# HABITAT USE BY THE TEXAS RIVER COOTER (*PSEUDEMYS TEXANA*)

# IN SPRING LAKE, HAYS COUNTY, TEXAS

THESIS

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by

Linda Catherine Osborne, B.S.

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## ABSTRACT

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SUPERVISING PROFESSOR: DR. THOMAS R. SIMPSON

Little information is available in the literature reporting underwater habitat use by freshwater turtles. Most investigators have focused on terrestrial and water surface habitat associations. Therefore, a major component of the habitat remains an unknown for these animals. Underwater habitat use by the Texas river cooter (*Pseudemys texana*) was studied in Spring Lake, Hays County, Texas. The lake is composed of a lotic spring-fed portion (main lake) and a lentic slough. The spring-fed portion has a constant temperature ($22 + 2^0$C) and a vigorous flow (average annual flow = 166.0 cfs). Hour-long dives were conducted in the main lake approximately twice a week for a year in order to detect variations in seasonal habitat use. Data recorded for each observed individual included its sex, behavior, habitat, and depth within the water column. Data were analyzed using a three factor ANOVA. Factors all had p-values less than 0.01, indicating differences in the number of turtles per dive across months, between depths, between habitats, and between sexes. The number of *P. texana* observed was higher in the winter and spring, with the greatest numbers occurring January through March. Turtles were found more often in shallow water (less than 1 m) during summer and fall, with an increase in the use of the 1-3 m and > 3 m depths during the winter and spring months. Differences in habitat correlated with differences in depth. There were also differences between the sexes, with males recorded more often than females, and an increase in the males from January to May. Further dive surveys, including mid-day and night, need to be conducted on *P. texana* in order to have a better understanding of the three dimensional habitat that the turtles are utilizing. Future studies on the dive profiles of the other turtles in Spring Lake will also give better insight into the community ecology that is found there.

# CHAPTER 1

## INTRODUCTION TO THE STUDY

A central issue of ecology is why and how animals use their habitat (Johnson 1980). Understanding habitat use by a species involves the study of how an organism uses the resources of food, cover, and water within an area given the extant environmental conditions (Johnson 1980).

Many studies assessing habitat use by an animal focus on quantifying spatial use in only two dimensions. For many terrestrial organisms, information based on two dimensional habitat use is sufficient, however, aquatic and arboreal organisms routinely use the habitat on a three dimensional scale. Quantifying arboreal three-dimensional habitat remains quite a challenge because forest canopies are less accessible to the biologist than the forest floor (Carey 1996). Similarly, quantifying three-dimensional aquatic habitat use has proven difficult because animals are difficult to observe in aquatic habitats (Hindell et al. 2002).

. Most studies of three-dimensional use of habitat involve canopy dwelling birds and mammals (Carey 1996). Marsupials, bats, rodents, carnivores, and primates commonly use forest canopies (Carey 1996). Therefore, the three-dimensional use of the canopy is a pertinent aspect of habitat use by these organisms. Three-dimensional use by arboreal mammals can be evaluated by ranking a species' use of trees (overstory and understory) and shrubs relative to its use of the forest floor for three activities: travel, nesting, denning, and foraging (Carey 1996). Studies of *Peromyscus* and *Ochrotomys* (Rossell and Rossell 1999), the red tree vole (Carey 1996), flying squirrel (*Glaucomys volans*) (Carey 1996), found that they used shrub, understory, and canopy strata of the forest (Bendel and Gates 1987).

Birds also utilize habitat in a three-dimensional spatial aspect, to nest and forage. Indeed, vegetation and structural characteristics are important cues for birds seeking nest sites (Coleman et al. 2002). Younger tree stands provide appropriate environmental conditions for breeding Sharp-shinned Hawks (Coleman et al. 2002), and in a study of avian communities in loblolly pine forests, understory nesters virtually disappeared after exclusion of fire because the developing midstory layer reduced the amount of understory cover available for nesting and foraging (Lohr et al. 2002). Also, the layering of vegetation in deciduous forests was more highly correlated with the number of bird species in an area (James and Wamer 1982).

Previous freshwater turtle investigations focused on terrestrial and aquatic habitat use from a horizontal or two-dimensional aspect. A radio telemetry study of subadult alligator snapping turtles (*Macroclemys temminckii*) showed that the turtles were found in the bald cypress forest habitat more often than the open channel habitat (Harrel et al. 1996). Bog turtles (*Clemmys muhlenbergii*) in southwestern Virginia selected multiple microhabitats within small home ranges in wetlands (Carter et al. 1999). Spotted turtles in Georgian Bay, Canada, displayed seasonal shifts in habitat use coinciding with changes in behavior during the yearly activity cycle (Litzgus and Brooks 2000). Spotted turtles used a variety of habitats including small vernal pools, a permanent bog, upland fields, early successional forests, and older, more established woodlands (Perillo 1997).

Three-toed box turtles (*Terrapene carolina triunguis*) in Fayetteville, Arkansas, shifted habitat use seasonally, from grasslands in late spring and early fall to forested areas in summer, late spring, and early fall (Reagan 1974). Ornate box turtles (*Terrapene ornata ornata*) in the Nebraska sandhills used distinct microhabitats, and in particular, activity level had a strong relationship to the amount of shrub cover used (Converse and Savidge 2003). Finally, the ecology of the river cooter (*Pseudemys concinna*) was investigated by exploring their habitat relationships in three different habitats including shallow water, aquatic macrophyte beds, and basking sites (Buhlmann and Vaughan 1991). They found that movements within pools were often attributed to the availability and location of basking sites that varied with river flow (Buhlmann and Vaughan 1991). Each of these studies was focused only on two-dimensional spatial use by a freshwater turtle; however, none looked at the three-dimensional spatial use in the aquatic habitat, the complete habitat of a freshwater turtle species.

Freshwater turtles often inhabit riverine systems and their semi-aquatic behavior makes them especially important for understanding the link between aquatic and terrestrial habitats (Bodie and Semlitsch 2000). The rapid decline in many turtle populations worldwide has increased the need to investigate the status of these turtle populations (DonnerWright et al.1999).

Perusal of species accounts with regard to text length and the number of cited ecological works reveals that two of the most neglected species in Texas are the Texas map turtle, *Graptemys versa*, and the Texas river cooter, *Pseudemys texana* (Lindeman 2001). Due to its frequently changing and confusing taxonomic status, very little ecological information about *Pseudemys texana* has been published under its current name. The majority of information regarding *Pseudemys texana* was published as *Pseudemys floridana* or *Pseudemys concinna* (Ernst et al. 1994). Ward (1984) elevated *Pseudemys texana* to specific status.

The Texas river cooter, *Pseudemys texana*, is a freshwater basking turtle of the family Emydidae (Ward 1984). It has an olive-brown carapace with a pattern of fine yellow reticulations, whorls, and ocelli, and the plastron is yellow with dark seams and a pattern of narrow black lines following the seams (Ernst et al. 1994). The skin is black with white to yellow stripes, and head markings are often variable (Ernst et al. 1994). Average adult carapace length ranges from 18-25.5 cm (Conant and Collins 1998). Males are often smaller than females, with longer, thicker tails, and they have elongated claws on the front feet (Conant and Collins 1998).

*Pseudemys texana* is endemic in the Colorado, Brazos, Guadalupe, and San Antonio watersheds of Central and South-Central Texas (Ernst et al. 1994). Its habitat includes streams and rivers with moderate currents, large lakes, spring runs, and occasionally brackish tidal marshes (Behler 1979). It may also be found in irrigation ditches, canals, and cattle tanks (Ernst et al. 1994).

Since *Pseudemys texana* is primarily an aquatic turtle, my goal was to study its habitat use under the water surface, a behavior that has not been documented in any other freshwater turtle species. Objectives of this study included describing and quantifying underwater habitat use, describing and quantifying behavior, and examining differences by months, depth, habitat, and sex.

# CHAPTER 2

## MATERIALS AND METHODS

### *Study Site*

This study was conducted at Spring Lake, Aquarena Center, Texas State University, in San Marcos, Hays County, Texas (29$^0$53'N, 97$^0$55'W). Spring Lake is an 8 ha reservoir at the headwaters of the San Marcos River (Towns et al. 2003). Initially dammed in 1849, the lake is fed by some 200 artesian springs that issue from the Edwards Aquifer along the San Marcos portion of the Balcones Fault (Fields et al. 2003). San Marcos Springs are the second largest in Texas and have historically exhibited the most constant discharge of any spring system in the southwestern United States (Saunders et al. 2001). San Marcos Springs has an annual discharge of 169 cfs (Groeger et al. 1997). Water temperature (mean 21$^0$ C) at the spring sources varies annually by less than 3$^0$ C (Groeger et al. 1997). The constant flow and thermal stability of this unique system has allowed the development of unique and often endemic flora and fauna (Kelsey 1996). Several species of turtles inhabit Spring Lake, including the Texas river cooter, the red-eared slider (*Trachemys scripta elegans*), the common snapping turtle (*Chelydra serpentina serpentina*), the common musk turtle (*Sternotherus odoratus*), and the Guadalupe spiny softshell (*Apalone spinifera guadalupensis*).

Spring Lake remains a unique system in which to conduct research, not only because of the constant temperature and flow, but also because of the water clarity. The crystal clear water has a visibility on most days of 10 m or better. This makes Spring Lake an ideal place for an underwater study such as this because in many other riverine systems, the water is turbid, with visibility less than one meter. Also, the access to Spring Lake by the public is restricted. Consequently, alteration of turtle activities by anthropogenic sources is limited.

*Methods and Statistical Analyses*

To study the three-dimensional spatial patterns of *Pseudemys texana*, turtles were observed underwater during dives made two to three times per week. Activities of turtles were recorded on an underwater slate and with an underwater camera. Dives were one hour in length, occurred in the morning hours between 0800-1000, and were conducted throughout one year in order to detect variations in habitat use by month, sex, depth, and habitat. Turtles were counted while moving downstream along a 290 m transect running from the dive training area to Cypress Point. Data recorded included sex, depth, habitat, and behavior. Juveniles were not included in the statistical analyses because few were observed. Depth included three categories, < 1m, 1-3 m, and > 3 m, and were determined by using a depth gauge. Habitat was divided into six categories, including open water with vegetation (OWV), open water without vegetation (OW), steep side with vegetation (SV), steep side without vegetation (SO), benthic with vegetation (BV), and benthic without vegetation (BO). Behaviors were divided into 5 categories, including at the surface (A), foraging (F), resting or stationary on a substrate (R), swimming (S), and suspended in the water column (SU). Because vegetation was thick in many places in

Spring Lake, detection of turtles was limited in these areas. However, visibility measurements indicated that visibility remained unchanged along the main transect throughout the year.

Factorial analysis of variance (Sokal and Rohlf 1995) allowed me to analyze simultaneously three or more factors. The assumptions underlying multiway anova are the same as those for two-way and single factor anova (Sokal and Rohlf 1995), and include normality, homoscedasticity, and independence. Two three factor anovas were performed with the data. One three factor anova analyzed differences among the factors months, sex, and depth, while the other three factor anova analyzed differences among the factors months, sex, and habitat. Two three factor anovas were performed instead of one in order to use all months of the year. When analyzing the factors, months, depth, and sex, all 12 months, 3 depth categories, and both sexes were included in the analysis. However, when analyzing the factors months, habitats, and sex, only 9 months, 5 habitats, and both sexes were included in the analysis due to zero turtles observed in September, June, and August in 4 out of the 6 habitat categories. Also, one habitat category, steep side without vegetation, was not included in the analysis because turtles were only found in this habitat in a small number 4 out of the 12 months. Because dives per month was not the same throughout the year, for each factor the response variable was number of turtles per dive, therefore, there was not replication in the three factor anova. Independence, normality, and homoscedasticity assumptions were met so the parametric anova tests were performed without transforming data. Behavior was assessed graphically by comparing behaviors exhibited within each habitat.

# CHAPTER 3

## RESULTS

Anova analysis (Table 1) showed interactions among the factors were significant, with all having p-values less than 0.01. Thus, the main effect tests were irrelevant, and differences among the factors had to be assessed graphically.

There were differences among the number of turtles found at different depths during different times of the year (Fig. 1) (Appendix, Table 3 and Table 6). Although many turtles were found at < 1 m throughout the year, the other 2 depth categories changed dramatically across the months. In September, only 0.6 turtles per dive were counted at > 3 m, and only 3.0 turtles per dive were counted at a depth of 1-3 m. However, by January 11.4 turtles per dive were found at depths > 3 m, the most recorded at that depth all year. There were also 11.4 turtles per dive found at depths 1-3 m during January, a large increase from September. The numbers remained steady, and in March 15.6 turtles were counted per dive in the 1-3 m depths, the most recorded at that depth all year. At the > 3 m depth, 9.3 turtles were recorded per dive in March, a relatively large number, although a slight decrease from January. From there, the number of turtles recorded at the greatest depth, > 3 m, decreased drastically in April and May, with only 3.1 and 3.3 turtles recorded per dive, respectively. In the 1-3 m, 11.4 and 13.3 turtles

Table 1. Results of the first 3 factor ANOVA analysis for Texas river cooters in Spring Lake, Hays County, Texas. Interactions have significant p-values.

| | Df | Mean Sq | F-value | P-value |
|---|---|---|---|---|
| month | 11 | 20.4044 | 19.64 | |
| depth | 2 | 80.0362 | 77.22 | |
| sex | 1 | 217.9176 | 210.24 | |
| month:depth | 22 | 4.3244 | 4.17 | 0.0007* |
| month:sex | 11 | 10.2609 | 9.90 | < 0.0001* |
| depth:sex | 2 | 6.1283 | 5.91 | 0.0088* |
| month:depth:sex | 22 | 1.0365 | | |

*Significance (*) is based on a 2-tailed F-distribution ($\alpha = 0.05$)

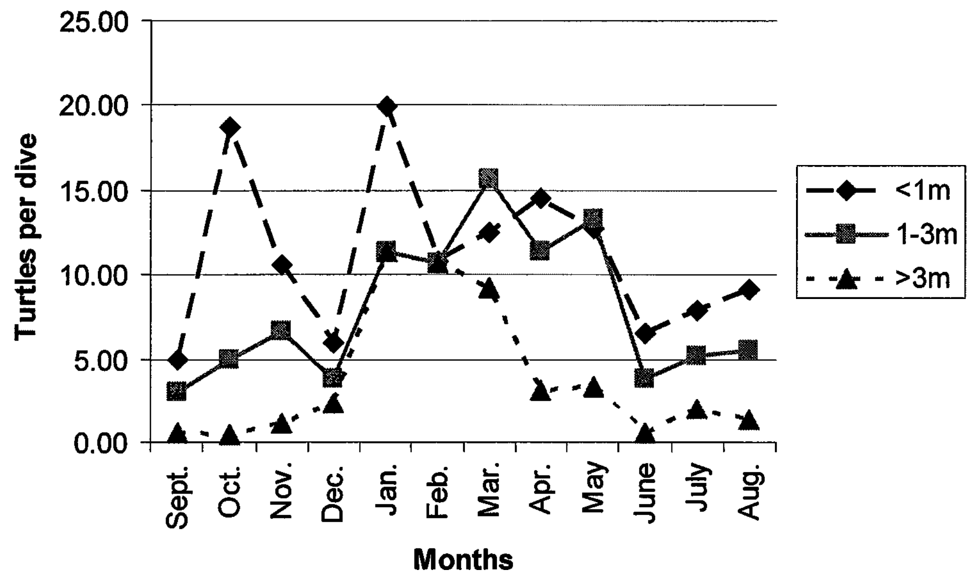


Figure 1. *Pseudemys texana* found in different depth categories at different times of the year.

were recorded per dive in April and May, a slight decrease from March. Turtles recorded at the different depths decreased substantially across the summer months, until the number of turtles within the depth categories in August were similar to numbers in September. In August, 5.5 and 1.3 turtles were recorded per dive in the 1-3 m, and > 3 m depths respectively. These numbers are slightly higher than numbers in September, but are drastically lower than numbers in the winter and spring months.

There was also variation in the number of turtles seen per dive across months of the year. The largest numbers of turtles were counted during December-February, and March-May (Fig. 2) (Appendix, Table 5). January had the most turtles counted, with 42.7 occurring per dive, and March had the second highest number, with 37.4 turtles counted per dive. The summer months (Jun-Aug), as well as early fall (Sept-Nov) had fewer turtles counted. The smallest number of turtles counted occurred in September, with only 8.6 turtles recorded per dive. June had the next smallest count, with 11.0 turtles per dive.

More males than females were found per dive throughout the 12 month study (Fig. 3) (Appendix, Table 3 and Table 7). Differences in depth between the sexes throughout the year varied slightly. In September, the number of males and females recorded per dive were similar, with 3.7 females recorded per dive and 4.9 males recorded per dive. Males and females were found at similar depths, with 2.3 females and 2.7 males recorded per dive in depths < 1 m. In the other two depth categories in September, 1.0 females and 2.0 males were recorded per dive in 1-3 m, and 0.4 females and 0.1 males were recorded per dive in depths > 3 m. The numbers of males per dive steadily increased, and by January, substantially more males than females were recorded

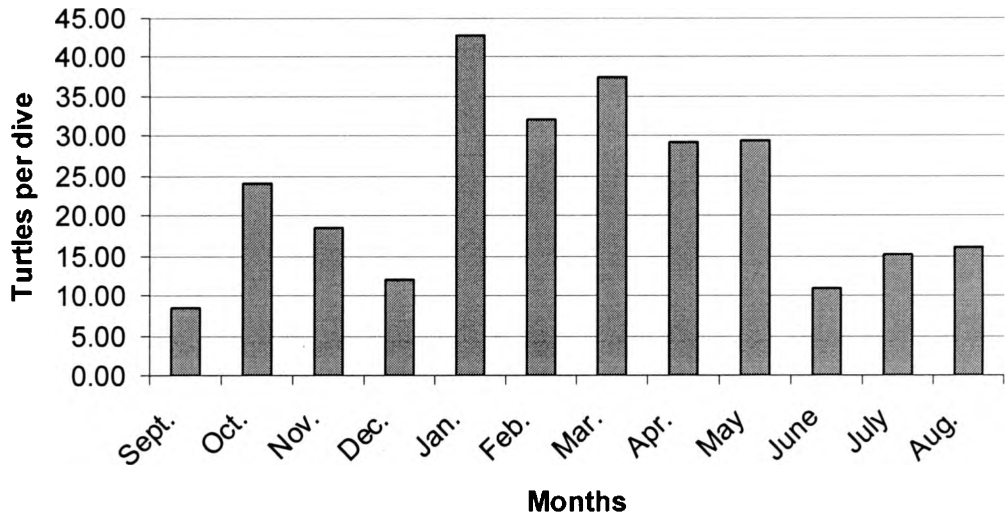


Figure 2. *Pseudemys texana* seen per dive each month from September through August. The most turtles recorded per dive was in January and the least was in September.

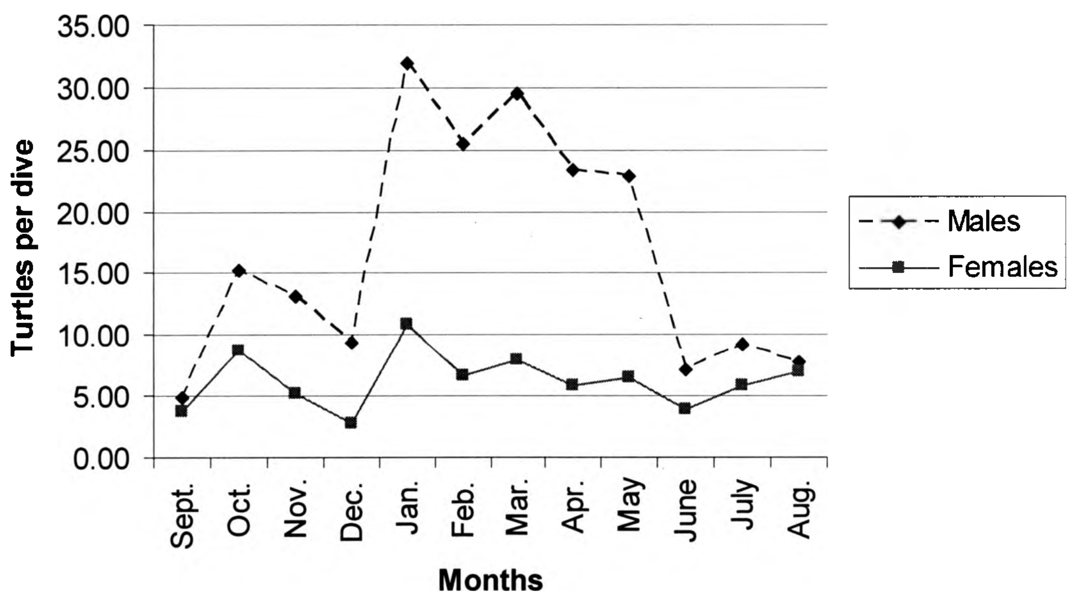


Figure 3. Comparison of the number of male and female Texas river cooters at different times of the year. Males increase drastically from December to January and have the largest numbers from January to May.

per dive, with 31.9 males recorded, and only 10.8 females recorded per dive. At this time more males than females were found at the different depths, with 14.3, 8.6, and 9.0 males recorded per dive in the < 1 m, 1-3 m, and > 3 m depths respectively, and only 5.6, 2.8, and 2.4 females recorded per dive in the < 1 m, 1-3 m, and > 3 m depths respectively. Numbers of males steadily decreased until May, with 22.9 males recorded per dive, and 6.4 females recorded per dive for that month. There were still more males than females recorded at the different depths during the month of May, with 10.1, 10.2, and 2.6 recorded per dive at < 1m, 1-3, and > 3 m respectively. Females recorded per dive included 2.6, 3.1, and 0.8 per dive at < 1m, 1-3 m, and > 3 m depths respectively. The number of males drastically decreased over the summer, until males and females recorded per dive were about equal in the month of august with 7.7 males and 7.0 females recorded per dive respectively. The depths at which the different sexes were found were again similar, with 5.1, 3.2, and 0.7 males recorded per dive, and 4.0, 2.3, and 0.7 females were recorded per dive at < 1 m, 1-3 m, and > 3 m respectively.

The second anova analysis (Table 2) showed interactions among the factors were also significant, all having p-values less than 0.015. Again, main effect tests are irrelevant, thus differences among the factors had to be assessed graphically.

Turtles were also found in different habitats at certain times of the year (Fig. 4) (Appendix, Table 4). The three most common habitats used by turtles were open water with vegetation, open water without vegetation, and benthic with vegetation. Steep side with vegetation and benthic without vegetation were the least occupied habitats. The open water without vegetation habitat was used steadily throughout the year, with 12.6 turtles recorded per dive in October to 15.9 recorded per dive in January, the most

Table 2. Results of the second 3 factor ANOVA analysis for Texas river cooters in Spring Lake, Hays County, Texas. Interactions have significant p-values.

| | Df | Mean Sq | F-value | P-value |
|---|---|---|---|---|
| month | 8 | 10.646 | 8.56 | |
| habitat | 4 | 82.5702 | 66.34 | |
| sex | 1 | 158.5632 | 127.49 | |
| month:habitat | 32 | 2.7668 | 2.22 | 0.0136* |
| month:sex | 8 | 5.1349 | 4.13 | 0.0018* |
| habitat:sex | 4 | 18.9312 | 15.22 | < 0.0001* |
| month:habitat:sex | 32 | 1.2437 | | |

*Significance (*) is based on a 2-tailed F-distribution ($\alpha = 0.05$)

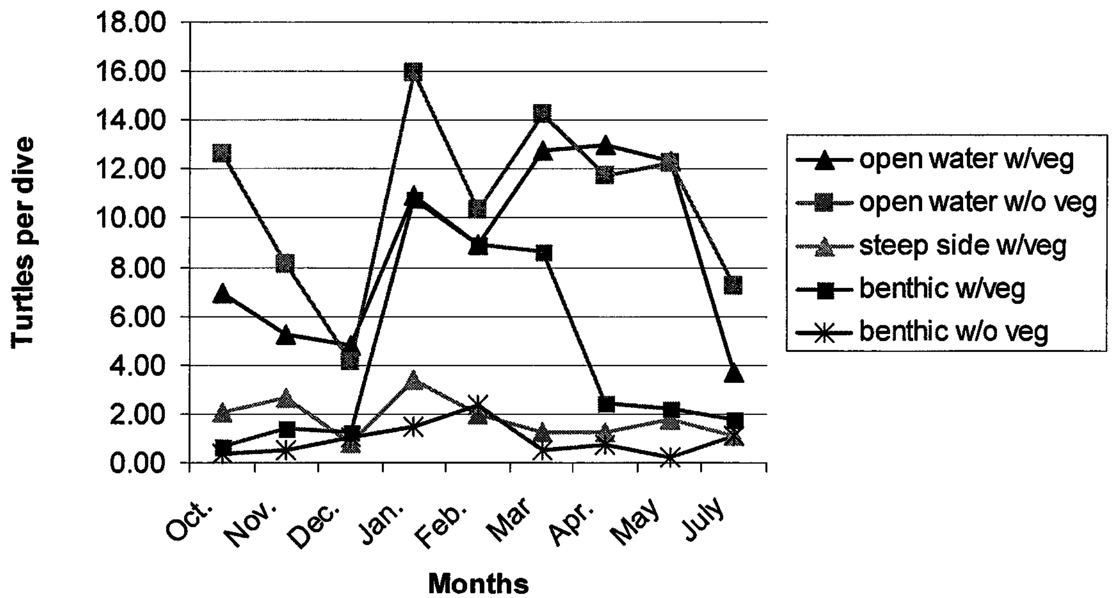


Figure 4. Comparison of *P. texana* found in 5 different habitat categories across different months throughout the year. Open water with vegetation had the most turtles recorded.

recorded in that habitat all year. The lowest number of turtles recorded per dive in this habitat was 4.1 in November, with 10 turtles per dive being the average seen in this habitat throughout the months of the year. Open water with vegetation, and benthic with vegetation substantially increased in winter and spring months from the low numbers in fall and summer months. In October, 6.9 and 0.7 turtles were recorded per dive in the open water with vegetation and benthic water with vegetation respectively. The number of turtles steadily increased, and in January, 10.8 turtles per dive were recorded, the most recorded in this habitat all year. Also in January 10.9 turtles per dive were recorded in the open water with vegetation habitat, an increase from the fall. The number of turtles recorded in the benthic with vegetation decreased from January, and by April, only 2.4 were recorded per dive. Conversely, numbers of turtles increased in the open water with vegetation habitat, with 13.0 turtles recorded per dive in April, the most recorded in this habitat all year. From there, the numbers continued to decrease in the open water with vegetation and benthic with vegetation habitats, with low numbers of turtles recorded in both habitats in July. In this month 3.7 and 1.8 turtles were recorded in the open water with vegetation and benthic with vegetation habitats, respectively. Steep side with vegetation and benthic without vegetation were habitats that were not utilized as frequently as the other habitats, and patterns of use were consistently low throughout the year.

Patterns of habitat use by males and females were not consistent throughout the year, except for in two of the particular habitats, which correlate with the change in the number of turtles recorded at different depths at those times of the year (Appendix, Table 8). In October, 2.9 females and 4.0 males were recorded per dive in the open water with vegetation habitat, and 0.6 females and 1.1 males were recorded in the benthic with vegetation habitat, respectively. Coinciding with the number of males recorded at deeper depths in the winter and spring months, the number of males recorded per dive also increased in the winter and spring months within these habitats. In the benthic with vegetation habitat, 8.3 males and 2.5 females were recorded per dive in January, the most recorded all year. After January, the number of turtles recorded per dive in this habitat steadily decreased, especially the males, until about the same number of males and females were recorded in this habitat per dive, with 0.7 females, and 1.1 males recorded in July. In the open water with vegetation, numbers substantially increased in January, with 2.8 females, and 8.1 males recorded per dive. Numbers continued to increase, until a peak number of 10.6 males per dive was recorded in April. Numbers decreased throughout the summer, until the numbers of males and females recorded per dive were about the same in the open water with vegetation habitat. By July, 1.6 females and 2.1 males were recorded per dive, a substantial decrease from the spring.

Behaviors were also recorded throughout the year within each of the habitats (Appendix, Table 9). Resting/stationary (R) was the behavior documented most in the open water with vegetation habitat, with a recorded number of 392 turtles exhibiting this behavior (Fig. 5). At the surface (A), and swimming (S) were the most recorded behaviors in the open water without vegetation habitat (Fig. 6). Total number of turtles recorded at the surface was 479, and 451 turtles were recorded swimming in this habitat.

Resting/stationary (R) was again the most recorded behavior in the steep side with vegetation habitat, with a documented number of 101 turtles exhibiting this behavior (Fig. 7). Resting/stationary (R) was the most recorded behavior in the other three habitats

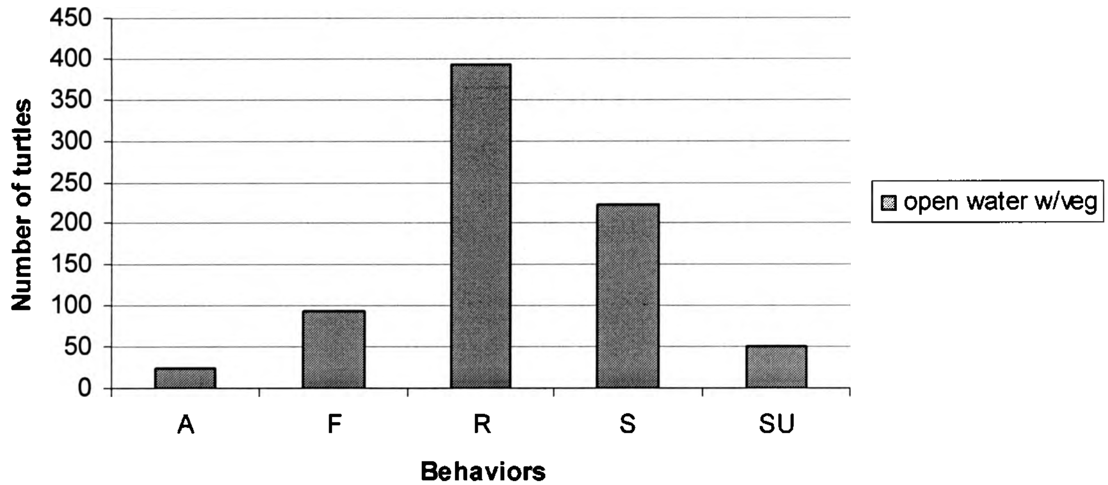


Figure 5. Behaviors exhibited by *P. texana* in open water with vegetation habitat.

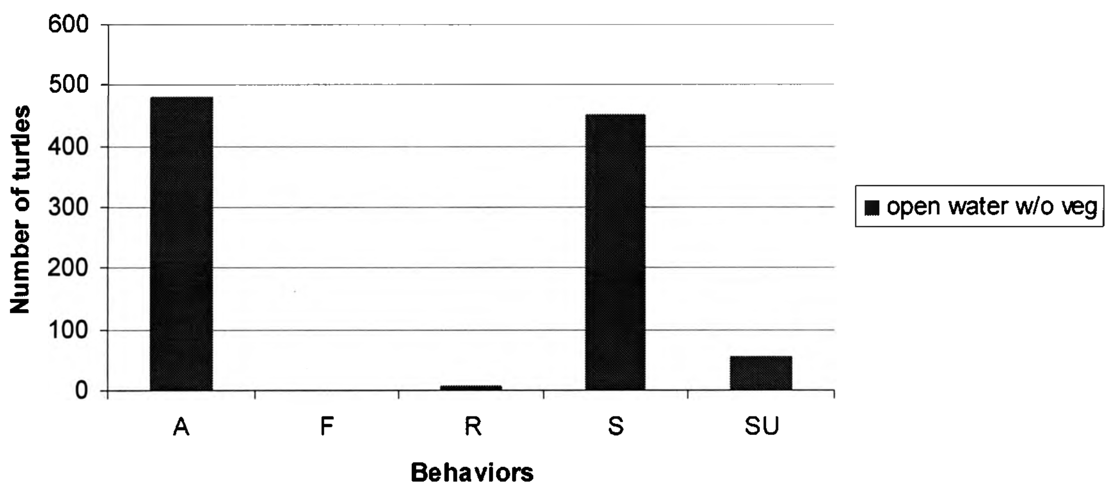


Figure 6. Behaviors exhibited by *P. texana* in open water without vegetation habitat.

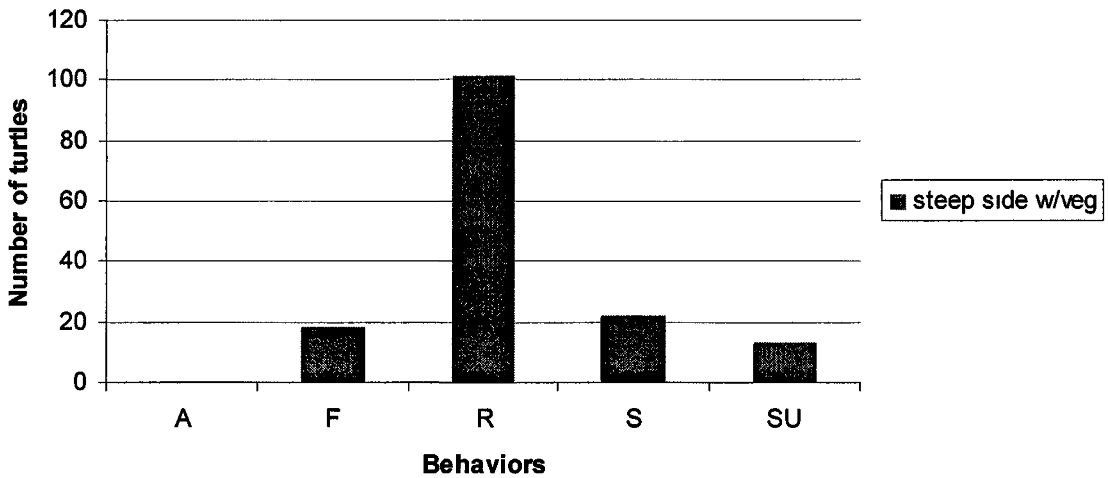


Figure 7. Behaviors exhibited by *P. texana* in steep side with vegetation habitat.

as well, with 9, 250, and 54 turtles recorded in the steep side without vegetation, benthic with vegetation, and benthic without vegetation habitats respectively (Fig. 8, Fig. 9, and Fig. 10).

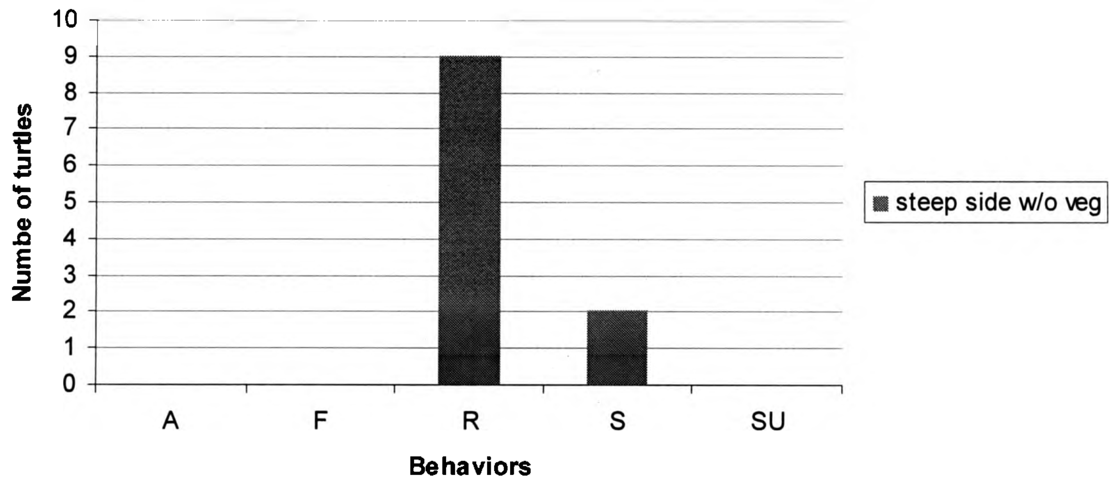


Figure 8. Behaviors exhibited by *P. texana* in steep side without vegetation habitat.

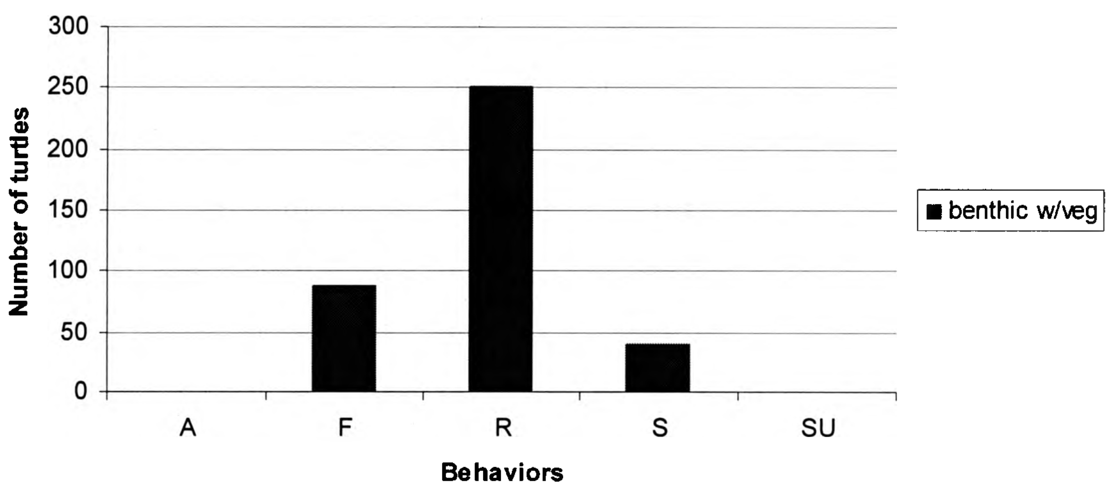


Figure 9. Behaviors exhibited by *P. texana* in benthic with vegetation habitat.

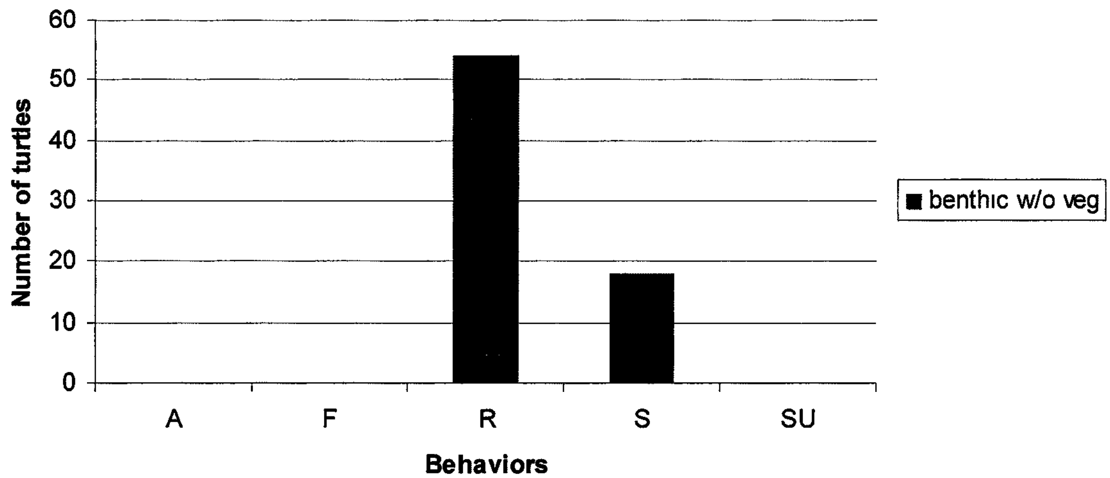


Figure 10. Behaviors exhibited by *P. texana* in benthic without vegetation habitat.

# CHAPTER 4

## DISCUSSION

In this study the main objectives included describing and quantifying underwater habitat use in a vertical context, describing and quantifying underwater behavior, and examining differences by months, depth, habitat, sex, and behavior. After analyzing the data, it was found that there were differences in the vertical utilization of habitats by *Pseudemys texana* in Spring Lake, Hays County, Texas.

Although most turtle species use terrestrial habitats for some aspect of their life cycle, many riverine species are tied to specific aquatic conditions (Bodie and Semlitsch 2000). The few studies that do encompass a large scale three-dimensional view of spatial dynamics underwater include marine turtles and a marine mammal. Dive-depth distributions have been established for loggerheads (*Caretta caretta*) (Polovina et al. 2003), olive ridleys (*Lepidochelys olivacea*) (Polovina et al. 2003), green turtles (*Chelonia mydas*) (Southwood et al. 2003), as well as for Weddell seals (*Leptonychotes weddellii*) (Hindell et al. 2002). The loggerhead dive-depth distributions indicated that these animals tended to remain at shallower depths than that of 100 m, while olive ridley sea turtles dived deeper, but only about 10% of their time was spent deeper than 100 m (Polovina et al. 2003). For green turtles, there was a significant difference between seasons in the amount of time that green turtles spent at shallow depths (Southwood et al. 2003). Weddell seals used the water column (vertical dimension) in a non-uniform manner, where most of the time spent diving (as opposed to being in the water resting or interacting with their pups) was spent in the top 50 m (Hindell et al. 2002). Earlier studies have described larger-scale spatial use patterns in 2 dimensions, e.g. in southern elephant seals, northern elephant seals, grey seals, and spotted dolphins (Hindell et al. 2002).

Other studies quantifying three-dimensional use of the habitat by freshwater turtles are not documented, therefore little literature is available for comparison to this study. The limited number of studies assessing three-dimensional spatial use by marine animals usually does not quantify the use throughout the year. However, a study with green turtles at Heron Island, Australia did quantify three-dimensional spatial use throughout the year. In the study it was found that the green turtles spent a larger proportion of time at sea in shallow water during winter than during summer, however, dive depths > 1 m were deeper during winter than during summer, and had a tendency towards longer dive durations in winter than in summer (Southwood et al. 2003). A large number of *P. texana* utilized < 1 meter depth throughout the year, however, in winter they also dove to greater depths and possibly remained there longer since more were recorded at a depth of > 3 meters in the winter than in the summer. There are a few possible explanations for this, including changes in photoperiod, or seasonal changes in food availability.

A number of aquatic species in temperate climates escape freezing temperatures by overwintering under water (Reese et al. 2002). Many turtles hibernate on the bottom of lakes and streams (Zug et al. 2001). Several studies report painted turtles and snapping turtles burying in the mud during winter (Reese et al. 2002). Even at the latitudes of Spring Lake, the turtles respond to winter temperatures by using the deeper water habitat during these months. Although the ambient air temperature changes throughout the year, the water temperature in Spring Lake remains constant at about $21^0$C. However, instead of in an inactive state of dormancy, *P. texana* was not only active at deeper depths during the cooler months, but dramatically increased in numbers. The use of deeper water during the winter months, despite the constant water temperature, was likely the result of an innate behavior triggered by photoperiods. Thus, *P. texana* was able to remain highly active due to the environment of Spring Lake.

Seasonal changes in food availability or location of preferred food may also contribute to shifts in depth preferences between summer and winter (Southwood et al. 2003). Polovina et al. (2003) found that the deeper diving seen in the olive ridley sea turtles resulted from foraging at depths associated with the deep scattering layer. Until recently, quantitative analysis of the diet of *P. texana* had not been thoroughly documented. Fields et al. (2003) found that *Pseudemys texana* is a herbivorous turtle species that forages selectively among available food plants, confining most of its foraging to four species of aquatic plants, hydrilla (*Hydrilla verticillata*), Carolina fanwort (*Cabomba carolina*), parrot's feather (*Myriophyllum sp.*), and common coontail (*Ceratophyllum demersum*). Carolina fanwort was a highly selected forage species by *Pseudemys texana*. If the availability of plants such as Carolina fanwort change with depth during the year, then turtle activity at different depths may change as well. Further investigation is needed to document the type and amount of vegetative changes with depth throughout the year.

Aquatic habitat use in this study was also assessed. Utilization by *P. texana* of benthic habitats corresponded with large numbers recorded at depths greater than 3 meters during the winter months. Open water habitat was utilized the most throughout the year. Increased numbers of *P. texana* was recorded in the winter and spring, with the largest recorded increase in males from January to May. Harrel et al. (1996) listed four reasons for turtle movements: basking, reproduction, feeding, and favorable hiding places. Litzgus and Brooks (2000) found that spotted turtles (*Clemmys guttata*) in Georgian Bay displayed seasonal shifts in habitat use, and behavioral changes within the yearly activity cycle. These changes were responses to thermophilic requirements (nesting and hibernation) or to increase the chances of encountering conspecifics for mating. Bodie and Semlitsch (2000) found that temporally, river and scour habitats were used almost exclusively during cool months while a diversity of habitats, especially more ephemeral ones, were used in warm months. The increased numbers of *P. texana* recorded in the winter and spring months with the decrease recorded in the summer months could be due to changes in their behavioral activity. Reproductive behaviors most likely increased in late winter and early spring since female *P. texana* nest April - July. The drastic decrease in turtles recorded after May and during the summer is most likely due to an increase in basking in other habitats in other parts of Spring Lake (i.e. the slough).

Perillo (1997) found that in the spring months between March and May, male spotted turtles (*Clemmys guttata*) migrated between wetlands possibly to increase their mating opportunities. In a study by Plummer et al. (1997), it was also found that male softshell turtles (*Trionyx spiniferus*) consistently had greater frequency of activity and movement, greater amount of movement, and greater home range size than females. Increased number of turtles recorded in late winter, early spring probably reflects increased courting (Rose pers. comm.). The decrease in females in the late spring and early summer months is also more than likely correlated with reproductive behavior since they are nesting at that time (Fig. 3). It is important to point out that the female Texas river cooters nest in a variety of places around Spring Lake, including areas adjacent to the slough (a lentic backwater area), as well as the golf course, which would correspond with the small number of females detected in the lake in the summer months.

Fine-scale habitat use is fundamental to understanding many key aspects of an animal's ecology (Hindell et al. 2002). At the present time, there is a limited number of aquatic studies that focus on the three-dimensional use of an organism's environment. The small amount of literature on the subject concerned with turtles, focuses on marine species. Freshwater species utilization of the aquatic habitat in a vertical aspect is an important concept that needs further exploration. Managers of these aquatic habitats must recognize the needs of organisms throughout their life cycles, both spatially and temporally (Bodie and Semlitsch 2000). While *P. texana* remains abundant in many areas and is not threatened or endangered, its range is still limited to central and western Texas in the Colorado, Brazos, Guadalupe, and San Antonio river drainages. Species introductions and habitat alteration are two of the most important threats to global biodiversity and ecosystem structure and function (Silliman and Bertness 2004). While these threats have not altered the abundance of *P. texana*, other species have suffered substantial losses due to the introduction of invasive exotics, as well as habitat degradation. Since the difficulties involved in studying threatened or endangered freshwater turtles from a three-dimensional viewpoint in their natural habitat are substantial, it was beneficial to undertake this study in a habitat conducive to such investigations on a similar turtle species, and can be applied to others. Furthermore, documenting three-dimensional spatial use in *P. texana* could be important in gathering an accurate population estimate, if there are certain times of the year and specific depths that more turtles can be found. Finally, patterns detected in three-dimensional use across seasons, depth, habitat, and sex could be important in further studies addressing population interactions such as inter- and intra-specific competition.

Relating habitat use to seasonal activity is an essential element of such management activities because there are often seasonal shifts in habitat use by animals (Litzgus and Brooks 2000). The variability reported in many of the numerous descriptive studies concerning how aquatic turtles move is interesting because of its possible evolutionary consequences (Plummer et al. 1997). Further assessment of *Pseudemys texana* in Spring Lake, Hays County, Texas, may help to answer many of these ecological questions. Future studies of this organism should include night dive surveys, as well as mid-day dive surveys, in order to more meticulously describe the three-dimensional habitat use of this organism. Other turtle species that inhabit Spring Lake should also have dive profiles created, in order to better understand the community ecology in Spring Lake, including competition. As aquatic systems continue to be drained, degraded, and isolated, riverine systems will play an increasingly important role in maintaining the ecological processes necessary to maintain regional populations in the future (DonnerWright et al. 1999).

Table 3. Number of male and female turtles per dive recorded at different depths during different months of the year.

| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb | Mar. | Apr | May | June | July | Aug. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Female < 1 | 2.30 | 7.10 | 3.10 | 1.40 | 5.60 | 2.90 | 3.10 | 3.70 | 2.60 | 2.40 | 3.00 | 4.00 |
| Male < 1m | 2.70 | 11.60 | 7.50 | 4.60 | 14.30 | 7.90 | 9.40 | 10.90 | 10.10 | 4.10 | 4.90 | 5.20 |
| Female 1-3 | 1.00 | 1.50 | 1.80 | 0.70 | 2.80 | 2.10 | 3.90 | 2.00 | 3.10 | 1.10 | 2.30 | 2.30 |
| Male 1-3 m | 2.00 | 3.50 | 4.90 | 3.10 | 8.60 | 8.60 | 11.80 | 9.40 | 10.20 | 2.70 | 2.90 | 3.20 |
| Female > 3 | 0.40 | 0.20 | 0.40 | 0.70 | 2.40 | 1.70 | 0.90 | 0.10 | 0.80 | 0.30 | 0.60 | 0.70 |
| Male > 3 m | 0.10 | 0.20 | 0.80 | 1.70 | 9.00 | 9.00 | 8.40 | 3.00 | 2.60 | 0.30 | 1.40 | 0.70 |

Table 4. Number of male and female turtles per dive recorded in different habitats during different months of the year.

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | July |
|---|---|---|---|---|---|---|---|---|---|
| Female OWV | 2.90 | 1.50 | 1.20 | 2.80 | 2.10 | 3.80 | 2.40 | 2.30 | 1.60 |
| Male OWV | 4.00 | 3.80 | 3.60 | 8.10 | 6.80 | 9.00 | 10.60 | 10.00 | 2.10 |
| Female OW | 4.50 | 2.10 | 0.60 | 4.20 | 2.20 | 2.60 | 3.00 | 2.80 | 2.70 |
| Male OW | 8.10 | 6.00 | 3.60 | 11.70 | 8.10 | 11.60 | 8.70 | 9.40 | 4.60 |
| Female SV | 0.60 | 0.80 | 0.20 | 1.00 | 0.40 | 0.30 | 0.10 | 0 30 | 0.20 |
| Male SV | 1.50 | 1.90 | 0.60 | 2.40 | 1.60 | 1.00 | 1.10 | 1.40 | 0.90 |
| Female SO | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 |
| Male SO | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 | 0.10 | 0.00 | 0.30 | 0.00 |
| Female BV | 0.60 | 0.50 | 0.30 | 2.50 | 1.60 | 1.10 | 0.10 | 0.70 | 0.70 |
| Male BV | 1.10 | 0.90 | 0.90 | 8.30 | 7.30 | 7.50 | 2 30 | 1.60 | 1.10 |
| Female BO | 0 10 | 0.10 | 0.30 | 0.20 | 0.40 | 0.10 | 0.10 | 0.10 | 0.70 |
| Male BO | 0.30 | 0.40 | 0.70 | 1.30 | 1.90 | 0.40 | 0.60 | 0.10 | 0.40 |

Table 5. Number of turtles per dive recorded throughout the year

| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Turtles | 8.60 | 24.10 | 18.38 | 12.10 | 42.70 | 32.10 | 37.40 | 29.10 | 29.30 | 11.00 | 15.10 | 16.00 |

Table 6. Number of turtles per dive recorded at different depths during different times of the year.

| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| < 1 m | 5.00 | 18.70 | 10.60 | 6.00 | 19.90 | 10.80 | 12.50 | 14.50 | 12.70 | 6.70 | 7.90 | 9.20 |
| 1-3 m | 3.00 | 5.00 | 6.70 | 3.80 | 11.40 | 10.70 | 15.70 | 11.40 | 13.30 | 3.90 | 5.20 | 5.50 |
| > 3 m | 0.60 | 0.40 | 1.10 | 2.30 | 11.40 | 10.70 | 9.30 | 3.10 | 3.30 | 0.60 | 2.00 | 1.30 |

Table 7. Number of male and female turtles recorded per dive during different times of the year.

| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Females | 3.70 | 8.80 | 5.30 | 2.80 | 10.80 | 6.70 | 7.90 | 5.90 | 6.40 | 3.90 | 5.90 | 7.00 |
| Males | 4.90 | 15.30 | 13.10 | 9.30 | 31.90 | 25.40 | 29.50 | 23.30 | 22.90 | 7.10 | 9.20 | 7.70 |

Table 8. Number of turtles per dive recorded in different habitats during different times of the year.

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | July |
|---|---|---|---|---|---|---|---|---|---|
| OWV | 6.90 | 5.30 | 4.80 | 10.90 | 8.90 | 12.80 | 13.00 | 12 30 | 3.70 |
| OW | 12.60 | 8.10 | 4.10 | 15.90 | 10.30 | 14.30 | 11.70 | 12.20 | 7.20 |
| SV | 2.10 | 2.60 | 0.80 | 3.40 | 2.00 | 1.30 | 1.30 | 1.80 | 1.10 |
| BV | 0.70 | 1.40 | 1.20 | 10.80 | 8.90 | 8.70 | 2.40 | 2.20 | 1.80 |
| BO | 0.40 | 0.50 | 1.00 | 1.50 | 2.30 | 0.50 | 0 70 | 0.20 | 1.10 |

Table 9. Number of turtles recorded exhibiting different behaviors in different habitats.

| | A | R | F | S | SU |
|---|---|---|---|---|---|
| OWV | 25 | 392 | 94 | 223 | 50 |
| OWV | 479 | 5 | 0 | 451 | 53 |
| SV | 0 | 101 | 18 | 22 | 13 |
| SO | 0 | 9 | 0 | 2 | 0 |
| BV | 0 | 250 | 87 | 40 | 0 |
| BO | 0 | 54 | 0 | 18 | 0 |

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## VITA

Linda Catherine Osborne was born in Valdosta, Georgia, on November 8, 1979, the daughter of Kathleen Louise Osborne and Travis Wayne Osborne. After graduating from Judson High School, Converse, Texas, in 1998, she entered University of Houston, in Houston, Texas. For the next four years, she worked towards her Bachelor's degree and swam on scholarship for the University of Houston Swim Team. She received the degree of Bachelor of Science in Biology from the University of Houston in May 2002. During the following year she was employed as an aquarist trainee at Sea World in San Antonio, Texas. In August 2003, she entered as a part time graduate student, and in January 2004 she entered as a full time graduate student in Wildlife Ecology at Texas State University-San Marcos. While working towards her Master's, she has been an IA for 1421 (Introduction to Biology), 1431 (Organismal Biology), and 4416 (Ecology). She has also been lab prep for 4 semesters in 1431 (Organismal Biology). She is getting married in May 2006, and plans to teach for a few years before going back to pursue her doctoral degree.

Permanent Address: 7702 Clear Ridge Drive

San Antonio, Texas 78239

This thesis was typed by Linda Catherine Osborne