

REPRODUCTIVE PATTERNS OF TEXAS RIVER COOTERS (*PSEUDEMYS
TEXANA*) AND RED-EARED SLIDERS (*TRACHEMYS SCRIPTA ELEGANS*) AT
SPRING LAKE, HAYS
COUNTY, TEXAS

THESIS

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by

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ABSTRACT

REPRODUCTIVE PATTERNS AND APPLICATION OF OPTIMALITY MODELS
TO TEXAS RIVER COOTERS (*PSEUDEMYX TEXANA*) AND RED-EARED
SLIDERS (*TRACHEMYS SCRIPTA ELEGANS*) AT SPRING LAKE, HAYS
COUNTY, TEXAS

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Chelonians are considered the most prolific amniote group, with some species laying up to 1000 eggs per year and nesting more than once during a single nesting season. Turtles have been used to test and developed optimality models predicting the strategy of maternal investment that will maximize maternal fitness within a population. Turtles are also ideal organisms for assessing the relationship of body size/body condition and reproductive fitness. I studied reproductive patterns of two species of emydid freshwater turtles, Texas river cooters (*Pseudemys texana*) and red-eared sliders

(*Trachemys scripta elegans*) at Spring Lake, Hays County, Texas during the 2009 nesting season, where I followed nesting turtles. After a female nested, I measured her plastron

length, carapace length, carapace width, and determined her mass. Eggs were taken to Texas State University-San Marcos laboratory, where I measured egg length, egg width, and determined egg mass. I used simple linear regression to assess correlations between female body size (plastron length) and reproductive parameters (mean egg mass, mean egg length and width, mean clutch size and mass, and nest distance from water).

Phenotype-habitat matching theory. (predicting increasing reproductive parameters with increasing body size) was followed for most of the reproductive parameters. However, those parameters did not show strong fit of data to the model ($r^2 < 0.3$). I found 30 Texas river cooters and 9 red-eared sliders nesting twice in a single nesting season. I used paired t-tests to determine if clutch parameters (number of eggs, egg mass, total clutch mass) decrease with subsequent clutches laid during the same nesting season. Paired t-tests showed that mean egg mass, mean egg length and width decreased in subsequent clutches in Texas river cooters, but the sample size for red-eared slider ($n=9$) was too small to make conclusions. Possible explanations for the weak correlation of body size with clutch parameters might be genetics of the population, weather conditions, or food availability. Repeating this study for several years would help get better understanding of reproductive patterns in those two populations. Optimal Egg Size theory tests showed contradictory results; while red-eared sliders supported OES, Texas river cooters did not. Therefore, it remains challenging to choose the correct optimality model for chelonians.

CHAPTER I

INTRODUCTION

Chelonians are considered the most prolific amniote group, with some species laying up to 1000 eggs per year and nesting more than once during a single nesting season (Harless and Morlock, 1979). Because there is no parental care after laying, egg size and number have direct consequences on hatchling survival. Therefore, female investment in an offspring is closely represented by the energy content in each egg, and egg size is directly related to hatchling survival (Congdon and Gibbons, 1987; Rowe, 1995). In addition, by multiple clutching, female turtles decrease the likelihood that the total reproductive output of one season will be consumed by a single predation event (Lee, 2007). Energy available for reproduction is finite: therefore, females partition their resources between egg size and number (Brooks and Rollinson, 2008). Turtles have been used as models to develop and test optimality models, predicting the strategy that will maximize maternal fitness within a population (Brooks and Rollinson, 2008). Turtles are also ideal for assessing relationships between body size/body condition and reproductive fitness (Litzgus and Mousseau, 2003).

Optimal egg size theory (OES) predicts that maternal fitness is enhanced by the production of the greatest number of optimally sized eggs, rather than by the production of bigger eggs (Litzgus et al., 2008). Litzgus et al. (2008) state that in small-bodied turtle species, the relationship between egg size and body size is confounded by the physical constraint imposed by the width of the pelvic girdle aperture and the size of the space

between the carapace and plastron through which the eggs must pass during oviposition. This means that egg width will be correlated with body size rather than egg length. Brooks and Rollinson (2008) hypothesized that individual egg mass will be more conserved than clutch size, meaning that clutch size, but not egg mass, varies with resource acquisition. Therefore, after removing the linear effect of body size, there would be no relationship between the absolute value of egg mass residuals (absolute difference between individual egg mass and mean egg mass) and body size, and the absolute value of clutch size residuals (absolute difference between individual clutch size and mean clutch size) should be positively correlated with body size. In addition, females that lay more than one clutch during a season should have smaller first clutches than females laying only one clutch, but individual egg mass should not differ (Brooks and Rollinson, 2008).

The phenotype-habitat matching concept states that female condition/size is correlated with reproductive parameters. For example, female phenotype, such as body size, influences nest site selection and, as a result, the environment for her hatchlings (Brooks and Rollinson, 2008). Consistent with this theory, Rowe (1994) found reproductive parameters (egg mass, clutch mass and clutch size) positively correlated with female body size in painted turtles (*Chrysemys picta bellii*). Also, assuming that larger females have more energy available, they can spend more time looking for optimal egg laying sites (nest greater distances from water), lay larger eggs and more eggs per nesting season (Rowe, 1994). If the trend of increasing reproductive parameters with increased female body size is followed, larger females would lay more clutches per season. However, that is not always the case. For example, no relationship was found

between female body size and clutch frequency in the yellow-bellied slider (*Pseudemys* = *Trachemys scripta*) and common mud turtle (*Kinosternon subrubrum*) (Gibbons et al., 1982). A study of southern spotted turtles (*Clemmys guttata*) had similar findings; clutch frequency was independent of body size (Litzgus and Mousseau, 2003).

Laying more than one clutch during a single nesting season is a common event in several taxa of freshwater turtles (Lee, 2007). Gibbons et al. (1982) studied clutch size and frequency in five species of freshwater turtles [yellow-bellied slider, common mud turtle, chicken turtle (*Deirochelys reticularia*), common musk turtle (*Sternotherus odoratus*), and Florida cooter (*Pseudemys floridiana*)], and concluded that all species but the Florida cooter laid two or more clutches per season. Southern spotted turtles also lay more than one clutch per season (Litzgus and Mousseau, 2003). Jackson and Walker (1997) concluded Suwannee cooter (*Pseudemys concinna suwanniensis*) may lay five or more clutches per year. Georges (1983) found that Australian freshwater turtles (*Emydura krefftii*) lay up to three clutches per season. There is variation in the number of clutches produced within the nesting season by turtles of the same species as well as the same genus (Wyneken et al., 2008). Several studies examined relationships among the size and shape of eggs, the number of clutches produced, and the size of the reproducing female, but the exact patterns/relationships between female body size and her reproductive output are still under investigation (Wyneken et al., 2008). In some species, such as yellow bellied sliders, Florida cooters, and common mud turtles, last clutches are smaller in number of eggs than clutches laid earlier (Gibbons et al., 1982). However, clutch size does not have to decrease with clutch number. In southern spotted turtles, the number of eggs in the second clutch is greater than that of the first (Litzgus and

Mousseau, 2003). For painted turtles (*Chrysemys picta*), first and second clutches are similar in size (Gibbons, 1982).

Nest site selection is an important life history factor for turtles. External environmental requirements, such as temperature, gas exchange, and moisture must be met for successful development of the embryo (Wyneken et al., 2008). Turtles use several environmental cues to select a nest site, such as slope, temperature, distance from water, substrate composition, moisture content (Wyneken et al., 2008). Because of high predation risk, nest site selection has consequences for population fitness (Spenser and Thompson, 2003). Spenser and Thompson (2003) found that nesting greater distances from water decreases the chances of predation. Multiple clutching also can be seen as a pattern for decreasing predation risk. Multiple clutching can be explained as an adaptive compromise for survival; separating clutches in time and space decreases risks of destroying eggs in one predation event (Harless and Morlock, 1979).

Clutch size and clutch frequency varies with latitude, with size increasing at higher latitudes and frequency increasing with decreasing latitude (Lee, 2007; Litzgus and Mousseau, 2003). Generally, because of longer nesting seasons at lower latitudes, turtles produce smaller clutches but deposit eggs more frequently (Lee, 2007). Clutch frequency also varies annually in individuals as well as in populations and therefore may be the key variable which controls overall annual reproductive output (Gibbons, 1982).

I focused this research on two species of emydid freshwater turtles, the Texas river cooter (*Pseudemys texana*) and red-eared slider (*Trachemys scripta elegans*). They are ubiquitous in Spring Lake and the San Marcos River, Hays County, Texas. Both

species are known to produce more than one clutch per single nesting season (Vincenzo, 2002).

The number of females laying two or more clutches is substantially smaller than those laying only one clutch during a single nesting season (Tucker, 2001). Tucker (2001) reported that 8.1% of female red-eared sliders nested twice while only 0.3% nested three times. Several authors reported data on reproductive output of the Texas river cooter, but I have not found any studies dealing with clutch frequency in this species (Lindeman, 2007; Rose et al., 1996).

Apart from optimality models, understanding relative reproductive output of individuals is fundamental to understanding the demography of a population (Broderick et al., 2003; Gibbons, 1968). Although my study will focus on two common species of freshwater turtles, the results will help define the general patterns in reproductive output of turtles that might be useful in turtle conservation and manipulation of harvest.

In my research, I addressed the following questions:

- 1) Do bigger females nest at greater distances from water?
- 2) Do distances from nest to water become shorter with subsequent nesting?
- 3) Is the number of clutches per season related to female size?
- 4) Are the clutch parameters (mean clutch size, mean egg size, and mean egg mass) related to female size?
- 5) Are clutch parameters smaller with subsequent laying?

By answering these questions, I explored the application of optimality theories to these species.

CHAPTER II

MATERIALS AND METHODS

Study Site

The study site was Spring Lake in Hays County, San Marcos, Texas (29°53'N, 97°55'W). The lake is an ~8 ha reservoir at the head waters of the San Marcos River. The lake, initially dammed in 1849, is fed by 200 springs that issue from Edwards Aquifer (Fields et al., 2003). In 1994, Spring Lake was acquired by Texas State University-San Marcos and now serves as an education and research center. The lake has a relatively constant physicochemical environment and supports a diverse and abundant aquatic macrophyte community (Lemke, 1989). Spring Lake provides habitat for numerous freshwater turtles, such as the common musk turtle (*Sternotherus odoratus*), common snapping turtle (*Chelydra serpentina*), Texas river cooter, and red-eared slider. Texas river cooters and red-eared sliders are commonly observed searching for nest sites and excavating nests in this area.

Spring Lake is composed of the main lake and the slough, a back water section of the lake (Figure 1). Turtles and nests for this research were collected primarily from the public golf course which surrounds the slough. The golf course provides suitable nesting habitat for turtles, and open conditions facilitate spotting turtles.

Methods

Although follicles of turtles laying multiple clutches tend to enlarge in groups (Harless and Morlock, 1979), previous studies showed that observing ovarian anatomy and recording enlarged follicles is not a reliable estimate of clutch frequency in freshwater turtles (Tucker, 2001). For example, Tucker (2001) overestimated clutch frequency of red-eared sliders using this model. Therefore, I followed female turtles as they emerged from the slough to nest.

Because nesting season usually starts in early spring and lasts throughout the summer, I visited the site every day from 1 April to 1 August 2009 searching for nesting turtles and collecting eggs for measurements. On 7 May 2009, I stopped collecting eggs from previously unobserved Texas river cooter females because of uncertainty that this was her first nesting attempt. Because of insufficient number of Red-eared slider females found nesting, I continued collecting eggs throughout the nesting season. Average time spent on the site was 8 hours/day (from 6-10 hours/day).

Most of the turtles were marked previously for ongoing research projects. Marking was done with passive integrated transponders (Gibbons and Andrews, 2004) and by notching marginal scutes of the carapace or engraving individual numbers on the plastron. Additionally, nesting turtles were marked temporarily with yellow spray paint on the carapace for easy visual recognition during subsequent nesting attempts. It is known that females have several failed nesting attempts before they successfully nest (Brooks and Rollinson, 2007). Therefore, I concluded that individuals laid more than one clutch if she was seen twice on the golf course more than 8 days apart (Brooks and Rollinson, 2007).

After nesting, I measured plastron length, carapace length, carapace width, and determined the mass of each female. I recorded GPS coordinates of the nest for determining nesting distances from water. Eggs were removed from the nest and carefully transported in zip-lock bags to a laboratory for measuring and incubating. I recorded egg length, egg width, egg mass, and number of eggs per clutch. After hatching, the young were released at Spring Lake.

I used paired t-tests to compare mean egg size, mean egg mass and mean number of eggs between first and second clutch. I used simple linear regression for estimating relationships between female body size and mean egg size, mean egg mass, mean clutch size, and mean nesting distance from water (Gibbons, 1990). Plastron length is a standard linear measurement of body size (Bowden et al., 2004); therefore, I used female plastron length as an indication of body size in all regression analysis. In addition, I used plastron length under assumption that pelvic aperture width increase as female body size increases (Rowe, 1994). For the females that laid more than once, I used the measurements of the first clutch in the regression analysis (Brooks and Rollinson, 2008). I used logistic regression to determine the relationship between female body size and clutch frequency. To test OES I used clutch size residuals and egg mass residuals (residuals are absolute differences between individual sample and sample mean) to assess relationship with female plastron length (Brooks and Rollinson, 2008). All statistical analysis was conducted using R program.

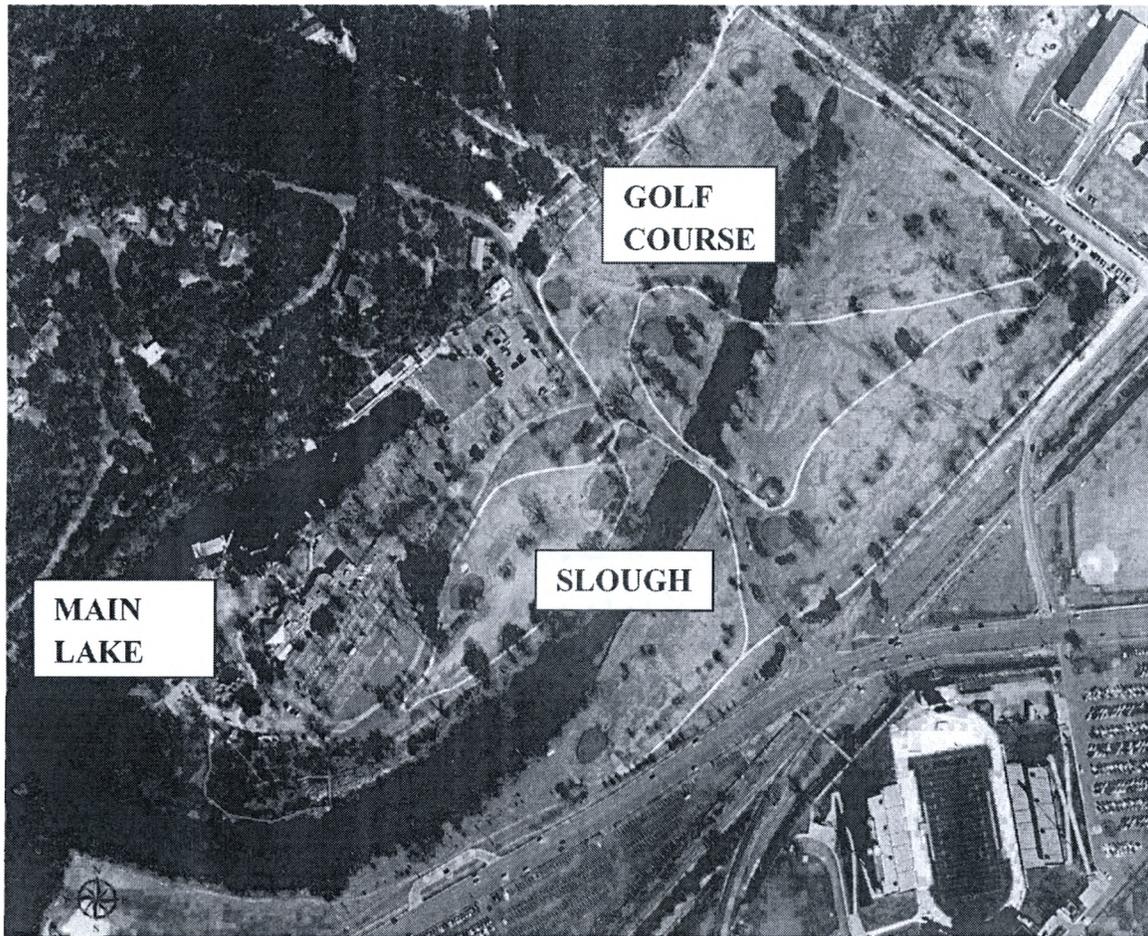


Figure 1. Aerial View of Spring Lake, the slough, and golf course

CHAPTER III

RESULTS

Texas River Cooter

From 1 April to 7 May, 2009, I collected the eggs of 82 female Texas river cooters that nested at least once. Of the 38 females (46%) that were found nesting more than once, 30 nested twice, five nested three times, two nested four times, and one nested five times. The first nesting female was found on 8 April 2009. The peak period for nesting was during the third through fifth week of the nesting season- late April to early May (Figure 2). The interesting period varied from 18 to 66 days. The means of the body size of nesting individuals as well as their reproductive parameters are given in Table 1.

Table 1. Characteristics of Nesting Texas River Cooters and Eggs

Characteristic	Min	Max	Mean (SD)	N
Female plastron length (mm)	197.0	280.0	255.8 (14.3)	77
Clutch mass	65.0	402.4	244.2 (72.0)	82
Clutch size	3.0	19.0	12.1 (3.4)	82
Egg mass (g)	14.3	24.8	20.2 (2.2)	82
Egg length (mm)	39.4	47.2	42.8 (1.6)	82
Egg width (mm)	24.6	30.5	28.5 (1.3)	82
Distance from water (m)	8.2	173.4	83.1 (38.3)	81

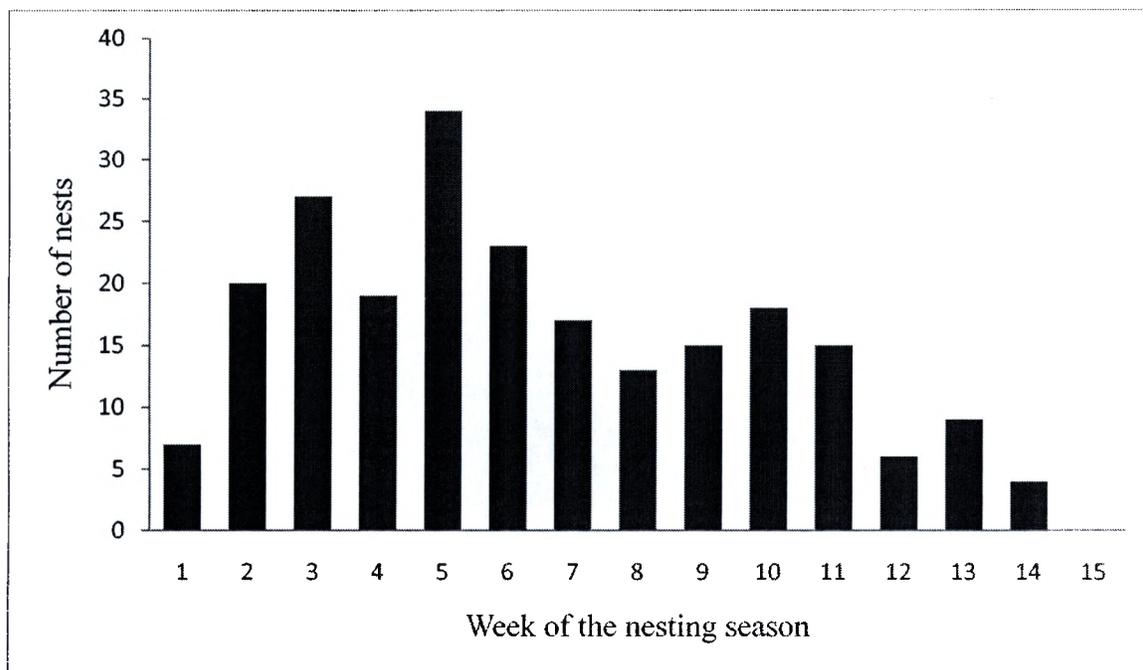


Figure 2. Distribution of Captures for Nesting Texas River Cooters during 2009 Nesting Season. Week one started on 8 April, when the first female was found nesting

In the regression analysis, there was one outlier female with plastron length being considerably smaller than others in the sample. Therefore, I reported results including and excluding the outlier (Table 2).

I found significant relationships between plastron length and clutch size and between plastron length and mean egg mass (Table 2.) In addition, there was a significant relationship between plastron length and mean egg width, but not between plastron length and mean egg length. There was no significant relationship between plastron length and nesting distance from water. However, none of the statistically significant regressions had strong relationships (Table 2)

Table 2. Relationships of Clutch Size, Clutch Mass, Egg Measurements, and Nest Distance from the Water with Female Body Size (Plastron Length) in Texas River Cooters at Spring Lake. Results with (N = 77) and without (N = 76) outlier are represented

Characteristic	N	r ²	p
Mean clutch size	77	0.1713	0.00018*
	76	0.1355	0.00011*
Mean clutch mass (g)	77	0.2438	0.00000*
	76	0.2044	0.00004*
Mean egg mass (g)	77	0.1142	0.00264*
	76	0.0891	0.00881*
Mean egg length (mm)	77	0.0344	0.10630
	76	0.0153	0.28710
Mean egg width (mm)	77	0.1999	0.00004*
	76	0.1687	0.00023*
Mean distance from water (m)	77	0.0392	0.08453
	76	0.0107	0.37470

* indicates significant results

When comparing clutch parameters of the first and the second clutch, paired t-tests were done twice for each parameter. In the first trial, I included all females (n=30) recorded as nesting twice. In the second trial, I included only the females (n=18) that had an interesting period ≤ 35 days. The second trial gave more conservative results because of the possibility that I missed the actual second clutch for females that had interesting period of ≥ 35 days. Females that laid more than twice were excluded from analysis. There was no significant difference between the two trials (Table 3). Also, two outliers were conspicuous in analysis. One female laid 11 eggs in the first clutch, but only one

egg in the second clutch. Another female laid three eggs the first time, but 20 eggs the second time.

Results showed mean egg mass, mean egg length, and mean egg width decreased significantly with subsequent laying while other reproductive parameters, including the distance from water to nest showed no difference between the first and the second clutches (Table 3).

Table 3. Paired t-tests of Reproductive Parameters in Texas River Cooters at Spring Lake. Two results are presented: one including all females that laid twice ($df=30$), and one that excludes all females whose interesting period was ≥ 35 days ($df=18$)

Characteristic	t-value	df	p
Mean clutch size	-0.1226	29	0.54840
	-1.4686	17	0.91990
Mean clutch mass (g)	1.0526	29	0.15060
	-0.7056	17	0.75500
Mean egg mass (g)	4.6611	29	0.00003*
	3.3201	17	0.00202*
Mean egg length (mm)	4.3758	29	0.00007*
	5.0437	17	0.00005*
Mean egg width (mm)	3.5129	29	0.00074*
	3.1851	17	0.00271*
Mean distance from water (m)	0.6181	28	0.27070
	-0.5772	16	0.2859

* indicates significant results

Logistic regression showed that there is no relationship between plastron length and clutch frequency ($p=0.272$).

To test OES theory, I analyzed the correlation between mean egg mass residual and clutch size residual with plastron length. The correlations for mean egg mass was significant ($r^2=0.0757$, $p=0.01615$) while correlation for clutch size ($r^2=0.01358$, $p=0.3162$) was not significant (Figures 3, 4).

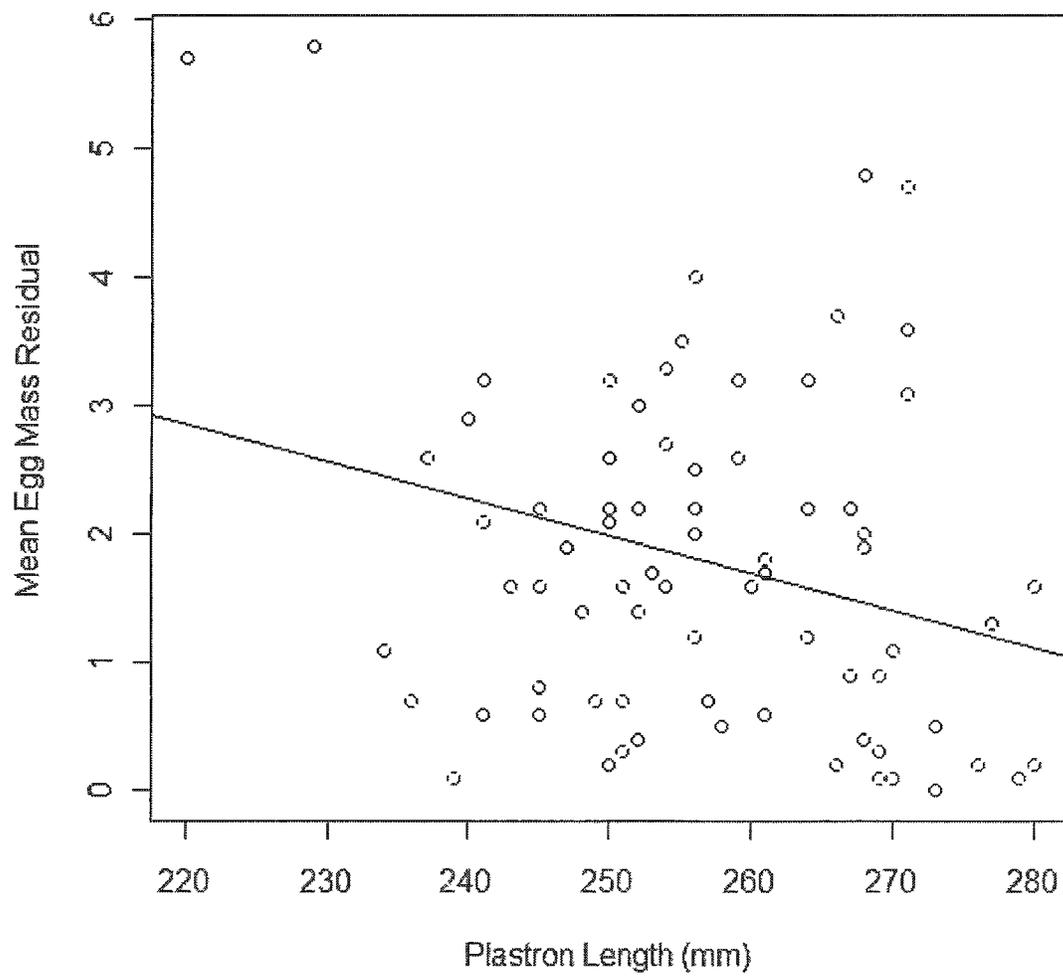


Figure 3. Residuals of Linear Relationships between Plastron Length and Mean Egg Mass in Texas River Cooter

Red-eared Slider

I found 50 red-eared sliders that nested at least once, and nine that nested at least twice. I continued to collect all females coming out to nest throughout May and June because of the fewer numbers (than Texas river cooters) found nesting in April. The first nesting female was found on 3 April 2009, and I found most females nesting during weeks five and nine of the nesting season- May (Figure 5). Internesting period varied between 22 and 63 days. The mean plastron length of nesting females as well as their reproductive parameters is given in Table 4.

Table 4. Characteristics of Nesting Red-eared Sliders and Eggs

Characteristic	Min	Max	Mean (SD)	N
Female plastron length (mm)	173.0	243.0	209.3 (17.6)	46
Clutch size	2.0	12.0	7.5 (2.1)	46
Mean clutch mass (g)	32.7	192.0	107.3 (34.3)	46
Mean egg mass (g)	10.4	19.2	14.3 (2.0)	46
Mean egg length (mm)	36.4	46.7	40.9 (2.5)	46
Mean egg width (mm)	21.0	27.6	24.4 (1.3)	46
Distance from water (m)	26.7	175.4	88.5 (36.8)	45

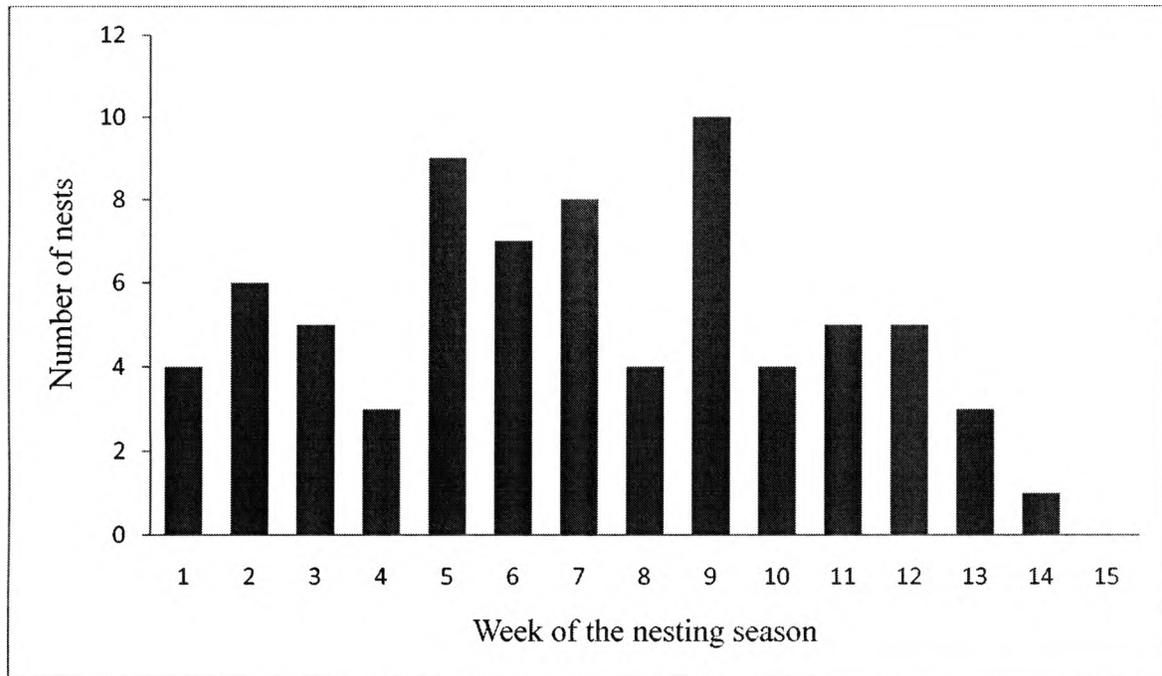


Figure 5. Distribution of Captures for Nesting Red-eared Slider during 2009 Nesting Season. Week one started on 3 April, when the first female was found nesting

Simple linear regressions showed positive relationships of mean clutch mass, mean egg mass, mean egg length, and mean egg width with plastron length (Table 5). Clutch size and mean distance from water did not show significant relationships to plastron length. Similar to Texas river cooter, there is not a strong fit of the data to the model.

Table 5. Relationships of Clutch Size, Clutch Mass, Egg Measurements, and Nest Distance from the Water with Female Body Size (Plastron Length) in Red-eared Sliders at Spring Lake

Characteristic	N	r ²	p-value
Clutch size	46	0.0161	0.40120
Mean clutch mass (g)	46	0.1193	0.01875*
Mean egg mass (g)	46	0.2776	0.00017*
Mean egg length (mm)	46	0.0897	0.04314*
Mean egg width (mm)	46	0.2665	0.00024*
Mean distance from water (m)	45	0.0194	0.36150

* indicates significant results

I did not have an adequate sample size ($n = 9$) to conduct any comparisons of the first and the second clutch.

The correlation between plastron length and mean egg mass residual ($r^2=0.01808$, $p=0.373$) was non-significant, and correlation between plastron length and clutch size residual ($r^2=0.1275$, $p=0.01487$) was significant (Figures 6 and 7).

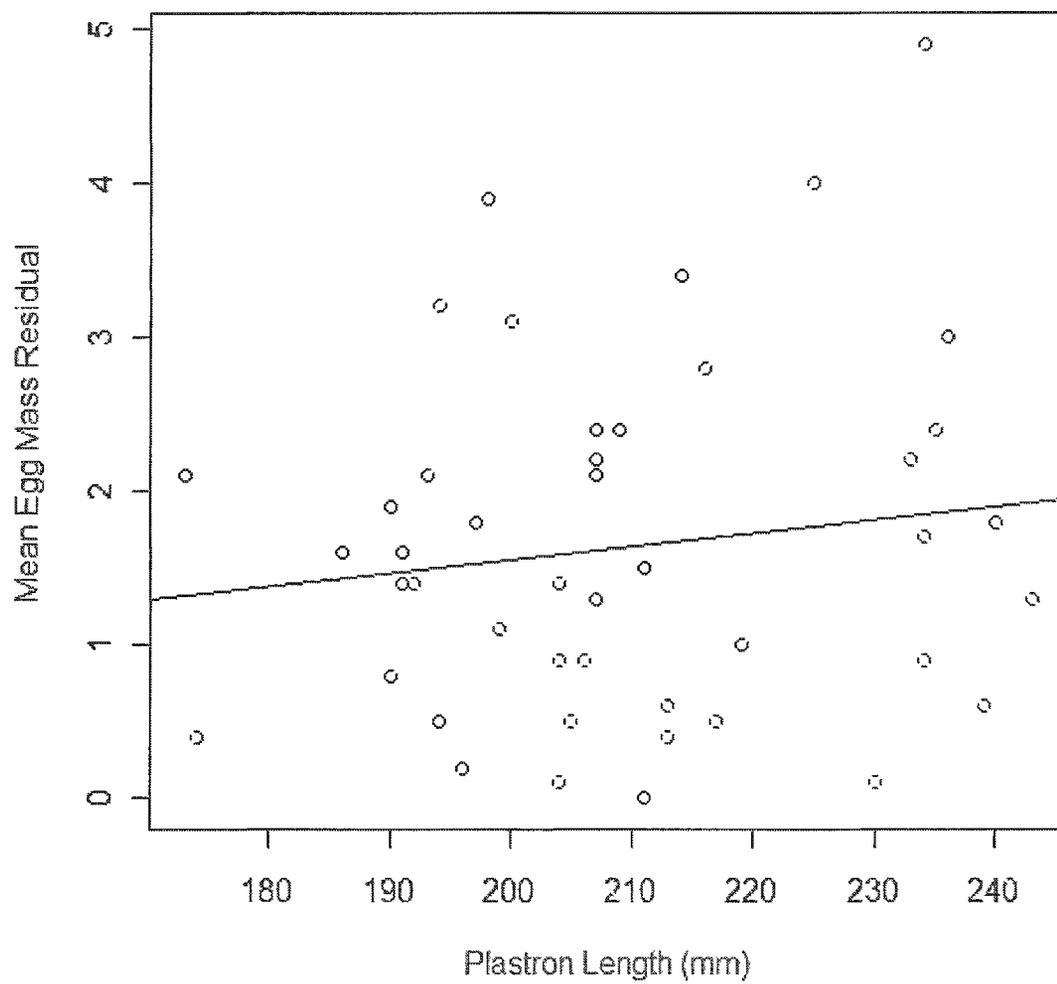


Figure 6. Residuals of Linear Relationships between Plastron Length and Mean Egg Mass

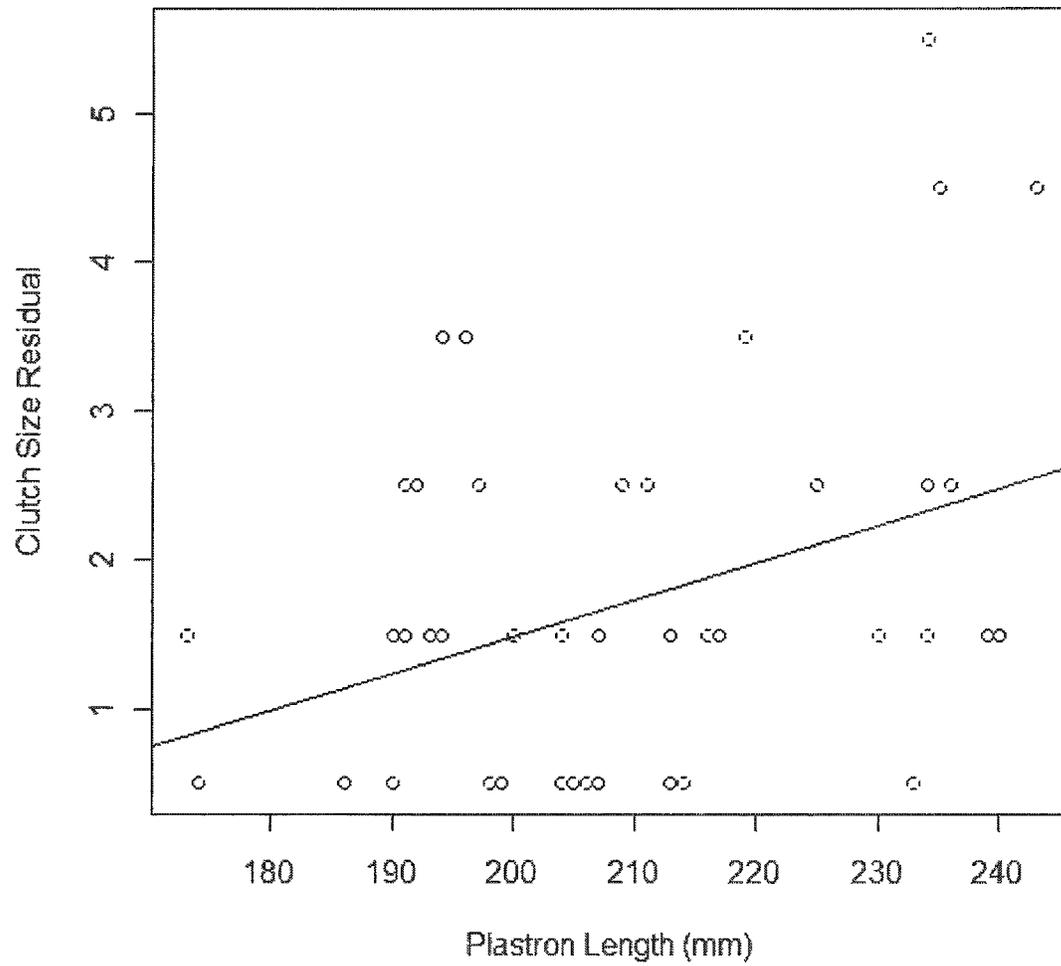


Figure 7. Residuals of Linear Relationships between Plastron Length and Clutch Size

CHAPTER IV

DISCUSSION

I detected similar relationships between female plastron length and reproductive measures in both Texas river cooters and red-eared sliders. Consequently, I discuss my findings for both species together. All reproductive parameters, except nest distance from water (in both species), clutch size (in red-eared-slider), and mean egg length (in Texas river cooter) showed a positive correlation with plastron length. Therefore, the majority of reproductive parameters follow phenotype-habitat matching predictions. However, the r^2 values were weak ($\leq 34\%$). In addition, clutch frequency of Texas river cooters was not dependant on plastron length, contradicting habitat-phenotype matching theory.

Significant positive relationship between plastron length and mean egg width and non-significant relationship between plastron length and mean egg length in Texas river cooter supports the theory of physical constraint imposed by the width of the pelvic girdle aperture in small bodied turtles. However, in red-eared slider, both the parameters (mean egg width and mean egg length) were significantly related to plastron length.

Several other authors proposed alternative explanations of what influences the reproductive output of the season, such as genetics of the population or temperatures (Rowe, 1994; Rollinson and Brooks, 2007). Litzgus et al. (2008) used “length adjusted mass” as an estimate of body condition, instead of just body mass or body length. Genetics is mentioned as an important aspect for reproductive output, but results of

detailed studies are not yet available. For example, genetic basis of life history traits in turtles are unknown, as well as how certain genotype varies over generations (Brooks and Rollinson, 2007). These issues should be a focus of future studies (Rowe, 1994).

As mentioned before, according to OES theory, clutch size but not egg mass varies with resource acquisition. In my study, two species showed contradictory results. For Texas river cooter, mean egg mass residuals were significantly related to plastron length while clutch size residuals were not. That means that egg mass but not clutch size varies with resource acquisition, which is opposite OES theory prediction. On the other hand, for red-eared sliders, mean egg mass residual was not significantly correlated with plastron length while clutch size residuals were positively related to plastron length. Therefore, red-eared sliders follow OES theory.

My results raise the question: are the optimality models species specific? In my case study, we have two species with similar life histories, occupying the same habitat. However, results of OES theory tests show different tendencies in two species. Texas river cooters spend surplus energy producing bigger eggs while red-eared sliders spend surplus energy producing more eggs. Therefore, we cannot accept any optimality theories as a general pattern in chelonians. To further demonstrate differences in reproductive output in these two species, I conducted analysis of covariance (type III) to see if clutch size differed between two species considering the influence of plastron length. The ANCOVA revealed significant interaction between species and plastron length and clutch size (Table 6, Figure 8).

Table 6. Results of an analysis of covariance based on species of turtle and plastron length on clutch size.

Source	df	SS	F-value	P-value
Intercept	1	5.88	0.7339	0.39337
Species	1	35.14	4.3883	0.03832*
Plastron Length (mm)	1	3.27	0.4084	0.52403
Species * Plastron Length	1	44.77	5.5916	0.01968*
Error	118	944.81		

To report deeper analysis of OES theory for Texas river cooter, I examined the differences in clutch mass between the first clutch of females laying \geq one clutch and the clutch of females laying only one clutch. OES predicts clutch mass of the first clutch of females laying more than one clutch should be smaller than clutch mass for those that laid only one clutch (Rollinson and Brooks, 2008). Results of t-tests showed no significant results, meaning there were no differences between mass of the first clutch of females laying more than one clutch and those laying only one clutch ($t_{(76)} = -0.9362$, $p = 0.824$). These findings, again, oppose OES theory. I did not have enough red-eared sliders that nested more than once to conduct the same analysis.

The most common explanation of OES theory is apparent physical constraint. width of pelvic aperture in reptiles (Litzgus et al., 2008). However, Bowden et al. (2004) explored physiological constraints and concluded that testosterone has important role in the evolution of egg size, and consequently, reproductive output. Therefore, future studies must focus on physical and physiological factors influencing reproductive patterns.

It is important to emphasize that my results are based on a short term study. I followed marked females for only one season. Other environmental factors might influence the outcome of the reproductive season, with climate being one of the most obvious. Although no specific tests were done, it was noticeable that on rainy days females left water to nest more often. Jackson and Walker (1997) reported that Suwannee cooters nest more frequently during or after rainfall and suggested that this behavior may reduce predation on eggs and females. However, Aresco (2004) reported no association between rainfall and nesting in the cooters (*Pseudemys concinna* and *Pseudemys floridiana*). Therefore, it would be interesting to see if reproductive output is a precipitation-moderated effect, or is precipitation just a trigger for turtles to emerge from the water. Rollinson and Brooks (2008) suggested that increased air temperatures result in decreased egg mass and clutch size. In my study, Texas river cooters laying two clutches per season had smaller mean egg mass of the second clutch, but there was no difference in clutch size. These results might be explained by the influence of temperature. Thornhill (1982) found that water temperatures are positively correlated with clutch parameters. However, it remains questionable how environmental factors, such as air temperatures, trigger animals that live in the water to emerge and nest and is

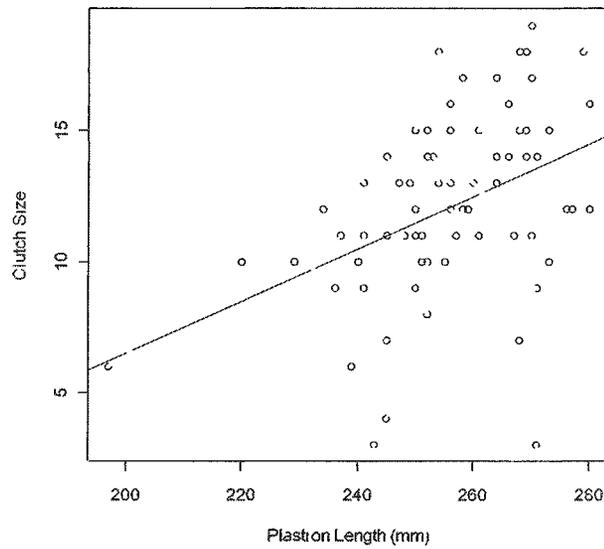
their reproductive output fully dependent on the environment. For a clearer understanding, this study would have to be conducted for at least several more seasons, and variations between nesting seasons would have to be analyzed. In addition, Tinkle et al. (1981) reported that some turtles do not nest every year, giving us more reasons to repeat this study to obtain precise data on clutch size and frequency.

Litzgus et al. (2008) proposed that in environments where hatchling mortality is unpredictable, and adult mortality is predictable, females will maximize reproductive output in “good years”. That means that during the season with optimal conditions, turtles will lay more eggs and larger eggs while in “bad years” reproductive output will be poor. This is one more reason to repeat this study for several years.

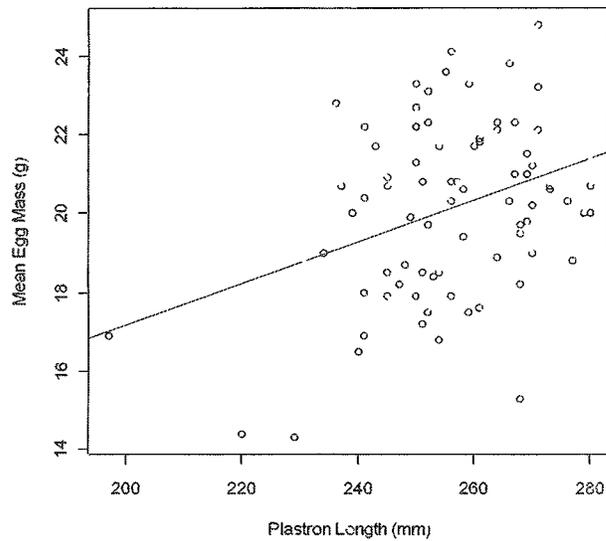
It remains challenging to choose an optimality model that would fit patterns of maternal investment. It also remains questionable what theory or what kind of trade-off is more advantageous for turtles. Even if OES theory is generally accepted, either fewer large eggs or more small eggs could be argued to be advantageous. Producing an additional egg is more advantageous because it provides a larger maternal fitness benefit than investing more heavily in existing individual offspring (Litzgus et al., 2008). On the other hand, because offspring survival can increase with offspring size, maternal fitness would increase with increased maternal investment per offspring (Litzgus et al., 2008).

APPENDIX A

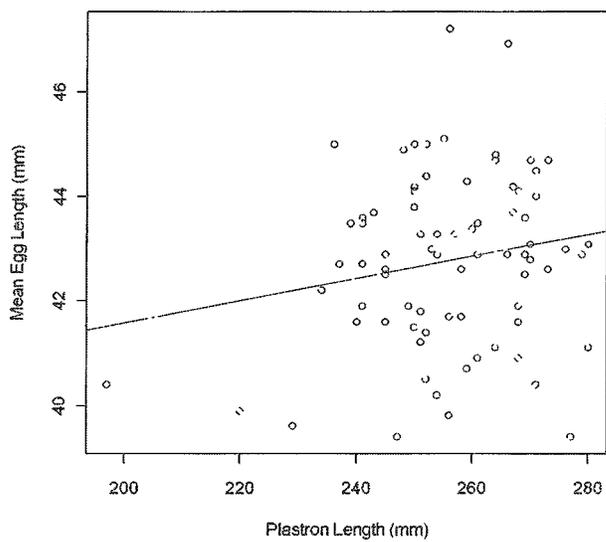
LINEAR RELATIONSHIPS BETWEEN PLASTRON LENGTH OF TEXAS RIVER COOTER AND REPRODUCTIVE PARAMETERS



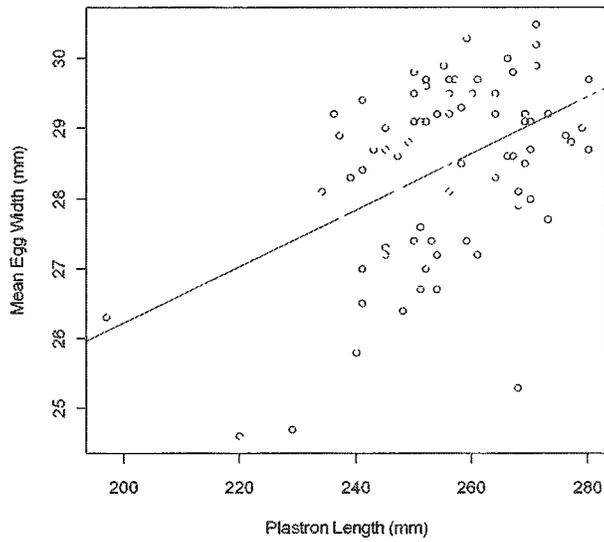
Linear Relationship between Female Body Size (Plastron Length) and Clutch Size in *Pseudemys texana* including the Outlier



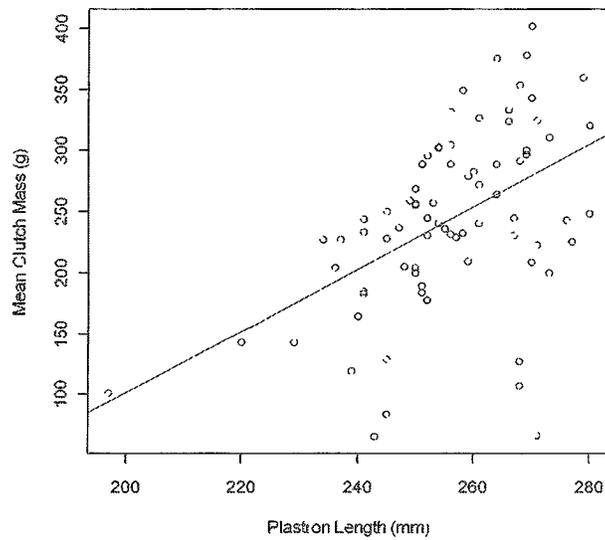
Linear Relationship between Female Body Size (Plastron Length) and Mean Egg Mass in *Pseudemys texana* including the Outlier



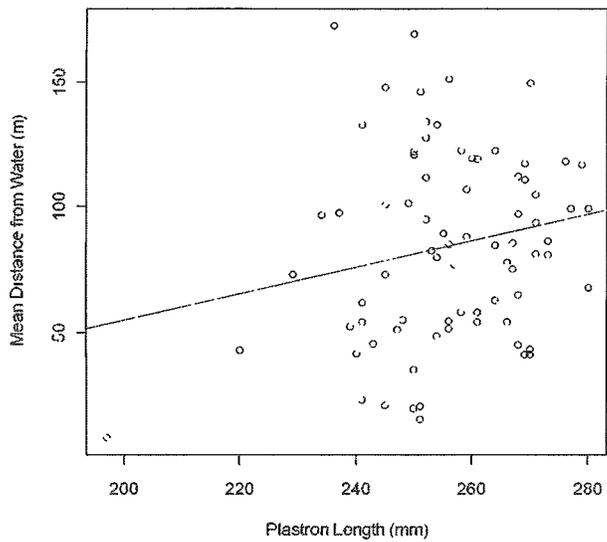
Linear Relationship between Female Body Size (Plastron Length) and Mean Egg Length in *Pseudemys texana* including the Outlier



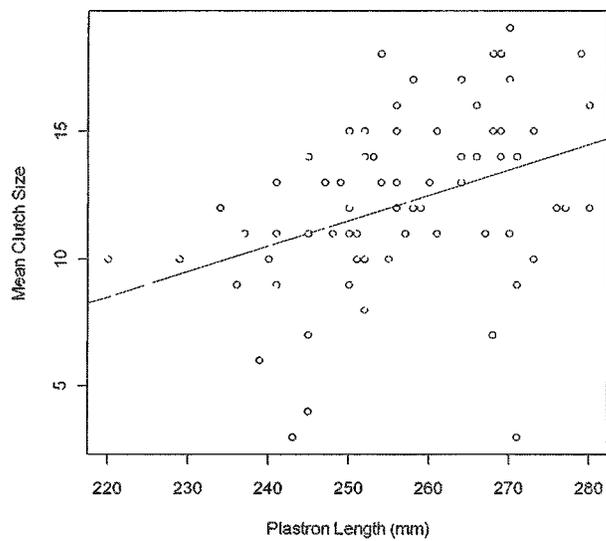
Linear Relationship between Female Body Size (Plastron Length) and Mean Egg Width in *Pseudemys texana* including the Outlier



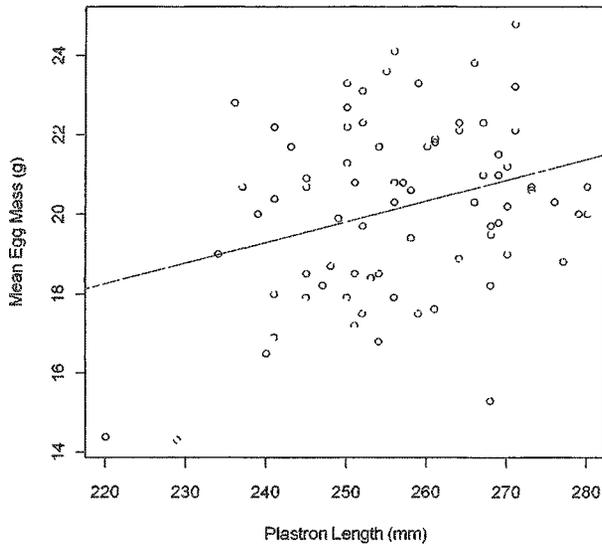
Linear Relationship between Female Body Size (Plastron Length) and Clutch Mass in *Pseudemys texana* including the Outlier



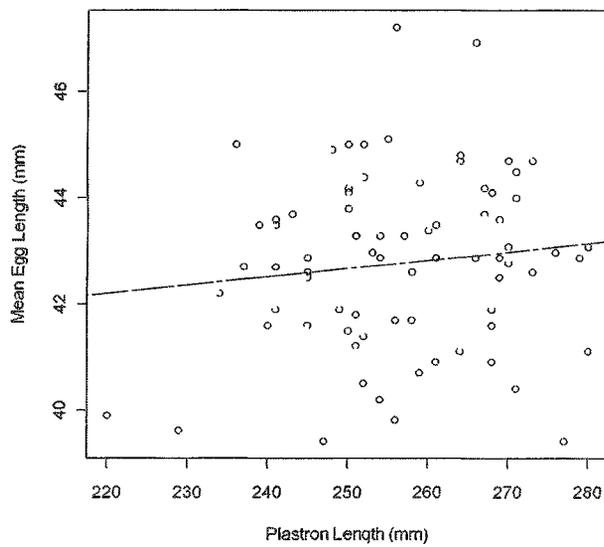
Linear Relationship between Female Body Size (Plastron Length) and Nest Distance from Water in *Pseudemys texana* including the Outlier



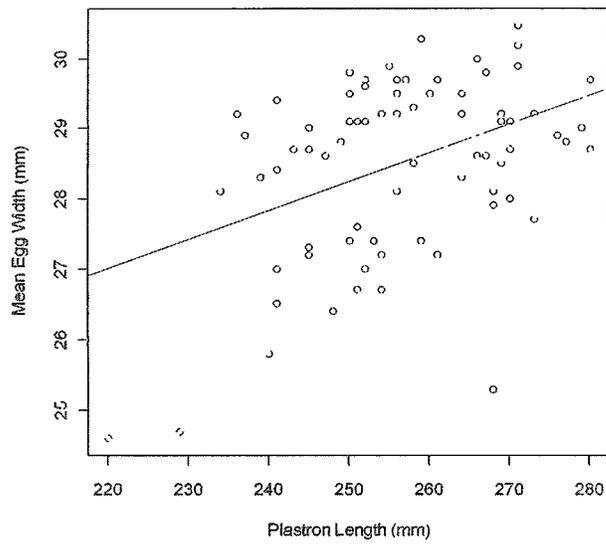
Linear Relationship between Female Body Size (Plastron Length) and Clutch Size in *Pseudemys texana* excluding the Outlier



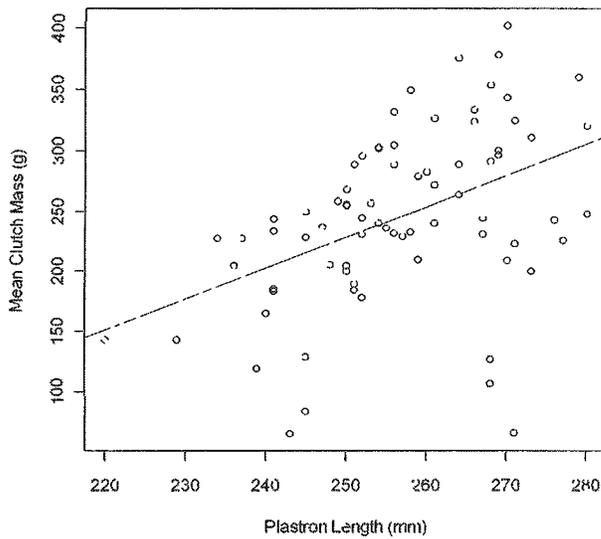
Linear Relationship between Female Body Size (Plastron Length) and Mean Egg Mass in *Pseudemys texana* excluding the Outlier



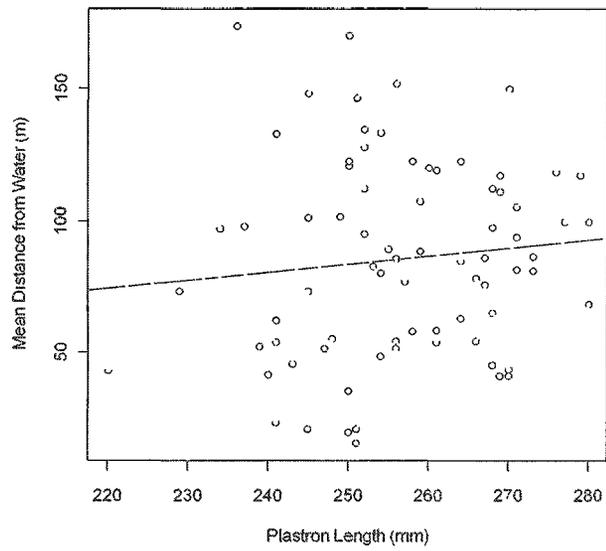
Linear Relationship between Female Body Size (Plastron Length) and Mean Egg Length in *Pseudemys texana* excluding the Outlier



Linear Relationship between Female Body Size (Plastron Length) and Mean Egg Width in *Pseudemys texana* excluding the Outlier



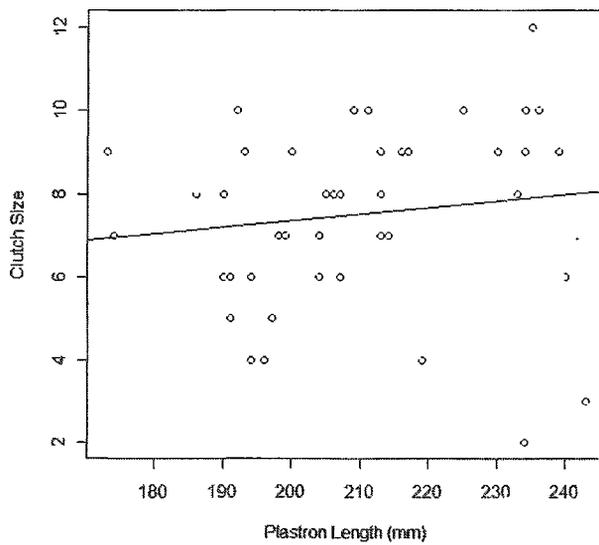
Linear Relationship between Female Body Size (Plastron Length) and Clutch Mass in *Pseudemys texana* excluding the Outlier



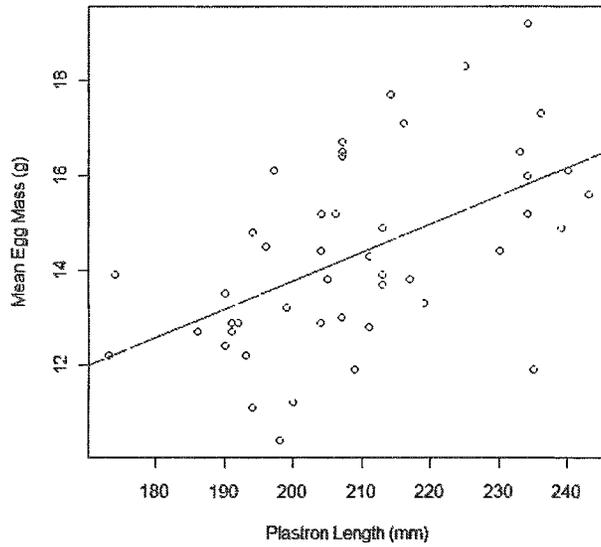
Linear Relationship between Female Body Size (Plastron Length) and Nest Distance from Water in *Pseudemys texana* excluding the Outlier

APPENDIX B

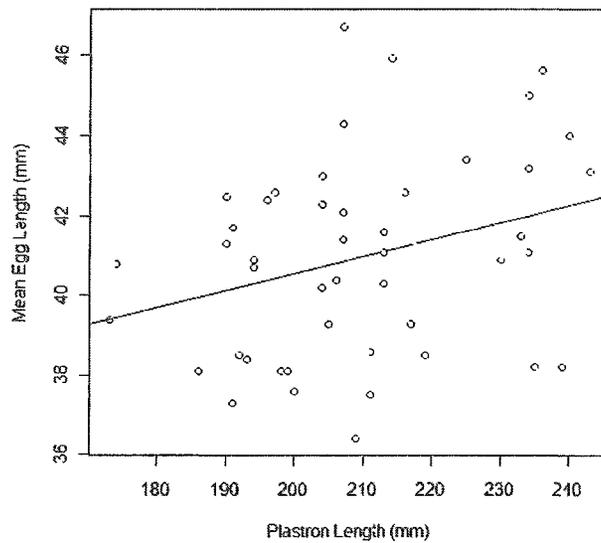
APPENDIX B: LINEAR RELATIONSHIPS BETWEEN PLASTRON LENGTH OF RED-EARED SLIDER AND REPRODUCTIVE PARAMETERS



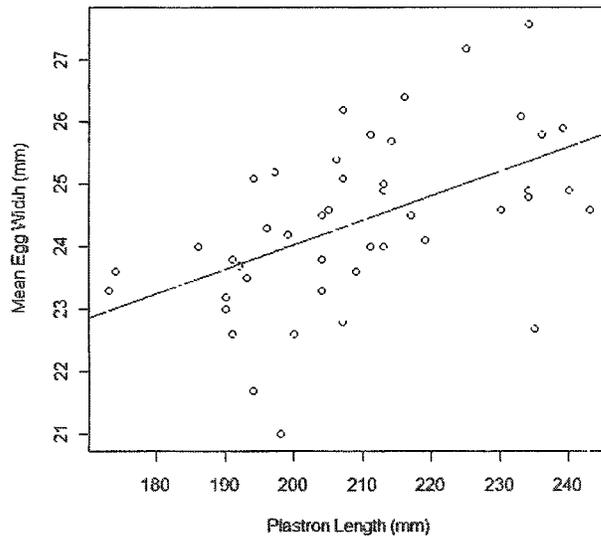
Linear Relationships between Female Body Size (Plastron Length) and Clutch Size in *Trachemys scripta elegans*



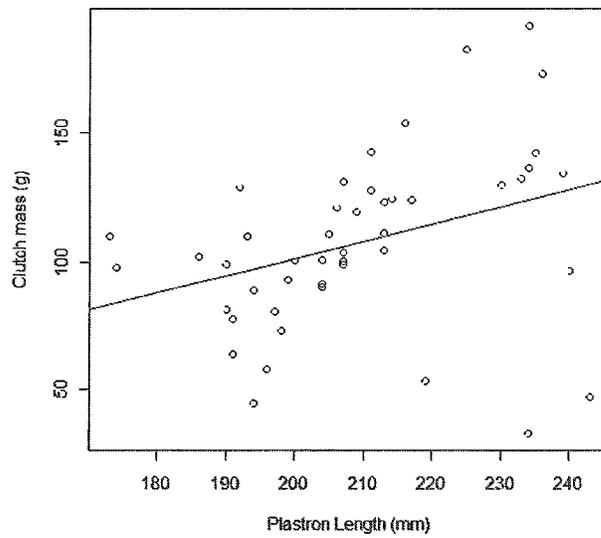
Linear Relationships between Female Body Size (Plastron Length) and Mean Egg Mass in *Trachemys scripta elegans*



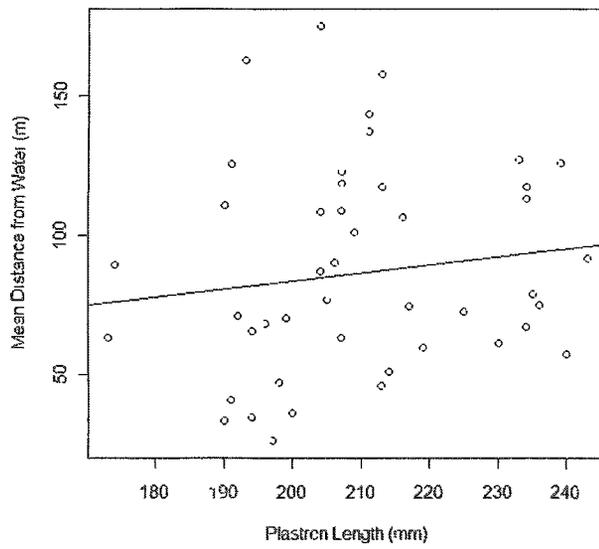
Linear Relationships between Female Body Size (Plastron Length) and Mean Egg Length in *Trachemys scripta elegans*



Linear Relationships between Female Body Size (Plastron Length) and Mean Egg Width in *Trachemys scripta elegans*



Linear Relationships between Female Body Size (Plastron Length) and Clutch Mass in *Trachemys scripta elegans*



Linear Relationships between Female Body Size (Plastron Length) and Nest Distance from Water in *Trachemys scripta elegans*

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VITA

Ivana Mali was born in Novi Sad, Serbia, on February 25, 1983. While studying in Serbia, she got an opportunity to come to the United States, where she was offered a full scholarship to play volleyball. Although playing volleyball did not give her any free time, she has never lost her passion for science and nature. She received the degree of Bachelor of Science from Henderson State University in May 2008. In August 2008, she entered the Graduate College of Texas State University-San Marcos.