

- I. Title: Sustaining Lizard Populations on Campus
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- III. Introduction

In Southern Arizona, lowland deserts and washes, have become increasingly fragmented due to increasing urban sprawl. As conversion of native Sonoran Desert to urban development increases, the count of buildings increases, traffic noise becomes louder, and the introduction of invasive species is more common. Depression of the original habitat has resulted in a decrease in wildlife activity and abundance. A few species thrive in the anthropogenic environments compared to others, especially in reptilian species.

Despite recognition of the lack of reptilian adaptation data in response to urban sprawl, the taxon continues to be understudied. Radio telemetry and mark-recapture surveys allow scientists to demonstrate the differentiation of responses between species as well as sexes. The purpose of this study was to demonstrate research dedicated to reptilian species by including students, communities and the general public; To attain the goal of the research an average of five undergraduate researchers were hired to fulfill a leadership role and acquire the skills of a field researcher. The undergraduate field researchers developed skills in collecting weather data from a kestrel, handling and capturing reptilian species, analyzing data, tool use and public speaking. Students would present posters to the community or general public every 2-3 months. These public outreach events included classrooms, conferences, club meetings, and the school hosted events. Furthermore, before an outreach event a social media post, Instagram or Facebook, would advertise our research as well as invite others to the event. The outreach events allow the public to become educated in the field of conservation as well as herpetology.

IV. Methods

A. Study Sites

The University of Arizona is in the center of Tucson and was founded in 1885. Since then, it has been expanded to 392 acres of land and a city has been built around it. Surrounding the university are urban homes and small- scaled buildings for businesses. Houses within the area are within close proximity of each other and preserve minimal or none of the original Sonoran Desert habitat. Desert habitat has been replaced with invasive vegetation, authentic décor, and multiple sized homes/buildings. Original desert habitat that is preserved is used for authentic reasons and includes the planting of common desert plants such as saguaros and velvet mesquites. Much of the current preserved desert habitat on the university campus was restored, the Krutch Garden, or manipulated, Old Main, to fulfill the desert authenticity as well. Though, the campus expanded alarmingly, few desert species were able to thrive in the urbanized environment. These species include a variety of birds and a few reptilian species that have taken advantage of human structures and resources.

Rio Vista Natural Resources Park is located Northeast from the University of Arizona and became a retired horse ranch after 2005. Today, the 40-acre natural resources park is used by

cyclists, pedestrians, and horsemen that all have separate areas assigned for recreation. The bike path runs along the Rillito wash for 12 miles. Pedestrians designated areas include the parks center grass area, playground, and marked trails. At the south edge of the park there is a horse arena that opens to horse trails that do intersect pedestrian's trails. On the designated trails there is preserved desert habitat where many species of birds, snakes, lizards, and small mammals thrive. People, pets and wildlife cross paths frequently at the park as a result of the man-made trails.

B. Handling, Capture, Marking

We captured all lizards using a long, telescoping fishing pole fitted with a noose in the end. We recorded behavior, substrate, microhabitat, the nearest cover and the distance to it, at the moment the lizard was captured. In addition, we recorded environmental data, such as temperature, humidity, cloud cover and wind using a kestrel. Using a GPS, we collected the UTM coordinates of the location of capture. When needed, we put lizard in cloth bags or coolers, and transported to our lab for processing (e.g., measuring, sexing).

We permanently marked Desert Spiny (*Sceloporus magister*) and Sonoran Spotted whiptail (*Aspidoscelis sonorae*) lizards by injecting a PIT tag (passive integrated transponder) under the skin. Ornate Tree lizards (*Urosaurus ornatus*) were temporarily marked with a painted number on their skin (Fig. 1). PIT tags gave each lizard a 12-digit code that could be displayed using a PIT tag reader. For each lizard captured, we recorded sex, age class, snout-vent length (SVL), mass, tail length and if broken or not.

For mark recapture and radio telemetry purposes we only processed lizards when first caught. For recaptures or visual re-encounters, we collected environmental and behavioral data, and UTM coordinates. If the same lizard was recaptured in a different season, processing would be repeated to collect new measurements.



Figure 1. Lizard temporarily marked with a painted number on its skin.

C. Mark-Recapture Surveys

In July and August 2017, we conducted mark-recapture surveys in 4 different plots located in the University of Arizona campus. In June of 2018, we repeated the surveys in two different plots. Mark-recapture surveys consist on capturing all observed individuals within an area, marking them and releasing them back to their original location, using UTM's and flagging. This method is repeated for five consecutive days and collected data can be used to estimate population sizes and relative abundances.

We spent four hours in each plot, per survey session. We captured all visible Ornate Tree lizards, Sonoran spotted whiptail, and Desert spiny lizards within the plot. For each individual caught, we followed our processing protocol (Methods, part B). When we would visually re-encounter or recapture a marked individual, we recorded location, environmental and behavioral data.

In 2017, we started our mark-recapture surveys on four plots located in the U of A campus. The first plot was the Krutch garden, a garden located in the middle of campus that contains a variety of species of desert plants. The second plot was the Pond, containing a turtle pond surrounded by palm trees and olive trees. The third plot was located by the U of A Medical center, characterized by a wash area and big trees. The last plot surveyed in 2017 was the pharmacy, located by the University of Arizona College of Pharmacy, that contained a large grassy area, trees and man-made structures, such as concrete tables and benches. In 2018, we used two new plots for our mark-recapture surveys, the Old Main and the Anthropology wall/AZ State Museum. Old Main is characterized by palm trees, gravel, rocks and grassy patches, while the Anthropology wall/AZ

State Museum is characterized by a large grassy area with wood benches, small shrubs, trees and a rock wall.

D. Radio Telemetry

We used radio telemetry to locate individual lizards and track their movements. Radio telemetry works using radio signals, where a transmitter that sends a radio signal, is attached to the animal. The radio signal is picked up by an antenna connected to a receiver, from where a beeping sound comes. The closer the receiver gets to the transmitter, the louder the sound gets, allowing the animal to be located.

A 1.5g transmitter was glued to the back of captured lizards (Fig. 2) that had a minimum mass of 30g, meaning the transmitter was 5% or less of the lizard's mass. We used the clear silicone waterproof sealant when attaching the transmitter and waited about 10 minutes for part of the glue to dry. We kept the lizard in the laboratory for 24 hours to ensure the glue was fully dried and followed by releasing the lizard back to the location where it was captured. The transmitters have a 14-week battery life, unless a premature battery failure happens. We attempted to capture all telemetered lizards before the battery died.

From July 2017 to June 2019, we captured and tracked a total of 36 lizards in the University of Arizona campus. In August 2018 we started using radio telemetry in a new site, the Rio Vista Natural Resources Park, where we tracked a total of 11 lizards until June 2019. We tracked individuals weekly, about 1-3 times a week, and at different times of the day, mornings (8:00-10:00), afternoons (13:00-15:00) and evenings (17:00-19:00). Every time we tracked an individual, located it and found it was visible, we followed protocol (Radio Telemetry, part D). In addition, we observed the individual from a reasonable distance (~5-10 meters), to not initiate a flight response, for 15 minutes and recorded the displayed behavior. When an individual was tracked, located but not visible, therefore in cover (e.g., in a burrow, in a bush), we still collected the same data, excluding behavioral data. We used the collected GPS locations from every time an individual was tracked and displayed in Google Earth. We used the GPS locations in Google Earth and we outlined polygons to determine home range sizes and movement distances.



Figure 2. Radio transmitter being attached to the lizards' back, using clear silicone waterproof sealant.

E. Social Media

Undergraduate student researchers started two social media pages to create awareness about herpetofauna, educate the public and announce events the team would be participating in. Social media included a Facebook page and an Instagram page. Each post would include a species fact, details about the project, or an accomplishment a team member had achieved.

F. Signs

We designed and placed one interpretive sign on lizard ecology on the University of Arizona campus. The sign was designed to educate the UA community on the lizards present on campus. It contains facts about each species, common behaviors, and urban ecology.

G. Education and Outreach

1. Herpetology class

We collaborated with Dr. John Wiens, an instructor of the undergraduate herpetology class at the UA, to present our project and give students within the class the opportunity to learn some of the field techniques we use in our research.

2. Scientific meetings/symposia

We participated in many scientific meetings and symposiums, where we gave poster presentations on our project and its results. We created three different posters throughout these two years, each time updating and adding to the information we had on our results section.

3. Public presentations

We planned to give presentations of our research and results to local community organizations, such as the public library. Our goal with these presentations is to engage the local community in the wildlife observed in their backyards and throughout Tucson.

H. Data Analyses

V. Results

A. Mark-Recapture Surveys

In 2017, we captured a total of 166 lizards, and recaptured or visually re-encountered lizards 136 times. Of the total lizards observed, we captured 45 Sonoran whiptails (ASSO), 90 tree lizards (UROR), and 31 desert spiny (SCMA) (Table 1).

Species	# of Individuals	# of Observations
ASSO	45	27
UROR	90	96
SCMA	31	13
Total	166	136

Table 1. Summary of mark-recapture performed on all plots of 2017, at the University of Arizona campus.

In 2018, we only performed mark recapture surveys on desert spiny lizards, and we captured a total of 30 individuals. Each individual was recaptured or visually re-encountered 40 times (Table 2). In the year of 2017, we captured 31 desert spiny during mark-recapture surveys, in comparison to 30 in 2018. However, we recaptured or visually re-encountered lizards more than the second year. Out of the 30 individuals, 12 were females, 17 were males and 1 we were unable to determine sex (Table 3).

Site	# of Individuals	# of Observations
Old Main	18	29
Anthro Wall/ Museum	12	11
Total	30	40

Table 2. Summary of mark-recapture performed on both plots of 2018, at the University of Arizona campus.

Year	# of Individuals	# of Observations
2017	31	13
2018	30	40

Table 3. Comparison on the numbers of individuals and observations, from mark recapture surveys of desert spiny performed in 2017 and 2018.

B. Radio Telemetry

We attached radio transmitters into a total of 47 desert spiny lizards, 36 on the UA campus and 11 in Rio Vista Natural Resources Park. On campus we located them 796 times, from July 2017 to June 2019, and in Rio Vista we located 151, from August 2018 to June 2019. Due to premature failure of radio transmitters, some lizards were not added to our average home range calculations.

Lizard ID	Sex	n	Home range size (m2)
TS007	male	46	2781
TS008	male	37	2079.5
TS011	male	40	4706
TS026	male	33	2631
TS030	male	31	477.5
TS036	male	38	4095.5
TS037	male	25	2237.5
TS038	male	35	13484.5
		Mean	4061.563

Table 4. Home range size, in squared meter for all the lizards radio telemetered in 2017, in the University of Arizona campus.

Lizard ID	Sex	n	Home range size (m2)
TS028	male	10	459.5
TS043	male	16	2697
TS044	male	16	550.5
TS045	male	13	3555.5
TS047	male	13	3540.5
TS048	male	28	2442.5
TS059	male	19	5953
TS068	male	22	666
TS069	female	22	142
TS076	male	27	9232.5
TS077	male	22	1466.5
TS078	female	18	325.5
TS079	female	47	914
TS080	male	28	482
Mean			2316.214

Table 5. Home range size, in squared meter for all the lizards radio telemetered in 2018, in the University of Arizona campus.

Lizard ID	Sex	n	Home range size (m2)
TS087	male	19	4799
TS088	male	21	262
TS089	female	14	9221.5
TS090	female	17	798.5
TS091	male	15	2068.5
TS092	male	12	2334
Mean			3247.25

Table 6. Home range size, in squared meter for all the lizards radio telemetered in 2019, in the University of Arizona campus.

Lizard ID	Sex	n	Home range size (m2)
TS001	male	21	600.5
TS004	female	14	49.5
TS005	male	12	390.5
TS006	female	17	218
TS011	male	11	361
Mean			323.9

Table 7. Home range size, in squared meter for all the lizards radio telemetered in 2018, in Rio Vista Natural Resources Park.

Lizard ID	Sex	n	Home range size (m2)
TS015	male	19	481
TS016	female	19	935.5
TS017	female	18	375.5
TS019	male	10	1700.5
TS020	male	11	313
Mean			761.1

Table 8. Home range size, in squared meter for all the lizards radio telemetered in 2019, in Rio Vista Natural Resources Park.

C. Social Media

Students created two social media pages, Instagram and Facebook. Instagram held a follower base of over 300 followers and Facebook with over 150 followers. Undergraduate researchers shared pictures biweekly of their new-found knowledge and accomplishments. Posts contained pictures of the talks at JAM, bookstores, meetings and specimens found.

D. Signs

We placed the sign (Fig. 3) in a heavily traveled area on the UA campus, the Northwest corner of Old Main (Fig. 4). The Old Main area is also home for all of the species of lizards found on campus, allowing students and visitors to search and identify them. Dennis Caldwell was the designer for the artwork in the sign.



Campus Lizards

Lizard Behavior

Push-ups & Head Bobbing

Male lizards use push-ups and head bobbing as a display to attract females, and to defend their territory from other males. These displays are critical for maintaining the complex social system of many lizard species.

Feeding

Each species of lizard has their own unique diet, but there is some overlap between species. Large lizards, like the Desert Spiny lizard, can be found eating insects and even smaller lizards. Smaller lizards, such as the Sonoran Spotted Whiptail and the Ornate Tree lizard, can be found eating a variety of insects and spiders. You could say they are the perfect natural pest control.

Basking

Lizards are ectotherms that derive their body temperatures from the environment; therefore, they need an external source of warmth to get moving. They get warm by exposing themselves to sunlight and lying on warm rocks. Lizards are experts at thermoregulation, keeping their body temperature more or less constant even though their surrounding temperatures are constantly changing.

Urban Ecology

Thousands of people walk around the UA campus every day. The presence of humans has forced lizard populations to adjust to buildings, roads, and cars in their habitats. Three species of lizards, the Desert Spiny, the Sonoran Spotted Whiptail, and the Ornate Tree lizard, have been successful at living together with large numbers of humans.

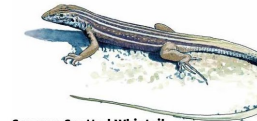
UA Green Fund

The University of Arizona Green Fund is a student-led organization that provides support for projects that increase sustainability on campus. By studying how lizards on campus respond to changes brought on by humans, we can design green spaces that support urban wildlife. Urban ecology has an important role to play in connecting people with the natural world, educating them about how important it is to maintain wildlife and the habitats on which they depend.



Desert Spiny Lizard (*Sceloporus magister*)

The largest lizard found on campus, they are usually seen on trees or buildings, but watch your step, as they occasionally cross streets, or sun themselves on low vegetation and the ground. You might think these lizards are difficult to spot, but look for their bright blue bellies, used to display to females.



Sonoran Spotted Whiptail (*Aspidoscelis sonoriensis*)

Have you noticed a lizard on campus with a very long tail? It was probably a Sonoran Spotted Whiptail. They are an all-female species that reproduces asexually. They are usually seen looking for food on the ground or running away at high speed.



Ornate Tree Lizard (*Urosaurus ornatus*)

Despite their small size, they are very territorial. Just like the Desert Spiny Lizard, males have bright blue bellies. They are harder to spot, because their scales look just like the bark of trees. However, if you pay close attention, you will notice them on practically every tree on campus.

Figure 3. Sign on lizard ecology designed and placed in the UA campus.

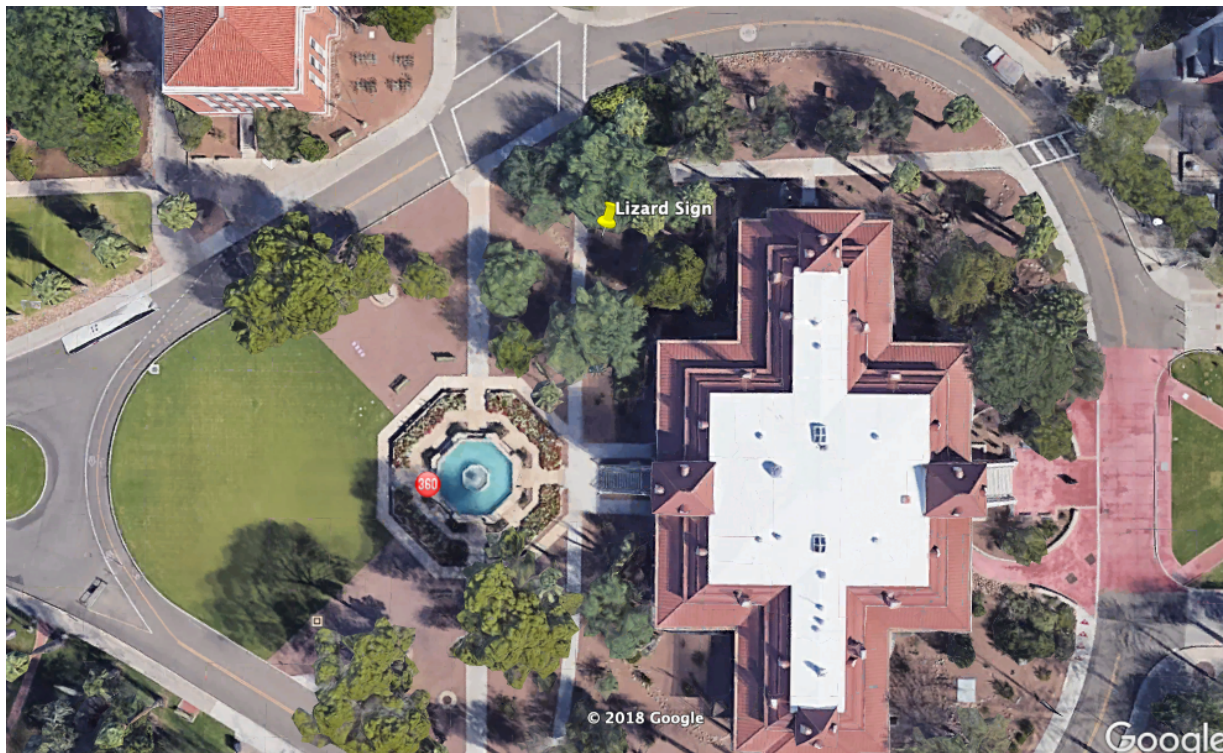


Figure 4. Lizard sign location.

E. Education and Outreach

1. Herpetology class

We prepared a PowerPoint presentation on our research to present in Dr. John Wiens herpetology class. In both lab sections of the class we presented a presentation that included the objectives and methods of our research. In addition, we took the students outside of the classroom to Old Main, to track one of our lizards and to capture a new one. By doing so, we were able to show the students how we caught, handled and processed each lizard used in our study, and how we track them using radio telemetry.

2. Scientific meetings/symposia

We participate in a total of five poster presentations, they are listed below followed by date and location (Table x).

Scientific meetings/Symposia	Date	Location
oSTEM	December 1 st , 2017	Tucson, AZ
JAM* 2018	February 2-3 rd , 2018	Flagstaff, AZ
Biology of Lizards	May 23-26 th , 2018	Rodeo, NM
Earth Day	April 11 th , 2018	Tucson, AZ
JAM* 2019	February 7-9 th , 2019	Albuquerque, NM
ALVSCE**	March 22 nd , 2019	Tucson, AZ

Table 9. List of all the scientific meetings/symposia we participated.

* Joint Annual Meeting – Arizona/New Mexico Chapter.

** UA - Agriculture, Life and Veterinary Sciences, and Cooperative Extension.

3. Public presentations

We held two public presentations throughout the project. The first presentation was during the School of Natural Resources and Environment Earth Day, on April 12, 2018. We had a desert spiny lizard on display, as well as the equipment we use to catch the lizard and radio track them (Fig. 5). We explained to the visitors the purpose of our project and how we used radio telemetry to find the lizards.

The second presentation was held at Barnes and Noble, on November 18, 2018. The University of Arizona's VIDA club allowed us to participate in their fundraising event by educating the customers. We had a table set up and brought a desert spiny lizard for public viewing, as well as our poster used in scientific meetings (Fig. 6).



Figure 5. SNRE Earth Day. Students from left to right, Alexis Cazares, Caitlin Brenton and Luiza Samora.



Figure 6. Barnes and Nobles presentation, for the UA VIDA club. Students from left to right, Brianna Whitehair, Alyssa Salazar, Samantha Johnson and Luiza Samora.

VII. Discussion

A. Mark-Recapture Surveys

The Desert Spiny Lizard, Sonoran Whiptails and Ornate Tree Lizards were marked successfully using paint methods similar to past and current studies with other species of herpetofauna. This contributed promise for the mark-recapture field application in detectability, harsh weather conditions and regular shedding cycles of the species. A pink-colored paint was sufficient to mark multi-sized/aged lizards of all species used within the study and was observed to have no influence on species behavior.

In 2018, painted species contained only the Desert Spiny Lizard. The Desert Spiny Lizard contributed more interest in the group of undergraduates hired and was caught successfully at a higher rate than other species due to their larger body size. Detectability of the species was significant with the paint of choice resulting in marked individuals from 2017 being observed more commonly in 2018. Results showed that a higher rate of sightings in 2018 could be in response to seasonal opportunities. Hibernation, during colder months, for the Desert Spiny Lizard creates lower detectability and difficulty to mark new individuals. When the species began to emerge from their burrows and crevices, after hibernation, there was an increased rate of marked and unmarked individuals detected.

B. Telemetry

An increased focus on the Desert Spiny Lizard led to analysis of home range size and species distribution. The Desert Spiny Lizard was marked with paint methods, PIT-tagged and had an attached transmitter. These methods were used in relation to previous studies of herpetofauna, such as the Sonoran Gila Monster. Methods were determined to be useful and decreased conflicting the species behavior. Conflicting species behavior was considered by mass of the individual. Females were determined to be larger than 28g, and 30g for males in order to attach a transmitter.

The study site on UA campus was conducted between 2017-2019 where undergraduate researchers observed annual differences in home range size. Results showed the mean difference between 2017-2018 was $>1,175 \text{ m}^2$ and between 2018-2019 it was $>931 \text{ m}^2$. Means on campus were found to vary with sample size and sex. Sample size fluctuated throughout the study in response to detectability of individuals and female behavior. Females were concluded more difficult to catch resulting in an unproportioned sex ratio. Visual observations predict that females are more vigilant than males in order to sustain reproductive success.

Home range sizes varied at a high rate between UA campus and Rio Vista. Lizards on campus in 2018 and 2019 contained an average $>1500 \text{ m}^2$ compared to Rio Vista. Rio Vista's sample size is predicted to influence the mean by containing 5 individuals compared to campus with a count of individuals ≥ 6 . The sample size, for both study sites, were considered under the recommended number ($n=30$) and potentially influenced observations.

C. Social Media

Social media for the research conducted was considered a success with 50-100 followers gained each year of the study. Methods of recruitment exposed many majors of students to profound knowledge of herpetofauna on campus. Undergraduate students involved with the projects found themselves encourage to share pictures with the site and continue to share their knowledge with peers outside of the study.

D. Signs

The undergraduate researchers observed campus visitors and students reading the new signage outside of Old Main. There were also increased rates of both parties searching and looking to identify the range of species on campus. The signage was concluded to increase awareness of herpetofauna living on campus and the impact they make in their ecosystem.

E. Education and Outreach

The PowerPoint presentation delivered in the herpetology class employed students an enhanced understanding of field research and its components. Undergraduate researchers lead direction of the class and performed hands-on work. Students within the class were able to practice telemetry, enhance tool use and noose lizards on campus. The lab and undergraduate researchers received positive feedback about the skill set shared.