SURVIVING HURRICANE HARVEY: PRE AND POST FLOOD-EVENT SITE FIDELITY OF NORTHERN COTTONMOUTHS (*AGKISTRODON PISCIVORUS*) IN HARMON CREEK, WALKER COUNTY, TEXAS

William I. Lutterschmidt[1]*, Eric D. Roth[2], Zander E. Perelman[1,4], and J.M. Weidler[3]

[1]*Department of Biological Sciences, Sam Houston State University, Huntsville, TX 77341*
[2]*Department of Psychology and Brain Sciences, University of Delaware, Newark, DE 19716*
[3]*South Dakota Game, Fish and Parks, The Outdoor Campus, 4500 South Oxbow Avenue, Sioux Falls, SD 57106*
[4]*Current affiliation: Illinois Natural History Survey, University of Illinois at Urbana-Champaign, Champaign, IL 61820*
**Corresponding author; Email: lutterschmidt@shsu.edu*

Abstract.—Due to the impact and effects of Hurricane Harvey on several aquatic systems in southeast Texas, we investigated the potential impact of flood waters displacing individual cottonmouths *(Agkistrodon piscivorus*) from known site locations within Harmon Creek in Walker County, Texas. Using mark recapture data and GIS locations, we document that cottonmouths within our study area of Harmon Creek avoided potential displacement and mortality during unprecedented flooding. A comparison of distances between pre- (mean = 192.60 m, SE = 67.572, n = 7) and post- (mean = 97.91 m, SE = 24.953, n = 9) Hurricane Harvey snake locations did not differ and we recaptured 46 cottonmouths that were previously tagged in past sampling years prior to this unprecedented flood event. We finally discuss the importance of long-term monitoring programs that ultimately provide the data needed to evaluate the potential impacts of such disturbance events.

Keywords: natural disturbance, flooding, snake population, displacement

---

Hurricane Harvey made landfall east of Rockport, Texas on 26 August 2017 as a category-4 storm with wind speeds of 210 km/h and an atmospheric pressure of 937 mbar. Upon Harvey moving inland, the hurricane weakened rapidly to tropical storm status and stalled for two days on 28 August 2017, with the center of circulation drifting back towards the southeast just offshore in the Gulf of Mexico. The combination of a stalled and poorly organized storm and deep convection currents persisting north of the storm's center produced

OPEN ACCESS DOI 10.32011/txjsci_74_1_Article4
Received: 23 March 2022 | Accepted: 8 July 2022 | Published Online: 10 August 2022

record-breaking rainfall. During the four-day storm event (26–30 August 2017), Hurricane Harvey and its tropical depression produced more than 100 cm of rain over much of southeast Texas and associated watersheds which created unprecedented and catastrophic flood events (e.g., Blake & Zelinsky 2018).

The Trinity River watershed begins with the Clear, West, Elm, and East Forks north of the Dallas-Fort Worth area and extends *ca*. 1,140 km south to the Trinity Bay east of Houston. Within this watershed, we conduct yearly surveys of a 5.3 km section of Harmon Creek extending ~2.5 km north and 1.5 km south of the Pineywoods Environmental Research Laboratory (formerly Center for Biological Field Studies) in Walker County, Texas. This section of Harmon Creek is a shallow, sandy-bottomed perennial stream with variable depth, intermittent pools, and steep vegetated streambanks (Dent & Lutterschmidt 2001). Smaller tributaries of Tan Yard, Spring, and Wayne (a.k.a. Wynne) Creeks flow into this section of Harmon Creek with all confluence then flowing northward and entering the Trinity River in Walker County just north of Riverside, Texas.

A USGS Trinity River gage station (USGS 08066250 Trinity River near Goodrich, Texas) located below the Lake Livingston dam, records both gage height (ft) and water discharge (ft^3/sec). During Hurricane Harvey, gage height and discharge increased from 3.35 m (11.00 ft) and 204.45 m^3/sec (7,220 ft^3/sec) at 0000 h on 26 August to peaks of 14.73 m (48.34 ft) at 1900 h on 29 August and 3114.85 m^3/sec (110,000 ft^3/sec) between 1400 and 1930 h on 29 August. Water level was *ca.* 3.8 m above flood stage gage height (10.97 m; 36 ft) for this location. Since this gage was established on 01 October 2007, there has been no flood event to approach 45 ft prior to Hurricane Harvey, thus the 48.34 ft peak gage height for this location during Hurricane Harvey was unprecedented.

Data more pertinent to potential water levels in Harmon Creek are recorded at U.S. Highway 19 just north of Riverside, Texas (USGS 08066000 Trinity River at Riverside, Texas). Gage height rose more than two meters from 39.91 m (130.93 ft) at 0000 h on 26 August to a peak of 41.96 m (137.66 ft) at 1500 h on 29 August. No USGS data are available for Harmon Creek, but water level rose ca. 4.8 m (15.7 ft.) flowing over the road where the creek intersects Highland Drive, Huntsville, Texas (WIL pers. obs.).

While the anthropogenic impacts of the storm are well documented (e.g., Frame et al. 2020; Qin et al. 2020; Schulte et al. 2020; Bozick 2021), there is limited information regarding its potential impact on wildlife populations. A typical problem with attempting to investigate the effects of disturbance is the lack of data prior to a disturbance event (e.g., Perelman et al. 2021). Fortunately, we (WIL & EDR) began marking Northern Cottonmouths (*Agkistrodon piscivorus*) in 2006 with passive integrated transponder (PIT) tags. In 2015 we began archiving field survey and recapture data to include GPS locations and habitat use, allowing us to serendipitously investigate the potential pre and post disturbance impact of Hurricane Harvey on the site fidelity of cottonmouths within Harmon Creek. While some work has addressed the spatial ecology of cottonmouths in Texas (Ford 2002; Delisle et al. 2019; 2020), there are no detailed reports of year-to-year site fidelity. More relevant to this study, there are no data on site fidelity or the potential displacement of cottonmouths in the context of a natural disaster such as Hurricane Harvey.

Harmon Creek supports a population of cottonmouths (*Agkistrodon piscivorus*) that has served as the subject of numerous investigations (e.g., Roth et al. 2003; Roth & Johnson 2004; Roth et al. 2006; Lutterschmidt et al. 2007; Roth & Lutterschmidt 2011; Miller & Lutterschmidt 2014; Weidler et al. 2017; Weidler & Lutterschmidt 2021; Lutterschmidt et al. 2021; Lutterschmidt et al. 2022). Cottonmouths typically use microhabitats along vegetative banks of Harmon Creek within 10 m of the water (Roth 2005a; 2005b). Because of the rapid 4.8 m rise in water level and its associated increase in flow rate within Harmon Creek, we questioned if cottonmouths were potentially displaced down stream of their documented GPS localities. Here we report the year-to-year observations of frequency, captures per sampling effort, recaptures, and GPS locations of PIT tagged cottonmouths to investigate pre and post effects of Hurricane Harvey.

MATERIALS & METHODS

Field Survey & Sampling of Cottonmouths.–Each year we survey sections of Harmon Creek along a 5.3 km stretch of the stream during the month of July as part of a long-term population and capture-recapture study. We typically wade the creek beginning at dusk (~2100 h) and search for cottonmouths which have moved from their diurnal use of concealed and heavily vegetated microhabitats on the streambanks (Roth 2005a; 2005b) to more conspicuous foraging sites within the stream (Lutterschmidt et al. 2022). Using LED headlamps (e.g., Princeton Tec® Model# QUAD-BK), sections of the creek are walked at ~40 m per min. by at least two observers to ensure a thorough survey of both the west and east sides of the creek.

At the start of each survey, we measured air temperature (T_a) and percent relative humidity (RH) using a Kestrel® 3500 Pocket Weather Meter. Upon encountering a cottonmouth, we recorded date, time, GPS location (< 5 m accuracy), activity (coiled, outstretched, or active travel), and flagged the capture site immediately following capture of the snake. Cottonmouths were caught with snake tongs, placed in labeled snake bags and transported in buckets (18.9 L; 5 gal). The following morning, snakes are processed in the laboratory where they are scanned for the presence of a PIT tag, sexed, and measured to determine body mass, snout-vent-length, and tail length. Snakes are housed in the laboratory during July for additional study and then released to their specific capture sites within 30 days of capture. Our year-to-year recapture localities suggest that this short-term captive housing of cottonmouths has no significant influence on their movements and site fidelity. Previous studies of North American pitvipers (e.g., Reinert 1992; Reinert and Rupert 1999; Nowak et al. 2002; Sealy 2002; Smith et al. 2009) have shown that captive housing of snakes and subsequent surgical implantation of transmitters, handling in the field, transporting in buckets, and short distance translocations do not significantly impact movement patterns and site fidelity following release.

GIS Calculations of Year-to-Year Distance.–We used archived data of snake capture dates and times with GPS locations of latitude (northing) and longitude (easting) along Harmon Creek to calculate distances between each snake's year-to-year location within the creek channel. Beginning with capture and location data from 2014, we first determined which snakes were captured in consecutive years. These year-to-year snake GPS locations were mapped using the National Hydrography Dataset (NHD) downloaded from the National Map (https://apps.nationalmap.gov/downloader/#/) on 18 September 2020. Cottonmouth locations were snapped to the closest stream NHD segment and projected to the NAD 1983 UTM Zone 15N coordinate system (e.g., Lutterschmidt et al. 2019). Using ArcGIS Pro 2.6.1 and this coordinate system, the distance (in meters) between each snake's consecutive year capture location was measured following the NHD line segments. This more accurately measures maximum distance traveled between localities within the stream bed. Cottonmouths most likely transverse and follow the contour of the stream banks (Roth 2005a, b) for changes in site location, rather than following a simple straight line between point localities.

RESULTS & DISCUSSION

The relative number or frequency of cottonmouths observed each July greatly depends on sampling effort. However, once controlling for sampling effort (snakes/survey), we compared year-to-year captures per unit effort (Table 1). Additionally, we increased survey efforts (n $\geq$ 8 survey nights) for cottonmouths beginning in 2016 as part of our long-term population and capture-recapture study. Using the yearly

Table 1. Comparison of yearly recaptures of Northern Cottonmouths (*Akistrodon piscivorus*) in Harmon Creek, Texas. Adjusted catch per unit effort is shown in the fourth column with snakes per survey night. The number of recaptures from the previous years are shown with the percent (%) of recaptures of the total number of snakes sampled. The mean distance in meters (m) is shown for prior year to current year recapture locations followed by standard error and sample size (SE; n) of recaptures with complete GIS location information allowing for distances of site fidelity to be calculated.

Sampling Year	Total Snakes	Survey Nights	Snakes per Survey Night	Recaptures (%)	Mean Distance (m)
2014	11	3	3.67		
2015	26	6	4.33	1 (3.8%)	154.2 (0.00; 1)
2016	53	9	5.89	5 (9.4%)	210.8 (117.22; 4)
2017	70	8	8.75	11 (15.7%)	175.3 (108.33; 2)
2018	138	18	7.67	32 (23.2%)	97.9 (24.95; 9)
2019	74	9	8.22	36 (48.6%)	79.8 (14.99; 36)
2020	71	10	7.10	15 (21.1%)	122.9 (51.12;15)
2021	49	10	4.90	18 (36.7%)	164.1 (74.47; 18)

samples with at least eight survey nights, we investigated the potential variability in year-to-year cottonmouth frequency per survey (Table 1) from 2016 to 2021 using a log-likely goodness of fit G-test (Zar 2010) and found no difference ($G = 1.55$, $df = 5$, $P > 0.05$). More specifically, we questioned the decrease in cottonmouths/survey from 8.75 (2017, pre-hurricane) to 7.67 (2018, post-hurricane) and found also that this difference was not significant ($G = 0.07$, $df = 1$, $P > 0.05$).

Assuming small home range (Roth 2005a) and site fidelity in year-to-year location, we assumed that the associated distance between these year-to-year locations should not differ. We used a model-I, one-way ANOVA to test this null hypothesis. We found that mean year-to-year location distance (Table 1) for years 2016 to 2021 did not statistically differ ($F = 0.77$; $df = 5, 78$; $P = 0.571$). More specifically, we questioned if the observed distances in 2015, 2016 and 2017, prior to Hurricane Harvey ($n = 7$) differed from observed distances in 2018, immediately following the flood event ($n = 9$). A comparison of pre- (mean = 192.60 m, SE = 67.572, n = 7) and post- (mean = 97.91 m, SE = 24.953, n = 9) Hurricane Harvey location distances did not differ significantly ($t = 1.26$, $df = 14$, $P = 0.229$). Using the data from the

USGS Trinity River gage station (USGS 08066250), we investigated if year-to-year peak water levels can explain differences in year-to-year mean snake distances. We found both water level ($F = 0.80$; df = 1, 5; $P = 0.415$; $r^2 = 0.136$) and the rate of water discharge ($F = 0.92$; df = 1, 5; $P = 0.382$; $r^2 = 0.155$) to have no effect on year-to-year mean snake distances ($n = 7$) from 2015 to 2021. Additionally, mean snake distance in 2018, following Hurricane Harvey, was smaller than previous years (Table 1).

Finally, we note that after this unprecedented flood event, we recaptured 46 cottonmouths during our July 2018 study season that were previously tagged within the population. Of these 46 previously tagged snakes, 32 individuals, representing 23.2% of the 2018 sample (Table 1), were tagged in July 2017 a month prior to Hurricane Harvey. Results of similar cottonmouth frequency per sampling effort, year-to-year distances between snake localities, and a 23.2% recapture rate suggests that cottonmouths “survived” this unprecedented flood event.

Although our yearly collection records cannot provide evidence of mortality nor evidence of individuals that may have been displaced by the flood event, we can document that several individual snakes within this population were resampled and thus avoided being displaced downstream beyond our study area within Harmon Creek. We cannot ignore the potential that snakes displaced downstream from flood surge may have traveled back to their original home ranges. However, it is more likely that snakes retreated to higher refuge sites within their home ranges along the creek. Because this storm event occurred late in the activity season, displaced snakes would have needed to travel and find known localities within a few weeks of lower fall temperatures. Translocated snakes demonstrate increased movement patterns to find familiar habitat sites (e.g., Reinert 1991; Reinert & Rupert Jr 1999). However, the small home range and site fidelity of cottonmouths in this population (Roth 2005a; 2005b) suggest that snakes likely retreated from rising waters and did not travel long distances to return from displaced downstream locations. However, without the use of radio-telemetry and repeated observations of individuals during the event, we

Figure 1. Example site fidelity for five cottonmouths (82, 93, 94, 95 & 109) along Harmon Creek before and after Hurricane Harvey. White circles indicate 2017 pre-hurricane localities and gray circles indicate 2018 post-hurricane localities. Numbers within circles indicate each snake by identification number. Three individuals (A-82, 94 & 109) have up-stream relocations while two individuals (A-93 & 95) have down-stream relocations. Observed distance between the 2017–2018 relocations for these snakes ranged from 34.7 to 73.2 m (mean = 56.6, SE = 7.55, n = 5).

cannot offer conclusive evidence for how such a flood surge was avoided or if displaced snakes were able to return from distant relocations. However, the data presented here asserts that cottonmouths within our study area of Harmon Creek avoided potential mortality and displacement due to unprecedented flooding.

Here we asked a simple question regarding the site fidelity of cottonmouths prior to and after an unprecedented flood event and showed that snakes "survived" being displaced from their activity ranges (Fig. 1). Understanding how such an unprecedented disturbance event may impact survival, site fidelity, and basic ecology of wildlife is important. Long-term research and monitoring programs ultimately provide the data needed to evaluate such impacts and should be supported. Additionally, locations where severe weather events (e.g., hurricanes, tornados, flooding, extreme temperature, etc.) regularly occur should receive increased interest regarding how climate change may alter weather patterns which then may alter both populations and communities. Future year-to-year surveys and research will continue to document the spatial ecology and demographics of individuals in this population with greater attention to documenting potential and local disturbances within Harmon Creek. Such research considerations may ensure pre- and post-disturbance analyses, should unexpected (e.g., Perelman et al. 2021) and unprecedented events occur.

Acknowledgments

We thank Alan Byboth for his assistance as manager of the Pineywoods Environmental Research Laboratory and acknowledge field assistance by Greyson I. and Nicolas C. Lutterschmidt. We thank Ross Guida for assistance in acquisition and review of flood data associated with Hurricane Harvey. We also thank the anonymous reviewers for their helpful comments and review of this research report prior to publication.

LITERATURE CITED

Blake, E. S. & D. A. Zelinsky. 2018. NOAA National Hurricane Center Tropical Cyclone Report: Hurricane Harvey (AL092017). https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf (Accessed 9 Feb 2022).

Bozick, R. 2021. The effects of Hurricane Harvey on the physical and mental health of adults in Houston. Health & Place 72(2021):102697. https://doi.org/10.1016/j.healthplace.2021.102697 (Accessed 9 Feb 2022).

Delisle, Z. J., D. Ransom Jr., W. I. Lutterschmidt & J. Delgado-Acevedo. 2019. Site-specific differences in the spatial ecology of northern cottonmouths. Ecosphere 10(1):1–11, Article e02557, https://doi.org/10.1002/ecs2.2557 (Accessed 8 Feb 2022).

Delisle, Z.J., D. Ransom Jr., W.I. Lutterschmidt & J. Delgado-Acevedo. 2020. Multiscale spatiotemporal habitat selection of northern cottonmouths. J. Herpetol. 53(3):187–195.

Dent, L. and W.I. Lutterschmidt. 2001. The ichthyofauna of Harmon and Wynne Creeks sampled with the Center for Biological Field Studies, Walker County, Texas. Texas J. Sci. 53(2):139–146.

Ford, N. B. 2002. Ecology of the Western cottonmouth (*Agkistrodon piscivorus leucostoma*) in Northeastern Texas. Pp. 167–177, *in* Biology of the Vipers (G. W. Schuett, M. Hoggren, M. E. Douglas, & H. W. Greene, eds.), Eagle Mountain Publishing, Eagle Mountain, Utah, USA, 580 pp.

Frame, D. J., M. F. Wehner, I. Noy & S. M. Rosier. 2020. The economic costs of Hurricane Harvey attributable to climate change. Climatic Change 160(2):271–281.

Lutterschmidt, W. I., B. Cornell, E. D. Roth & J. M. Weidler. 2022. Fine-scaled summer observations of temporal and structural riparian habitat use by foraging northern cottonmouths (*Agkistrodon piscivorous*) in an east Texas perennial stream. Herpetol. Notes 15(2022):317–328.

Lutterschmidt, W. I., Z. E. Perelman, D. R. Neyland, M. L. Thies & E. D. Roth. 2021. *Agkistrodon piscivorus* (Northern Cottonmouth) - Diet. Herpetol. Rev. 52(3):655–556.

Lutterschmidt, W. I., E. D. Roth, K. G. Wunch, E. Levin & L. H. James. 2007. Bacterial microflora of the anterior digestive tract of two Agkistrodon species: additional evidence for food partitioning? Herpetol. Rev. 38(1):33–35.

Lutterschmidt, W. I., J. M. Weidler & C. M. Schalk. 2019. Hot moments and hot spots in the bayou: spatiotemporal patterns of road occurrence in a snake assemblage in Louisiana, USA. Herp. Conserv. Biol. 14(2):533–545.

Miller, M. A. & W. I. Lutterschmidt. 2014. Cutaneous water loss and epidermal lipids in two sympatric and congeneric pitvipers. J. Herpetol. 48(4):577–583.

Nowak, E. M., T. Hare & J. McNally. 2002. Management of "nuisance" vipers: effects of translocation on western diamond-backed rattlesnakes (*Crotalus atrox*). Pp. 533–560, *in* Biology of the Vipers (G. W. Schuett, M. Hoggren, M. E. Douglas & H. W. Greene, eds.), Eagle Mountain Publishing, Eagle Mountain, Utah, USA, 580 pp.

Perelman, Z. E., M. K. Takahashi, E. L. Hundermark & C. Parenzan. 2021. An eDNA-based assessment of the impact of a 207,000-liter gasoline spill on local populations of Eastern Hellbenders (*Cryptobranchus alleganiensis alleganiensis*), an imperiled giant salamander. Northeast. Nat. 28(4):484–496.

Qin, R., N. Khakzad & J. Zhu. 2020. An overview of the impact of Hurricane Harvey on chemical and process facilities in Texas. Intern. J. Disaster Risk Reduction 45(2020): 101453. https://doi.org/10.1016/j.ijdrr.2019.101453

Reinert, H. K. 1991. Translocation as a conservation strategy for amphibians and reptiles: some comments, concerns, and observations. Herpetologica 47(3):357–363.

Reinert, H. K. 1992. Radiotelemetric field studies of pitvipers: data acquisition and analysis. Pp. 185–198, *in* Biology of the Pitvipers (J. A. Campbell & E. E. Brodie, Jr., eds.), Selva, Tyler, Texas, USA, 467 pp.

Reinert, H. K. & R. R. Rupert Jr. 1999. Impacts of translocation on behavior and survival of timber rattlesnakes, *Crotalus horridus*. J. Herpetol. 33(1):45-61.

Roth, E. D. 2005a. Spatial ecology of a cottonmouth (*Agkistrodon piscivorus*) population in east Texas. J. Herpetol. 39(2):308–312.

Roth, E. D. 2005b. Buffer zone applications in snake ecology: a case study using cottonmouths (*Agkistrodon piscivorus*). Copeia 2005(2):399–402.

Roth, E. D., W. D. W. Ginn, L. J. Vitt & W. I. Lutterschmidt. 2003. *Agkistrodon piscivorus leucostoma* (Western Cottonmouth), Diet. Herpetol. Rev. 34(1):60.

Roth, E. D. & J. A. Johnson. 2004. Size-based variation in antipredator behavior within a snake (*Agkistrodon piscivorus*) population. Behav. Ecol. 15(2):365–370.

Roth, E. D. & W. I. Lutterschmidt. 2011. Experimental validation of sex differences in spatial behavior patterns of free-ranging snakes: implications for social interactions. Ethol. 117(10):852–858.

Roth, E. D., W. I. Lutterschmidt & D. A. Wilson. 2006. Relative medial and dorsal cortex volume in relation to sex differences in spatial ecology of a snake population. Brain Behav. Evol. 67(2):103–110.

Schulte, J., A. Haynes, E. A. Smith, J. Fleming, K. Kleinschmidt & B. Roth. 2020. Trends in snakebites related to Texas tropical storms and hurricanes, 2000–2017. Wilderness & Enviro. Med. 31(2):197–201.

Sealy, J. B. 2002. Ecology and behavior of the timber rattlesnake (*Crotalus horridus*) in the upper piedmont of North Carolina: identified threats and conservation recommendations. Pp. 561–578 *in* Biology of the Vipers (G. W. Schuett, M. Hoggren, M. E. Douglas & H. W. Greene, eds.), Eagle Mountain Publishing, Eagle Mountain, Utah, USA, 580 pp.

Smith, C. F., G. W. Schuett, R. L. Earley & K. Schwenk. 2009. The spatial and reproductive ecology of the copperhead (*Agkistrodon contortrix*) at the northeastern extreme of its range. Herpetol. Monogr. 23:45–73.

Weidler, J. M. & W. I. Lutterschmidt. 2021. Nature or nurture: can prey-based diets influence species-specific physiological performance traits of epidermal lipid content and cutaneous water loss? Integ.Org. Biol. 3(1):1–11.

Weidler, J. M., M. L. Thies, A. Smith-Herron, E. J. Tivador III, E. D. Roth & W. I. Lutterschmidt. 2017. *Agkistrodon piscivorus leucostoma* (Western Cottonmouth), unusual field injury. Herpetol. Rev. 48(3):664–665.

Zar, J. H. 2010. Biostatistical Analysis, Fifth Edition. Pearson, Upper Saddle River, New Jersey, 944 pp.