ROAD DENSITY AS A PROXY FOR URBANIZATION EFFECTS ON *TRACHEMYS SCRIPTA ELEGANS* IN THE LOWER RIO GRANDE VALLEY

THESIS

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment of
the Requirements

for the Degree

Master of SCIENCE

by

Brian Erik Dickerson, B.S.

San Marcos, Texas
December, 2010

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Committee Members Approved:

Michael R. J. Forstner, Chair

Thomas R. Simpson

Clay Green

Todd Swannack

Approved:

J. Michael Willoughby
Dean of the Graduate College

ACKNOWLEDGMENTS

I primarily thank Donald Brown, a fellow graduate student whom recognized a pattern while conducting his Master's thesis that became the basis for my thesis. Much gratitude to my advisor Dr. Michael R. J. Forstner for pushing me past what I thought my limits were, "good for us". I would like to thank my committee members Dr. Thomas R. Simpson, Dr. Clay Green, and Dr. Todd Swannack for guiding me to completion. Thanks to Dr. James R. Dixon, Donald Brown, Amanda Schultz, Bei De Volld, and Joseph Flores whom helped me collect data in the heat of south Texas. I am grateful to Max Pons of the Lennox Southmost Preserve of the Texas Nature Conservancy for providing a field station and friendship. Appreciation goes to the following for allowing myself and others access to water bodies used in this study: U.S. Fish and Wildlife Service refuge system, various city officials, and private landowners. Thanks to Texas Parks and Wildlife for providing funding that allowed this project to take place. Most importantly, thanks to my wife Jennifer and son TJ for supporting me during my physical and mental absences while pursing this degree.

This manuscript was submitted on 19 October 2010.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

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SUPERVISING PROFESSOR: MICHAEL R. J. FORSTNER

Trachemys scripta elegans (red-eared slider) is one of many turtle species often encountered in our lakes and streams and seen crossing the roads of Texas. Turtles are regularly killed while attempting to travel across roadways (Ashley and Robinson 1996). The expansion of roadways in the United States has been linked with an increase in male biased turtle populations beginning as early as the 1930s (Gibbs and Steen 2005). The Lower Rio Grande Valley is an appropriate locality to currently examine this phenomenon since this region of Texas has and is currently experiencing extreme levels of urbanization. I conducted this study at 36 sites within three counties (Willacy, Cameron and Hidalgo) of the lower Rio Grande Valley; these three counties vary in their level of urbanization. I selected an even number of sites within each county with variable road densities (i.e. high, medium, or low) within a 1 km buffer of the trapping site. I sampled each site for 50 trap days (1 trap day = 1 trap in the water for 24 hours). I recorded morphological measurements including carapace length, carapace width, plastron length, plastron width, body depth, and mass. I analyzed urbanization effects by comparing capture rates and sex ratios among counties and among road density classes. I used single factor ANOVAs with mean carapace length and mean Fulton-type condition factor to detect changes in populations among road density classes. Differences in capture rates were not detected among counties or road density classes but sex ratios were significantly male biased in Cameron County and the high road density class. Single factor ANOVAs revealed that for both males and females mean carapace length was smallest in the high road density class and increased as road density class decreased. This result was significantly different in females between high and low road density classes. No differences in Fulton-type condition factors were detected among road density classes. I conclude that roads are contributing to changes in the population structure of wild *T. s. elegans*; however, I cannot simply attribute these changes to roads. Historically, high levels of market hunting of these animals and broad land use changes in this region are also likely contributing to these changes.

CHAPTER 1

INTRODUCTION

Urbanization is a familiar concept in today's society with concomitant growth of infrastructure following that of human populations. Roads are the ultimate manifestation of urbanization (Andrews and Jochimsen 2007). Adverse impacts of roads on wildlife are numerous. Cypher et al. (2009) lists these impacts to include direct mortality from vehicles, habitat fragmentation and loss, altered community structure and function, disturbance, exposure to contaminants, introductions of exotic species, and increased access by humans. Effects of these impacts generally go unnoticed until there are increasing levels of negative wildlife/human interactions (Finder et al. 1999, Gagnon et al. 2007) or in cases where species are already being monitored due to its threatened or endangered status (Cypher et al. 2009). Schwabe and Schuhmann (2002) estimate deer-vehicle collisions at 700,000 annually and rising. Forman (2000) estimates the total kilometers of public roads in the United States at 6.2 million and that 22% of the contiguous United States is ecologically altered by roads. Vertebrate mortality linked to road collisions is rising for many taxa (Forman and Alexander 1998). Most wildlife research funding is directed at large, rare, and endangered mammals, but herpetofauna vulnerability to road effects remains an area lacking in research (Coffin 2007).

Of the affects on wildlife listed by Cypher et al. (2009), roads and vehicles have direct and indirect effects on individuals, populations, and communities of herpetofauna through direct mortality, habitat loss, fragmentation, and ecosystem alterations (Andrews and Jochimsen 2007). Research indicates that herpetofauna populations decrease in areas of high road density (Rosen and Lowe 1994, Fahrig et al. 1995, Vos and Chardon 1998, Marchand et al. 2002, Boarman and Sazaki 2006, Langen et al. 2009). Connor et al. (2005) suggests that impacts of urbanization and development on turtle populations are significant. Multiple stressors on turtle populations as a result of urbanization include increased opportunities for harvest (either commercially for food or as a pet item), degradation of habitat, and direct mortality consequent of collisions with automobiles, commercial freight, and other traffic.

One of the more significant factors influencing turtle populations is direct mortality as a result of vehicles on roads (Ashley and Robinson 1996). Turtles may encounter roadways as they search for mates, nesting sites, or simply move between habitats (Buhlmann and Gibbons 2001, Szerlag and McRobert 2006). Ashley and Robinson (1996) noted that road mortality in turtles is common. Road mortality may bias the sex ratio in aquatic species due to the nesting behavior of females (Steen and Gibbs 2004, Aresco 2005b, Gibbs and Steen 2005). Sex ratios of turtle populations have been reported to vary both within and among species (Ernst and Lovich 2009). The adult sex ratio is an important metric of demography because of influences each sex can have on population dynamics (Gibbons 1990). Therefore, accurate sex ratios must be established in order to infer trends in population growth. Four factors can influence the sex ratio in a population: (1) sex ratio at birth, (2) differential mortality of the sexes, (3) differential migration, and (4) age at first reproduction (Gibbons 1990). Among the hypotheses postulated for biased sex ratios, differential mortality between sexes is thought to have increased over recent years due to human-mediated mortality on roadways (Gibbs and Shriver 2002; Gibbs and Steen 2005). Adult female turtles are thought to be more vulnerable to road mortality due to an increase in terrestrial movements during the nesting season (Steen and Gibbs 2004). This may lead to population declines as turtle populations are at risk when there is a decrease in reproductive adults (Brooks et al. 1991).

Trachemys s. elegans, described in 1839 (Ernst and Lovich 2009), is a medium to large freshwater species commonly found in Texas. As the world's most widespread turtle species (Ernst and Lovich 2009), this turtle is thought of as a habitat generalist utilizing many types of water bodies including: rivers, ditches, lakes, ponds, or sloughs (Morreale and Gibbons 1986). Gibbons and Coker (1977) noted that *T. s. elegans* could be found in or near salt marches while Gibbons (1990) noted that *T. s. elegans* thrived in polluted waters giving further evidence for the vigor of this species. *Trachemys s. elegans* is a foraging generalist. This feeding strategy along with the ability to move between habitats terrestrially gives it an advantage over other turtle species (Morreale et al. 1984, Parker 1984).

Trachemys s. elegans is active every month of the year in its southern range (Bancroft et al. 1983) with females being most active during the nesting season between May and July (Ernst and Lovich 2009). Females of the species can travel over land up to

1.6 km to find suitable nesting habitat (Cagle 1950) while males have been known to travel up to 3.5 km (Morreale et al. 1984). Ingold and Patterson (1988) indicated that most captures in Texas take place between May and September. Bancroft et al. (1983) found that *T. s. elegans* could be caught throughout the day. These characteristics make this an ideal species to test the effects of urbanization using road densities as a proxy.

As a small non-game group of animals, turtles receive little funding for research but their life history characteristics indicate a particular vulnerability to urbanization and associated infrastructure. Though turtles are a long-lived taxa, life history characteristics such as late sexual maturity results in an inability of these animals to cope with high rates of adult mortality (Brooks et al. 1991). Previous research has shown that road mortality affected female turtles more than males (Gibbs and Steen 2005). If *T. s. elegans* females are experiencing higher mortalities on roadways, then this might lead to a decline in turtle populations due to lower recruitment because females are more susceptible to road mortality due to their search for nesting sites (Steen et al. 2006). Also, females may be finding suitable nesting sites next to roadways resulting in more hatchling mortality (Congdon et al. 1983, Steen et al. 2006). Further, female *T. s. elegans* mature later than males and this delayed sexual maturity may add to the effects that roads have on population structure (Steen et al. 2006). Brown (2008) replicated a 1977 study of turtles in the Lower Rio Grande Valley (LRGV) and found more males than females in some sites and also noted the potential for a relationship between sex ratios and distances to roads.

CHAPTER II

STUDY AREA

The Lower Rio Grande Valley represents a unique opportunity to test the effects of urbanization on turtles. The LRGV increased in human population by 119 percent from 1981 to 2007 (U.S. Census Bureau 1992, 2008) (Table 1, Fig. 1). The result of this increase is urbanization and more roads. The LRGV is in extreme south Texas within the boundaries of Willacy, Hidalgo, and Cameron counties (Fig. 2). The study area is unique in that it offers an element of data depth in the form of a turtle survey conducted Grosmaire (1977) with replications of that trapping effort conducted in both 2008 (Brown) and 2010 (Schultz). The county with the smallest level of urbanization was Willacy with a 1981 population of 17,495 which increased to 20,513 in 2007 for an overall increase of 17%. Cameron County had an overall increase of 85% from 1981 to 2007 while Hidalgo County had a 151% increase (U.S. Census Bureau 1992, 2008) (Table 1, Fig. 1). Trapping took place at 12 locations in each county, totaling 36 discrete locations throughout the LRGV (Fig. 2).

Table 1. Human population increase among the 3 counties sampled in the Lower Rio Grande Valley (U.S. Census Bureau 1992, 2008).

Year		County	
	Hidalgo	Cameron	Willacy
1981	283,323	209,727	17,495
2007	710,514	387,210	20,513
% increase	151%	85%	17%

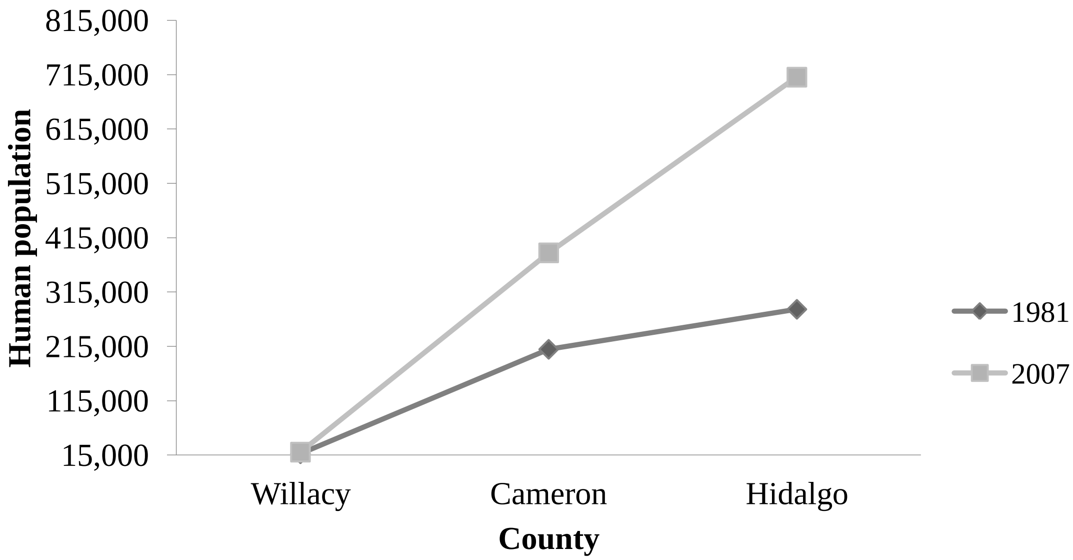


Figure 1. Human population increase among the 3 counties sampled in the Lower Rio Grande Valley (U.S. Census Bureau 1992, 2008).

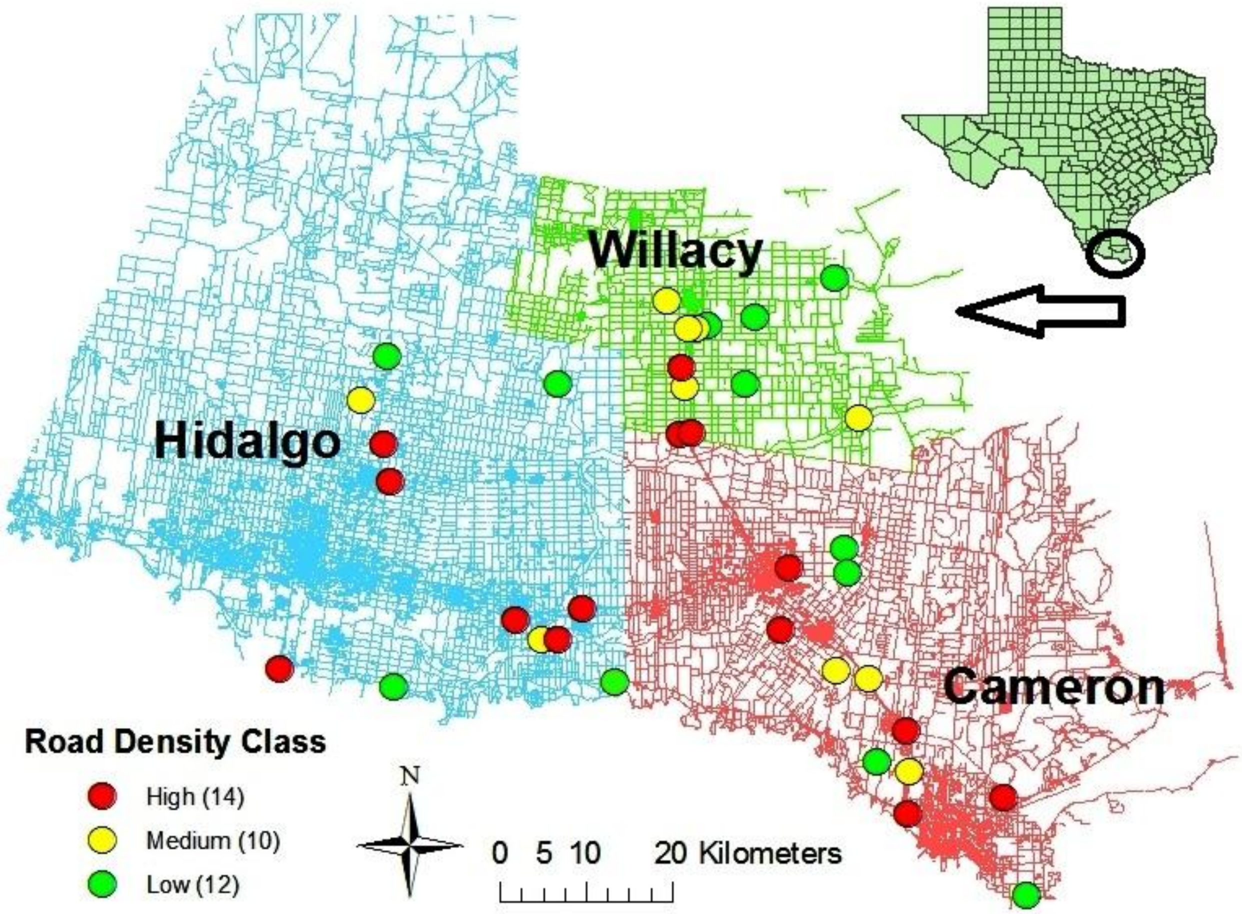


Figure 2. Three counties in the Lower Rio Grande Valley of Texas included in study of urbanization effects using road density as a proxy. Points on map indicate trapping locations (12 locations within each county for 36 total sites). Points in red, yellow, and green indicate road density class of high, medium, and low respectively.

CHAPTER III

METHODS AND MATERIALS

Site Selection

The purpose of my study was to determine the effects of urbanization on *T. s. elegans* in the LRGV using road densities as a proxy. I selected a total of 36 sites within 3 counties (Willacy, Cameron, and Hidalgo) (Fig. 2) using various methods such as county level water body layers in ArcGIS 9.3.1 (ESRI, Redlands, CA), state road maps, and ground truthing. Sites were selected based on ability to access the site. Once a potential site was found to be suitable for trapping, I classified each of 12 sites within a county according to road density: high, medium, or low. I determined road density classifications by buffering the water body with a 1 km buffer using Arc GIS 9.3.1 (Table 4). The total kilometers of roads within that buffer was used to designate the site as high (>11km), medium (6km – 11km), or low (<6km). Each county in the study was originally designed to have an even number (4) of sites classified as high, medium, and low road density. Road segment lengths were calculated manually and placed into corresponding road density classes (Table 4). This resulted in Hidalgo County having a high (6), medium (2), and low (4) road density distribution shift while Cameron County became high (5), medium (3), low (4) and the Willacy County distribution became high

(3), medium (5), low (4) (Table 2, 3). The distribution of the road density classes is depicted in red (high), yellow (medium), and green (low) (Fig. 2). All sites were similar to those of Brown (2008) in Cameron, Hidalgo, and Willacy counties with the addition of new sites (Tables 2, 3).

Table 2. Trap site locations arranged by county and road density classification.

County	Coordinates*	Road Density Class	Water Body Type	Public/Private
Cameron	N25.94081 W097.53367	High	Pond	Public
Cameron	N26.19973 W097.66992	High	Canal	Public
Cameron	N26.02798 W097.53451	High	Lake	Public
Cameron	N25.95721 W097.42191	High	Pond	Private
Cameron	N26.13431 W097.68015	High	Resaca	Private
Cameron	N25.98525 W097.53091	Medium	Pond	Private
Cameron	N26.09206 W097.61568	Medium	Lake	Private
Cameron	N26.08031 W097.58646	Medium	Pond	Private
Cameron	N25.85400 W097.39600	Low	Resaca	Private
Cameron	N26.19527 W097.60181	Low	River	Public
Cameron	N25.97581 W097.56631	Low	Resaca	Private
Cameron	N26.22029 W097.60605	Low	Reservoir	Public
Willacy	N26.34240 W097.78249	High	Reservoir	Public
Willacy	N26.41082 W097.79362	High	Reservoir	Private
Willacy	N26.34016 W097.79479	High	Reservoir	Private
Willacy	N26.45274 W097.78563	Medium	Pond	Private
Willacy	N26.38979 W097.79706	Medium	Canal	Public
Willacy	N26.48132 W097.80981	Medium	Canal	Public
Willacy	N26.45281 W097.77656	Medium	Pond	Public
Willacy	N26.35752 W097.58618	Medium	Canal	Public
Willacy	N26.45585 W097.76262	Low	Pond	Private
Willacy	N26.50422 W097.61408	Low	Pond	Public
Willacy	N26.39359 W097.71994	Low	Canal	Public
Willacy	N26.46308 W097.70819	Low	Pond	Private
Hidalgo	N26.14711 W097.98901	High	Pond	Private
Hidalgo	N26.12569 W097.93893	High	Lake	Private
Hidalgo	N26.15823 W097.91043	High	Canal	Private
Hidalgo	N26.29287 W098.13384	High	Pond	Private
Hidalgo	N26.33105 W098.14077	High	Reservoir	Private
Hidalgo	N26.09688 W098.26227	High	Reservoir	Private
Hidalgo	N26.12626 W097.95634	Medium	Pond	Private
Hidalgo	N26.08143 W097.87392	Medium	Pond	Private
Hidalgo	N26.39495 W097.93847	Low	Canal	Private
Hidalgo	N26.37959 W098.17015	Low	Canal	Public
Hidalgo	N26.07771 W098.13068	Low	Lake	Private
Hidalgo	N26.42475 W098.13612	Low	Pond	Private

*Coordinates in decimal degrees, WGS 84 datum

Table 3. Site labels with corresponding names of sites.

County	Site Label*	Site Name
Cameron	C-H-1	Ruben Torres Jr./Laredo St.
Cameron	C-H-2	Olmito Lake
Cameron	C-H-3	Susan St. Canal
Cameron	C-H-4	Nicols Resaca
Cameron	C-H-5	FedEx Pond
Cameron	C-M-1	Los Ebanos Preserve
Cameron	C-M-2	TPWD Fish Hatchery
Cameron	C-M-3	Cam 2 Valenzuela
Cameron	C-L-1	Resaca De La Palma State Park
Cameron	C-L-2	Site 3, Arroyo Colorado at Cemetary
Cameron	C-L-3	Southmost, Resaca
Cameron	C-L-4	Abbott Reservoir
Willacy	W-H-1	Lyford Reservoir
Willacy	W-H-2	Sebastian Water Pit
Willacy	W-H-3	Sebastian Reservoir
Willacy	W-M-1	BUS 77 Canal
Willacy	W-M-2	Tire Pond
Willacy	W-M-3	Retention Pond
Willacy	W-M-4	Willamar Canal 2
Willacy	W-M-5	Raymondville Canal
Willacy	W-L-1	Frank Quintero Laguna
Willacy	W-L-2	Site 20 Canal
Willacy	W-L-3	Site 11 Pond
Willacy	W-L-4	Rep Site 9
Hidalgo	H-H-1	Mercedes Canal
Hidalgo	H-H-2	Frontera Audubon
Hidalgo	H-H-3	Hidalgo Irrigation District No. 1 Reservoir
Hidalgo	H-H-4	Edinburg Scenic Wetlands
Hidalgo	H-H-5	Llano Grande Lake Park
Hidalgo	H-H-6	Old Hidalgo Pumphouse
Hidalgo	H-M-1	Estero Llano Grande State Park
Hidalgo	H-M-2	Lake Edinburg Canal
Hidalgo	H-L-1	Santa Maria Ranch
Hidalgo	H-L-2	Delta Lake Canal
Hidalgo	H-L-3	Santa Maria LRGV NWR
Hidalgo	H-L-4	Santa Ana NWR, Pintail Lake

*Site labels indicate county, road density classification, and site number (Ex. C-H-1 is Cameron county, High road density, and the first of *x* sites in that county within that particular road density classification).

Table 4. Summation of road segment lengths within 1 km buffer of trap sites.

COUNTY	FID	SITE	SUM_SEG_LE	SUM_SEG_LE*
Cameron	8	Ruben Torres Jr./Laredo St.	35.03	31.23
Cameron	6	Olmito Lake	33.75	27.55
Cameron	1	Susan St. Canal	26.54	23.29
Cameron	3	Nicols Resaca	24.55	21.91
Cameron	9	FedEx Pond	20.49	18.62
Cameron	5	Los Ebanos Preserve	12.02	9.11
Cameron	4	Cam 2 Valenzuela	10.23	6.86
Cameron	7	TPWD Fish Hatchery	8.17	7.28
Cameron	11	Resaca De La Palma State Park	8.08	5.11
Cameron	10	Southmost, Resaca	6.26	3.99
Cameron	2	Site 3, Arroyo Colorado at Cemetary	6.16	4.97
Cameron	0	Abbott Reservoir	3.87	2.83
Willacy	3	Lyford Reservoir	20.59	18.49
Willacy	1	Sebastian Water Pit	16.51	13.16
Willacy	9	BUS 77 Canal	14.03	9.93
Willacy	2	Sebastian Reservoir	12.47	11.41
Willacy	0	Tire Pond	11.50	9.11
Willacy	5	Retention Pond	11.01	8.12
Willacy	11	Willamar Canal 2	10.15	7.08
Willacy	8	Raymondville Canal	8.38	6.21
Willacy	4	Frank Quintero Laguna	7.42	5.16
Willacy	10	Site 20 Canal	5.75	3.93
Willacy	6	Site 11 Pond	4.67	3.02
Willacy	7	Rep Site 9	3.07	2.43
Hidalgo	6	Mercedes Canal	27.12	25.28
Hidalgo	5	Frontera Audubon	23.34	21.69
Hidalgo	3	Hidalgo Irrigation District No. 1 Reservoir	18.76	15.52
Hidalgo	4	Edinburg Scenic Wetlands	16.57	14.37
Hidalgo	8	Llano Grande Lake Park	13.73	11.48
Hidalgo	10	Old Hidalgo Pumphouse	12.00	11.23
Hidalgo	7	Estero Llano Grande State Park	10.64	9.52
Hidalgo	2	Delta Lake Canal	7.96	5.61
Hidalgo	0	Santa Maria Ranch	7.58	5.67
Hidalgo	1	Lake Edinburg Canal	7.24	6.22
Hidalgo	9	Santa Maria LRGV NWR	7.23	4.79
Hidalgo	11	Santa Ana NWR, Pintail Lake	5.63	4.16

*SUM_SEG_LE (Summary segment length) value after manual removal of road segments protruding outside of 1 km buffer

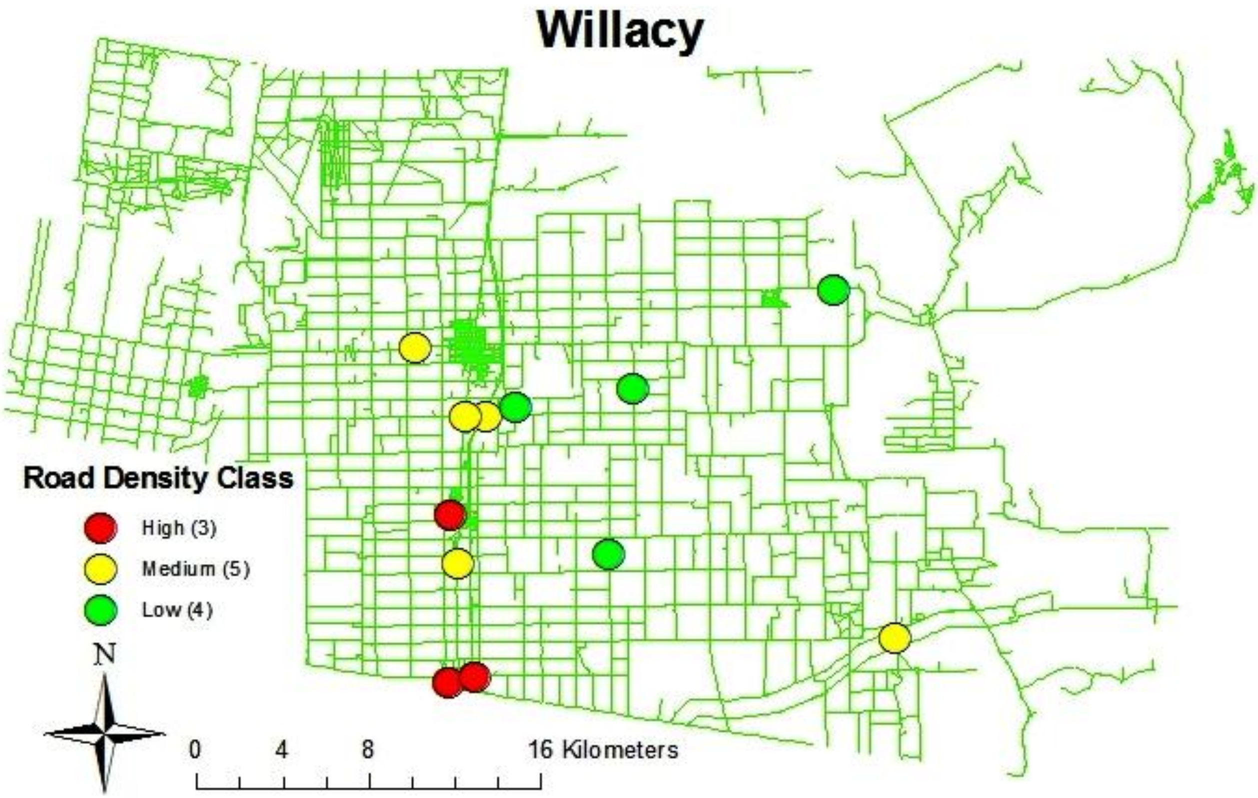


Figure 3. Map of Willacy county displaying road layer and 12 trapping locations. Sites are at least 1 km in distance from one another. This county has limited water bodies causing some sites to be clustered. Distribution of road density classes trapped in this county were uneven due to final calculation of road densities within 1 km buffer.

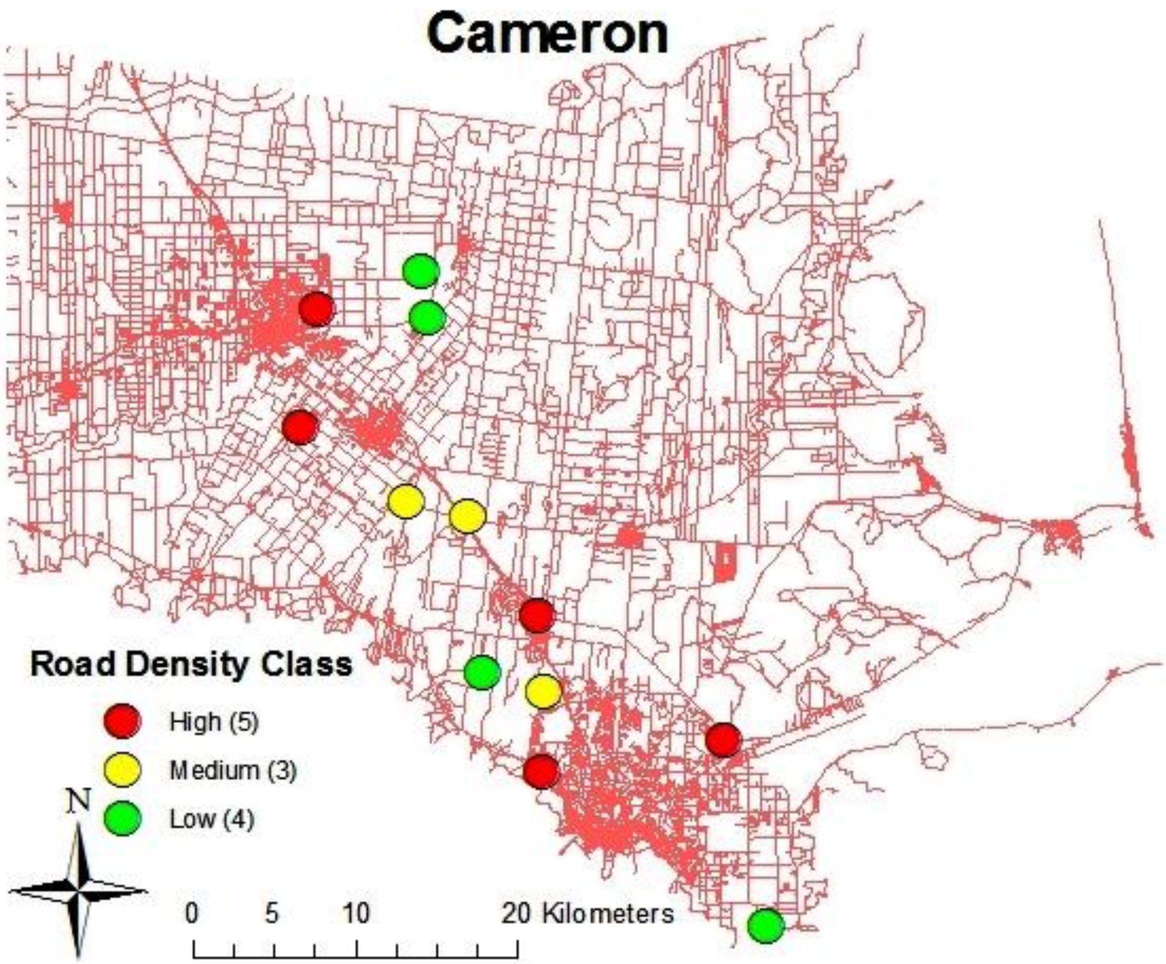


Figure 4. Map of Cameron County displaying road layer and 12 trapping locations. Distribution of road density classes trapped in this county were uneven due to final calculation of road densities within 1 km buffer.

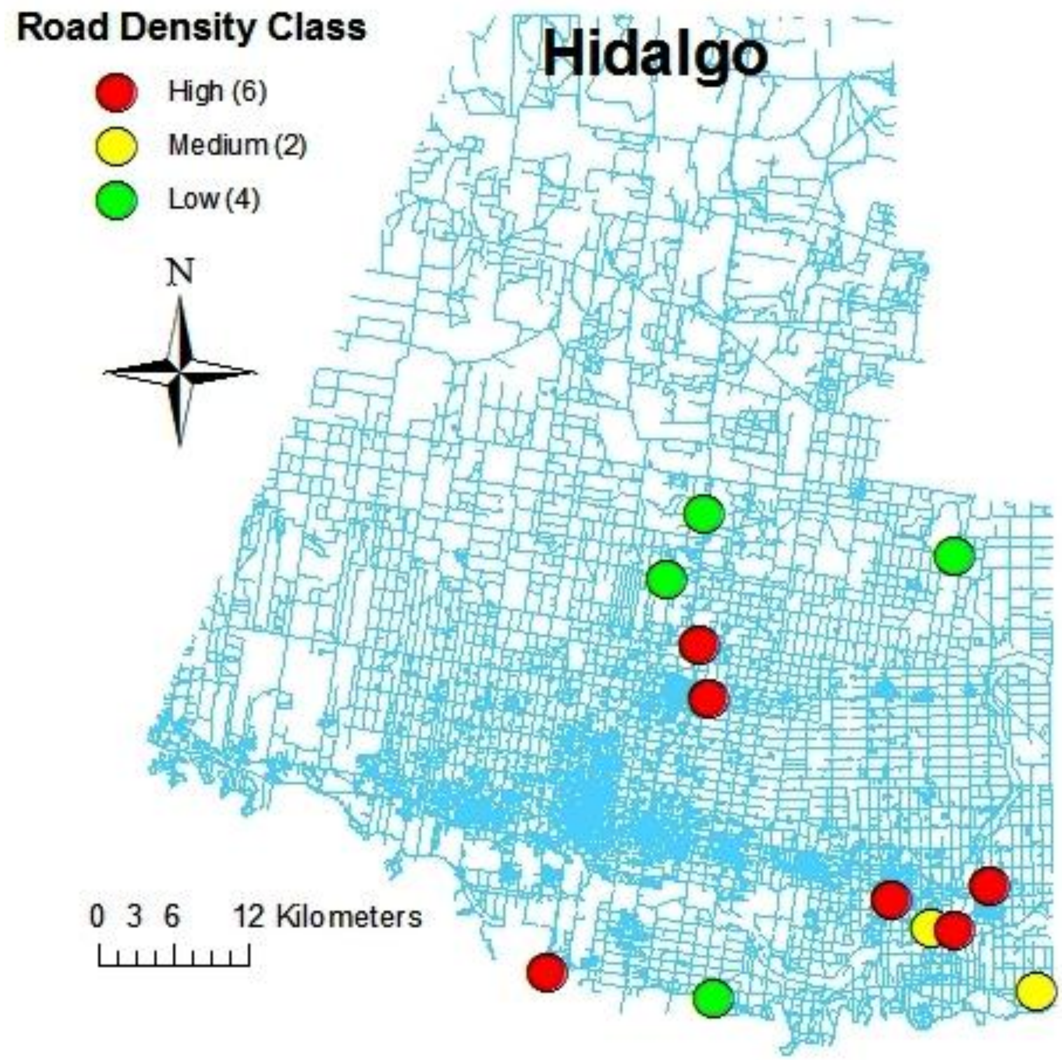


Figure 5. Map of Hidalgo County displaying road layer and 12 trapping locations. Distribution of sites in Hidalgo County were primarily in the southeast of the county due to the saline properties of the water bodies in the north end of the county. Sites were uneven due to final calculation of road densities within 1 km buffer.

Collecting

I trapped turtles using 76.2cm diameter hoop nets. I baited the hoop nets using sardines, squid, shrimp, or fresh fish with fish oil added. I placed bait in containers with drilled holes to attract turtles without allowing them to consume the bait. Bait was replaced after 48 hours. The number of traps used per site varied in order to achieve a minimum objective of 50 trap days per site (e.g., 50 traps over 24 hours equals 50 trap days or 25 traps over 48 hours equals 50 trap days). I recorded additional data such as incidental road mortalities or turtles found alive on roadways.

For each turtle, I recorded sex, carapace length, carapace width, plastron length, plastron width, body depth, and weight. I collected data for all turtle species captured, but I analyzed only *T. s. elegans* data for this project. I gave each turtle a unique code by notching the carapace (Cagle 1939) in order to avoid duplication of data and to facilitate mark recapture studies in the future (Fig. 6). I determined sex using secondary sexual characteristics such as elongated, curved fore claws and an anal opening on the tail which extends past the edge of the carapace for adult males; adult females lack these characteristics (Ernst and Lovich 2009). When secondary sexual characteristics were absent then it was labeled a juvenile. I took length, width, and body depth measurements using Haglof® tree calipers accurate to within 1.0 mm (Haglof, Madison, MS) and weight measurements using Pesola® precision scales accurate to 20 g (Pesola, Baar, Switzerland). I marked individuals by notching the outer scutes of the carapace according to a numbering system (Cagle 1939) using a Dremel® (Dremel, Racine, Wisconsin).

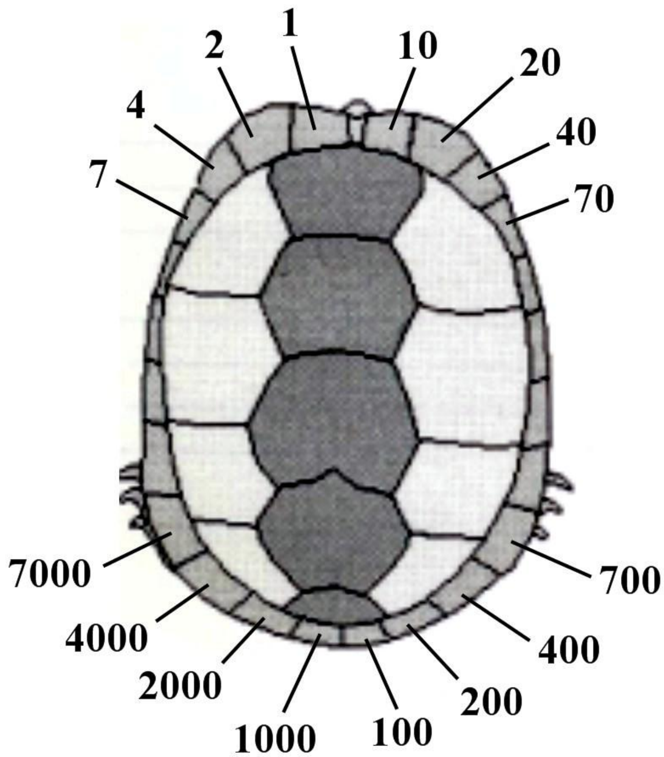


Figure 6. Illustration demonstrating the numbering system on the marginal scutes of the carapace. Ex. A *T. s. elegans* marked 211 would have a notch at 200, 10, and 1.

Statistical Analyses

I tested for the effects of urbanization on populations using single factor analysis of variance (ANOVA). I used nested Type “III” ANOVA to determine differences based on road densities within counties. Tests were conducted by sex using adult size classes as defined by Gibbons and Lovich (1990).

Response variables included mean carapace lengths and mean Fulton-type condition factors for respective counties or road density classes. Gibbons and Lovich (1990) described the carapace length as representing the total length of an individual turtle and being highly correlated with plastron (lower section of turtle shell) length. I determined Fulton-type condition factors using the following formula: $K = (W/L^3) * 100{,}000$ (Anderson and Neumann 1996). Fulton-type condition factors represent the health of populations in this case for a given county or road density class with a higher factor being a healthier population. The Fulton-type condition factor is commonly used in the fisheries science to provide a measure of health or well-being of fish when comparing groups (Anderson and Neumann 1996). I apply it here to compare groups of turtles. I used R version 2.10.1 software (The R Foundation for Statistical Computing, Vienna, Austria) for all ANOVA statistical analyses. I examined residual plots to verify assumptions of normality and homoscedasticity (Sokal and Rohlf 2003). I further analyzed significant factors with Tukey's Honestly Significant Difference multiple comparison procedure to determine which treatment means differed significantly.

I compared sex ratios using a chi-square goodness of fit test between road density classes and between counties using Excel® 2007 (Microsoft, Redmond, WA). I assumed parity as the expected ratios though Ernst and Lovich (2009) stated that most well-studied populations of *T. s. elegans* are male biased in some fashion. Aresco (2005a) and Gibbons (1990) both showed that *T. s. elegans* populations exhibited mean male-biased sex ratios. Interestingly, Rose and Manning (1996) studied a group of *T. s. elegans* in Texas ponds in which a 2:1 female to male ratio was observed.

I analyzed capture rates for adult *T. s. elegans* using mean capture rates among road density classes and among counties. I determined a ratio of capture-per-unit-effort by dividing the number of adult captures at a site by the total number of trap days (50). I then averaged these ratios for their respective road density class or county for a mean capture rate comparison via ANOVA in Excel® 2007.

CHAPTER IV

RESULTS

Trapping Effort

Capture rates by road density classification. – I conducted a total of 700 trap-days at 14 high density road sites, 500 trap-days at 10 medium road density sites, and 600 trap days at 12 low road density sites. The lowest mean capture rate of 0.11 was recorded at high road density sites. Mean capture rate was 0.14 for both medium and low road density sites (Fig. 7). There was not a difference in capture rate among road density classes ($F_{2,33} = 0.25$, $P = 0.78$).

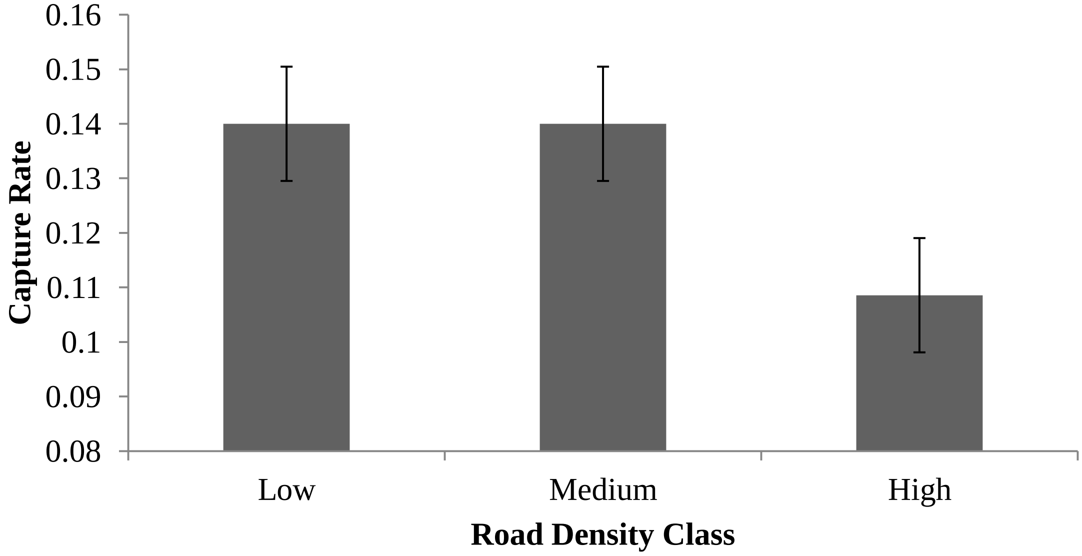


Figure 7. Mean capture rate by road density classification.

Capture rates by county. – Total captures for the study including all counties was 230 (102 F, 128 M) (Table 5). Hidalgo County had the least amount of captures at 38 (18 F, 20 M). Cameron County had 85 (30 F, 55 M) captures. Willacy County had the most successful capture rate of the 3 counties with 107 (54 F, 53 M) total captures . These captures resulted in the following average capture rates for Hidalgo, Cameron, and Willacy counties respectively: 0.06, 0.14, and 0.18 (Fig. 8). There was a nearly significant difference among capture rates at the county level ($F_{2,33}$ = 2.78, P = 0.077).

Table 5. Results from 50 trap days per location totaling 1,800 trap days with the number of *T. s. elegans* by county in Texas and road density classification.

County	Site	#*T. s. elegans* (adults)		
		F	M	Total
Cameron	C-H-1	9	9	18
Cameron	C-H-2	5	7	12
Cameron	C-H-3	0	1	1
Cameron	C-H-4	2	6	8
Cameron	C-H-5	1	3	4
Cameron	C-M-1	0	5	5
Cameron	C-M-2	2	7	9
Cameron	C-M-3	2	11	13
Cameron	C-L-1	1	3	4
Cameron	C-L-2	2	0	2
Cameron	C-L-3	5	2	7
Cameron	C-L-4	1	1	2
Willacy	W-H-1	4	5	9
Willacy	W-H-2	0	0	0
Willacy	W-H-3	0	0	0
Willacy	W-M-1	5	7	12
Willacy	W-M-2	3	3	6
Willacy	W-M-3	12	2	14
Willacy	W-M-4	3	1	4
Willacy	W-M-5	0	2	2
Willacy	W-L-1	2	7	9
Willacy	W-L-2	4	3	7
Willacy	W-L-3	4	7	11
Willacy	W-L-4	17	16	33
Hidalgo	H-H-1	0	2	2
Hidalgo	H-H-2	3	2	5
Hidalgo	H-H-3	1	0	1
Hidalgo	H-H-4	2	4	6
Hidalgo	H-H-5	3	5	8
Hidalgo	H-H-6	0	2	2
Hidalgo	H-M-1	2	1	3
Hidalgo	H-M-2	2	0	2
Hidalgo	H-L-1	0	3	3
Hidalgo	H-L-2	5	1	6
Hidalgo	H-L-3	0	0	0
Hidalgo	H-L-4	0	0	0
Total	**36 sites**	**102**	**128**	**230**

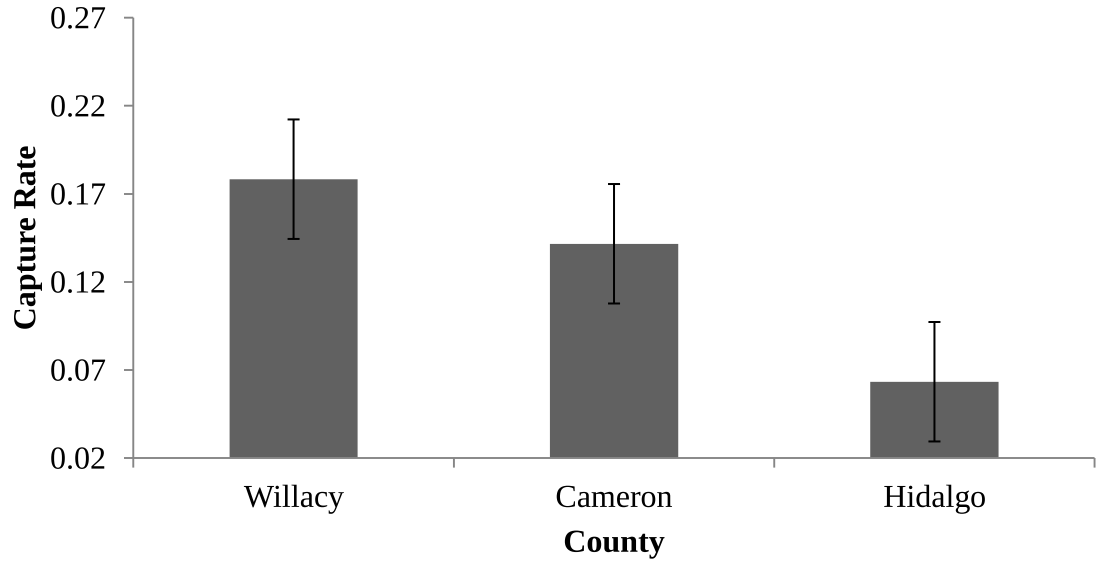


Figure 8. Mean capture rate by County.

Sex Ratios

Sex ratio by road density classification. – Sex ratios were also analyzed for the 3 road density classes. Interestingly, the road density classes trended from greatest male biased populations in the high category while decreasing to a 1:1 sex ratio in the low category. The high category had a significantly male biased population with 46 males and 30 females producing a 1.5:1 male to female sex ratio (x^2_1 = 4.84, P = 0.028) (Fig. 9). There were 39 males and 31 females in the medium category giving a 1.3:1 male to female sex ratio (x^2_1 = 1.44, P = 0.23) (Fig.9). There were 43 males and 41 females in the low road density category resulting in a 1:1 sex ratio to which no test for differences was needed (Fig. 9).

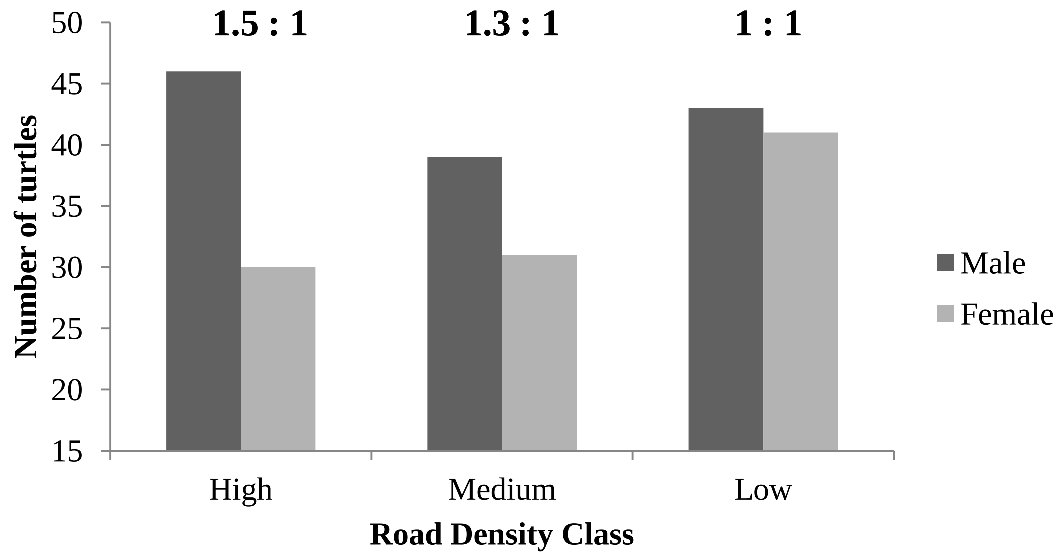


Figure 9. Sex ratio by road density class.

Sex ratio by county. – Sex ratios were examined by comparing the observed ratio to a 1:1 male to female ratio in a chi-square goodness of fit test. In Hidalgo County there were 20 males and 18 females giving a 1.1:1 male to female ratio (x^2_1 = 0.36, P = 0.55) (Fig. 10). Cameron County had a significantly male biased population of 55 males and 30 females giving a 1.8:1 male to female sex ratio (x^2_1 = 9.0, P = 0.0027) (Fig. 10). Willacy County produced a sex ratio closest to the expected with 53 males and 54 females resulting in a 1:1 male to female sex ratio to which a chi-square test was not necessary (Fig. 10).

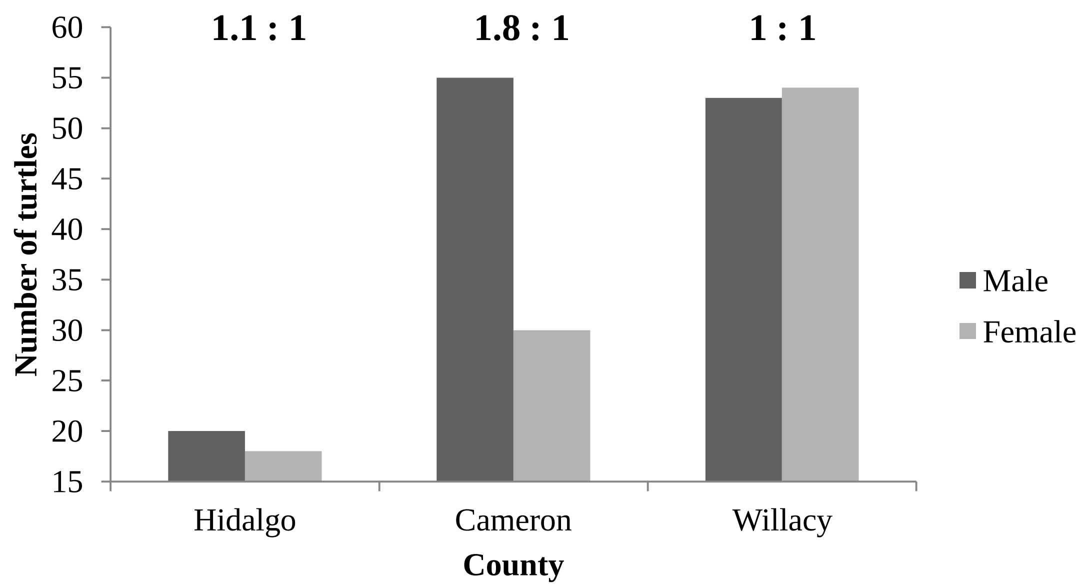


Figure 10. Sex ratio by County.

ANOVAs

Carapace length as a response variable in a single factor ANOVA. – The mean carapace lengths for males in high, medium, and low road density classes were 157.8, 162.1, and 167.5 respectively (Fig. 11). The mean carapace lengths for females were 209.5, 217.8, and 226.8 respectively (Fig. 12).

There were significant differences in mean female carapace length based on road density class ($F_{2,94}$ = 5.18, P = 0.007) (Fig. 12). Tukey's Honestly Significant Difference multiple comparison tests revealed that the significant difference was between high and low road density classes. There were no differences in mean male carapace length based on road density class ($F_{2,123}$ = 1.04, P = 0.36) (Fig. 11). Despite this, it is interesting to note that the average male carapace length in the high road density class was smallest and progressively became larger as road density class decreased.

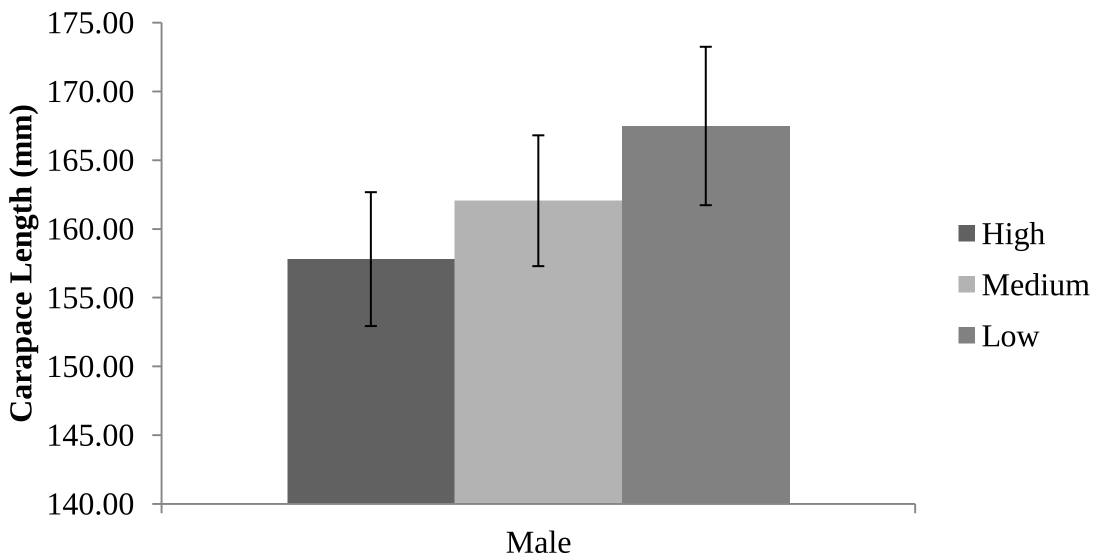


Figure 11. Mean carapace length (mm) for males among road density classification.

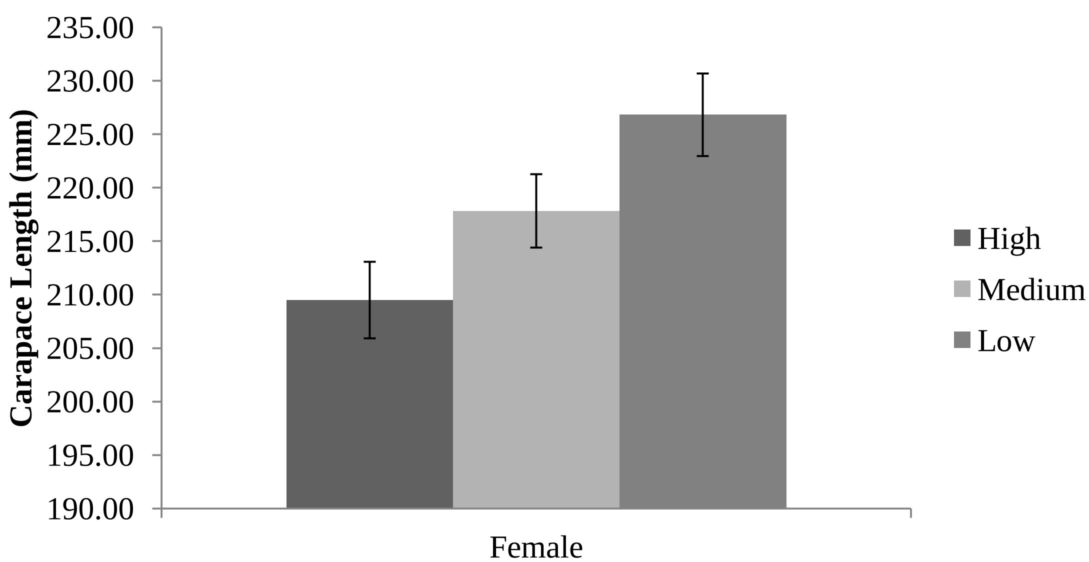


Figure 12. Mean carapace length (mm) for females among road density classification.

Carapace length as a response variable in a single factor type "III" nested ANOVA. – Given the differences in urbanization rates of the 3 counties in the study area (Table 1, Fig. 1), I wanted to test for differences in mean carapace length among road densities within respective counties. Significant differences were found for mean carapace lengths in females ($F_{6,114}$ = 4.88, P = 0.0002) and males ($F_{6,117}$ = 3.40, P = 0.004).

Fulton-type condition factors as a response variable in a single factor ANOVA. – The mean body condition score for males in high, medium, and low road density classes were 13.72, 13.84, and 13.86 respectively (Fig. 14). The mean body condition score for females were 14.67, 15.18, and 14.6 respectively (Fig. 13).

There were no significant differences in mean female body condition score based on road density class ($F_{2,91}$ = 2.20, P = 0.12) (Fig. 13). There were no differences in mean male body condition score based on road density class ($F_{2,121}$ = 0.15, P = 0.86) (Fig. 14). Despite this result it is interesting to note that the average male body condition score in the high road density class was smallest and progressively became larger as road density class decreased.

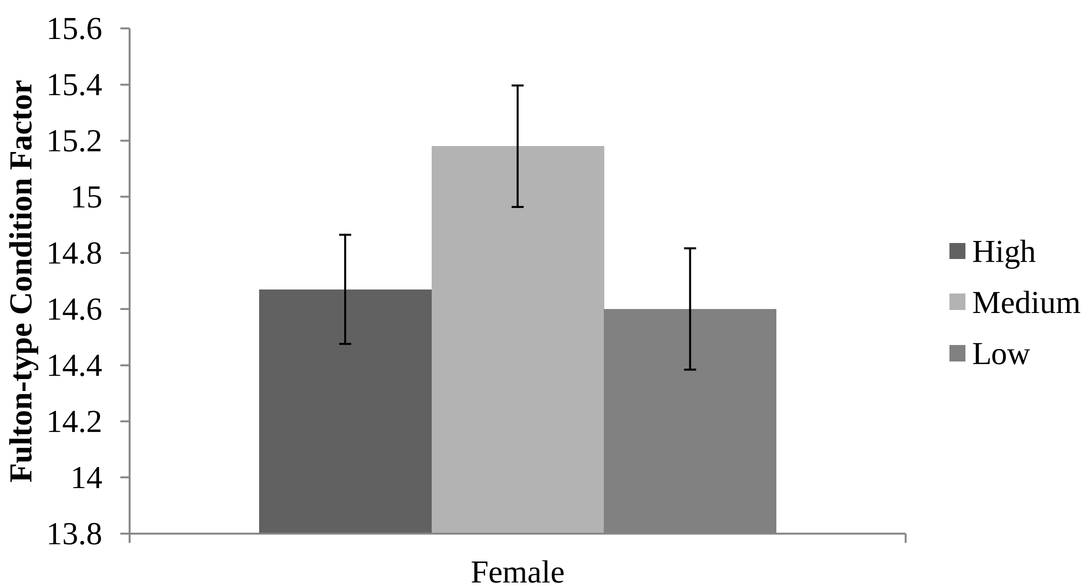


Figure 13. Mean Fulton-type condition factors for female *T. s. elegans* among road density classes.

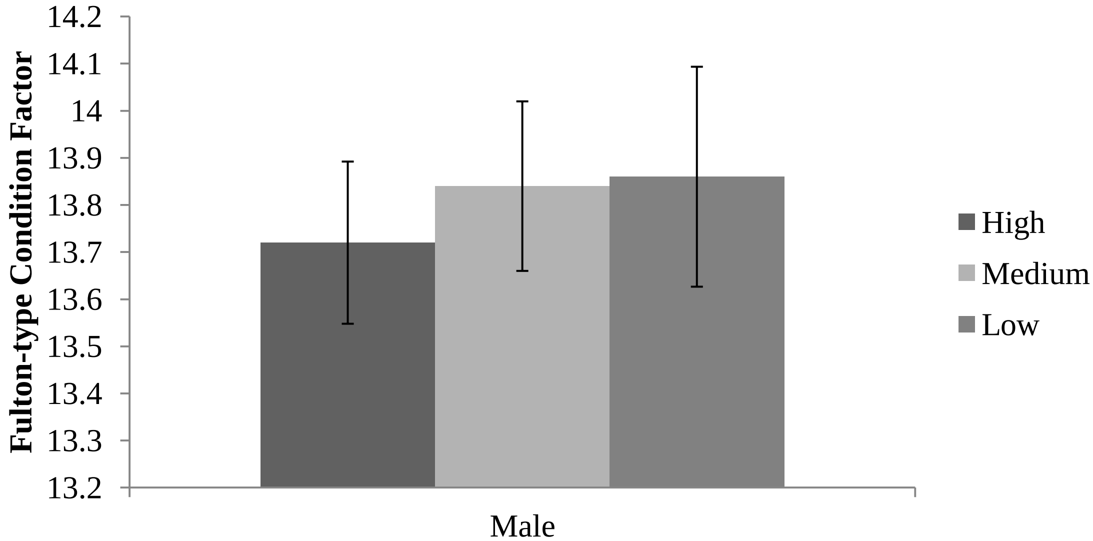


Figure 14. Mean Fulton-type condition factors for male *T. s. elegans* among road density classes.

Fulton-type condition factors as a response variable in a single factor type "III" nested ANOVA. – For similar reasons for comparing mean carapace lengths of turtle populations among road density classes within a county, I also examined mean body condition score. No significant differences were found for mean carapace lengths in females ($F_{6,85}$ = 1.89, P = 0.09) or males ($F_{6,115}$ = 1.68, P = 0.13).

CHAPTER V

DISCUSSION

In this study roads were used as a proxy for urbanization in order to determine if the lower capture rates for freshwater turtles in Hidalgo County, Texas (Brown 2008 and Schultz 2010) were a result of urbanization. The 3 counties making up the study area are within what is known as the Lower Rio Grande Valley in Texas. This area provided a unique scenario in which a baseline turtle trapping data set (Grosmaire 1977) was repeated three decades later (Brown 2008, Schultz 2010). These follow up studies both concluded that urbanization may be the cause of lower capture success they observed in the most heavily urbanized areas. Currently, studies examining the trends of urbanization and its impact on wildlife (particularly herpetofauna) are seldom reported. However, this study afforded me the opportunity to test for urbanization impacts on turtles with the advantage of a recent comparison across 30 years in which urbanization was concluded to be the reason for differences in overall turtle capture rates (Brown 2008, Schultz 2010).

In my study design, geopolitical boundaries were ignored and trapping sites were selected based entirely upon relative road density. Thus, even within the rural Willacy County, heavily urbanized sites were located to assess capture rates based purely on urbanization status, not spatial location within a given county. While prior assessments

(Brown 2008, Schultz 2010) concluded urbanization was the most likely explanation for lower capture rates in the now heavily urbanized Hidalgo County, the capture rates among the road density classes were not statistically different. A qualitative trend was apparent in which the low and medium road density classes had similar capture rates while the high road density class show decreased capture rates. The county with the highest level of population increase (Hidalgo) of 151% (U.S. Census Bureau 1992, 2008) (Table 1) had the lowest capture rate and overall capture rates were inversely proportional to that county's population increase. Cameron County had an 85% increase when comparing U.S. Census data (U.S. Census Bureau 1992, 2008) (Table 1) with a higher capture rate than Hidalgo, while Willacy County had only a 17% increase in population (U.S. Census Bureau 1992, 2008) (Table 1) and the greatest capture success. While not significant statistically, this result may indicate a decrease in overall turtle abundance as human populations increase.

Sex ratios were also compared within road density classes and counties. Sex ratios were significantly ($x^2_1 = 4.84$, $P = 0.028$) (Fig. 9) male-biased in the high road density class (1.5:1) and less biased as road density decreased. Among the road density classes, the total number of captures for each class was comparable, which indicates a difference in testing by geographic proximity and road density. This difference indicates that geographic proximity and road density can be independent. The significant difference in sex ratio for the high road density class may be a result of sex-specific behavior. Congdon et al. (1983) noted that females favor nesting in disturbed areas such as road banks while Gibbons (1990) suggests that adult females travel terrestrially further than males.

If, alternatively, the sex ratios are tested by county region, rather than by road density class the results are quite different. For example, despite high urbanization, the sex ratio in Hidalgo County was not significantly different from parity. Cameron County had a significantly male biased sex ratio of 1.8:1 while Willacy County had a 1:1 sex ratio. While the method of capture using hoop nets has been suggested as being a male-biased capture method (Ream and Ream 1966, Gibbons 1990, Thomas et al. 1999), it is also the most effective method of capture (Gibbons 1990). Brown et al. (in press) further suggests that the hoop nets may produce male-biased results due to the ability of females to escape from the traps. There were 85 captures in Cameron County and 107 in Willacy County yet there was a significantly male-biased population in Cameron and an equal sex ratio in Willacy. The male-biased populations may be due to increases in additive mortality to adult female *T. s. elegans* as they migrate to find nesting sites.

I used mean carapace length as a response variable in a single factor ANOVA and detected significant differences for adult females between road density classes. The difference between mean carapace length for female turtles was significant among road density classes and negatively correlated with mean road density. When conducting the same test for males I did not detect a significant difference but the pattern of shortest mean carapace length to longest was expressed from high to low road density classes.

Mean carapace length was also used in an ANOVA in which the road density classes were nested within the counties in order to determine if differences existed on a county level due to the varying levels of urbanization among the counties. The results for both females and males in these analyses revealed significant differences. However, a Tukey's HSD showed that these differences were between the counties in the test and not between the road density classes within counties. Brown (2008) and Schultz (2010) detected similar results in comparable analyses.

Additionally, I sought to determine if urbanization effects could be playing a role in the health or well-being of the turtles. I used the Fulton-type condition factor that is widely used in fisheries management. This body condition score corrects for size effects inherent in the ratio between weight and length of a species (Ney 1999). For inferences to be made among groups, one must compare groups of similar size. This was done by analyzing by sex and using adult size classes. These tests detected no significant differences in body condition among road density class for either sex or for road density class within a county. These results confirm that *T. s. elegans* are considered habitat generalist when compared with other turtle species (Gibbons 1990) and could be exhibiting a certain level of resilience with respect to body condition. Gibbons (1990) also notes that *T. s. elegans* not only survive but actually thrive in polluted waters.

This study was explicitly designed to test for urbanization effects on turtles via road densities. However these data suggest that urbanization is not responsible for the decrease in captures observed over the last 30 years. The statistically significant difference in capture rates could potentially be linked to anthropogenic harvest. Thus, the results here appear to represent evidence for impacts of the numerically large harvest occurring (78 percent of reported turtle harvest came from Hidalgo, Cameron, and Lamar counties in 1999) (Ceballos and Fitzgerald 2004) in these areas.

Conservation Implications

This study sought to detect differences in various parameters of turtle populations in extreme south Texas relevant to the levels of urbanization as implied by relative road densities. Trends were detected by analyses but statistical differences were found only for adult females when comparing the areas of highest road densities with the areas of lowest road densities. These negative results conflict with results by Brown (2008) and Schultz (2010) who suggested that lower capture success in their studies may be attributed to urbanization. This outcome may indicate that known turtle harvest levels (Ceballos and Fitzgerald 2004) in this area are the actual cause for the decrease in capture success.

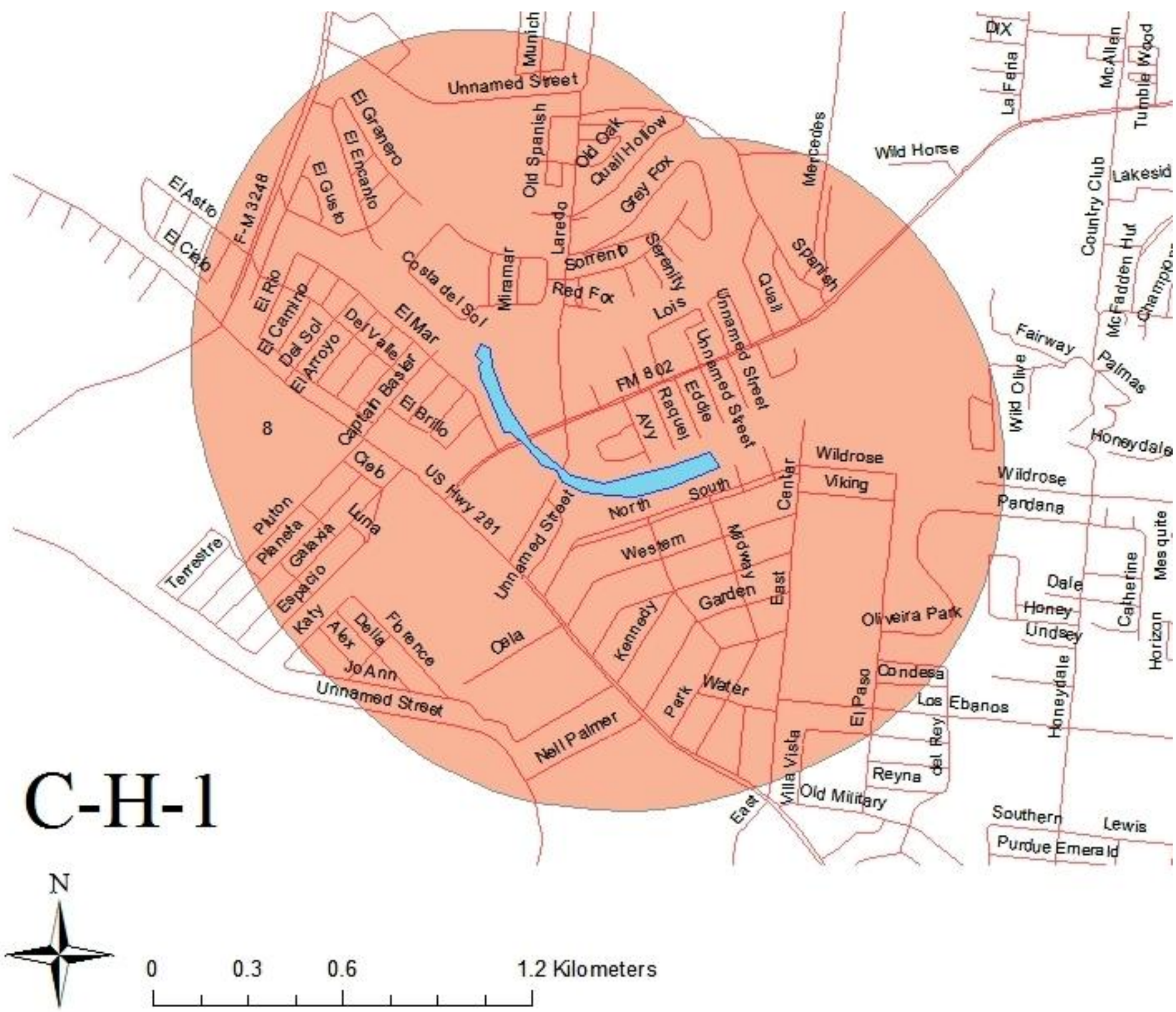
These data indicate that urbanization may be affecting adult female *T. s. elegans* population in the more heavily urbanized areas of the Lower Rio Grande Valley. It seems intuitive that as road densities increase the possibility of a turtle being struck by a vehicle, picked up as a pet item, or predated as a result of anthropogenically-supported predator populations will increase as well. Trends in the data suggest that larger individuals of both sexes may be affected by road densities; this effect is magnified for females who cover further distances and have greater cause for terrestrial movements.

This study will contribute to other research looking at reported high levels of commercial harvest of turtles (Ceballos and Fitzgerald 2004). Brown (2008) and Schultz (2010) conducted research to compare turtle populations to a turtle survey study conducted by Grosmaire (1977) to determine if harvest effects were detectable. They were not able to detect differences directly related to harvest but Brown (2008) attributed some differences to urbanization. Research has indicated that additive mortality as low as 1% to 5% in adult turtles is enough to produce negative effects on population growth (Doroff and Keith 1990, Congdon et al. 1993, 1994). This study detected that larger female turtles are being affected by urbanization. This may be due to increased road mortality, harvest effects, subsidized predator effects, or increased opportunity to take turtles as a pet. Marchand and Litvaitis (2004) state that areas with increased road densities alter the structure of turtle populations. These effects have been shown to be significant for females which travel terrestrially more often than males (Gibbons 1990). These data suggest that there may be a need for stricter harvest regulations in areas of high human populations. For example, the state of Florida banned the commercial harvest and sale of wild freshwater turtles after July 20, 2009 (as prescribed in FWC Rule 68A-25.002). I also suggest a more proactive education of the public on the movements of turtles as road mortality is a major threat. These two management activities will help ensure a viable turtle community for the future.

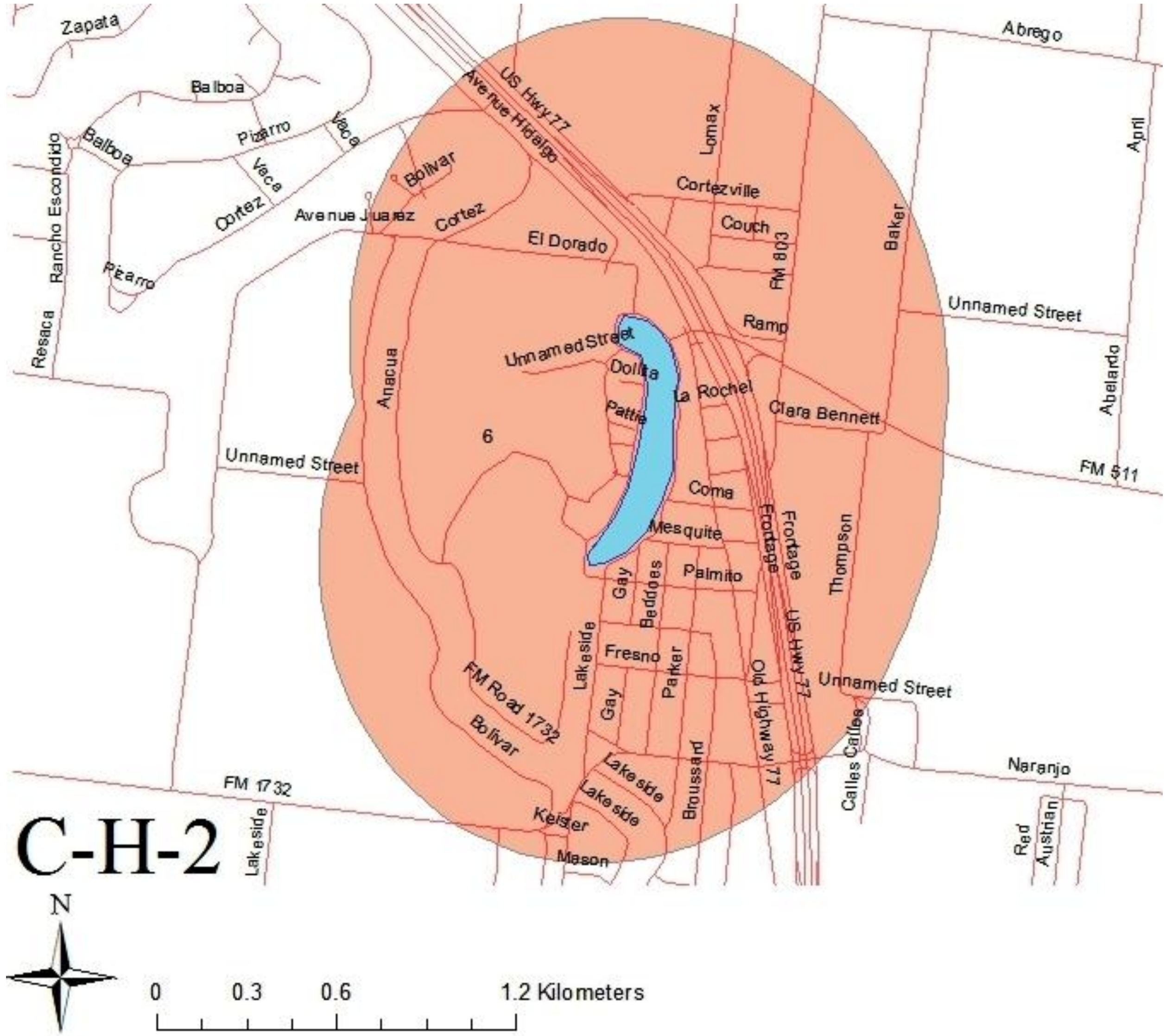
APPENDIX A: SITE LOCATION MAPS

Maps are presented using site labels in order by county, road density classification, and summary segment length (Tables 2,3,4).

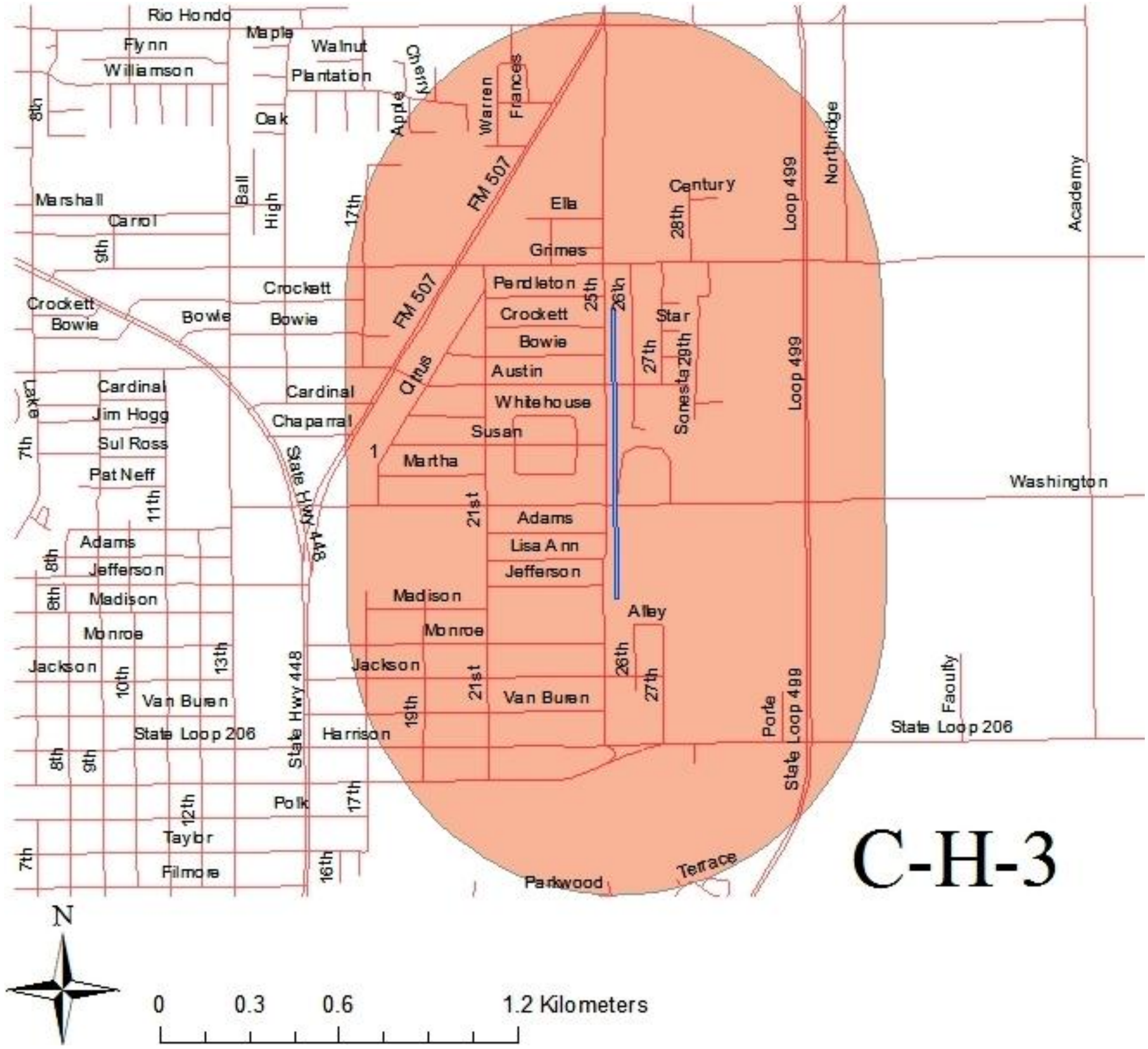
C-H-1: N25.94081 W097.53367, Total road segment within 1km buffer = 31.23



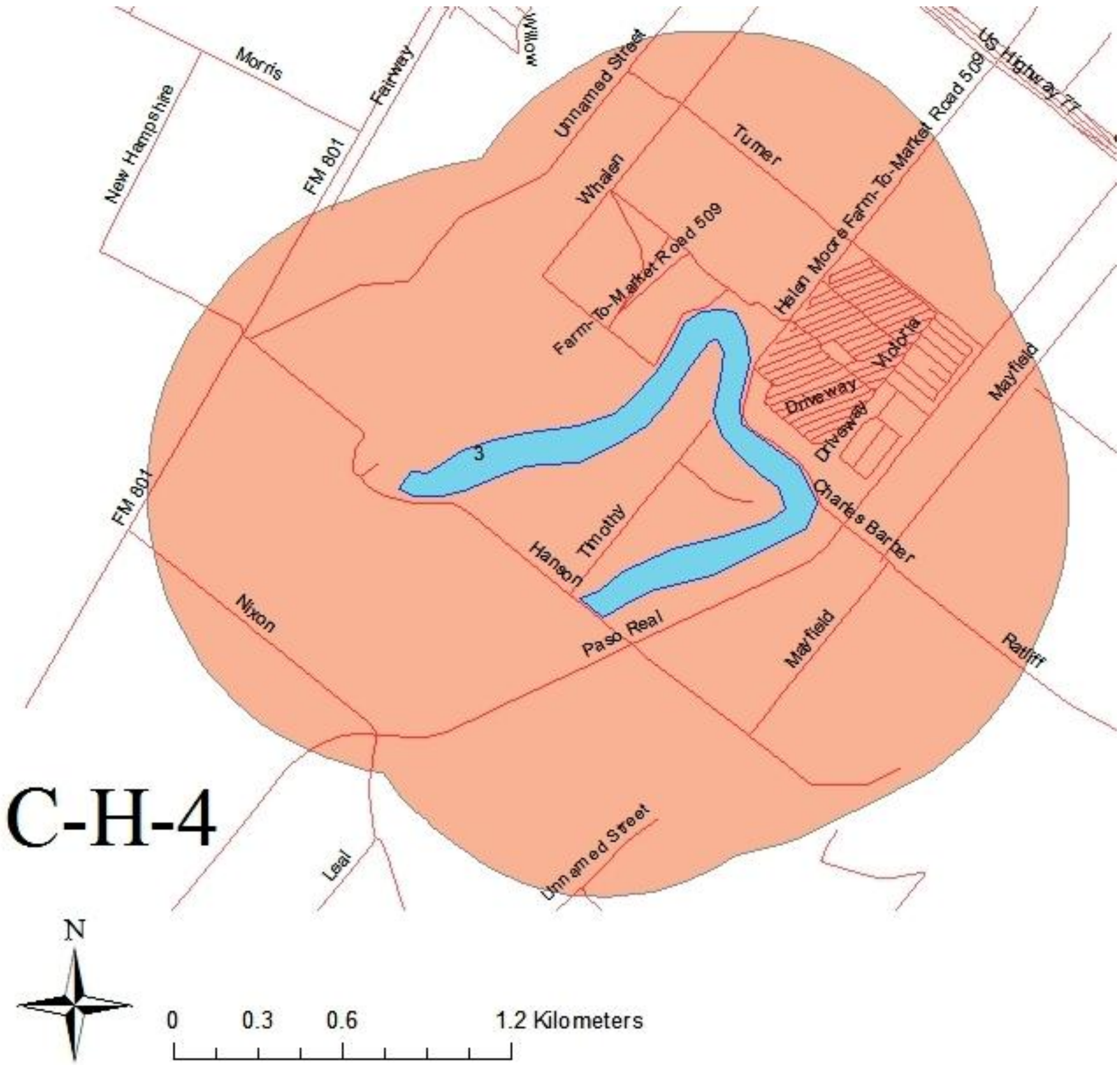
C-H-2: N26.19973 W097.66992, Total road segment within 1km buffer = 27.55



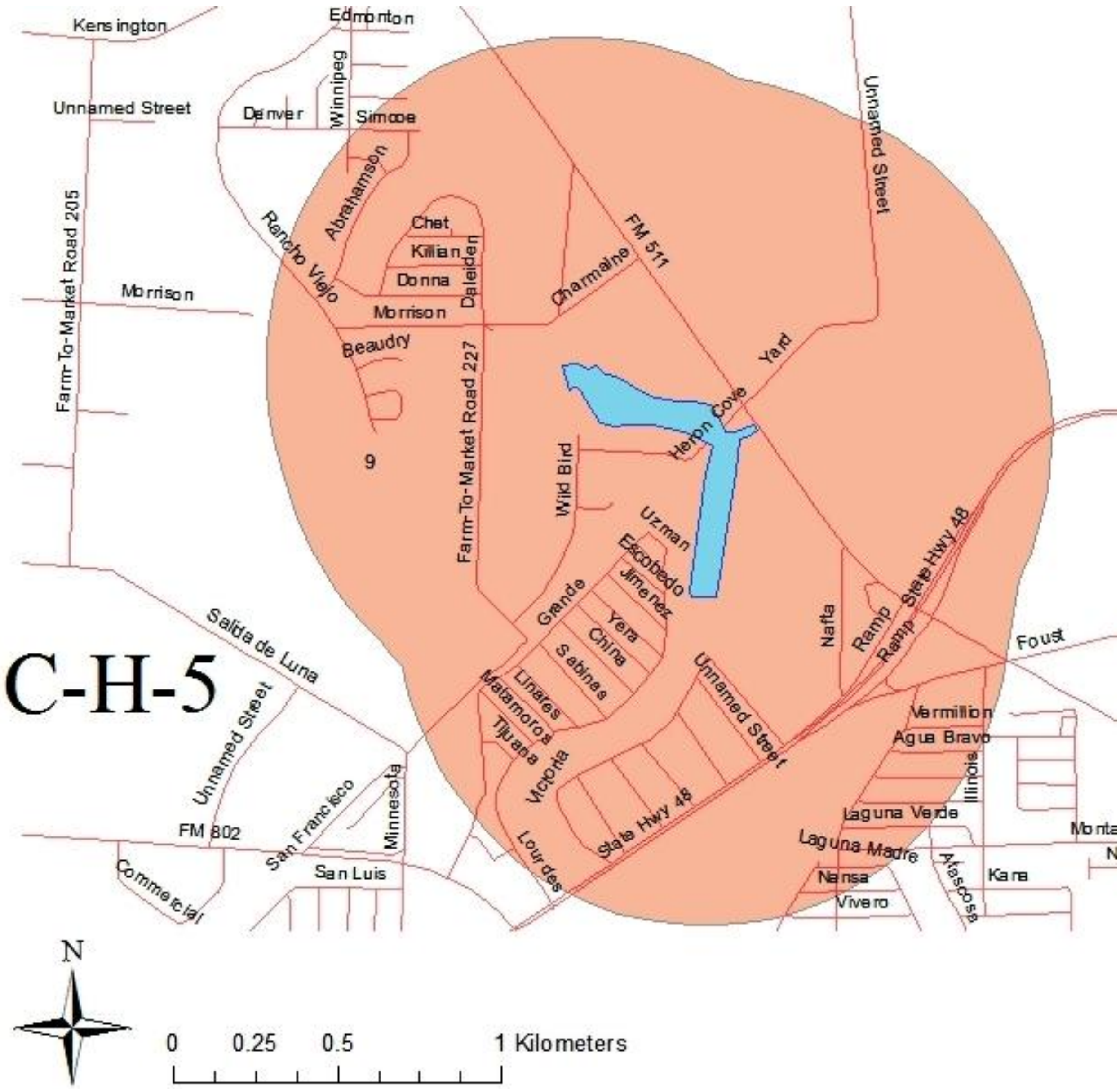
C-H-3: N26.02798 W097.53451, Total road segment within 1km buffer = 23.29



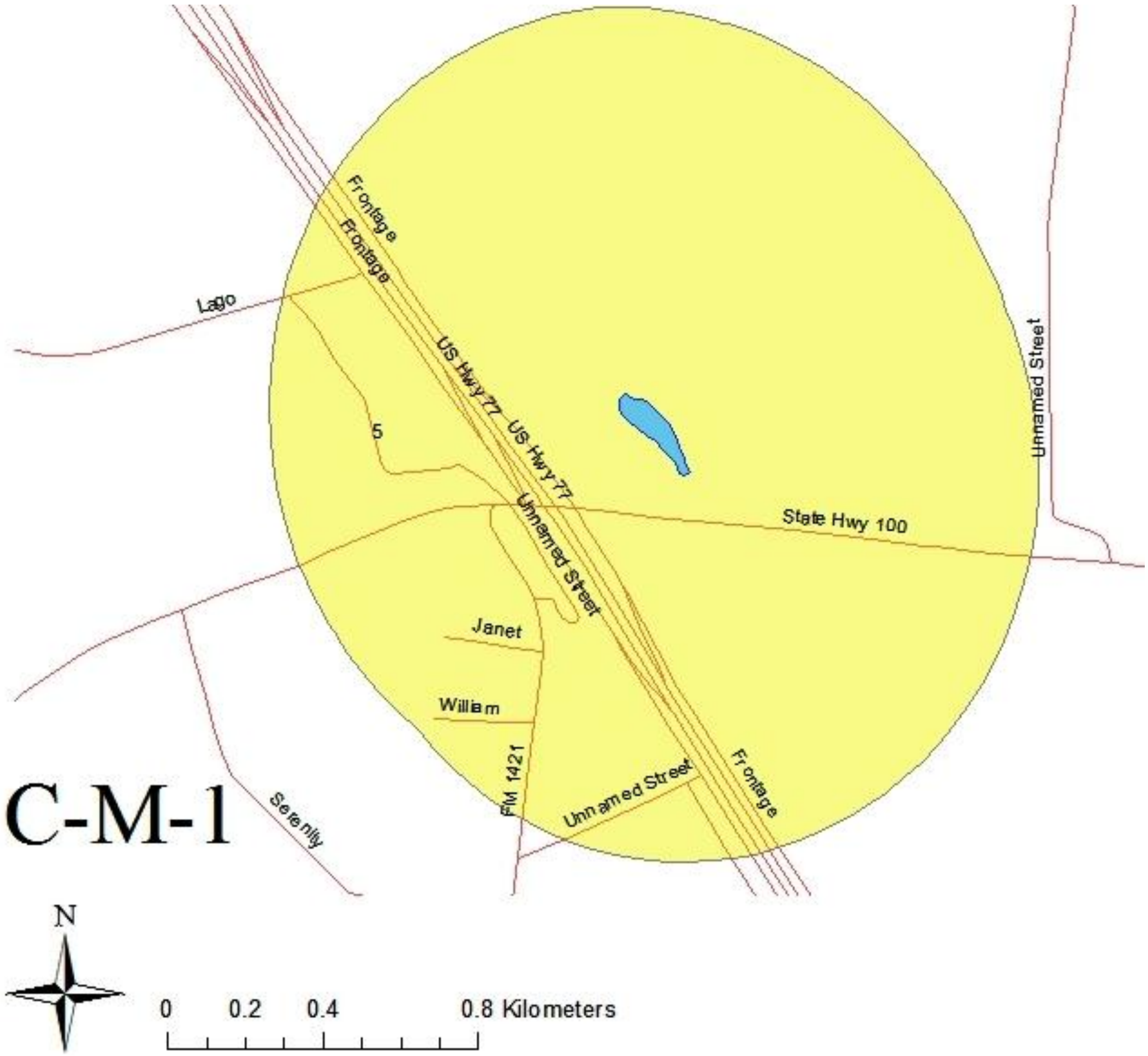
C-H-4: N25.95721 W097.42191, Total road segment within 1km buffer = 21.91



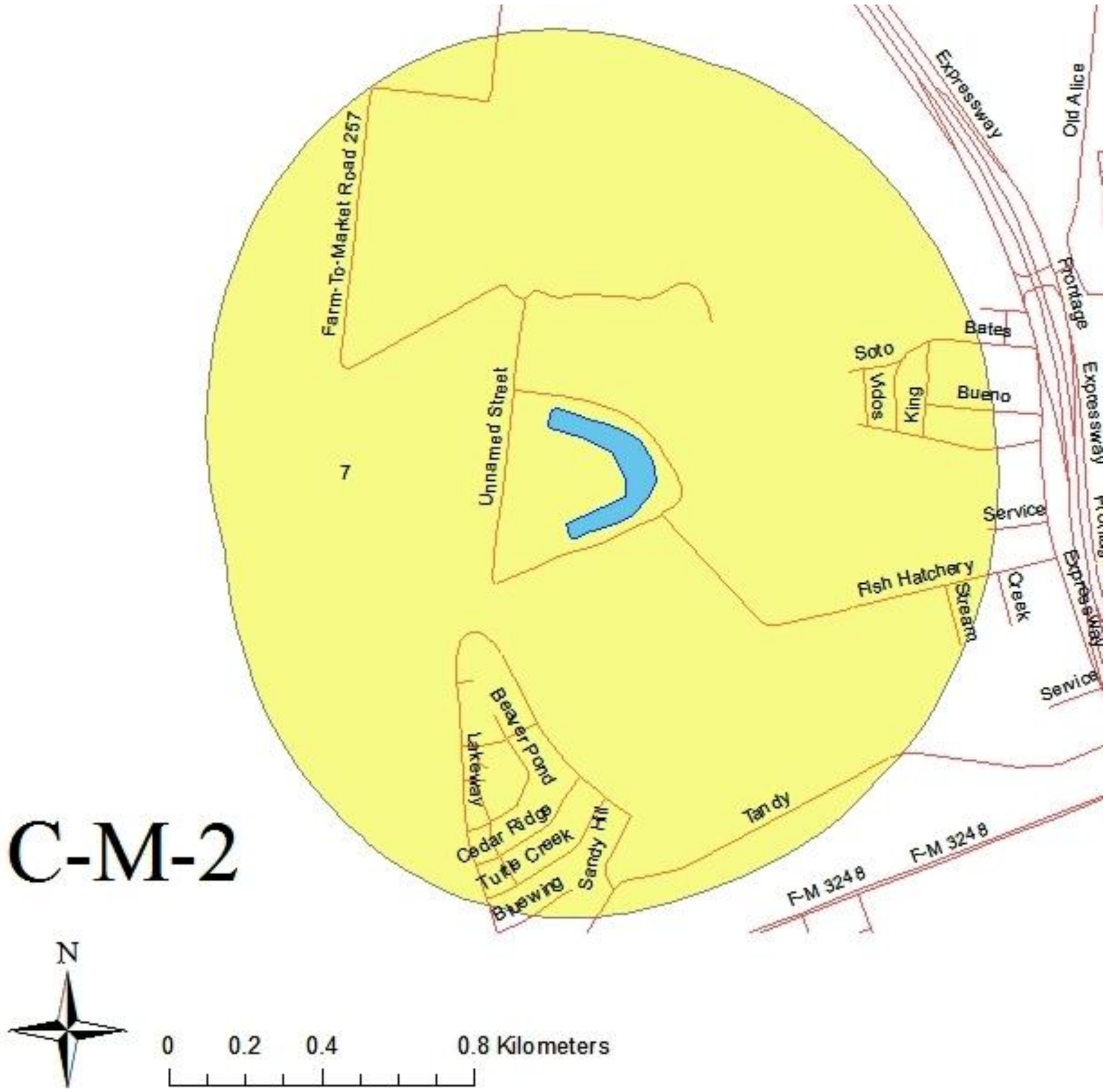
C-H-5: N26.13431 W097.68015, Total road segment within 1km buffer = 18.62



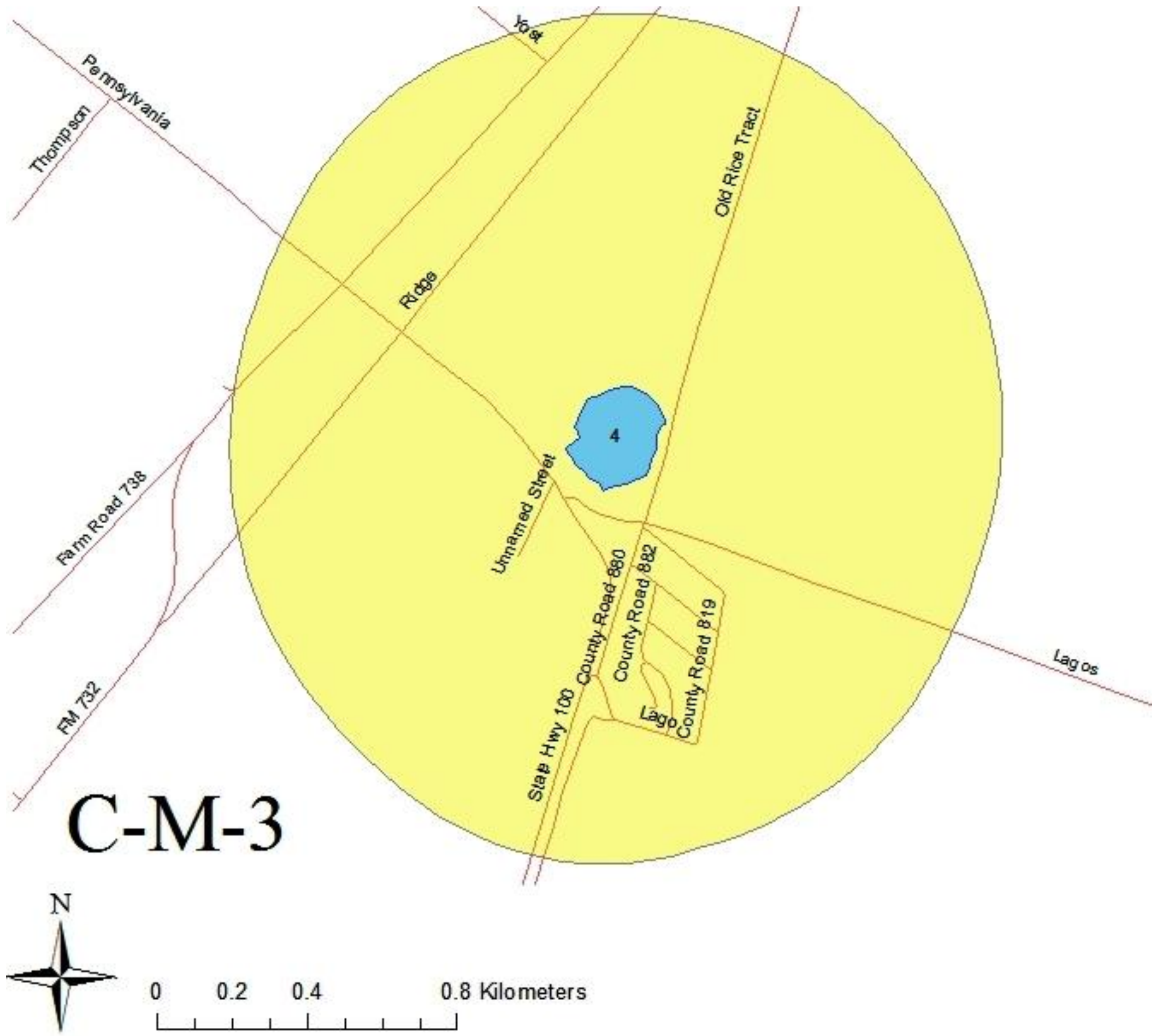
C-M-1: N25.98525 W097.53091, Total road segment within 1km buffer = 9.11



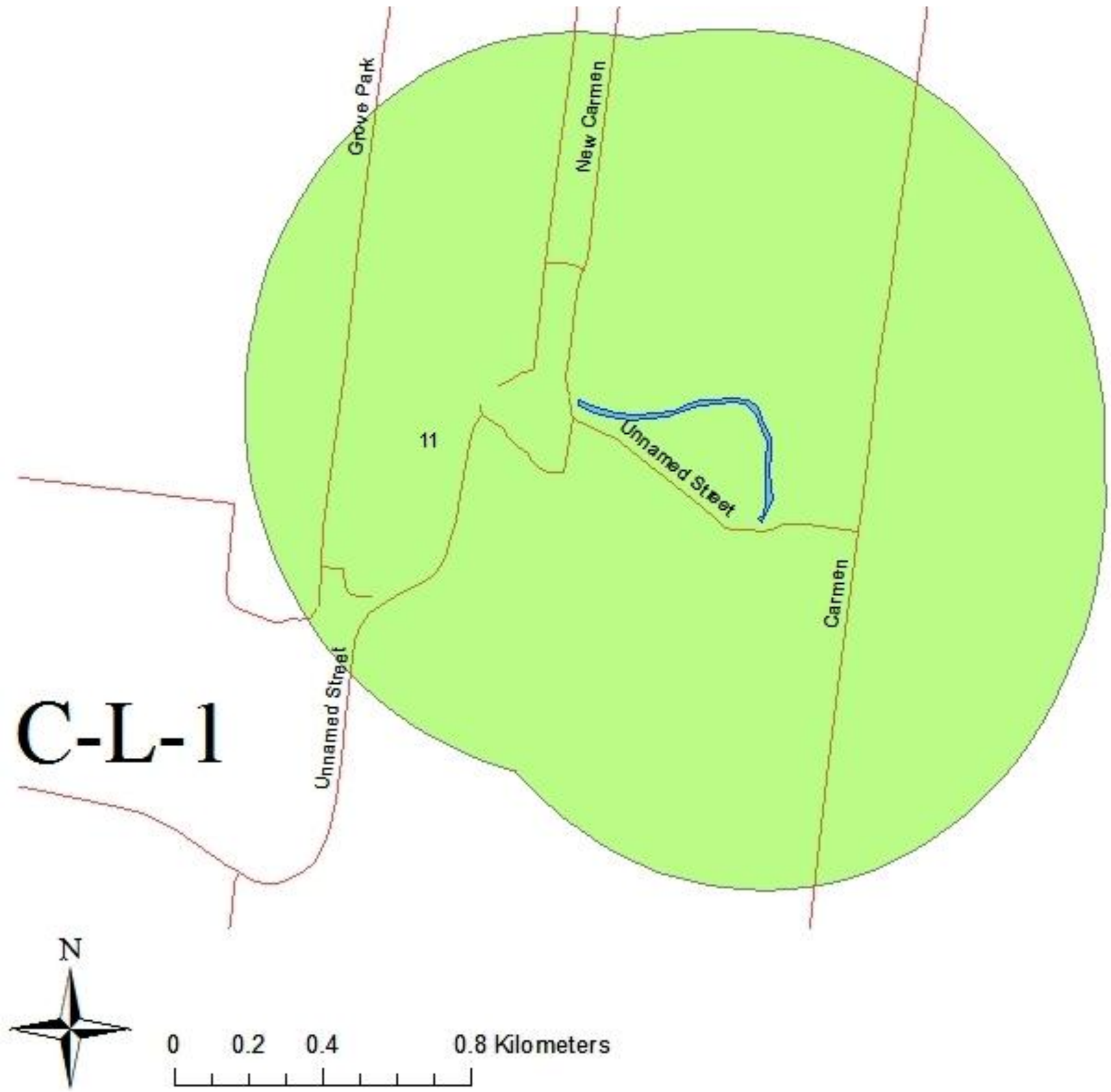
C-M-2: N26.09206 W097.61568, Total road segment within 1km buffer = 7.28



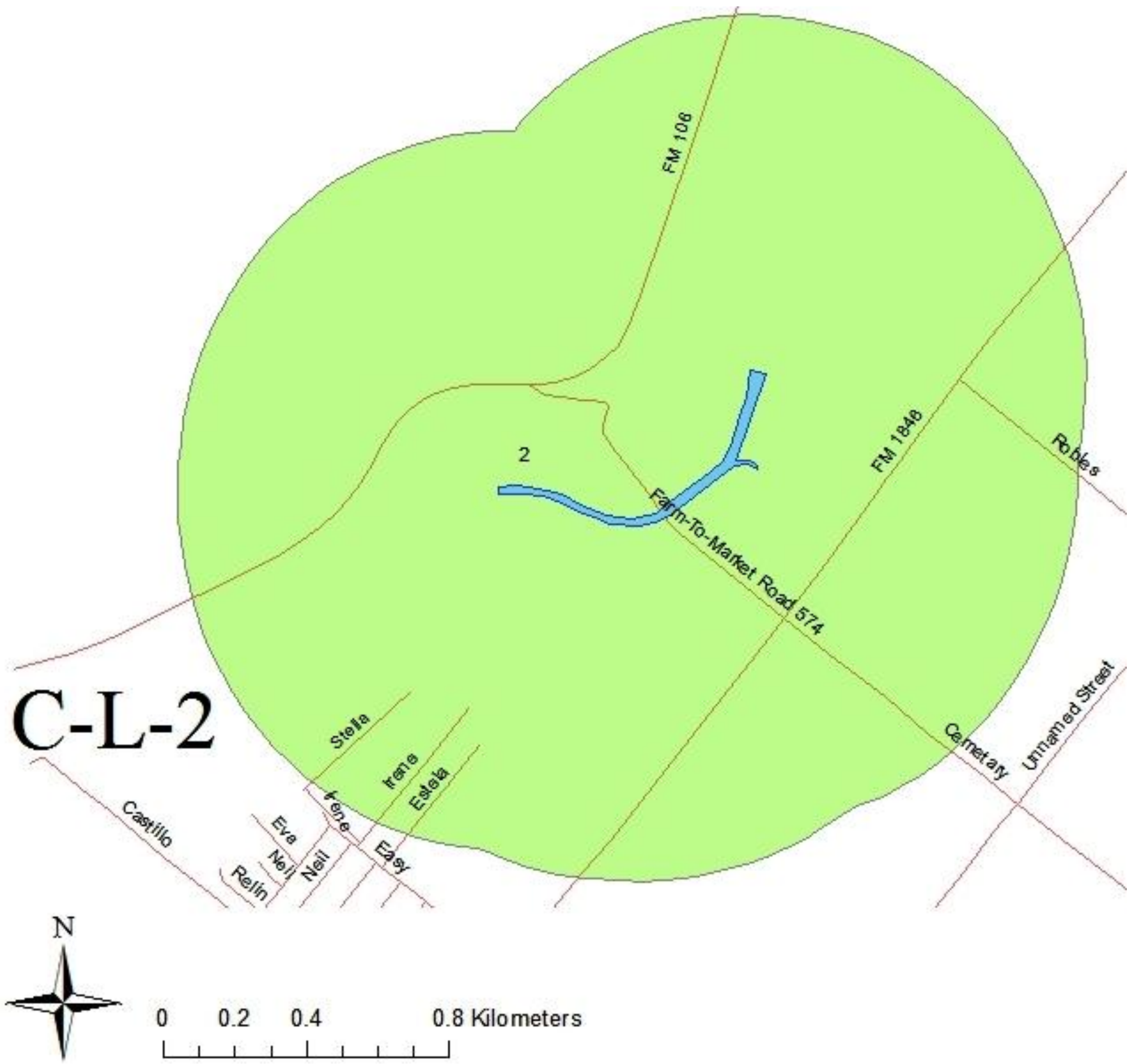
C-M-3: N26.08031 W097.58646, Total road segment within 1km buffer = 6.86



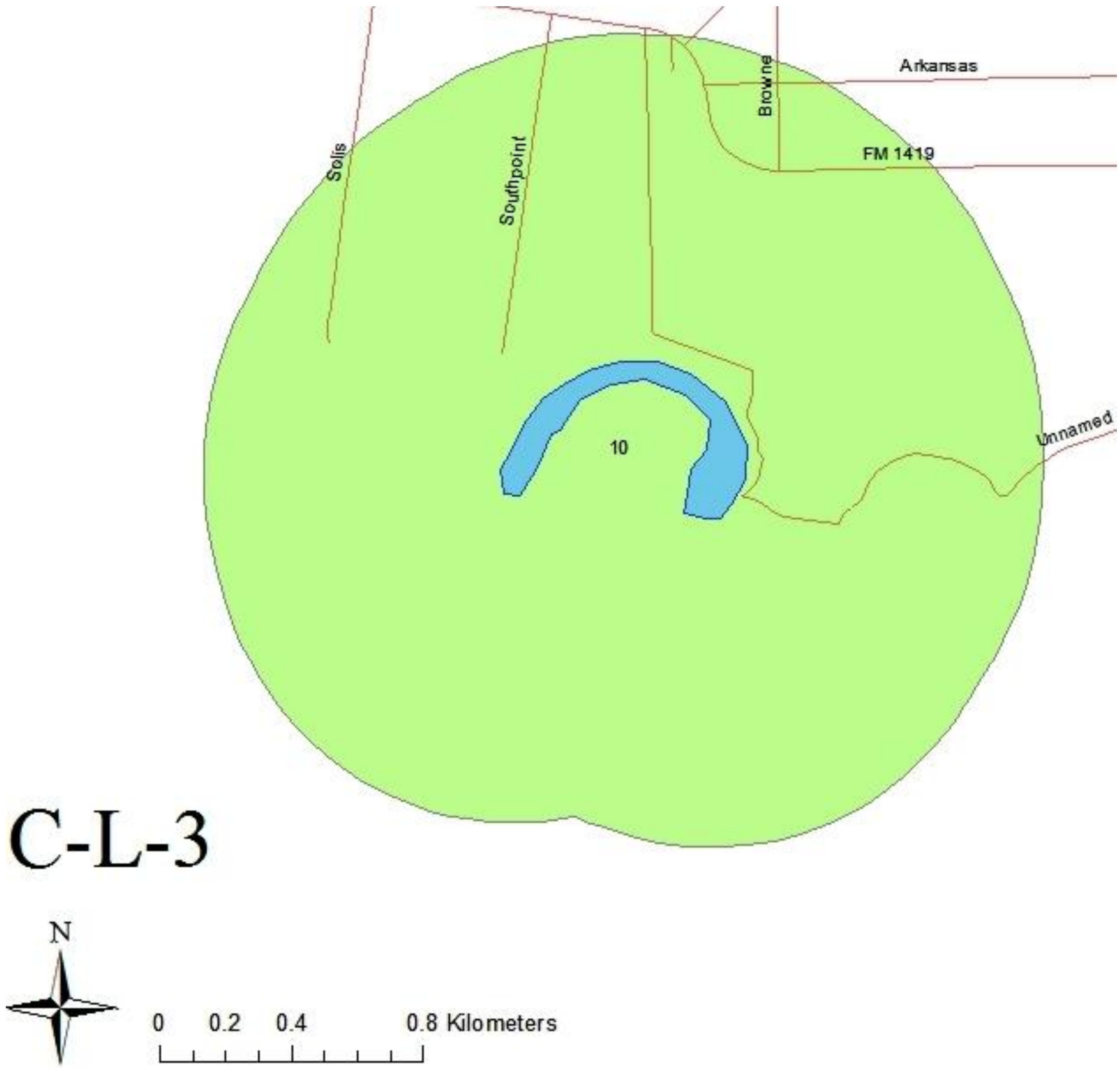
C-L-1: N25.85400 W097.39600, Total road segment within 1km buffer = 5.11



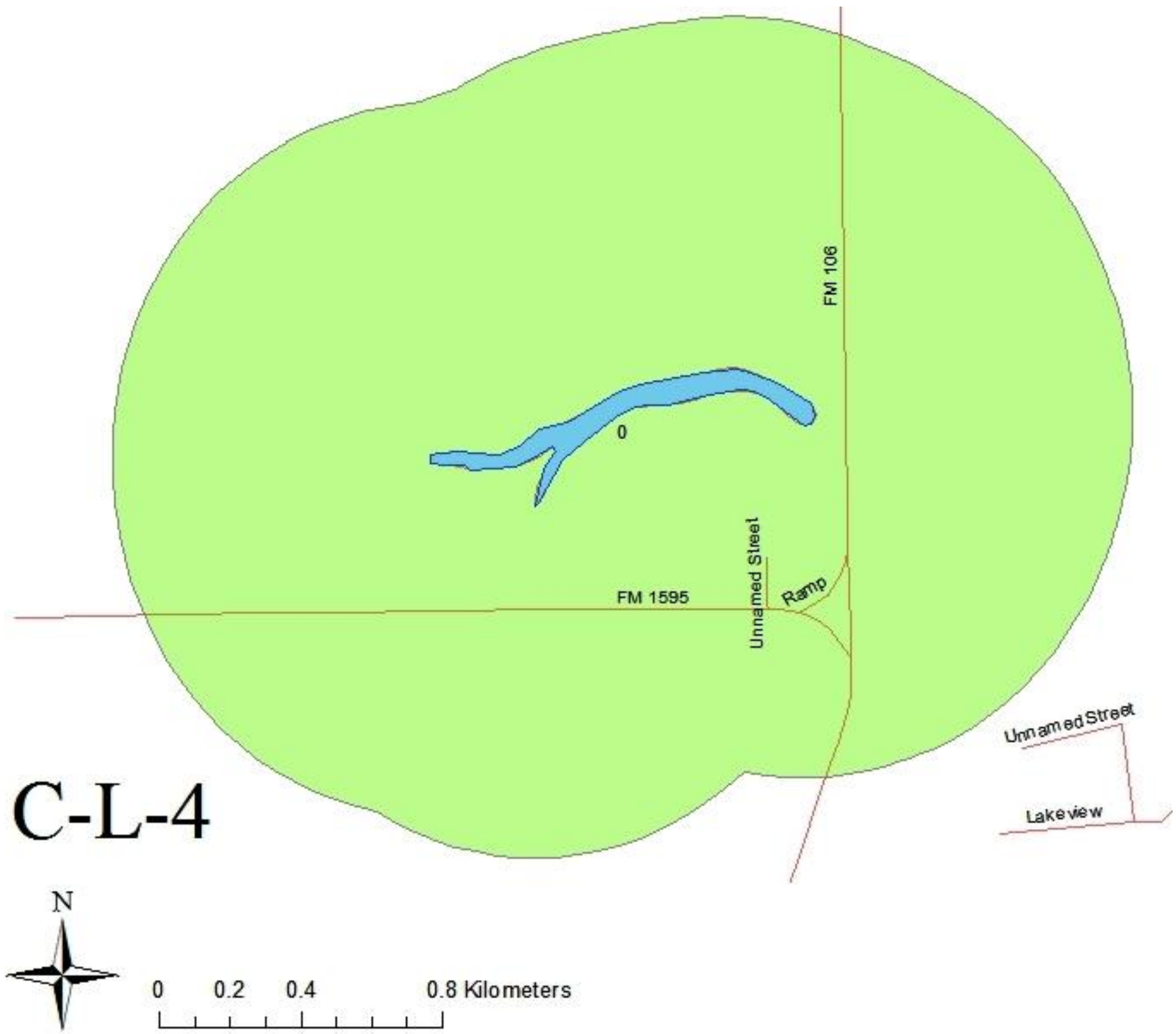
C-L-2: N26.19527 W097.60181, Total road segment within 1km buffer = 4.97



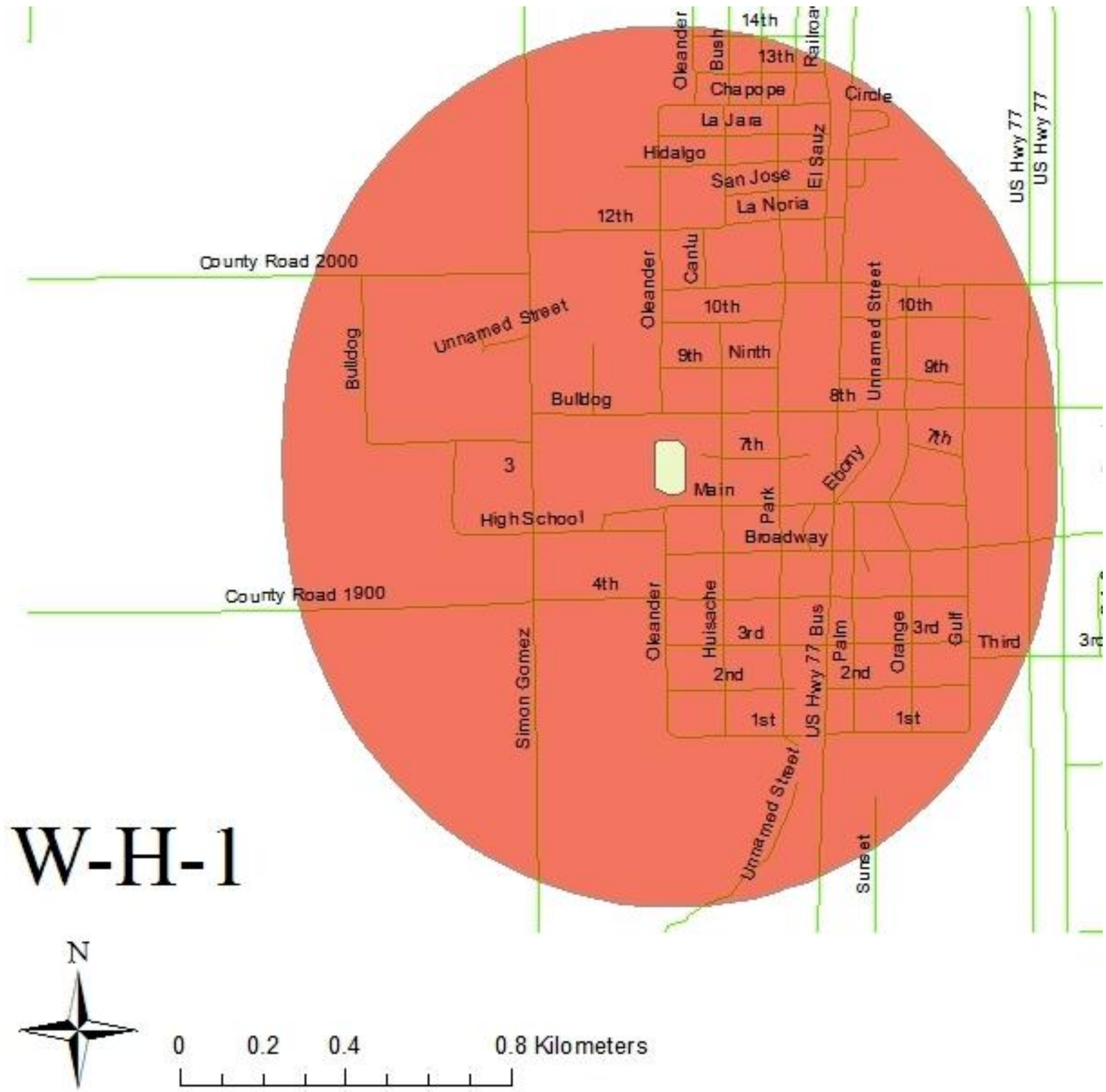
C-L-3: N25.97581 W097.56631, Total road segment within 1km buffer = 3.99



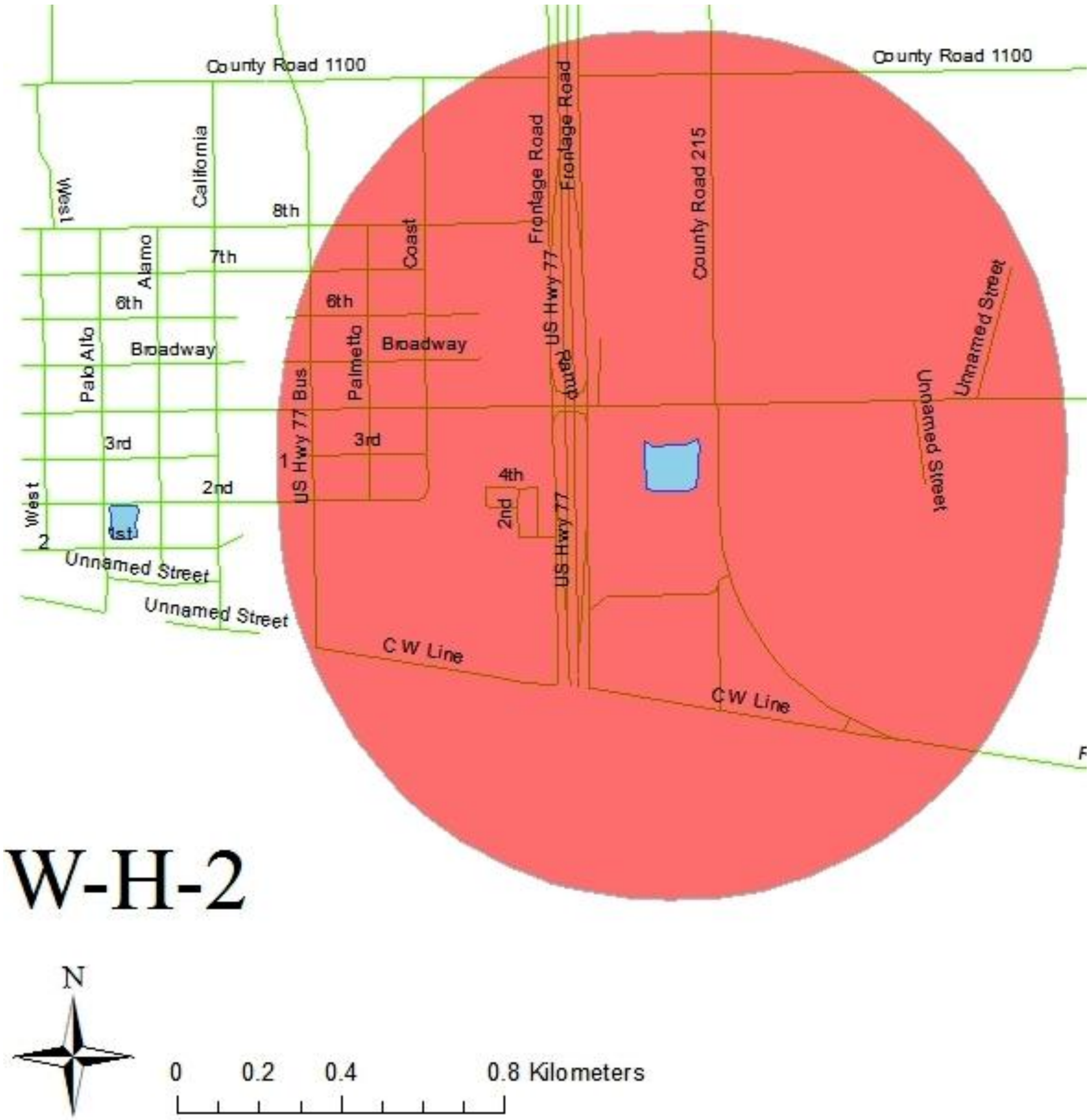
C-L-4: N26.22029 W097.60605, Total road segment within 1km buffer = 2.83



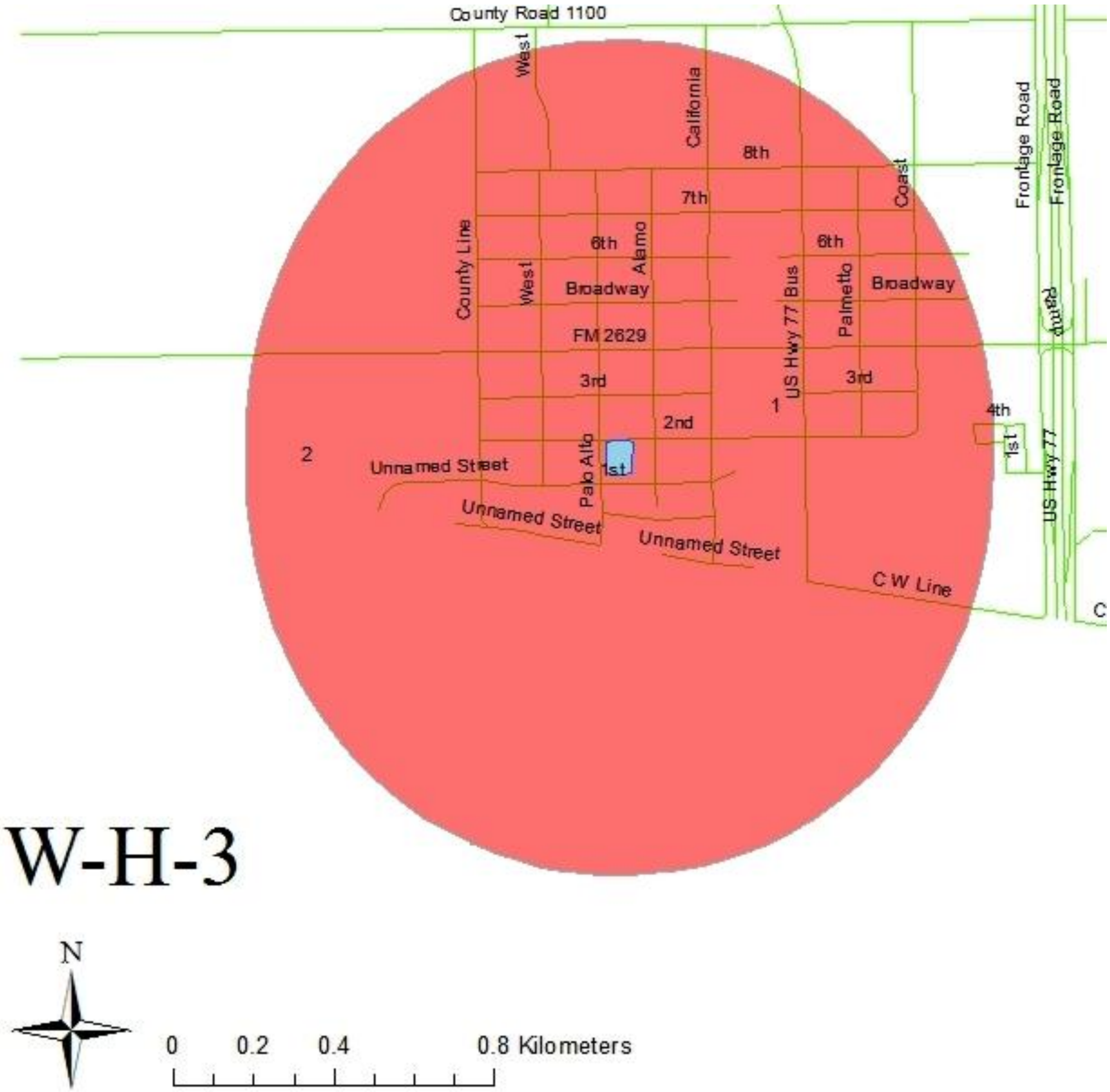
W-H-1: N26.34240 W097.78249, Total road segment within 1km buffer = 18.49



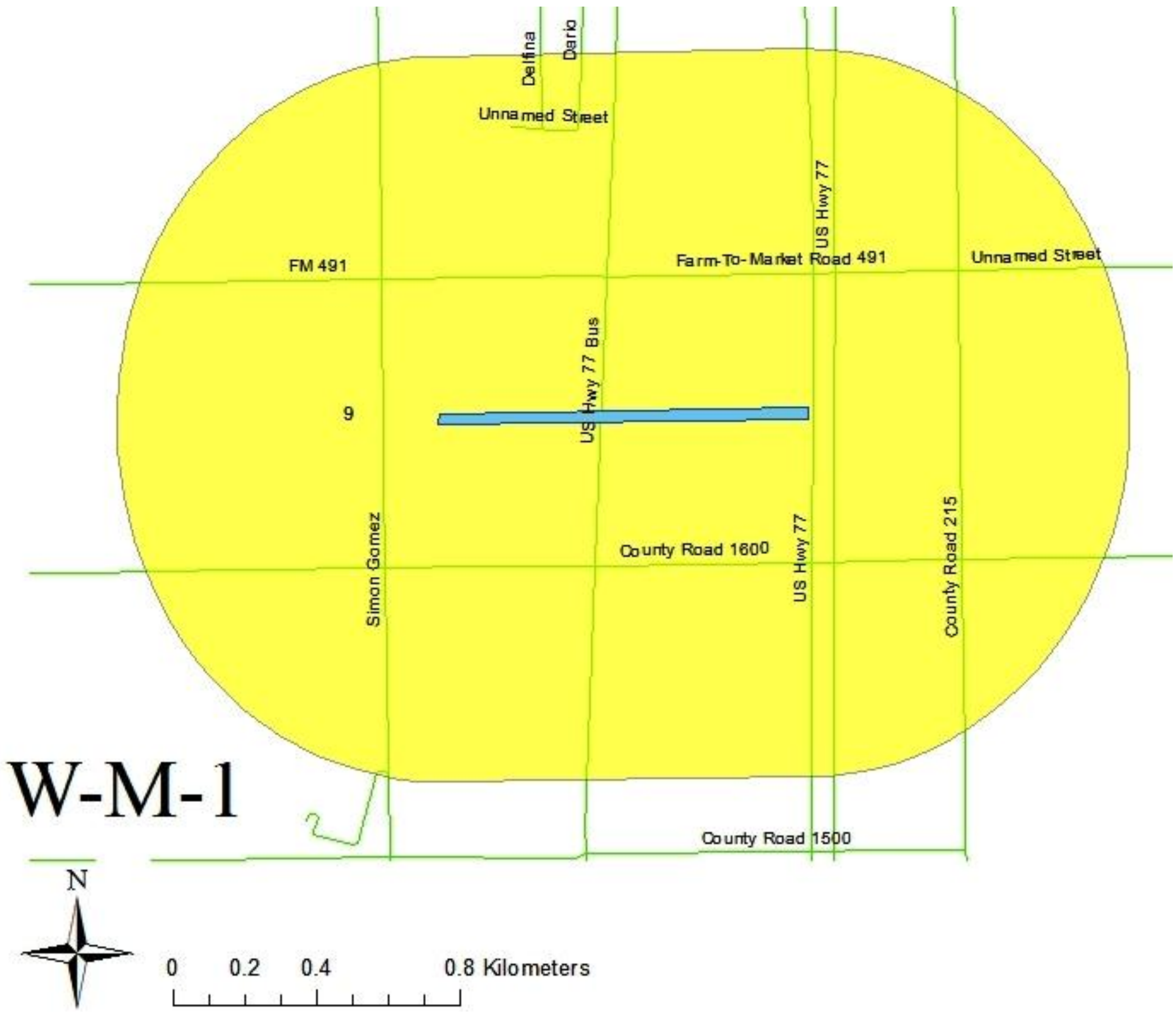
W-H-2: N26.41082 W097.79362, Total road segment within 1km buffer = 13.16



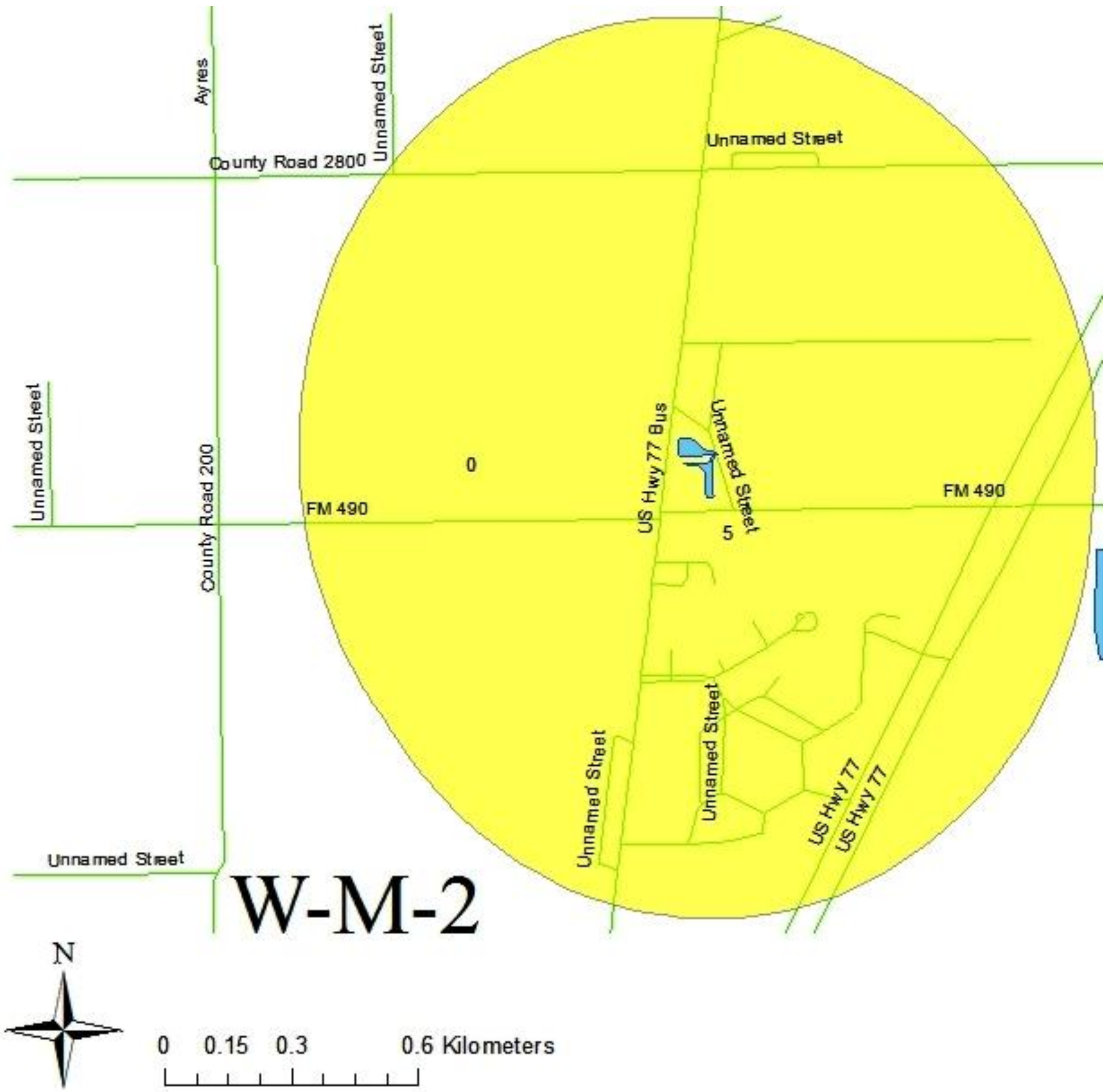
W-H-3: N26.34016 W097.79479, Total road segment within 1km buffer = 11.41



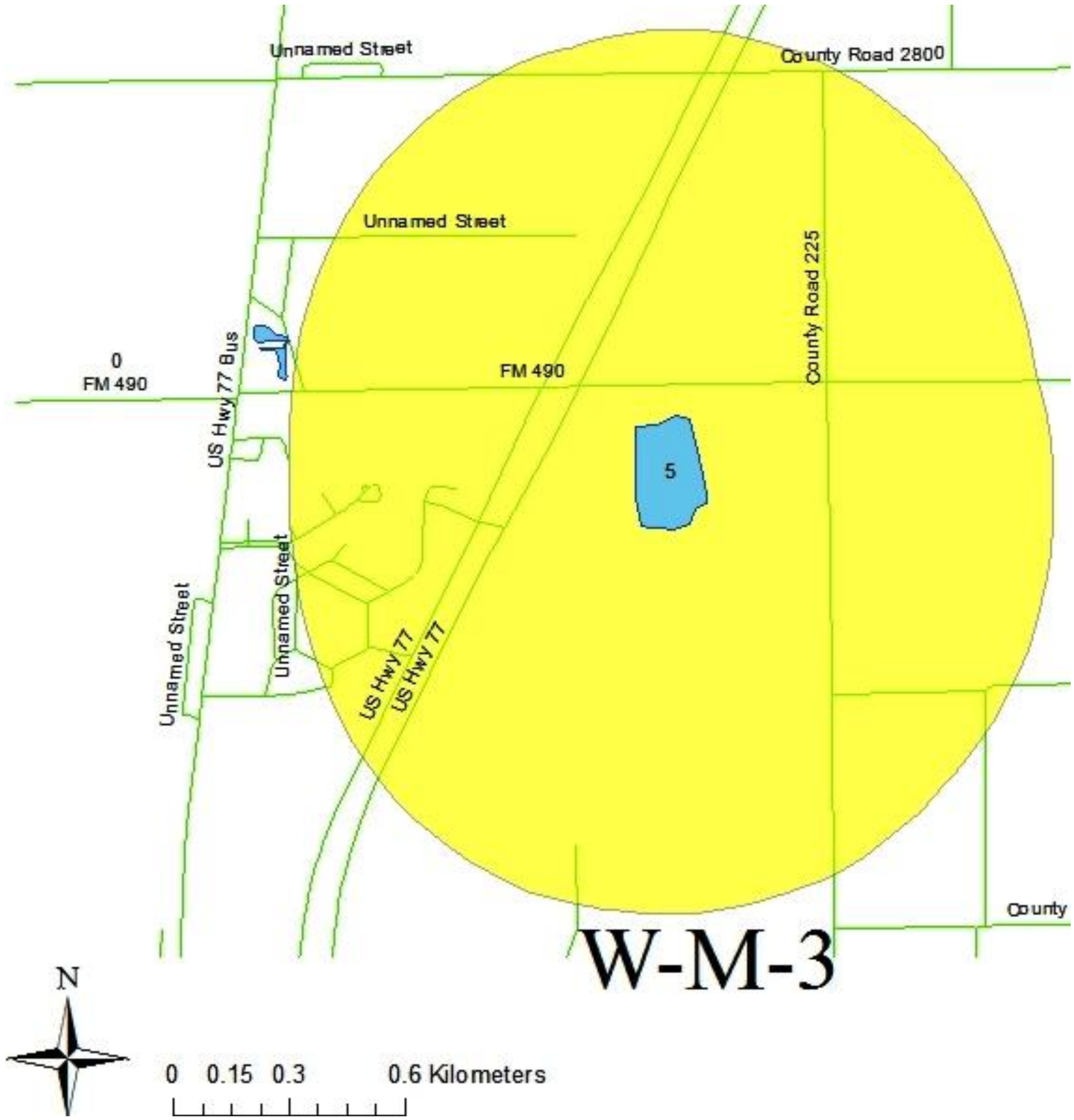
W-M-1: N26.45274 W097.78563, Total road segment within 1km buffer = 9.93



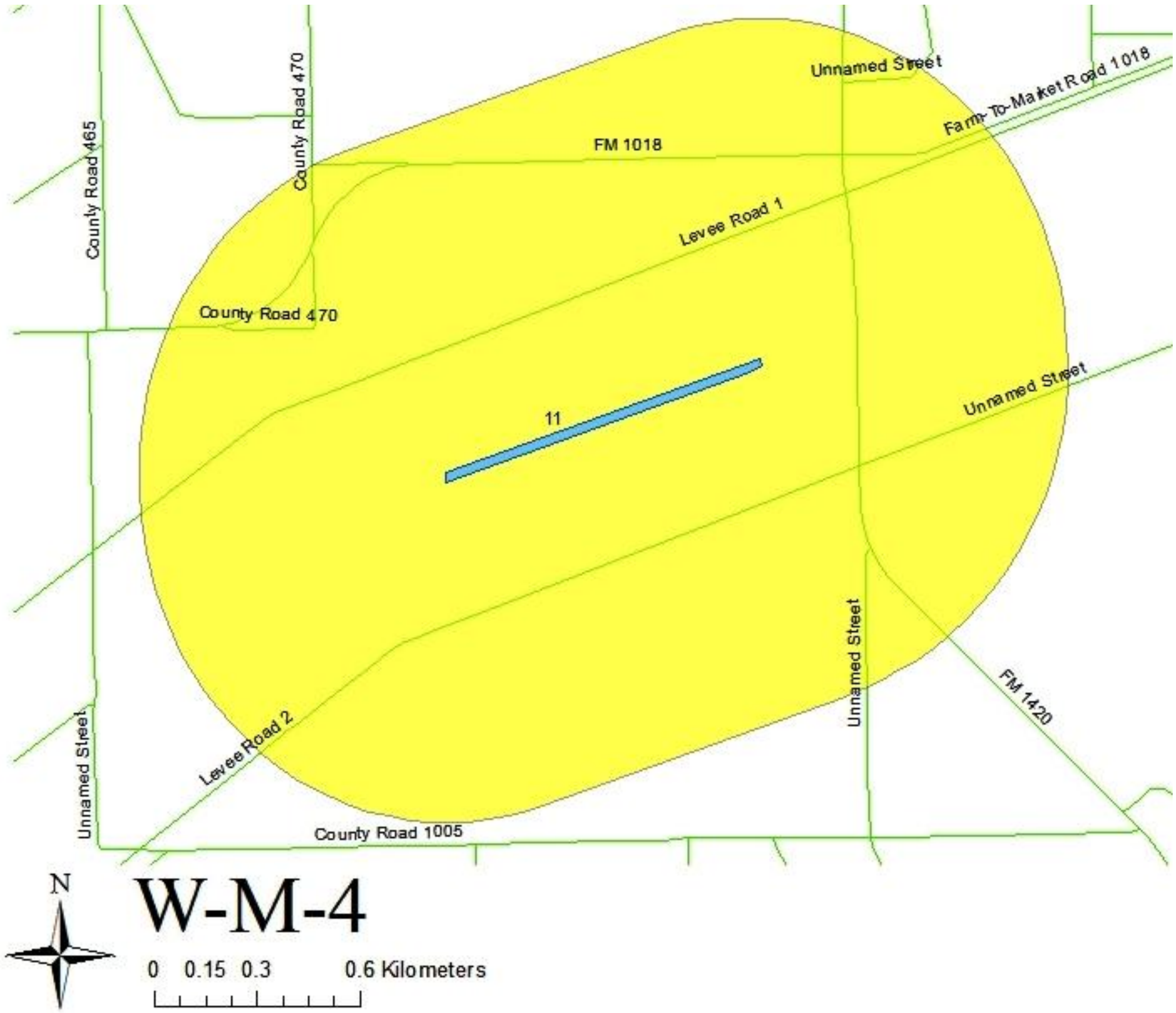
W-M-2: N26.38979 W097.79706, Total road segment within 1km buffer = 9.11



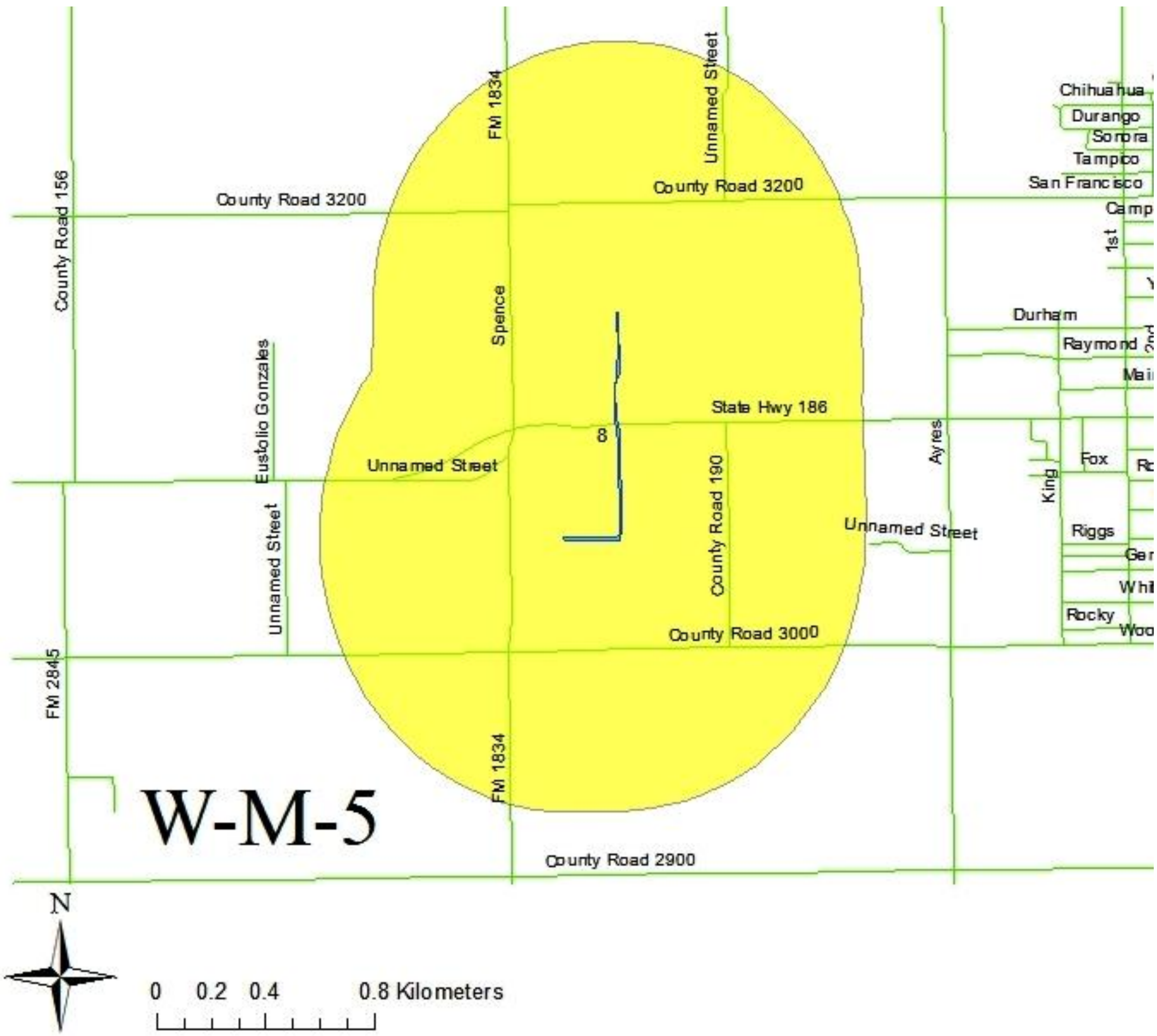
W-M-3: N26.48132 W097.80981, Total road segment within 1km buffer = 8.11



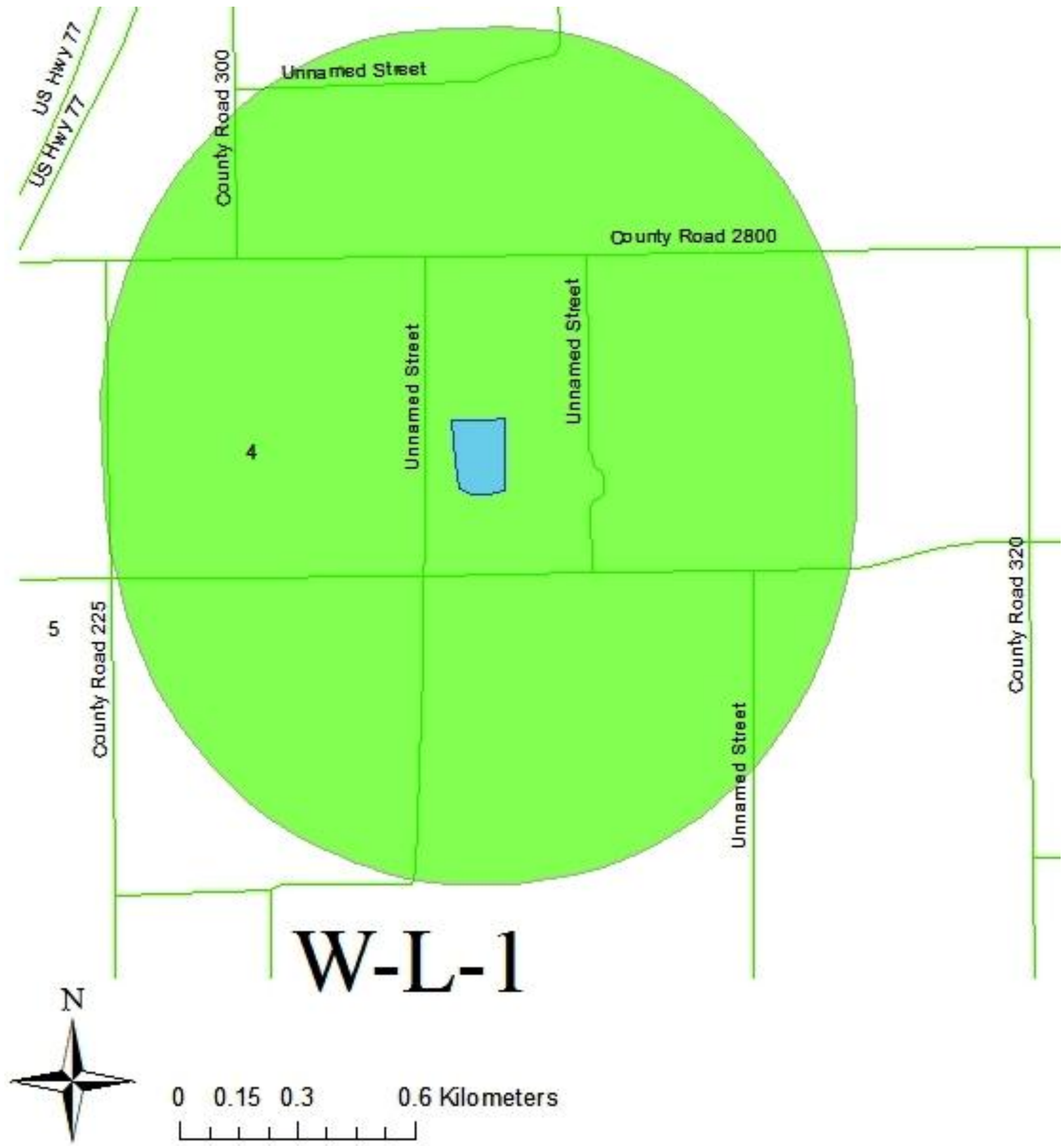
W-M-4: N26.45281 W097.77656, Total road segment within 1km buffer = 7.08



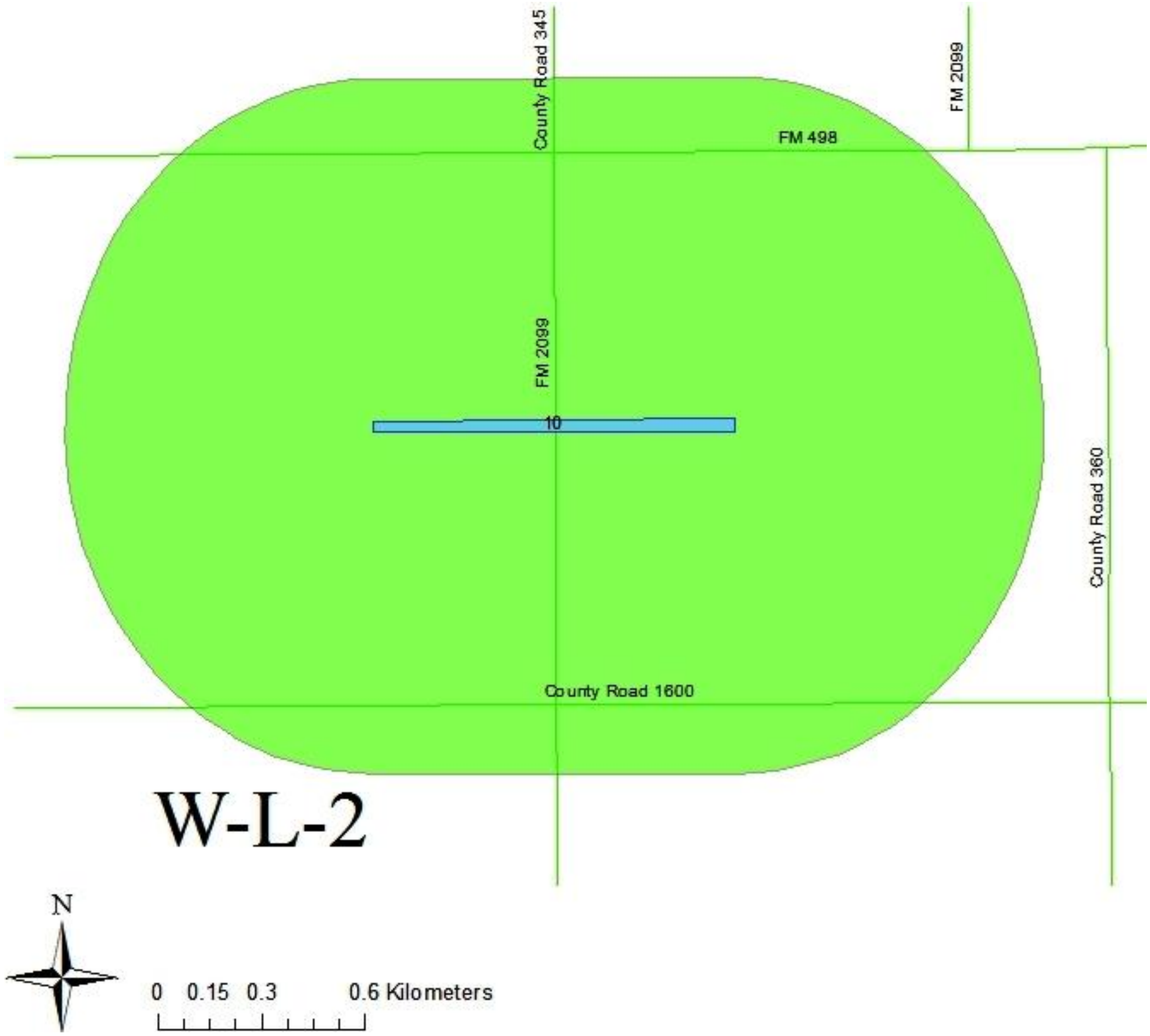
W-M-5: N26.35752 W097.58618, Total road segment within 1km buffer = 6.21



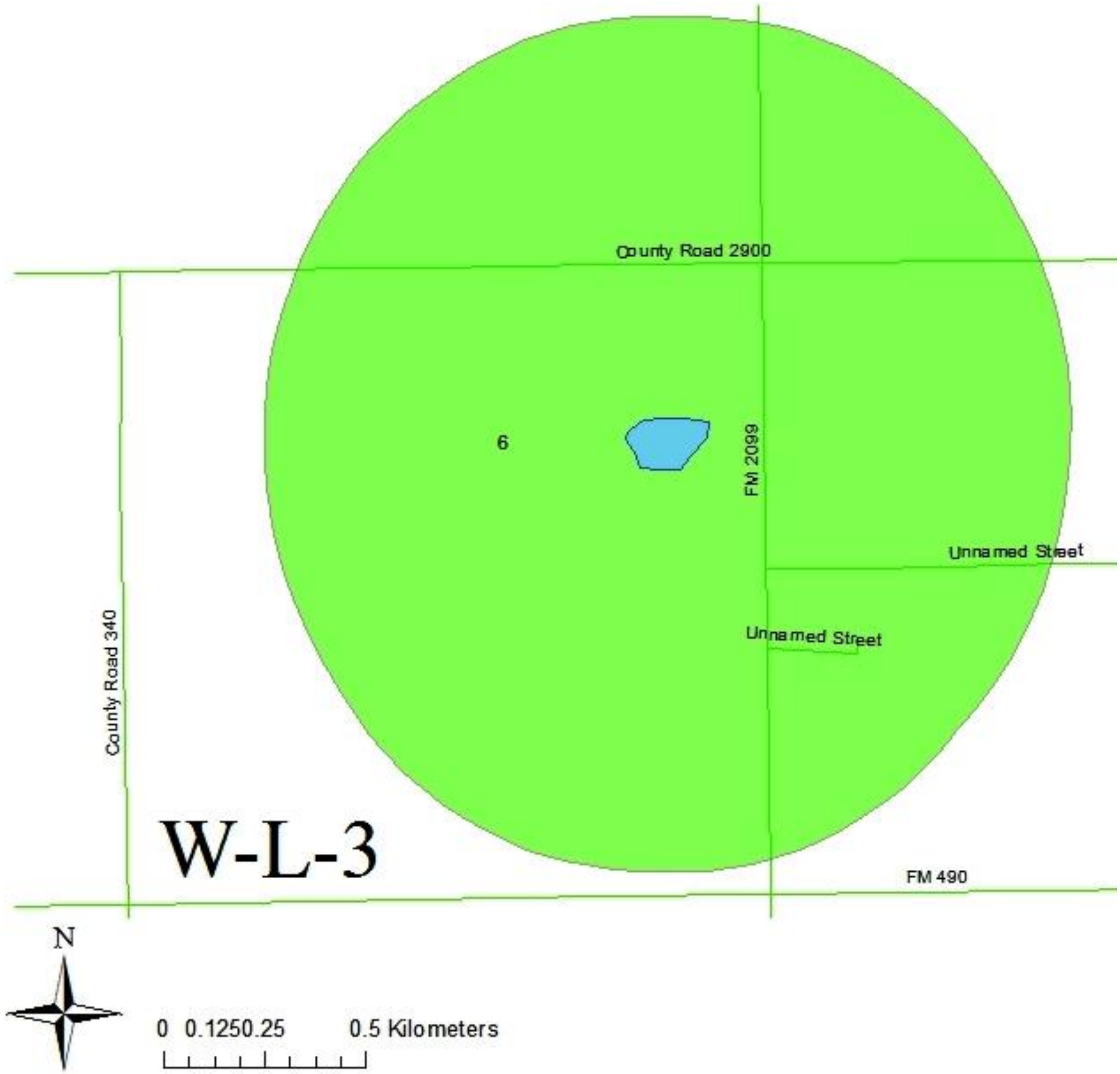
W-L-1: N26.45585 W097.76262, Total road segment within 1km buffer = 5.16



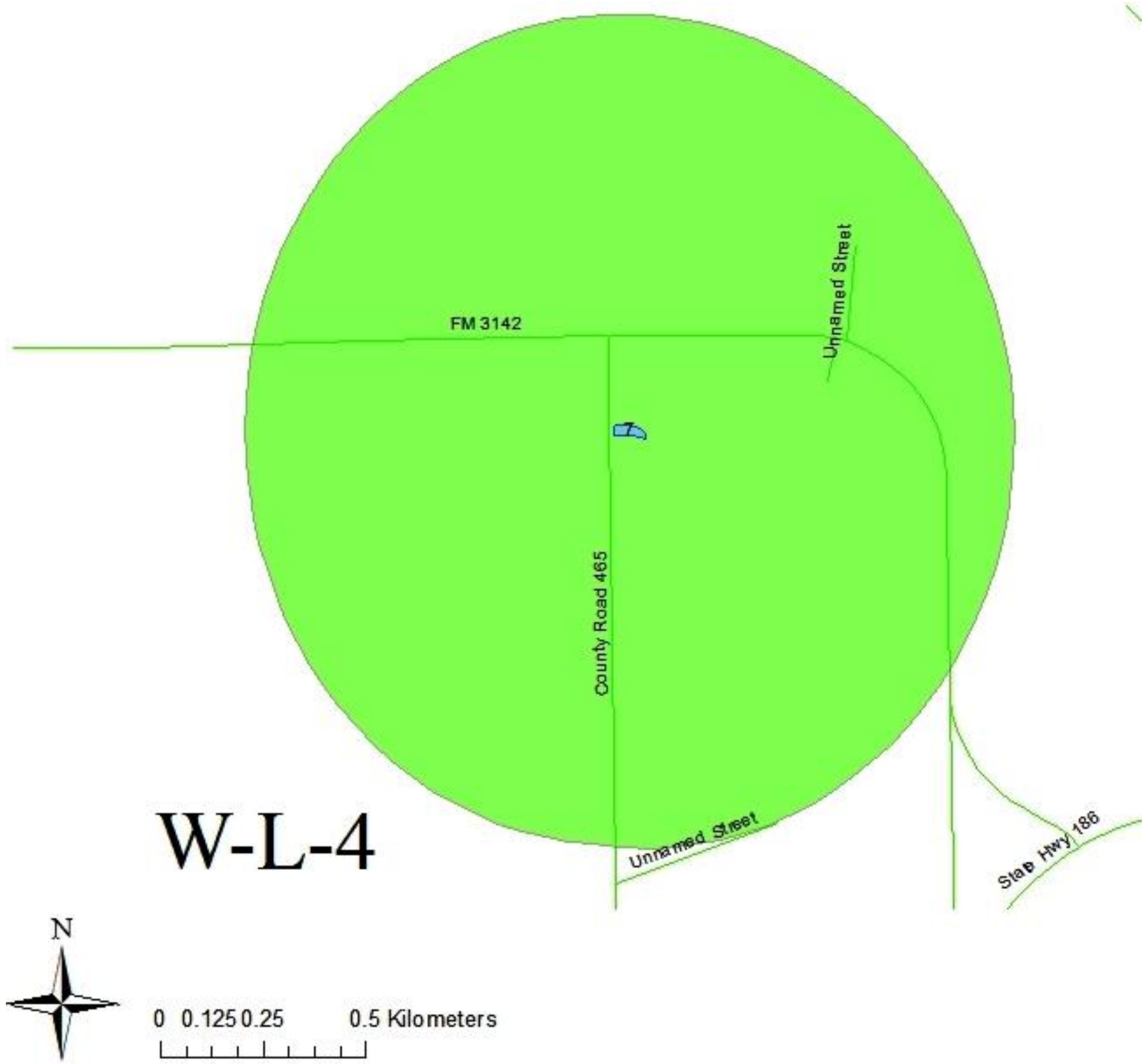
W-L-2: N26.50422 W097.61408, Total road segment within 1km buffer = 3.93



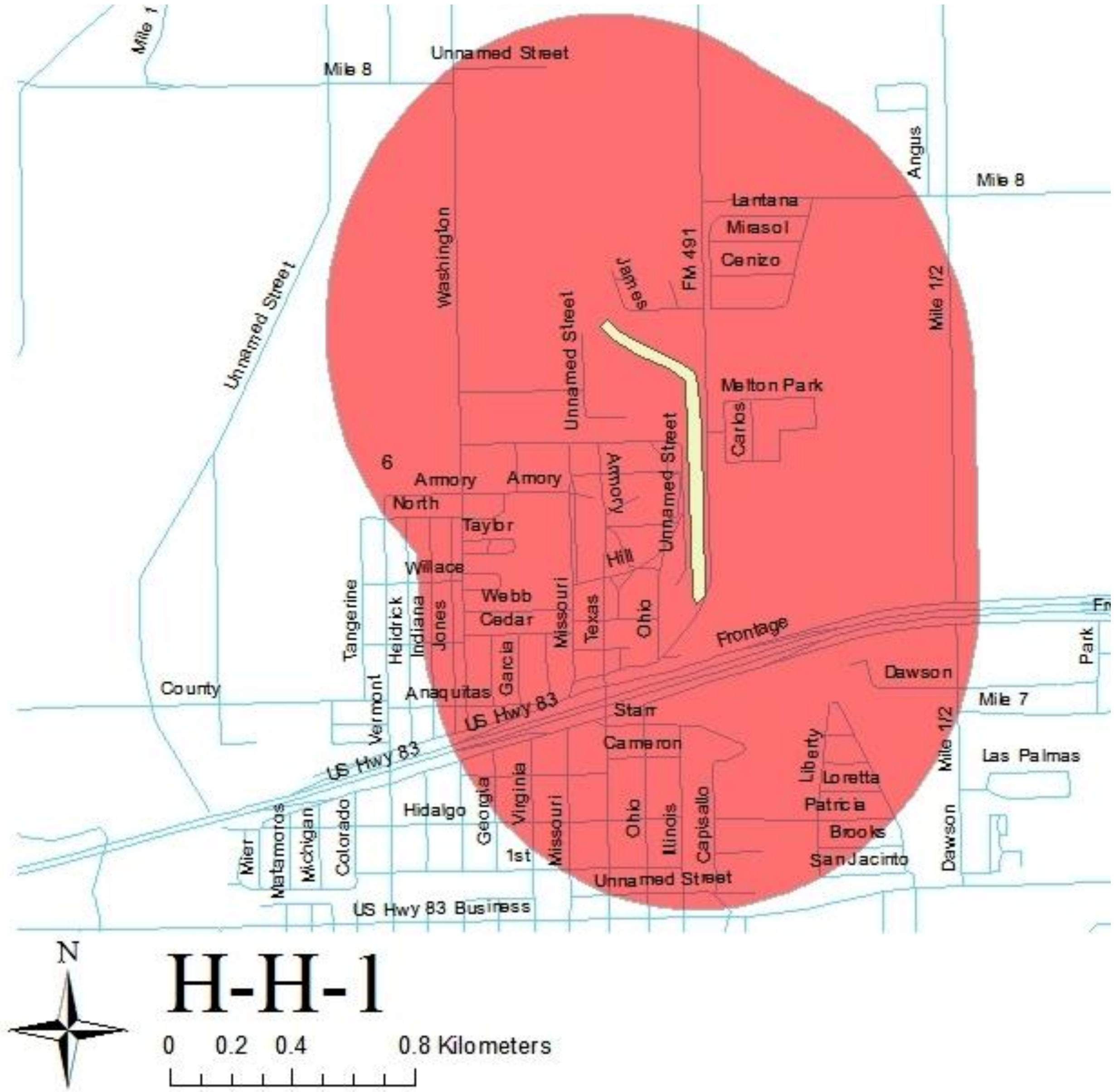
W-L-3: N26.39359 W097.71994, Total road segment within 1km buffer = 3.02



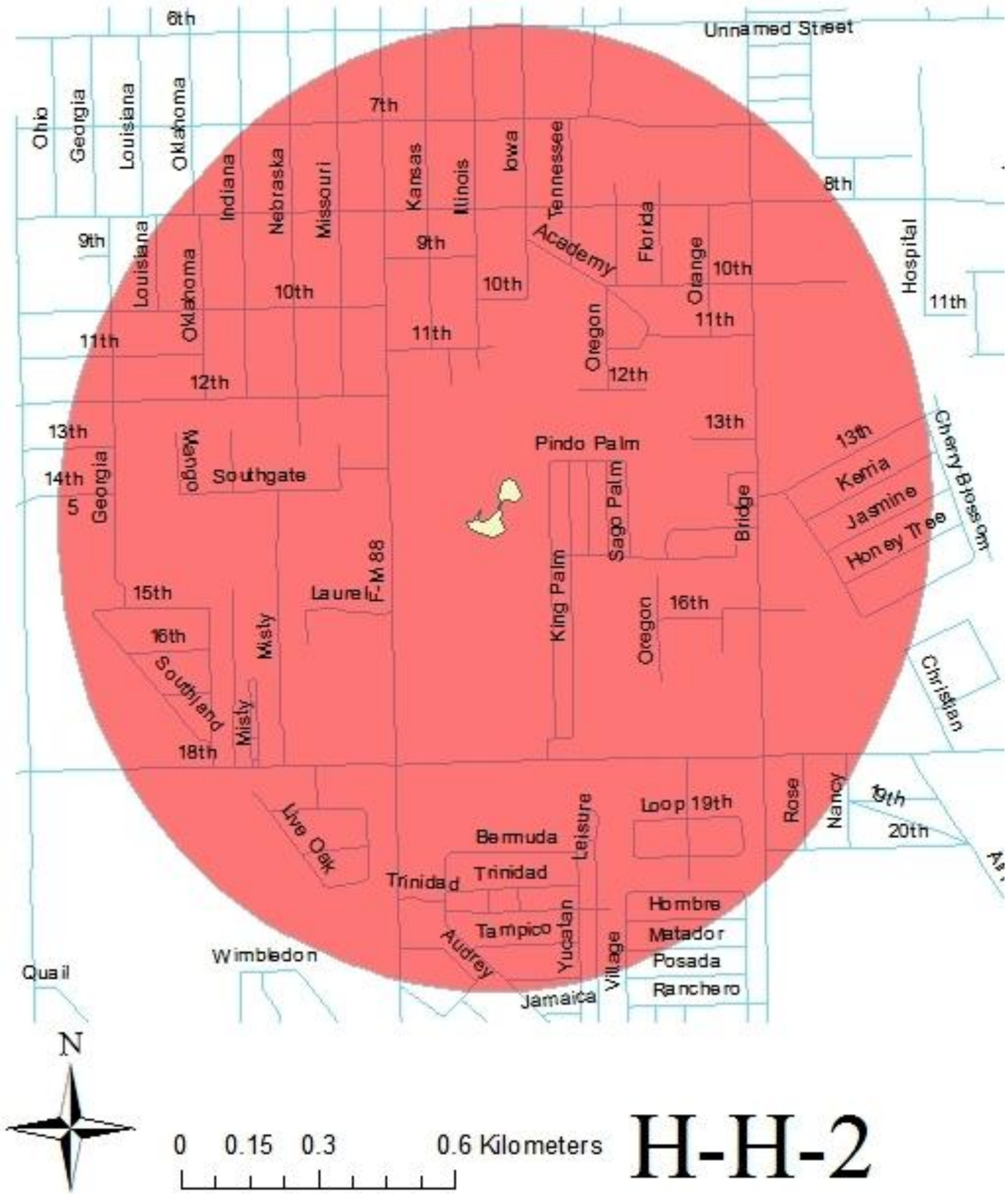
W-L-4: N26.46308 W097.70819, Total road segment within 1km buffer = 2.43



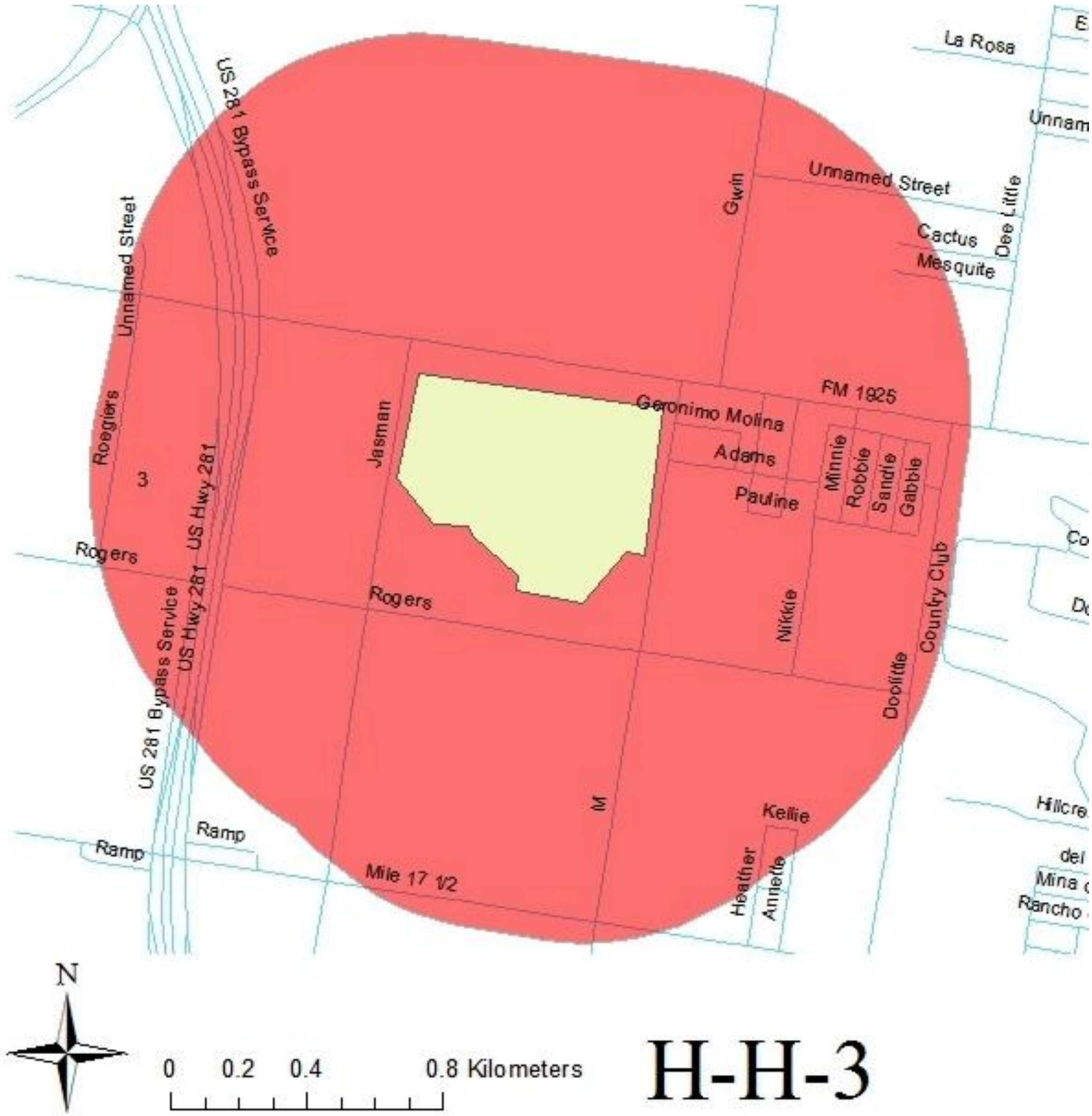
H-H-1: N26.14711 W097.98901, Total road segment within 1km buffer = 25.28



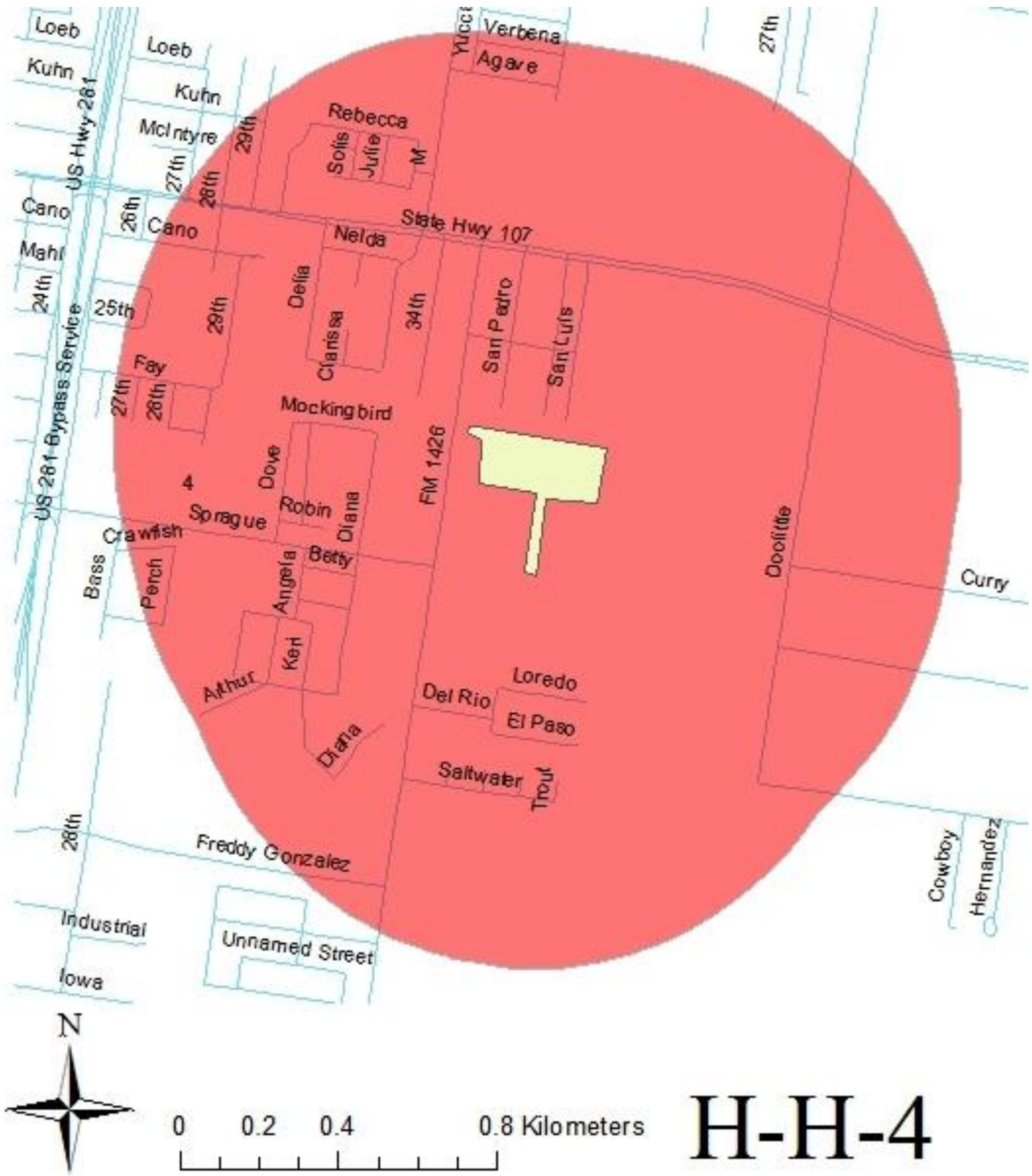
H-H-2: N26.12569 W097.93893, Total road segment within 1km buffer = 21.69



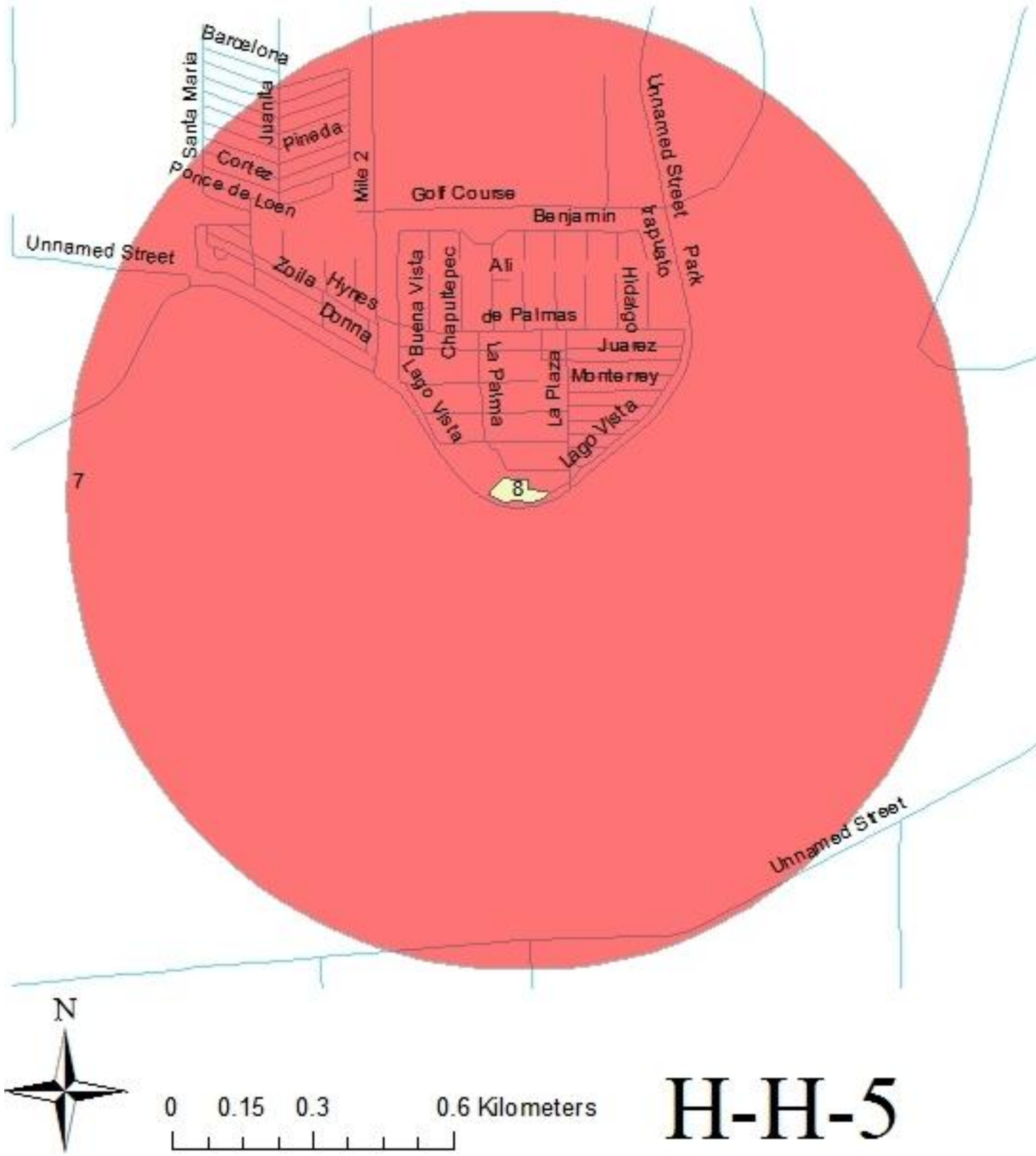
H-H-3: N26.15823 W097.91043, Total road segment within 1km buffer = 15.52



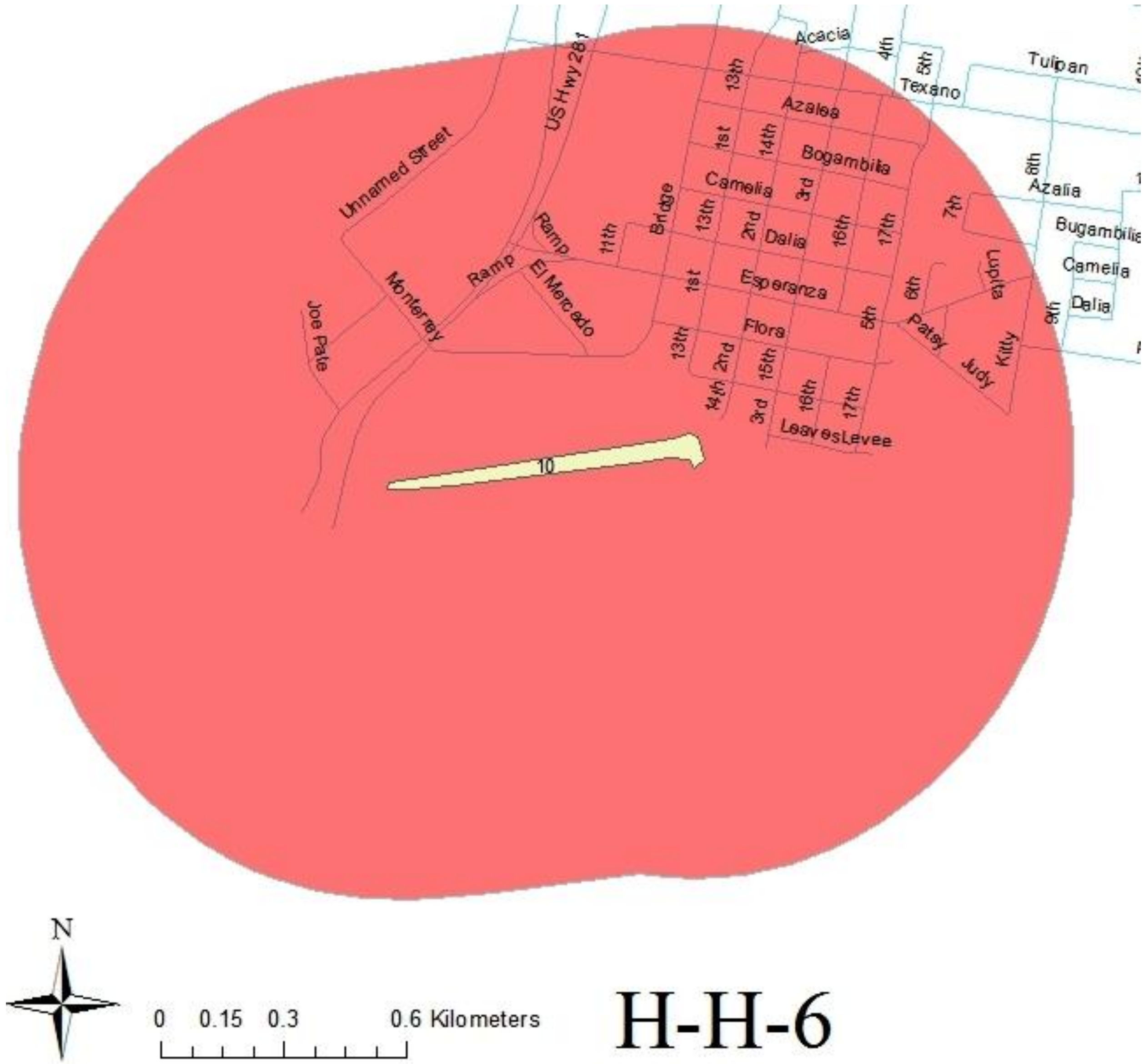
H-H-4: N26.29287 W098.13384, Total road segment within 1km buffer = 14.37



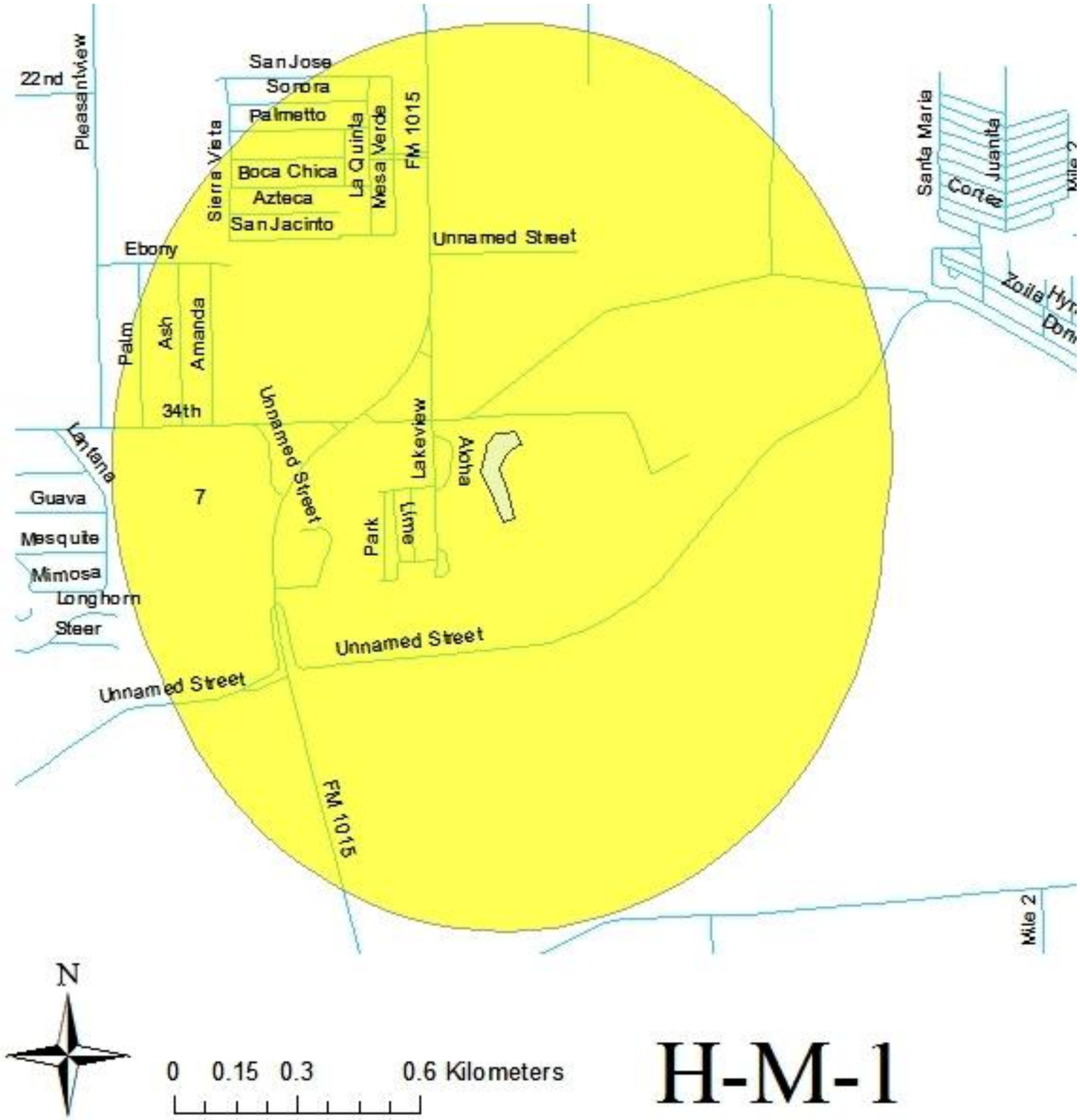
H-H-5: N26.33105 W098.14077, Total road segment within 1km buffer = 11.48



H-H-6: N26.09688 W098.26227, Total road segment within 1km buffer = 11.23

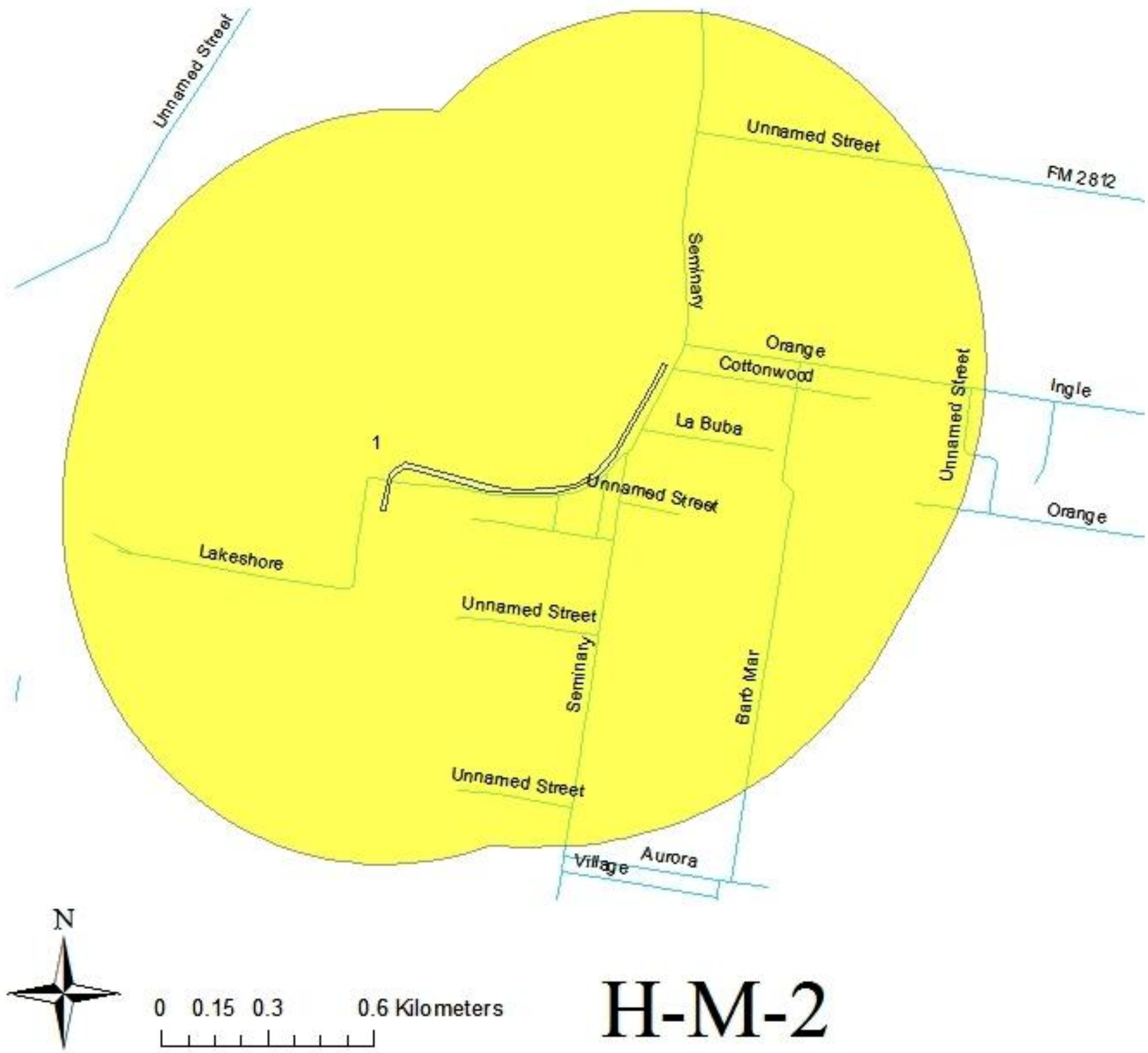


H-M-1: N26.12626 W097.95634, Total road segment within 1km buffer = 9.52


22nd
Pleasantview
San Jose
Sonora
Palmetto
Sierra Vista
Boca Chica
Azteca
San Jacinto
La Quinta
Mesa Verde
FM 1015
Unnamed Street
Ebony
Palm
Ash
Amanda
34th
Lantana
Guava
Mesquite
Mimosa
Longhorn
Steer
7
Unnamed Street
Lakeview
Aloha
Park
Lime
Unnamed Street
Unnamed Street
FM 1015
Santa Maria
Juanita
Cortez
Zoila
Mile 2
N
0 0.15 0.3 0.6 Kilometers

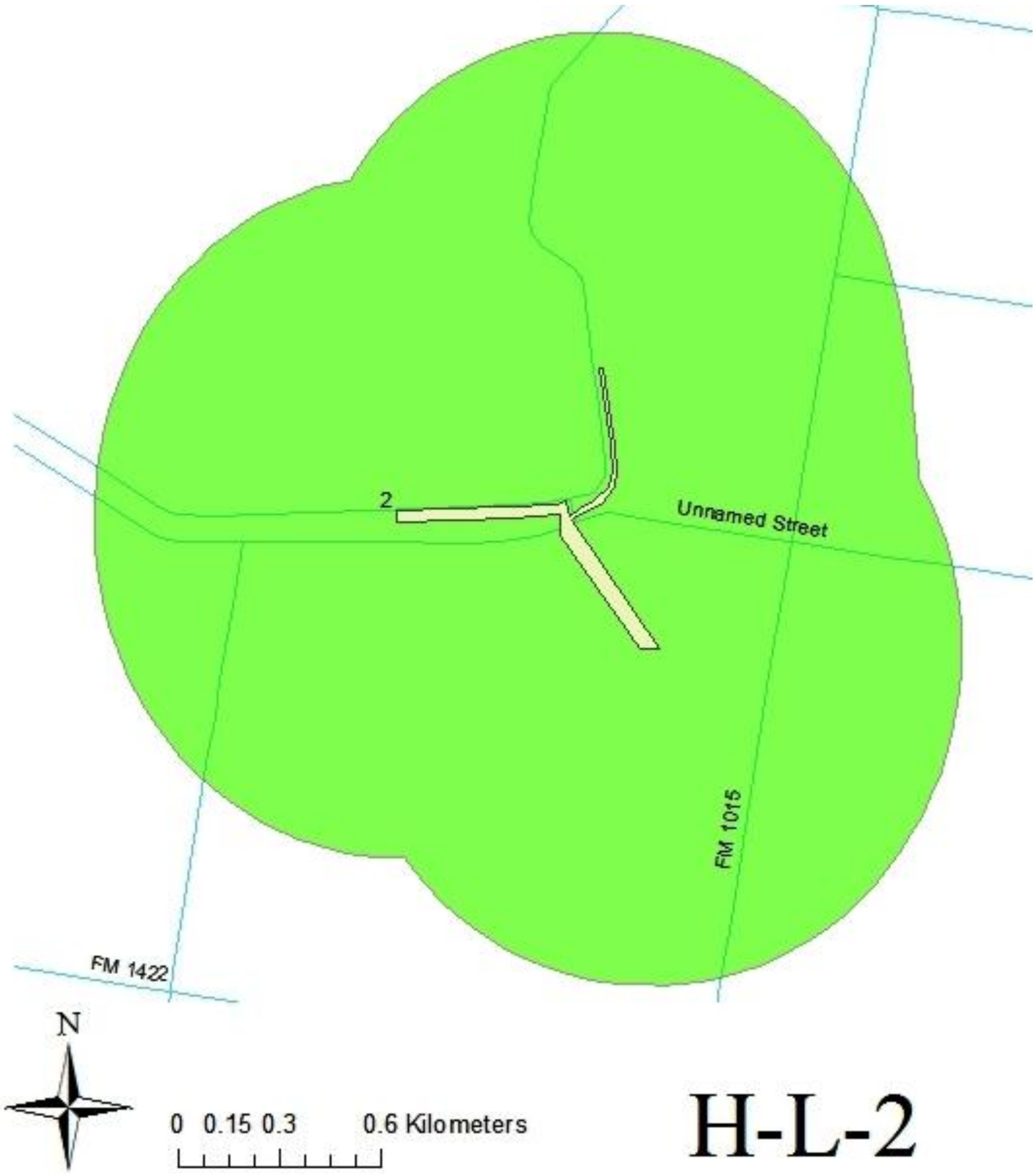
H-M-1

H-M-2: N26.08143 W097.87392, Total road segment within 1km buffer = 6.21

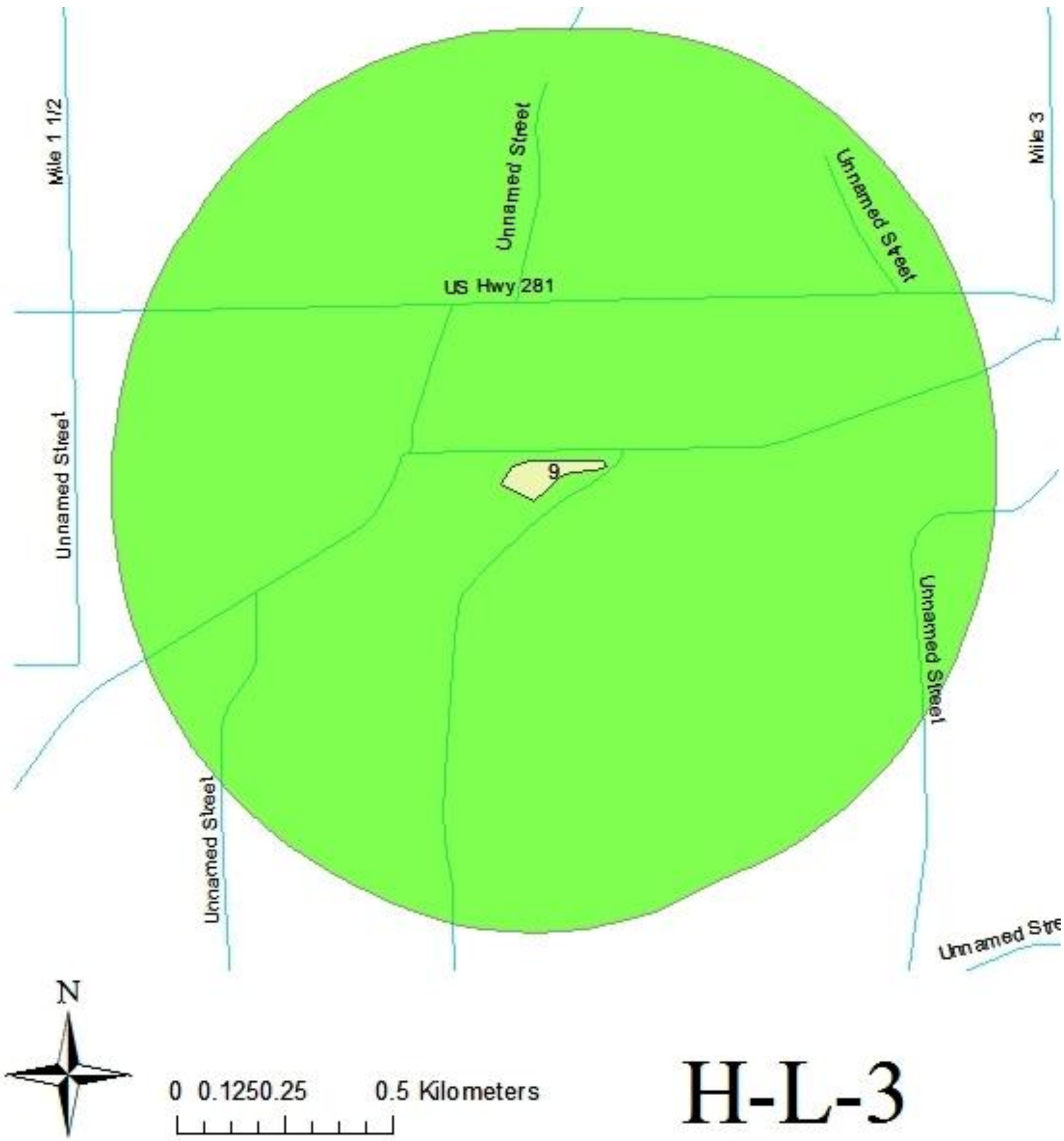


H-L-1: N26.39495 W097.93847, Total road segment within 1km buffer = 5.67

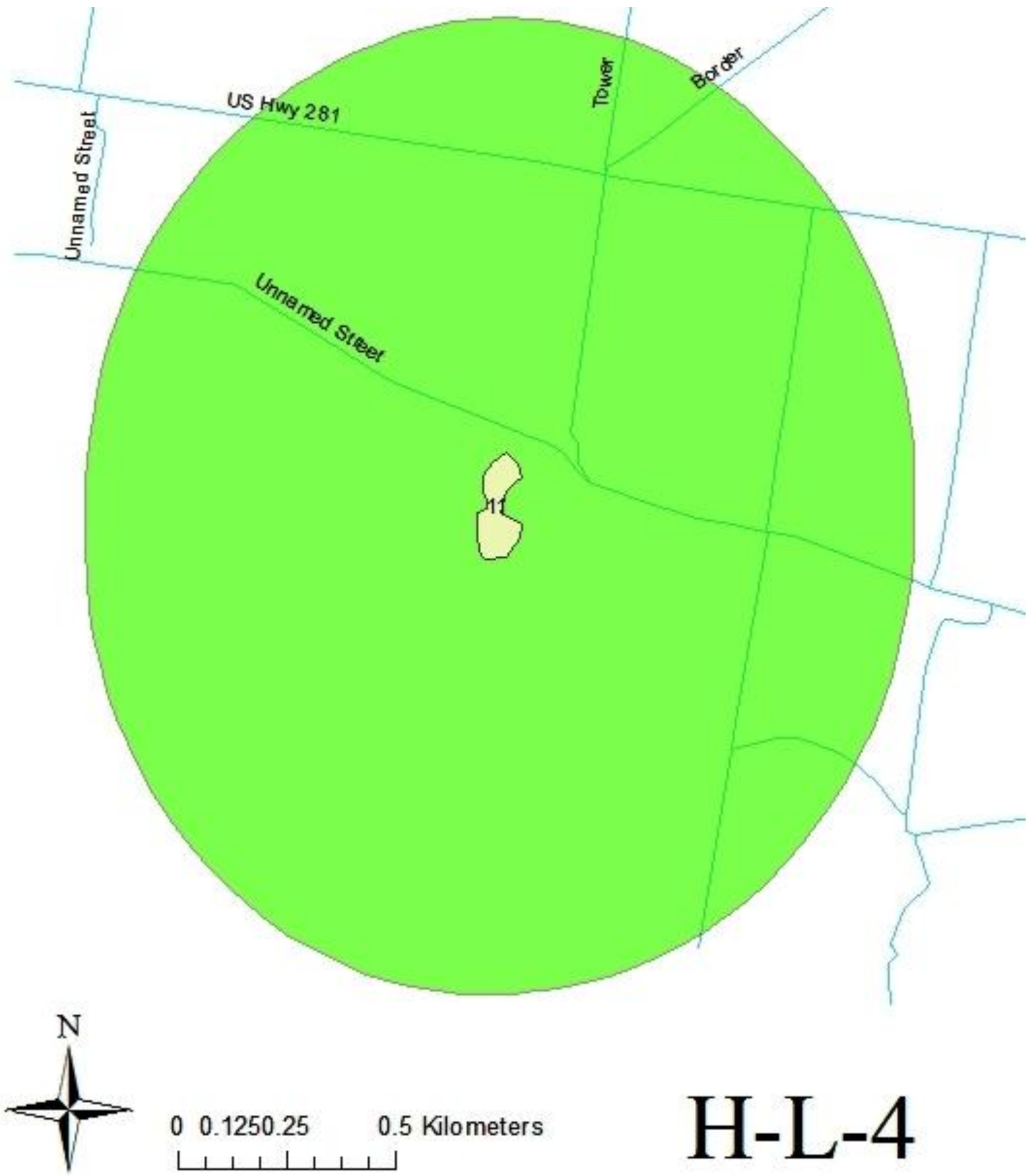
H-L-2: N26.37959 W098.17015, Total road segment within 1km buffer = 5.61



H-L-3: N26.07771 W098.13068, Total road segment within 1km buffer = 4.79



H-L-4: N26.42475 W098.13612, Total road segment within 1km buffer = 4.16



LITERATURE CITED

Anderson, R. O., and R. M. Neumann. 1996. Length, Weight, and Associated Structural Indicies. Pages 447-482 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Andrews, K. M., and D. M. Jochimsen. 2007. Ecological Effects of Roads Infrastructure on Herpetofauna: Understanding Biology and Increasing Communication. International Conference on Ecology and Transportation 2007:567-582.

Aresco, M. J. 2005a. The effect of sex-specific terrestrial movements and roads on the sex ratio of freshwater turtles. Biological Conservation 123:37-44.

Aresco, M. J. 2005b. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69:549-560.

Ashley, E. P., and J. T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the long point causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110:403-412.

Bancroft, G. T., J. S. Godley, D. T. Gross, N. N. Rojas, D. A. Sutphen, and R. W. McDiarmid. 1983. Large scale operations management test of use of the white amur for control of problem aquatic plants: The herpetofauna of Lake Conway; species accounts. Misc. Pap. A-83-5. Army Eng. Waterw. Exp. Stn., Vicksburg, Mississippi.

Boarman, W. I., and M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101.

Brooks, R. J., G. P. Brown, and D. A. Galbraith. 1991. Effects of a sudden increase in natural mortality of adults on a population of the common snapping turtle (*Chelydra serpentine*). Canadian Journal of Zoology 69:1314-1320.

Brown, D. J. 2008. Lower Rio Grande Valley freshwater turtle populations: three decades of change. Thesis, Texas State University-San Marcos, San Marcos, Texas, USA

Brown, D. J., B. DeVolld, and M. R. J. Forstner. In press. Escapes from hoop nets by red-eared sliders (*Trachemys scripta*). Southwestern Naturalist.

Buhlmann, K. A., and J. W. Gibbons. 2001. Terrestrial habitat use by aquatic turtles from a seasonally fluctuating wetland: Implications for wetland conservation boundaries. Chelonian Conservation and Biology 4:115-127.

Cagle, F. R. 1939. A system of marking turtles for future identification. Copeia 1939:170-173.

Cagle, F. R. 1950. The life history of the slider turtle, *Pseudemys scripta troostii* (Holbrook). Ecological Monographs 20:31-54.

Ceballos, C. P., and L.A. Fitzgerald. 2004. The trade in native and exotic turtles in Texas. Wildlife Society Bulletin 32:881-892.

Coffin, A. W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15:396-406.

Congdon, J. D., A. E. Dunham, and R. C. Van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. Conservation Biology 7:826-833.

Congdon, J. D., A. E. Dunham, and R. C. Van Loben Sels. 1994. Demographics of common snapping turtles (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. American Zoologist 34:397-408.

Congdon, J. D., D. W. Tinkle, G. L. Breitenbach, and R. C. van Loben Sels. 1983. Nesting ecology and hatching success in the turtle *Emydoidea blandingi*. Herpetologica 39:417-429.

Connor, C. A., B. A. Douthitt, and T. J. Ryan. 2005. Descriptive Ecology of a Turtle Assemblage in an Urban Landscape. American Midland Naturalist 153:428-435.

Cypher, B. L., C. D. Bjurlin, and J. L. Nelson. 2009. Effects of Roads on Endangered San Joaquin Kit Foxes. Journal of Wildlife Management 73:885-893.

Doroff, A. M., and L. B. Keith. 1990. Demography and ecology of an ornate box turtle (*Terrapene ornate*) population in south-central Wisconsin. Copeia 1990:387-399.

Ernst, C. H., and J. E. Lovich. 2009. Turtles of the United States and Canada. The John Hopkins University Press, Baltimore, Maryland.

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177-182.

Finder, R. A., J. L. Roseberry, and A. Woolf. 1999. Site and landscape conditions at white-tailed deer vehicle collision locations in Illinois. Landscape and Urban Planning 44:77-85.

Forman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology 14:31-35.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-+.

Gagnon, J. W., T. C. Theimer, N. L. Dodd, A. L. Manzo, and R. E. Schweinsburg. 2007. Effects of traffic on elk use of wildlife underpasses in Arizona. Journal of Wildlife Management 71:2324-2328.

Gibbons, J. W. 1990. The Life History and Ecology of the Slider Turtle. Smithsonian Institution Press. Washington D.C., 367 pp.

Gibbons, J. W., and J. W. Coker. 1977. Ecological and life history aspects of the cooter, *Chrysemys floridana* (Le Conte). Herpetologica 33:29-33.

Gibbons, J. W., and J. E. Lovich. 1990. Sexual dimorphism in turtles with emphasis on the slider turtle (*Trachemys scripta*). Herpetological Monographs 4:1-29.

Gibbs, J. P., and G. Shriver. 2002. Estimating the effects of road mortality of turtle populations. Conservation Biology 16:1647-1652.

Gibbs, J. P., and D. A. Steen. 2005. Trends in sex ratios of turtles in the United States: implications of road mortality. Conservation Biology 19:552-556.

Grosmaire, E. K. 1977. Aspects of the natural history of freshwater turtles within the Lower Rio Grande Valley of Texas. Thesis, Texas A&M University, College Station, Texas, USA.

Ingold, D. A., and W. E. Patterson. 1988. Population parameters and red-eared turtles in a Texas farm pond. Bull. Maryland Herpetological Society 24:27-40.

Langen, T. A., K. M. Ogden, and L. L. Schwarting. 2009. Predicting Hot Spots of Herpetofauna Road Mortality Along Highway Networks. Journal of Wildlife Management 73:104-114.

Marchand, M. N., and J. A. Litviatis. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18:758-767.

Marchand, M. A., J. A. Litvaitis, T. J. Maier, and R. M. DeGraaf. 2002. Use of artificial nests to investigate predation on freshwater turtle nests. Wildlife Society Bulletin 30:1092-1098.

Morreale, S. J., and J. W. Gibbons. 1986. Habitat suitability index models: slider turtle. Fish and Wildlife Service. U. S. Department of the Interior. Biological Report 82:10.125.

Morreale, S. J., J. W. Gibbons, and J. D. Congdon. 1984. Significance of activity and movement in the yellow-bellied slider turtle (*Pseudemys scripta*). Canadian Journal of Zoology 62:1038-1042.

Ney, J. J. 1999. Practical Use of Biological Statistics. Pages 167-191 in C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Parker, W. S. 1984. Immigration and dispersal of slider turtles *Pseudemys scripta* in Mississippi farm ponds. American Midland Naturalist 112:280-293.

Ream, C., and R. Ream. 1966. The influence of sampling methods on the estimation of population structure in painted turtles. American Midland Naturalist 75:325-338.

Rose, F. L., and R. W. Manning. 1996. Notes on the biology of the slider, *Trachemys scripta elegans* (Reptilia: Emydidae), inhabiting man-made cattle ponds in west Texas. Texas Journal of Science 48:191-206.

Rosen, P. C., and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68:143-148.

Schultz, A. D., 2010. Inferring population changes of freshwater turtles in south Texas. Thesis, Texas State University-San Marcos, San Marcos, Texas, USA.

Schwabe, K. A., and P. W. Schuhmann. 2002. Deer-vehicle collisions and deer value: an analysis of competing literatures. Wildlife Society Bulletin 30:609-615.

Steen, D. A., and J. P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143-1148.

Steen, D. A., M. J. Aresco, S. G. Beilke, B. W. Compton, E. P. Condon, C. K. Dodd, Jr., H. Forrester, J. W. Gibbons, J. L. Greene, G. Johnson, T. A. Langen, M. J. Oldham, D. N. Oxier, R. A. Saumure, F. W. Schueler, J. M. Sleeman, L. L. Smith, J. K. Tucker, and J. P. Gibbs. 2006. Relative vulnerability of female turtles to road mortality. Animal Conservation 9:269-273.

Sokal, R. R., and F. J. Rohlf. 2003. Biometry: the princinples and practice of statistics in biological research, 3rd edition. W. H. Freeman and Company, New York.

Szerlag, S., and S. P. McRobert. 2006. Road occurrence and mortality of the northern diamondback terrapin. Pages 27-37 *in* Applied Herpetology. Brill Academic Publishers.

Thomas, R. B., N. Vogrin, and R. Altig. 1999. Sexual and seasonal differences in behavior of *Trachemys scripta* (Testudines: Emydidae). Journal of Herpetology 33:511-515.

U. S. Census Bureau. 1992. Intercensal Estimates of the Resident Population of States and Counties. < http://www.census.gov/popest/archives/1980s/>. Accessed 12 Aug 2009.

U. S. Census Bureau. 2008. Annual Estimates of the Population for Counties of Texas: April 1, 2000 to July 1, 2007 (CO-EST2007-01-48). < http://www.census.gov/popest/archives/2000s/>. Accessed 12 Aug 2009.

Vos, C. C., and J. P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog Rana arvalis. Journal of Applied Ecology 35:44-56.

VITA

Brian Erik Dickerson was born 11 July 1980 to Bill and Debby Dickerson in Crown Point, Indiana. He graduated from La Porte High School in 1998 and then joined the U.S. Navy. His primary duty station was aboard the USS Port Royal home ported in Pearl Harbor, Hawaii. Brian received a A.S. in Biology from Blinn College and a B.S. in Wildlife & Fisheries Sciences from Texas A&M University in 2009. He entered the Graduate College of Texas State University-San Marcos in the summer of 2009. During the summer of 2010 Brian was selected for a U.S. Fish & Wildlife Service internship at the McFaddin and Texas Point NWR's.

Permanent email: dickersonbrian@yahoo.com

This thesis was typed by Brian Erik Dickerson.