NATIVE AND NON-NATIVE PLANTS ATTRACT DIVERSE BEES TO URBAN GARDENS IN CALIFORNIA

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Abstract—Bees visit native and non-native plant species for pollen and nectar resources in urban, agricultural, and wildland environments. Results of an extensive survey of bee-flower collection records from 10 California cities from 2005-2011 were used to examine host-plant records of native and non-native ornamental plants to diverse native and non-native bee species; five cities were from northern California and five were from southern California. A total of 7,659 bees and their floral host plants were examined. Of these, 179 were *Apis mellifera* and 7,390 were non-*Apis*. Only four other non-native species (all in Megachilidae) were recorded in the survey, and together they accounted for 402 individuals. These bees have been databased in preparation for deposition in the University of California-Berkeley Essig Museum of Entomology. We identified 229 bee species and 42 genera visiting native and non-native plant types in urban areas. Of the 229 species, 71 bee species were collected from only native plants; 52 were collected from only non-native host plants; and 106 were collected from both types of plants. Native bee species were common on native plants and non-native plants, but there were substantially more non-native bee species visiting non-native plants compared to native plants. Flowering periods in months were similar for both types of plants, but non-natives tended to flower later in the year. We propose that using native and non-native plants improves habitat gardening by increasing opportunities for attracting a richer diversity of bee species and for longer periods. Knowing basic bee-flower relationships in an area is key to planning a bee habitat garden with a variety of plant types, regardless of their geographic origin.

Keywords: *habitat gardens, urban bees, native plants, native pollinators, native bees, Apis mellifera*

INTRODUCTION

The importance of native pollinators, and especially bees, has generated increased attention in recent years in the scientific and popular press, propelled by recognition of their ecological importance, aesthetic value, and ecosystem services they provide (Owen 1991; Buchmann & Nabhan 1996; Losey & Vaughan 2006; NAS 2007; Tepedino et al. 2008; Winfree 2010; Mader et al. 2011; Garibaldi et al. 2013; O'Toole 2013; Williams et al. 2014; Atkins & Atkins 2016; Wilson & Carrill 2016; Hall et al. 2017; Embry 2018; Hanson 2018).

This interest is coupled with an awareness that pollinators are declining globally (Buchmann & Nabhan 1996; Cane & Tepedino 2001; Potts et al. 2010; Williams et al. 2014; Baldock et al. 2015; Atkins & Atkins 2016; Koh et al. 2016;). These trends have also prompted conservation efforts for bee pollinators in agricultural and urban environments (NAS 2007; Hernandez et al. 2009; Mader et al. 2011; Frankie et al. 2014, 2018; Kleijn et al. 2014; Baldock et al. 2015; Harrison et al. 2017).

With regard to urban areas, which are increasing worldwide, there has been a proliferation of papers recently on bee species richness and abundance in cities (Frankie et al. 2005, 2009a, 2013, 2014; Nates-Parra et al. 2006; Nemesio and Silveira 2007; Matteson et al. 2008; Pawelek et al. 2009; Tallamay 2009; Pardee & Philpott 2014; Baldock et al. 2015). Survey work has provided much evidence that urban areas can offer suitable habitat for reproduction and survival of many bee species. Frankie et al. (pg. xiv 2014 and unpublished.) opportunistically sampled 50+ urban sites for more than 15 years throughout California, and determined there were more than 400 bee species, which represents 25% of the known 1,600 bee species recorded from the state. Surveys in single small gardens also reveal relatively high species richness. Long-term monitoring in one small residential garden in Leicester, England yielded 51 bee species, which represents 20% of Britain's 256 native bee species (Owen 1991). Frankie et al. (2013) surveyed bees visiting 62 native and 40 non-native ornamental and weed plant species in two cities in NW Costa Rica over a 10-yr period and recorded 125 bee species, which represents about 18% of the 700+ bee species in the country. See other relevant studies by Jaime et al. (2009); Frankie et al. (2009b). Some papers have

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suggested ways to enhance bee activity, for example, through urban pollinator habitat gardens, hedgerows and other ways (NAS 2007; Pawelek et al. 2009; Mader et al. 2011; Frankie et al. 2014; Tallamay 2009).

In our California experience, one common question that emerges from urban audiences is, should native and non-native host plants be used to encourage bee species activity in gardens or similar types of plantings? There is growing interest and some debate on this question (Pardee & Philpott 2014; Salisbury et al. 2015; Frankie et al. 2018). See also Tepedino et al. 2008 and Williams et al. 2011 for different, but relevant views. In this paper, we offer a perspective on this question based on years of work conducted throughout California and other states. It seems clear that it is not always a simple question with a simple answer. Our perspective is based on extensive collection records and observational work on bee-flower relationships conducted in the state over 20 years of urban (and agricultural) field work.

Goals

Our goal was to examine past bee-flower records collected in urban California to evaluate the relative attractiveness of native versus non-native plants to bees in bee habitat gardens and other habitats with flowers. Using extensive survey data of bee-flower relationships gathered throughout northern and southern California gardens from 2005-2011 (Frankie et al. 2009a, 2014), we compared the most attractive native and non-native plants with native and non-native bees to make assessments by:

1. Comparing total number of native and non-native bee species and genera with native and non-native plants.

2. Comparing blooming periods of native and non-native plants.

MATERIALS AND METHODS

Site Descriptions

Bee-flower collection records from 10 California cities (Fig. 1 and see map on page xv in Frankie et al. 2014) were used to examine attraction patterns. Northern California cities were Redding, Ukiah, Sacramento, Santa Cruz, and Berkeley; southern cities were San Luis Obispo, Santa Barbara, Riverside, La Canada Flintridge (near Pasadena), and Palm Springs (Palm Desert). Sampling was conducted in diverse sites, which included botanic gardens, arboreta, community gardens, private home gardens, cemetery gardens, fallowed lots, and city/ county space within these cities.

Collections and observations

Collections and extensive observations were made by experienced bee collectors from the Urban Bee Lab at the University of California, Berkeley. Collecting was done when climatic conditions were favorable and collectors were available. Most sampling occurred during spring and summer months (March through August).

FIGURE 1: Map of Surveyed California Cities (figure is modified from map on Page xv of *California Bees & Blooms* (Frankie et. al., 2014))

Bees were collected directly from flowers using aerial nets. To standardize a visit, only bees that made contact with reproductive parts of flowers were collected. Collectors sampled opportunistically for 2-4 hours from mid-morning to mid-afternoon on days of at least 18 degrees C. Representative specimens of one or two bee species from each plant were collected and kept separate.

Bees were pinned and labeled at the Urban Bee Lab. J. Pawelek and R. Thorp identified the bees to species, which were then databased using Microsoft Access. The databased bees have been prepared for eventual deposition in the UC Berkeley Essig Museum of Entomology. A total of 7,569 bees were collected during the study. Of these, 179 were *Apis mellifera* and 7,390 were non-Apis. Only four non-native bee species other than *A. mellifera* were recorded in the survey: *Megachile rotundata* (N = 211 individuals), *M. apicallis* (N =82), *M. concinna* (N =28), and *Anthidium manicatum* (N =81).

We use the term "plant types" to represent well recognized plant species and others that represent cultivars, which were common in urban environments. After entries were made, the database was separated to include only plant types that were found in at least five of the 10 cities so as to focus on the more common species and cultivars. This narrowed our plant list from over 110 native and 115 non-native plant types to 15 natives and 19 non-natives. See Fig. 2 for origins of non-natives included in the study.

Of the 34 total plant types, 26 were easily identified to species level during collection events. The remaining eight types were determined only to genus as the large variety of species and cultivars within these genera are difficult to distinguish (e.g. natives: *Ceanothus* spp. + cvs. and *Erigeron glaucus* + cvs.; non-natives: *Gaillardia* spp. + cvs. and *Lavandula* spp. + cvs.). Lists of all bee collected from these 15 natives and 19 non-natives were then compiled for analysis.

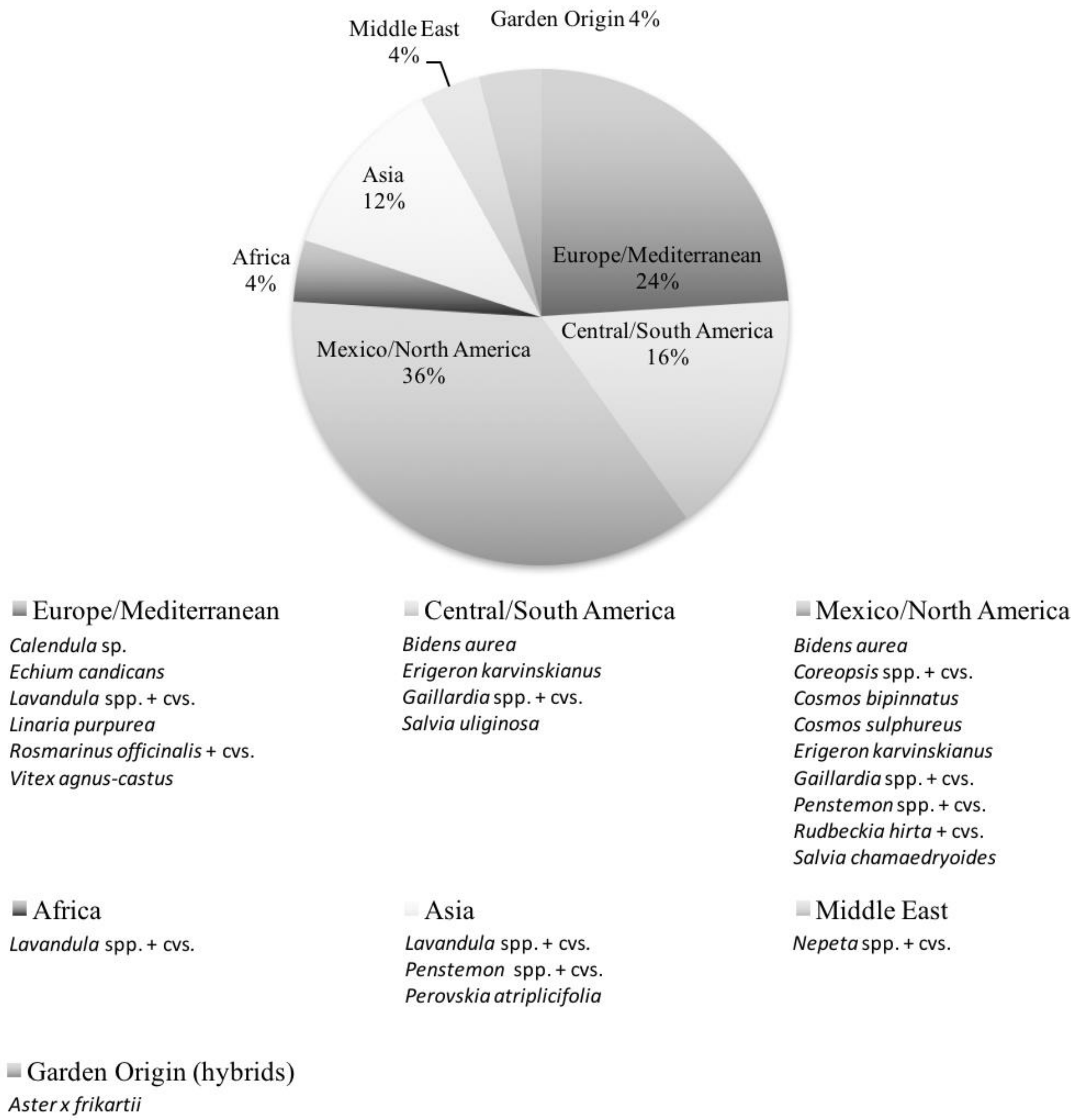

FIGURE 2: Origins of non-native plants surveyed in this study

TABLE 1: Number of native and non-native (in parentheses) bee species visiting native and non-native plant types in survey.

	Visit Native Plants Only	Visit Non-native Plants Only	Visit Native and Non-Native Plants	Totals
Number of Bee Species	71(0)	52(0)	101(5)	229
Number of Bee Genera	6(0)	3(0)	32(1)	42

TABLE 2: Native and non-native bee species and genera recorded from native plants. Number in parentheses represents consistent bee taxa for which there were three specimens recorded from the plant type in at least two different years.

Native Plant Type	Total Native Bee Species	Total Non-Native Bee Species	Total Bee Genera
Achillea millefolium L.	18 (4)	1 (0)	10 (2)
Arctostaphylos spp. + cvs.[1]	16 (5)	0 (0)	8 (3)
Berberis nevinii	10 (3)	0 (0)	6 (3)
Ceanothus spp. + cvs.[2]	51 (20)	0 (0)	12 (7)
Encelia californica Nutt.	30 (8)	0 (0)	16 (6)
Erigeron glaucus + cvs.[3]	34 (9)	2 (1)	18 (8)
Eriogonum fasciculatum Benth	22 (7)	1 (0)	12 (5)
Eschscholzia californica Cham.	42 (17)	0 (0)	15 (7)
Grindelia hirsutula Hook & Arn	16 (5)	1 (0)	12 (4)
Helianthus annuus L.	15 (7)	0 (0)	10 (4)
Phacelia tanacetifolia Benth	54 (16)	3 (0)	20 (12)
Salvia clevelandii (A. Gray) Greene	8 (2)	0 (0)	6 (2)
Salvia leucophylla Greene	19 (3)	0 (0)	11 (2))
Salvia mellifera Greene	32 (7)	1 (1)	15 (5)
Solidago californica Nutt	34 (11)	2 (1)	18 (5)

1. *Arctostaphylos densiflora* M.S. Baker, *Arctostaphylos hookeri* G. Don, *Arctostaphylos* 'Dr. Hurd', *Arctostaphylos pumila* Nutt., *Arctostaphylos* sp.
2. *Ceanothus thyrsiflorus* 'Skylark', *Ceanothus thyrsiflorus* Eshsch. , *Ceanothus* 'Julia Phelps', *Ceanothus* 'Marie Sim.', *Ceanothus* 'Cal Poly', *Ceanothus* 'Ray Hartman', *Ceanothus* 'Snow Flurry', *Ceanothus* 'Sierra Blue', *Ceanothus* 'Mountain Haze', *Ceanothus* 'Wheeler Canyon', *Ceanothus* 'Frosty Blue', *Ceanothus* 'Dark Star', *Ceanothus 'thyrsiflorus* 'Serra Snow', *Ceanothus hearstiorum* Hoover & J.B. Roof, *Ceanothus gloriosus* J.T. Howell, *Ceanothus griseus* (Trel.) McMinn, *Ceanothus maritimus* Hoover., *Ceanothus oliganthus* Nutt, *Ceanothus* 'Gentian plume', *Ceanothus* 'Bee's Bliss', *Ceanothus* sp.
3. *Erigeron glaucus* Ker Gawl., *Erigeron glaucus* 'Wayne Roderick', *Erigeron glaucus* 'Bountiful'

RESULTS

We identified 229 bee species and 42 genera visiting our selection of 15 native and 19 non-native plant types in urban areas (Table 1 and Appendix 1). Of the 229 species, 71 were from only native host plants; 52 were from only non-native host plants; and 106 were from both native and non-native hosts. Five of the 106 were non-native bee species. Of the 42 genera, six were from only native plants; three were from only non-native hosts; and 33 were from both native and non-native host flowers. Only one non-native bee species was recorded for both native and non-native hosts (Table 1). Cleptoparasitic bees were treated as potential pollinators as many or most individuals carry small amounts of pollen on their bodies and thereby have the potential to pollinate at low levels.

The six bee genera found visiting only native plants were *Calliopsis*, *Chelostoma*, *Conanthalictus*, *Melecta*, *Panurginus*, and *Perdita*. *Calliopsis* sp. and *Perdita* sp. were only found visiting the native *Eschscholzia californica*. *Chelostoma* sp. and *Conanthalictus* sp. were found visiting only the native *Phacelia tanacetifolia*. *Melecta* sp. was found visiting only the native *Salvia mellifera*. *Panurginus* spp. was found visiting the natives *Ceanothus* spp. + cvs. and *Phacelia tanacetifolia*. The three genera found only visiting non-native plants were *Anthophorula, Dolichostelis* and *Epeolus*. *Anthophorula* sp. was collected only from *Penstemon* spp. + cvs, *Dolichostelis* sp. was collected only from *Rosmarinus officinalis,* and *Epeolus* sp. was collected only from *Erigeron karvinskianus*.

Table 2 lists native plant types from which native and non-native bee species were collected. Native bee species were common, as expected, on native plants. Only seven of the 15 native plant types (47%) attracted a few non-native bees, with a low number of consistent species. Only three of the seven non-natives were recorded in this group.

Table 3 lists non-native plant types from which native and non-native bee species were collected. As with the native plants, native bee species were common on non-native plants. In contrast to native plants in Table 2, there were substantially more non-native bee species visiting non-native plants compared to native plants (Table 2). Sixteen of the 19 non-native plants (84%) attracted non-native bee species, and nine of the 16 had consistent visitors.

A plant type's status as native or non-native did not indicate how many bee species it can attract. For example, the native *Phacelia tanacetifolia*, *Ceanothus* spp. + cvs, and *Eschscholzia californica* attracted 57, 51, and 41 bee species respectively. The non-native *Lavandula* spp. + cvs., *Nepeta* spp + cvs., and *Aster* x *frikartii* attracted 53, 52, and 43 bee species respectively (Tables 2 & 3).

Native and non-native plant types often attracted different bee taxa. Based on years of extensive bee visitation or frequency counts in California, most urban bee plants attracted certain predictable taxonomic groups and rarely others (Frankie et al., 2009a, 2014; see also Frankie et al. 2013 for similar findings in Costa Rica). There were some variations with this generalization, but hundreds of counts made over multiple years support this generalization. Comparing the non-native *Salvia chamaedryoides* and the native *Salvia clevelandii* illustrated this phenomenon (Table 4). *Salvia chamaedryoides* attracted 8 bee species, and *S. clevelandii* also attracted 8 bee species. Together, they attracted 12 bee species. Planting *S. chamaedryoides* with *S. clevelandii* could invite an additional four bee species that do not visit *S. clevelandii* into a garden, thus increasing overall pollinator diversity.

Comparing blooming activity of 19 non-native with that of 15 native plant types illustrate similarities. Ranges of flowering periods were 3-8 months and 3-12 months, respectively, for natives versus non-natives (3-8 months for both if the 12 months of *Erigeron karvinskianus* is excluded). Average flowering periods were also similar, 4.8 +/- SD 1.52 months for natives and 5.1 +/- SD 2.12 months for non-natives. Non-native plants bloom later and longer in the year than native plants (Figs. 3 and 4). The ratio of non-native to native plants in flower increased as the year progresses. In February, only 16.7% of the plants in flower were non-native. In June, 61% were non-native, and in October, 86% of the flowering plants were non-native with only 14% of flowering plants being native.

TABLE 3: Native and non-native bee species and genera recorded from non-native plants. Number in parentheses represents "consistent" bee taxa for which there were at least three specimens recorded in at least two different years.

Non-Native Plant Type	Total Native Bee Species	Total Non-Native	Total Bee Genera
Aster x frikartii	40 (17)	3 (3)	22 (11)
Bidens aurea (Aiton) Sherff	22 (8)	2 (2)	15 (7)
Calendula sp.	16 (4)	2 (0)	8 (2)
Coreopsis spp. + cvs.[1]	33 (12)	2 (2)	16 (7)
Cosmos bipinnatus Cav.	31 (8)	1 (0)	13 (6)
Cosmos sulphureus Cav.	9 (2)	1 (0)	7 (2)
Echium candicans L.f.	18 (5)	0 (0)	12 (4)
Erigeron karvinskianus Dc.	29 (4)	2 (2)	17 (5)
Gaillardia spp. + cvs.[2]	26 (8)	0 (0)	14 (6)
Lavandula spp. + cvs.[3]	51 (29)	2 (0)	21 (13)
Linaria purpurea (L.) Mill.	20 (4)	2 (2)	11 (4)
Nepeta spp. + cvs.[4]	49 (23)	3 (2)	21 (13)
Penstemon spp. + cvs.[5,6]	34 (9)	0 (0)	15 (7)
Perovskia atriplicifolia Benth.	26 (13)	2 (1)	16 (9)
Rosmarinus officinalis + cvs.[7]	27 (9)	2 (1)	19 (7)
Rudbeckia hirta + cvs.[8]	22 (5)	1 (0)	16 (5)
Salvia chamaedryoides	9 (2)	1 (0)	7 (2)
Salvia uliginosa	28 (9)	1 (0)	15 (8)
Vitex agnus-castus L.	37 (17)	2 (1)	16 (11)

1. *Coreopsis verticillata* L., *Coreopsis grandiflora* Hogg, ex Sweet, *Coreopsis* sp., *Coreopsis* 'Sunray', *Coreopsis* 'Domin', *Coreopsis tinctoria* Nutt, *Coreopsis* 'Nana', *Coreopsis* 'Sunny Day', *Coreopsis* 'Flying Saucers', *Coreopsis lanceolata* L., *Coreopsis auriculata* L.
2. *Gaillardia* sp., *Gaillardia aristata* Pursh, *Gaillardia x grandiflora, Gaillardia x grandiflora* 'Oranges & Lemons',
3. *Lavandula* sp., *Lavandula heterophylla, Lavandula* 'Provence', *Lavandula dentata. var. Candicans* L.; *Lavandula stoechas* L., *Lavandula* 'Helmsdale'
4. *Nepeta* sp., *Nepeta tuberosa, Nepeta x faassenii, Nepeta* 'Six Hills Giant', *Nepeta grandiflora* M. Bieb,
5. *Penstemon* sp., *Penstemon 'Midnight,' Penstemon parryi* (A. Gray) A. Gray
6. This list excludes the *Penstemon* spp. that are native to California.
7. *Rosmarinus officinalis* L., *Rosmarinus officinalis* 'Lockwood de Forest'
8. *Rudbeckia hirta* L., *Rudbeckia hirta* 'Indian Summer'

TABLE 4: Native bee species recorded from non-native *Salvia chamaedryoides* and native *Salvia clevelandii* in study survey

Salvia chamaedryoides (non-native)	*Salvia clevelandii* (native)	Both *Salvia chamaedryoides* and *Salvia clevelandii*
Anthidium maculosum	*Agapostemon texanus*	*Halictus tripartitus*
Anthophora californica	*Andrena candida*	*Melissodes tepida timberlakei*
Anthophora urbana	*Bombus melanopygus*	*Xylocopa tabaniformis orpifex*
Melissodes communis alopex	*Xylocopa varipuncta*	*Bombus californicus*

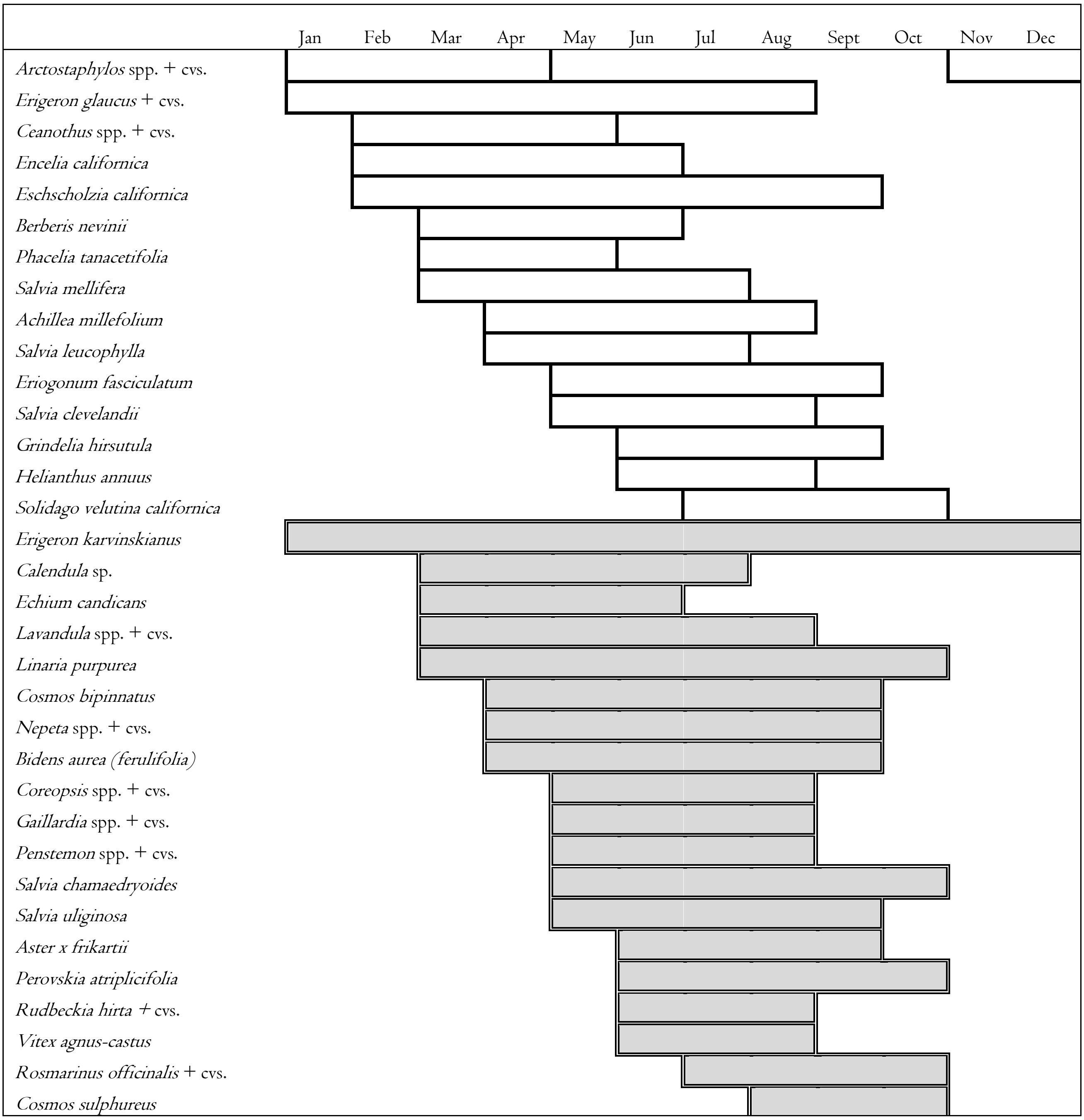

FIGURE 3. Blooming periods of native and non-native plant species in study survey. Open bars represent native plants and gray represent non-native plants

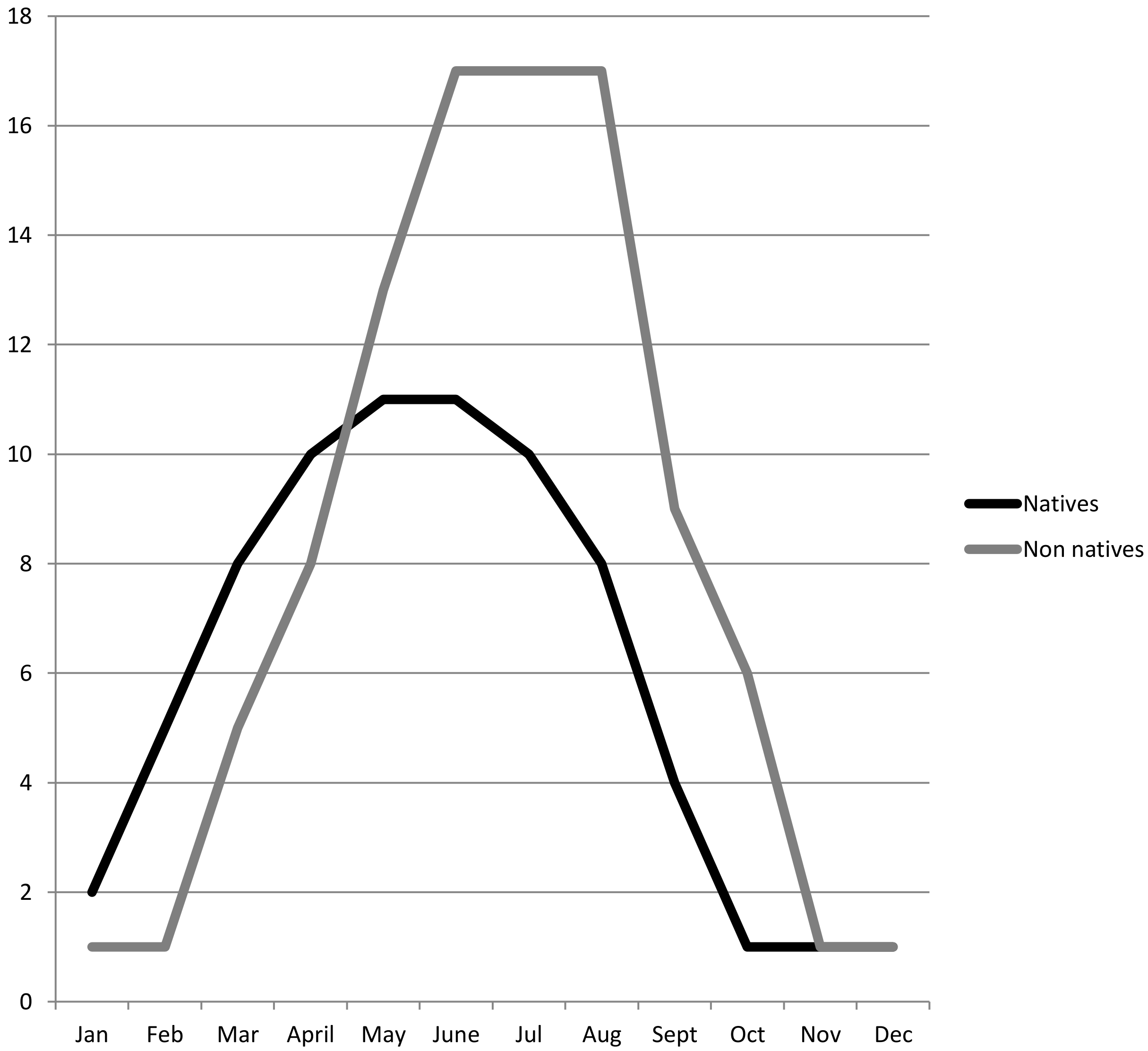

FIGURE 4. Number of 15 native and 19 non-native species in bloom throughout year (see Table 2 and 3)

Examining flowering phenologies of *S. chamaedryoides* and *S. clevelandii* one observes overlap between a plant's bloom time and flight activity period of bees that visit the plants (Tables 2, 3, & 5). Non-native *S. chamaedryoides* flowered from May until October, whereas native *S. clevelandii* bloomed earlier in the season from March until August. *Salvia chamaedryoides* bloomed for an additional two months more than *S. clevelandi,* and this was associated with the flight seasons of bees that are attracted to this non-native plant. Including *S. chamaedryoides* in a garden may introduce new species like *Anthidium maculosum, A. manicatum*, and *Anthophora urbana* that rely on floral resources provided by plants that bloom through October, as these bees' flight periods extend into the fall months.

DISCUSSION

Our survey research indicates that incorporating both native and non-native ornamental plants into habitat gardens may be beneficial by providing more diverse habitat for bees in urban areas. This supports the larger concept that non-native species can provide conservation benefits by providing food and habitat for native species as well as providing desirable ecosystem functions (Schlaepfer et al. 2011). A prevailing attitude amongst many urban gardeners with whom we work is that native plant gardening is a "best practice" for habitat gardening, leading many to work exclusively with natives. There are, of course, many benefits to native plant gardening as native plants are often well-adapted to local climates and provide food and shelter to wildlife (Tallamay 2009). Gardening with select non-native plants, however, can supplement floral resources to support more diverse bee populations. Bees require flowers for both nectar and pollen, and many bee species are generalists in their choice of plants. Incorporating native and non-native plant types into a bee garden can increase the total number of bee species found there.

Of the 229 bee species found visiting the 34 plant types in this study, 52 bee species were recorded only from non-native plants (Table 1). Plants having the most consistent bee species visiting them were *Lavandula* spp. + cvs with 29 bee

TABLE 5: Flight Periods of Native Bee Species Visiting *S. chamaedryoides* and *S. clevelandii*

Flight Season of Native Bees Visiting *Salvia chamaedryoides* (nonnative)	Flight Season of Native Bees Visiting *Salvia clevelandii* (native)
Anthidium maculosum: June - Oct	*Agapostemon texanus:* March - Oct
Anthophora californica: March - July	*Andrena candida:* Feb - June
Anthophora urbana: April - October	*Bombus melanopygus:* Jan - Aug
Melissodes communis alopex: June - Aug	*Xylocopa varipuncta:* March - Sept.

species visitors, *Nepeta* spp. + cvs with 25 bee species visitors, *Aster* x *frikartii* with 20 bee species visitors, and *Ceanothus* spp. + cvs also with 20 bee species visitors (Table 3). These first 3 plants are all non-native, followed by the native *Ceanothus* spp. + cvs (Table 2).

Tepedino et al. (2008) assessed which bee species were visiting 10 selected plant taxa (7 native, 3 invasive) in Capitol Reef National Park, Utah and reached similar conclusions. They found that non-native plant species had as many or more native bee species and individuals as did native plant species, and thus played an important role in increasing the Park's native bee carrying capacity. Their study focused on a wildland habitat and weedy plants, whereas the current study focused on urban habitats and installed ornamental plants. Both have important conservation implications regarding the design of pollinator habitats.

Beyond increasing overall species abundance, another reason for incorporating non-native plants into a bee garden is that they may extend a garden's flowering time, thus providing more resources for bees later in the year and possibly attracting new bee species. Many non-alpine California native plants typically bloom earlier in the year as a result of the region's Mediterranean climate, in which wet winters encourage flowering in the spring and early summer months before the dry summer sets in. Of the plants highlighted in this study, there are more non-native taxa in bloom later in the season (summer/fall) compared to earlier in the season (winter/spring) (see Figs. 3 and 4). A study conducted in the UK recorded a similar pattern: non-native plants extended the flowering season (Salisbury 2015). Tepedino et al. (2008) noted that non-native plants have actually increased wildland native bee carrying capacity in Capitol Reef National Park potentially because they filled in a mid-summer gap in floral resources. Although percentages calculated from our study (16.7% of the plants in flower in February are non-native, and 86% are non-native in October) would only be valid of a garden made up of our highlighted 34 plant types. A study conducted in Poznan, Poland by Banaszak-Cibicka & Zmihorski (2011) demonstrated that presence of a bee species in an urban area depends on the species' flight season and phenologies of the area's floral resources. This study found that the recorded low numbers of early spring bees in the urban area was "likely due to a lack of appropriate floral resources during flight times of these bees."

Providing floral resources for the entire duration of the bee season (mid-December through October) in California is an important factor to consider when planning a bee habitat garden. Many bee species only have a single generation per year and, are active as adults for only a short period (e.g. *Melissodes robustior*). Other species are multi-generational, having a longer flight season as adults, as they will emerge from their nest cavities at multiple points throughout the year (e.g. *Agapostemon texanus*). Some species are social and also have a long flight season as their colonies are active throughout the year (e.g. *Bombus vosnesenskii*). Plants that flower later in the season are important resources for not only single-generation bees that are active in either the summer and fall, but multi-generation bees and social bees, too, such as honey bees.

Supporting diverse bee populations via habitat gardening can be an important tool in larger conservation work involving native bees. Urban areas can act as refuges for bee diversity (Hall et al. 2016). California's 1,600 native bee species have coevolved with California's 6,000+ flowering plant species, forming a relationship that is integral to ecosystem health and the state's natural resource heritage. Furthermore, urban landscape gardens can be ideal sites for long-term pollinator monitoring because they are usually intensively managed, and usually provide more consistent floral resources than wild landscapes where floral resource availability may be limited by factors such as drought, and even fire. Urban areas can even serve as genetic reserves for pollinators and other species that are beneficial for humans, some of them undoubtedly being a resource for the pollination of agricultural crops (Owen 1991; Frankie et al. in press). Bees in urban environments can also be subjects of environmental education, offer aesthetic pleasure, and pollinate garden plants (both edible and non-edible) (Mader et al. 2011; Frankie et al. 2014; Embry 2018; Hanson 2018).

We have presented evidence from our years of field collections and observations on bees and their host flowers that native and non-native plants, when grown together, in a garden can support native bees. The key is knowing basic relationships between bees and their preferred plants in an area, and then acting accordingly on these relationships to construct gardens to support them. When we construct bee habitat gardens in urban and agricultural areas, our focus is on plants that bees prefer for pollen and nectar and not on whether the plants are native or non-native. This knowledge has been useful for designing urban habitat gardens where the emphasis is usually on achieving high species diversity and abundance (Frankie et al. 2009b; Jaime et al. 2009).

Knowing basic relationships can also extend into agricultural areas, where we have used them in northern and southern California studies to attract native bees to crop flowers (Frankie et al., in press). We have used this knowledge for constructing native bee habitat gardens in hedgerow plantings where we first begin by overstocking the rows with a wide variety of plants known to attract a generally wide diversity of bees. After a year or more of monitoring, we select plants that attract bees that are also visiting and pollinating crop flowers and focus on installing these plants, and at the same time reducing plant types that were not supporting bees that pollinate crop flowers. Selecting plants to be used for target bee species does not involve determining origins of the plants.

All of the 7500 + bee-flower collection records from this survey will soon be available for examination and further study at the Essig Museum of Entomology at the University of California, Berkeley. These individual, bar-coded bee records could be useful as baseline information for climate change research in the future as they were compiled from 2005 - 2011, just as the current drought conditions were starting to be felt. Bee numbers have been declining since 2010 all over the state, but especially in southern California.

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APPENDICES

Additional supporting information may be found in the online version of this article:

APPENDIX I. List of 229 bee species and the flowers they visit

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