SITE SELECTION AND SURVIVAL OF *PSEUDEMYS TEXANA* AND *TRACHEMYS SCRIPTA ELEGANS* NESTS AT SPRING LAKE IN SAN MARCOS, TEXAS

THESIS

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SITE SELECTION AND SURVIVAL OF *PSEUDEMYS TEXANA* AND *TRACHEMYS SCRIPTA ELEGANS* NESTS AT SPRING LAKE IN SAN MARCOS, TEXAS

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Dedication

To my grandmothers, Catherine and Inez.

ACKNOWLEDGMENTS

I would like to give special thanks to everyone who contributed to the completion of this project and the quality of my experience while pursuing my graduate degree.

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ABSTRACT

SITE SELECTION AND SURVIVAL OF *PSEUDEMYS TEXANA* AND *TRACHEMYS SCRIPTA ELEGANS* NESTS AT SPRING LAKE IN SAN MARCOS, TEXAS

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Turtle eggs and embryos may succumb to a variety of causes of mortality, including vertebrate and invertebrate predators. Characteristics of nest sites selected by turtles may influence survival of offspring. Spring Lake in San Marcos, Hays County, Texas supports several native, non-native, and endangered species. It also serves as an educational and recreational area. This study investigated the survival and causes of mortality of the eggs of Texas river cooters (*Pseudemys texana*) and red-eared sliders (*Trachemys scripta elegans*) at Spring Lake. A total of 122 nests were monitored during the 2006 and 2007 nesting seasons. Random nests were protected from vertebrate predators and excavated approximately 70 days after oviposition to determine hatchling success, while others were not protected from predation. Combined data from both years reflected a 59.21% (n = 45) predation rate by raccoons on unprotected nests. After excavation, 45.65% (n = 21) of protected nests yielded live hatchlings, 45.65% (n = 21) were unsuccessful, and 8.7% (n = 4) were false nests. Protected nests that were unsuccessful were a result of excessive water (rainfall), desiccation, or various other causes including incomplete development and ants. Six parameters (distance from water, distance from nearest tree, distance from nearest man-made structure, substrate, slope, direction of slope in relation to water, and canopy cover) were recorded from 60 nest sites and 60 random non-nest sites. A MANOVA of these data suggested that nest-site selection did occur ($P < 0.0001$). Principal Components Analysis (PCA) suggested that distance from water was the principal component in nest-site selection. These data suggest that raccoon predation and moisture-related factors are the primary causes of mortality of turtle nests at Spring Lake.

CHAPTER I

INTRODUCTION

Texas river cooters (*Pseudemys texana*) and red-eared sliders (*Trachemys scripta elegans*) are fresh water turtles commonly found in central Texas (Conant and Collins, 1998). These species are found in rivers, lakes and other fresh water areas with plentiful vegetation (Vermersch, 1992; Conant and Collins, 1998). Red-eared sliders and Texas river cooters produce clutches of 4-19 eggs (Vermersch, 1992; Marlen and Fischer, 1999; Iverson, 2001; Lindeman, 2007) and are capable of producing several clutches per year (Vermersch, 1992; Tucker, 2001;).

Raccoons, red foxes (*Vulpes vulpes*), striped skunks (*Mephitis mephitis*), gulls (*Larus atricilla*) and crows (*Corvus brachyrhynchos*) are common vertebrate predators of turtle eggs and hatchlings in North America (Burger, 1977; Feinberg and Burke, 2003; Aresco, 2004). Raccoons are an aggressive turtle nest predator, predating over 90% of turtle nests within 48 hours of oviposition (Feinberg and Burke, 2003; Butler et al., 2004). They maintain consistent predation pressure even outside of peak nesting season (Wilhoft et al., 1979). Raccoon predation has impacted Florida loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and green turtles (*Chelonia mydas*), which are endangered (Engemann et al., 2005). Secondary effects of their depredation include exposing nests to environmental elements such as extreme temperatures and making remaining eggs more accessible to other predators including birds and smaller mammals (Engemann et al., 2005). Conservationists resorted to trapping, euthanasia, and other predator control methods to protect these threatened turtle populations (Engemann et al., 2005). Freshwater turtles utilize areas near ponds or rivers for nesting (Baldwin et al., 2004). This may reduce female and hatchling mortality by reducing travel distance to water. However, in some areas raccoons are observed concentrating foraging efforts near pond edges, where nests may be abundant (Marchand and Litvaitis, 2004).

In addition to vertebrate predators, invertebrates may also predate turtle nests. The red imported fire ant (*Solenopsis invicta*) from South America is an omnivorous invasive invertebrate species introduced to the United States via Alabama in the 1930's (Callcott and Collins, 1996; Wojcik et al., 2001). They spread from Alabama throughout the Southeastern United States (Wetterer and Moore, 2005). Their presence has been detrimental to vertebrate and invertebrate species through competition and predation (Callcott and Collins, 1996). Fire ants compete with native ant species and other invertebrates (Parris et al., 2002). They also prey upon mammals, birds, reptiles and amphibians (Wojcik et al., 2001). Mount et al. (1981) reported a decrease in populations of the six-lined racerunner (*Cnemidophorus sexlineatus*) after the introduction of fire ants. Holway et al. (2002) suggested that ant invasions may lead to declines in vertebrate populations, namely those whose young emerge from eggs. Loggerhead sea turtles emerging from nests invaded by fire ants had a lower success rate than those not invaded (Moulis, 1996). Ant presence was detected in failed bird and reptile nests, although it is unknown if ants were the direct cause of nest failure (Holway et al., 2002). Fire ants are attracted to sources of proteins, sugars, lipids, and moisture found in eggs (Wojcik et al., 2001). Previous studies reported fire ant predation on eggs and hatchlings of gopher tortoises (*Gopherus polyphemus*), loggerhead sea turtles (*Caretta caretta*), green turtles (*Chelonia mydas*), and sliders (*Trachemys scripta*) (Holway et al., 2002; Parris et al., 2002). Holway et al. (2002) suggested that fire ants were responsible for the decline of hognose snake populations in the southeastern United States.

Buhlmann and Coffman (2001) provided evidence of fire ant predation of *T. scripta* eggs and hatchlings. Predation in nests occurred on hatchlings completely out of the egg and on pipped eggs- those that were opened, but hatchlings had not emerged (Allen et al., 2004). Fire ants were reported as being unable to penetrate intact eggshells (Allen et al., 2001; Buhlmann and Coffman, 2001; Allen et al., 2004). However, evidence suggests that they penetrate eggs at Aquarena Center (F. Rose, personal communication, 2006). Both Texas river cooters and red-eared sliders initiate egg deposition during the warm spring months, coinciding with fire ant brood production (Wojcik et al., 2001; Aresco, 2004). Fire ants colonize in open, sunlit areas where the canopy has been disturbed by agriculture, vehicular traffic, or some form of development. These open areas also serve as nesting sites for freshwater turtles (Buhlmann and Coffman, 2001). Fire ant foraging behavior includes the creation of foraging tunnels several centimeters below the soil surface, a strategy that would make turtle nests ideal targets (Markin et al., 1975). Ants have no distinct foraging pattern. However, they are more likely to raid nests adjacent to nests that have already been predated than nests that are isolated from predated nests (Kopachena et al., 2000).

Characteristics of nest sites selected by fresh water turtles can have a pronounced impact on offspring survival and fitness (Kolbe and Janzen, 2002b). Female turtles contribute a low level of parental investment; however, maternal decisions may impact offspring incubation time, embryo size, hatchling fitness, and clutch sex-ratio (Gibbons, 1990; McGehee, 1990; Kam, 1994; Packard, 1999; Kolbe and Janzen, 2002b). Incubation time and sex-ratio are influenced by nest temperature (Janzen, 1994; Kam, 1994). Nest temperature may be influenced by the amount of canopy cover and the level of moisture at the nest site (Janzen, 1994; Kolbe and Janzen, 2002b). The slope of a nest site may impact the amount of water the nest receives. When traveling on land during nesting season, females face a trade off between nesting close to the [water] edge, risking nest predation, and nesting farther from the edge, risking offspring predation or desiccation (Kolbe and Janzen, 2002a). Kolbe and Janzen (2002a) found a negative correlation between distance from water edge and probability of nest predation. Some turtles exhibit gregarious behavior when choosing nest sites and deposit eggs close to the water's edge. This creates an easy target for vertebrate nest predators (Baldwin et al., 2004). However, Robinson and Bider (1988) found no correlation between distance from water and nest survival. Habitat fragmentation and human land use may involve increased road construction in turtle habitat. Turtles may encounter roads while searching for food, water, breeding or nesting sites (Szerlag and McRobert citing Ashley and Robinson, 1996). Road mortalities can decrease a local turtle population. It may also contribute to skewed sex ratio, as females are lost while nesting (Szerlag and McRobert, 2006). Previous studies have indicated that red-eared sliders display a degree of nest-site fidelity and stress the importance of a female's ability to return to these sites (Tucker, 2001). It is important to consider if human disturbance prevents females from returning to nest sites.

Previous studies on the turtles at Spring Lake, Hays County, Texas focused on population composition and food habits (Fields et al., 2003; Swannack and Rose, 2003). The survival and causes of mortality have yet to be investigated. It has yet to be determined if nest-site selection occurs in the area around Spring Lake, a habitat that experiences extensive human disturbance. The objectives of my research were: a) examine the mortality of the eggs of Texas river cooters and red-eared sliders in the area around Spring Lake; b) determine the percentage of nests that are depredated and the time frame in which vertebrate predation occurs; c) assess the number of eggs and/or hatchlings that succumb to other causes of mortality, including desiccation and invertebrate predation; d) determine if nest-site selection occurs in the area around Spring Lake; and e) determine the principal component of site selection. This information will contribute to understanding the biotic and abiotic factors that impact turtle populations at Spring Lake.

CHAPTER II

STUDY SITE

The study site was Spring Lake in San Marcos, Hays County, Texas. Spring Lake is an ~8 ha reservoir formed by the damming of the San Marcos River in 1849 (Lemke, 1989). San Marcos River was formed by the output of several springs along the Balcones fault (Lemke, 1989; Swannack and Rose, 2003). The river is fed by San Marcos Springs, the second-largest spring system in Texas and flows southeastward to join the Guadalupe River in Gonzalez County, Texas (Lemke, 1989). Spring Lake supports a variety of organisms including native and non-native flora and fauna. Several threatened and endangered species inhabit Spring Lake. Fountain darters (*Etheostoma fonticola*), Texas blind salamanders (*Eurycea rathbuni*), San Marcos gambusias (*Gambusia georgei*) and Texas wild rice (*Zizania texana*) are listed as both state and federally endangered species. San Marcos Salamanders (*Eurycea nana*) are listed as threatened (United States Geological Survey 1997). The area is home to abundant populations of Texas river cooters, red-eared sliders, and snapping turtles (*Chelydra serpentina*) (Swannack and Rose, 2003). Aquarena Center, a facility on Spring Lake owned by Texas State University-San Marcos, is used as an educational facility to educate the public about wildlife with an emphasis on wetland ecology. A lentic backwater of the lake, known as the slough, is surrounded by a nine-hole golf course. Disturbances in vegetation caused by the golf course, walk-ways, and roads to the facility make the area around the slough suitable for ant colonies and turtle nests. The study site was divided into four quadrants by a road that divides the golf course (Laurel Ridge) and the slough (Figure 1). Data were collected from these four quadrants.

Figure 1. Aerial image of four quadrants (A, B, C, and D) surrounding slough of Spring Lake. Image provided by Chris Reynolds, facilities inventory coordinator at Texas State University-San Marcos.

CHAPTER III

MATERIALS AND METHODS

During the spring (March through May of 2006), Aquarena Center was monitored weekly for nesting activity marking the beginning of the nesting season. Nesting season began when numerous females were observed out of the water on consecutive visits. Consistent nesting activity began in May. May through August of 2006 and 2007, the study site was visited about three times per week. Most monitoring was conducted between 0800 and 1300 hours, when temperatures were moderate. Each visit, each quadrant (Figure 1) was monitored for nesting females and recently deposited nests. If nesting behavior was witnessed, the turtle was scanned with minimum disturbance for a passive integrated transponder (PIT) tag in the right forelimb. Identification numbers of PIT tagged females were recorded.

Survival

All nests were monitored for evidence of predation by raccoons (Figure 2). Depredated nests were recorded and marked with florescent spray paint to avoid duplicate nest counts. Random nests were covered with approximately 30 X 30cm hardware cloth secured to the ground with metal spikes to protect the nests from raccoons (Figure 3). Approximately 70 days after oviposition, protected nests were excavated and examined. Excavated nests were examined for degree of development, evidence of ant predation, desiccation, and/or water-related damage. Data collected from intact nests were total number of offspring present, number of live hatchlings, and number of dead individuals (if determinable).

Nest-Site Selection

In 2006, various nest site parameters were collected. These parameters were distance of nest from water (DW), distance from nearest tree (DT), distance from nearest man-made structure (DS). In addition, substrate (SUB), slope (SL), direction of slope (DSL) (in relation to water), and canopy cover (CC) were recorded. The time of day, air temperature, soil temperature (within six inches of new nests) and relative humidity were also noted at times when nesting behavior was witnessed. These values were recorded while turtles were excavating nests and depositing eggs.

Six parameters (DW, DT, DS, SL, DSL, and CC) were also collected from random waypoints at Spring Lake. The random points were generated using ArcGis. A polygon map was used to ensure that these points occurred in areas where nesting was possible (i.e. out of the water).

A multivariate analysis of variance (MANOVA) was performed to compare five parameters, DW, DT, DS, SL, CC (DSL excluded), from nest and non-nest sites. A t-test was performed to compare slope direction between nest sites and the random sites. A t-test was also performed to compare the distance from water of depredated and non-depredated nests. A Principal Components Analysis (PCA) was performed to determine which parameter was the principal component of nest-site selection. All analyses were performed using “R”.

Figure 2. Image of nest after raccoon predation. Note small entry hole and scattered egg shells indicative of raccoon predation.

Figure 3. Image of nest protected from raccoon predation. Metal hardware cloth (30 X 30cm) secured to the ground with metal spikes.

CHAPTER IV

RESULTS

Survival

A total of 122 nests were monitored between the 2006 and 2007 nesting seasons. In 2006, 68 uncovered nests were monitored for predation. Of these nests, 45 (68.18%) were depredated by raccoons. Nests with small holes (~10cm) giving access to eggs and scattered eggshells were indicative of raccoon predation. Most predation (>50%) occurred within two days of oviposition (Table 1).

Table 1: *Procyon lotor* predation of *Pseudemys texana* and *Trachemys scripta elegans* nests at Spring Lake in Hays County, Texas.

Time after oviposition	Number of nests	Percentage of Depredated nests
1 day	16	35.55%
2 days	7	15.55%
3 days	3	6.67%
4 days	4	8.89%
5 days	8	17.78%
>5 days	7	15.55%

Twelve nests were protected from vertebrate predation in 2006. Seven (58.33%) nests yielded live hatchlings. Four (33.33%) nests were unsuccessful, yielding undeveloped or dead offspring. In 2007, eight uncovered nests were monitored for vertebrate predation. None were depredated. Thirty-four nests were protected from vertebrate predation. Fourteen (41.18%) nests yielded live hatchlings and 17 (50%) were unsuccessful. Combined data between both years reflect a 59.21% (n = 45) predation rate in open and unprotected nests. Over two seasons, 46 nests were protected. After excavation, 21 (45.65%) of protected nests yielded live hatchlings and 21 (45.65%) were unsuccessful.

Protected nests that were unsuccessful were a result of excessive water (rainfall), desiccation, or various other causes including incomplete development and ants. After excavation, some nest sites were determined to be "false nests". False nests occurred when nesting activity was observed, but oviposition did not occur. A small percentage of excavated nests, 8.89% (n = 4), were determined to be false (Table 2).

Table 2: *Pseudemys texana* and *Trachemys scripta elegans* nest success at Spring Lake in Hays County, Texas.

	2006	2007	Total
Unprotected	(n = 68)	(n = 8)	
Depredated by raccoons	45	0	45
Protected	(n = 12)	(n = 34)	
Live Hatchlings	7	14	21
Dead Eggs/Embryos	4	17	21
False Nest	1	3	4
Total Observed	80	42	122

Nest-Site Selection

Nesting activity was not observed during visits to Spring Lake in the late afternoon or early evening. Also, visits to Spring Lake on two consecutive days did not result in new nest discoveries on the second day, which suggests turtles only deposit nests during the day. Time of nesting activity is known for 54 turtles. Air temperature, soil temperature, and relative humidity were recorded during the depositing of these nests. Air temperature ranged from 23.9° to 35.2° C (mean ± SD = 30.69 ± 2.49°C, n = 54). Relative humidity ranged from 29.8% to 74.3% (mean ± SD = 51.74 ± 9.77%, n = 54). Soil temperature was taken within 6 inches of new nests. Soil temperature ranged from 21.9° to 28.3°C (mean ± SD = 23.93 ± 1.47, n = 49).

Six parameters of nest sites (DW, DT, DS, SL, DSL, and CC) were collected from 60 nests from the 2006 nesting season and 60 random non-nest sites. Distance of nests from water ranged from 14.63 to 153.63m (mean ± SD = 84.04 ± 38.76m, n = 62). Distance of nests from nearest tree ranged from 0.61 to 38.12m (mean ± SD = 7.04 ± 6.49m, n = 88). Distance of nests from nearest man-made structure ranged from 0 to 50.29m (mean ± SD = 11.91 ± 14.9, n = 85) (Table 3). The majority of the man-made structures at Spring Lake were paved roads for vehicles and sidewalks and trails for pedestrians and golf carts. Slope of the nest sites ranged from 0 to 15° (mean ± SD = 3.94 ± 3.59°, n = 85). The direction of the slope of the nest in relation to water was recorded for 85 nests. Of these nests, most (n = 37) sloped toward the water (Table 4). Canopy cover of nest sites ranged from 0 to complete cover (Table 5). The average canopy cover was 47.11% cover (N = 87). Nineteen nests had no cover and 10 nests had complete cover. Most turtles nested on grass (Table 6). Turtles also nested on bare soil and substrate that were mixes of grass, bare soil and/or mulch. Between the two seasons, 81.61% of nests were located in grass (N = 136).

Table 3: Distance parameters of nest sites at Spring Lake.

Parameter	Mean(m) (SD)	Range(m)	n
Distance to water	84.04 (38.76)	14.63 - 153.63	62
Distance to nearest tree	7.04 (6.49)	0.61 - 38.12	88
Distance to nearest structure	11.91 (14.9)	0.00 - 50.29	85

Table 4: Nest site slopes at Spring Lake.

Slope direction	Number of nests	Percentage of nests
Towards water	37	43.53%
Away from water	23	27.06%
No slope	25	29.41

Table 5: Nest site canopy covers at Spring Lake.

Canopy cover	Number of nests	Percentage of nests
0-25%	31	35.63
25.1-50%	13	14.94
50.1-75%	19	21.84
75.1-100%	23	26.44

Table 6: Nest site substrates at Spring Lake

Substrate	Number of nests		Percentage of total nests
	2006	2007	
Grass	67	44	81.62%
Bare soil	6	3	6.62%
Mix	15	1	11.76%

A MANOVA that compared five parameters (DW, DT, DS, SL, and CC) suggested that there are significant differences between nest sites and random points ($P < 0.001$). A t-test comparing slope direction suggested that there is no difference between nest sites and random points ($t = 1.534$, $df = 113$, $p = 0.1276$). A Principal Components Analysis (PCA) of the previously mentioned five parameters of nest sites suggested that distance from water was the principal component, and was responsible for 82.37% of the variation among nest sites. A t-test was performed to compare distance from water of depredated nests to non-depredated nests from 2006. No significant difference was found ($t = 0.0151$, $p = 0.988$).

CHAPTER V

DISCUSSION

Survival

All vertebrate predation occurred after nests were completed and covered. Most vertebrate predation occurred at night. There was no evidence of mammals or birds taking eggs during oviposition. Each year, one nest was observed complete with eggs but uncovered. It is likely that the female(s) abandoned these nests due to human disturbance. The high raccoon predation rate observed agrees with previous studies (Feinberg and Burke, 2003). Prompt predation (within two days of oviposition) agrees with the findings of Burke et al. (2005). No raccoon predation was observed in 2007. It is unknown if there was a decrease in the raccoon population or in nest predation efforts.

Unsuccessful protected nests that were a result of desiccation, excessive water (rainfall), invertebrate predators (fire ants), and developmental problems. In 2006, desiccation was a common cause of death in both eggs and hatchlings. Hays County, Texas experienced a drought for several years. The average rainfall for the three seasons prior to this study was less than seven centimeters. The average rainfall for the 2006 nesting season was five centimeters, similar to that of previous years (Table 7). Parts of the area around Spring Lake were irrigated with a sprinkler system, mainly the fairways and greens of the golf course. Other areas were maintained by keeping grass short, but were not irrigated.

Water impacts embryo incubation time, development and survival (Gibbons, 1990; McGehee, 1990; Packard, 1999). Water from the environment is absorbed through the eggshell and contributes to egg mass. Moist environments yield larger embryos (Gibbons, 1990). High levels of moisture also contribute to the fitness of hatchlings as dehydrated turtles are unable to perform as well in tests of performance as turtles with higher levels of hydration (Packard, 1999). Although water is essential for embryo development, excess water can be detrimental. Eggs that are exposed to excess water for relatively brief periods absorb water in amounts that are beneficial to the embryo. However, eggs exposed to excess water for extended periods, as during flooding, might suffer mortality (Kam, 1994). During the 2007 nesting season, Spring Lake experienced an unusually large amount of rainfall (Table 7). The rainfall average was 12.6 centimeters for this season. During the peak of the nesting season, Spring Lake experienced heavy flooding to a degree that resulted in standing water on the roads and on potential nest sites. Although access to Spring Lake was limited during this time due to road closures, a decrease in nesting activity was observed.

Excessive rainfall appeared to have contributed to the mortality of several nests. Excavated nests yielded turgid eggs that absorbed large amounts of water and unsuccessful eggs covered in mold. High moisture levels are favorable for fungal growth, especially when embryos are already deceased (McGehee, 1990). It has not been determined if fungi cause mortality or if fungal growth occurs after eggs/embryos succumb to some other cause of death (McGehee, 1990). Excess water also seemed to increase incubation time, which agrees with the findings of Kam (1994). During the 2006 season, excavation began as early as 65 days after oviposition. All surviving hatchlings were fully hatched at that time. In 2007, the first two excavation attempts occurred approximately 70 and 77 days after oviposition, respectively. The first nest displayed a collection of turgid eggs. The soil was replaced to allow more incubation time, but all eggs failed to develop. The second nest also had extremely turgid eggs and two underdeveloped hatchings that still had yolks attached. The smaller of the two offspring died before the excavation and appeared to have pipped before it was fully developed. The larger of the two offspring survived after being incubated in a lab. The eggs from this nest were also incubated in a lab but did not survive. Since the high levels of rainfall that occurred in 2007 were unusual for Hays County, Texas, it is assumed that these water-related mortalities are uncommon as well.

Table 7: Rainfall (cm) during turtle nesting season (May –August) in Hays County, Texas for 2003-2007.

Month	2007	2006	2003-2005(avg)
May	11.23	7.19	5.54
June	11.35	6.17	13.61*
July	23.90	5.41	5.71
August	3.99	1.47	3.07

* *June of 2004 received an unusually high level of rainfall (10.39 cm).*

There were fire ants in several excavated nests both with and without live hatchlings. Nests with live hatchlings had fewer ants than unsuccessful nests. Some unsuccessful nests with ants also displayed evidence of desiccation or water damage. Whether invertebrate predation or moisture-related factors were the direct cause of mortality was undetermined (Figure 4). Ants may have consumed the contents of eggs that were already destroyed by other factors. It is also possible that the ants pipped the eggs to consume the embryos and weather-related factors damaged the remains after this predation. Although ants were present in excavated nests, they did not appear to contribute significantly to offspring mortality.

Figure 4. Image of unsuccessful eggs. Cause of death unknown.

Nest-Site Selection

All nesting behavior was observed from morning until late afternoon. There was no evidence of nocturnal nesting behavior. Grass was the most common substrate for the nest sites. Grass is also the most prevalent substrate at Spring Lake. Other substrates used were bare soil and mulch, mulch being the least used. Mulch may have been undesirable due to consistent human disturbance from landscaping maintenance. The gravel substrate that comprised the walking trails seemed to be too compacted for females to penetrate. As previously mentioned, some of the grass was irrigated. However, no data were collected to determine if nests were placed in irrigated areas more frequently than non-irrigated areas, or if nests placed in irrigated areas were more successful.

PCA analysis suggested that distance from water was the principal component in nest-site selection. Kolbe and Janzen (2002a) suggest that probability of nest predation decreases as distance from water increases. This probability leveled off at 25m, 35m, and 40m, depending on the year. The mean nest distance from water observed at Spring Lake was 84 meters. When comparing depredated nests to non-depredated nests from 2006, there is no significant difference in distance from water. However, this analysis was conducted after eliminating data of nests that were protected from predation, making the sample size small and the results unreliable. Future studies may determine if water distance impacts probability of nest predation. This may be a maternal investment strategy that impacts offspring survival at Spring Lake. This would be significant because the amount of land suitable for nesting is limited. The area east of the lake is bordered by fencing and a 4-lane roadway (Aquarena Springs Drive). The area west of the lake has buildings and parking areas, but may be by-passed by females. The land beyond this area is wooded and has significantly less human disturbance. Although this study determined distance from water to be the principal component in nest-site selection, there may be more significant characteristics that were not measured in this study. There may also be more significant spatial characteristics that influence vertebrate predation at Spring Lake.

Observed nests displayed approximately 50% canopy cover on average. However, when broken into four categories, the category with the largest number of nests was that of nests that had 0-25% canopy cover. Nineteen nests had no cover. Freshwater turtles often place nests in "areas that are exposed to full sunlight during some portion of the day" (Gibbons, 1990). It seems that this higher occurrence of low to no canopy cover is due to human disturbance. A considerable amount of the trees at Spring Lake have been altered and/or removed to accommodate the golf course. Previous studies have found correlations between canopy cover and nest temperature. Nests with less shade have higher temperatures (Kolbe and Janzen, 2002a). Both the Texas river cooter and red-eared slider display temperature-dependant sex determination.

At Spring Lake, adult turtles were observed away from the water only during the nesting seasons, so it was assumed that only females travel on land. Turtles that were basking were observed on floating logs or on the water edges. Males do not need to travel on land to bask or to find food and therefore do not risk succumbing to road mortality as often as females. Two turtles were witnessed killed by cars during field observations. Both the decreased canopy cover and the frequent vehicular traffic from human use of Spring Lake may influence the mortality of the turtle population at Spring Lake.

The data collected during this study support the conclusion that raccoons are the primary cause of mortality of turtle eggs in the area surrounding Spring Lake. Moisture-related mortality is also common. Desiccation appeared to be a common cause of mortality during the 2006 nesting season, when weather conditions were similar to recent years. The 2007 nesting season experienced an unusually high amount of rainfall. During this year several water-related mortalities were observed.

The extent to which invertebrate predation contributes to egg mortality is unknown. It has also been determined that nest-site selection does occur at Spring Lake. Of the nest site parameters measured, distance from water was determined to be the principal component. Futures studies must be conducted to evaluate the impact that human disturbance has on nest-site selection and the sex-ratio of the turtle population in the area. The human population of Central Texas is steadily increasing. It is important to understand the current state of turtle populations and the impact that human activity has on them to prepare for future conservation efforts.

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