A HERPETOLOGY SURVEY OF EDITH L. MOORE NATURE SANCTUARY: A NATURE SANCTUARY WEST OF DOWNTOWN HOUSTON

An Undergraduate Research Scholars Thesis

by

DILLON JONES

Submitted to the Undergraduate Research Scholars program at
Texas A&M University
in partial fulfillment of the requirements for the designation as an

UNDERGRADUATE RESEARCH SCHOLAR

Approved by Research Advisor: Dr. Lee Fitzgerald

May 2018

Major: Wildlife and Fisheries Sciences

TABLE OF CONTENTS

ABSTRACT

A Herpetology Survey of Edith L. Moore Nature Sanctuary: A Nature Sanctuary West of Downtown Houston

Urban herpetology "deals with the interaction of amphibians and reptiles and humans with each other and their environment in urban or urbanizing settings" (Mitchell et al. 2008). Miller (2006) urges that human experience with nature is necessary for the public to gain a greater appreciation for conserving biodiversity. As such, well-preserved urban natural areas can be important tools for conservation education. Edith L. Moore Nature Sanctuary is an 18-acre wooded sanctuary located west of downtown Houston, Texas and is the headquarters to Houston Audubon. By comparing historical and citizen science data with results from visual encounter surveys and aquatic funnel traps, we hope to create a complete checklist of the herpetofauna diversity at Edith L. Moore. A comparison of our results show that Edith L. Moore contains 24 species of reptile and amphibians, however common species to the surrounding area are entirely absent from the park's history.

ACKNOWLEDGEMENTS

I would like to thank Houston Audubon, the Applied Biodiversity Conservation Scholars Program, the Undergraduate Research Scholars Program, and the Academy of Undergraduate Researchers Across Texas for funding; my advisor, Dr. Lee Fitzgerald, for assisting so heavily with methodology and logistics of the research; Edith L. Moore Nature Sanctuary and their staff for hosting me and my research and finally, any friends, volunteers or sanctuary staff who have assisted me during survey dates.

NOMENCLATURE

Herpetofauna	Descriptive term referencing both reptiles and amphibians
ELM	Edith L. Moore Nature Sanctuary
Flora	Plant life including fungi
Fauna	Animal life

CHAPTER I

INTRODUCTION

Urban Areas

Increasing pressure from human disturbance and expansion is threatening global wildlife populations (Butchart 2010; Hamer 2010). According to Pimm (2014), the rate of extinction for wildlife around the world is 1,000 times higher than the rate of extinction without human disturbance (Pimm 2014). Human disturbance includes increased human expansion, consumption of natural resources, and urbanization, the expansion of urban areas into previously rural areas (Pimm 2014, Veach 2017). As human activities continue to affect global wildlife populations, urbanization remains one of the fastest growing issues related to biodiversity and wildlife conservation. (Veach 2017, United Nations 2014).

Urbanization is a global phenomenon. The world's population is growing rapidly and by 2050, 66% of the world's population will be residing in urban areas (United Nations 2014). As we expand into these areas, near permanent changes occur to the natural ecosystem (Guneralp 2013). Habitat fragmentation and alteration, introduction of invasive species, and pollution of various types (noise, artificial light, sewage etc.) all have negative effects on native fauna (Cureton II et al. 2014, Hunt 2013, Riley 2005, Rebele 1994, Ciach 2017). The evidence clearly show that urbanization has extreme consequences on native species.

Herpetofauna (reptiles and amphibians) are especially at risk. Globally, 41% of amphibians and 19% of reptiles are threatened with extinction (IUCN 2017; Bohm et. al. 2013). Urbanization has been shown to have direct effects on herpetofauna populations, with urban areas displaying lower herpetofauna biodiversity and richness (Rubbo and Kiesecker 2005;

Hamer 2010). As urbanization increases, herpetofauna communities continue to be at risk for extinction. For this reason, it is paramount to study herpetofauna conservation as it relates to urban areas.

Urban herpetology "deals with the interaction of amphibians and reptiles and humans with each other and their environment in urban or urbanizing settings" (Mitchell et al. 2008). Miller (2006) urges that increased interaction with biodiversity results in a greater appreciation for wildlife and conservation efforts. Placing education in the context of natural protected areas may have dramatic effects on future conservation efforts. (Jiminez 2015). Results from Sousa (2016) found that teenage students who had contact with ponds as part of their education had an improved attitude and knowledge toward biodiversity and its related functions. Laladhas (2013) finds that students who are involved with their local biodiversity show increased respect and a greater understanding of nature at large. It is for these reasons that maintaining proper biodiversity in local regions can have dramatic effects future actions as they relate to conservation.

Study Area

Houston Texas is the 4th largest city in America and has undergone rapid expansion (U.S. Census Bureau 2012). Compared to a national growth rate of 24%, Houston underwent 50% population growth over the same 20 year period (U.S. Census Bureau 2012). Houston's rapid growth was not without negative effects. Increased flooding events, extreme heat events, and runoff into watersheds have all been noted in Houston in response to its growth rate (Munoz 2017, Conlon 2016, Francisco 2007). While Houston maintains 370 developed parks and 200 greenways throughout its city (Houston Parks), the effects of urbanization all directly affect

Houston's flora and fauna. Due to its rapid growth, affinity for green spaces and urban parks, and its spot as one of America's major urban areas, Houston serves as an ideal location to study urban effects on wildlife.

Edith L. Moore Nature Sanctuary is an 18-acre wooden preserve located near the intersection of Beltway 8 and I-10 (GPS: 29°46'15.6"N 95°34'05.6"W). The sanctuary began as ranchland in 1931, maintained by the late Edith L. Moore and her husband. In 1976 the 18-acre reserve was willed to Houston Audubon under the condition that it be maintained as a nature preserve. Today, it serves as the headquarters for Houston Audubon and has been kept according to Ms. Moore's wishes.

The habitat is a mix of pine and hardwood forest located within the Gulf and Prairie Marsh ecoregion (TX Ecoregions). The park borders a portion of Rummel Creek, a watershed of Buffalo Bayou, and exhibits periodic flooding and erosion events along its banks (HCFCD Buffalo Bayou). Surrounding the sanctuary is the Nottingham subdivision. The park is maintained by Houston Audubon staff and a series of volunteers. Although heavily active in community conservation efforts, to date they have never had a traditional herpetology survey.

The park was heavily flooded by Hurricane Harvey with some areas flooded by over 15 feet of water. Although we began this study shortly after Harvey, there is no way to know the impact Harvey had on herpetofauna communities within the park. Without a baseline study of species presence, it is impossible to know exactly what existed prior to Hurricane Harvey. Although Hurricanes have been shown to have negative effects on herpetofauna (Schriever 2006), for the purpose of this study we will not look at the effects of the Hurricane.

Citizen Science

Citizen science involves collaboration between researchers and non-scientists in the research process. Citizens who participate (Citizen scientists) are often involved in the data collection or analysis process (Silvertown 2009, Dickinson 2010, Kullenburg 2016). Although a new tool in research, it has grown considerably in recent years and has been highly effective in ecology based research (Dickinson 2010, NATURE Editorial 2015). In particular, ecological surveys of urban areas can benefit from crowdsourcing observation data (Cooper et al 2007). Citizen science has the benefit of scale, the ability to engage local communities into conservation, and allows projects that normally would be impossible to be completed otherwise (Cooper et al 2007). Citizen science is often accomplished through websites, mobile apps and software which allows citizens to contribute to a global dataset.

The popular website and mobile app, iNaturalist (www.inaturalist.com), uses a crowdsourced species identification system and an organism occurrence recording tool that easily allows users to contribute at the click of a button. Users can post pictures of flora and fauna through a mobile application or through their website. Uploads contain GPS, Date, Time, Photos and any information the user deems necessary. Records are then checked by both knowledgeable citizens and professional scientists for validity. iNaturalist records become Research Grade when more than 2/3 of the identifiers agree on a species-level ID or lower . Given this quality of observation system, records that iNaturalist denotes as Research Grade can be seen as mostly reliable.

CHAPTER II

METHODS

This study uses a mix of the citizen science software, iNaturalist, and traditional survey techniques for herpetofauna. By using this multifaceted approach, we hope to gain a better picture for what herpetofauna exists at Edith L. Moore. iNaturalist data was pulled from February 2015 to May 2018 and surveys were conducted twice a month from January to May 2018. Survey events consisted primarily of Visual Encounter Surveys (VES) and aquatic minnow traps. Specifics are listed below.

iNaturalist Data

iNaturalist data was pulled from between February 11, 2015 and April 1, 2018. The location pulled was labeled as the "Edith L. Moore Nature Sanctuary – Local Administrative Area" (See Figure 1). All data downloaded contains date, time, GPS coordinates, taxonomy down to species, pictures and any notes filled out by the user. Only "Research Grade" records were used and all records were re-checked for correct identification. As stated above, iNaturalist records become Research Grade when more than 2/3 of the identifiers agree on a species-level ID or lower.

Records were analyzed down to the lowest taxonomic record. Records that could not be identified to family were not considered. Because individuals caught via other survey techniques were also uploaded to iNaturalist, those records were eliminated from the analysis of iNaturalist records. Records that were uploaded to iNaturalist from survey events were treated as survey events.

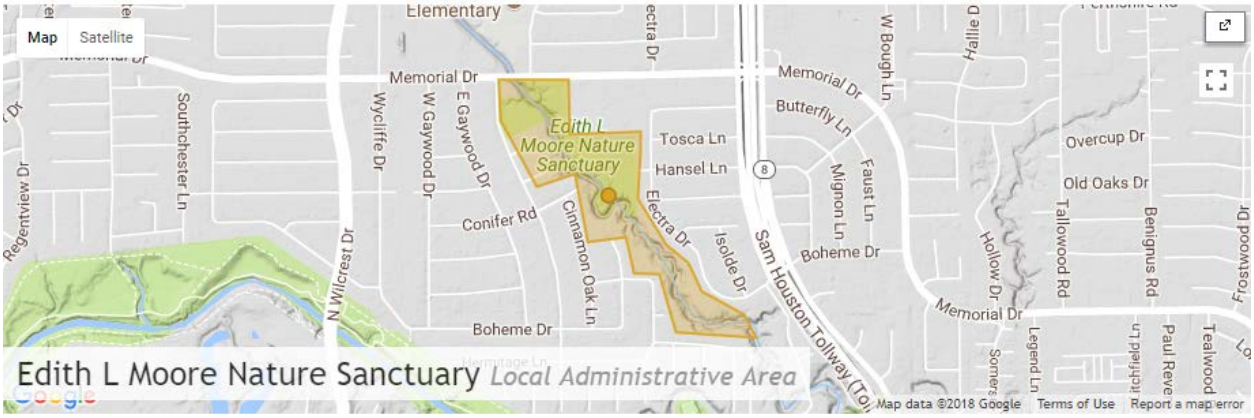


Figure 1- Edith L Moore Nature Sanctuary Local Administrative Area. Screen Clip taken from the iNaturalist website

Visual Encounter Survey

Visual Encounter Surveys are a standard method used in herpetological surveying. VES is an opportunistic search for target species along specified routes and transects (Dodd 2016). VES is easy and relatively inexpensive to run and has proven to be effective at estimating presence of a variety of faunal groups (Flint 2005, Rodrigues 2015, Donnelly 2005).

VES was conducted both along the main trails and through transects. Surveys were conducted twice for each survey day. Once 3 hours before sunset and again 1 hour after sunset. Surveys ended when the entire trail was walked. Refugia including logs, rocks, or other debris, was flipped within 5 meters of the trail. Transects were performed in two parts of the park that had little to no direct trail access. Transects were walked in straight lines as terrain and foliage allowed. Transects were started in the same spot on each trail. The transect path was created to cover the areas typically not covered. The path taken is shown in Figure 2.

Figure 2 - Image of Edith L. Moore Nature Sanctuary trail map. Red dots indicate the path taken during survey dates

Any individuals collected were either measured at the collection site, or stored in plastic containers or pillow cases and measured at the cabin. Individuals taken to the cabin were later released in the same location following all survey events. Measurements taken are explained in further detail in the "Data Collection" section below.

Aquatic Funnel Traps

Traps were placed in a permanent pond close to the cabin. 10 traps were placed in the pond at the same location each survey day. Traps were placed 30 minutes before sunset, and checked the following morning. Funnel traps placement is shown in Figure 3. Traps were partially submerged in water such that any caught animals retained the ability to breathe.

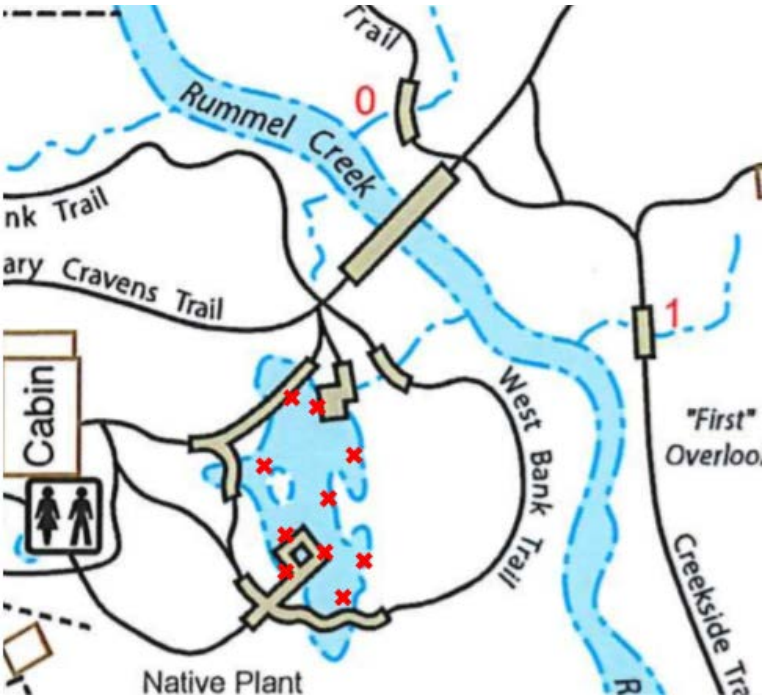


Figure 3 - Map of Edith L. Moore with focus on permanent pond. Red X's indicate where aquatic minnow traps were placed

Traps were originally baited with dry dog food. However, heavily manipulation by Racoons ultimately required traps to stop being baited. Manipulation in this case was defined as traps being placed on their side, dragged onto land, or having holes ripped through the mesh. Notes on if the traps were manipulated appear in the data section as well.

Although Rummel Creek is present throughout the park, traps were not placed in Rummel creek. Rummel Creek is a flood path for Buffalo Bayou and as such the water level may rapidly rise over 3 meters without warning. For the welfare of any caught animals, these sites were omitted.

Data Collection

Any specimen sighted and/or captured was logged using the ODK Collect mobile app utilizing an .XLS survey. The .XLS survey was custom made and included fields for date, time, GPS coordinates, species, weight and length measurements, pictures of the individual, and any notes. Mobile digital survey collection allows for easy and consistent data collection that is exported to a single spreadsheet. In conjunction with this .XLS survey, a field notebook was kept with basic information about each specimen collected (Time, date, species, count) in the event of app failure. The .XLS sheet layout and a flowchart of the survey is displayed in Appendix 1-3.

GPS coordinates were taken using native phone GPS capability. Although accuracy is a concern, in an urban area we were able to get accuracy within 10 meters. This also allowed for good comparison to iNaturalist data that also uses native phone GPS. Weights were collected in grams using a digital scale. Length measurements included snout vent length and tail length for snakes, lizards, and amphibians or plastron and carapace length for testudines. These measurements were taken with digital calipers and/or measuring tape. Pictures were taken either with a phone or with a zoom lens on a DSLR camera to be able to identify the species later. Surveys were uploaded once the phone was in range of wi-fi and all records uploaded were checked for validity.

CHAPTER III

RESULTS AND DISCUSSION

iNaturalist Data

The results from iNaturalist showcased 126 individual sightings found by citizen scientists at Edith L. Moore. A total of 5 amphibian species, from 4 families and 3 genera, and 16 reptiles species (3 turtle, 8 snake, and 5 lizard) from 6 families and 12 genera were found from iNaturalist data. In total 21 species from 10 families and 15 genera were pulled from iNaturalist at Edith L. Moore. A heat map of observations from both iNaturalist and survey data is shown in Figure 4.

Figure 4- (Left) Heat map of survey event observations. (Right) Heatmap of iNaturalist data observations. Red indicates increased frequency of observations. Both maps show high prevalence of observations at the cabin and permanent pond (Top left of each map). The bottom right of each map also have large numbers of observations from basking turtles at a sharp bend in Rummel Creek.

Survey Data

The results from our surveys represent a more directed search of herpetofauna at Edith L. Moore. A total of 102 individuals were recorded during survey events. From that 6 amphibian species, from 4 families and 4 genera, and 9 reptiles species (3 turtle, 2 snake, and 4 lizard) from 6 families and 8 genera were found during survey events. In total 15 species from 10 families and 12 genera were found during survey events. A heat map of observations is shown in figure 4. Pictures of several individuals observed during survey events is in Figure 5.

Figure 5 – Pictures of several species found during survey events. Note: this is not all the species found during survey events as some individuals did not have high quality images

Discussion

The results of our survey show that Edith L. Moore nature sanctuary contains a wide range of herpetofauna. Combined survey and iNaturalist data shows a total of 24 species (7 amphibian species, from 5 families and 4 genera, and 17 reptiles species [4 turtle, 8 snake, and 5 lizard] from 7 families and 13 genera) from 12 families and 17 genera. When comparing survey data to iNaturalist data we find that iNaturalist data includes *Heterodon platirhinos, Hyla cinerea, Micrurus tener, Nerodia erythrogaster, Nerodia rhombifer, Plestiodon laticeps, Pseudemys concinna, Storeria dekayi, Thamnophis Proximus* where survey data does not. Conversely, the survey data contains *Terrapene carolina, Lithobates sphenocephalus, Eluetherodactylus cystignathoides* where iNaturalist data does not. Despite these differences when combined, survey data and iNaturalist data combined provides a complete picture of the herpetofauna existing at Edith L. Moore (see Table 1)

Table 1 - This table shows all observations by both iNaturalist and Survey Event data. Species, broken into class and family, are shown in the leftmost column. The data is organized by iNaturalist, Survey, and then combined data.

Taxon	iNaturalist	Survey	Total
Amphibia	**17**	**25**	**42**
Bufonidae	**5**	**4**	**9**
Incilius nebulifer	5	4	9
Eleutherodactylidae		**4**	**4**
Eleutherodactylus cystignathoides		4	4
Hylidae	**1**		**1**
Hyla cinerea	1		1
Microhylidae	**1**	**1**	**2**
Gastrophryne carolinensis	1	1	2
Ranidae	**10**	**16**	**26**
Lithobates catesbeianus	8	7	15
Lithobates clamitans	2	5	7
Lithobates sphenocephalus		2	2
Not Idable to sp.		2	2
Reptilia	**109**	**76**	**185**
Chelydridae	**3**	**1**	**4**
Chelydra serpentine	3	1	4
Colubridae	**60**	**4**	**64**
Haldea striatula	4	3	7
Heterodon platirhinos	9		9
Nerodia erythrogaster	16		16
Nerodia fasciata	16	1	17
Nerodia rhombifer	9		9
Storeria dekayi	1		1
Thamnophis Proximus	5		5
Dactyloidae	**15**	**8**	**23**
Anolis carolinensis	6	2	8
Anolis sagrei	9	6	15
Elapidae	**1**		**1**
Micrurus tener	1		1
Emydidae	**22**	**36**	**58**
Not Idable to sp.		12	12
Pseudemys concinna	1		1
Trachemys scripta	21	24	45
Scincidae	**8**	**26**	**34**
Plestiodon fasciatus	6	17	23
Plestiodon laticeps	1		1
Plestiodon sp.		1	1
Scincella lateralis	1	8	9
Testudines		**1**	**1**
Terrapene carolina		1	1
Totals	**126**	**101**	**227**

However compared to all of Harris county both survey and iNaturalist results do not show 10 species of amphibians (*Acris blanchardi, Ambystoma maculatum, Ambystoma texanum, Gastrophryne olivacea, Hlya squirella, Hyla versicolor, Lithobates areolatus, Notophtalmus viridescens, Pseudacris fouguettei and Siren intermedia)* and 32 species of reptiles *(Agkistrodon controtrix, Agkistrodon piscivorus, Alligator mississippiensis, Apalone spinifera, Aspidoscelis sexlineata, Coluber constrictor, Coluber flagellum, Crotalus atrox, Crotalus horridus, Deirochelys reticularia, Diadophis punctatus, Farancia abacura, Graptemys psuedogeographica, Hemidactylus turcicus, Kinosternon subrubrum, Lampropeltis calligaster, Lampropeltis holbrokki, Macrochelys temminckii, Nerodia clarkia, Nerodia cyclopion, Opheodrys aestivus, Ophisaurus attenuates, Pantherophis obsoletus, Phelsuma laticauda, Plestiodon septentrionalis, Psuedemys concinna, Pseudemys texana, Ramphotyphlops braminus, Regina grahamii, Sternotherus carinatus, Sternotherus odoratus,* and *Terrapene ornate).* Note that there are several species listed here that are invasive/have low numbers of occurrence. In spite of this, the species found at Edith L. Moore represent only a snapshot of all the possible species in Harris county.

CHAPTER IV

CONCLUSION

Protection of urban nature sanctuaries is necessary for conservation efforts. Without them, urban residents lose an important avenue to connect with nature. However, having these parks simply exist in name is not enough. Although the diversity of Herpetofauna at Edith L. Moore Nature Sanctuary contains a variety of species, several species common to the surrounding area are entirely absent. In order for the public to gain a greater appreciation of conservation efforts it is imperative that Edith L. Moore properly maintains their biodiversity. In order to do this, future work should include continued monitoring with improved surveying techniques that target specific species. Additionally, further research into understanding why usually common species are absent is vital for Edith L. Moore to continue to create proper habitat for the herpetofauna, as well as for the public, to continue to enjoy.

REFERENCES

Böhm, M., B. Collen, J. E. M. Baillie, P. Bowles, J. Chanson, N. Cox, G. Hammerson, M. Hoffmann, S. R. Livingstone, M. Ram, A. G. J. Rhodin, S. N. Stuart, P. P. van Dijk, B. E. Young, L. E. Afuang, A. Aghasyan, A. García, C. Aguilar, R. Ajtic, F. Akarsu, L. R. V. Alencar, A. Allison, N. Ananjeva, S. Anderson, C. Andrén, D. Ariano-Sánchez, J. C. Arredondo, M. Auliya, C. C. Austin, A. Avci, P. J. Baker, A. F. Barreto-Lima, C. L. Barrio-Amorós, D. Basu, M. F. Bates, A. Batistella, A. Bauer, D. Bennett, W. Böhme, D. Broadley, R. Brown, J. Burgess, A. Captain, S. Carreira, M. del R. Castañeda, F. Castro, A. Catenazzi, J. R. Cedeño-Vázquez, D. G. Chapple, M. Cheylan, D. F. Cisneros-Heredia, D. Cogalniceanu, H. Cogger, C. Corti, G. C. Costa, P. J. Couper, T. Courtney, J. Crnobrnja-Isailovic, P.-A. Crochet, B. Crother, F. Cruz, J. C. Daltry, R. J. R. Daniels, I. Das, A. de Silva, A. C. Diesmos, L. Dirksen, T. M. Doan, C. K. Dodd, J. S. Doody, M. E. Dorcas, J. Duarte de Barros Filho, V. T. Egan, E. H. El Mouden, D. Embert, R. E. Espinoza, A. Fallabrino, X. Feng, Z.-J. Feng, L. Fitzgerald, O. Flores-Villela, F. G. R. França, D. Frost, H. Gadsden, T. Gamble, S. R. Ganesh, M. A. Garcia, J. E. García-Pérez, J. Gatus, M. Gaulke, P. Geniez, A. Georges, J. Gerlach, S. Goldberg, J.-C. T. Gonzalez, D. J. Gower, T. Grant, E. Greenbaum, C. Grieco, P. Guo, A. M. Hamilton, K. Hare, S. B. Hedges, N. Heideman, C. Hilton-Taylor, R. Hitchmough, B. Hollingsworth, M. Hutchinson, I. Ineich, J. Iverson, F. M. Jaksic, R. Jenkins, U. Joger, R. Jose, Y. Kaska, U. Kaya, J. S. Keogh, G. Köhler, G. Kuchling, Y. Kumlutaş, A. Kwet, E. La Marca, W. Lamar, A. Lane, B. Lardner, C. Latta, G. Latta, M. Lau, P. Lavin, D. Lawson, M. LeBreton, E. Lehr, D. Limpus, N. Lipczynski, A. S. Lobo, M. A. López-Luna, L. Luiselli, V. Lukoschek, M. Lundberg, P. Lymberakis, R. Macey, W. E. Magnusson, D. L. Mahler, A. Malhotra, J. Mariaux, B. Maritz, O. A. V. Marques, R. Márquez, M. Martins, G. Masterson, J. A. Mateo, R. Mathew, N. Mathews, G. Mayer, J. R. McCranie, G. J. Measey, F. Mendoza-Quijano, M. Menegon, S. Métrailler, D. A. Milton, C. Montgomery, S. A. A. Morato, T. Mott, A. Muñoz-Alonso, J. Murphy, T. Q. Nguyen, G. Nilson, C. Nogueira, H. Núñez, N. Orlov, H. Ota, J. Ottenwalder, T. Papenfuss, S. Pasachnik, P. Passos, O. S. G. Pauwels, N. Pérez-Buitrago, V. Pérez-Mellado, E. R. Pianka, J. Pleguezuelos, C. Pollock, P. Ponce-Campos, R. Powell, F. Pupin, G. E. Quintero Díaz, R. Radder, J. Ramer, A. R. Rasmussen, C. Raxworthy, R. Reynolds, N. Richman, E. L. Rico, E. Riservato, G. Rivas, P. L. B. da Rocha, M.-O. Rödel, L. Rodríguez Schettino, W. M. Roosenburg, J. P. Ross, R. Sadek, K. Sanders, G. Santos-Barrera, H. H. Schleich, B. R. Schmidt, A. Schmitz, M. Sharifi, G. Shea, H.-T. Shi, R. Shine, R. Sindaco, T. Slimani, R. Somaweera, S. Spawls, P. Stafford, R. Stuebing, S. Sweet, E. Sy, H. J. Temple, M. F. Tognelli, K. Tolley, P. J. Tolson, B. Tuniyev, S. Tuniyev, N. Üzüm, G. van Buurt, M. Van Sluys, A. Velasco, M. Vences, M. Veselý, S. Vinke, T. Vinke, G. Vogel, M. Vogrin, R. C. Vogt, O. R. Wearn, Y. L. Werner, M. J. Whiting, T. Wiewandt, J. Wilkinson, B. Wilson, S. Wren, T. Zamin, K. Zhou, and G. Zug. 2013. The conservation status of the world's reptiles. Biological Conservation 157:372–385.

Butchart, S. H. M., M. Walpole, B. Collen, A. van Strien, J. P. W. Scharlemann, R. E. A. Almond, J. E. M. Baillie, B. Bomhard, C. Brown, J. Bruno, K. E. Carpenter, G. M. Carr, J. Chanson, A. M. Chenery, J. Csirke, N. C. Davidson, F. Dentener, M. Foster, A. Galli, J. N. Galloway, P. Genovesi, R. D. Gregory, M. Hockings, V. Kapos, J.-F. Lamarque, F. Leverington, J. Loh, M. A. McGeoch, L. McRae, A. Minasyan, M. Hernández Morcillo, T. E. E. Oldfield, D. Pauly, S. Quader, C. Revenga, J. R. Sauer, B. Skolnik, D. Spear, D. Stanwell-Smith, S. N. Stuart, A. Symes, M. Tierney, T. D. Tyrrell, J.-C. Vié, and R. Watson. 2010. Global biodiversity: indicators of recent declines. Science (New York, N.Y.) 328:1164–1168.

Ciach, M., and A. Fröhlich. 2017. Habitat type, food resources, noise and light pollution explain the species composition, abundance and stability of a winter bird assemblage in an urban environment. Urban Ecosystems 20:547–559.

Conlon, K., A. Monaghan, M. Hayden, and O. Wilhelmi. 2016. Potential Impacts of Future Warming and Land Use Changes on Intra-Urban Heat Exposure in Houston, Texas. PLOS ONE 11:e0148890.

Cooper, C., J. Dickinson, T. Phillips, and R. Bonney. 2007. Citizen Science as a Tool for Conservation in Residential Ecosystems. Ecology and Society 12. <https://www.ecologyandsociety.org/vol12/iss2/art11/>. Accessed 26 Mar 2018.

Cureton II, J. C., M. Janis, W. I. Lutterschmidt, C. P. Randle, D. C. Ruthven III, and R. Deaton. 2014. Effects of urbanization on genetic diversity, gene flow, and population structure in the ornate box turtle (Terrapene ornata). Amphibia-Reptilia 35:87–97.

Dickinson, J. L., B. Zuckerberg, and D. N. Bonter. 2010. Citizen Science as an Ecological Research Tool: Challenges and Benefits. Annual Review of Ecology, Evolution, and Systematics 41:149–172.

Dodd, C. K. 2016. Reptile Ecology and Conservation: A Handbook of Techniques. Oxford University Press.

Donnelly, M. A., M. H. Chen, and G. G. Watkins. 2005. Sampling amphibians and reptiles in the Iwokrama Forest ecosystem. Proceedings of the Academy of Natural Sciences of Philadelphia 154:55–69.

Flint, W. D., and R. N. Harris. 2005. The Efficacy of Visual Encounter Surveys for Population Monitoring of Plethodon punctatus (Caudata: Plethodontidae). JOURNAL OF HERPETOLOGY 578.

Güneralp, B., and K. C. Seto. 2013. Futures of global urban expansion: uncertainties and implications for biodiversity conservation. Environmental Research Letters 8:014025.

Hamer Andrew J., and Mcdonnell Mark J. 2010. The response of herpetofauna to urbanization: Inferring patterns of persistence from wildlife databases. Austral Ecology 35:568–580.

Harris County Flood Control District (HCFCD) - Buffalo Bayou. n.d. <https://www.hcfcd.org/projects-studies/buffalo-bayou/>. Accessed 9 Apr 2018.

Houston, Texas. Our Parks and Greenspaces. n.d. <http://www.houstontx.gov/parks/parksites/index.html>. Accessed 9 Apr 2018.

Hunt, S. D., J. C. Guzy, S. J. Price, B. J. Halstead, E. A. Eskew, and M. E. Dorcas. 2013. Responses of riparian reptile communities to damming and urbanization. Biological Conservation 157:277–284.

IUCN. 2017. The IUCN Red List of Threatened Species 2017

Jiménez, A., M. Monroe, N. Zamora, and J. Benayas. 2017. Trends in environmental education for biodiversity conservation in Costa Rica. Environment, Development & Sustainability 19:221–238.

K. P. Laladhas, N. Preetha, B. BaijuLal, and O. V. Oommen. 2013. Region-specific biodiversity education – the role of People's Biodiversity Register. Current Science 1653.

Kullenberg, C., and D. Kasperowski. 2016. What Is Citizen Science? – A Scientometric Meta-Analysis. PLoS ONE 11:1–16.

Miller, J. R. 2006. Restoration, reconciliation, and reconnecting with nature nearby. Biological Conservation 127:356–361. Urbanization.

Mitchell, J., R. Jung Brown, and B. Bartholomew, editors. 2008. Urban Herpetology. Society for the Study of Amphibians and Reptiles.

Muñoz, L. A., F. Olivera, M. Giglio, and P. Berke. 2018. The impact of urbanization on the streamflows and the 100-year floodplain extent of the Sims Bayou in Houston, Texas. International Journal of River Basin Management 16:61–69.

Olivera Francisco, and DeFee Buren B. 2007. Urbanization and Its Effect On Runoff in the Whiteoak Bayou Watershed, Texas1. JAWRA Journal of the American Water Resources Association 43:170–182.

Pimm, S. L., C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M. Roberts, and J. O. Sexton. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science 344:1246752.

Rebele, F. 1994. Urban Ecology and Special Features of Urban Ecosystems. Global Ecology and Biogeography Letters 4:173–187.

Riley, S. P. D., G. T. Busteed, L. B. Kats, T. L. Vandergon, L. F. S. Lee, R. G. Dagit, J. L. Kerby, R. N. Fisher, and R. M. Sauvajot. 2005. Effects of Urbanization on the Distribution and Abundance of Amphibians and Invasive Species in Southern California Streams. Conservation Biology 19:1894–1907.

Rise of the citizen scientist. 2015. Nature News 524:265.

Rodrigues, J. B., S. C. A. Gama, G. A. P. Filho, and F. G. R. França. 2015. Composition and Ecological Aspects of a Snake Assemblage on the Savanna Enclave of the Atlantic Forest of the Guaribas Biological Reserve in Northeastern Brazil. South American Journal of Herpetology 10:157–164.

Rubbo, M. J., and J. M. Kiesecker. 2005. Amphibian Breeding Distribution in an Urbanized Landscape. Conservation Biology 19:504–511.

Schriever, T. A., J. Ramspott, B. I. Crother, and C. L. Fontenot. 2009. Effects of Hurricanes Ivan, Katrina, and Rita on a Southeastern Louisiana Herpetofauna. Wetlands 29:112–122.

Silvertown, J. 2009. A new dawn for citizen science. Trends in Ecology & Evolution 24:467–471.

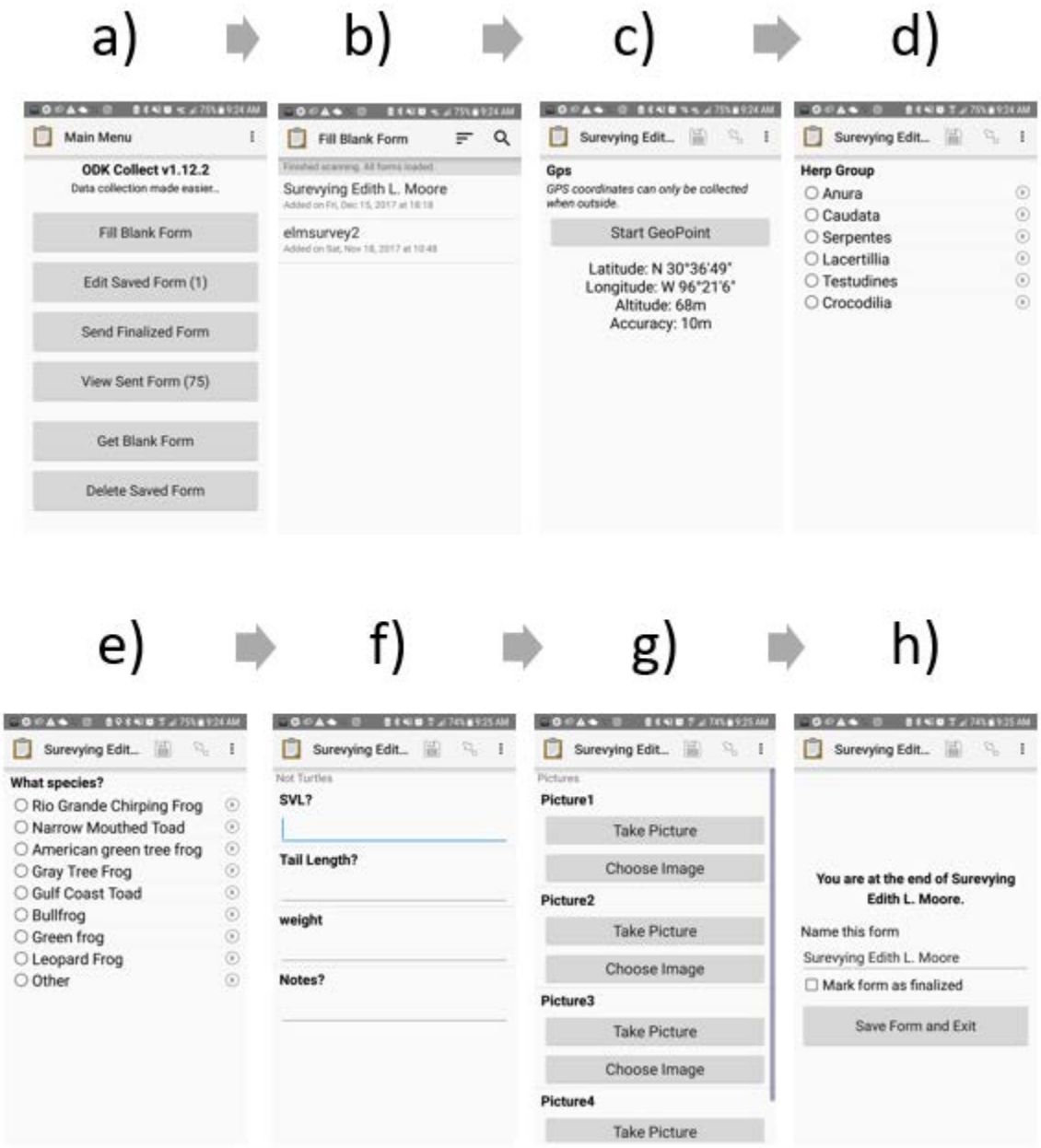
Sousa, E., V. Quintino, J. Palhas, A. M. Rodrigues, and J. Teixeira. 2016. Can Environmental Education Actions Change Public Attitudes? An Example Using the Pond Habitat and Associated Biodiversity. PLoS ONE 11:1–13.

Texas Ecoregions — Texas Parks & Wildlife Department. n.d. <https://tpwd.texas.gov/education/hunter-education/online-course/wildlife-conservation/texas-ecoregions>. Accessed 9 Apr 2018.

United Nations, and Department of Economic and Social Affairs. 2014. World urbanization prospects, the 2014 revision highlights. United Nations, New York.

Veach, V., A. Moilanen, and E. Di Minin. 2017. Threats from urban expansion, agricultural transformation and forest loss on global conservation priority areas. Plos One 12:e0188397–e0188397.

APPENDIX



Appendix 1- **a) Start Screen b) Form selection c) GPS**- Auto stops when accuracy is at or below 10 meters **d) Selection of Herp Group.** Herp Groups represent frogs, salamanders, snakes, lizard, turtles, and crocodilians respectively. **e) Species selection**. Common names were decided upon for ease of use for volunteers assisting who may not be well versed in latin nomenclature. If Other is chosen an additional window that states "What do you think it is?" is displayed. **f) Measurements screen.** Snout Vent Length (SVL) Tail length, weight and any notes. If this screen is selected under the testudines herpgroup, this window displays carapace and plastron length as opposed to SVL and tail length. **g) Picture screen** Field to take/upload up to 4 pictures. Pictures stored are uploaded to google drive **h) Finalize form screen.** Finalizing form allows the results to be uploaded.

type	name	label	hints	constraints	required	choice_filter	relevant
start	Time	Time			yes		
today	Date	Date			yes		
geopoint	storegps	Gps			yes		
select_one herp_type	HerpGroup	Herp Group					
select_one herps	Species	What species?				herp_group = ${HerpGroup}	
begin group	other	Other					
text	other	What do you think it is?					selected(${Species}, 'other')
end group							
begin group	Turtles	Turtles					selected(${HerpGroup},'testudines')
integer	plastron	Plastron Length					
integer	carapace	Carapace Length					
end group							
begin group	NotTurtles	Not Turtles					
integer	svl	SVL?	in cm.				
integer	taillength	Tail Length?	in cm.				
end group							
integer	weight	weight					
text	notes	Notes?					
begin group	pictures	Pictures					
image	pic1	Picture1					
image	pic2	Picture2					
image	pic3	Picture3					
image	pic4	Picture4					
end group							

Appendix 2- .XLS survey organization as displayed on Google Sheets. Layout and reference guide can be found at http://xlsform.org/

list name	name	label	herp_group	scientific_name
herp_type	Anuran	Anura		Anura
herp_type	Caudata	Caudata		Caudata
herp_type	Serpentes	Serpentes		Serpentes
herp_type	Lacertillia	Lacertillia		Lacerta
herp_type	Testudines	Testudines		Testudine
herp_type	Crocodilia	Crocodilia		Crocdylia
herps	Agkistrodon contortix	Copperhead	Serpentes	Agkistrodon contortix
herps	Agkistrodon piscivorus	Cottonmouth	Serpentes	Agkistrodon piscivorus
herps	Anolis carolinensis	Green Anole	Lacertillia	Anolis carolinensis
herps	Anolis sagrei	Brown Anole	Lacertillia	Anolis sagrei
herps	Apalone spinifera	Spiny soft-shelled turtle	Testudines	Apalone spinifera
herps	Chelydra serpentina	Common Snapping Turtle	Testudines	Chelydra serpentina
herps	Coluber constrictor	Racer	Serpentes	Coluber constrictor
herps	Elaphe guttata	Western Rat Snake	Serpentes	Elaphe guttata
herps	Eleutherodactylus cystignathoides	Rio Grande Chirping Frog	Anuran	Eluetherodactylus cystignathoides
herps	Gastrophryne carolinensis	Narrow Mouthed Toad	Anuran	Gastrophryne carolinensis
herps	Haldea striatula	Rough Earthsnake	Serpentes	Haldea striatula
herps	Hemidactylus turcicus	House Gecko	Lacertillia	Hemidactylus turcicus
herps	Heterodon platirhinos	Eastern Hognose	Serpentes	Heterodon platirhinos
herps	Hyla cinerea	American green tree frog	Anuran	Hyla cinerea
herps	Hyla versicolor	Gray Tree Frog	Anuran	Hyla versicolor
herps	Incilus nebulifer	Gulf Coast Toad	Anuran	Incilus nebulifer
herps	Kinosternum subrunum	Eastern Mud Turtle	Testudines	Kinosternum subrunum
herps	Lithobates catesbeiana	Bullfrog	Anuran	Lithobates catesbeianus
herps	Lithobates clamitans	Green frog	Anuran	Lithobates clamitans
herps	Lithobates sphenocephalus	Leopard Frog	Anuran	Lithobates sphenocephalus
herps	Micrurus tener	Texas Coral Snake	Serpentes	Micrurus tener
herps	Nerodia erythrogaster	Plain Belly Water Snake	Serpentes	Nerodia erythrogaster
herps	Nerodia fasciata	Banded Water Snake	Serpentes	Nerodia fasciata
herps	Nerodia rhombifer	Diamondback Water Snake	Serpentes	Nerodia rhombifer
herps	Plestiodon fasciatus	Common five-lined skink	Lacertillia	Plestiodon fasciatus
herps	Psudemys cocinna	River Cooter	Testudines	Psudemys cocinna

Appendix 3- Choices tab for the .XLS Survey. The “list_name” column denotes which group it falls under. This was used to list all the species that could be found at the park and offer a method to cascade selection choices based on the type of organism found. Further documentation can be found at http://xlsform.org/