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Urban Nature Gardens at the Natural History Museum of Los Angeles County attract "wildlife spectacle" of insect pollinators

EMILY A. HARTOP[1,2], ELIZABETH LONG[1,3,4], CAROL BORNSTEIN[1], LISA GONZALEZ[1] & BRIAN V. BROWN[1]

[1] *Natural History Museum of Los Angeles County, Los Angeles, California, United States of America*
[2] *Corresponding author, e-mail: emily.a.hartop@gmail.com*
[3] *Mohonk Preserve, New Paltz, New York, United States of America*
[4] *La Kretz Center for California Conservation Science, University of California Los Angeles, United States of America*

Abstract

The newly-constructed Nature Gardens at the Natural History Museum of Los Angeles County (California, USA) were purposefully built to attract wildlife. In this study we wanted to find out to what extent this manufactured environment is successful in attracting native insect fauna to the urban core of the city when compared to the surrounding neighborhoods or natural areas on the periphery of Los Angeles. To determine this, a one-year Malaise trap catch from the Nature Gardens was compared with samples from four neighboring sites within a five-kilometer radius, as well as a site adjacent to natural habitat located sixteen kilometers away. Our analysis focused on the diversity and abundance of three pollinator groups: bees, flower flies and butterflies contrasted with a single non-pollinator group: scuttle flies.

Our findings show that the Nature Gardens support greater abundance and diversity than any of the nearby sites or the natural site for all pollinator taxa examined. In contrast, the natural site supported much higher abundance and diversity of the non-pollinator scuttle flies when compared to the Nature Gardens. Calculated evenness of all taxa was lower in the Nature Gardens than at the natural site and Shannon Diversity indices were highest in the Nature Gardens for flower flies and butterflies, but lower in the Nature Gardens than at the natural site for bees and scuttle flies. These results indicate that biodiversity in an urban environment can be selectively manipulated through management of green spaces, but may not duplicate the communities found in natural spaces. Rather, targeted management (through plantings, ground cover and other substrates, watering, pest management techniques, etc.) can increase fauna predictively to create a "wildlife spectacle" of charismatic microfauna.

Key words: urban garden, pollinators, native bees, butterflies, flower flies, scuttle flies, urban ecology, urban biodiversity, insect survey, Los Angeles

Introduction

Urban environments are a tessellation of fragments of natural habitat (altered to varying degrees), areas of dense urbanization, and purposefully-built systems (like backyards, parks, and gardens). Many studies on urban biodiversity focus on fragmentation or gradation of natural habitats in metropolitan areas (Bolger *et al.*, 2000; Brown & Freitas, 2002; Gibb & Hochuli, 2002; Avondet *et al.*, 2003; Banaszak-Cibicka & Żmihorski, 2011; Fortel *et al.*, 2014). These studies indicate that there are widely varying responses to factors of urbanization by different types of organisms. A two-year study of bees along an urbanization gradient in France found that the abundance of wild bees was negatively correlated with the proportion of impervious surface present, the richness of the bee communities was at a maximum at an intermediate level of surface imperviousness, and the community varied along the gradient (Fortel *et al.*, 2014). A similar study in Poland found that diversity and richness of bee communities remained stable along an urban gradient with only the composition of the communities changing (Banaszak-Cibicka & Żmihorski, 2011). A study of carabid beetles in three cities across the Holarctic region found that there was little division of communities on an urban-rural gradient, but a study of *Drosophila* flies along an urban gradient in Ohio, U.S.A. found that community composition varied along the gradient, but diversity did not (Niemelä *et al.*, 2002; Avondet *et al.*, 2003). In our own work in Los Angeles, California, U.S.A., we discovered that communities of scuttle flies varied in both richness and abundance across the cityscape (Brown & Hartop, 2016).

While fragmentation and gradient studies focus on the losses that occur from urbanization, an increasing body of work focuses on the creation of environments built to attract wildlife. Hall *et al.* (2017) reviewed the literature on urban bee species diversity and abundance. They stressed the ecological and conservation importance of urban landscapes as refuges for diverse communities of wild bees, including instances where cities support more diverse and abundant communities of native bees than nearby rural areas. Many of the studies on manufactured urban environments focus on pollinator groups like bees and butterflies, as many gardens are targeted toward these charismatic taxa (Matteson *et al.*, 2008; Wojcik *et al.*, 2008; Frankie *et al.*, 2009; Pawelek *et al.*, 2009; Matteson & Langellotto, 2010, 2011; Pardee & Philpott, 2014; Makinson *et al.*, 2016; Quistberg *et al.*, 2016; Plascencia & Philpott, 2017; Salisbury *et al.*, 2017). These created or altered ecosystems vary tremendously in composition and purpose, and therefore have varied results in their effectiveness supporting pollinator communities. Frankie *et al.* (2009) studied gardens in seven California cities over three years and determined that targeted plantings could predictably increase bee fauna. Similarly, a study of a community garden in San Luis Obispo, California showed an increasing diversity of bees over a two-year period after education of gardeners and implementation of a pollinator-oriented planting program (Pawelek *et al.*, 2009). A study in New York City determined that small scale additions of native plants to community gardens did not have a strong influence on insect richness, and that beneficial insects heavily utilize exotic plants (Matteson & Langellotto, 2011). Similarly, studies by the Royal Horticultural Society in the United Kingdom found that the availability of floral resources and canopy cover were more important than focused planting of native species, as both native and exotic were utilized by plant-associated invertebrates (Salisbury *et al.*, 2015, 2017). A study of sixteen backyards in Ohio found that the presence/absence of native plants in combination with other local and landscape characteristics influenced bee diversity in the urban environment (Pardee & Philpott, 2014). A study of community gardens in New York City found that sunlight and floral resources were the biggest determining factors of bee and butterfly diversity, suggesting that habitats isolated in urban spaces can be managed to increase local pollinator diversity (Matteson & Langellotto, 2010). It is clear that green spaces in cities can be selectively manipulated to enhance the abundance and diversity of target groups. What remained to be seen is whether selective enhancement brings about increases in non-target taxa, resulting in an overall increase of biodiversity in the urban ecosystem.

In this study, we examine the Natural History Museum of Los Angeles County (NHMLA) Nature Gardens, a series of connected gardens planted around the Natural History Museum in Los Angeles beginning in 2012. The planning and construction of the gardens was centered around the purpose of creating a "wildlife spectacle" by attracting as much of the native fauna as possible to an oasis of resources near the urban core. To sample the entomofauna of the gardens, a Malaise trap was installed in 2012 (yellow arrow, Fig. 2). In late 2013 this trap became the first site of the BioSCAN (Biodiversity Science: City and Nature) Project, and 29 additional Malaise traps were erected across Los Angeles in late 2013 to capture and study the flying insects of the city (Fig. 3) (Brown *et al.*, 2014). This study analyzes the 2014 catch of butterflies (Lepidoptera: Rhopalocera), bees (Hymenoptera: Apoidea), and two families of flies, scuttle flies and flower flies (Diptera: Phoridae and Syrphidae) from the urban Nature Gardens. It compares that catch to four sites within a five-kilometer radius, as well as a site adjacent to natural oak woodland on the periphery of the Los Angeles Basin sixteen kilometers away (Figs. 3, 4).

We chose to contrast pollinators with a non-pollinator group because, while pollinators are of extreme public interest (and were specifically targeted in the construction of the Nature Gardens), they represent only a small slice of the biodiversity in the ecosystem we are trying to recreate. The western honey bee (*Apis mellifera*), in particular, is widely acknowledged for its pollination services, but both other bees and flower flies can be equally (and in some cases more) efficient as pollinators (Rader *et al.*, 2009). In contrast, the pollination services performed by butterflies are typically less important than those carried out by bees and flower flies, but butterflies are often considered umbrella species for other, less charismatic insect groups. Butterfly abundance offers a quick and easy way to assess nectar availability throughout the calendar year, and because of their dependence on plants during both the adult and larval stages, they provide a rudimentary indication of plant diversity and abundance. Furthermore, butterflies are typically viewed favorably by the general public, easily identified by sight, and exhibit diversity in size and life history strategy.

Inclusion of the large and diverse scuttle flies in our study means that our analysis represents a much wider range of lifestyles than an examination of pollinator groups alone. Scuttle flies are known to have lifestyles ranging from saprophagy, herbivory, fungivory, parasitism, to predation (Disney, 1994). They therefore reflect on more aspects of the natural environment as they depend on varied and complex resources. A single gargantuan genus in this group, *Megaselia*, is the most diverse genus of all insects in terms of larval lifestyle (Bickel, 2009). Scuttle flies in Los Angeles depend on plants, water, soil, other insects, fungi, carrion, detritus, and sometimes even associations with humans (Brown & Hartop, 2016). Their presence can be tightly correlated to specific resources, as is the case with one Los Angeles species found associated with a single species of fungus (Brown & Hartop, 2017). The relationship between scuttle fly biodiversity to urbanization is the focus of current work by some of the authors. What is already clear is that the scuttle flies are positively associated with more natural environments, and are therefore excellent organisms to assess biodiversity (Disney and Durska, 2008; Brown and Hartop, 2016).

Here we compare species diversity and abundance across a variety of urban habitat types using these four diverse taxa. We examine whether a large urban garden can recruit and sustain an insect community at similar biodiversity levels to those found in an intact wildland area, and whether the taxa found in this urban refuge differ from those of the surrounding neighborhoods.

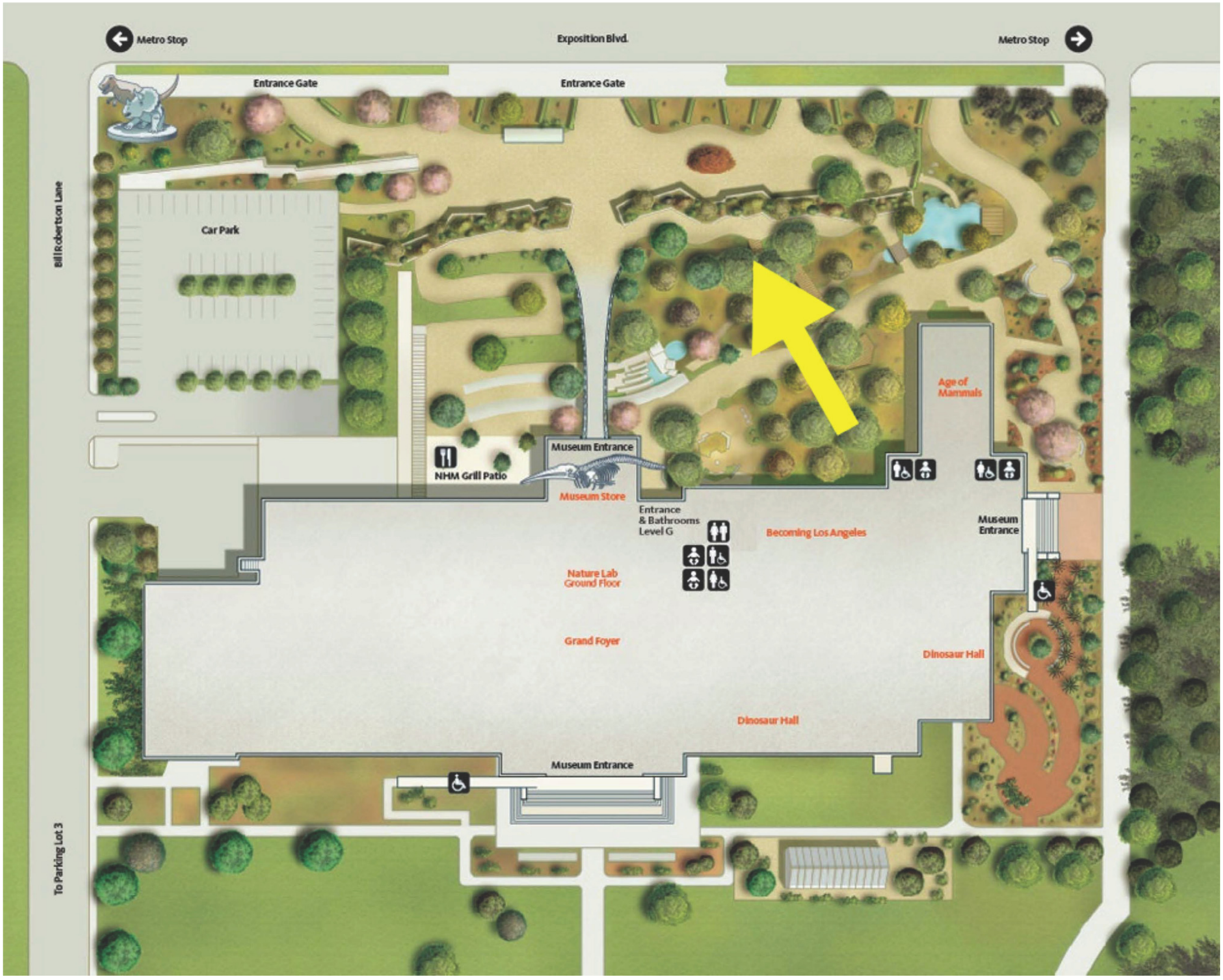

FIGURE 1. Map of NHMLA Nature Gardens indicating placement of the BioSCAN Malaise trap

FIGURE 2. Map of the Exposition Park neighborhood with NHMLA centered and the NHMLA Nature Gardens highlighted in green.

FIGURE 3–4. Maps of the 2014 BioSCAN transect, sites used in this analysis are indicated in red. The NHMLA Nature Gardens are centered and a 5 kilometer radius is indicated.

Materials & Methods

Specimens were collected by Malaise traps (Townes lightweight model purchased from Sante Traps), captured and preserved in 95% ethanol (Townes, 1972). Specimens were examined using Leica M165C and Leica M80 stereo microscopes and an Olympus BX40 compound microscope. Butterflies were sorted and identified from all weekly catches over 2014, whereas bees and flies were sorted from the first week's sample from each month. All specimens are deposited in the Natural History Museum of Los Angeles County, USA (LACM). Maps were created using Google Earth (Google Earth, 2017).

Analysis

Fly and butterfly specimens were identified to species with only a few exceptions that proved impossible to determine past the generic level. Most bees were determined to the generic level. At each site, richness (S) and abundance were calculated for flower flies, scuttle flies, bees, and butterflies.

We used the Shannon diversity index to calculate species evenness (H) between sites for each taxonomic group (Shannon & Wiener, 1963). Calculations were performed in MS Excel.

Given the large number of scuttle flies present, we were able to calculate a non-metric multidimensional scaling (NMDS) ordination analysis for this group. NMDS was calculated using R with the Vegan package (Oksanen *et al.* 2017; R Core Team, 2017). The data from the pollinator groups were not sufficient to plot in this same way. Instead, we present a more detailed look at the composition of each pollinator group across sites.

Nature Gardens at the NHM

The NHM Nature Gardens are a series of connected habitats designed to attract a diversity of wildlife to the center of urbanized Los Angeles. Construction began in 2012, and the gardens opened to the public the following year. The gardens are constantly evolving as plants grow, die, or are replaced; the degree of management varies depending upon design intent with respect to a naturalistic versus manicured aesthetic. The gardens border the museum on the north and east sides, taking up a three-and-a-half acre space that used to be asphalt parking lots, lawns, and scattered exotic trees (Figs. 1, 2). Included in the gardens are an edible garden, a pollinator meadow, a naturalistic pond, a massive elevated stone planter containing mostly desert species, a seasonally dry creek bed, a birdwatching platform set within a woodland, fountains, a children's area, and an amphitheater. The gardens function as an outdoor extension of the museum; they are at once teaching, research, exhibit, event, and relaxation space. The gardens include over 600 species of plants (excluding seasonal vegetables and annual wildflowers); approximately 60% of these are native to California.

Special attention was given to the planting of host plants to attract pollinators, including many plants from the daisy family (Asteraceae), mint family (Lamiaceae), and rose family (Rosaceae). Many of the floral resources planted are native (for example; eight species of sage, nine species of buckwheat, several California sunflowers, etc.), while others are popular non-native ornamentals including many herbs (four species of lavender and several varieties each of mint, rosemary and thyme, etc.). Additionally, several bee hotels were constructed and erected in the gardens to attract cavity-nesting native bee species. The decision to include a substantial number of non-native plant taxa was made to reflect the "blended nature" that comprises the built landscape of Los Angeles, an acknowledgement of the horticultural history and cultural diversity of the region. The planning team also wanted museum guests to feel welcome and comfortable exploring the gardens; immediate recognition of common landscape plants provided this entree. In most areas of the garden, wood chip mulch is used to conserve moisture, suppress weeds, moderate wide fluctuations in soil temperature, and slowly add organic matter to the soil. The pollinator meadow was left un-mulched so that ground-nesting insects would have easy access to the soil. Originally, organic mulch was installed on top of the Living Wall stone planter but this was later removed to better replicate the sparse organic debris found on the soil surface of desert regions, where most of the Living Wall plants are from. The wall itself was built from imported boulders. In total, 3.2 million pounds of sandstone boulders were imported to construct the Living Wall, pond, and retaining walls. The sandy loam soil from the site was recontoured during construction.

As each section of the gardens was built, soils were sampled prior to planting. In some cases, analysis indicated high concentrations of metals [zinc in particular] known to be harmful to plants. These soils were exported and replaced with soils imported from 5 locations. Irrigation is done by smart controllers made by ET Water. The gardens are broken into 80 zones that are manipulated independently and take into account everything from the maturity of the plantings, the type of vegetation, soil type, and light exposure. The system is linked to a weather satellite to compensate for natural conditions, and is further regulated by a series of algorithms. There are six recharge wells that collect 100% of the storm water. In keeping with the goal to create habitat for wildlife, the Nature Gardens are managed organically. Museum horticulturists use the integrated pest management approach to control troublesome wildlife such as Argentine ants, agave root weevils, aphids, eastern fox squirrels, etc., relying upon beneficial insects and corrective cultural practices to reach equilibrium. Organic fertilizers and compost help correct any nutrient deficiencies and bolster the soil food web.

Five other sites were compared to the NHMLA Nature Gardens: four sites within a five-kilometer radius of the gardens (three backyards and one community garden), and a final backyard site located adjacent to natural habitat (Figs. 3, 4). All sites were part of the 30-site transect of the BioSCAN project in 2014; this analysis includes Site 1 (the NHMLA Nature Gardens), Sites 3, 8, and 10 (nearby backyards), Site 25 (the nearby community garden, hereafter referred to as "community garden") and Site 13 (the backyard site on the periphery of the Los Angeles basin adjacent to natural oak woodland habitat, hereafter referred to as "natural site"). We chose these sites for this analysis to evaluate how the NHMLA Nature Gardens entomofauna compared with natural habitat, and how it differed (or not) from that found in the neighborhoods surrounding the Museum.

In comparison to the flora of the Nature Gardens, the other sites vary significantly. The closest site to the Museum, Site 3, is a backyard that is 50% watered grass lawn, 30% concrete patio, and 20% exotic plantings (approximately fifty species, none are native). This site contains several popular ornamentals known to provide pollen and nectar resources to pollinators, including lavender and rosemary. West of the NHMLA by a few kilometers are Sites 8 and 10; both are sparsely planted with few floral resources. Site 8 is 90% irregularly watered grass lawn, and 10% bushes with a few exotic trees. Site 10 is 40% irregularly watered grass lawn, 60% cement driveway and patio, with no trees or bushes. Site 25, the community Garden, is several kilometers to the northwest of NHMLA and is 50% fruit trees, vegetables and edible greens, 30% bare soil paths, and 20% ornamentals. Finally, sixteen kilometers to the northwest is Site 13, the natural site adjoining native habitat of the Verdugo Mountains. The backyard itself is 25% cement pool, 25% lawn, 50% soil with leaf litter and oak trees. The backyard plantings are a mixture of native and exotic, and include several common floral resources like rosemary and lavender, and at least one native sage. The Malaise trap was located along the hind fence of the backyard at the edge of native habitat. While the acreage across sampling sites varied, we assume that flying insects were being trapped across similar distances, therefore we include satellite imagery of the general vicinity of each site (Appendix II).

Results

Overall trends

Scuttle flies were far more abundant and species rich than any of the pollinator groups (Table 1) (Brown & Hartop, 2016). Scuttle fly numbers were much higher at the natural site and community garden than in the NHMLA Nature Gardens or backyards (Fig. 5, Table 1) and many more species of scuttle fly were present at the natural site than in any of the more urban sites (Fig. 6, Table 1). In contrast, the pollinator groups had both the highest number of species and the highest numbers of individuals present in the Nature Gardens (Appendix I). The Nature Gardens had nearly twice as many species of both flower flies and butterflies as the natural site (Fig. 6, Table 1).

The evenness and Shannon diversity indices (SDI) were calculated for each group across habitat types (Fig. 7, Fig. 8, Table 2). Although the NHMLA Nature Gardens support the highest species richness and abundance for the pollinator groups, evenness was lower than for the natural site and differed from the community garden and backyard sites. This is due to the dominance of a small number of common pollinator taxa in the garden fauna. Many of the taxa represented in the gardens were rare, decreasing evenness but increasing overall richness of the community (Table 2).

Both the flower fly and butterfly diversity indices were highest in the Museum gardens. The bee diversity index was only slightly lower in the gardens when compared with the natural site, but the diversity index for the scuttle flies was much higher at the natural site than at any of the other sites (Fig. 8, Table 2).

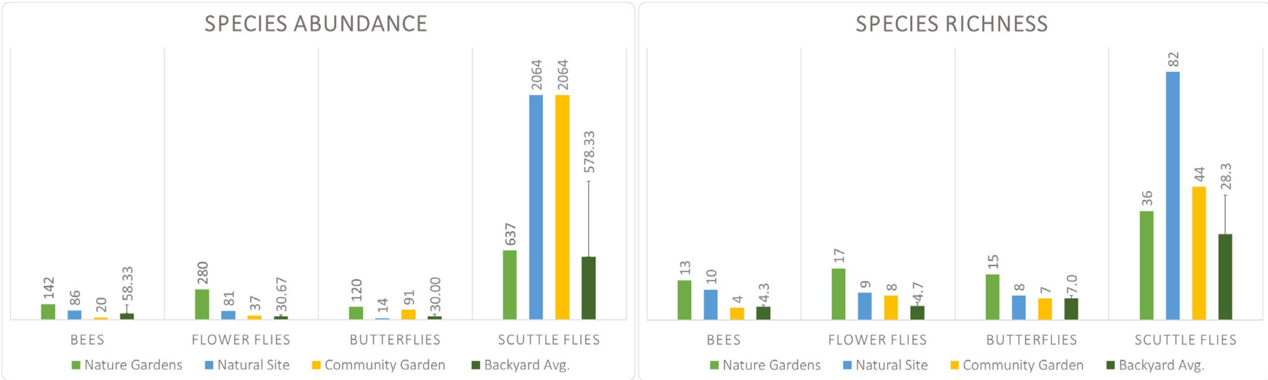

FIGURE 5–6. Species abundance and richness of four study taxa across habitat types.

TABLE 1. Species Richness (S) (left columns) and total abundance (right columns) of four study taxa across six sampling sites.

	Nature Gardens	Natural Site	Community Garden	Site 3	Site 8	Site 10
Bees	13, 142	10, 86	4, 20	5, 148	4, 13	4, 14
Flower Flies	17, 280	9, 81	8, 37	4, 32	4, 44	6, 16
Butterflies	15, 120	8, 14	7, 91	8, 52	6, 24	7, 14
Scuttle Flies	36, 637	82, 2064	44, 2064	43, 1375	19, 105	23, 255

FIGURE 7–8. Evenness and Shannon diversity indices of four study taxa across habitat types.

Using the scuttle fly data, we put the species in ordination space and found that the communities show the clearest division between the natural habitat and the more urban habitats (Fig. 9). This is due, in large part, to the high number of species that are found exclusively at the natural site. The community garden clusters closest to the natural site, and the Nature Gardens and backyards appear to have similar communities. This indicates the same ordered diversity shown in the SDI plot.

TABLE 2. Evenness (left columns) and Shannon diversity (right colums) indices of four study taxa across six sampling sites.

	Nature Gardens	Natural Site	Community Garden	Site 3	Site 8	Site 10
Bees	0.65, 1.66	0.74, 1.70	0.80, 1.11	0.70, 1.12	0.79, 1.09	0.71, 0.99
Flower Flies	0.50, 1.41	0.57, 1.25	0.67, 1.39	0.81, 1.12	0.73, 1.01	0.79, 1.42
Butterflies	0.83, 2.24	0.92, 1.91	0.73, 1.42	0.72, 1.51	0.86, 1.54	0.94, 1.82
Scuttle Flies	0.68, 2.44	0.73, 3.21	0.72, 2.72	0.65, 2.44	0.56, 1.64	0.64, 2.00

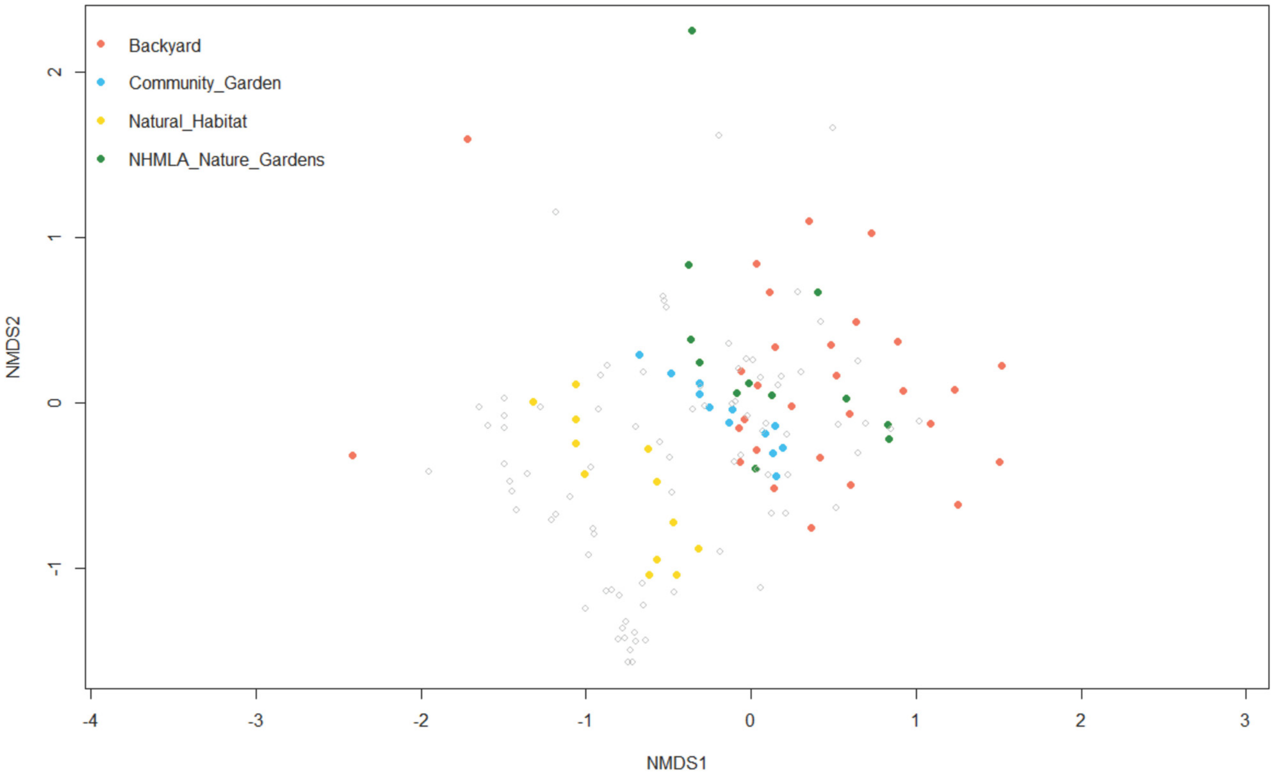

FIGURE 9. NMDS plot of scuttle flies across habitat types. Species are represented by open grey circles, monthly site catches are represented by solid dots colored by habitat type (see legend).

Taxon Composition

The scuttle fly fauna was likely so much more abundant and diverse than the pollinator groups due to their small size; this group was covered in detail by Brown & Hartop (2016). Scuttle flies were found to be dominated by a small number of fungivorous species likely supported by the heavily watered landscapes of Los Angeles.

Bee abundance overall was much higher at the Nature Gardens and Site 3 than the other sites. The natural site had a medium abundance, comparatively, and Sites 8, 10 and the community garden came in far behind in total numbers (Fig. 10). The two overwhelmingly abundant species were ground-nesting sweat bees (*Lasioglossum (Dialictus)* sp.) and the western honey bee (*Apis mellifera*) (Fig. 10).

Despite the high abundance, Site 3 only supported five species of bees compared with the thirteen species found at the Nature Gardens and the ten species found at the natural site (Fig. 11, 12, 14). The Nature Gardens supported five species of bees that were not found at the other sites examined, compared to the natural site's three. Sites 8, 10, and the community garden each supported four species (Figs. 13, 15, 16).

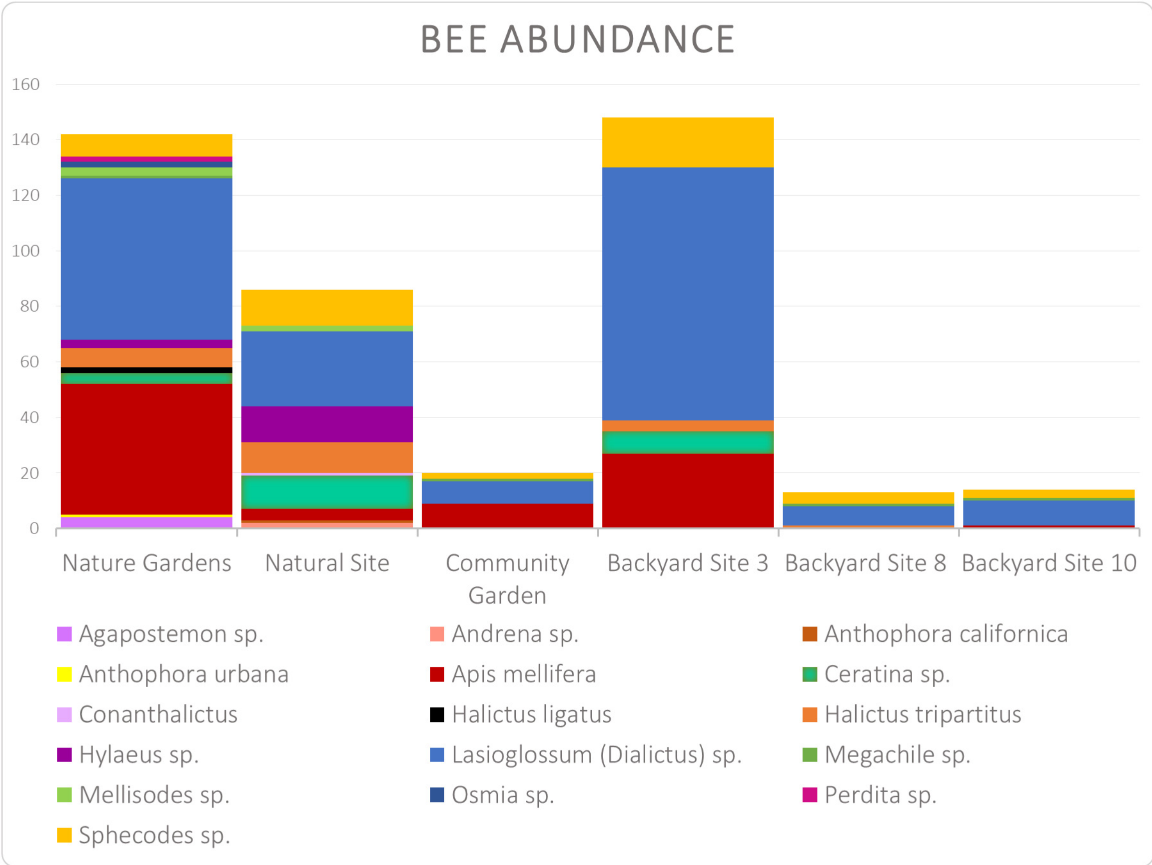

FIGURE 10. Bee abundance across six BioSCAN study sites compiled for 2014.

Flower flies were over three times more abundant at the Nature Gardens than at the next most abundant site, the natural site. Numbers at all four sites close to the museum were much lower still (Fig. 17, Table 1). The flower fly fauna is dominated by the common and widespread species *Dioprosopa clavata* and *Paragus haemorrhous*; both of these species have larvae that are predaceous on aphids (Insecta: Aphidoidea). Removing the large numbers of these two most abundant species and re-plotting (Fig. 18), it can be seen that the third and fourth most common and abundant species are *Allograpta obliqua* and *Toxomerus marginatus*, both of whom also have predaceous aphid-feeding larvae.

The Nature Gardens supported 17 species of flower flies, nearly double the 9 species found at the natural site (Fig. 17, Table 1). Five species were only found in the Nature Gardens. The community garden supported 8 species, while sites 3, 8 and 10 supported 4, 4, and 6 species, respectively.

The butterfly fauna showed high numbers of a diverse number of taxa in the Museum gardens (Fig. 19). The other sites all contained much lower species richness, but varying abundance. The butterfly abundance at the natural site was equal to the abundance at Site 10, the backyard site with the lowest overall diversity and abundance, although species composition differed between these sites.

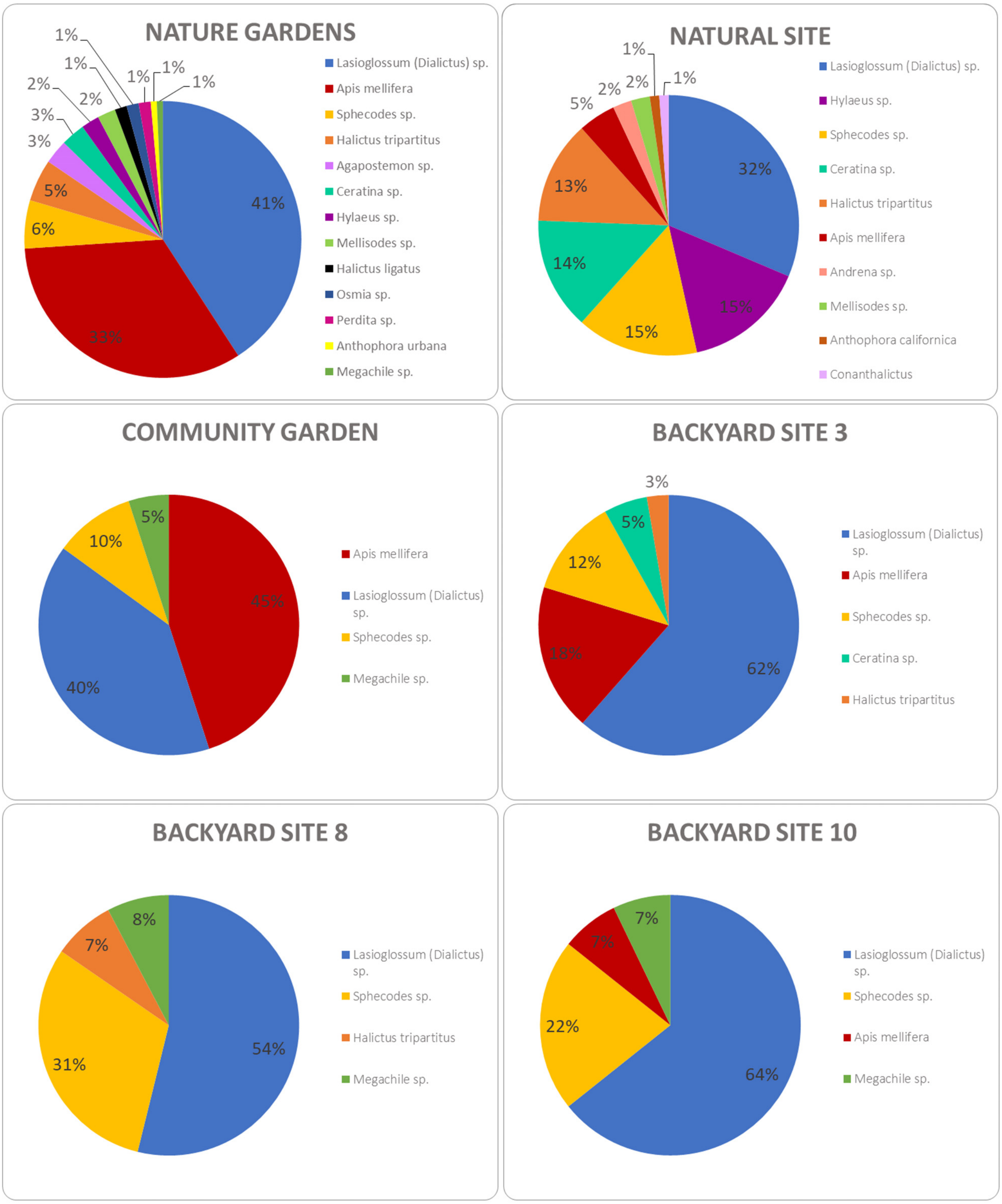

FIGURE 11–16. Bee diversity across six BioSCAN study sites compiled for 2014.

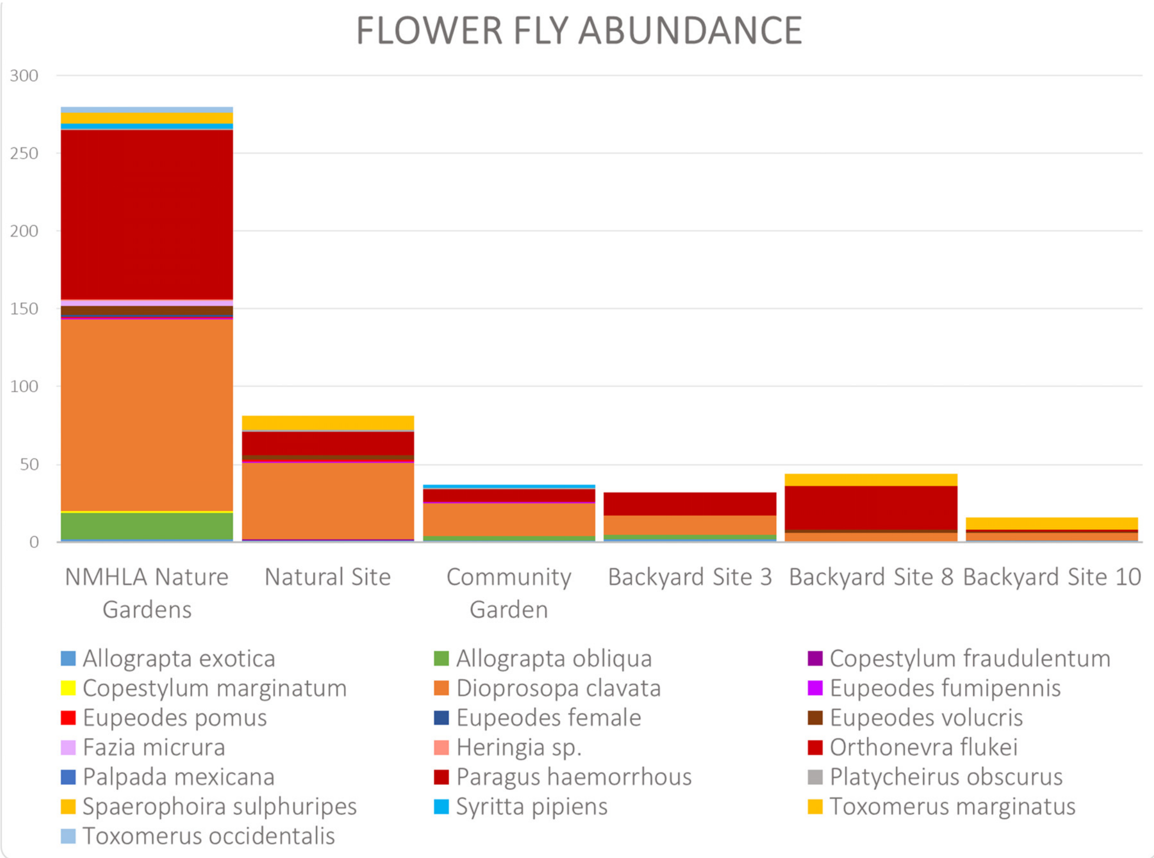

FIGURE 17. Flower fly abundance across six BioSCAN study sites compiled for 2014.

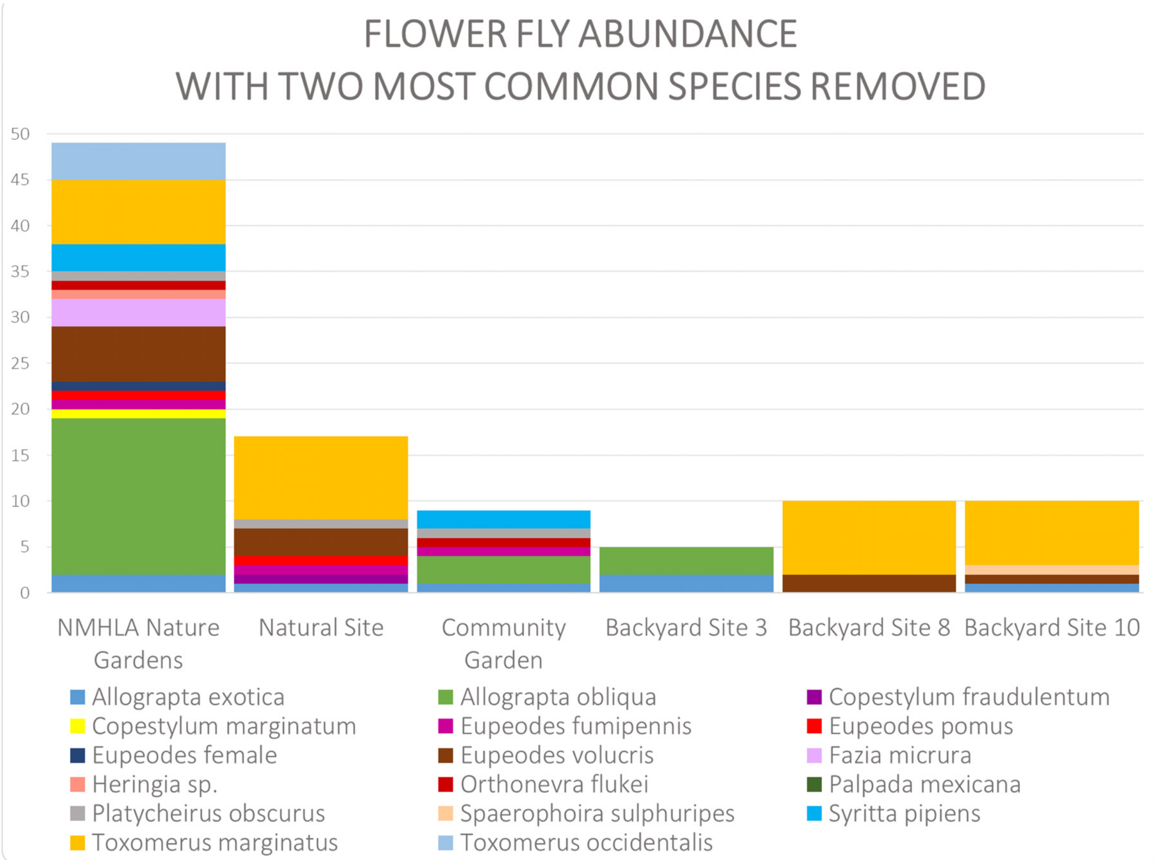

FIGURE 18. Flower fly abundance across six BioSCAN study sites compiled for 2014, with two most common species removed.

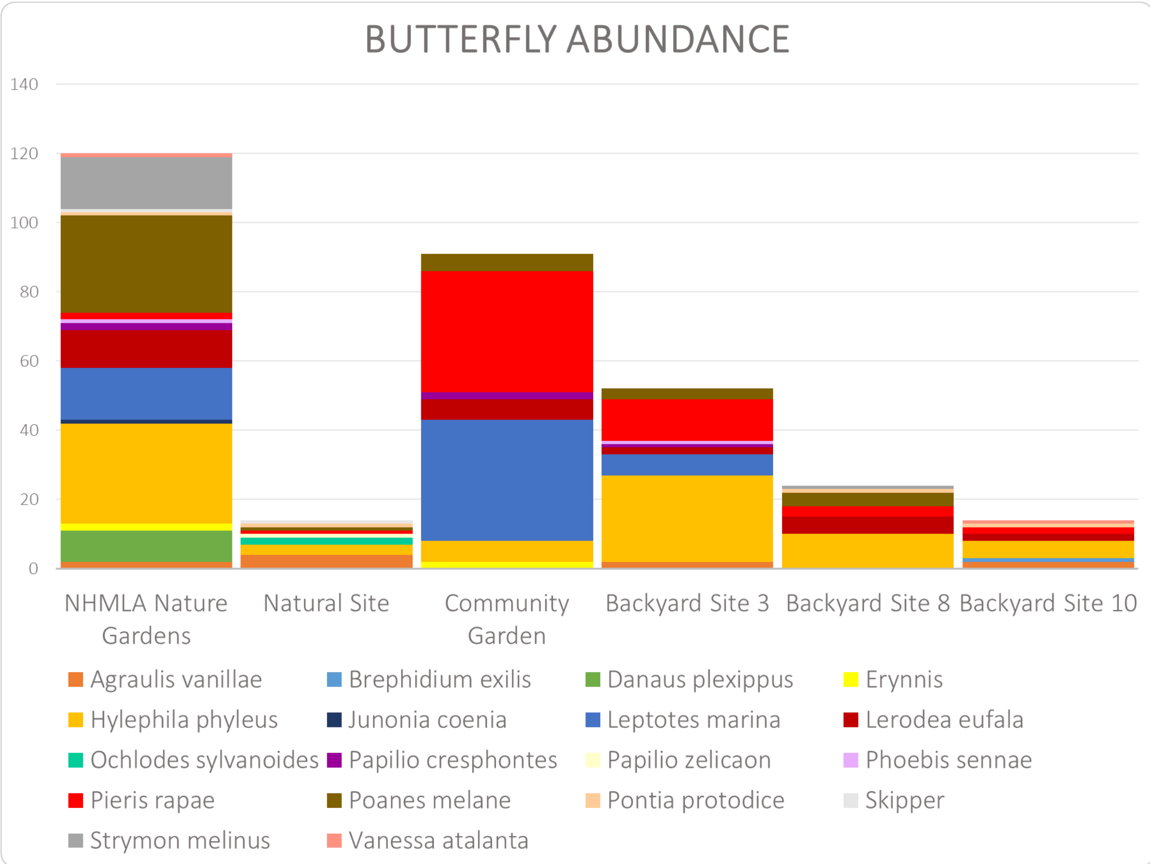

FIGURE 19. Butterfly abundance across six BioSCAN study sites compiled for 2014.

Discussion

The entomofauna of the NHMLA Nature Gardens differs from that of both the nearby sites and of the natural habitat, with the Nature Gardens supporting richer, more abundant communities of the pollinator groups (butterflies, bees and flower flies) overall but many fewer species and individuals of the non-pollinator group (scuttle flies) when compared to those supported by the natural site. The Nature Gardens are clearly succeeding in attracting the pollinator fauna of Los Angeles to the urban core. The high richness and abundance of taxa in the Museum gardens when compared to nearby backyards clearly indicate that the gardens are functioning as a "super-environment" capable of attracting a diverse and plentiful pollinator fauna, thereby creating the "wildlife spectacle" that the gardens were designed to produce.

The high abundance of bees in both the Nature Gardens and at backyard site 3 is likely to be a product of the abundant flora in combination with available substrates for nesting. The two most abundant species, ground-nesting sweat bees and the western honey bee, are both generalists that can utilize the variety of flowers found at the Nature Gardens and backyard site 3 (see Methods). The high numbers of bees at backyard site 3, despite the complete lack of native vegetation, is not surprising given the findings of Matteson & Langellotto (2011) and Salisbury *et al.* (2015, 2017) who found that pollinators utilize exotic species. The presence of large numbers of western honey bees at both sites indicates that a hive was likely in close proximity; honey bee nests are large, with thousands of workers, and require a large structure for attachment. The natural site supported a lower abundance of bees overall (Fig. 10). This may be due to the drought conditions during sampling, as a high diversity of bees was still found at this site indicating resources may be diverse but not plentiful. The low abundance at backyard sites 8 and 10 and the community garden was not surprising, as these sites offer few floral resources for bees (see Methods).

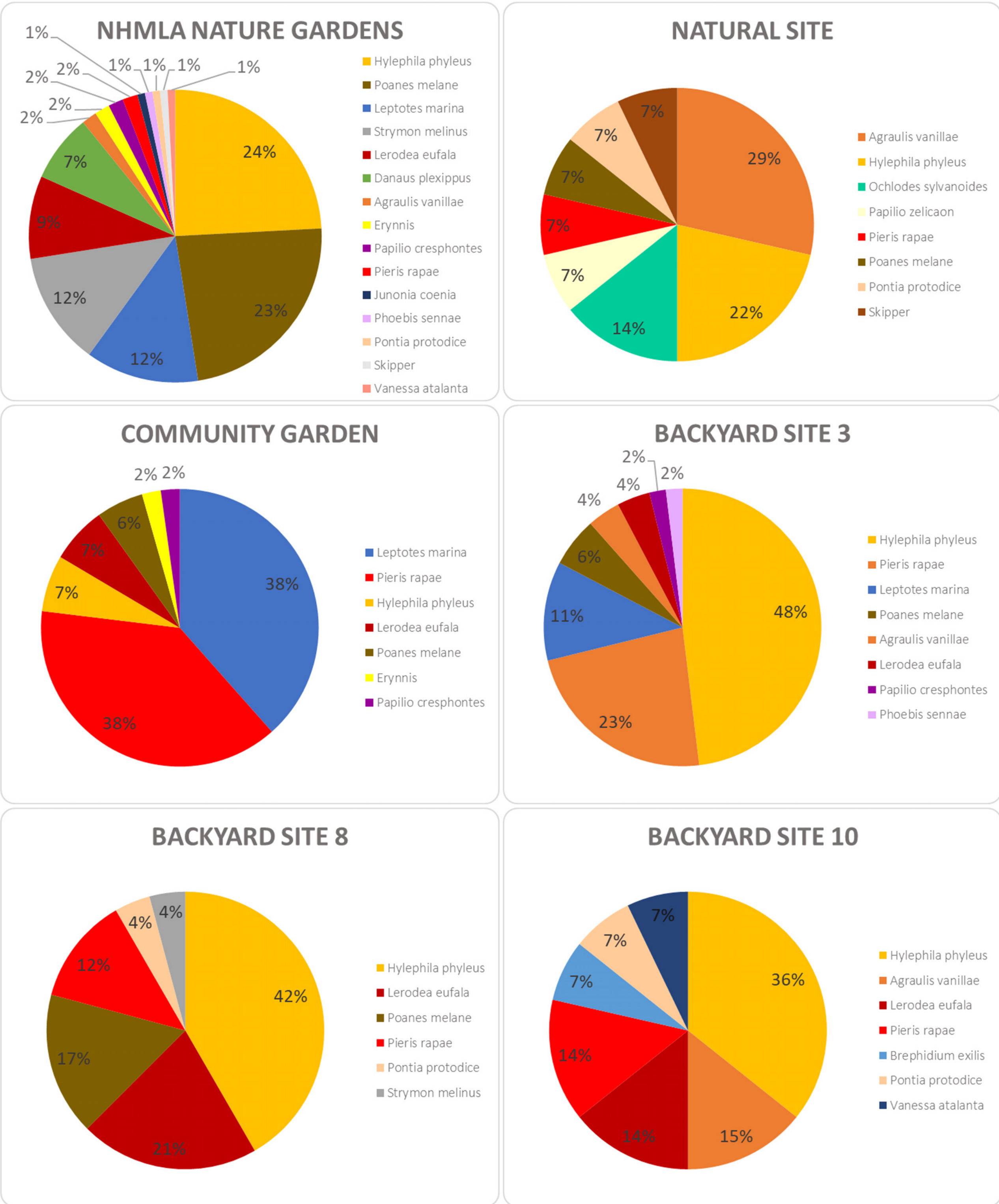

FIGURE 20–25. Butterfly diversity across six BioSCAN study sites compiled for 2014.

In addition to low abundance, backyard sites 8 and 10 and the community garden also supported a low diversity of bees (four species each). This was not surprising given the aforementioned lack of floral resources at these sites. Site 3 supported only five species despite having very high abundance, likely due to the lack of diverse resources at this site (however plentiful). All bee species found at the four low diversity sites are generalists, with ground-nesting sweat bees, the western honey bee, and cuckoo bees (*Sphecodes* sp.)

dominating the fauna. Also found, but in lower numbers, were leaf-cutter bees (*Megachile* sp.), small carpenter bees (*Ceratina* sp.), and sweat bees (*Halictus tripartitus*), all known to utilize a variety of resources for both energy and nesting substrates. It is worth noting that cuckoo bees are kleptoparasites of both *Lasioglossum* and *Halictus*, so their presence is encouraged by the high numbers of bees of the host genera.

The Nature Gardens and the natural site supported higher diversity of bees (13 and 10 species, respectively), likely due to more diverse resources at these sites. Both of these sites supported the six species found at the low-diversity sites, with the one exception that leaf-cutter bees (*Megachile* sp.) were absent from the natural site. In addition to the six common species, both of the high-diversity sites had *Hylaeus* sp. and long-horned bees (*Mellisodes* sp.). Long-horned bees are often specialists on flowers in the sunflower family (Asteraceae), so it is not surprising to find them in the Nature Gardens (where a number of species from this family are planted, see Methods), or adjacent to natural habitat where many species of California natives of this family may occur. The three species of bees found only at the natural site (mining bees (*Andrena* sp.), *Anthophora californica*, and another genus of sweat bees (*Conanthalictus* sp.)) are all ground-nesting, and the presence of these bees may be indicative of the availability of preferred nesting substrate in addition to floral resources. Species of *Conanthalictus* are known to be oligolectic specialists on flowers in the Hydrophylloideae (a subfamily of the Boraginaceae), so these bees may be dependent on native resources in the adjoining natural habitat (Michener 2007). Four bees were found only in the Nature Gardens: metallic sweat bees (*Agapostemon* sp.), mason bees (*Osmia* sp.), *Perdita* sp., and *Anthophora urbana*. Although we cannot know for certain if associations with specific host plants or nesting substrates is responsible for the presence of these taxa at this time, the *Agapostemon* sp. are frequently seen on the native flowering mallow species in the Gardens and the *Osmia* sp. have been observed utilizing the provided bee hotels, so these resources are certainly contributing to the abundance of these species.

Our results indicate that pollinator-targeted management had the desired effect of a richer, more abundant bee fauna in the Nature Gardens, similar to the findings of Frankie *et al.* (2009) and Pawelek *et al.* (2009). The specific factors responsible (floral and nesting resources, availability of water, etc.), and to what extent, we hope to examine further in future work.

The domination of the flower fly fauna by *Dioprosopa clavata* and *Paragus haemorrhous* (both common and widespread species with aphid-feeding larvae) indicates that the abundance of flower flies is likely influenced by the presence of flora that support aphid communities as well as the presence of nectar resources for adults. Similarly, a 2009 survey of flower flies in the mountains surrounding the Los Angeles basin found that the most common species found were also all aphid feeders as larvae (*Eupeodes fumipennis*, *Paragus haemorrhous*, and *Eupeodes volucris*) (Brown *et al.*, 2011). Only one of these species (*Paragus haemorrhous*) was found in high abundance in both studies; both *Eupeodes* species were found less frequently and in much lower numbers in our urban transects than in the local mountains. The differences between these studies indicate that, while aphid-feeding as a larval strategy may be advantageous in the Los Angeles region, other factors are clearly at work in determining abundance across the cityscape.

Butterfly presence/absence is tightly correlated with larval host plant presence/absence, and with nectar availability. The NHMLA Nature Gardens supported the highest abundance of butterflies in comparison to the other sites, and supported the highest species diversity. This indicates that the large number of native plants growing in the Nature Gardens provide larval host plant habitat for a number of butterfly species, and that butterflies from around the urban Los Angeles core have been successful at colonizing the garden. While all of the butterfly species found at the garden are ruderal and are commonly found throughout the Los Angeles Basin, including the urbanized portions, the garden is supporting a more abundant butterfly fauna than a typical backyard. However, many species that have been documented in mountainous wildlands surrounding the urban basin were not found in the Nature Gardens, even when their host plants were present (Bonebrake and Cooper, 2014). It remains to be seen whether these species may colonize the Nature Gardens given enough time, or if the dispersal distance is too great from existing populations.

Only three butterfly species identified in this study were absent from the Nature Gardens: the anise swallowtail, *Papilio zelicaon*; western pygmy-blue, *Brephidium exilis*; and the woodland skipper, *Ochlodes sylvanoides*. The absence of *P. zelicaon* from the Nature Gardens is interesting, considering that this species utilizes host plants commonly found in and around the Nature Gardens (including members of the parsley and citrus families), and there is no obvious explanation for this absence. *P. zelicaon* was found at the natural site, albeit in low abundance. The absence of *B. exilis* from the Nature Gardens is similarly interesting, as the Gardens contain several hosts plants from the goosefoot family (*Chenopodiaceae)* including a couple large specimens of *Atriplex lentiformis*. This butterfly species was only found at one of the backyard sites (10), and in low abundance. One other species, *O. sylvanoides*, was found only at the natural site. This species is common in chaparral areas such as the wildland areas surrounding the urban core of Los Angeles, and the larvae feed on various grasses. Although the NHMLA Nature Gardens include numerous types of native grasses, this butterfly species was absent, again possibly due to dispersal distance.

The large discrepancy between both species richness and abundance between the Nature Gardens and the natural site for the butterflies is notable. It is possible that this observation is, at least in part, a result of the historic five-year drought that this region was experiencing at the time of the study. Because the Nature Gardens' plants were watered to maintain good health, pollinators inhabiting this landscape experienced an almost constant supply of nectar for adults, and larval host plants were healthier and more abundant than most plants in the wildlands surrounding the urban core. The natural site exhibited the lowest butterfly abundance of any of the study areas, including the backyard sites that contained very little vegetation (Sites 8 and 10). However, the species recorded at those sites largely consisted of generalists (e.g. *S. melinus, P. rapae*) and grass-feeding skippers (*H. phyleus, L. eufala, P. melane*). In fact, the most abundant butterfly species at any of the three backyard sites was *H. phyleus*, the fiery skipper, which is commonly known to utilize Bermuda grass and other lawn grasses as its larval host plant, and tends to thrive in urban and suburban areas. Arguably the only specialist butterfly found at any of the backyard sites, the gulf fritillary (*A. vanillae*), uses passion vine (*Passiflora* spp.) as its larval host plant. *Passiflora* is common and well-established across Los Angeles, and this butterfly species is a strong flyer, making its presence at these sites unremarkable.

The high abundance and diversity of pollinator taxa in the NHMLA Nature Gardens show that the gardens are behaving as a diverse refuge for the pollinator groups of Los Angeles. However, the low abundance and diversity of scuttle flies in the gardens when compared to the natural site indicates that the natural ecosystem is not being recreated. Rather, our analysis finds that through careful construction and maintenance of a manufactured environment it is possible to create the "wildlife spectacle" desired for targeted groups. Future work on this data will focus on factors of urbanization and garden creation that selectively impact biodiversity for different groups. Additionally, continued work on pollinator groups may include supplemental trapping to complement the "catch everything that flies" method of Malaise trapping that was herein employed for the larger purpose of the BioSCAN general inventory.

Our results show that a habitat isolated in an urban environment can be managed to increase local pollinator diversity, as was suggested by Matteson & Langellotto (2010). In fact, we show that an isolated oasis of resources in the urban core of a cityscape can actually support *higher* diversity and abundance of targeted groups than either the surrounding areas or nearby natural habitat! This indicates that the increase of some aspects of biodiversity in our cities may be, to some extent, within our control as homeowners and stewards of gardens and other green spaces.

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APPENDIX I. Pollinator catch across sites

	NHMLA Nature Gardens	Natural Site	Community Garden	Backyard Site 3	Backyard Site 8	Backyard Site 10
Bees						
Agapostemon sp.	4	0	0	0	0	0
Andrena sp.	0	2	0	0	0	0
Anthophora californica	0	1	0	0	0	0
Anthophora urbana	1	0	0	0	0	0
Apis mellifera	47	4	9	27	0	1
Ceratina sp.	4	12	0	8	0	0
Conanthalictus sp.	0	1	0	0	0	0
Halictus ligatus	2	0	0	0	0	0
Halictus tripartitus	7	11	0	4	1	0
Hylaeus sp.	3	13	0	0	0	0
Lasioglossum (*Dialictus*) sp.	58	27	8	91	7	9
Megachile sp.	1	0	1	0	1	1
Mellisodes sp.	3	2	0	0	0	0
Osmia sp.	2	0	0	0	0	0
Perdita sp.	2	0	0	0	0	0
Sphecodes sp.	8	13	2	18	4	3
Flower Flies						
Allograpta exotica	2	1	1	2	0	1
Allograpta obliqua	17	0	3	3	0	0
Copestylum fraudulentum	0	1	0	0	0	0
Copestylum marginatum	1	0	0	0	0	0
Dioprosopa clavata	123	49	21	12	6	5
Eupeodes fumipennis	1	1	1	0	0	0
Eupeodes pomus	1	1	0	0	0	0
Eupeodes female	1	0	0	0	0	0
Eupeodes volucris	6	3	0	0	2	1
Fazia micrura	3	0	0	0	0	0
Heringia sp.	1	0	0	0	0	0
Orthonevra flukei	1	0	1	0	0	0
Palpada mexicana	0	0	0	0	0	0
Paragus haemorrhous	108	15	7	15	28	1
Platycheirus obscurus	1	1	1	0	0	0
Spaerophoira sulphuripes	0	0	0	0	0	1
Syritta pipiens	3	0	2	0	0	0
Toxomerus marginatus	7	9	0	0	8	7
Toxomerus occidentalis	4	0	0	0	0	0
Butterflies						
Agraulis vanillae	2	4	0	2	0	2
Brephidium exilis	0	0	0	0	0	1

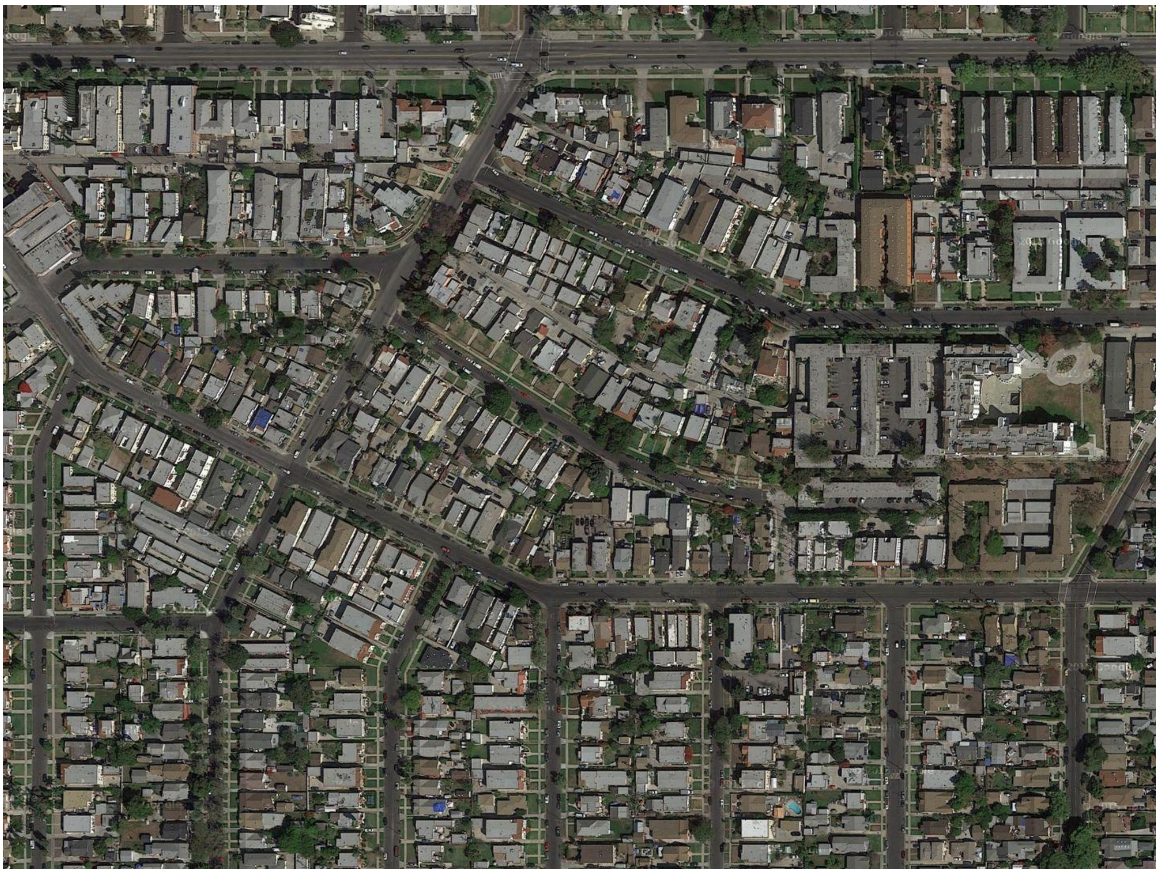
...Continued on next page

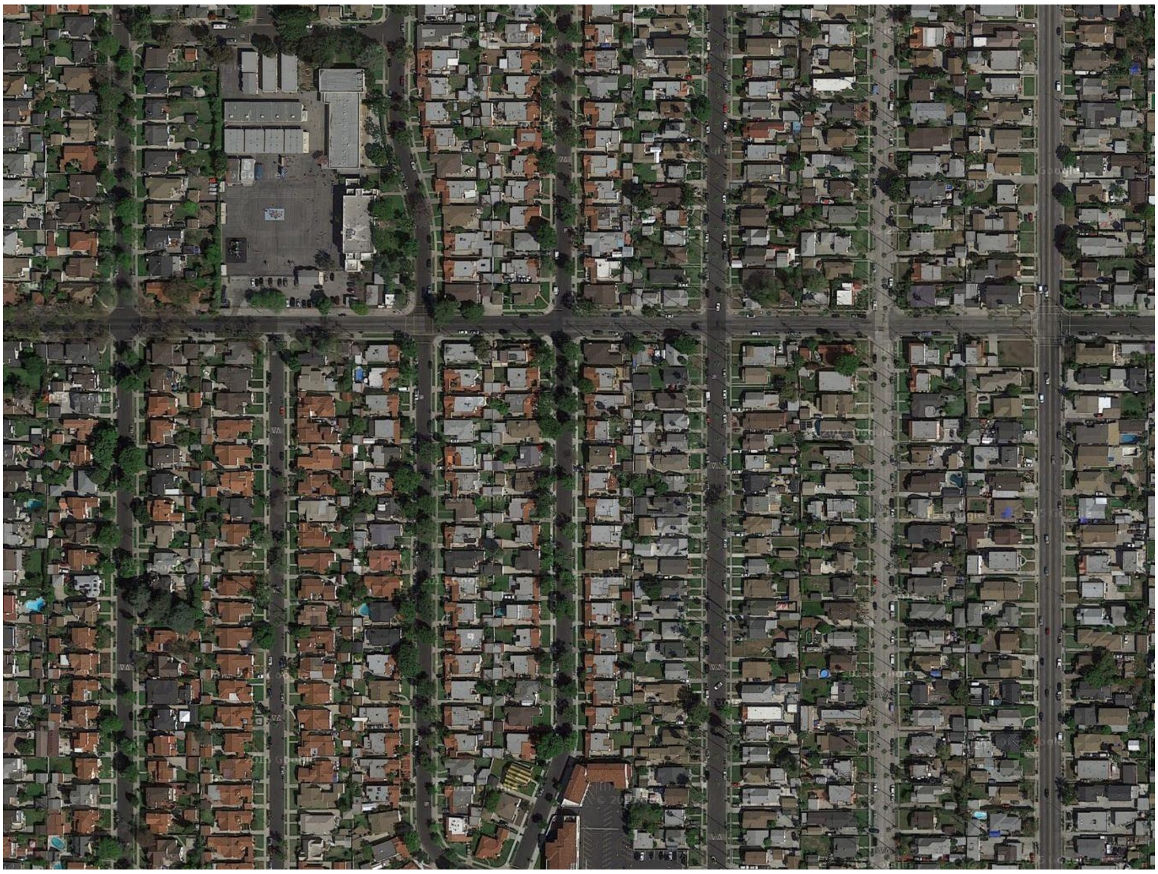
APPENDIX 1. (Continued)

	NHMLA Nature Gardens	Natural Site	Community Garden	Backyard Site 3	Backyard Site 8	Backyard Site 10
Danaus plexippus	9	0	0	0	0	0
Erynnis sp.	2	0	2	0	0	0
Hylephila phyleus	29	3	6	25	10	5
Junonia coenia	1	0	0	0	0	0
Leptotes marina	15	0	35	6	0	0
Lerodea eufala	11	0	6	2	5	2
Ochlodes sylvanoides	0	2	0	0	0	0
Papilio cresphontes	2	0	2	1	0	0
Papilio zelicaon	0	1	0	0	0	0
Phoebis sennae	1	0	0	1	0	0
Pieris rapae	2	1	35	12	3	2
Poanes melane	28	1	5	3	4	0
Pontia protodice	1	1	0	0	1	1
Skipper sp.	1	1	0	0	0	0
Strymon melinus	15	0	0	0	1	0
Vanessa atalanta	1	0	0	0	0	1

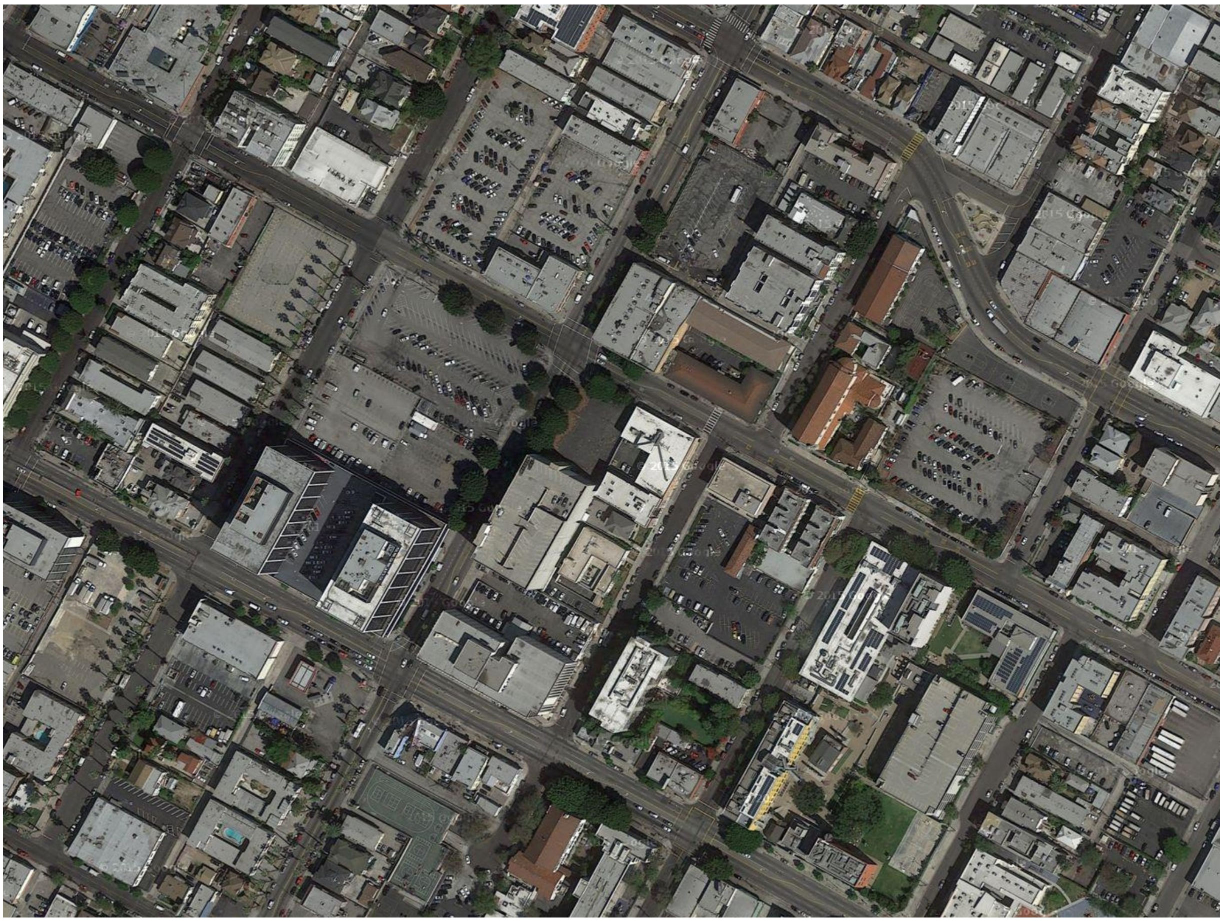
APPENDIX II. Satellite images showing general vicinity of sites

Sites 1 (NHMLA Nature Gardens), 3





Sites 8, 10



Sites 13 (natural site), 25 (community garden)