Urban Ecology and Conservation of Reptiles
Wallace Research Foundation

Final Report for 2019

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Introduction

Urbanization is one of the greatest threats facing wildlife, often resulting in habitat destruction and a loss of biodiversity. Urbanization is cause for growing concern in the southwestern U.S., and specifically in Arizona, as cities continue to expand into the once uninhabited deserts. As the cities of Tucson and Phoenix continue to sprawl, it becomes increasingly important to understand the impacts of urban development on the diverse wildlife of the Sonoran Desert. Within the field of urban ecology, there has been little research on the effects of development on snakes and lizards. Our long-term (2002-2013; 2017-2019) project at Stone Canyon focuses on effects of ongoing urbanization on a snake community and Gila Monster population situated at the urban fringe in Oro Valley, a rapidly growing suburb of Tucson. In this report, we present the results of our study from 2017-2019, and we interpret our findings in the context of our 12-year legacy dataset.

Methods

From May-August, a group of undergraduate students at the University of Arizona conducted nightly reptile surveys of the golf cart path and roads surrounding the Stone Canyon development at the base of the Tortolita Mountains. We captured all snakes and Gila Monsters encountered, recorded weather data and location information, and transported animals back to our lab for processing the next day. Processing included body measurements, determination of sex and age class, obtaining fecal and tissue samples for genomic analyses, and implantation of Passive Integrated Transponder (PIT) tags (small microchips) for individual identification. We returned animals to the exact point of capture the following day. We recorded effort (i.e., miles driven) for each survey, allowing us to make comparisons across years.

In mid-summer 2017, we installed two rain gauges at the site. One on the golf course, and another in a nearby location off the golf course (Fig. 1). Through 2019, we regularly recorded precipitation at each gauge during the summer field season. We then compared daily "precipitation," including golf course overspray at the gauge on the golf course, to examine differences in natural and anthropogenic water availability.

Figure 1: On and Off course rain gauge locations at Stone Canyon.

Using NASA's Application for Extracting and Exploring Analysis Ready Samples (AρρEEARS), we extracted the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) for shapefiles containing Stone Canyon's golf course and a similarly sized comparison site located ~1 km north of Stone Canyon (Fig. 2). These metrics represent the relative "greenness" of the vegetation in each location, with the EVI being a better measure of greenness in arid landscapes.

To compare capture rates for all species over time, we determined the number of species captured per mile of survey in each year and plotted the capture rate over time. We separated road cruising captures from cart path survey captures, as the number of captures on the cart path is almost twice as high per mile than the road.

Given the numerical importance of rattlesnakes (three species) at Stone Canyon, we performed more detailed analyses of this group. To analyze rattlesnake activity at a daily scale, we constructed a Poisson regression model to predict the number of rattlesnakes seen on a single survey. We retrieved daily and monthly climate data from the PRISM climate model and determined the cumulative rainfall from October to February leading up to each sampling season, cumulative rainfall in the monsoon season (June-Sept) of the previous year, and cumulative 30-day rainfall for each survey date to account for seasonal and yearly climate variation. We determined the number of completed houses in each year as an index of urbanization at the site and examined the relationship between the number of completed houses and daily rattlesnake counts.

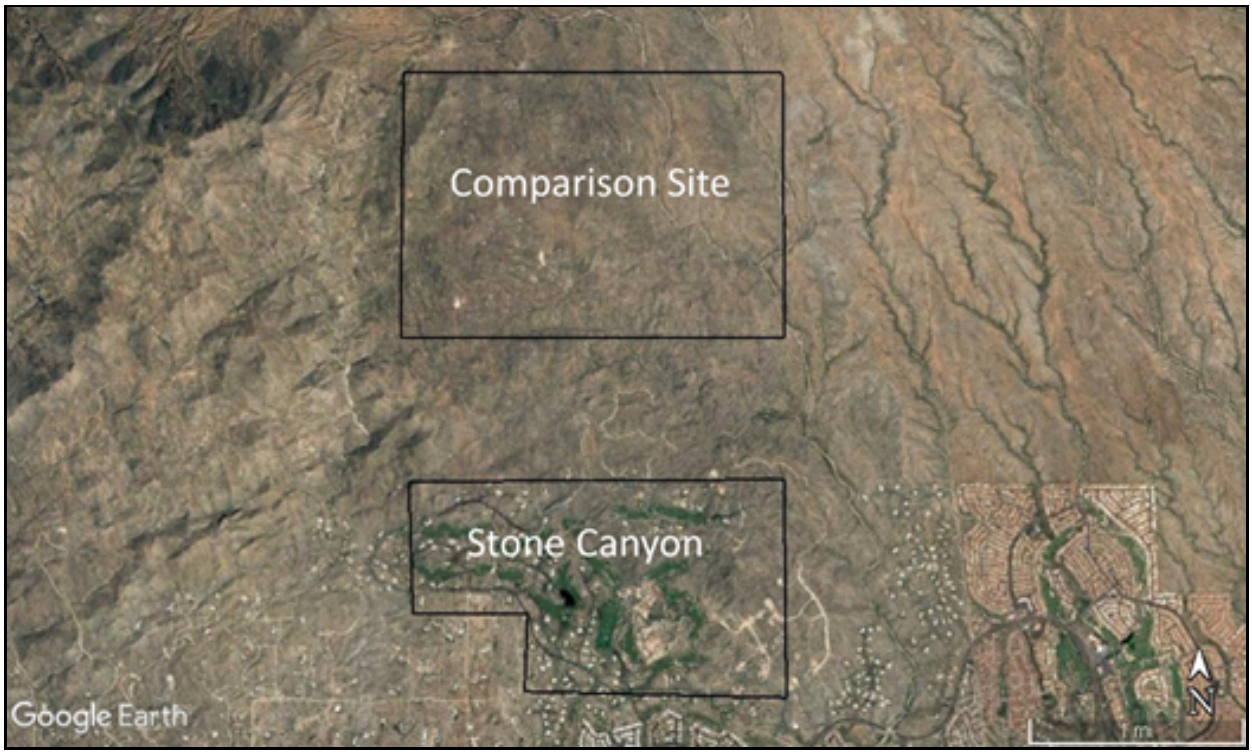

Figure 2: Location of Stone Canyon and comparison site for analyses of vegetation "greenness."

Results

From 2017-2019, mean daily "precipitation" during the summer months was 2.56 and 1.28 mm/day for on and off course rain gauges, respectively (Fig. 3). The amount of water received on the golf course was 89-128 (95% CI = 1.15-1.65) greater than away from the golf course. There was considerable annual variation in natural precipitation, ranging from 24.9 mm in 2019 to 176.8 mm in 2018, which represents a greater than seven-fold difference (Table 1).

Table 1: Collected rainfall data from Stone Canyon over the past three field seasons. Rain amounts are represented in millimeters.

Month	May	June	July	August	Amount	Checked
2019 On Course	6.4	42.8	76.5	35.4	161.1	65
2019 Off Course	0.8	0	21.9	2.2	24.9	67
2018 On Course	18.5	47.7	103.9	117.5	287.7	72
2018 Off Course	0	16.9	76.2	83.7	176.8	65
2017 On Course	Not Recorded	Not Recorded	44.3	65.9	110.2	22
2017 Off Course	Not Recorded	Not Recorded	32.2	48.8	81	15

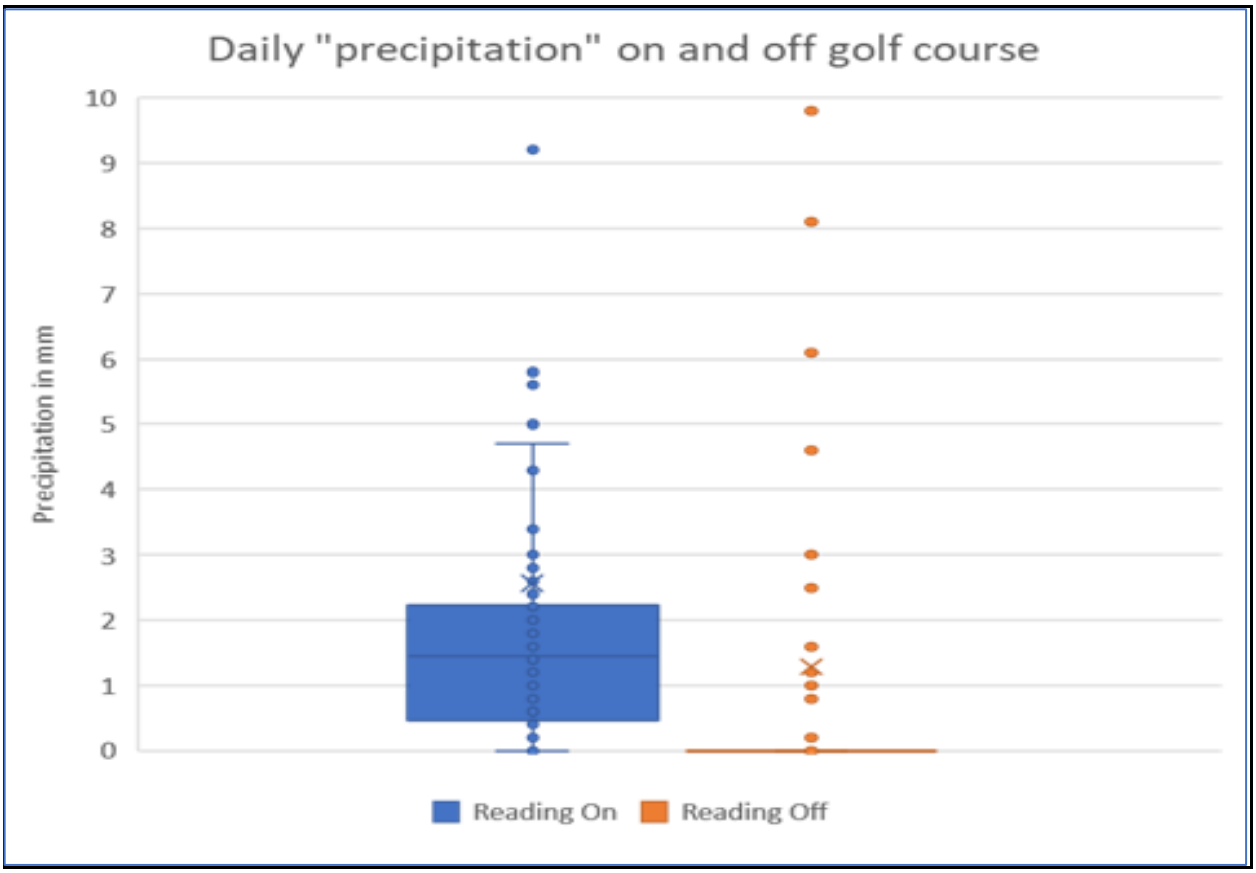

Figure 3: Comparison of daily "precipitation" on and off the golf course.

Both NDVI and EVI values were significantly greater at Stone Canyon ($P < 0.0001$, $N = 436$) compared to the natural reference site, with 95% confidence intervals of 0.038-0.041 (a 15-17% increase) for NDVI values, and 0.036 – 0.039 (a 23-25% increase) for EVI values (Fig. 4).

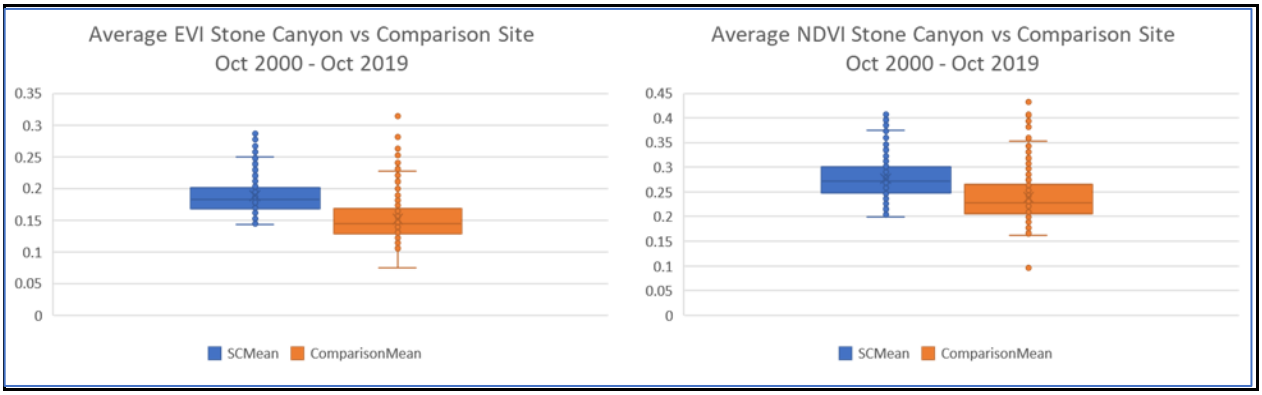

Figure 4: Comparison of NDVI and EVI values between Stone Canyon and natural site.

Total snake captures per mile were variable over the years, 2006 only had 9 surveys on the road, and shorter surveys on the cart path, likely explaining the increase in captures per mile for that

year. Overall, there is no clear trend in snake captures when looking at the entire snake community (Fig. 5).

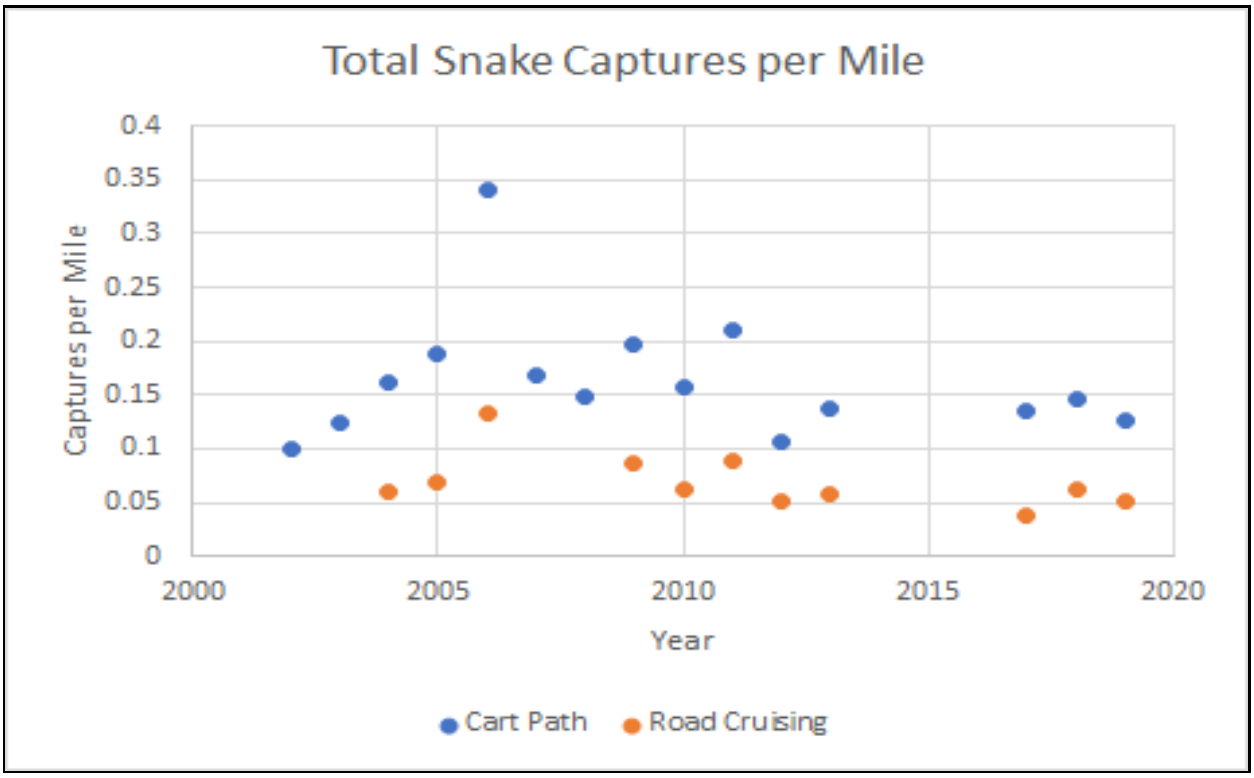

Figure 5: Snake Captures per mile by year.

Despite the lack of clear trends in the entire snake community, results of our nightly count models revealed an influence of urbanization on rattlesnake species. We also found that this effect is different between different species of rattlesnakes (Fig. 6).

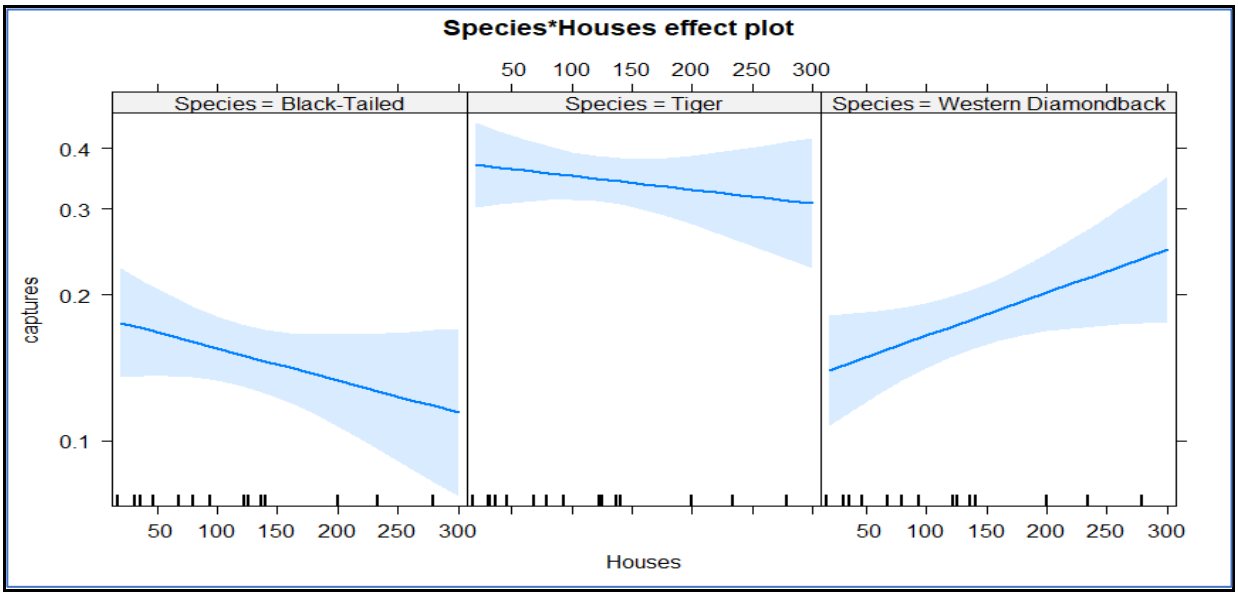

Figure 6: Effect-size plot of number of houses by number of rattlesnake captures by species.

Specifically, an increase in the number of houses (from 17 in 2002 to 278 in 2019) was correlated with an increase in the number of Western Diamondback Rattlesnakes, but a decrease in the number of Black-Tailed Rattlesnakes, and Tiger Rattlesnakes. Overall, the counts of tiger rattlesnakes are still greater at the site than either of the other two species (Table 1).

2017-2019 Data

We have now completed our third year of funding from Wallace Research Foundation, which has resulted in 371 cart path and road surveys, 11,897 km driven (Table 2), 794 snake captures (19 species) and 128 Gila Monster captures (Table 3).

Table 2. Survey effort from 2017-2019. Data from all three years are from the period May 25-August 25 to allow for among-year comparisons.

	Days of Survey	Road Surveys	Road Km Driven	Road Loops Driven	Cart Surveys	Cart Km Driven	Cart Loop Driven
2019	68	68	3385.91	134.2	66	1344.75	129
2018	72	69	3204.01	134	68	1320.46	129.5
2017	53	46	1644.2	82	54	998.25	100.67

Table 3: Snake captures and encounters from 2017-2019 by species and survey method. Encounters represent sightings and captures represent individuals brought back to the laboratory for further processing. Capture data exclude individuals that eluded capture or individuals caught within 30 days of the previous capture.

Species	2019 Road Encounters	2019 Cart Encounter	2019 Captures	2018 Road Encounters	2018 Cart Encounters	2018 Captures	2017 Road Encounters	2017 Cart Encounters	2017 Captures
Arizona Elegans	0	0	0	0	0	0	0	0	0
Chilomeniscus stramineus	27	5	32	30	6	35	4	1	5
Crotalus atrox	31	38	62	51	57	95	8	26	28
Crotalus molossus	3	19	21	12	22	34	2	12	13
Crotalus tigris	43	39	76	49	54	97	14	36	47
Diadophis punctatus	1	2	3	1	3	3	0	1	1
Heloderma suspectum	32	32	60	21	17	41	9	16	27
Hypsiglena chlorophaea	10	4	14	6	1	7	2	0	2
Lampropeltis getula	1	6	7	9	3	11	2	1	3
Leptotyphlops humulis	9	0	9	3	0	3	2	0	2
Coluber bilineatus	2	1	1	4	1	1	0	0	0
Coluber flagellum	1	0	1	0	0	0	0	0	0
Micruroides euryxanthus	6	3	7	4	0	4	0	1	1
Phyllorhynchus decurtatus	0	0	0	0	0	0	0	0	0
Phyllorhynchus browni	4	1	5	1	0	1	0	0	0
Pituophis catenifer	1	3	4	6	4	9	0	6	6
Rhinocheilus lecontei	15	13	26	7	5	11	6	4	10
Salvadora hexalepis	0	3	2	2	2	4	2	0	0
Sonora semiannulata	1	0	1	1	0	1	0	0	0
Tantilla hobartsmithi	2	0	2	4	0	4	0	0	0
Thamnophis cyrtopsis	4	1	4	2	0	1	1	0	0
Trimorphodon lambda	15	14	25	14	23	37	7	9	16
Totals	208	184	362	227	198	399	59	113	161

Discussion

Relative abundance (counts) of total species between years did not correlate strongly with time; however, we observed species-specific changes in daily counts of rattlesnakes as the site became more urbanized, using number of houses as a proxy for urbanization). These findings support the hypothesis that urbanization is expected to have a differential effect on snake species, likely due

to a variety of factors, such as life history traits, relative abundance, seasonal activity patterns, and ability to acclimate to the human-built environment. Further analyses are needed to investigate variation in snake numbers associated with environmental factors, such as temperature, humidity, and moonlight illumination, and other explanatory variable related to urbanization (i.e., amount of land converted from natural areas to developed areas, number and type of roads, and traffic volume).

Results from analyses of rain gauge data and relative "greenness" indicate that vegetation at the site has benefitted from supplemental water, especially from golf course overspray and drip irrigation along roads and golf course features. Overall, persistence of snakes and Gila Monsters over the 18-year period of construction and human habitation is somewhat surprising. It seems likely that the input of water and associated increase in primary productivity, as well as preservation of a large proportion of native habitat, are likely important contributing factors that have ameliorated the expected negative effects of urbanization. In addition, peak human activity occurs during the winter months when snakes are inactive, thereby resulting in low levels of anthropogenic mortality (e.g., roadkill, human-snake conflicts). We speculate that negative impacts from urbanization are likely much greater in urban areas characterized by high-density housing, increased traffic, and year-round residency.

Other Project Activities

In addition to conducting field work throughout the summer months, we attended and presented at local, national and international scientific meetings and conferences. These activities provided undergraduates with the opportunity to share the results of our research and expand their knowledge by learning from professionals in the field. These events included:

1. Joint Annual Meeting of the Arizona and New Mexico Chapters of the The Wildlife Society and American Fisheries Society in Albuquerque, NM from February 7-9, 2019
    - Oral presentations (2) on "The Effects of Moon Illumination on Relative Snake Abundance" by John Bosak and "Effects of Urbanization on a Gila Monster Population in Oro Valley, Arizona" by Alexus Cazares
2. Arizona/NASA Space Grant Symposium in Tempe, AZ from April 12-13, 2019
    - Oral presentation on "Effects of Urbanization on Gila Monsters" by Alexus Cazares
3. The University of Arizona Department of Ecology and Evolutionary Biology in Tucson, AZ on April 28, 2019
    - Poster presentation on "Effects of Urbanization on Gila Monsters" by Alexus Cazares. ***People's Choice Award for all undergraduate presentations.***
4. The University of Arizona Honors College Poster Session in Tucson, Arizona on April 28, 2019
    - Poster presentation on "Effects of Urbanization on Gila Monsters" by Alexus Cazares
5. Biology of Pit Vipers 3 in Rodeo, NM from July 11-14, 2019
    - Oral presentation on "The Ecology of Three Sonoran Desert Rattlesnake Species at an Urbanizing Site" by Diego Huerta
6. Joint Meeting of Ichthyologists and Herpetologists in Snowbird, UT from July 24-28, 2019

- Oral presentations (3) on “The Effects of Moon Illumination on Relative Snake Abundance” by John Bosak, “Effects of Urbanization on Gila Monsters in Arizona” by Alexus Cazares, and “Desert Rattlesnake Species at an Urbanizing Site” by Diego Huerta

7. Venomous Snakes as Flagship Species Symposium in Arnhem, NL from October 10-12, 2019
    - Oral presentation on “What’s It Like to Be a Tiger Rattlesnake?” by Matt Goode
8. Future for Nature Academy at Leiden University in Leiden, NL on October 15, 2019
    - Invited seminar on “Stone Canyon Snake and Gila Monster Research” by Alexus Cazares
9. Sabino Canyon Recreation Area in Tucson, AZ on October 24, 2019
    - Oral presentation on “Sabino Canyon Snakes” by John Bosak

We also shared our research with the greater Tucson community to promote science learning in school-age children and local reptile conservation. This was completed through the following outreach events:

1. The University of Arizona School of Natural Resources and the Environment Film Festival in Tucson, AZ on March 25, 2019
    - Goode Lab Snake Project (https://www.youtube.com/watch?v=yfWu3_8vZjc)
    - ***Awarded Second Place ($100)***
2. El Pueblo Center Snake Outreach Event in Tucson, AZ on July 2, 2019
    - Oral presentation to school aged children on the diversity of snake species and their importance to the environment
3. Flowing Wells High School Population Study in Tucson, AZ on August 10, 2019
    - Allowed a high school student to shadow field research at Stone Canyon to teach them about local snake populations and the impact of urbanization on their population size.
4. Sam Hughes Elementary School Mark-Recapture Project in Tucson, AZ on September 9 and 13, 2019
    - Mark-recapture study of the lizard populations on the grounds of Sam Hughes Elementary School with the 4th grade students to teach them about the scientific process.

The lab is currently working on publishing three manuscripts from data collected over the past three field seasons. Topics will cover the effects of moon illumination on snake relative abundance, effects of urbanization on rattlesnake species at the site, and effects of urbanization on Gila Monsters at the site. This research, along with the work of others in the lab, will be presented at The 53rd Joint Annual Meeting of the Arizona-New Mexico Chapter of The Wildlife Society in early February 2020, as well as at the Biology of Heloderma conference in July 2020. We will also continue to outreach efforts throughout the greater Tucson community to further share the knowledge we have gained from this project, with presentations scheduled for January 2020 to the Institute for Learning in Retirement at Sun City in Oro Valley and to the Saddlebrooke Community in Catalina.

And finally, we have maintained an active social media effort to further disseminate our results and educate the general public about reptile ecology and conservation. For up to date information on the activities of the Goode Lab and the Stone Canyon Snake Project follow us on any of our social media platforms:

Website:	https://herpetology.arizona.edu/
Instagram:	https://www.instagram.com/uaherpetology/
Facebook:	https://www.facebook.com/uaherpetology/