JT SCIENCE

A newsletter to promote a better understanding of the natural, physical, & cultural environment in Joshua Tree National Park

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JT SCIENCE

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OUR MISSION
Joshua Tree National Park Association (*www.joshuatree.org*) works in partnership with Joshua Tree National Park to help in its achievement of programming goals in education and interpretation, along with scientific and historical research and activities.

BEING A PART OF THE ADVENTURE
We operate four visitor centers and one park store that are often the first stop for visitors from around the world. We also offer a field institute, with classes taught by experts in natural sciences, cultural history, and the arts; and we raise funds via donations and our membership program. Visit a park store to learn about wildflower identification, birding, geology, stargazing, native plants and local history; pick up climbing and hiking guides; or sign up for a Desert Institute field class and make the park your classroom.

YOUR MEMBERSHIP MATTERS
As a member you support scientific research, the park's historical collections, youth programs, and assist in the preservation of our fragile desert. Email **membership@joshuatree.org** to find out more!

JT SCIENCE
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Questions?
Contact jtresearchgrant@joshuatree.org

Welcome to JT Science

The mission of JT Science is to promote a better understanding of the natural, physical, and cultural environment in Joshua Tree National Park (JTNP). Each issue highlights scientific endeavors being conducted in JTNP and provides an opportunity for scientists, land managers, and the general public to know and appreciate this desert region.

In memory of Marian Huff Tremblay
In May of 2023, we lost one of our long-standing and ardent supporters, Marian H. Tremblay. Marian was the Director of Business Operations at the Joshua Tree National Park Association for 18 years. While she performed her job with fervor and proficiency, she did more than manage budgets and programs for the park. Marian truly cared about the future of JTNP and all things desert. To honor Marian's many years of hard work and dedication to the previous iterations of the Graduate Student Research Grant, we have renamed the grant; it is now called the Marian Huff Tremblay Science Scholarship.

The Joshua Tree National Park Association is providing funding for the JTNP Science Research Grant Program, directly supporting this science-based newsletter for the public, as well as annual funding for the Marian Huff Tremblay Science Scholarship. The goal of the scholarship is to support graduate student researchers conducting independent field studies in JTNP and more specifically to support high-priority research needs that inform park management of socio-cultural, natural, and wilderness resources identified by park management.

Grant awardees will participate in the *Slice of Science* lecture series hosted by the Desert Institute. In addition, the students will provide manuscripts for JT Science, public outreach materials for JTNP Interpretation staff, as well as final reports summarizing their findings. By offering up to $5,000 to each student, this program provides opportunities for the student to gain experience with grant and report writing skills, budget management, and most importantly, to demonstrate how their research can apply to land management issues.

To date, we have supported over 40 students, through which we have gained insight on such things as visitor awareness of tortoises; conservation implications for fringe-toed lizards and Joshua trees; microbial diversity in soils; rare plant life history; insect inventories; and discoveries of new-to-science species of poppies and green algae. The impact of the JTNP Science Research Grant Program and the contributions made by these scientists have been richly rewarding.

Enjoy the newsletter.

Variations in Visitor Engagement Through Mojave Desert Tortoise Interpretive Signs

By Rachel Shively[1] and Jessica Wilkes[2]

Figure 1. A Mojave Desert tortoise (*Gopherus agassizii*). **Photo by Rich Good.**

ABSTRACT

The Mojave Desert tortoise (*Gopherus agassizii*) population has been in decline. Well-designed interpretive signage and participant recruitment in Nature-based Citizen Science (NBCS) can contribute to increased awareness and conservation efforts from park visitors to benefit species in peril, such as the Mojave Desert tortoise. We tested six different sign designs with interpretive information about the Mojave Desert tortoise to determine which interpretive elements are most likely to catch the attention of visitors and increase awareness along with NBCS participation. We observed high rates of visitor engagement with signage that had emotional and anthropomorphic themes. Participation in NBCS through reported observations increased over 8-fold while the signs were in place in Joshua Tree National Park (JTNP). Interpretive signage is a cost-effective approach to increase visitor engagement.

BACKGROUND

The Mojave Desert tortoise (*Figure 1*) is listed as critically endangered by the International Turtle Conservation Coalition (*1*) and as threatened under the US Federal Endangered Species Act (*2*). Human activity (e.g., habitat loss and vehicular collisions) and effects of climate change, like decreasing annual precipitation and increasing average temperatures in the region, continue to cause declines in the species' population across its habitat range, including JTNP (*3-6*). Turtles and tortoises are among the most threatened vertebrate lineages in the world making long-term monitoring efforts crucial for tracking population trends and the success of conservation strategies (*1,7*). The negative population trends in the species' critical habitat indicate it is on the path to extinction (*3*). Due to the bleak outlook for this species, intervention is necessary to slow continued population decline in JTNP (*5*). Sustainable co-existence between visitors and wildlife should be the ultimate goal for research and management plans in wildlife tourism (*8*).

Expanding urbanization has led to a decrease in the natural environment, so protected areas are the most common place for people to encounter nature and be exposed to new

[1]Bureau of Land Management, Arizona Strip District Office, St George, UT
[2]Natural Resources Conservation Service, Manhattan Service Center, Manhattan, KS

ideas about the environment (*9*). This project used an iterative and collaborative approach by deploying interpretive signage about the Mojave Desert tortoise that included stewardship messaging which has been empirically tested in other natural park settings.

Signs are a cost-effective element of interpretive programs.

Messaging incorporated on different signs included communicating the following concepts: the human-wildlife connection (*10*), that humans are visitors in the species' home (*8*), and wildlife sightings are subject to nature and cannot be guaranteed (*11*). These messages have been shown to decrease destructive behavior (*8*), increase visitor satisfaction, and create greater connections to nature, even at the expense of the visitors' personal comfort (*12*). Signs were designed based on these tested messages combined with design elements (e.g., images, text chunking, blank space) to identify which of the selected combinations led to the highest engagement levels (*13-15*). Previous signage in JTNP about Mojave Desert tortoise was scarce and did not include information about Nature-based Citizen Science (NBCS). We hypothesized that increasing interpretive signs focused on the vulnerable Mojave Desert tortoise along with invitations to participate in a NBCS Mojave Desert tortoise sighting project would increase JTNP visitor awareness of the species and lead to higher rates of reported sightings.

OBJECTIVES

The main objective of this study was to identify which interpretive sign elements lead to the highest percentage of visitor attention, longest reading times, and highest rates of follow-through (website visitation) with the following management goals:

1. Deploying interpretive signs about Mojave Desert tortoise in JTNP to increase awareness of the species and its vulnerability to human impacts.

2. Using interpretive signs to increase volunteer reporting of Mojave Desert tortoise in JTNP through NCBS (i.e., iNaturalist).

METHODS

Six interpretive signs were placed within JTNP for this project (*Figures 2-8*). Signs contained tortoise information and included illustrations to enhance visitor interest (*8*). Each sign included its own shortened website address linking visitors to a Mojave Desert tortoise iNaturalist project (https://www.inaturalist.org/projects/desert-tortoises-of-joshua-tree-national-park). Researchers worked with park staff to develop the sign designs. Additionally, researchers used the proofreading application, *Hemingway* (Hemingway, Ltd.), to estimate reading levels and times. Elements within the signs including messaging, appropriate reading levels and times, and percentages of images to words (*Table 1*), were based on six interpretive techniques of sign design recommended by Ballantyne & Hughes (*13*) and word limits and mixed images as explained by Moscardo (*14*) and Wandersee & Clary (*15*). Trail cameras were placed near each sign enabling researchers to count the number of visitors who stopped to view signs and estimate how long they spent reading the signs, providing a comparison of the visitor engagement with each sign design. Signs and trail cameras remained in place for six months, from November 2022 through May 2023, to capture peak visitation months.

SITES

Sign locations (e.g., trailheads, visitor centers, campgrounds) were selected based on visitor traffic and park staff consultation (*Figure 2*). Sign design was selected based on the location with the following rationale for placement at the six sites.

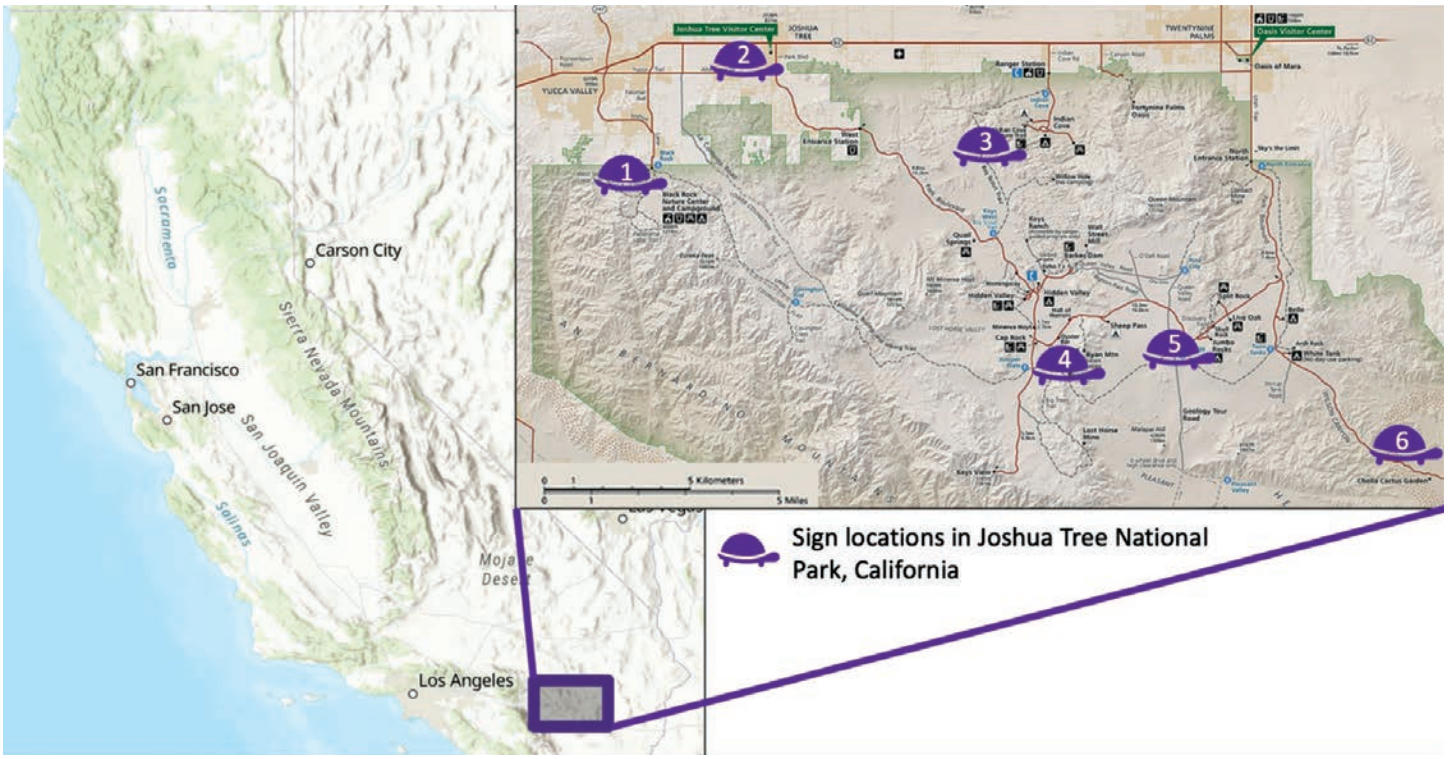
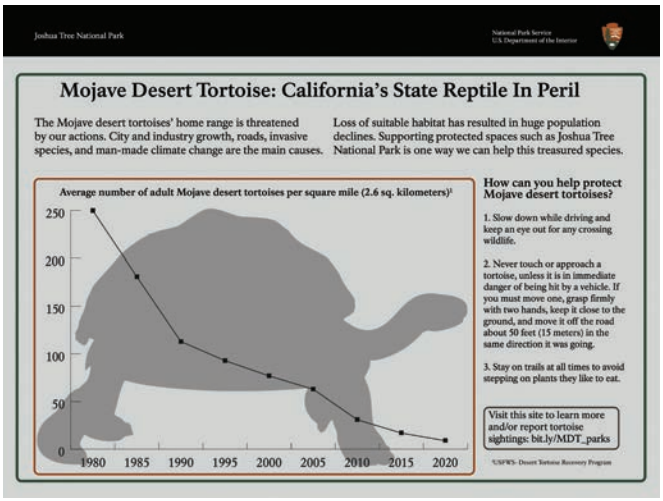


Figure 2. Sign locations with numbers corresponding to the sign designs described on the following pages.

Black Rock Nature Center (34.073435, -116.390695)

There are 99 campsites in the campground and several trailheads near this nature center. This sign was located to the right of the north entrance of the nature center, next to the trash/recycling and bike rack. This area is also accessible to visitors without driving through an entrance station and may reach visitors who choose an alternate area to the sites along Park Blvd and Pinto Basin Rd. This area is listed as the most likely region in JTNP to spot a Mojave Desert tortoise, so this sign communicates expectations for an actual sighting (*Figure 3*).

Figure 3. Sign located at Black Rock Nature Center.



Joshua Tree Visitor Center (34.13394, -116.31550)

The highest visitor traffic of the three visitor centers in JTNP. The sign has the most text of all signs, but visitors likely intend to spend more time at a visitor center compared to a trailhead. The sign is located in the rock garden within the exterior walls, outside the visitor center front doors and is not near other interpretive signage. Due to the likelihood of visitors stopping here before they have entered the park boundary, the sign communicates the importance of JTNP to visitors at the beginning of their visit (*Figure 4*).

Figure 4. Sign located at Joshua Tree Visitor Center.

Indian Cove Nature Trail (34.094516, -116.168451)

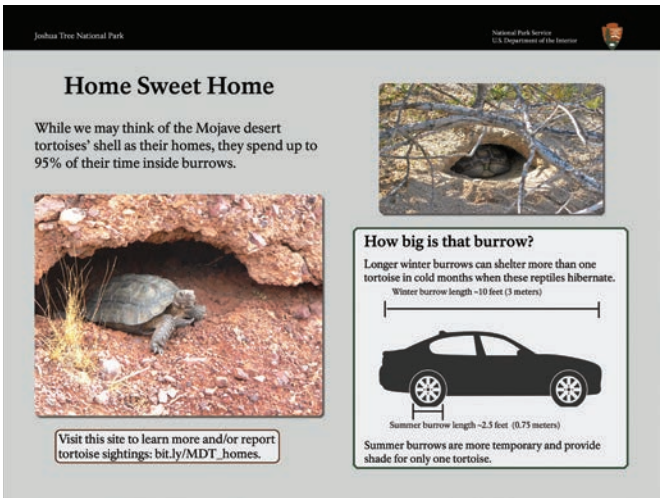
There are 100 campsites in this campground and the sign is located next to a parking area and vault toilet at the trailhead. Visitors staying in the campground or parking at the trailhead have the opportunity to practice the stewardship message in this sign by checking under their vehicle before driving. Additionally, the "Be Tortoise Aware" graphic is posted at each campsite, so this sign reinforces other park communication. The trailhead is accessible without passing through the entrance station and may get frequent use by locals (*Figure 5*).

Figure 5. Sign located at Indian Cove Trailhead.

Ryan Mountain Trailhead (34.002548, -116.135895)

One of the most popular hikes in the park and located along Park Blvd, this trailhead also has ample parking and a restroom. According to iNaturalist, the foods listed on the sign can be found seasonally along the trail and this provides an opportunity to engage the readers while they recreate by communicating information about the Mojave Desert tortoise diet (*Figure 6*).

Figure 6. Sign located at Ryan Mountain Trailhead.



Jumbo Rocks Campground (33.991693, -116.067769)

There are 124 campsites in this campground. The sign was installed in the only area of the campground accessible to vehicles that are not staying in the campground. The "Home Sweet Home" message focused on burrows was intentionally used in a campground as an analogy to the visitors' temporary home (*Figure 7*).

Figure 7. Sign located at Jumbo Rocks Campground.

Cholla Cactus Garden, (33.925175, -115.928902)

A popular site to visit for a collection of unique flora and an easy place for people to stop and park their vehicles and take a short hike if desired. There is minimal interpretive information present currently. Visitors of all types are likely to stop here, and the life messaging is interesting to a wide audience (*Figure 8*).

Figure 8. Sign located at Cholla Cactus Garden.

SIGN DESIGN ELEMENTS

The six signs combined variations in the amount of text, interpretive elements, and images (*Table 1*).

Sign Message and Location	"WHERE" at Black Rock Nature Center *(Site 1, Fig. 2)*	"POPULATION" at Joshua Tree Visitor Center *(Site 2, Fig. 3)*	"HOW TO SAVE" at Indian Cove *(Site 3, Fig. 4)*	"FAVORITE FOODS" at Ryan Mountain Trailhead *(Site 4, Fig. 5)*	"HOME" at Jumbo Rock Campground *(Site 5, Fig. 6)*	"LIFESPAN" at Cholla Cactus Garden *(Site 6, Fig. 7)*
Sign Components	• Questions • Stories • Anthropomorphic (hiding, where would you hide) • Interactive (where would you hide, sight) • Learning Theme	• Emotional Theme (shrinking habitat) • Behavioral Theme (support the park) • No photo • Graph	• Questions • Suggestions • Illustration (sign with tire prints) • Behavioral Theme	• Questions • Asks visitors to look for plants (interactive using sight) • Learning Theme	• Questions • Stories • Illustrations (car for size) • Anthropomorphic (home sweet home) • Learning Theme • Text chunking (not one paragraph)	• Questions • Stories • Anthropomorphic (Birth, Childhood, Adulthood) • Emotional Theme (death and survival) • Text chunking (not one paragraph)
Sign Statistics	• Number of words: 85 • Reading level: 5th grade • Reading time: 20 seconds • Imagery: 73.1% 1 large background photo • Text: 15.9%	• Number of words: 198 • Reading level: 4th grade • Reading time: 47 seconds • Imagery: 34% 1 illustration • Text: 21%	• Number of words: 93 • Reading level: 4th grade • Reading time: 22 seconds • Imagery: 71.1% 1 photograph, 1 illustration • Text: 17.9%	• Number of words: 73 • Reading level: 4th grade • Reading time: 17 seconds • Imagery: 77% of total sign, 5 photographs • Text: 12%	• Number of words: 88 • Reading level: 4th grade • Reading time: 21 seconds • Imagery: 38.3% 2 photographs, 1 illustration • Text: 14.4%	• Number of words: 133 • Reading level: 1st grade • Reading time: 31 seconds • Imagery: 29% 2 photographs • Text: 17.5%

Table 1. One sign was placed at each of the six sites (*Figure 2*). Each sign was designed to incorporate specific interpretive components with varying amounts of text and imagery (*13-15*).

TRAIL CAMERAS

All trail cameras were motion-triggered Bushnell HD Trophy Cams and set to capture one image per trigger with a 5-second delay between triggers. Cameras were placed at the optimal angle to capture visitors looking at the signs. Researchers replaced the camera batteries and SD cards (32 GB) every three months. As a proxy for the percentage of visitors engaging with the signs out of the total number of visitors passing by the sign, the number of photos capturing visitors and the number of photos capturing visitors looking at the signs were counted. The timestamps for the first and last photos of each visitor looking at the sign were recorded to capture the total amount of time spent reading the sign.

RESULTS

Over a six-month period, trail cameras collected 128,112 images in 624 camera days. Not every site had the same number of camera days because of equipment failure and the capacity limit of the SD cards. Due to SD card capacity, Cholla Cactus Garden had the fewest camera days but also the highest number of images (*Table 2*). The sign at Cholla Cactus Garden resulted in the highest number of website visits and also had a high percentage of visitors stopping to read the sign (*Figure 7 and Table 2*). Black Rock Nature Center had a high level of visitor activity but the lowest level of visitor engagement with only 1% of observed

visitors stopping to read the sign (*Figure 2 and Table 2*). Visitors spent the longest time reading on average at Joshua Tree Visitor Center and Cholla Cactus Garden (*Figures 3, 7, and Table 2*) for 30±7s and 29±10s, respectively. Of note, the sign at Joshua Tree Visitor Center was the only sign with a graph and no image. This site had a low average number of photos per day (38.73) despite the fact that this is a busy site within the park. Thus, we believe the graph and lack of images did not grab the attention of many visitors. We captured the fewest images of visitors on Wednesdays and the most on weekends which was the same pattern we saw for the number of visitors observed reading signs by day of the week (*Figure 9*).

NBCS

Participation in NCBS was measured through the number of observations posted to the linked iNaturalist project per year. While iNaturalist has been available for use for years, there was previously no specific project designated to capture Mojave Desert tortoise sightings within JTNP, and thus no signage or website driving traffic to iNaturalist for that purpose. The rate of Mojave Desert tortoise observations within JTNP uploaded to the iNaturalist project increased while the signs were in place. Observations include photos of tracks, scat, or tortoises. There were 50 Mojave Desert tortoise observations within JTNP uploaded between May 2013 and September 2022, for an average of 0.45 photos per month. From November 2022 through May 2023, 23 observations were uploaded. That's 8.5 times the previous rate with an average of 3.83 photos per month.

MANAGEMENT IMPLICATIONS

Interpretive signs play a crucial role in fostering a deeper connection between park

Sign	Camera Days	Total Photos	Average Photos/Day	Percentage of Visitors Reading Sign	Average Observed Reading Time (seconds ± SD)	Number of Words on Sign	Average Seconds/ Word	Website Visits
Jumbo Rocks Campground	90	6578	73.09	33%	15 ± 5	88	0.17	0
Black Rock Nature Center	168	34,820	207.26	1%	14 ± 14	85	0.16	0
Joshua Tree Visitor Center*	166	6429	38.73	61%*	30 ± 7	198	0.15	4
Cholla Cactus Garden	44	43,789	995.20	50%	29 ± 10	133	0.21	11
Ryan Mountain Trailhead	79	14,533	183.96	24%	23 ± 36	73	0.31	0
Indian Cove	77	21,963	285.23	20%	13 ± 10	93	0.14	1
Total	624	128,112						

Table 2. Summary of interpretive sign data. The average number of photos per day provides information about how busy each site was comparatively as most photos were triggered by visitors (<1% of photos were triggered by animals or windblown vegetation).
**Camera angle at the Joshua Tree Visitor Center did not capture the majority of visitors passing to the visitor center site, which would have led to an inflated percentage rate.*

visitors and the environment, particularly in the realm of Nature-based Citizen Science (NBCS). This project aimed at enhancing volunteer participation in NBCS, contributing to species population monitoring, and ultimately increasing engagement among park visitors. Previous studies have demonstrated that participation in NBCS correlates with a heightened sense of connectedness between participants and the natural park they explore (*16*).

The success of this initiative has broader implications for park management, highlighting the effectiveness of interpretive signage in creating meaningful connections between visitors and specific species.

Furthermore, the impact of interpretive signage extends beyond the immediate project area, presenting an opportunity for park management to leverage effective signage strategies to deepen visitors' connections with various species. The participatory stewardship fostered through interpretive signage not only enhances visitors' overall experiences but also opens doors to novel ways of understanding the environment, both within natural settings and in visitors' daily lives. In this context, the resulting signage and presentations significantly contribute to raising awareness about the Mojave Desert tortoise, supporting broader conservation efforts across National Park Service units, including those beyond JTNP.

The project's findings suggest that interpretive signage designs can be successfully implemented in other park units, offering a cost-effective means of engaging visitors and fostering awareness. Mojave Desert tortoise habitat spans across multiple National Park Service units, making the interpretive signage from this project applicable to locations such as Death Valley National Park, Zion National Park, Mojave National Preserve, Tule Springs Fossil Beds National Monument, and Castle Mountain National Monument (*17*). The potential for replicating success of the interpretive signage is particularly promising,

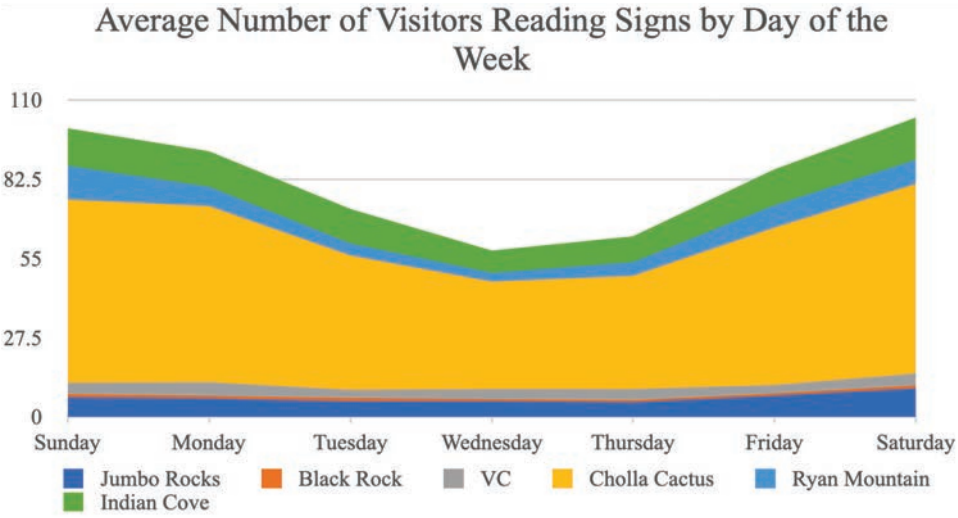


Figure 9. Average number of visitors observed reading signs by day of the week and site.

with the identification of key elements contributing to visitor engagement. Specific elements that should inform future plans for interpretive displays include considerations such as sign placement, orientation, and site activity levels. Notably, the signs employed in this project deviated from standard wayside exhibits by being shorter, placing them at eye level for children and individuals in wheelchairs. This non-standard format was chosen in hopes it would stand out and increase the curiosity of those who noticed it. This intentional design led to increased engagement, with children often taking the lead in reading the signs and involving adults in the process. Moreover, the success of a particular sign was attributed to its placement in a high-activity site with few other exhibits, featuring an emotional theme and an image of a baby tortoise (*Figure 7*). These insights highlight the importance of tailoring interpretive signage to specific locations, considering factors like traffic flow and visual appeal to maximize engagement.

In conclusion, the project's emphasis on interpretive signage as a cost-effective method for increasing park visitors' engagement in Nature-based Citizen Science has far-reaching implications for park management. By recognizing the potential of interpretive displays in fostering connections, raising awareness, and enhancing visitor experiences, parks can leverage this approach to support conservation efforts and create lasting impressions on the diverse range of individuals exploring these natural spaces.

SUMMARY

Visitors were more highly engaged with signs that included a moderate amount of text and anthropomorphic and emotional themes. Signage with distinct photographs, including the photograph of the baby tortoise, caught the attention of high rates of visitors and resulted in more follow-up through website visits. Sites with lots of infrastructure may not be as effective for placement of signs due to competition for visitor attention and the possibility of visitors having more things to do at those sites (e.g., sort and toss trash, register for campsite, etc.). Future studies could compare different heights and orientations of the same sign to determine the potential impact physical sign designs have on visitor engagement. Overall, interpretive signage is a cost-effective option for increasing visitor awareness and NBCS engagement.

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Protecting Biodiversity, One Plant at a Time

By Maggie McMillin[1]

Figure 1. *A*) Triple-ribbed milkvetch (*Astragalus tricarinatus*) has delicate yellow flowers and unique leaves consisting of small, widely-spaced, gray-green leaflets. *B*) A mature triple-ribbed milkvetch plant. **Photos by T. La Doux**

First-time visitors to the rocky, mountainous terrain around Eureka Peak would be forgiven for believing they'd left Joshua Tree National Park (JTNP). Trade the creosote-dotted desert of Park Avenue for this 5,500-foot peak in the Little San Bernardino Mountains and you get lush pinyon oak woodlands and annual wildflowers that bloom into late spring.

On a sunny day in late May, I joined park botanist Tasha La Doux at Eureka Peak for rare plant monitoring. As we set off on what she promised would be an off-trail adventure, she ran through the basics with me—why, how, and where we were going that day. We were headed to a plot of triple-ribbed milkvetch (*Astragalus tricarinatus*), a short-lived herbaceous perennial with small gray-green leaflets and yellow flowers (*Figure 1*). The plant is endemic to California—in other words, it occurs nowhere else on earth. It has only ever been recorded in San Bernardino and Riverside Counties.

To reach our plot, we dropped down into a narrow canyon, hopped a few boulders, pushed through some shrubs, and scrambled back up the adjacent slope. As we caught our breath on a ridgeline, La Doux pointed out a distinct gray-green patch of ground on a nearby slope (*Figure 2*). The color is a telltale sign of the crumbly soil favored by triple-ribbed milkvetch. It was this coloring that helped park employees find more populations of this rare plant in a prolonged survey effort that started in 2006. Their effort led to the establishment of two permanent monitoring plots in 2013, including the one we were scrambling to.

Each year monitoring teams visit the two plots, both of which occur in unstable soils on nearly 45-degree slopes (*Figure 2*). When we reached

[1]Joshua Tree National Park.

the Eureka Peak plot for this year's monitoring, I found an out-of-the-way place to perch with my clipboard while La Doux deftly navigated the steep terrain (*Figure 3*).

> As with all rare plants studied by JTNP staff, there is a tailor-made monitoring protocol for triple-ribbed milkvetch.

Staff count the plants in the plot, record their location on a map, and measure the height and width of each individual plant. They also note the presence of any buds, flowers, or fruits. The number of plants in the Eureka Peak population fluctuates from year to year, but with over 200 plants in a good year, it's one of the largest known populations in the world.

Our knowledge of this population is a testament to the success of previous monitoring efforts. When the US Fish & Wildlife Service first listed triple-ribbed milkvetch as endangered in 1998, fewer than 100 individuals had ever been documented. All of them had been observed on sandy benches along wash corridors, which led to the misconception that this plant preferred this kind of habitat. Luckily, survey efforts by botanists in the early 2000s revealed several populations above those drainages harboring larger numbers of the triple-ribbed milkvetch. This meant that the lower plants are waifs – plants growing in an uncharacteristic place, likely due to a seed that was washed downslope from a natural population.

Triple-ribbed milkvetch was thought to be extirpated from JTNP until 2006, when La Doux noticed one lonely plant in the lower reaches of a major drainage in the Little San Bernardino Mountains. "Once I found that waif," says La Doux, "I knew there had to be populations upstream, growing in more typical soils on the steep mountain slopes." The park's botany team combed the area and collected visual clues like the aforementioned soil coloration that led them to upslope "mother" populations. "The arduous surveys were well worth it," La Doux says. "We now have detailed information on 19 occurrences, including the Eureka Peak population."

Figure 2. From a distance, the friable gray-green soil that is preferred by triple-ribbed milkvetch is quite noticeable. This helped park botanists (note the person in the upper lefthand corner) find new occurrences of this rare plant in JTNP. **Photo by T. La Doux**

Figure 3. JTNP botanist Tasha La Doux monitoring a permanent plot of triple-ribbed milkvetch near Eureka Peak. **Photo by B. Winckelmann**

When it comes to protecting these plants, researchers and park staff start by learning about basic biology. "We can't even begin to develop a plan until we know some basic things," says La Doux. This includes information about where the plant occurs in the park, its habitat preferences, survival rates, and how varying rainfall impacts its reproduction. Ideally, this data will help JTNP learn enough about triple-ribbed milkvetch to protect it in an uncertain future.

For example, ten years' worth of demographic and reproductive data show us that most individuals (82%) will die within their first year and fewer than 4% make it past 3 years. That, according to La Doux, means that "the species is acting like an annual in many ways." The problem with this high mortality rate is that those first-year plants aren't reproducing at a rate that is viable long-term. For this reason, La Doux thinks that protecting intact corridors, mechanisms of dispersal (like pollinators), and habitat is essential for the long-term survival of triple-ribbed milkvetch. The botany team at the park has designated "no disturbance" zones in known triple-ribbed milkvetch habitat. These prevent any kind of ground disturbance, fire suppression activities like digging fire lines, and new trail establishment in areas where triple-ribbed milkvetch grows.

As a rare plant with an extremely limited distribution and small population sizes, triple-ribbed milkvetch is especially vulnerable to the issues that threaten biodiversity in the Mojave Desert. Fires, habitat loss, illegal OHV activity, competition from non-native and invasive plants, and disruption to pollinators all threaten its long-term viability. Populations in the park enjoy the additional protections associated with NPS land, but because of its narrow geographic range, even relatively minor disturbances could put its survival in jeopardy. The number of known individuals has increased since it was listed as endangered in 1998, but these numbers can be deceiving; populations fluctuate from year to year. The number of individuals in the Eureka Peak monitoring plot has ranged from zero in 2022 to 179 in 2015, according to La Doux. These extreme fluctuations combined with small population sizes (70% of known occurrences have fewer than 15 individuals in them) make for a precarious future.

It's not possible for the park's small monitoring team to visit the Eureka Peak plot multiple times a year, which makes it hard to record certain kinds of data. For example, success rates of fruits developing from open flowers or the percentage of healthy seeds that are produced each year would both require multiple visits to the plot each season. And because of the fragility of the plant's habitat, increased monitoring could damage existing populations. When La Doux comes up against these limitations, she explores other options. For example, JTNP has already sent some triple-ribbed milkvetch seeds to the California Botanic Garden for long-term storage. These "seed banks" protect the genetics of endangered plants in case there comes a time when nursery-grown plants are needed to restore dwindling populations. The park

has also collaborated with scientists from the California Botanic Garden and the University of California, Riverside, to learn more about seed viability, germination requirements, population genetics, soil properties, and nitrogen-fixing bacteria found in the plant's roots.

Before we reached the Eureka Peak plot, La Doux had warned me that we may not see many plants this year. Last year's monitoring had revealed an empty plot after two years of limited rainfall. She explained that desert plants can take a long time to study because they respond to wildly fluctuating conditions from year to year. This, plus the climate extremes they experience, may necessitate years of dormancy or reduced reproductive efforts that require several years of observation to fully understand. This year, to our surprise, the plot was full of tiny seedlings, 129 to be exact. Most of those seedlings will die before next year's monitoring visit, but capturing fluctuations between years of die-off and years of robust growth is exactly what we're trying to do. In the context of a decade's worth of data, this year's seedling count can help JTNP better understand things like life expectancy and the impact of precipitation on seedling growth.

When our monitoring was finished, I followed La Doux on the slow trek back to our truck. Along the way, the park's floristic diversity was alive around us. There were pink flowers of granite prickly phlox (*Linanthus pungens*) emerging from the rocky slopes, dense lavender collections of desert woollystar (*Eriastrum eremicum*), and clumps of fiery red scarlet bugler (*Penstemon centranthifolius*) at the mountaintop. She paused at a small cluster of leaves hugging the ground. They were the basal leaves of a long-stem buckwheat (*Eriogonum elongatum* var. *elongatum*), which was not known to exist in the park until she observed it in this area several years ago.

> "It's often assumed that we've already discovered all there is to discover, but that's not true," says La Doux.

From more common plants as well-known as the eponymous Joshua tree (*Yucca brevifolia*) to rare plants like the elusive triple-ribbed milkvetch, there is always more to learn.

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Preliminary Insights into the Blow Flies (Diptera: Calliphoridae) of Joshua Tree National Park

Hannah Chu[1]

Figure 1. Adult blow fly. **Photo by Erik Karits**

INTRODUCTION

Spanning the Mojave and Sonoran Deserts, Joshua Tree National Park (JTNP) is home to a unique array of natural wonders, including Joshua trees, imposing boulders, and a diverse range of wildlife such as desert tortoise and quail. The impact of visitor activity on the park's ecosystems extends beyond these charismatic landscapes and animals, reaching even the smallest creatures, such as insects. Recent research has shed light on a fascinating correlation between blow flies (Diptera: *Calliphoridae*) (*Figure 1)* and human activity (*1*). Often seen hovering around dumpsters and pet waste in urban areas, blow flies, commonly iridescent green or blue, are considered a nuisance. Despite their much-maligned reputation, blow flies play crucial ecological roles as decomposers, breaking down organic matter and recycling nutrients back into the environment. The immature stages of blow flies, referred to as maggots, feed on decomposing tissue to complete their life cycle. This reliance on decomposition has made blow fly maggots valuable in forensic investigations for estimating the time since death. Furthermore, the presence of specific blow fly species can indicate whether remains have been moved from one location to another, including cases of animal poaching (*2*). Apart from their role in legal investigations, blow flies have been suggested for use as indicators of environmental change because of their strong association with human activity (*3-5*). Therefore, this project had two objectives: 1) to establish a database of blow fly species in the park to aid in future legal investigations, and 2) to investigate whether blow fly activity reflects visitor activity. The results from this work can inform management practices and conservation strategies by providing insights into the effects of visitor activity and increased waste.

BLOW FLIES 101

With over 75 species of blow flies in North America that occupy almost every terrestrial habitat, their presence and distribution have become increasingly recognized as potential indicators of human disturbance. Blow flies lead fascinating lives and contribute to many ecosystem services, such as pollination as adults. When immature, blow flies survive in maggot masses in decomposing tissue, which aids in their ability to feed and break down organic material. Interestingly, the maggot mass can create optimal temperatures for development and survival in harsh conditions, for example, to avoid freezing they increase the temperature of their mass through movement (*6, 7*).

Exploring the multifaceted contributions of blow flies to various ecological processes not only underscores their significance but also emphasizes the need for further research into their biology and geographic distribution across diverse environments.

DECOMPOSITION

Known as primary decomposers, blow flies are among the first animals to arrive at a decomposing carcass. Adult females lay their eggs on the decaying organic matter and the developing maggots feed on decomposing tissue. This feeding activity accelerates the decomposition process, aiding in nutrient recycling and ecosystem functioning. The entire life cycle of a blow fly (*Figure 2*) can take up to a few weeks, but their developmental timing is highly dependent on temperature and humidity (*2*).

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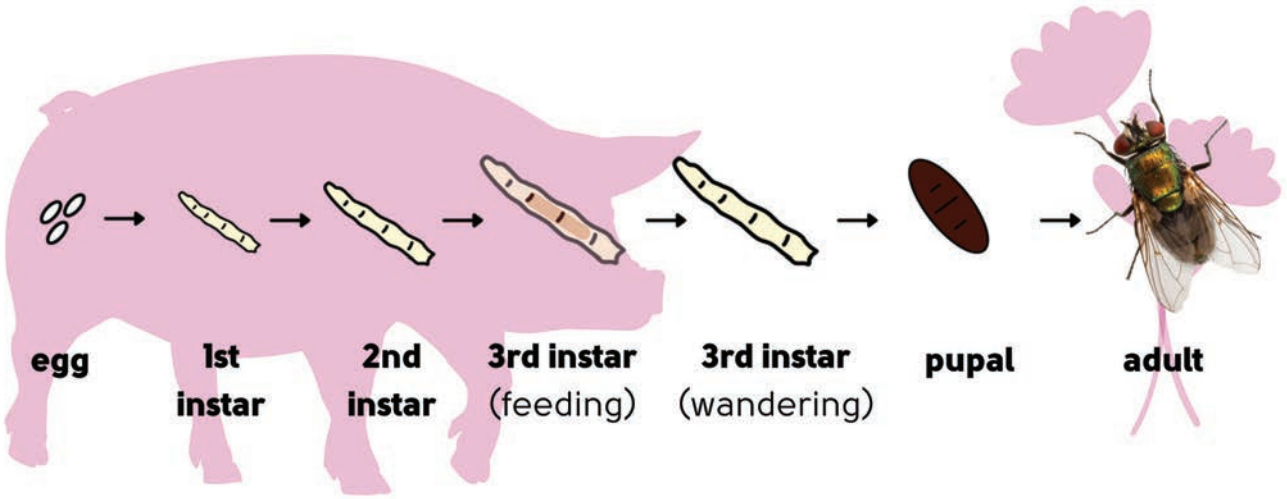

Figure 2. General life cycle of blow flies. They feed on decomposing animal tissue as immatures (maggots) and wander to a dry area to pupate before emerging as adults that feed on nectar. **Illustrated by Hannah Chu**

FORENSIC ENTOMOLOGY

Blow flies play a crucial role in death investigations that involve insect evidence and the estimation of postmortem intervals (PMI), commonly known as determining the time of death. It is important to note that determining the time of death precisely is a complex task, as forensic entomologists aim to identify the time of colonization (TOC), which reflects the onset of insect egg-laying (*Figure 3*). The TOC can be significantly influenced by environmental factors such as cold weather and precipitation (*2*). By studying the life cycle of blow flies and the patterns of insect colonization on a body, experts can estimate the time since death, providing valuable information for criminal investigations and court proceedings. It is worth noting that forensic entomology encompasses other subfields beyond medicolegal investigations, such as urban forensic entomology and stored-pest forensic entomology (learn more here: www.bit.ly/forensicent).

HUMAN AND ANIMAL HEALTH

Blow flies have long been known to transmit various pathogens because of their reliance on decomposition and waste (*8*). For example, they can pick up and transmit *E. coli*, known to cause gastrointestinal illnesses, as well as deadly bacteria, like *Anthrax* species, in the environment (*8, 9*). This highlights the importance of monitoring blow fly populations, especially during disease outbreaks or in regions where specific pathogens are prevalent. By tracking the presence and distribution of blow flies, researchers can gain valuable insights into the potential spread and transmission of infectious diseases. However, blow flies are not all bad! Lab-reared maggots can be applied to infected wounds, where they feed only on the necrotic tissue and aid in healing. This is known as "maggot therapy." (learn more here: www.bit.ly/maggotherapy).

POLLINATION

While bees and butterflies often steal the spotlight as pollinators, flies, including blow flies, also contribute significantly to the pollination of various plant species. In urban areas or disturbed habitats where bee populations may be limited, flies can step in as important pollinators. Recent work has revealed the significant contribution of blow flies to the pollination of wildflowers in urban environments emphasizing the need for broader research on pollinators beyond bees (*10*).

ENVIRONMENTAL DETECTION AND CONSERVATION

Given their role as mechanical transmitters of pathogens, particularly in wildlife populations, blow flies can serve as invaluable

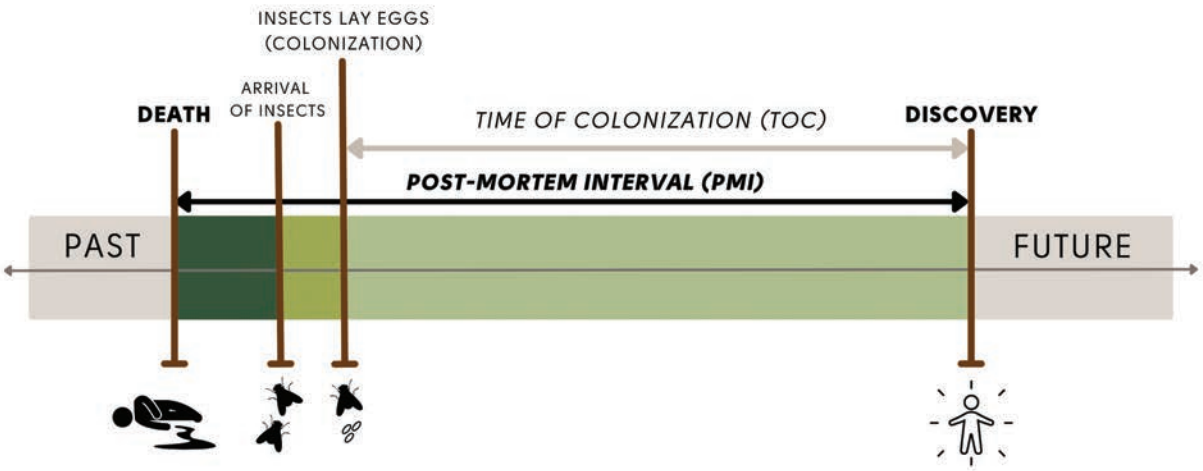

Figure 3. Visual representation of what forensic entomologists aim to find, time of colonization (TOC), to narrow down a post-mortem interval (PMI). Adapted from Tomberlin et al. 2011.

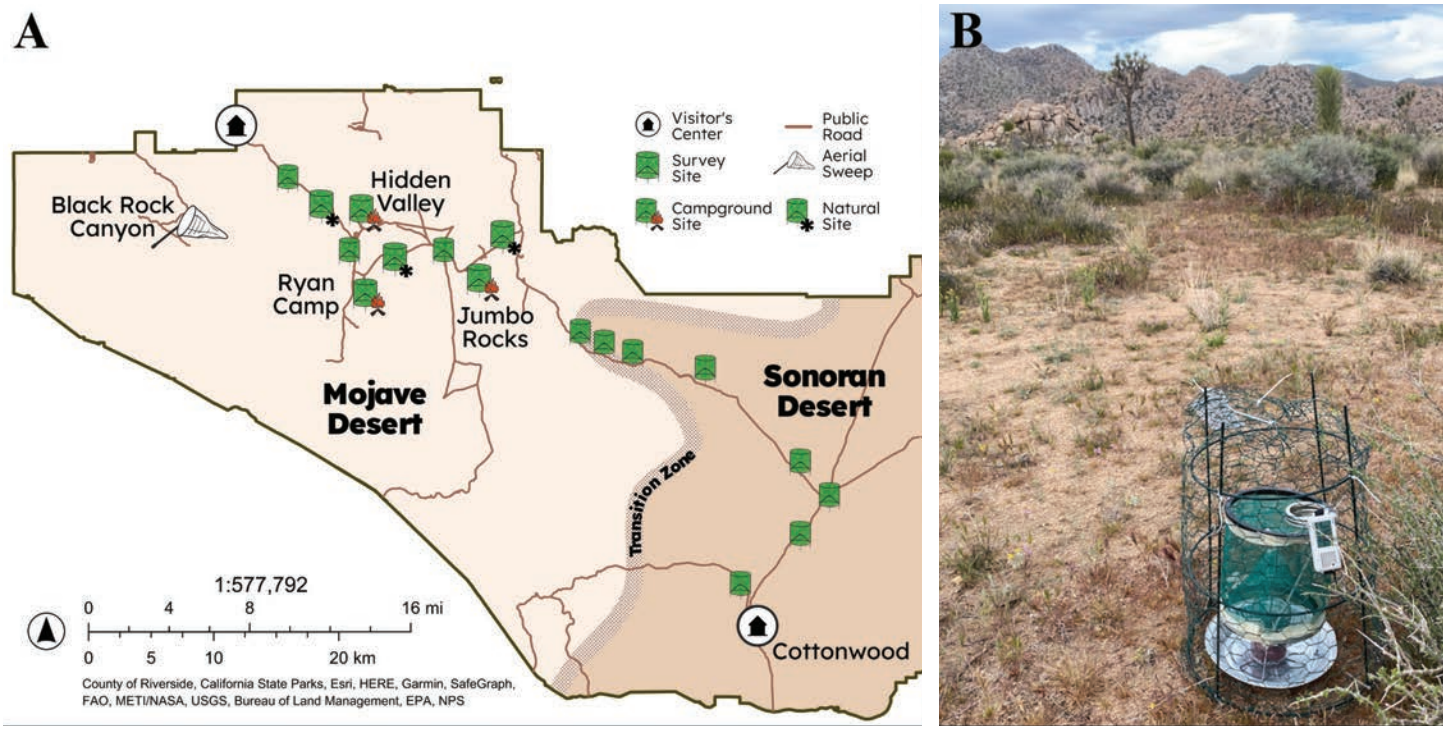

Figure 4. (*A*) map of sites at Joshua Tree National Park (*B*) image of squid-baited trap and temperature/relative humidity data logger attached to cage.

"environmental drones" for monitoring emerging disease patterns that threaten wildlife (*11, 12*). Previous studies have demonstrated that vertebrate fecal matter and DNA can be successfully recovered from adult blow fly gut contents to monitor invasive and native mammals (*12, 13*). This innovative approach offers an inexpensive and more efficient alternative to monitoring large species while still contributing to conservation and management efforts.

WHAT BLOW FLIES CAN BE FOUND AT JTNP?

The diverse desert landscapes within JTNP that include two deserts and a transition zone provide a unique opportunity to study changes in blow fly species composition across different environments. However, limited information is available regarding the specific blow fly species present in the park. Because blow flies are widespread and ecologically important decomposers, researchers in Baja California propose the use of blow flies in understanding and identifying differences in desert environments (*5*). These researchers advocate for more research on blow fly distribution in known regions, such as the two deserts of JTNP to establish potential patterns of urbanization and environmental shifts. Therefore, the first objective of this project was to establish a list of blow fly species found in JTNP, spanning its two deserts.

TRAPPING FOR BLOW FLIES

Fifteen sites were chosen throughout the park, six in the Mojave Desert, three in the transition zone, and six in the Sonoran Desert (*Figure 4A*). We visited the park once a month starting in August 2022 to collect adult blow flies using traps baited with squid 3-4 days old (*Figure 4B*). These traps were then brought back to the lab at UC Riverside and placed into ethanol for morphological identification.

FINDINGS

While our collections are still ongoing, we have so far identified a total of eleven blow fly species across five genera within JTNP (*Figure 5*). This is similar to a previous study that surveyed blow flies in Los Angeles County that identified twelve species (*14*). The two most encountered species thus far are *Phormia regina* (*Figure 6A*) and *Cochliomyia macellaria* (*Figure 6B*), commonly known as the black bottle fly and secondary screwworm, respectively. These two species are typically found in Southern California and are native to North America. This contrasts with *Chrysomya* spp., which are non-native, originating from Australasia and likely transported to North America through trade. Most species were distributed across the park, with the exception of two *Lucilia* species, which were found only in the Mojave Desert and the Transition Zone. We are currently preparing a comprehensive species list for publication.

Interestingly, during the hottest months, we primarily captured flesh flies (*Sarcophagidae*), while blow flies only began to appear as the weather started to cool down in the fall, following the first rain of the season.

DO BLOW FLY COMMUNITIES REFLECT INCREASED JTNP VISITOR ACTIVITY?

Understanding the impact of human activity on species composition is crucial for effective conservation and management of protected areas. In the context of national parks, it is important to assess how fly species composition varies between areas closer to human activity (e.g., campgrounds) and less traversed "natural" sites. Recent research reports that non-native fly species are more closely associated with less natural environments (*1*). Areas with higher human activity and developments such as buildings may also buffer temperature changes in short periods of time, shaping blow fly distributions within the park (*15*). Our second objective aimed to investigate the differences in species composition between campgrounds and natural sites. We hypothesized that there would be a higher species richness (number of species) and higher abundance of flies in campgrounds because of the consistent food availability from campers. We also expected to see more non-native species in areas with high visitor activity based on previous studies.

TRAPPING FOR BLOW FLIES

To understand whether blow fly communities reflect increased JTNP visitor activity, we monitored blow fly abundance and species composition at three campgrounds and three non-visitor "natural" sites. Collections at the park occurred every two weeks under favorable weather conditions, utilizing the same squid-baited traps at six designated locations: three campsites and three natural sites. After a 5-hour collection period, the captured flies were transported back to the laboratory at UC Riverside for morphological identification.

FINDINGS

Thus far, we have collected a total of 867 blow flies from campgrounds and 582 blow flies from natural sites. As hypothesized, campgrounds exhibited a higher abundance of most blow fly genera. However, species richness did not differ between campgrounds and natural sites. Notably, flies belonging to the genera *Lucilia* and *Chrysomya* were more abundant in natural sites, suggesting a higher likelihood of encountering them while hiking on trails (*Figure 7*). While *Lucilia* species are native to the Americas, *Chrysomya* species have only been reported in North America in the past 50 years. Some species within the genus *Chrysomya*, such as *Chrysomya rufifacies*, are facultative predators and may prey on larvae, which has raised concerns for native blow fly species. Despite the expanding range of *Chrysomya* spp., native blow fly species continue to persist. During our study, we found that non-native genera are relatively more abundant in natural areas, which may also be a concern for the conservation of wildlife as some species have been reported to be more likely to mechanically vector antibiotic-resistant bacteria (*16-18*). It has been suggested that species within the *Chrysomya* and *Lucilia* genera rely on different thermal strategies. For instance, *Chrysomya* species may thrive in high temperatures but struggle to survive once temperatures exceed their optimal range. A recent study from Phoenix, Arizona, found similar species as the ones in JTNP; however, abundances vastly differed, likely because of the study's urban environment (*19*). Further research is necessary to investigate these hypotheses and enhance our understanding of the dynamics between native and non-native blow fly species.

CONCLUSIONS

This project aims to establish a blow fly species database for future legal investigations and explore the potential relationship between blow fly activity and visitor activity in JTNP. The findings can provide valuable insights for management practices and shed light on the effects of visitor activity and increased waste in the park. For example, if areas with high visitor activity attract non-native blow flies that compete with native species, frequency of waste disposal can be increased. Additionally, if visitors are bringing in blow flies that have made their way into large vehicles, the park can post information on how to avoid transporting flies into the park. A detailed report will be published once all blow fly collections and identifications are complete.

In conclusion, blow flies play critical ecological roles and have diverse implications for various fields, ranging from forensic investigations to environmental monitoring. These findings can inform management strategies and conservation efforts, ensuring the preservation of this unique desert ecosystem and its inhabitants. By monitoring changes in the populations and behaviors of blow flies and other insects, we gain valuable insights into the broader impacts of human activities on our environment and the interconnectedness of species within ecosystems.

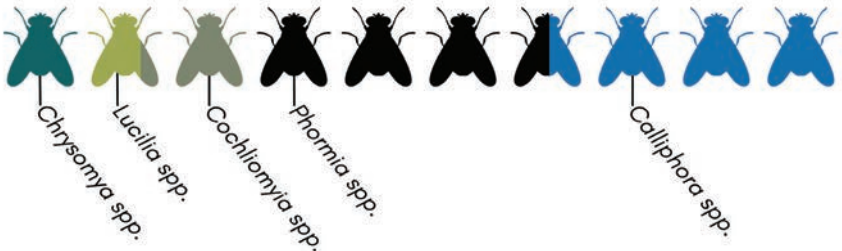

Figure 5. List of genera of blow fly species and visualization of the relative percentages of species collected from each genus represented by the colors.

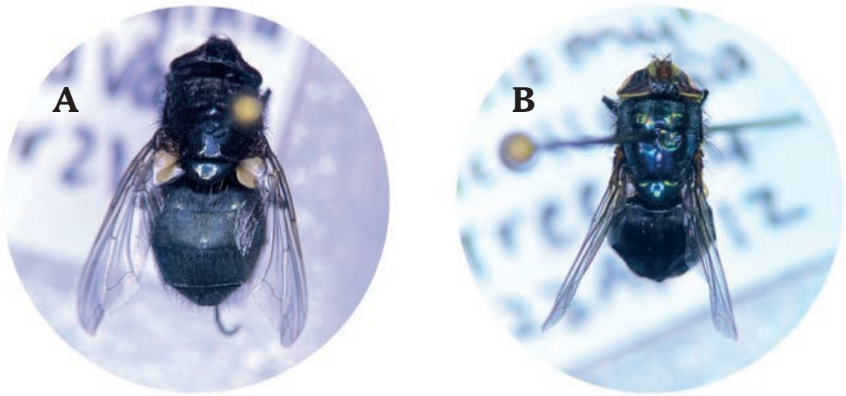

Figure 6. (*A*) adult *Phormia regina* and (*B*) *Cochliomyia macellaria*.

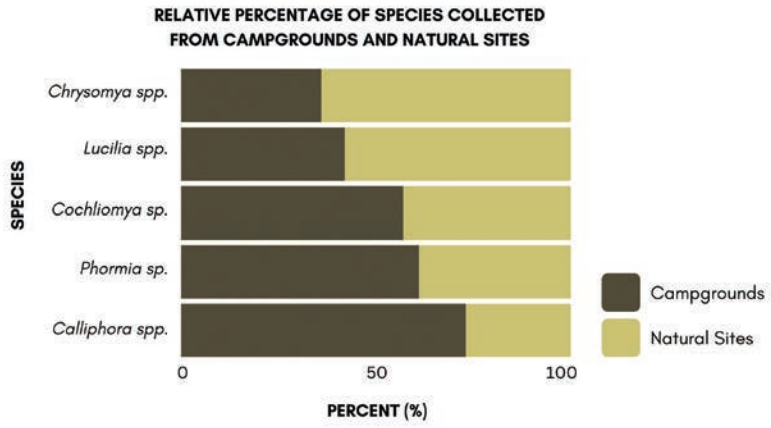

Figure 7. Relative percentages of genera collected from campgrounds and natural sites.

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Butterfly Monitoring at Joshua Tree National Park: *An Update*

Joe Zarki[1] and Marilyn Lutz[1]

Figure 1. *A*) Silver-banded hairstreak *(Chlorostrymon simaethis sarita)*. *B*) A rare Texan crescent *(Anthanassa texana)*. Both observed during JTNP butterfly counts in 2020 and 2022. **Photos by B. LaHaye (left) and Joe Zarki (right).**

Since the authors last wrote about Joshua Tree National Park (JTNP) butterflies for JT Science in 2021 (*1*), a number of events and additional discoveries have occurred that led to our being asked to write an update to the original article.

The worldwide COVID-19 pandemic was enormously impacting to so many activities, and butterfly fieldwork at JTNP was no exception. The park was closed for several months in 2020, but luckily, field research activities were allowed to continue. The authors conducted a two-person spring butterfly count in the Cottonwood area on March 29 and recorded 17 species, including the first American snouts found on the Cottonwood count. Permission was obtained to include a small number of additional field observers for the spring 2020 JTNP count, and eight observers found 35 species on May 2, a record high for any North American Butterfly Association (NABA) count within the park (*2*). The first silver-banded hairstreak (*Chlorostrymon simaethis sarita*) found on a JTNP count was observed in the Smith Water Canyon area (*Figure 1, Table 1*).

Extreme drought conditions during early 2021 negatively impacted spring surveys. The March 27 Cottonwood count produced only five species and 13 total butterflies, and the May 3 JTNP count set a record low of just three species with only 32 butterflies. Monsoon rains in summer provided a brief respite from the drought so the October 15 fall count tallied 24 species and 286 individuals, including the first Mexican yellows (*Eurema mexicana*, *Figure 4A*) seen on a park NABA count (*2*).

Most significant was the publication in September 2022 of a comprehensive work on park lepidoptera, *The Butterflies and Skippers of Joshua Tree National Park* (*3*). This new book covers 96 of the known, or expected, butterflies from JTNP and the nearby Big Morongo Canyon Preserve (*Figure 2*). Dr. Gordon Pratt and his co-authors bring decades of fieldwork and intensive studies of California's butterflies together in a thorough examination of the life histories, ecology, and distribution of butterflies across the park with special attention paid to the immature life stages of butterfly development.

Continued drought once again led to reduced count results in the spring of 2022. The April 1 Cottonwood count recorded just 13 species and the April 30 JTNP count found 18 species, with one new species for the spring count, a red admiral (*Vanessa atalanta*). Numbers of individual butterflies remained well below historic count averages.

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Significant rainfall in summer and fall of 2022 began to ease drought conditions resulting in greatly improved responses by park butterfly populations. Most remarkable was the influx of a number of subtropical migrants into the California Desert. The fall count was held on October 2, and 29 species were recorded including eufala skipper (*Lerodea eufala*), a new species for the park's NABA counts (*2*).

In October of 2022, we documented new sightings of three species not previously reported in the park. On October 14, Joe Zarki found a white patched skipper (*Chiothion georgina georgina*) on a blooming rabbitbrush just east of the Hidden Valley area (*Figure 4C*). This sighting turned out to be the third time this species was observed in California and was the first with photographic documentation (*4*).

Numerous reports of rarely seen migrants from Northern Mexico were turning up across Southern California, so a field trip was planned for the next week to the south boundary area of the park with hopes of finding more rarities. On October 21, Tom Haworth, Cathy Wiley, and Joe Zarki found 27 species including such seldom seen butterflies as pipevine swallowtail (*Battus philenor*), large orange sulphur (*Phoebis agarithe*), and Mexican yellow (*Abaeis mexicana*).

> But the find of the day were two tattered individuals that were eventually identified as Texan crescents (*Anthanassa texana*). This was not only a new record for JTNP, but it was a first record for Riverside County and the first California record outside of the spring season.

Texan crescents (*Anthanassa texana*) are normally found in southeastern Arizona, east to Florida, and south to Honduras (*Figure 1B*) (*5*).

On the same day, Susan Forgrave found a North American polygon (*Polygonus arizonensis*) in the Smoke Tree Wash area (*Figure 3A*) (*6*). This was also a new park record. The southwestern subspecies, *arizonensis*, occurs mainly as strays and is found near

Figure 2. Authors of the new book, *Butterflies and Skippers of Joshua Tree National Park*, gathered in Anza, California, on October 1, 2022, at a native plant sale and book signing. *From l. to r.:* Joe Zarki, principal author Dr. Gordon Pratt, and Dennis Walker.

COMMON NAME	SCIENTIFIC NAME	DATE OBSERVED	OBSERVER(S)
Pipevine swallowtail	*Battus philenor*	10/13/2014	Bill Truesdell
Western giant swallowtail	*Heraclides rumiko*	7/10/2007	Marilyn Lutz
Large orange sulphur	*Phoebis agarithe*	3/27/2015	Marilyn Lutz
Mexican yellow	*Abaeis mexicana*	10/24/2014	Joe Zarki
Silver-banded hairstreak *	*Chlorostrymon simaethis sarita*	4/30/2017	Bob Cullen, Tom Haworth, Donna Thomas
Mallow scrub-hairstreak	*Strymon istapa clenchi*	3/29/2014	Robb Hannawacker
Variegated fritillary	*Euptoieta claudia*	4/26/1997	Marilyn Lutz
Texan crescent	*Anthanassa texana*	10/21/2022	Tom Haworth, Cathy Wiley, Joe Zarki
North American polygon	*Polygonus arizonensis*	10/21/2022	Susan Forgrave
Arizona powdered skipper	*Systasea zampa*	5/5/2001	Joe Zarki
Mojave sootywing	*Hesperopsis libya*	5/6/2000	Marilyn Lutz
White-patched skipper	*Chiothion georgina georgina*	10/14/2022	Joe Zarki
Fiery skipper **	*Hylephila phyleus*	9/29/2015	Tom Haworth
Sandhill skipper	*Polites sabuleti*	5/5/2001	Marilyn Lutz

* There is a record for *C. simaethis* from April 16, 1992 by Kelly Richers on Utah Trail near the park's North Entrance, however it cannot be determined if the location was within the park's 1992 boundaries. Earlier, unverified records may exist for certain species.

** An exotic species.

Table 1. *Butterfly sightings at Joshua Tree National Park. All sightings represent first park records generated by Citizen Science.*

riparian streamsides where it often flies in shady settings.

In recent years, the authors have intensified their focus on pallid dotted-blues (*Euphilotes pallescens elvirae*), one of the park's rarest butterflies.

These small pallid dotted-blues fly only in the fall season from mid-August to early October and are closely associated with yucca buckwheat (*Eriogonum plumatella*). However, they have not been observed in many parts of the park where yucca buckwheat grows commonly. Pallid blue larvae are dependent on their association with ants that protect the growing caterpillars during their larval stage, so it's possible the butterflies occur only in areas where both the ant and suitable yucca buckwheat stands occur.

For a long time, the identity of the ant species linked with the park's pallid blues was not known. During 2021, ants were found tending the pallid dotted-blue caterpillars (*Figure 4B*), and a small number of ants were collected and sent to Dr. Pratt for identification. These turned out to be *Formica xerophila*, a species with a largely unknown distribution within the park (G. F. Pratt, personal communication, October 31, 2021). It's possible that better knowledge of the distribution of *F. xerophila* at JTNP could lead to finding additional locations where pallid blues occur.

What we have learned about pallid blues so far is that they occur in relatively small populations, and are currently known from only one limited area of the park. They favor open areas along fairly gentle alluvial slopes and valleys where yucca buckwheat is found growing in sizeable stands. Numbers of adult blues at any given location are quite small. During a single season we have never found more than about 60 individual butterflies, and 20 is the most found on any single day. Due to this rarity, the pallid dotted-blue populations in JTNP should be considered highly vulnerable. Pallid dotted-blue larvae pupate underground close to their host plants, and they can remain in an extended diapause condition for as long as 30 years before emerging as adults. This gives them an ability to withstand prolonged periods of drought, an adaptation that suits them well for their desert lifestyle.

3A

3B

Figure 3. *A*) A new park record with a sighting of a North American polygon (*Polygonus arizonensis*). *B*) Behr's hairstreak (*Satyrium behrii*). **Photos by Susan Forgrave (left) and Joe Zarki (right).**

In recent years, the areas with known pallid dotted-blue populations in the park have experienced increases in recreational use that may impact their survival. Illegal off-road driving has occurred in areas where pallid dotted-blue larvae have been recorded. It's unknown if this kind of ground disturbance is threatening the larvae, but in populations of such limited numbers, this is a disturbing trend. Other threats include the spread of exotic plants that may compete with native buckwheats, and long-term climate alteration that may affect vegetative communities, soil temperature, and moisture.

One positive development for pallid dotted-blues was the discovery in 2022 of an active population at the Pioneertown Mountains Preserve about 15 km northwest of the park. While this population also appears to be quite small, a second nearby population does provide a bit of additional stability for this rare blue. A handful of other pallid dotted-blue populations are known from other locations in eastern California, but little is known about the status of *E. pallescens elvirae* rangewide. Some scientists have speculated that the *elvirae* population of pallid blues may be found to be a distinct species someday.

Our earlier article discussed several species of hairstreaks (Lycanidae) that may become victims of climate change at JTNP. Behr's hairstreaks (*Satyrium behrii*) (*Figure 3B*), hedgerow hairstreaks (*Satyrium saepium*), mountain mahogany hairstreaks (*Satyrium tetra*), and thick hairstreaks (*Loranthromitoura spinetorum*) are species dependent on plants that may be declining due to the warming climate. Antelope brush (*Purshia tridentata*), desert ceanothus (*Ceanothus greggii* var. *perplexans*), mountain mahogany (*Cercocarpus betuloides*), and dwarf pine mistletoe (*Arceuthobium divaricatum*), are all higher elevation plant species at JTNP whose habitat may disappear as global temperatures continue to increase.

During the authors' 30 years of fieldwork at the park, only two of these species have been found in recent years. On June 5, 2020, a single Behr's hairstreak was seen near Warren Peak (*7*), and on May 21, 2021, a hedgerow hairstreak was found on California buckwheat near Barker Dam (*8*). These are the first park sightings of these butterflies since the early 1990s. However, it is likely that they represent stray individuals as opposed to the re-emergence of a sustained population as no recent evidence of breeding activity (immature stages) has been found within the park.

Forecasts for a wet El Niño winter in 2023/2024 may bring more rain to the desert and hopefully lead to a strong 2024 butterfly season. Regardless of how 2024 turns out, volunteer butterfly watchers will be on hand to document it at Joshua Tree National Park.

Once again, the authors would like to thank all the many volunteers who have helped over the years with butterfly counts and other surveys within the park. Your efforts are much appreciated!

Figure 4. *A)* Mexican yellow *(Abaeis mexicana). B) Formica xerophila* ant tending a pallid dotted-blue larva. *C)* White-patched skipper *(Chiothion georgina georgina).* **Photos by Joe Zarki.**

AUTHOR BIOGRAPHIES

Originally from Maryland, **Joe Zarki** thoroughly enjoyed a 38-year career as a National Park Service ranger. He had stints at Death Valley, Denali, Tuzigoot National Monument, Yellowstone, and he served as Chief of Interpretation at Badlands National Park and at Joshua Tree (1995-2013). Long active in citizen science activities, Joe coordinates Christmas Bird Counts at Joshua Tree National Park and Morongo Valley. Together with his wife Marilyn Lutz, he helps organize butterfly counts at Joshua Tree National Park, Big Bear Lake, and the San Jacinto Mountains.

Marilyn Lutz has been interested in butterflies since she first assisted Dr. Gillian Bowser with fieldwork for a butterfly phenology project in Yellowstone NP in 1984. She compiled the first North American Butterfly Association (NABA) count in Yellowstone in 1990, followed by counts in Badlands NP 1991-94, and Joshua Tree 1995 to present.

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Front cover: Fortynine Palms Oasis at sunset. **Image by Jessy Wilkes.**
Back cover: Spring wildflowers in Joshua Tree National Park. **Image by Joe Zarki.**

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