FORAGING ACTIVITY TIME AND REFUGE SITE SELECTION IN THE NORTHERN COTTONMOUTH, *AGKISTRODON PISCIVORUS*

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Brittany Cornell

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ABSTRACT

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The Northern Cottonmouth (*Agkistrodon piscivorous*) is a semi-aquatic pit viper that utilizes riparian microhabitats within Harmon Creek for nocturnal foraging as well as for retreat sites if there is a perceived threat. The population of Northern Cottonmouths that are found within Harmon Creek were observed over three nights to determine hourly activity levels of the snakes within the creek. During these nights, a transect of Harmon Creek was walked once per hour from 1900 to 0700 to observe snakes. Snakes from this area were captured, later released and allowed to select a refuge site. Both collection and refuge sites were analyzed for microhabitat structure. Microhabitat structure was compared for four habitat types: random, refuge site, capture site, and the banks opposite of these sites. I found the timing of activity time for foraging by cottonmouths to be consistent over the course of the scotophase and while prey availability is most likely high. Peak activity occurred at 0200 h. My results indicate that snakes prefer the east bank of the creek and microhabitat selection is influenced by leaflitter, underbrush, and overhanging branches.

KEY WORDS: Cottonmouth, Foraging activity, Refuge site, Site selection, *Agkistrodon piscivorous,* Activity, habitat selection

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CHAPTER I

Introduction

Species Description

The Northern Cottonmouth (*Agkistrodon piscivorus)* is a viper commonly found in southern states along the Gulf and East Coast of the United States. This species may occur in high densities, with populations ranging from an estimated 130 to 370 individuals and they have the largest body size of the *Agkistrodon* genus (Ford 2002). The range of *A. piscivorus* extends southeast from Virginia to Texas in the west and North along the Mississippi River into parts of Indiana and Illinois (Powell et. al. 2016). The subject of this study will include individuals from a Texas population of *A. piscivorus.* Common habitats in this area include lowland floodplains, ponds, streams, or drainage ditches (Powell et. al. 2016).

Coloration can vary greatly among individuals; however, dark brown or black is most common (Gloyd and Conant 1990). Individuals have a cheek stripe that extends from the eye to the neck that is either brown or black (Gloyd and Conant 1990). The body is patterned with 10 to 15 cross of half bands that can vary in color and intensity from light brown to black; this pattern is not visible in many adults and is most visible in younger individuals (Gloyd and Conant 1990). The belly scales are most commonly a cream color, but these can also be mottled or black in coloration (Gloyd and Conant 1990). In adults, the tail is consistent with the coloration of the body, but in juveniles the tail is bright green or yellow (Gloyd and Conant 1990, Wharton 1960).

Behaviors

Northern cottonmouths exhibit a variety of antipredator behaviors. One bluff behavior called mouth gaping, from which the name cottonmouth is derived, is used to dissuade predators by indicating a willingness to strike. The inside of the mouth in this species is a strikingly pale color, and mouth gaping occurs most often in individuals that do not flee from threats (Gibbons and Dorcas 2002). Other bluff behaviors include defensive postures, like tail rattling and emitting musk (Gibbons and Dorcas 2002, Roth and Johnson 2004). When stressed, or if bluffing does not work, the animal may strike or bite the potential threat (Herr et. al. 2017, Roth and Johnson 2004). Cottonmouths tend to stand their ground and display these threat behaviors or slowly move away from the perceived threat (Powell et. al. 2016). These antipredator behaviors vary with size of the individual. Although cottonmouths of any size are equally likely to flee from a possible threat; however, studies have found the warning behaviors are size dependent and decreased with decreasing body size (Roth and Johnson 2004).

Because they are semi-aquatic, swimming is one of the most commonly observed cottonmouth behaviors. While swimming, cottonmouths will keep most of their body above the water as they move. When compared to other semi- aquatic snakes, such as watersnakes, swimming patterns allow for simple distinction between species as watersnakes will swim with most of their body submerged below the water's surface (Powell et. al. 2016).

Intraspecific behaviors may be related to courtship or territorial disputes. One such observed behavior is dancing. This is a swaying of the head in unison until both snakes strike at each other with an unopened mouth. The individuals become tangled and

must right themselves before facing off again (Perry 1978). This may be courtship behavior between a male and female or combat between two competing males (Perry 1978).

Feeding Behavior

The *Agkistrodon* genus hunts using a combination of visual, chemical and thermal cues (Buning 1983). The pits of the viper gather thermal information; these pits are membranous with many sensitive nerves located on the upper lip of the snake (Glaudas and Gibbons 2005). The thermal cues are processed along and in the same part of the brain as visual cues (Buning 1983, Glaudas and Gibbons 2005). Chemical cues are gathered by tongue flicking and interaction of the tongue and jackobson's organ (Chizsar et. al. 1979). The rate of tongue flicking will increase after the detection of prey or if the prey item was struck and released (Chiszar et. al. 1979). All three of these cues are required in conjunction for effective hunting and prey acquisition (Buning 1983). Nighttime foraging is the most common time for prey acquisition in *Agkistrodon piscivorous* (Lilywhite and McCleary 2008, Lillywhite and Brischoux 2012). Larger cottonmouths have been observed using their territory for active foraging more often than smaller or juvenile snakes (Eskew et. al. 2009, Roth 2005 a.). These snakes are most commonly sit and wait predators that will ambush unsuspecting prey. Aquatic habitats are often utilized while searching for fish or frogs (Eskew et. al. 2009). Cottonmouths will strike at fish from above the surface of the water to as deep as 10 cm deep (Vincent et. al. 2005). When striking, they will rear their head above the water and strike down (Vincent et. al. 2005). When hunting in terrestrial habitats, cottonmouths commonly exhibit trailing behaviors to capture missed prey. The snake will follow the scent trail of

the prey by frequent tongue flicking to pinpoint the prey item's position. This behavior occurs even if the prey was not successfully struck; the snake will leave strike position to follow the animal (Chiszar et. al. 1986). Juvenile cottonmouths, as well as juveniles of other species in the *Agkistrodon* genus, exhibit unique luring behaviors (Wharton 1960). The young will waggle their discolored tail tip to lure unsuspecting prey that may mistake the tail for a food item (Wharton 1960). Scavenging has been observed in all subspecies to some degree. *Agkistrodon piscivorus* have been observed scavenging deceased *Nerodia* (Devault and Krochmal 2002).

Diet

The typical cottonmouth diet consists of fish, juvenile and adult amphibians, mammals and other snakes (Ford et. al. 2004). This species is the only viper that uses fish as a prey resource (Vincent et. al. 2005). *Nerodia* species (watersnakes), *Regona rigida* (the crayfish snake), *Thamnophis* species (gartersnakes), and on one observed occasion *Coluber constrictor* (eastern racer) are among the snake species that cottonmouths are known to have taken as prey (Roth et. al. 2003). Some less common prey items, found through gut content analyses of cottonmouths, include turtles, salamanders, lizards, birds, small alligators, invertebrates, vegetation, and detritus (Lilywhite and McCleary 2008, Gloyd and Conant 1990). Invertebrates, vegetation and detritus are typically accidentally ingested; however, through gut content analysis some cases of cottonmouths intentionally praying upon invertebrates have been reported (Gloyd and Conant 1990). Prey preference in adults varies based on sex. Males prefer fish, while females prefer reptiles, usually snakes (Vincent et. al. 2004). Despite the high variation in diet and the generalist

foraging style of cottonmouths, fish still makes up a majority of the diet and account for 44% of the volume of prey eaten by these snakes (Vincent et. al. 2005).

Thermoregulation

During thermoregulation, semi- aquatic snakes tend to select higher temperatures for terrestrial basking sites, as they are spending time in cold water. As the snake is swimming, locomotor performance will decrease in conjunction with decreased body temperature (Aubret and Michniewicz 2010). Cottonmouths often utilize exposed logs, vegetation, and nearby riparian microhabitats to bask near water systems (Mueller and Gienger 2019). These snakes will, on rare occasion, also climb into trees to bask. Most snakes will coil on terrestrial or aquatic substrate; however, shrubby tree bask occurs in ~25% of cottonmouths in observations of a small population (Graham 2013). Snakes observed basking in shrubs and trees were neonates or juveniles (Graham 2013). Terrestrial basking sights are most commonly utilized by cottonmouths. The estimated preferred temperature range for cottonmouths is between 22.6 and 29.2 Celsius (Mueller and Gienger 2019).

Habitat Use

Common habitats of the Northern cottonmouth involve relatively flat woodlands with streams or standing water, with soil composed of decaying vegetation and loamy sand (Ford et. al. 1991). Cottonmouths are the most abundant snake species in these types of habitats (Ford et. al. 1991). Streams are the most highly used by cottonmouths. In previous studies, 83% of the individual used in the study were found within 10 meters of the stream habitat (Roth 2005b.).

Microhabitat choice is based upon if the snake is able to satisfy physiological needs as well as prey availability (Eskew et. al. 2009). Individuals can select ambush or foraging sites in areas often visited by prey items by using chemical cues. Larger, more mature snakes use aquatic habitats more often, most commonly for foraging for fish (Eskew et. al. 2009). Home ranges of individuals tend to increase with the size of the snake, differ by sex, and may overlap (Macartney et. al. 1988). Home range estimates provided in the existing literature vary dramatically. One study indicated that males have an average home range size of 0.17 hectares, while females have an average home range of 0.14 hectares (Macartney et. al. 1988). More recent studies provide much different estimations: 1.86 ha for males and 0.372 ha for nongravid females (Roth 2005 a.). Home range estimations vary based on sampling methods, habitat type and habitat availability (Deslisle et. al. 2019). Gravid females approximately double their home range (Roth 2005 a.). Home ranges of individual may shift depending on variation in local aquatic habitats (Rose et. al. 2010b.) Aggregations of individuals will also occur if resources, such as prey items, are limited (Rose et. al. 2010b., Roth and Lutterschmidt 2011). These types of aggregations have been observed denning, feeding or basking together (Tavano et. al. 2007). Overlap of home range may also occur which increases intraspecific interactions, though this more common in females (Roth and Lutterschmidt 2011).

In some populations, seasonal migrations occur, with individuals typically moving to the winter habitat in October and November then returning around July (Glaudas et. al. 2007). In North- Central Texas, standard western cottonmouth populations migrate between woodlands and river habitats (Rose et. al. 2010 a.). Migration behavior is most common with populations from more variable systems (Rose et. al. 2010 a.).

Activity Levels

Activity levels of *A. piscivorus* vary by season and by sex of the individual. Female activity is highest in spring with great amounts of foraging behaviors taking place; greater than that of males (Ford 2002). Male foraging activity often peaks in mid to late summer (Ford 2002). Breeding occurs generally in early spring; some populations are known to breed in early summer (Roth 2005 a., Ford 2002). Traveling distances peak in early spring for females, while males are traveling greater distances in spring and fall (Deslisle et. al. 2019). Prevalence of cottonmouths also increased in late summer and fall, likely as a result of neonate activity (Ford et. al. 1991). From May to September, individuals will most often be found above ground being active or coiled; during winter and early spring they will be found underground (Deslisle et. al. 2019).

On a daily basis, *A. piscivorus* are sedentary snakes. They travel less distance on average than other semi- aquatic snakes, such as *Nerodia* species (Ford 2002). Previous studies have determined that males of one population moved an average distance of 110.07 meters a week and females of the same population moved an average distance of 45.04 meters per week (Deslisle et. all 2019). At night, cottonmouths usually are coiled or active in streams or other aquatic habitats (Rose et. al. 2010 b.). Conversely, during the day, nearly half of an individual's time is spent coiled and inactive (Rose et. al. 2010 b.).

Interspecific competition may be a driver of habitat use activity patterns. Other water snake species, like those in the genus *Nerodia,* are known to utilize the banks of Harmon Creek. Like *A. piscivorus, Nerodia* often forage in the creek at night; however, foraging strategies differ between these two genera. *Nerodia* spp. will actively search for

prey items, such as fish or frogs, which they are known to attack from the bank or from above the water (Himes 2003, Hampton 2018). This is in direct contrast to foraging methods used by *A. piscivorus* that are primarily ambush predators that will sit and wait for prey to come within striking range. Like *A. piscivorus,* nocturnal activity in *Nerodia* spp. peaks during summer months (Himes 2003). These snakes are known to shift home ranges multiple times a season at random intervals, which is related to food availability (Roth and Greene 2006). Conversely, *A. piscivorus* travel shorter distances and will change home ranges less frequently (Ford 2002). Like *A. piscivorus*, *Nerodia* will restrict themselves to habitats near water, especially in summer months (Roth and Greene 2006). Due to habitat overlap and the differences in activity and foraging strategies between species, the timing of foraging activity of the Northern cottonmouth may be partitioned to avoid direct competition with *Nerodia.*

Hypotheses

The population of cottonmouths in this study and their use of Harmon Creek is well established; however, it is unknown when the snakes are leaving the creek after a night of foraging. Due to their nocturnal foraging behaviors, they would probably be using the creek for all hours of the night with different individuals coming and leaving after a successful capture or after deciding to move away. Therefore, I hypothesized that snake activity would begin around sundown and continue throughout the night until morning.

Snakes will choose habitats to meet their specific physiological needs. Different habitat types will likely provide different benefits and lead to a preference for certain habitat types. If so, habitat type prevalence in sites chosen by snakes could be used to

determine any differences between random sites as well as preferable habitats for cottonmouths. Therefore, I hypothesized that habitat types would influence cottonmouth selection. During the snake releases, I noticed snakes seemed to choose the east bank more often. My resulting, final hypothesis was that there is a difference between the east and west banks of Harmon Creek that can be described by the habitat types. To investigate these hypotheses, I created a set of methods to determine hourly cottonmouth activity and refuge site choice.

CHAPTER II

Methods

Study Site

This study took place during June, July and September 2019 at the Pineywoods Environmental Research Laboratory (formerly the Center for Biological Field Studies, CBFS). PERL is a 247-acre field station owned and maintained by Sam Houston State University (30.743000°N, 95.473000°W). The field station is located in Huntsville, Texas of Walker County in an area adjacent to the northern boundary of the Sam Houston National Forest. The area has a humid subtropical climate with hot, humid summers and brief winters that are typically mild in temperature. The property includes a variety of stream, forest, prairie and pond habitats. Within the PERL, there is a portion of Harmon Creek; this creek is a shallow, slow flowing stream with a few deeper pools and steep banks (Dent and Lutterschmidt 2001). This stream flows northeasterly year-round with variable depth that is a result of local precipitation. Heavy rain events often result in large amounts of shifted sand substrate, resulting in frequent habitat change. This property has a well-established *A. piscivorus* population that is known to utilize Harmon Creek.

Field Observations of Cottonmouth Occurrence

Observations were conducted on three separate nights over a 12-hour period. A 1223 m transect along Harmon Creek was walked each hour from 1900 h – 0630 h to determine the timing and number of snakes occurring. This transect was walked by two observers to survey both the right and left banks of the creek at the same speed (X=36.92 m/min, SE= ±5.79). At 1900 h, air temperature, water temperature, and humidity were

taken and the first walk of the transect began from that starting point and finish at the end point of the transect. (Figure 1) When an individual was seen, its GPS and time of observation were recorded. Data were taken to not disturb snakes; from the middle of the creek. Once the end point of the transect was reached, time was recorded and the transect would be walked in the reverse direction after taking temperature and humidity data for the hour. This pattern continued until the final transect time (0600 h) was walked. Observations took place on nights with similar weather and creek conditions. On nights when rain occurred during a sampling event, the data was discarded, and a new sampling night was chosen.

Figure 1. Map of the PERL and Harmon Creek. The 1223 transect of Harmon Creek is circled in yellow. The first transect of the night was walked North from the hot tub to the second point. The next hour, the observers would walk south to the original starting point at the hot tub.

Foraging and Refuge Habitat Selection

As part of a different study (IACUC # 19–07–11–1003–3–02) snakes were released to their specific capture localities within Harmon Creek. Once a capture location was found, data for the site were taken and the matching individual was prepared for release. Pictures of the foraging spot and the opposite creek bank were taken. The foraging spot is the exact spot from which the snake was captured, where the animal had chosen to coil and wait for food. For release, each snake was placed into a plastic tube that was then balanced above the water with two wooden stakes facing the middle of the creek. This was set up just before the capture site and the opposite bank. The snake would then exit the tube and choose a refuge site. The time it took each snake to reach a bank after leaving the tube as well as the time it took each snake to hide after reaching a bank was recorded. Pictures were then taken of the refuge site and of the same point on the opposite bank, and it was recorded if the snake returned to the same bank as the foraging site or if the opposite bank was chosen for refuge.

During this process, four pictures were taken for each snake release. These include east pre-release (epr), east release (er), west pre- release (wpr), and west release (wr). Pre- release photos were those taken of the foraging site and the opposite bank; release photos were those taken of the refuge site and of the opposite bank. Pictures were taken consistently. For each picture a meter stick was used for consistent picture size and for picture analysis.

Random bank pictures were sampled randomly in the transect for comparison the sites selected by snakes. The 1223 meter transect was broken into 100 equally sized sections, of which, 20 sections were selected at random for sampling. At each point, one

side of the creek was chosen by a coin flip and a picture was taken for inclusion in the picture analysis.

Once all the habitat pictures were taken, ImageJ bundled with java 1.9.0_172 was used for analysis. A 10 x 10 grid was made that is the equivalent of a 1-meter x 1-meter section of the creek. This grid was used to determine the majority habitat category type in each box. The percentage of habitat types for each location was determined. Habitat categories include sand, leaf litter, rocks, grass, underbrush, roots, sticks, logs, canes, branches, and dirt (Table 1).

Habitat Type	Description
Grass	tall and short grass, unbranched plants
Canes	hollow plants, standing straight or blown over, provide minimal cover
Rocks	rocky substrate or larger rocks and boulders
Dirt	uncovered ground, more clay than sand
Sand	uncovered ground, typically closest to water, sandbars
Underbrush	branched, bushy or shrubby plants that provide ground cover
Leaf Litter	clusters of fallen leaves of any depth
Sticks	small fallen branches, provide no cover
Branches	coverage from intact tree branches, higher than underbrush
Logs	fallen branches or trees
Roots	Roots from trees, sometimes creating holes or cover

Table 1. Descriptions of Habitat Categories. These are the categories used during image analysis. For each picture, the most common habitat category in each box of the Image J grid was determined.

Analysis

After the four observation nights, the data was pooled to determine average activity levels by hour that occur in a typical night (Durtsche et.al. 1997). This pooled data was graphed to show the variation in activity level in Harmon Creek by hour and

when cottonmouths are preset in Harmon Creek. This data was used to make a histogram of snake frequency by hour.

For habitat analysis, habitat type percentages were compiled. IBM© SPSS statistical software will be used to conduct a principle components analysis (PCA) to determine if there are significant differences between the east and west creek banks. The random habitat photos were used to compare habitats chosen by snakes to random points in the creek as well as to determine the level of heterogeneity of habitats in the creek.

CHAPTER III

Results

Field Observations of Cottonmouth Occurrence

Over the three-night sampling period for observations of occurrence, I found the frequency of cottonmouths to vary with both time and day. A total of 47 cottonmouths were observed. On June 8th and July 7th, 15 snakes were observed and on June 21st, 17 snakes were observed. The greatest frequency of snakes observed during any particular sampling hour was four. My first observation of foraging activity beginning at 2000 h. The occurrence of foraging activity increase at 2100 h and this activity was sustained throughout the evening hours until 0600 h (Figure 2).

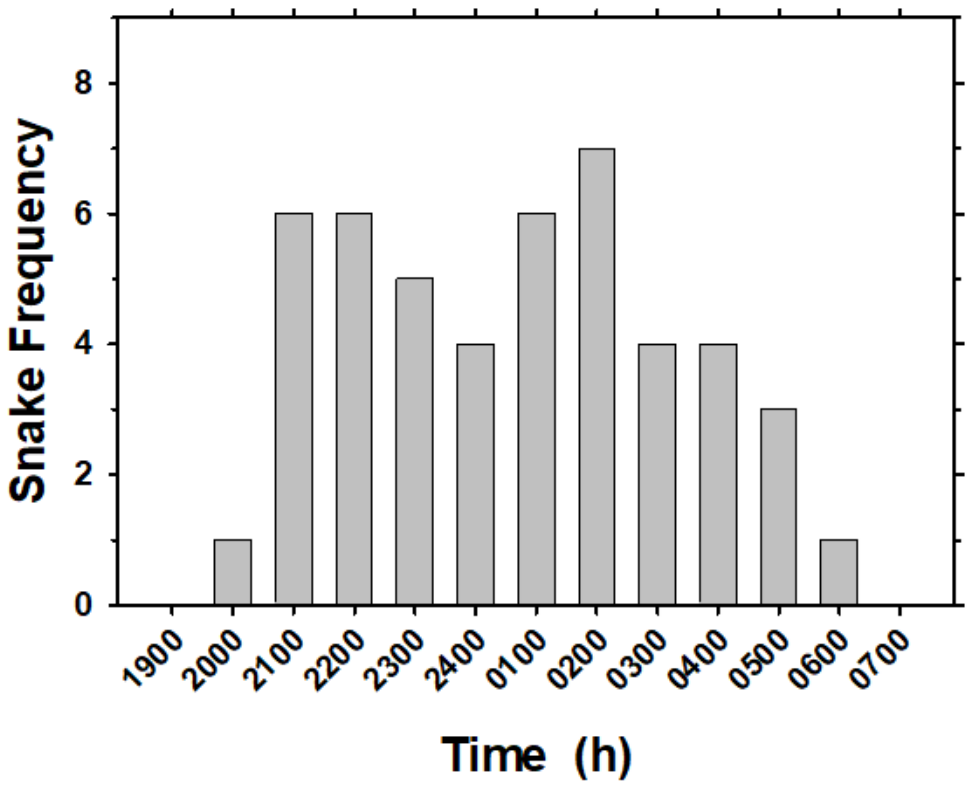

Figure 2. Snake Occurrence by Time. Snakes begin to appear in the creek at 2000 h and were no longer present by 0700 h. Occurrence of observed foraging activity by cottonmouths begins at 2100 h and is sustained through the scotophase until 0500 h.

At hours 1900 h and 0700 h, no cottonmouths were observed. Snake occurrences by time resulted in a nearly normal distribution of activity. Some individuals were observed in the same spot for long periods of time; one individual was seen in four consecutive sampling hours. This was the highest number of consecutive observations for an individual; however, two or three consecutive observations of an individual was common.

Foraging and Refuge Habitat Selection

A discriminant function analysis (IBM© SPSS) was used to determine possible differences between the habitat types. These habitats were defined as random habitat sites, snake microhabitat sites, snake habitat sites, and retreat sites. The random habitat sites where chosen and sampled at random by a number generator and coin flip. The microhabitat sites include both east and west banks at the spot where the snake chose to be and the opposite bank. Snake habitat and retreat sites were the specific habitats that were chosen by snakes for foraging and capture, respectively. This statistical analysis indicates that Function 1 and Function 2 explain 67.7% and 27.7% of the variation between the 4 habitat types, respectively. There is little variability between snake microhabitat sites, snake habitat sites, and retreat sites; however, based on Function 1, there is variability between these three types of habitat and the random habitat sites (Figure 3). Based on this analysis, when choosing habitat, leaf litter is highly significant. Underbrush and branches are approaching significance. Underbrush is loading the heaviest at 1.346 for Function 1, which transitions to leaf litter at -0.086. For function 2, branches are the highest at 0.741 and the lowest is sticks at -0.689 (Table 2).

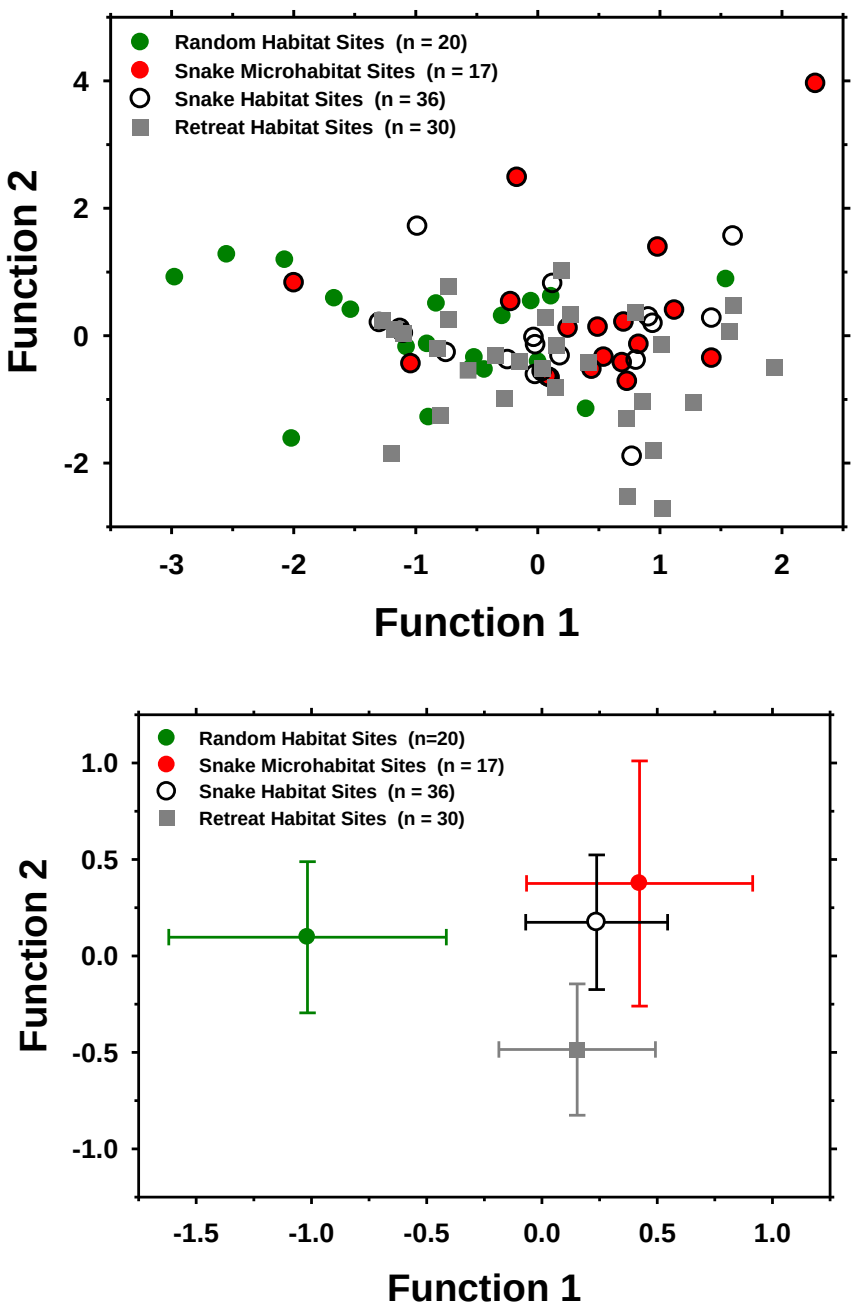

Figure 3. Discriminant Function Analysis. Discriminant function analysis showing Function 1 and Function 2 for the analysis of the habitat variables. The red circles represent snake microhabitat sites, green circles represent randomly chosen habitat sites, white circles indicate snake habitat sites, and the grey squares indicate retreat habitat sites. These graphs indicate that snake microhabitat, snake habitat sites, and retreat sites can be grouped and have little variability. Based on Function 1, random habitat sites show variability from the other habitats that were selected by snakes.

Standardized Canonical Discriminant Function Coefficients

	Function	
	1	2
Sand	0.813	-0.122
Leaf Litter	-0.086	0.383
Rock	-0.203	0.099
Grass	0.399	-0.362
Underbrush	1.346	0.223
Roots	0.443	0.193
Sticks	0.692	-0.689
Logs	0.066	0.409
Cane	-0.146	-0.123
Branches	0.641	0.741

Table 2. Discriminant Function Eigenvalues. The eigenvalues for Factors 1 and 2. For Factor 1, leaf litter loads heavily negative and transitions to underbrush. For factor 2, sticks load negatively and transitions to logs.

While releasing snakes, I noticed more cottonmouths seemed to choose the east bank over the west. To determine if they were choosing the east bank more, a chi-squared test was used with the capture site and retreat site data. The null hypothesis was there is no difference between the number of snakes choosing the east or west for capture and retreat sites. I expected that each bank would be chosen by 50% of the cottonmouths for release and capture sites. For the capture sites, the west bank was chosen four times and the east bank was chosen 12 times. For retreat sites, the west bank was chosen six times and the east bank was chosen 10 times. For capture site, $P < 0.05$ and X^2=4, so the null hypothesis was rejected. There is a statistical difference in how many times the east and west bank were chosen by the snake as a capture site. For retreat site, $P > 0.05$ and $X^2 = 1$, so the null hypothesis was accepted. There is no statistical difference between the number of times the east or west bank was chosen.

Because the snakes showed a slight preference for the east bank, a discriminant function analysis (IBM© SPSS) was used to determine possible differences between the west and east banks of Harmon Creek. The discriminate function explained 100% of the variation between creek banks (Figure 4) with the habitat variable grass being the most significant variable (P = 0.047) in the variation between creek banks. The habitat variable, branches was the only other variable that approached significance (P = 0.080). Sand has the heaviest loading for east banks (1.496) and rock (-0.130) loaded heaviest for west banks (Figure 4).

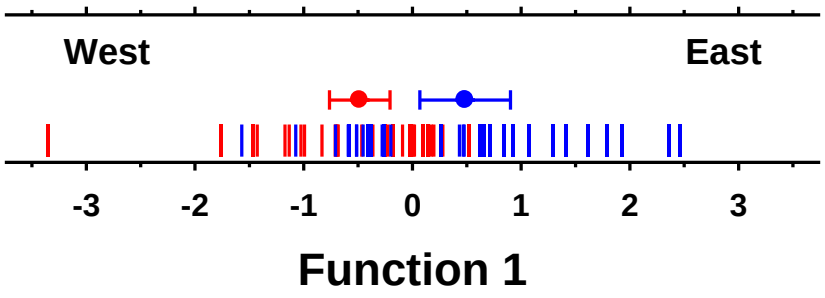

Figure 4. East and West Discriminant Function Analysis. Discriminant function analysis showing the difference between west and east creek banks with relation to habitat variable. The habitat variable that loaded heaviest were rock (-.130) transitioning to sand (1.496). of Function 1 For East and West Bank Comparison. Function 1 explains 100% of the variation between the east and west banks of Harmon Creek. The left most negative factor is rock, and the right most positive factor is sand.

CHAPTER IV

Discussion

Field Observations of Cottonmouth Occurrence

Prey availability and hunting behaviors likely have an impact on the hourly activity patterns of cottonmouth in Harmon Creek. They are known to be nocturnal foragers that rely on aquatic habitats for prey acquisition, with a diet primarily composed of frogs, fish, small mammals, and other snakes that are found in riparian or wetland habitats (Ford et. al. 2004, Vincent et. al. 2005, Lillywhite and Brischoux 2012). Cottonmouths were observed utilizing the creek and creek bank habitats between the hours of 2000 h and 0600 h. This may be the result of prey activity patterns or availability, particularly frogs (Eskew et. al. 2009). I observed that the frogs began calling each night between 2143 h and 2214 h. The first snakes of the night were also observed in either 2100 h or 2200 h, often within a few minutes of the frogs starting to call. Snake frequency declined after 0500 h and stopped entirely by 0700 h, which coincided with when frog calls ceased.

The hours of 2000 h and 0600 h are times when cottonmouths are likely moving from daytime refugia into foraging habitats in the creek. Of the whole observation period, only one snake was observed during the 2000 h and 0600 h transect walks. These individuals were farther up the bank, travelling into or out of Harmon Creek. Aside from these hours,20 cottonmouth activity and behavior within the creek is consistent.

As ambush predators, cottonmouths find a suitable habitat for prey acquisition, coil, and wait for a prey item to move within striking distance (Buning 1983). Snakes that were observed for two to four consecutive hours were always coiled, waiting to

ambush passing prey. These individuals likely moved upon prey encounter and capture. There is the potential that disturbances produced by observers may have also influenced movement from foraging sites, despite walking in the center of the creek to maintain distance from the snakes. One snake was startled by a passing observer, but the individual settled after the observers passed and remained in the same position during the next hourly walk.

Activity patterns might have also been affected by competition between cottonmouths and watersnakes. Of the few watersnakes observed, all were exhibiting active foraging behaviors by continuously moving up and down the creek. The erratic movements of watersnakes or competition for prey might result in cottonmouths moving to search for sites that are less active. During my observations in the creek, the cottonmouths and watersnakes seemed to avoid using the same habitat for prey acquisition. This might be due to competition for prey. Watersnakes moving erratically in an active search for prey might disturb anything that would wander by a waiting cottonmouth. This could also be predator avoidance by watersnakes, as cottonmouths have been known to prey upon them. Studies focusing on the competition between cottonmouths and watersnakes in overlapping habitat or foraging sites might reveal more about foraging site selection and fidelity.

Foraging and Refuge Habitat Selection

Habitats such as leaflitter, underbrush, and branches appear to be the most important to cottonmouths when choosing microhabitat sites. The habitats that appear to be least desirable are canes, sticks, rocks and roots. Dense leaflitter, underbrush, and branches would provide the most camouflage and hiding spots, especially when

compared to the other available habitat types such as sand, rocks, canes, or grasses. Capture sites were microhabitats that the snakes had chosen during their normal time of activity while foraging. Retreat sites were chosen by the snake looking for a place to hide upon release. Based on the habitat categories, the retreat habitat sites, snake microhabitat sites, and snake habitat sites were grouped together while the random habitat sites were statistically different. The grouped habitats had greater amounts of the preferable habitat types, such as underbrush and leaf litter. The random habitat sites had more grasses, canes, dirt, and roots: habitats that were shown in the analyses to be less preferred by the snakes. These types of habitat would not only provide less protection for a cottonmouth fleeing a perceived threat but would also be unsuitable foraging habitat. Habitats that have underbrush and branches would provide more coverage for a cottonmouth waiting to ambush prey, keeping the snake safe from its own predators.

Though most of the snakes chose preferred foraging and refuge sites, some individuals did not. One snake was captured in the middle of the creek, likely before choosing a foraging spot. Another individual did not choose a refuge site upon release but decided to sit in the middle of the creek. As a result, data from the two snakes were excluded from statistical analysis.

During the snake releases and analysis of the data set, I noticed that a greater number of snakes chose the east over the west bank for capture and refuge sites. To this end, I used ImageJ and a discriminate function analysis to quantify any differences between the habitats on the east and west banks of Harmon Creek that might drive a preference for the east bank.

When comparing habitat structure between east and west creek banks, rock loaded most negatively and transitioned to the most positively loaded factor, sand. Rock had the highest prevalence on the west bank, and although sand had the highest prevalence on the east bank, it was closely followed by underbrush, branches and grass. Rock was one of the habitats I found to be undesirable for cottonmouths as it was not prevalent in their chosen habitats. However, based on the same analysis, underbrush and branches are preferred habitats for foraging and refuge. The choice for the east bank is likely related to the higher availability of preferred habitats. Due to creek topography and canopy cover, one bank receives greater sun exposure. This variation might result in a higher frequency of vegetation in microhabitats found on the east creek banks.

When thinking about where the snakes are when captured, the higher prevalence of sand found on their preferred bank also makes sense. The snakes are often found on flat sandy patches within proximity of trees or underbrush. These sandy areas are sometimes small patches at the very edge of the bank or incorporated in an area that is composed of a small percentage of sand. They can sit and wait for prey to pass by in an area where prey species are most likely to do so, but they can still benefit from underbrush and tree branches that provide over coverage and protection for the snake. The habitats in the creek that reflect this topography may also act as a sort of drift fence for the snakes. Prey species that rely on, or are restricted to, the creek will naturally be moving past waiting cottonmouths. Whereas habitats in the creek only composed of sand or underbrush and branches, might only fill one of the snake's needs, food or protection. Easily acquired prey, as well as, foliage acting as protection from their own predators

would make these sites with sand, underbrush and branches the most beneficial habitat type.

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Education:

2017- Present — Sam Houston State University

Graduate student under Dr. William Lutterschmidt

Thesis: Foraging and Refuge Site Selection in the NorthernCottonmouth, *Agkistrodon piscivorous*

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TRIES Aquatics Lab

Assisted with field work and field identification on herpetological survey conducted at Camp Bowie

Assisted with insect identification and sorting to order and pinning for Camp Bowie and Eagle Mountain invertebrate survey

Assisted with mesocosm maintenance, assembly and project preparation at Center for Biological Field Studies

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Houston Galveston Area Council Clean Rivers Project (HGAC CRP)

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Assisted with research pertaining to *Pteronotropis hubbsi* and other fish species at Caddo Lake, Texas

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Classes Taught:

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Research Experience:

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Presentations:

Joint Meeting of Ichthyologists and Herpetologists (JMIH) 2019:

Poster presentation of "Variation of the Atlas- Axis Complex in Gekkota"

World Congress of Herpetology 9 (WCH9) 2020:

Oral presentation for "Variation of the Atlas- Axis Complex in Gekkota"

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Presented poster highlighting master's thesis research *Foraging Activity Time And Refuge Site Selection In The Northern Cottonmouth, Agkistrodon piscivorous*

Community Service & Outreach:

2017-2018 — 2018 SHSU Bioblitz

Herpetological sampling of Pineywoods Ecological Research Laboratory

Informed the public on the types of amphibians and reptiles found at the PERL and their importance

Set up and clean up

2018-2019 — 2019 SHSU Bioblitz

Herpetological sampling of the Pineywoods Ecological Research Laboratory (PERL)

Set up and Clean up at the PERL

Weird Science Night

Reaves Elementary, Conroe, Texas

Engaged in reptile education with school children and parents

Sam Houston State University Biolunch

Co-founder, speaker and discussion organizer

2018-2019 continued	Biological Sciences graduate student lunches to facilitate scientific discussion and thinking
	Habitat Restoration for the Red-Cockaded Woodpecker
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2019-2020	Sam Houston State University Biolunch
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Professional Societies:

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