojcik et al. 2008; Hernandez et al. 2009), and in other gardens throughout the state, such as Descanso Gardens near Pasadena, and a cemetery garden in Sacramento. We increased the floral diversity at those sites, to varying degrees, continued monitoring bees for the last four years, and have seen a steady increase in the diversity of bees at each site (Frankie et al. 2009a).

In addition to the community garden in San Luis Obispo we have also created and modified other gardens in the state with the goal of attracting native bee pollinators. We have worked with school gardens in Marin and San Francisco Counties, home gardens in Ukiah (Mendocino Co.) and Soquel (Santa Cruz Co.), and the University of California Santa Cruz Arboretum (Frankie et al. 2009b). With the decline of managed honey bee populations due to colony collapse disorder (CCD), native bees and other pollinators have received more attention creating increased interest in gardening to attract and conserve pollinators in other areas as well. There are two major pollinator gardens in the planning stages now – the Pollinator Park in Guelph, Canada (http://www.pollinator.ca/guelph/), and the Honey Bee Haven Garden in Davis, California (http://entomology.ucdavis.edu/news/honeybeehavenwinner.html). Also, a honey bee sanctuary called the Melissa Garden in Healdsburg, California was started in the fall of 2007 and designed by Kate Frey, a garden designer focusing on habitat gardening for insects and birds (Frey 2009).

Educating gardeners at Emerson Park added another level to our project. By giving presentations and utilizing surveys we were able to evaluate gardeners' interest and merge the human component with the science. Without their interest we would not have had the space to incorporate the new bee attractive plants, as their cooperation was essential. After two years of our project the gardeners developed their own mission statement and based on our recommendations have been planting their own bee plants.

The importance of cooperators cannot be overlooked or underappreciated when beginning a project of this type. We have cooperators at all our sites throughout the state and have found that it is crucial to form relationships with "lead gardeners" as well as home owners and garden managers, as they will be our main contact for future work. We rely heavily on lead gardeners and other cooperators to manage plants we bring to the gardens. Lead gardeners also help by keeping us informed about the type of audience we are working with and their interests. They are also essential in maintaining project momentum and they often educate and promote our work to others.

Environmental education is an extremely important part of our work as we expect to transmit information from scientific research to interested individuals and groups in the public sector. Often this is not the case as there can be a division between scientific research and what is communicated to the public. The important point is for scientists to learn how to package technical information into user-friendly language - both verbal and written (Jacobson 1999; Vergano 2009).

At the national level, several NGO organizations and U.S. governmental agencies are involved in promoting pollinators, especially bees, and habitat gardening. Three prominent NGO institutions are leading the way: North American Pollinator Protection Campaign (www.nappc.org), National Wildlife

Federation (www.nwf.org), and Xerces Society (www.xerces.org). At least five governmental agencies including the National Park Service, the U.S. Forest Service, the Bureau of Land Management, the U.S. Fish and Wildlife Service, and the USDA, including NRCS (Natural Resources Conservation Service), have new mandates to promote awareness, protection, and conservation of pollinators (www.nappc.org). Additionally, other groups such as landscape designers have expressed interest and have the ability to collaborate with the scientific community to promote insect conservation in urban areas (Hunter and Hunter 2008).

These habitat gardens have the potential to be used for many purposes and can be a great meeting ground for communication of ideas. Habitat gardens for pollinators may serve as conservation of genetic reserves for the future as well (Owen 1991). With the results of our work in the Emerson Park garden we think that is it possible that more gardens could be modified and designed with the goal of attracting and conserving wildlife, especially pollinators (Frankie 2009a,b).

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Appendix A. San Luis Obispo Emerson Park Gardener Survey
Urban Bee Project

Demographics: Circle one.

1. Age: 20-30 31-40 41-50 51-60 60+

2. Gender: Male Female

3. How long have you been gardening?
Less than 1 yr 1-2 yrs. 3-5yrs. 5-10 yrs. 10-15 yrs. 15+ yrs.

4. How long have you been gardening at Emerson Park?
Less than 1 yr. 1-2 yrs. 3-5 yrs. 5+ yrs.

5a. How many hours a week during the summer do you garden at Emerson?
1-2 hrs. 2-5 hrs. 5-10 hrs. 10+ hrs.
5b.How many hours a week during the winter do you garden at Emerson?
1-2 hrs. 2-5 hrs. 5-10 hrs. 10+ hrs.

6. What size plot do you have? Full Half

7. What is your main purpose in gardening at Emerson?
Food/vegetables Ornamentals Herbs Other_____

8. What is your profession? Retired?
_____

9. Are you familiar with the project at Emerson Park to add plants to the garden to attract native CA bee pollinators?
Yes No

10. Have you made your plot available to add some of the bee attractive plants?
Yes No

11. If yes, do you like the added plants?
Yes No

12. Do you like the general concept of adding new plants to Emerson to attract native bee pollinators?
Yes No Not sure

13. Have you observed an increase in the number and diversity of bees in the general Emerson garden since the project began in 2006?
Yes No Not sure

14. Have you visited the urban bee garden website of UC Berkeley at:
http://nature.berkeley.edu/urbanbeegardens ?
Yes No

15. If yes, did you find the information useful?
Yes No Not sure

16. Would you like to have a presentation at Emerson on the bee garden project by researchers from UC Berkeley?

Yes No

17. Would you like to see the native bee project continue at Emerson?

Yes No Not sure

18. Please provide us with a few general comments on the project.

Thank you!