RESULTS FROM A HERPETOLOGY SURVEY OF EDITH L. MOORE NATURE SANCTUARY WITH NOTES ON MANAGEMENT RECOMMENDATIONS

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ABSTRACT

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. This report also contains management recommendations related to habitat maintenance, restocking, and continued monitoring of the parks herpetofauna.

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CHAPTER I

INTRODUCTION

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.

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 1, 2015 to May 5, 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 May 12, 2018. The location pulled was labeled as the "Edith L. Moore Nature Sanctuary – Local Administrative Area" in the iNaturalist system (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.

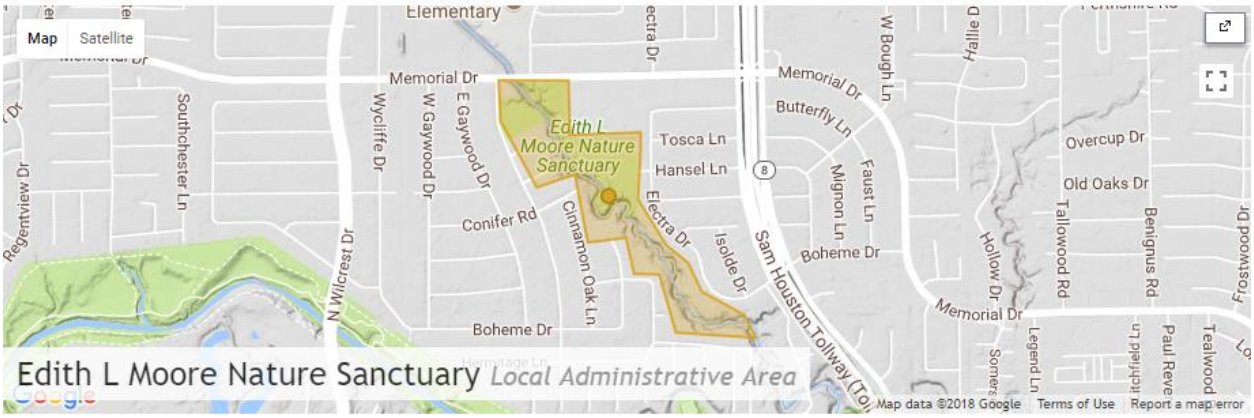

Figure 1- Edith L Moore Nature Sanctuary Local Administrative Area. Screen Clip taken from the iNaturalist website

Visual Encounter Survey

Visual Encounter Surveys (VES) 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.

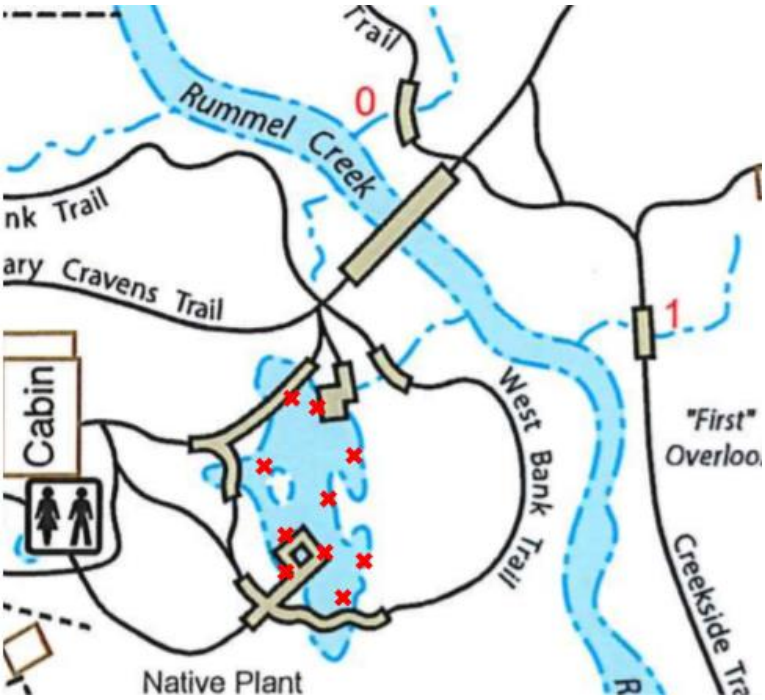

Figure 3 - Map of Edith L. Moore with focus on permanent pond. Red X's indicate where aquatic minnow traps were placed

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 142 individual sightings found by citizen scientists at Edith L. Moore. A total of 5 amphibian species, from 4 families and 4 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 16 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 158 individuals were recorded during survey events. From that 6 amphibian species, from 4 families and 4 genera, and 10 reptiles species (4 turtle, 2 snake, and 4 lizard) from 6 families and 9 genera were found during survey events. In total 16 species from 10 families and 13 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 300 observations from 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)

Taxon	iNaturalist	Survey	Total
Amphibia	**19**	**36**	**55**
Bufonidae	**5**	**6**	**11**
Incilius nebulifer	5	6	11
Eleutherodactylidae		**5**	**5**
Eleutherodactylus cystignathoides		5	5
Hylidae	**1**		**1**
Hyla cinerea	1		1
Microhylidae	**1**	**2**	**3**
Gastrophryne carolinensis	1	2	3
Ranidae	**14**	**23**	**37**
Lithobates catesbeianus	12	14	19
Lithobates clamitans	2	5	7
Lithobates sphenocephalus		2	2
Not Idable to sp.		2	2
Reptilia	**109**	**122**	**185**
Chelydridae	**5**	**2**	**4**
Chelydra serpentine	5	2	4
Colubridae	**64**	**5**	**69**
Haldea striatula	4	3	7
Heterodon platirhinos	10		10
Nerodia erythrogaster	16		16
Nerodia fasciata	17	2	19
Nerodia rhombifer	9		9
Storeria dekayi	1		1
Thamnophis Proximus	7		7
Dactyloidae	**15**	**10**	**25**
Anolis carolinensis	6	2	8
Anolis sagrei	9	8	17
Elapidae	**1**		**1**
Micrurus tener	1		1
Emydidae	**27**	**55**	**82**
Not Idable to sp.		12	12
Pseudemys concinna	1	2	3
Trachemys scripta	26	41	67
Scincidae	**9**	**49**	**58**
Plestiodon fasciatus	7	37	44
Plestiodon laticeps	1		1
Plestiodon sp.		1	1
Scincella lateralis	1	11	13
Testudines		**1**	**1**
Terrapene carolina		1	1
Totals	**142**	**158**	**300**

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.

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.

Future Management Directions

Maintaining Habitat

In order to properly maintain the ecosystem of Edith L. Moore, creating and maintaining habitat that can contain a wide variety of biodiversity should be given the upmost priority. Best practices should include keeping habitats wild and relatively undisturbed, while also making

efforts to return disturbed habitat to a more natural state. For example, Edith L. Moore lies in the Gulf Prairie and Marsh Ecoregion. However, the majority of the park is wooded with only a few spots that remain seasonal marshes (See Figure 6). These sites are marshy for brief periods of time following rains, but exhibit long periods of drying out; This effectively removes their possibility as permanent sites for many species. By even maintaining small pockets of marsh habitats, Edith L. Moore could contain a large number of native species that are currently rare or entirely absent in the park.

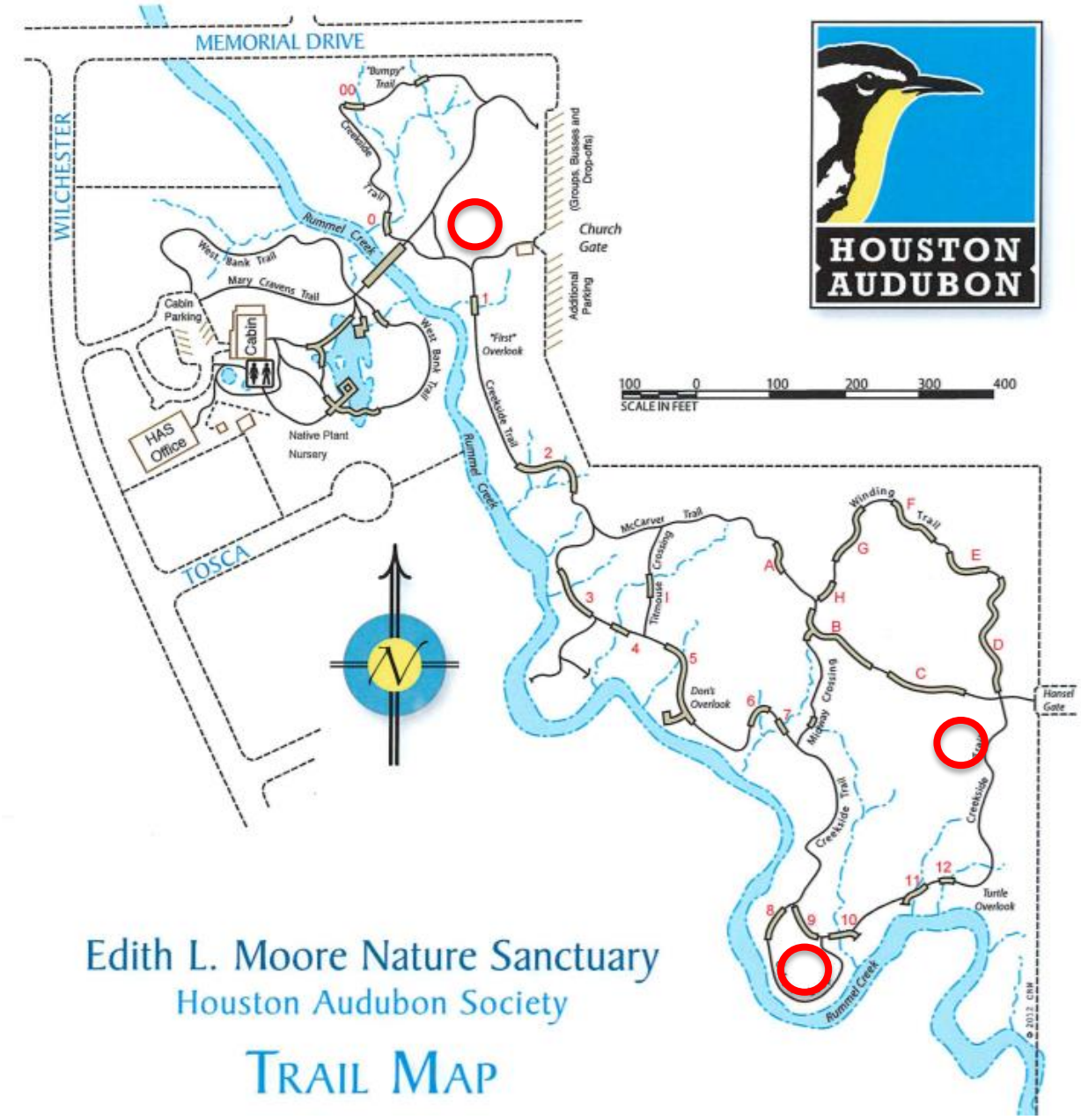

Figure 6. Trail map with ephemeral marshes circled

Although a fair sized pond located near the main cabin could serve the needs of marsh land species, the high population of bullfrogs (*Lithobates catesbeianus)* is likely to have an extreme negative effect on populations of native birds, reptiles, other amphibians, fish and small mammals (Snow 2010). Bullfrogs are able to eat a large variety of prey, and often outcompete

native species both directly and indirectly. Notable species of Tree frogs (*H. cinerea, H. versicolor, and H. squirella)* have been absent from the park, despite being a common species throughout Harris County. It is entirely likely that bullfrogs are consuming treefrogs, as well as other species, at every stage in their life cycle contributing to their local extinction in the park.

Tree frogs serve as an important species in the ecosystem as they consume large quantities of small insects and are a prey species for many species of snakes, predatory fish and other animals (EOL). Reintroducing tree frog populations into Edith L. Moore may have effects on all levels of the park's ecosystem. While the control of bullfrog populations is a logical choice, it may prove to be difficult, costly, or largely ineffective. Bullfrog are an incredibly robust species with current eradication by hand capture or traps involve a large amount of work and time. Additionally, management through pond draining or chemical means may have drastic effects on other species (Snow 2010). Given these key issues, the best method to reintroduce tree frogs may be to reestablish prime habitat and keep it free of bullfrogs.

The locations circled in Figure 6, represent 3 key areas that may prove to be suitable sites to create marshland. These sites already collect water and are relatively clear of flora, such as dense trees or scrubby brush, that may hinder development of a marsh. Additionally, geographic barriers – largely Rummel Creek- may help to impede the movement of bullfrogs to these sites. Improving these sites could be as simple as digging a shallow depression in the ground and adding plastic lining. Next steps would be to plant native flora that attracts not only tree frogs but other species such as dragonflies, butterflies, hummingbirds.

Restocking

Restocking Edith L. Moore with absent species was a topic often discussed throughout the surveying period. Restocking may prove beneficial in increasing the parks biodiversity with absent species and is easily attainable. Stock animals can be obtained from a reputable source and released at areas that fit that specific species niche; e.g. releasing an adult water snake near a source of permanent water. Assuming that proper habitat exists, and that native, healthy animals can be obtained easily, restocking can be an extremely viable option.

Continued Monitoring

As a final measure for managing Edith L. Moore, continued survey methods should be performed. Following the methods section outlined in this report, park staff and volunteers can continue to measuring the biodiversity of Edith L. Moore with relative ease. Visual Encounter Surveys made up the bulk of survey events, and could be replicated weekly, biweekly, or even monthly. Instead of using the ODK Collect app, pictures can simply be taken of species found and uploaded directly to the iNaturalist project page.

Increased promotion, support and use of the iNaturalist website, is imperative to improving the knowledge of the biodiversity of the park. Not only does iNaturalist make it easy to track and see what species are present, it will also heavily involve the community. Involving locals in the data collection process can increase volunteer involvement at Edith L. Moore and contribute heavily to the robustness of data collected.

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/