Urban Naturalist

No. 32 2020

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Cover Photograph: Adult female Alligator Snapping Turtle (*Macrochelys temminckii*) captured within our study site in Metropolitan Houston. The background depicts the broken and atypical landscape that we are finding this species in within this location. Photograph © Hailey J. Munscher.

The ***Urban Naturalist*** (ISSN # 2328-8965) is published by the Eagle Hill Institute, PO Box 9, 59 Eagle Hill Road, Steuben, ME 04680-0009. Phone 207-546-2821 Ext. 4, FAX 207-546-3042. E-mail: office@eaglehill.us. Webpage: http://www.eaglehill.us/urna. Published on an article by article basis. **Special issue proposals are welcome**. The *Urban Naturalist* is an open access journal. **Authors**: Submission guidelines are available at http://www.eaglehill.us/urna. **Co-published journals:** The *Northeastern Naturalist*, *Southeastern Naturalist*, *Caribbean Naturalist*, and *Eastern Paleontologist*, each with a separate Board of Editors. The Eagle Hill Institute is a tax exempt 501(c)(3) nonprofit corporation of the State of Maine (Federal ID # 010379899).

Discovery of an Alligator Snapping Turtle (*Macrochelys temminckii*) Population in Metropolitan Houston, Harris County, Texas

Eric Munscher[1, 2*], Jordan Gray[1], Arron Tuggle[2], Day B. Ligon[3], Valeria Gladkaya[1], Carl Franklin[4], Chris Drake[5], Viviana Ricardez[4], Brian P. Butterfield[6], Kelly Norrid[7], and Andrew Walde[1]

Abstract - Habitat loss through urbanization is an important threat to many wildlife species. While some species thrive in suboptimal urbanized conditions, many species appear to be incapable of adapting to urbanization. Despite the adaptability of some reptile species to urban habitats, populations are often small in comparison to those that inhabit areas outside of urban areas where habitat alterations are far less extreme and suitable habitat more expansive. Globally, a disproportionate number of turtle species are facing population declines, local and regional extirpations, and extinction. In the United States, many species are suffering regional population declines. The Alligator Snapping Turtle is the largest species of freshwater turtle in the United States. Despite its large geographic range, distribution data gaps exist for this iconic species. Notably, research on this species in the westernmost portion of its Texas range has been sporadic and not all-encompassing. In surveys beginning in 2016, we documented the presence of a seemingly robust Alligator Snapping Turtle population inhabiting waterways in and around Harris County, Texas, the third most-populous county in the United States. We trapped turtles on a monthly basis from December 2016–October 2018 and captured 23 males, 22 females, and 12 juveniles. Catch-per-unit effort, expressed as captures per net-night, ranged from 0.00–0.83 turtles per net-night, with an overall rate of 0.40 turtles per net-night. Future work with this population should include increasing trapping efforts to calculate population estimates and demographics such as density, biomass, and annual survivability.

Introduction

Habitat loss is one of the most significant factors driving declines of reptiles worldwide (Gibbons et al. 2000), and urbanization, in particular, can dramatically affect reptile diversity and ecology (Hamer and McDonnell 2010, Hunt et al. 2013, Rebelo et al. 2011). However, while many species are simply intolerant of the dramatic environmental changes wrought by urbanization, others manage to persist—and some even thrive—in such fragmented landscapes. This has been notably true for a small, but diverse, suite of lizard species such as the Cuban brown anole, Italian wall lizard, and Mediterranean house gecko that thrive in urban environments even outside of their native ranges (Angetter et al. 2011, Burke et al. 2002, Meshaka et al. 2006). City parks and other pockets of relatively undisturbed habitat frequently support other reptiles, as well (Baneville and Bateman 2012, Dawson and Hostetler 2008, Ferguson et al. 2008). Despite the persistence of some reptile species in urban areas, populations are often small in comparison to those that inhabit areas outside

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Manuscript Editor: Travis Ryan

of cities where habitat alterations are generally less extreme and suitable habitat more expansive (Rebelo et al. 2011).

As is true of many turtles world-wide, *Macrochelys temminckii* (Troost in Harlan) the Alligator Snapping Turtle is declining throughout much of its range (Lovich et al. 2018; Pritchard 1989, 2006; Riedle et al. 2008; Rhodin et al. 2018; Turtle Taxonomy Working Group 2017; Wagner et al. 1996). The species' distribution may be even more constricted than presently reported because many locality records in recent decades are based upon observations of single specimens that may be lone relicts rather than representative of viable populations (Riedle et al. 2008, Shipman et al. 1995). Nonetheless, robust populations remain in pockets of the species' historic range.

In Texas, much of what is known about the species' range is based upon occurrence records, with no studies establishing population densities or demographics. Alligator Snapping Turtles are generally described as ranging as far west as the Trinity River watershed (Dixon 2013), although a fossil specimen from the Brazos river drainage suggests that it once occurred farther westward (Hay 1911). The species was added to the state list of protected species in 1987 (Texas Register 1987). Recent surveys, in combination with verified incidental observations, have documented the species in 36 counties of Texas, and there are unverified records from another four counties (Dixon 2013, Rudolf et al. 2002; Fig. 1).

Here, we describe the presence of an unusual population of Alligator Snapping Turtles that inhabits waterways in metropolitan Houston, Texas, the third most-populous city in the United States.

Methods

Study Site

We conducted our study in Buffalo Bayou in Harris County, Texas, USA. Buffalo Bayou lies to the west of the Trinity River, but both drain into Trinity Bay. Our trapping sites were all within the city limits of Houston. Fed by a combination of groundwater discharge and surface runoff, Buffalo Bayou is an approximately 85-km slow-moving river flowing in a sinuous meander through suburban, urban, and parkland environments. The Buffalo Bayou is contained within a 264-km^2 watershed within the San Jacinto River basin (Aulbach 2012, Harris County Flood Control District 2013). Greater than 80% of the watershed is urbanized; a 2010 census reported a human population of more than 2.3 million (Harris County Flood Control District 2013). The principal waterway of Harris County and the Greater Houston metropolitan area, the Buffalo Bayou connects to a multitude of associated bayous and tributaries, including Carpenters, Greens, Sims, and Brays bayous, and Rummel, Soldiers, and Turkey Creeks (Harris County Flood Control District 2013). To the west of our study site, two reservoirs completed by the US Army Corps of Engineers in the 1940s exert some control over water flow in the Buffalo Bayou (Aulbach 2012, Harris County Flood Control District 2018).

The 37 km segment of Buffalo Bayou in which we conducted our surveys featured an assortment of adjacent habitat types including urban parkland featuring forested riparian buffers; private golf courses; open, managed parkland with little to no riparian buffer; bicycle and walking paths; and private and commercial real estate. This section of the Buffalo Bayou is characterized by moderate and variable water flow, high turbidity, and an abundance of submerged and emergent structures and sand bars. Water levels in these areas fluctuate with rainfall and releases from upstream dams. Furthermore, the easternmost 3.6 river-km is tidally influenced and brackish (Bosquez 2010). Trapping locations were limited by availability of access points in the city, and to periods of low water and

favorable weather forecasts in order to avoid the risk of submerging traps and potentially drowning turtles (Fig. 2). We have not reported precise study locations to protect the sites from potential poaching or molestation.

Sampling Technique

Following an initial survey conducted in October 2016 that confirmed the presence of Alligator Snapping Turtles, we conducted three-day trapping sessions monthly from December 2016 until October 2018. However, due to flooding and inclement weather we were unable to sample in March, May, August, September 2017 (Fig. 2). In 2018, we were forced to skip trapping sessions in January, February, May, July, August, and September due to unsafe flow rates. An additional sampling session was added in April 2018 to augment the paucity of trapping during the winter months (January, February, and March). For most sampling sessions, we deployed five single-throated hoop nets (1.2 m dia., 3.6 m long; Louisiana Sports Net, Baton Rouge, Louisiana, USA). In October 2018, up to 13 traps were deployed. Traps were set with a portion of the trap above water to provide trapped turtles

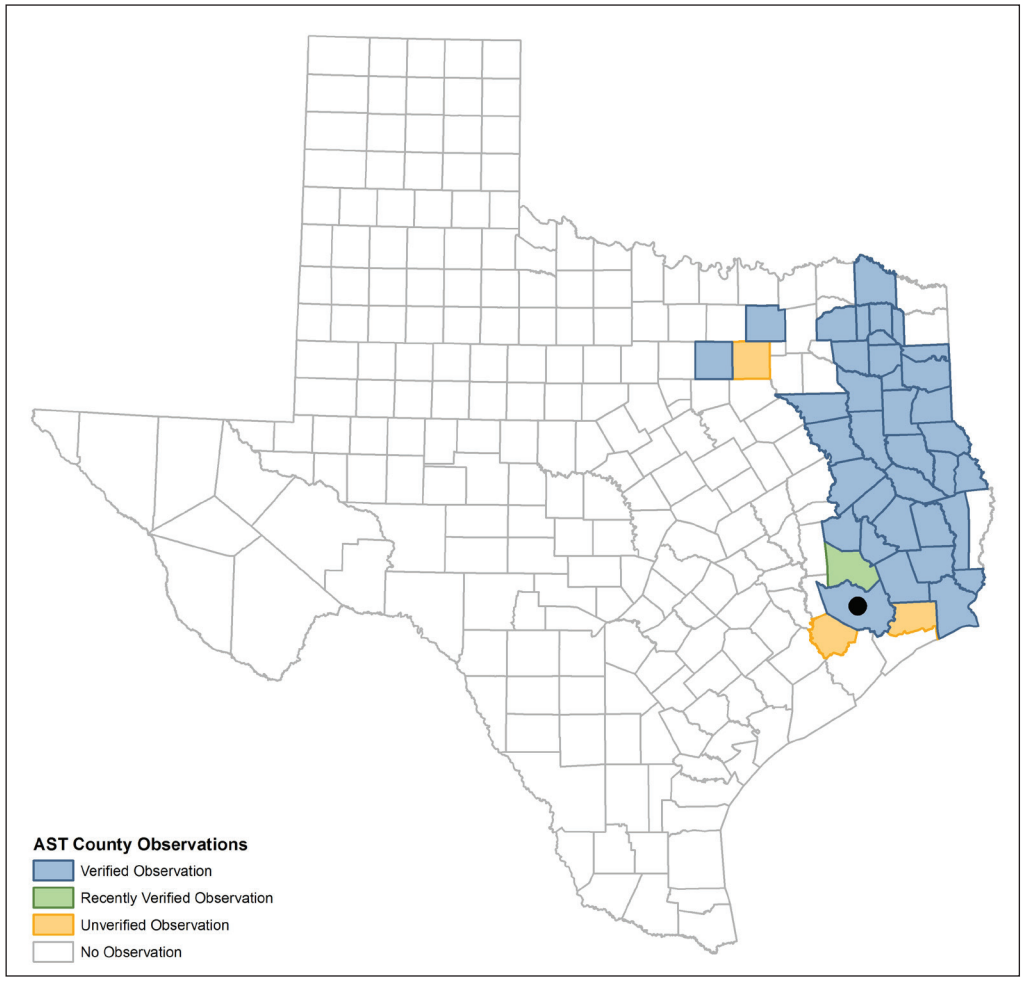

Figure 1. Map of Texas counties showing the known distribution of Alligator Snapping Turtles in the state. There was just one historical record in Harris County (denoted with a closed circle) prior to this study.

with access to air. Traps were adjusted to accommodate the rise and fall of water levels to ensure that any trapped turtles would not drown due to an overnight influx of rainfall and/or dam release (Fig. 2). We baited and rebaited traps daily with either whole or fileted *Oreochromis aureus* (Steindachner) (Blue Tilapia), cut *Ictalurus punctatus* (Rafinesque) (Channel Catfish), or *Ictiobus bubalus* (Rafinesque) (Smallmouth Buffalo). Bait was held in place by metal wire that was looped through the trap and through the fish. Traps were checked regularly over the next 40 hours and were never left unchecked for more than 16 hours.

We recorded straight mid-line carapace length (SCL) from the precentral (nuchal) to postcentral marginal scutes to the nearest mm using 700-mm aluminum tree calipers (Haglof Inc., Madison, Mississippi, USA), save for the first six captured turtles (two males, two females, and two juveniles) as we did not have the necessary equipment on hand at the time of capture. Sex of turtles was determined by visual inspection of sexually dimorphic characters, including distance from the cloaca to the posterior edge of the plastron, proportional head width, and overall size (Ernst and Lovich 2009). Male Alligator Snapping Turtles have more distally positioned cloacae, larger heads, and reach larger sizes than females (Ernst and Lovich 2009). We measured mass of all turtles using a 130-kg hanging scale (Cabela's Inc., Sidney, Nebraska, USA). Turtles were marked using a variation of the shell notching technique described by Cagle (1939) and Riedle et al. (2016) and with passive integrated transponder (PIT) tags (Buhlmann and Tuberville 1998). We released turtles back into the Buffalo Bayou at their capture location immediately after processing.

We calculated the mean and standard deviation SCL of juveniles, females, and males. In instances when individuals were recaptured one or more times, only the first set of measurements was included in analyses. We conducted a Chi-Square goodness of fit test to determine if the adult sex ratio differed from parity. We compared SCL between males and females using a two-sample *t*-test. We set the threshold for significance at $\alpha = 0.05$ for both tests.

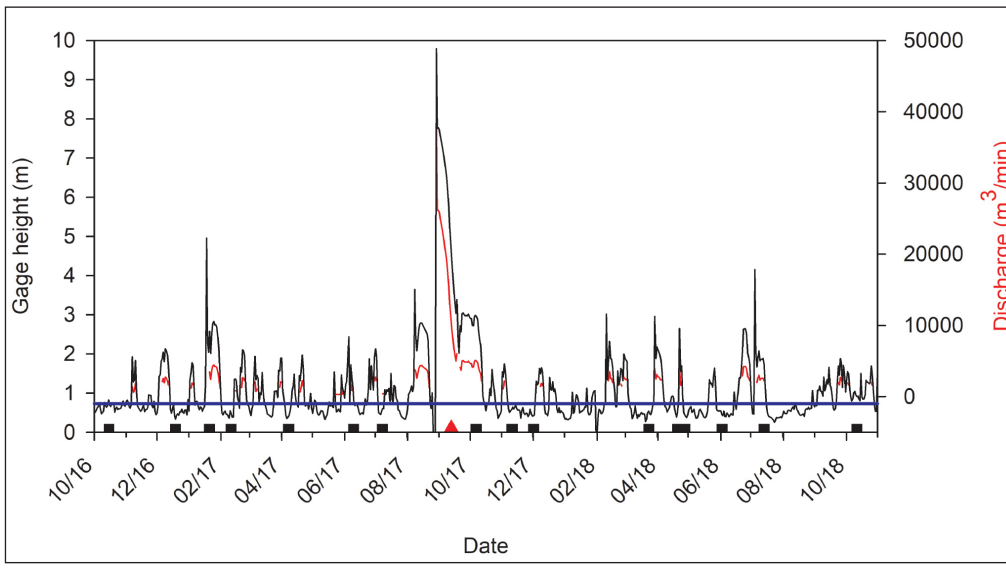

Figure 2**.** Fluctuations in mean daily gage height and discharge rate during the span of reported sampling efforts. The large spike in September 2017 was the result of Hurricane Harvey. The horizontal line indicates the median gauge height. Black points along the x-axis indicate trapping sessions; the red triangle represents an Alligator Snapping Turtle that was recovered by Houston Police. Note that most trapping was conducted when water depth in Buffalo Bayou was below the median. Data obtained from USGS Gage Station 08074000; discharge data were patchy and were available for only 23% of days between 1 October 2016 and 31 October 2018.

Results

We conducted 16 sampling sessions totaling 173 net nights over a 26-month period, with at least one 2-day effort occurring in all seasons; however, surveys did not occur in August and September of either year due to flooding (Fig. 2, Table 1). At least one Alligator Snapping Turtle was captured during 15 of the 16 sampling sessions, and specimens were captured in all seasons.

We made 69 captures of 57 individual Alligator Snapping Turtles comprising 23 males, 22 females, and 12 juveniles (1.05:1.00 male:female ratio) (Fig. 3). The sex ratio did not deviate from parity ($\chi^2 = 0.0221$, P = 0.882). We captured an average of four Alligator Snapping Turtles per sampling period, but results were variable, ranging from 0 to 19. Similarly, catch-per-unit effort (CPUE), expressed as captures per net-night, was variable among sampling sessions, ranging from 0.00–0.83 turtles per net-night (Table 1), with an overall rate of 0.40 turtles per net-night.

Female SCL; and males were significantly larger than females ($t_{df=39} = 3.19$, $P < 0.001$); the mean ± s.d. SCL of males was 503 ± 104.7 mm (range: 289–647 mm, n = 21) whereas females averaged 422 ± 46.8 mm (range: 323–477 mm, n = 20). The mean SCL for juveniles was 269 ± 40.0 mm (range 218–335 mm, n = 10; Fig. 3).

Discussion

Little is known about Alligator Snapping Turtle populations in Texas because few population-level studies have been conducted (Fitzgerald and Nelson 2011, Rudolf et al. 2002). The paucity of information, compared to other western states in the species' range such as Oklahoma, Arkansas, and Louisiana, may in part be a consequence of land ownership patterns in the state, where approximately 94% of land is privately owned and access for wildlife research is limited (Texas Center for Policy Studies 2000, Texas General Land Office 2019). Most of our knowledge of distribution in the state of Texas is derived from a combination of historic records and a statewide survey from 1998–2001, which produced 48 captures across 17 survey sites (Rudolf et al. 2002). However, the chief objective of that survey effort was to generate presence-absence data, so survey efforts at each location were typically short, and were ended when the species was detected. Alligator Snapping Turtles were detected in all major drainages in eastern Texas between the Sulphur and Navasota rivers and new county records were documented in Angelina, Jasper, Leon, Nacogdoches, San Jacinto, Collin, Sabine, and San Augustine Counties (Rudolf et al. 2002). The Collin County record was obtained in a heavily developed urbanized area, conditions that were similar to those we surveyed in our study. However, Rudolph et al. (2002) did not survey Harris County due to a perceived lack of suitable habitat. Notably, our efforts to characterize demographics of Alligator Snapping Turtles in Buffalo Bayou were nearly coincident with two incidental observations that were made in the same calendar year (iNaturalist 2016a, b).

Among the seven counties that border Harris County, there are no records of the species in three counties, unconfirmed records in two counties, one recently confirmed record in Montgomery County (Munscher et al. 2019) and records based on museum specimens in one county. Prior to our study, there was one historical record from Harris County. This observation occurred on August of 1968, on White Oak Bayou, a large man-made bayou with a cement bottom that flows into Buffalo Bayou from the northwest. The individual was found approximately 10 miles northwest of the Buffalo Bayou confluence (Biodiversity Research and Teaching Collections at Texas A&M University -specimen TCWC - 103149 and Baylor University, Mayborn Museum Complex - Specimen R 11196).

Table 1. Alligator Snapping Turtle captured from Buffalo Bayou from October 2016 through October 2018.

Date	No. Net Nights	Males	Recaptured Males	Females	Recaptured Females	Juveniles	Total	CPUE
2016								
15–16 Oct	10	2	–	2	–	2	6	0.60
18–20 Dec	10	2	–	–	–	–	2	0.20
2017								
20–22 Jan	10	4	–	–	–	–	4	0.40
10–12 Feb	10	2	–	1	–	1	4	0.40
7–9 Apr	10	–	(1)	5	–	–	5(1)	0.60
9–11 Jun	10	–	–	–	–	4	4	0.40
7–9 Jul	10	1	–	1	–	–	2	0.20
13 Sep[†]	0	–	(1)	–	–	–	(1)	N/A
6–8 Oct	10	1	–	1	–	–	2	0.20
10–12 Nov	10	2	–	–	(1)	–	2(1)	0.30
1–3 Dec	10	–	(2)	2		–	2(2)	0.40
2018								
23–25 Mar	10	3	–	1	(1)	1	5(1)	0.60
20–22 Apr	10	1	–	–	–	0	1	0.10
27–29 Apr	10	–	–	1	–	1	2	0.20
2–4 Jun	10	1	–	1	–	1	3	0.30
13–15 Jul	10	–	–	–	–	–	–	0.00
11–13 Oct	23	4	(2)	7	(4)	2	13(6)	0.83
Totals	173	23	6	22	6	12	57(12)	0.40

[†]No traps were set. Incidental capture by Houston police.

Our trapping results suggest that a reproductively viable population of Alligator Snapping Turtles inhabits Buffalo Bayou in the heart of downtown Houston. At this time, we do not have sufficient data to calculate population estimates; however, overall CPUE is consistent with results from robust populations in Arkansas (Trauth et al. 1998, Wagner et al. 1996), southern Alabama (Folt and Godwin 2013), and with *Macrochelys suwanniensis* (Suwannee Alligator Snapping Turtle, Thomas et al. 2014) in western Florida (Moler 1996), and Southern Georgia (Jensen and Birkhead 2003). Our CPUE was noticeably higher than has been reported in areas with known harvest and poaching. For example, Boundy and Kennedy (2006) reported an average rate of 0.06 turtles per trap night in Southeastern Louisiana and a recent survey conducted by Huntzinger et al. (2019) in Southwestern Louisiana resulted in an even lower CPUE of 0.021. In Oklahoma, a capture rate of 0.058 was reported by Riedle et al. (2005) and in Missouri, Lescher et al. (2013) documented a CPUE value of 0.116. In most of these studies with low CPUE, the authors reported more juveniles than adults being captured, suggestive of populations where adults have been removed by harvest. Many of the studies within Appendix 1 were extensive regional or state-wide surveys that listed CPUE values for individual trapping locations as well as an average CPUE for their entire study. It must be noted that CPUE values in Appendix 1 are illustrative, with

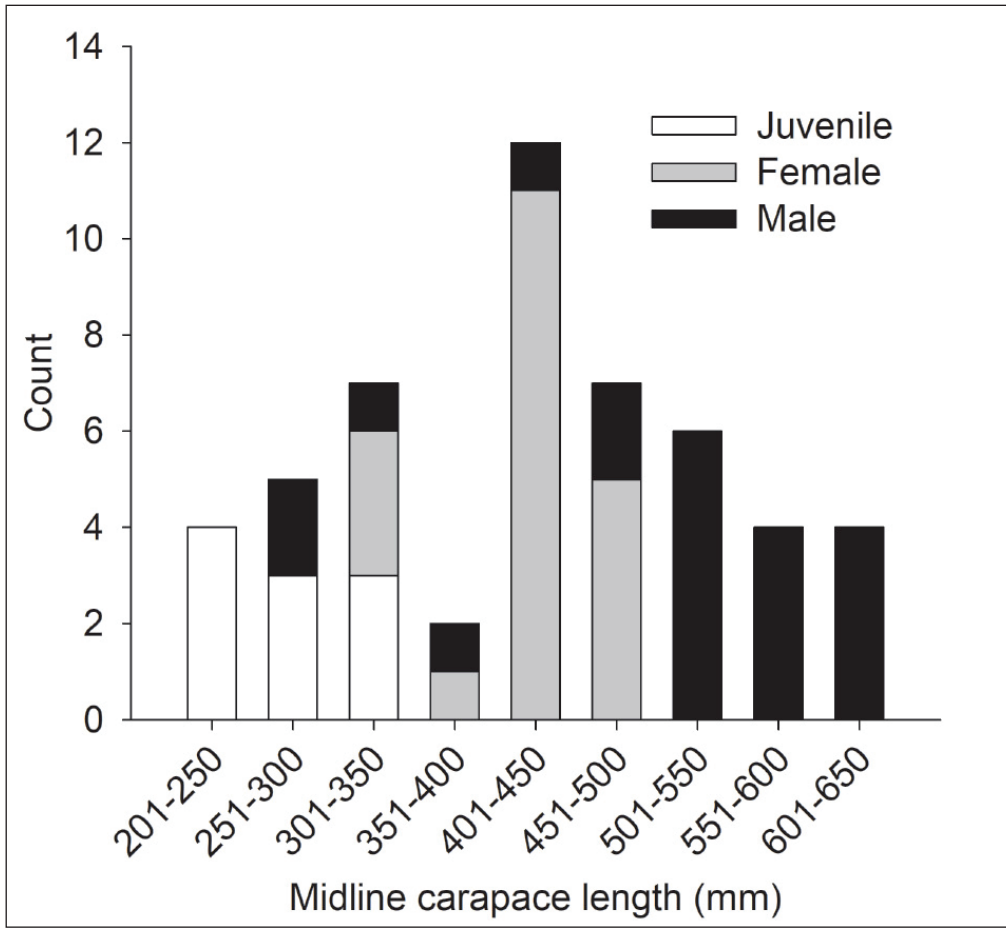

Figure 3. Size classes, based on midline carapace length, of *Macrochelys temminckii* captured at Buffalo Bayou in metropolitan Houston, Texas. The first six turtles captured were marked but were not measured and therefore are not included.

trends showing that harvested areas have lower CPUE. However, we caution strict interpretation as studies that present multiple sites could have lower results due to sites with low, or no, CPUE values being averaged into the study results.

Extreme water temperatures typically suppress Alligator Snapping Turtle activity and detectability (Fitzgerald and Nelson 2011, Riedle et al. 2005). Our overall capture rate of 0.40 turtles per net-night includes efforts from mid-summer and mid-winter survey work when water temperatures are very warm and very cold, respectively. Alligator Snapping Turtles' activity levels are known to be suppressed during periods characterized by temperature extremes (Spangler 2017), and capture rates appear to decline as a result (Riedle et al. 2006). We predict that surveys restricted to the times of year when the species is most active would result in capture rates at least comparable to those reported from the most robust populations reported in neighboring Oklahoma and Arkansas (Howey and Dinkelacker 2013, Riedle et al. 2008, Trauth et al. 2016, Wagner et al. 1996) and studies of the Suwannee Alligator Snapping Turtle (Folt and Godwin 2013, Johnson et al. 2015, Moler 1996, Thomas et al. 2014). While we suspect that our calculated capture rate is likely reduced due to constraints on when we were able to successfully survey, we question whether we will ever be able to conduct surveys in this system during more typical trapping periods due to the corresponding highly stochastic weather patterns at those times of year. Despite this constraint, however, our survey results support the conclusion that a robust and demographically viable population of Alligator Snapping Turtles inhabits Buffalo Bayou.

The city of Houston is the third most populous city in the United States, and the most populous city in the southern United States (Morris 2016). As the principal waterway of Harris County and the city of Houston, alterations have been made to the structure and riparian zones of Buffalo Bayou, in part to facilitate draining water from the Greater Houston metropolitan area with greater efficiency during periods of high precipitation (Harris County Flood Control District 2018). These alterations turn segments of a usually low energy, meandering aquatic system into segments with much higher energy. Additionally, rain-induced flooding events are common, and occasionally extreme, as in 2017 during Hurricane Harvey and 2019 Tropical Storm Imelda. Such events have the potential to effectively scrub the channel of submerged structures resulting in habitat that is thought to be less favorable for Alligator Snapping Turtles (Riedle et al. 2005).

Adding to anthropogenic pressure along the Buffalo Bayou, Houston is the largest US city to have no zoning laws (Boburg and Reinhard 2017). From 2010 to 2017, more than 7,000 residential buildings were constructed in Harris County in areas within the 100-year flood plain (Boburg and Reinhard 2017). Furthermore, for decades, Buffalo Bayou has been—and continues to be—subject to pollutants emanating from runoff and sewage discharge (Suayan 2018). Along with overharvesting and incidental drowning from abandoned fishing equipment, habitat alteration and pollution are considered primary causes for the decline of this species across its range (Reed et al. 2002, Riedle et al. 2005, Shipman and Riedle 2008, Sloan and Lovich 1995). As such, a highly urbanized and anthropogenically impacted watershed such as Buffalo Bayou drainage basin differs markedly from the more rural watersheds of the Trinity, Neches, and Sabine river basins. Despite these many factors that would seem to reduce Alligator Snapping Turtle numbers, the results of our initial surveys suggest that the species has a robust population within this environment despite atypical and seemingly suboptimal conditions. River and land-management practices should continue to be scrutinized, as further degradation of this habitat could lead to the decline of this, and other species of wildlife, in and along the Buffalo Bayou. Additionally, the results from our research thus far lend credence to

the notion that the Buffalo Bayou's surroundings in one of the nation's largest cities has acted as a refugium for this frequently hunted species. Local, state, and county park law enforcement should remain vigilant in guarding against potential poaching threats.

Our discovery of a seemingly robust, reproductively active population of the Alligator Snapping Turtle in the Houston metropolitan area was unexpected but potentially encouraging for the species' long-term persistence in southeastern Texas. The fact that this large species remained undetected in a heavily populated area for so long suggests that other populations may exist in nearby watersheds. These observations, in combination with the recent discussed elevation of the species' to state-level conservation status to Critically Imperiled, (Texas Parks and Wildlife, Austin, TX, 2018 pers. comm) support the need for concerted survey efforts to better characterize the presence of Alligator Snapping Turtles in East Texas. In particular, neighboring counties with no records of the species may yet support cryptic populations similar to the one we discovered here. Furthermore, the persistence of an Alligator Snapping Turtle population in a highly altered and heavily impacted habitat, where they were presumed to have been extirpated, provides hope that other populations may occur in similar riverine habitats in Texas and other states within the species' range.

Future work on this population should include continued trapping efforts to estimate the population size and describe its demographics. Additionally, this population is well suited to study the effects that a suite of challenges that typify urban habitation (including restricted nesting habitat, altered flow regimes, and high levels of pollution) can have on Alligator Snapping Turtles. Finally, the proximity of Buffalo Bayou to the Gulf of Mexico provides an opportunity to study the species' use of brackish habitat, including its behavioral and physiological responses to high and variable salinity.

Acknowledgments

We would like to thank the Texas Parks and Wildlife Department for managing this important species, providing support, and making this research possible. We thank the Hess Foundation for provided much needed funding for this project. Additionally, we would like to express our gratitude to the Memorial Park Conservancy, specifically Carolyn White and Shellye Arnold for their support. We also thank all the Turtle Survival Alliance—North American Freshwater Turtle Research Group members who assisted. Finally, we are grateful to SWCA Environmental Consultants for their constant support. We would like to offer our appreciation to Jeff Stein of SWCA Environmental Consultants for making the state distribution map. Texas Parks and Wildlife Department approved all capture and handling protocols, and all methods conformed to the ASIH/SSAR animal use guidelines (American Society of Ichthyologists and Herpetologists, the Herpetologists League, and the Society for the Study of Amphibians and Reptiles 2001). We conducted the study under a Texas Parks and Wildlife Department (TPWD) permit (# SPR-0212-019).

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Appendix 1. Review of published Alligator Snapping Turtle catch per unit effort (CPUE), sex ratios, trapping effort, and population estimates.

Source	Location	Study Type	CPUE	Total Net Nights	Sex Ratio	Number of Individuals	Estimated Population Size
			Macrochelys temminckii				
This Study	SE Texas	Single site	0.40	173	1:1	57	NA
Rudolf et al. (2002)	Texas	Statewide	0.046	1,009	1:1	48	NA
Huntzinger et al. (2019)	SW Louisiana	Three river drainages	0.021	731	Juvenile bias	14	NA
Boundy and Kennedy (2006)	E Louisiana	Multiple sites	0.06	3,504	1:1	200	NA
Riedle et al. (2005)	Oklahoma	Multiple sites	0.059–0.620	1,085	1:1	63	NA
Riedle et al. (2008)	Oklahoma	Multiple sites	NA	565	1:1	157	127.5 ± 24.5
East et al. (2013)	Oklahoma	Multiple sites	NA	NA	Juvenile bias	40	22 ± 5
Wagner et al. (1996)	Arkansas	Statewide	0.234	1,905	NA	445	NA
Trauth et al. (1998)	NE Arkansas	Multiple sites	0.28	352	NA	98	NA
Trauth et al. (2016)	Arkansas	Multiple sites	0.24–0.92	416	Male bias	163	105–282
Lescher et al. (2013)	SE Missouri	Multiple sites	0.09	557	NA	51	NA
Shipman and Riedle (2008)	SE Missouri	Multiple sites	0.12	396	1:1	47	NA
*Folt and Godwin (2013)	S Alabama	Multiple sites	0.048	716	Female bias	35	NA
*Folt and Godwin (2013)	S Alabama	Multiple sites	0.081	570	Female bias	46	NA
*Folt and Godwin (2013)	Fowl River - Alabama	Single river	0.478	46	Female bias	22	NA
Howey and Dinkelacker (2013)	S Alabama	Multiple sites	0.10–0.13	NA	1:1	103	NA
			Macrochelys suwanniensis				
Enge et al. (2014)	Suwannee River - Florida	Single river	0.25	NA	3.5:1	132	780−1,171
Moler (1996)	W Florida	Multiple sites	0.251	367	NA	92	NA
Mays et al. (2015)	Florida Panhandle	Multiple sites	0.01–0.53 (mean = 0.30)	308	1.5:1	88	NA
Johnston et al. (2015)	N Florida	Santa Fe River	0.006–0.181	1,727	1:1	109	NA
Jensen and Birkhead (2003)	S Georgia	Multiple sites	0.2	281	1:1	55	NA
King et al. (2016)	Georgia	Multiple sites	0.09	683	1:1	52	NA

It must be noted that CPUE values in Table 2 are illustrative, with trends showing that harvested areas have lower CPUE.
*Folt and Guyer sampled multiple locations across southern Alabama. Fowl river locality was taken out of paired site calculations to illustrate extremely high CPUE value.