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Cover Photograph: A dish of spiders in ethanol from among the thousands submitted to the Los Angeles Spider Survey. Photograph © Kelsey Bailey.

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Urban Spider Diversity in Los Angeles Assessed Using a Community Science Approach

Janet K. Kempf[1], Benjamin J. Adams[1,2], and Brian V. Brown[1*]

Abstract - Spiders are ubiquitous organisms in all but the most hostile terrestrial environments and are frequently encountered in urban areas. Assessing spider diversity in cities can require a significant investment of time and resources because the majority of the land is privately owned and fragmented into thousands of difficult-to-access properties. To overcome these challenges, the Natural History Museum of Los Angeles County began the Los Angeles Spider Survey in May 2002. This project, using a community (= citizen) science collecting approach, attempts to inventory the fauna and assess the prevalence of introduced spiders in the greater Los Angeles area. Through 2016, a total of 6,896 spiders have been collected, representing 241 species or morphospecies in 39 families. Nine species, including some of medical importance, represented new records for the area at the time of collection. A comparison to a survey performed in 1904 shows larger changes in the spider fauna.

Introduction

Spiders are an important part of terrestrial ecosystems. They exist in vast numbers in virtually any habitat and are the primary predators of equally common insects. Their small size and ecological flexibility allow them to exist in urban areas at high population levels, even inside buildings and homes (Bertone et al. 2016). Some are highly synanthropic, rarely occurring outside of close association with humans. These factors make spider introductions into new areas a frequent, worldwide phenomenon.

In spite of their importance and abundance, there have been few large-scale surveys of urban spiders (Fraser and Frankie 1986; Shochat et al. 2004; but see Lowe et al. 2014, 2018; Varet et al. 2014). As one of the largest international port cities in the USA, as well as a city with high levels of human immigration and exotic tropical landscaping, Los Angeles represents a prime candidate for documenting urban spider diversity and exploring accidental introduction of new species from other parts of the world. In fact, several of the most common spiders in Los Angeles probably have been introduced over the last hundred years because of these factors. During this same period, urbanization has extended throughout the city and county of Los Angeles and into surrounding counties, replacing many natural areas and former agricultural areas and their spider faunas.

Previously, there were no truly large collections of urban spiders from the Los Angeles urban area, as most collectors concentrated on studying natural areas, nor are there any ongoing studies to monitor the spider populations in Los Angeles (other than ours). Los Angeles area spiders in the NHM collections tend to be from natural areas, collected in small numbers as part of entomological surveys for other organisms.

Because of the venom they use to subdue their prey, spiders provoke a level of concern above that raised by most small arthropods. Often, the public attribute almost any unexplained lesions, bumps, or other irregularities of the skin to "spider bites", even though no

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spider was seen or captured. As a result, spiders are the most common subjects of inquiry to the Natural History Museum of Los Angeles County's (NHM) entomology staff, principally through concerns about Brown Recluse spiders (*Loxosceles reclusa* Gertsch & Mulaik), Black Widows (*Latrodectus hesperus* Chamberlin & Ivie), and Brown Widows (*Latrodectus geometricus* Koch). These inquiries have the potential to reveal important information about spider occurrences throughout the greater Los Angeles urban area if documented, but they have mostly been overlooked.

In this paper, we discuss past and ongoing efforts to improve the understanding of spider species composition in Los Angeles. We show that the urban spider community is diverse and composed of both native and introduced species; however, the most commonly encountered spiders in urban environments are often introduced species. Also, we compare our current efforts to historical surveys to consider how urbanization is continuing to impact and change the Los Angeles metropolitan area spider community. Finally, we demonstrate that involving community scientists can greatly increase the reach of museum efforts.

Methods

Most of the spiders from our study were collected for the NHM Los Angeles Spider Survey (LASS), the first large-scale, ongoing study of urban spiders in Los Angeles. The public were invited to participate as community scientists by collecting spiders in their houses and gardens and bringing them to the museum, along with their recorded collection data. The goal of the LASS is to determine the makeup of the current spider fauna of the greater Los Angeles area, to evaluate the incidence of introduced spiders, and to determine how widespread introduced species are in the urban landscape.

The LASS (also called "the survey") was begun during the NHM's annual Bug Fair in May 2002. The survey was publicized in local newspapers, on radio and television, in museum publications, on the museum's website, and at museum events. Detailed information about the survey, how to participate, and how to safely catch spiders was included on the museum's website together with a form for recording collection data. The spiders in the study were collected by members of the general public in their houses, gardens, and other urban areas, and in survey-led collecting events. Although the survey was originally designed to cover only Los Angeles County, public interest and participation have resulted in submissions of spiders from throughout the greater Los Angeles area, including northern Orange, western Ventura, Riverside, and San Bernardino counties.

Geographically, the greater Los Angeles area is a hilly coastal plain bounded by the Santa Monica Mountains to the north, the San Gabriel Mountains to the east, and the Pacific Ocean on the south and west. Most of the area within the basin is now urban and suburban housing or commercial zones. The Los Angeles River and its tributaries wander from the mountains to the ocean. Many areas along its banks have returned to semi-natural landscapes. The mountain ranges, as well as several areas within the urban landscape, are relatively undeveloped.

In addition to the urban collections, data from several surveys of natural areas have been included. These additional data include collections made during surveys conducted for the Santa Monica Mountains Recreation Area (SMMNRA), for a National Geographic BioBlitz in 2008 (also in the SMMRA), at the Nature Gardens of the NHM, at Griffith Park, and along the Los Angeles River. Spiders collected as part of surveys done by other agencies and submitted to NHM's Department of Entomology for identification and archiving have also been included in this survey report. These data include spiders collected during surveys at the James San Jacinto

Mountains Reserve, the Burns Piñon Ridge Reserve in the Mojave Desert, Placerita Canyon Nature Area, and the Santa Rosa Plateau in southern Riverside County as well as a survey of tortoise burrows at Fort Irwin and collections from field entomology classes at Santa Monica College.

Given the community science approach, the LASS is not intended to be a comprehensive, structured survey of spider diversity. Collection methods were described on the museum's website, but no attempt was made to standardize the public's collection techniques. There are inherent biases in the collection methods since spiders collected by the public have tended to be those most often encountered in houses and gardens and those that are larger in size. Less common spiders, smaller species, and those occupying cryptic habitats, such as within leaf litter or under rocks, are probably underrepresented but were specifically targeted by LASS staff during any group collections. Formal surveys conducted in the SMMNRA and during a National Geographic BioBlitz are more representative of actual populations since standard collecting procedures were followed, including hand collecting, sweeping, beating, pitfall trapping, and leaf litter sifting. However, these collections represent a much smaller portion of the total number of spiders collected and were in no way collected strategically to function as a comparison to the ongoing LASS survey. Collections from the Santa Rosa Plateau and Placerita Canyon were submitted to the museum without any further data. Spiders from various field entomology classes were collected as bycatch in general insect surveys, similar to collection methods of LASS participants.

When received, each specimen was assigned an original spider survey number and identified, and the collection data were entered into the survey database. The spiders are stored in 75% ethanol in the collections of the NHM Entomology Department. Data are stored in the NHM KEmu database.

Results

The public reaction to the announcement of the LASS was overwhelming and heartening. On the first weekend of sample collection, ~1,000 spiders were contributed. Over 500 individuals or families have participated. In terms of geographic inclusion, a much larger coverage of the city was attained than could have been done by the few staff in the NHM Department of Entomology. From May 2002 to January 2016, a total of 6,896 individual spiders were collected. As expected, the majority of spiders were collected outdoors, largely around gardens, garages, and fences. However, 1,360 spiders were collected indoors. Female spiders were collected slightly more frequently than male spiders, with females representing about 60% of individuals that could be sexed. To our knowledge, no spider bites or other injuries took place in the collection of these specimens.

We identified a total of 4,861 individual spiders to 241 species or morphospecies representing 125 genera in 39 families collected in the greater Los Angeles area (Supplemental Table 1, available online at https://eaglehill.us/URNAonline2/suppl-files/urna-180-Brown-s1.pdf). The 10 most common families accounted for 50% of all the spiders collected, and the 10 most commonly collected species (Table 1) accounted for 52% of all spiders identified. The 10 most commonly collected spiders were almost exclusively urban and were in 7 families and 9 genera. Eight of the 10 are introduced species and were collected mostly in urban areas, but *Parasteatoda tepidariorum* was also collected in the SMMNRA. The 2 native species, *Hololena curta* and *Latrodectus hesperus*, were both widespread and found in all areas. Approximately 14% of all species recorded during the LASS were classified as introduced.

Many of the submitted specimens were immature (n = 2,028), and those specimens have been identified only to family level. A small number of specimens remain unidentified (n = 7). We were able to determine the sex of many of the spiders we examined, even if we could not always identify them to species. The survey recorded 2,286 females and 1,555 males, which includes adult spiders identified to species and immature spiders that were identified to genus.

The following 10 families were the most commonly collected and identified during the survey:

Theridiidae: With 1,427 spiders collected in 8 genera and 34 species or morphospecies, this family is the most common found in the survey. The various species are widespread in urban areas and/or natural areas. Three species, *Euryopis californica*, *Euryopis formosa*, and *Steatoda fulva*, were only collected in desert areas. Three of the most common (*Latrodectus geometricus*, *P. tepidariorum*, and *Steatoda grossa*) are introduced species. *Latrodectus hesperus*, a native species, was one of the most common spiders collected, but most of these specimens were collected during the first years of the survey. By 2005, they were not collected except in natural areas. The introduced *L. geometricus*, which was first collected by NHM staff in 2003, was found in increasing numbers throughout the area (Fig. 1).

Pholcidae: Six species or morphospecies are represented in the survey. *Psilochorus utahensis*, a native species, was collected in the SMMNRA and the desert. Both *Pholcus phalangioides* and *Holocnemus pluchei* are introduced, cosmopolitan, synanthropic species and found only in urban areas.

Gnaphosidae: Twenty-nine species or morphospecies in 12 genera were collected. Members of this family are widespread throughout the survey area. Gnaphosids found only in the desert include *Gnaphosa dentata*, *Haplodrassus eunis*, *Haplodrassus maculatus*, and *Nodocion utus*. Three species are introduced and synanthropic: *Urozelotes rusticus*, *Trachyzelotes lyonneti*, and *Scotophaeus blackwalli*. Of these, *S. blackwalli* is one of the most commonly collected spiders in the survey.

Agelenidae: Ten species or morphospecies in 4 genera are represented in the survey. *Hololena curta* was by far the most numerous and was widespread throughout the area. All Agelenids are native except for the *Tegenaria* species.

Table 1. The ten most commonly collected spiders during the Los Angeles Spider Survey.

Family	Species	Count	Percentage
Theridiidae	*Steatoda grossa* (C. L. Koch)	594	12.2
Pholcidae	*Pholcus phalangioides* (Fuesslin)	373	7.7
Agelenidae	*Hololena curta* (McCook)	284	5.8
Theridiidae	*Parasteatoda tepidariorum* (C. L. Koch)	213	4.4
Gnaphosidae	*Scotophaeus blackwalli* (Thorell)	209	4.3
Theridiidae	*Latrodectus hesperus* Chamberlin and Ivie	195	4.0
Eutichuridae	*Cheiracanthium mildei* L. Koch	193	4.0
Oecobiidae	*Oecobius navus* Blackwall	162	3.3
Theridiidae	*Latrodectus geometricus* C. L. Koch	159	3.3
Amphinectidae	*Metaltella simoni* (Keyserling)	155	3.2

Araneidae: These spiders are among the most noticeable because of their orb webs. They are represented by 12 genera and 35 species or morphospecies. Most are native species; exceptions are *Neoscona crucifera* and *Zygiella x-notata* as well as the recently introduced *Larinioides sclopetarius* and *Metazygia zilloides*. Most species are widespread. Several species were found only in natural areas.

Salticidae: Thirty-four species or morphospecies in 17 genera were collected, primarily in urban areas. Nine species were found in natural areas, and 4 of these species were found only in the desert. With 3 exceptions, these widespread spiders are native to the area. The exceptions are *Menemerus bivittatus*, *Plexippus paykulli*, and *Mexigonus minutus*. Of these, *M. minutus* is a new record for Los Angeles.

Lycosidae: Eight genera and 18 species or morphospecies of lycosid were collected. These spiders are widespread throughout the area of the survey.

Eutichuridae: Both species in this family collected in the survey, *Cheiracanthium mildei* and *Cheiracanthium inclusum*, are introduced. Although *C. inclusum* has previously been recorded as common in the area (Edwards 1958), only 1 specimen was collected in the survey, in Griffith Park. *Cheiracanthium mildei* is one of the most common spiders collected and is found exclusively in urban areas.

Oecobiidae: One genus, Oecobius, was represented by one described species (*O. navus*) and one further morphospecies. Found only in urban areas, both were probably introduced from elsewhere. They were remarkably commonly collected (n = 162), given their small size.

Amphinectidae: One introduced species, *Metaltella simoni*, was first collected in the mid-1990s in urban Riverside County and is now widespread in the area.

Significant Single Site Collections

Excluding collections made by the authors, several participating community scientists, dubbed "super spider collectors", collected in their homes and gardens over several months, submitting hundreds of spiders to the survey. Some sent individual spiders to the museum as they were collected, while others submitted their accumulated collection at the end of several months. The top 6 collectors, based on number of spiders submitted and length of time they each collected, each submitted over 100 individual spiders (mean ± SD = 180 ± 50;

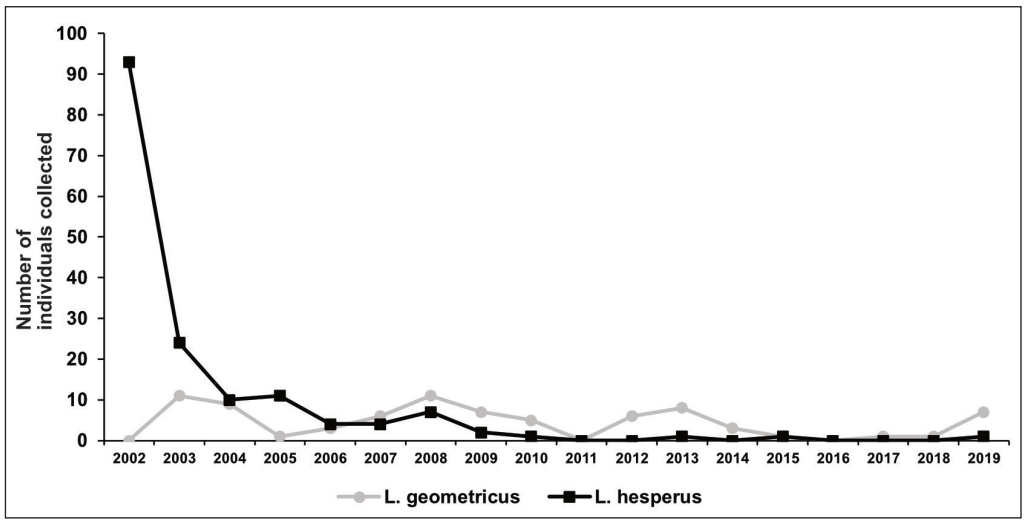

Figure 1. Collections of introduced *Latrodectus geometricus* (gray circles) and native *Latrodectus hesperus* (black squares) from 2002–2019.

range = 138–260 spiders) and collectively submitted a total of 1,077 spiders representing 112 species or morphospecies from 72 genera in 34 families. These super spider collectors on average submitted 31 ± 11 (mean ± SD) species from their homes.

Four species were collected in all super spider collector homes and gardens: *C. mildei*, *P. phalangioides*, *P. tepidariorum*, and *S. grossa*. All are introduced species and among the most common collected in the survey. Four additional spiders were represented in 5 of the 6 large collections: *H. curta*, *Dysdera crocata*, *S. blackwalli*, and *M. bivittatus*. Another 2 were present in 4 collections: *Anyphaena pacifica* and *L. hesperus*.

Faunal Changes During the Survey (2002–2016)

One notable change has taken place in the fauna during the survey: the southern African Brown Widow, *L. geometricus*, was encountered in the southern part of Los Angeles County (in Torrance) in 2003 and later in other nearby cities. It was then recorded across the entire Los Angeles area in 2007, being found in Encino and San Gabriel, both in the northern part of the county. Today, it is ubiquitous in Los Angeles (Vetter et al. 2012, Vincent et al. 2009).

Announcements of other, less spectacular, introductions were also reported as a result of the LASS (Martinez et al. 2014, Vetter et al. 2008). Several species were new records for the Los Angeles area (Table 2). Significantly, most of these spiders were collected in the Long Beach area near the Port of Los Angeles.

Faunal Changes Since 1904

Banks (1904) reviewed existing collections in California and published a list of 74 species found in southern California. His review is not as representative as our survey of the modern spider fauna in southern California, since it was limited in both area surveyed and duration of collection effort, while the LASS represents several years of collecting over a much greater area. In the Banks's review, most of the spiders collected were from Claremont (eastern Los Angeles County) or "just" Los Angeles with no further locality description. Banks reported 74 species in 23 families and 62 genera. Many records represent just a single genus and 1 or 2 individual spiders.

Five families collected in large numbers in our survey were not represented in Banks's review. Of these, Anyphaenidae and Tengellidae are native to the area; Dysderidae, Desidae, and Amphinectidae have been introduced. Of the 74 species reported by Banks to occur in southern California, 47 have been collected in the survey and 28 have not (Table 3).

Table 2. New records of spiders for the Los Angeles area.

Family	Species	Location
Araneidae	*Larinioides sclopetarius* (Clerck)	Long Beach
Araneidae	*Metazygia wittfeldae* (McCook)	Long Beach
Araneidae	*Metazygia zilloides* (Banks)	Long Beach
Linyphiidae	*Tenuiphantes tenuis* (Blackwall)	Los Angeles
Salticidae	*Mexigonus minutus* (F. O. Pickard-Cambridge)	Santa Monica
Salticidae	*Plexippus paykulli* (Andouin)	Los Angeles, Santa Monica
Theridiidae	*Latrodectus geometricus* Koch	Widespread
Theridiidae	*Steatoda nobilis* (Thorell)	Thousand Oaks
Zodariidae	Undetermined species	Thousand Oaks

Additionally, Saylor (in Chamberlin and Ivie) reported on spiders collected mostly in California (Chamberlin and Ivie 1941), likely representing the areas where professional arachnologists were actively collecting. Seventeen species in 9 families and 17 genera were reported as collected in southern California, in Pomona and Santa Ana. Of these, 1 species, *Schizocosa avida* (Walckenaer), was not collected in the LASS.

Of the combined 86 species reported by Banks and Saylor, 60 were collected in our survey and 26 were not. Three of the spiders reported by Banks were among the most common collected in the present survey: *P. phalangioides*, *S. blackwalli*, and *P. tepidariorum*. Two of the 10 most common spiders in the current survey (*S. grossa* and *C. mildei*) were not reported by Banks. However, a different species of *Cheiracanthium*, *C. inclusum*, was

Table 3. List of all spiders collected by Banks (1904) that were not collected in the current survey.

Family	Species
Agelenidae	*Hololena pacifica* Banks
Araneidae	*Araneus angulatus* Clerck
Araneidae	*Araniella displicata* (Hentz)
Corinnidae	*Castianeira crocata* (Hentz)
Cybaeidae	*Cybaeus minor* Chyzer
Dictynidae	*Emblyna sublata* (Hentz)
Dictynidae	*Dictyna volucripes* Keyserling
Diguetidae	*Diguetia canities* (McCook)
Gnaphhosidae	*Herpyllus hesperolu*s Chamberlin*
Gnaphosidae	*Micaria palliditarsa* Banks
Linyphiidae	*Oaphantes pallidulus* (Banks)
Linyphiidae	*Spirembolus fasciatus* (Banks)
Lycosidae	*Pardosa atromedia* Banks
Lycosidae	*Schizocosa avida* (Walckenaer)
Lycosidae	*Sosippus californicus* Simon
Pholcidae	*Psilochorus apicalis* Banks
Salticidae	*Habronattus elegans* (Peckham and Peckham)
Salticidae	*Habronattus signatus* (Banks)
Salticidae	*Habronattus tarsalis* (Banks)
Salticidae	*Phanias harfordi* (Peckham and Peckham)
Salticidae	*Phidippus octopunctatus* (Peckham and Peckham)
Salticidae	*Platycryptus californicus* (Peckham and Peckham)
Segestriidae	*Segestria pacifica* Banks
Tetragnathidae	*Leucauge venusta* (Walckenaer)
Tetragnathidae	*Tetragnatha laboriosa* Hentz
Theridiidae	*Steatoda grandis* Banks
Thomisidae	*Mecaphesa schlingeri* (Schick)**
Philodromidae	*Thanatus coloradensis* Keyserling

*Listed as *Herpyllus validus* (Banks). **Listed as *Runcinia californica* Banks.

common in the Banks survey. Only 1 specimen of *C. inclusum* has been collected in our survey, from Griffith Park. None of the most common species collected in our survey were reported by Saylor.

Discussion

Enthusiastic participation in the LASS by community scientists has resulted in over 6,500 spiders collected for the survey from the greater Los Angeles area as of January 2016. The most common spiders that were collected are introduced, cosmopolitan species. Some species were found exclusively in urban areas, other species just in natural areas or only in the desert. Many were collected in both urban and natural areas. Several new records were recorded for the Los Angeles area. Some common species appear to have been introduced in the last 100 years, based on their absence from historical surveys; conversely, some species from previous surveys are not reported in our survey.

Our data show that the spiders most frequently encountered by the general public in Los Angeles have changed markedly over 100 years. The most commonly encountered spider in Los Angeles today, *S. grossa*, was not recorded 100 years ago. Also not known at that time were *C. mildei*, a common indoor house spider, and *L. geometricus*, the Brown Widow. Only in the latter case, however, do we have an indication of the changes wrought by the introduced species. The near disappearance of Black Widows in Los Angeles is strongly associated with the colonization of the entire city by Brown Widows (Vetter et al. 2012).

The pattern of introductions observed in our survey differs from the findings of studies on other urban animals. For example, studies of birds worldwide have found that the majority of urban species are native to the area in which the city is located (Aronson et al. 2014). Smaller creatures, like spiders, however, are easily transported via natural (Decae 1987) and human-mediated dispersal events (Luo and Li 2015) and often remain undetected until specialized and more targeted studies are done. Additionally, the mild Mediterranean climate and high levels of international commerce might make Southern California more conducive to hosting exotic animal species than are other cities that have been studied. It is important to note that, globally, urban plant communities tend to host a higher percentage of exotic species (averaging 21%) compared to the percentage of introduced spider species we detected here (Aronson et al. 2014). However, unlike spiders, urban plants are often intentionally introduced and managed as part of urban landscaping.

Community science programs have many benefits but can also suffer from various issues, in terms of both data collections and representation, depending on how they are structured. In general, broad unstructured community science programs can provide much-needed data on populations of species, including potential changes in distribution over time. This benefit is especially true for otherwise inaccessible areas, such as private property, which is common in heavily urbanized and industrialized areas (MacPhail and Colla 2020). The LASS succeeded in documenting a broad sample of the current spider population over the large metropolitan area of Los Angeles and attracted participation from over 500 individuals, groups, and families. This success is in part due to publicizing the event to museum members and at the museum's annual Bug Fair, which is one of the most heavily-attended events held by the museum. Museum members and Bug Fair attendees are both groups that are likely to already be engaged in science and interested in topics like spider diversity. It is important to note that, although spiders were received from all over Los Angeles County and beyond, there were areas that were underrepresented, mostly in South and East Los Angeles, which tend to be minority neighborhoods. This survey was one of the first by the

museum to actively engage the public as community scientists and has been followed by several other community science projects (Brown et al. 2014).

The level of experience and ability to provide accurate data by participants have also been cited as limitations in community science projects (MacPhail and Colla 2020); however, almost anyone can catch a spider. In fact, the number of people willing to collect live Black Widows was astounding. In our survey, the only major requirement was interest since identification was handled entirely by museum experts and collection data were minimized. In some cases, location or collection dates were incomplete or missing, but this situation was rare.

The data in this survey suggest several areas for future research. Since the goal of the LASS was to assess the current spider population in the Los Angeles area using citizen scientists, there was no attempt to standardize collection techniques. The survey succeeded in documenting much of the current spider population, but participants from the general public are likely to oversample large, conspicuous spiders, leaving the smaller, more cryptic species undersampled. Future structured surveys conducted by museum scientists throughout the same study area would complement LASS data. Special efforts also could be made, such as engaging the participation of the super collectors or providing training to participants on how to capture the species expected to be less well-represented. Undersampled areas also need to be surveyed through more targeted recruitment of community scientists, by surveys conducted by museum scientists, or both.

Finally, monitoring the dynamics of urban spiders in Los Angeles remains a key role for the survey. We know that further species introductions are coming, and given this inevitability, it will be important to carefully document their introduction points, mode of spread, and effects on other species in the Los Angeles Basin.

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