# CHANGES IN HABITAT WITH SUBSEQUENT CHANGES IN DIET OF THE TEXAS RIVER COOTER IN SPRING LAKE, HAYS COUNTY, TEXAS

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Vanessa Piña, B.S.

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CHANGES IN HABITAT WITH SUBSEQUENT CHANGES IN THE DIET OF THE TEXAS RIVER COOTER IN SPRING LAKE, HAYS COUNTY, TEXAS

Committee Members Approved:

______________________________
Thomas R. Simpson, Chair

______________________________
Francis L. Rose

______________________________
Floyd W. Weckerly

Approved:

______________________________
J. Michael Willoughby
Dean of the Graduate College

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**ABSTRACT**

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SUPERVISING PROFESSOR: Thomas R. Simpson

A fall-winter food habit study of Texas river cooters (Pseudemys texana) was conducted at Spring Lake, Hays County, Texas, from January 2010 to March 2011. My objectives were to determine current diets of Texas river cooters and the composition of the vegetative community in Spring Lake. I quantified aquatic vegetation in Spring Lake using Daubenmire frames along 26 transects placed across the lake. I captured 45 turtles using dipnets and basking traps and collected 32 stomach contents from flushed and fecal samples. I identified food items in the samples to the lowest possible taxon. To evaluate selective foraging, I compared the availability of aquatic vegetation in Spring Lake to the proportion of each taxon found in the diet in a log-likelihood chi-square analysis with confidence intervals. I calculated Manly's alpha indices to determine if the turtles foraged selectively. Ninety percent of the diet was composed of four plant taxons including filamentous algae, *Cabomba caroliniana*, *Ceratophyllum demersum*, and

*Myriophyllum* spp. Only filamentous algae, *C. caroliniana*, and watermilfoil species were selected for during the 2011 fall-winter diet. I compared my results to the results of a similar study conducted during October 1996 to March 1997. There was a change in *P. texana* food habits and availability of food resources since the Seaman et al. (1997) study in Spring Lake.

# INTRODUCTION

Nearly half of documented dependent freshwater turtle species are listed as threatened on the International Union for Conservation of Nature (IUCN) red list (Revenga et al. 2005). Increasing human encroachment into freshwater habitats has positively correlated with the transformation of turtle communities through their differential survival rates (Smith et al. 2006). Human impact and environmental pressures can alter the diets, interactions, and resources that structure these environments (Huestis and Meylan 2004). As a relatively long-lived group, turtles can provide valuable insight through their responses to the changes in these ecosystems.

The Texas river cooter (*Pseudemys texana*) is an endemic emydid turtle found throughout the watersheds of South-central Texas (Iverson 1992, Lindeman et al. 1999) including the Colorado, Brazos, Guadalupe, Nueces, and San Antonio drainages. This species is generally distinguished by broad yellow head markings along with hingeless, yellowish plastron with whorls (Carr 1952). Sexually dimorphic characters are present in this species (Ernst et al. 1994, Conant and Collins 1998). Males tend to have longer claws and tails, and are generally smaller in size than the females. Body sizes and carapace patterns may display considerable geographic variation (Killbrew and Porter 1989, Lindeman 2007). They can produce multiple clutches with 4-17 eggs per clutch per year (Vermersch 1992).

Natural history information on Texas river cooters is confusing due to taxonomic ambiguity prior to Ward's (1984) elevation of the turtle to species status. It is difficult to check the accuracy of species identification in earlier studies of this species. Some clarifications were published with an attempt to interpret older misidentifications in the literature. Strecker (1927) described the diet of the adult Texas river cooter to be predominantly molluscivorous. However, this information was contradicted by more recent findings, which noted that adult river cooters are primarily herbivorous (Seaman 1997, Fields et al. 2003, Lindeman 2007). Several studies since that time have expanded information on Texas river cooters' life history and ecological role in fresh water habitats (Killbrew and Porter 1989, Rose et al. 1996, Seaman 1997, Lindeman 2007, Rose 2011).

My research was designed to document changes in food habits in response to changes in habitat. Most dietary studies of turtles focus on snapshots of food habits and were made for a single season in a particular location (Seaman 1997, Lindeman 2007). However, this information fails to give a clear picture of how turtles respond to changes in their habitat as proportions of selected vegetation disappear or increase. My project is a repeated dietary study in Spring Lake, Hays County, Texas. The results from my study were compared to Seaman's (1997) study, which reported dietary selectivity and available aquatic vegetation in Spring Lake in 1997.

Vegetation as a primary food source for herbivorous wildlife has bottom-up controls (Aresco 2009). While many herbivorous mammal diet studies (Holechek et al. 1982) have been undertaken in the past 50 years, a new focus has been aimed at reptilian diets. Dietary behaviors affect an animal's energetics, home range, niche, and life history. As these freshwater habitats sustain less elasticity from external disturbances, these temporal and spatial shifts in dietary responses provide baseline information needed to make appropriate management, protection, and policy (Revenga et al. 2005). By investigating these temporal trends through droughts, fragmentation, and human encroachment, a new understanding of their needs and plasticity can aid in anticipating their requirements and restrictions.

## MATERIALS AND METHODS

### Study Site

Spring Lake, Aquarena Center, Hays County, Texas is the headwaters of the San Marcos River and the second largest spring system in Texas (Brune 2002). It straddles the Balcones fault line dividing the Edwards Plateau and the Oak and Prairie ecoregions. The lake, approximately 7.89 ha in surface area, is fed from over 200 springs flowing from the Edwards Aquifer. The main lake containing the spring run is a lotic system, while a backwater area, the slough, provides a lentic habitat (Swannack and Rose 2003). The main lake maintains a relatively stable temperature throughout the year that ranges from 21-22.5 $^{o}$C near the springs (Groeger et al. 1997).

In the 1940s the site was altered to form an amusement park, Aquarena Springs. Several amusement rides and glass bottom boats operated in the lake, and exotic, invasive vegetation and animals were added to the ecosystem. Spring Lake and the surrounding property were purchased by Texas State University-San Marcos in 1991. The property, now known as Aquarena Center, promotes research and education.

The aquatic vegetation has changed significantly throughout the history of the lake due to the anthropogenic introduction of non-native flora and fauna. Introduced animals include nutria (*Myocastor coypus*), swans (*Cygnus* spp.), Asiatic clam (*Corbicula fluminea*), and giant ramshorn snail (*Marisa cornuarietis*) (Arsuffi et al. 2000). Introduced fish include Blue tilapia (*Tilapia aurea*), Rio-grande cichlids

(*Cichlasoma cyanoguttatum*), Mexican tetra (*Astyanax mexicanus*), and Sailfin molly (*Poecilia latipinna*) (Seaman 1997). Restoration efforts began in 1996 to restore the lake to its natural condition.

Non-native vegetation includes elephant ear (*Colocasia esculenta*), common water hyacinth (*Eichhornia crassipes*), Eurasian watermilfoil (*Myriophyllum spicatum*), Parrot feather watermilfoil (*Myriophyllum brasiliense*), Florida elodea (*Hydrilla verticillata*), Brazilian elodea (*Egeria densa*) (Watkins 1930, Devall 1940, Lemke 1989). Within the past five years, pale yellow iris (*Iris pseudacoris*), alligatorweed (*Alternanthera philoxeroides*), and eel grass (*Vallisneria spiralis*) have also been introduced into the lake (Williams et al. 2011). Efforts were made by divers, faculty, and volunteers to remove exotic species. However, methods of removing exotic flora and fauna are highly controversial due to the presence of endangered species and the federal regulations that protect them.

Brune (2002) reported three floods (1998, 2001, and 2002) that impacted Spring Lake since the study by Seaman (1997). Spring Lake and the San Marcos River were heavily impacted by these floods. Towns (2002) reported that the flood of 1998 removed a large proportion of the submerged aquatic vegetation in the slough exposing large amounts of bare substrate.

**Vegetation Transects**

To measure the availability of plants in the lake in November 2011, I placed 284 (100 cm x 20 cm) daubenmire frames (Daubenmire 1959) at 5 m intervals along 26,100 m transects, located approximately 50 m apart throughout the lake (Fig. 1). I identified plant species and cataloged each as submerged and floating vegetation. I recorded percent coverage of each plant species viewed within the frame to a depth of 1m beneath the surface (Coulloudon et al. 1999). Majority of the common names were found in a technical report (Westerdahl and Getsinger 1988). All other common names were found on the United States Department of the Agriculture plant database (U.S. Department of Agriculture 2012).

**Vegetation Reference Slides**

I made twenty-three plant species reference slides using histological techniques (Gray 2002) to identify any aquatic macrophytes that were present in the vegetation transects. Macroscopic slides for gross identification were created with full leaf specimens and stem-cuts. To view characteristic epidermal cells for a plant species (Fig. 2), I placed approximately 5 g of each identified species in a blender with 20 ml of tap water and blended the contents at high speed. Using a pipette, I mounted shredded portions on a labeled slide. Mount-quick™ aqueous solution was used to seal in the coverslip and remove air bubbles in the slides. The epidermal cells from reference slides were used to identify cells in stomach contents or fecal samples (Zyznar and Urness 1969).

**Turtle Collection Techniques**

I set basking traps (MacCulloch and Gordon 1978) from February to March in 2012 at three sites in Spring Lake where numerous Texas river cooters were observed (Gamble 2006). I used the same canoe design as Seaman (1997) for using dipnets to capture turtles at night. All procedures were conducted under the Institutional Animal Care and Use Committee (IACUC) protocol number 1027_0909_22. The canoe was equipped with two spotlights positioned at different heights, which provided visibility


Figure 1. Five regions of Spring Lake, Hays County, Texas with positions of vegetation transects in 2011.

while dip-netting at night. A crew of three people manned the canoe. One person paddled from the stern. Another handled a free-ranging spotlight in the center of the hull. The third person dip-netted from the bow of the canoe. This method of night collections had the best results with male turtles in the slough region of the lake. During January 2011, daytime dip-netting was used near shallow, thick vegetation. Dense beds of muskgrass sp. (*Chara* sp.) in the center of the basin region enabled the technique of corralling surface-basking Texas river cooters. This was a prime area to find females basking during the end of January though both sexes were present.

Permanent marking of turtles using Passive Integrated Transponders (PIT tags) and Cagle's (1939) standardized notching system was already in use at Spring Lake for other research projects. Additionally, I temporarily marked successfully flushed turtles on the carapace with neon green spray paint. These methods enabled an accurate identification protocol in the lake and in the laboratory to prevent redundant sampling and stress to the turtles. Identification numbers from previously marked turtles were recorded. If I captured an unmarked turtle, it was marked and added to the database. I measured carapace length, carapace width, and plastron length with calipers. Marking also allowed me to evaluate whether the captured turtle met the minimum size requirements for flushing in this study. The smallest successfully flushed specimen had a carapace length of 189 mm and a plastron length of 165 mm.

**Stomach Flushing and Fecal Collection**

I processed turtles within 5-10 hours of capture. All turtles were kept in individual bins before and after flushing. I used a modified Legler technique to flush the turtles (Legler 1977, Fields et al. 2000). I used an anesthetic to sedate and reduce trauma

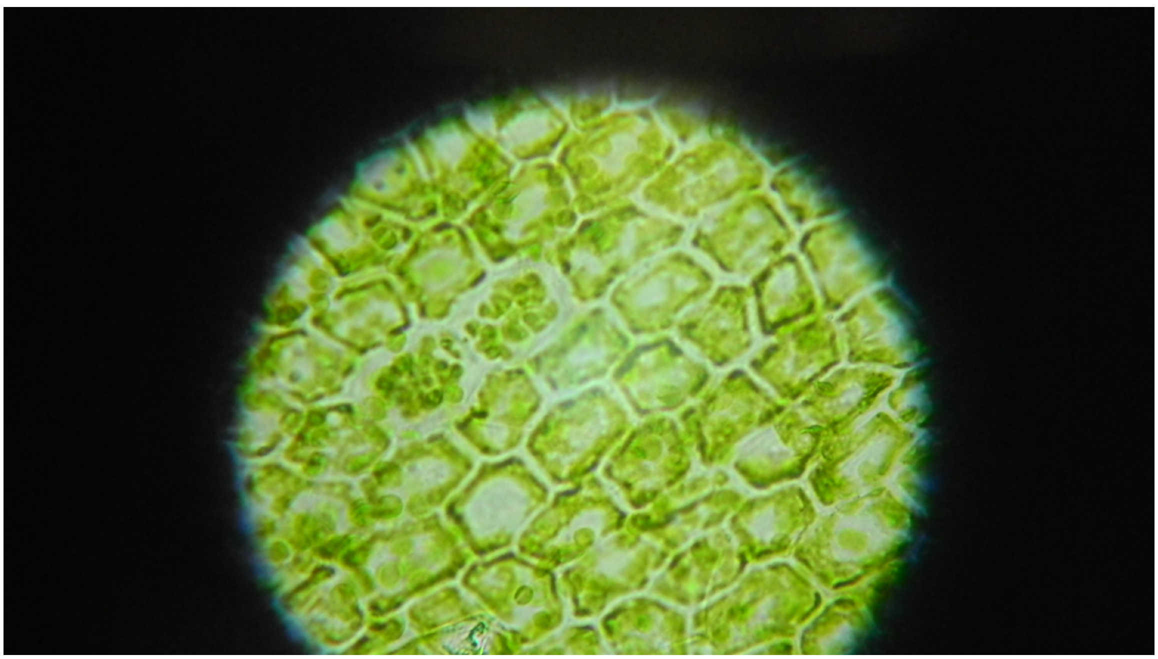

Figure 2. 40x magnification of the epidermal cells of *Ceratophyllum demersum.*

to the turtles. I attempted to use isoflurane as an alternative to ketamine HCl; however, this was unsuccessful due to their respiratory physiology. By January, I operated under the supervision of a local veterinarian, Dr. Jeff Jorgenson, in administering 50 mg/ kg ketamine HCl intramuscularly into the turtles (Mader 2006). Thirty minutes to an hour was adequate for the sedative to take effect. Slowed reflexes, extended neck, and lack of struggle indicated that the animal was successfully sedated and was ready to be flushed.

I used the same table (60 cm x 28 cm) and equipment as described by Seaman (1997). The table consisted of a non-skid pad on a 35$^{o}$ inclined table with a web strap to secure the turtle upside-down. The turtle was positioned with the plastron up and the head in a downward angle. Once secured to the pad, a burette clamp was placed behind the angle of the jaw to hold the neck in an extended position (Fig. 3). A lubricated feeding tube was inserted through the esophagus and into the stomach. A hand-operated transfer pump was used to keep a low continuous flow of water to the turtles' stomach reducing the amount of air bubbles entering its system. If two liters of clear water was pumped to the stomach without flushing food, the turtle was considered to have an empty stomach. All flushed stomach contents were appropriately labeled and preserved in 95% ethanol within400 ml jars. I placed all sedated and flushed turtles in individual bins overnight for recovery. Any fecal material left behind was collected and preserved in 95% ethanol. All turtles were returned to their point of capture in the lake the following day.

**Specimen Analysis**

Stomach contents or fecal samples were washed through a sieve and placed in 50 ml of tap water in a 7.5 in. x 6.0 in. rectangular glass tray. I placed a laminated grid with

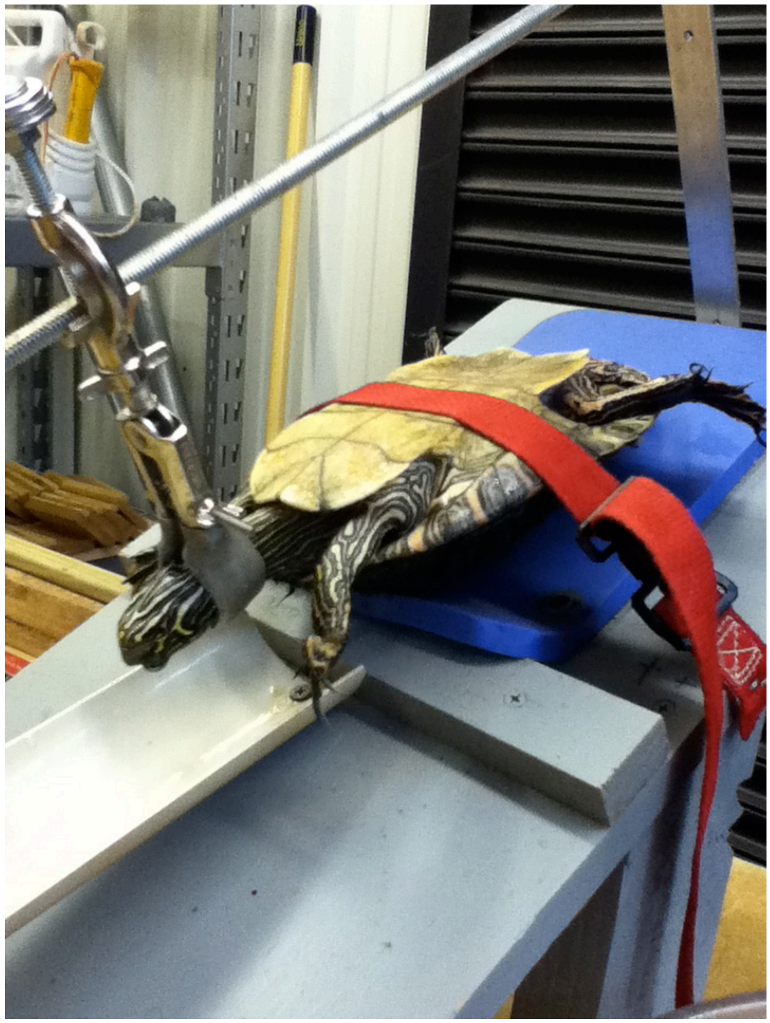

Figure 3. Demonstration of modified Legler technique and constraint of *Pseudemys texana.*

lines 2 cm apart under the clear tray (Fig. 4). The sample was immersed in approximately 30 ml of tap water and stirred vigorously to even its distribution in the tray. I selected 50 samples from the grid line intersections for identification with a dissecting or compound microscope (Scalise 2011). I compared epidermal cells from stomach or fecal samples to digital pictographs of epidermal cells from reference slides for identification to species level (Zyznar and Urness 1969). After removing and identifying sample material from 50 grid intersections, I remixed the stomach or fecal material and selected another 50 items for identification. I identified a total of 100 items from each stomach or fecal sample. All finished samples were sieved once more and placed in 95% ethanol again for storage.

**Aquatic Vegetation Surveys**

I surveyed the vegetation of Spring Lake during November 2010 to obtain an estimation of plant cover, species richness, and percent cover by species throughout the lake. The vegetation was estimated utilizing a Daubenmire frame and technique (Daubenmire 1959). I positioned 26 transects 50 m apart across all sections of Spring Lake and the slough. A 100 cm x 20 cm (0.20 $m^2$) Daubenmire frame was placed every 5 m along each transect. In addition to percent composition by species, I recorded percent bare substrate and open water. I defined open water as the surface area of the frame that only consisted of water. I defined bare substrate as the absence of vegetation resulting in exposed substrate on the floor of the lake. Clippings were noted and added to the appropriate taxon within the quadrat.

I estimated percent cover by averaging the cover class percentage for each food item divided by the sum of averaged classes for all aquatic macrophytes including open

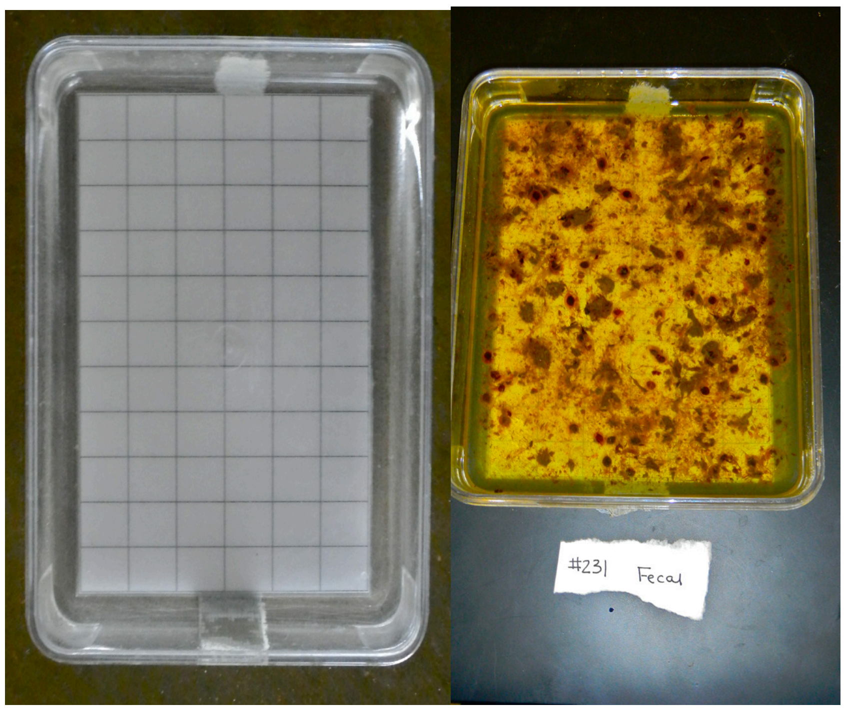


Figure 4. Modified tray used for the specimen analysis.

water and bare ground (% cover of plant $species_i$ = mean percent cover for plant $species_i$/Σ mean percent cover for all categories). I estimated the area covered (ha) for each species by multiplying the estimated cover percentage for each vegetation category by the area of the lake (7.89 ha). The percent composition excluded open water and bare ground categories (Bonham et al. 2004).

**Forage Selectivity**

I compared the availability of aquatic macrophytes in Spring Lake to the proportion found within the stomach contents to determine whether Texas river cooters were selectively foraging on particular plant species (Krebs 1999, Manly et al. 2002). Availability was identified as the proportion of available units for each vegetation category (Towns 2002). I calculated availability as $a_i/A_i$ ($a_i$ = number of observations of available vegetation in quadrats; $A_i$ = the sum of observations of all available vegetation categories). Usage was defined as the proportion of used units for each vegetation category found in the stomach content samples. I calculated usage as $u_i/U_i$ ($u_i$ = number of observations of vegetation in the stomach content samples, $U_i$ = the sum of observations of all vegetation categories in the stomach content samples).

I identified dietary selectivity as the disproportionate usage of aquatic macrophytes in comparison to availability in Spring Lake (Krebs 1999). Primary food items are plant taxa that were found in more than 50% of the stomach contents and made up more that 10% of the diet. I calculated a log-likelihood chi-square analysis on the 4 primary food items to test the null hypothesis that Texas river cooters consumed aquatic macrophytes in exact proportion to the plant's availability within Spring Lake (Neu et al. 1974). I calculated confidence intervals for each primary food item to encompass the range of expected values. I conducted a Bonferonni correction to adjust the $\alpha$ (0.05) to provide a smaller range in the confidence intervals.

I used a Manly's alpha preference index to distinguish between selectivity or avoidance of aquatic macrophytes by Texas river cooters (Krebs 1999). I defined selectivity by a Manly's alpha larger than 1/m (m= the number of food items used in the analysis). I assumed avoidance when Manly's alpha was smaller than 1/m.

# RESULTS

## Dietary Analysis

I collected 32 dietary samples from 52 captured turtles from January to March 2012. Stomach samples refer to flushed food items and fecal samples refer to fecal deposits. Dietary samples refer to both stomach and fecal samples. Thirty-three percent (n=15) of flushed turtles yielded sufficient samples. Eleven of the flushed samples were from males. I collected seventeen fecal samples from 56 turtles. Twelve fecal samples were from females. I collected stomach and fecal samples from four turtles, but used only the stomach samples. I pooled data from stomach and fecal samples (Caputo and Vogt 2008) to offset possible underrepresentation of vegetative material due to limitations of both methods (Table 1). I identified 3,200 items taken from the dietary samples (n=32). Four species of aquatic macrophytes comprised over 90% of the diet of the Texas river cooters from my study (Table 2). These macrophytes included Carolina fanwort (*Cabomba caroliniana*) (26.78%), coontail (*Ceratophyllum demersum*) (14.94%), Eurasian watermilfoil (*Myriophyllum spicatum*) (13.09%), and filamentous algae (36.22%).

Florida elodea (*Hydrilla verticillata*) comprised 2% of the diet and was present in 9.38% of the stomachs. Twoleaf watermilfoil (*Myriophyllum heterophyllum*) made up 1.38% of the diet and was present in 25% of the stomachs. Delta arrowhead (*Sagittaria*

Table 1. Percent composition of stomach contents collected from *Pseudemys texana* by flushing and fecal techniques in Spring Lake, Hays County, Texas from December 2010 to March 2011.

| Common Name of Food Item | Percent Composition of Dietary Samples (pooled data) (n=32) | Percent Composition in the Flushed Samples (n=15) | Percent Composition in the Fecal Samples (n=17) |
|---|---|---|---|
| Carolina fanwort | 26.78 | 36.47 | 18.24 |
| Coontail | 14.94 | 11.60 | 17.88 |
| Florida elodea | 2.00 | 0.00 | 3.76 |
| Eurasian watermilfoil | 13.09 | 7.20 | 18.29 |
| Twoleaf watermilfoil | 1.38 | 2.33 | 0.53 |
| Delta arrowhead | 0.56 | 0.60 | 0.53 |
| Cone-spur bladderwort | 0.13 | 0.00 | 0.24 |
| Cedar elm | 3.38 | 0.13 | 6.24 |
| Filamentous algae | 36.22 | 41.00 | 32.00 |
| Insects | 0.63 | 0.00 | 1.18 |
| Other | 0.16 | 0.00 | 0.29 |
| Unknown | 0.75 | 0.67 | 0.82 |

Table 2. Percent composition of aquatic macrophytes in the stomach samples collected from *Pseudemys texana* from January 2010 to March 2011 in Spring Lake, Hays County, Texas.

| Food Items | | Percent Composition in the Diet | Percent of Stomachs Containing Food Item |
|---|---|---|---|
| Common Name | Scientific Name | | |
| Carolina fanwort | *Cabomba caroliniana* | 26.78 | 96.88 |
| Coontail | *Ceratophyllum demersum* | 14.94 | 84.38 |
| Florida Elodea | *Hydrilla verticillata* | 2.00 | 9.38 |
| Eurasian watermilfoil | *Myriophyllum spicatum* | 13.09 | 62.50 |
| Two leaf watermilfoil | *Myriophyllum heterophyllum* | 1.38 | 25.00 |
| Delta arrowhead | *Sagittaria platyphylla* | 0.56 | 25.00 |
| Cedar elm | *Ulmus crassifolia* | 3.38 | 34.38 |
| Cone-spur bladderwort | *Utricularia gibba* | 0.13 | 12.50 |
| Filamentous algae | -------- | 36.22 | 87.50 |
| Insects | -------- | 0.63 | 12.50 |
| Other vegetation | -------- | 0.17 | 9.38 |
| Unknown | -------- | 0.75 | 43.75 |

*platyphylla*) made up 0.56% of the diet and was found in 25% of the stomachs. Conespur bladderwort (*Utricularia gibba*) made up 0.13% of the diet and was found in 12.5% of the stomachs. A unique food item was cedar elm (*Ulmus crassifolia*). Only the seeds were found in the stomach samples. It comprised 3.38% of the diet and was found in 34% of stomachs. Amphipods (Amphipoda) were found in 12.5% of the stomachs and comprised 0.63% of the diet.

The remaining vegetation, creeping primrose-willow (*Ludwigia repens*) and common water hyacinth (*Eichhornia crassipes*), only accounted for 0.17% of the diet composition and were found in 9.38% of the stomachs. These plants were most likely ingested incidentally. Unidentified vegetative matter made up 0.75% of the diet composition and was found in 43.75% of the stomachs.

**Aquatic Macrophyte Availability in Spring Lake**

Coontail was the dominant aquatic species throughout Spring Lake during the winter of 2010 to 2011 (Table 3). Coontail was distributed throughout the lake, covering 22.43% of the lake (1.77 ha) of the surface area and composed 37.71% of the aquatic macrophytes in the lake. Carolina fanwort was the second largest in percent coverage of the lake (7.42% cover, 0.59 ha, 12.94% of the aquatic macrophyte composition). It was observed less frequently on transects in the cove region. Two species of watermilfoil had a combined coverage of 7.01% of the lake (0.55 ha, 12.28% of the aquatic macrophyte composition). Eurasian watermilfoil covered 4.16% of the lake (0.33 ha, 7.29% of the aquatic macrophyte composition) was found throughout the lake. Twoleaf watermilfoil covered 2.85% of the lake (0.22 ha, 4.99% of the aquatic macrophyte composition) and was found predominantly in the slough and basin regions. Muskgrass (*Chara* sp.) covered

Table 3. Estimated percent cover and percent composition of aquatic vegetation from 284 Daubenmire frame samples along 26 transects in Spring Lake during November 2010.

| Cover Type | Common Name | Scientific Name | % Cover | % Composition |
|---|---|---|---|---|
| 1 | Carolina fanwort | *Cabomba caroliniana* | 7.42 | 12.94 |
| | Coontail | *Ceratophyllum demersum* | 22.43 | 37.71 |
| | Indian swampweed | *Hygrophilla polysperma* | 0.10 | 0.17 |
| | Eurasian watermilfoil | *Myriophyllum spicatum* | 4.16 | 7.29 |
| | Two leaf watermilfoil | *Myriophyllum heterophyllum* | 2.85 | 4.99 |
| | Delta arrowhead | *Sagittaria platyphylla* | 2.88 | 5.05 |
| | Muskgrass | *Chara* spp. | 1.34 | 2.35 |
| | Creeping primrose willow | *Ludwigia repens* | 0.94 | 1.64 |
| 2 | Mosquito fern | *Azolla caroliniana* | 0.05 | 0.09 |
| | Watersprite | *Ceratopteris thalictroides* | 0.06 | 0.10 |
| | Common water hyacinth | *Eichhornia crassipes* | 0.14 | 0.24 |
| | Water lettuce | *Pistia stratiotes* | 0.56 | 0.98 |
| | Slender riccia | *Riccia fluitans* | 1.97 | 3.45 |
| | Cone-spur bladderwort | *Utricularia gibba* | 1.09 | 1.90 |
| | Common duckweed | *Lemna minor* | 3.77 | 5.95 |
| | Giant duckweed | *Spirodela polyrhiza* | ---- | ---- |
| | Watermeal | *Wolffia papulifera* | ---- | ---- |
| 3 | Spatterdock | *Nuphar luteum* | 1.53 | 2.69 |
| | Elephant's ear | *Colocasia esculenta* | 0.18 | 0.31 |
| | Filamentous algae | ----- | 6.83 | 11.97 |
| | Pennywort | *Hydrocotyle umbellata* | 0.08 | 0.14 |
| | Water willow | *Justinia americana* | 0.01 | 0.02 |
| | Southern naiad | *Najas guadalupensis* | 0.01 | 0.02 |
| 4 | ---- | ---- | 40.85 | ---- |
| 5 | ---- | ---- | 0.75 | ---- |

1 = submerged vegetation; 2= free-floating; 3= Other vegetation; 4= Open water; 5= Bare substrate

1.34% of the lake (0.11 ha, 2.35% of the aquatic macrophyte composition) and was found primarily in the basin region. Indian swampweed (*Hygrophilla polysperm*a) covered 0.10% of the lake (0.01 ha, 0.17% of the aquatic macrophyte composition) was found primarily in the main lake and spring run regions of the lake. Delta arrowhead covered 2.88% of the lake (0.23 ha, 5.05% of the aquatic macrophyte composition) and was found throughout the lake. Creeping primrose willow covered 0.94% of the lake (0.07 ha, 1.64% of the aquatic macrophyte composition) and was primarily found in the cove region. Florida elodea did not occur along any of the line transects placed during this study. Common duckweed (*Lemna minor*), giant duckweed (*Spirodela polyrhiza*), and common watermeal (*Wolffia papulifera*) were collectively denoted as duckweed. The combined estimated cover was 3.77% (0.3 ha) and comprised 5.95% of the aquatic macrophyte composition of the lake. Carolina misquitofern (*Azolla caroliniana*) covered 0.05% of the lake and comprised 0.09% of the aquatic macrophyte composition of the lake. Slender riccia (*Riccia fluitans*) covered 1.97% of the lake (0.16 ha, 3.45% of the aquatic macrophyte composition) and was found amassed with cone-spur bladderwort. Cone-spur bladderwort covered 1.09% of the lake (0.09ha, 1.9% of the aquatic macrophyte composition) and was found in thick accumulations in the slough and basin. Watersprite (*Ceratopteris thalictroides*) covered 0.06% of the lake (0.10% of aquatic macrophyte composition) and was found along sunny shorelines throughout the lake. Two larger free floating aquatic macrophytes appeared to be restricted to the slough and basin regions of the lake. Common water hyacinth covered 0.14% of the lake (0.01 ha total, 0.24% of the aquatic macrophyte composition). Water lettuce (*Pistia stratiotes*) covered 0.56% of the lake (0.04 ha, 0.98% of the total aquatic macrophyte composition).

Filamentous algae covered 6.83% of the lake (0.54 ha, 11.97% of the aquatic macrophyte composition) and were found floating or layered over other submerged vegetation. The majority of the algae were identified as being within the genus *Lynbyga.* Spatterdock (*Nuphar luteum*) covered 1.53% of the lake (0.12 ha, 2.69% of aquatic macrophyte composition) and was a dominant species in the basin and slough region. Elephant ear (*Colocasia esculenta*) covered 0.18% of the lake (0.01ha, 0.31% of aquatic macrophyte composition) and was distributed along the shorelines throughout the lake. Pennywort (*Hydrocotyle umbellata*) covered 0.08% of the lake (0.14% of aquatic macrophyte composition) and also appeared restricted to the shallow shorelines. Water willow (*Justinia americana*) and southern naiad (*Najas guadalupensis*) were both observed sparsely in the cove region. They were each estimated covering merely 0.01% of the lake (0.02% of aquatic macrophyte composition).

Bare substrate (benthic), absent of vegetation, covered 40.85% of the lake (3.22 ha). The largest portion of this was found in the spring run region. Areas of exposed pipe and springs are kept bare for scientific flow measurements and educational purposes.

A recent extensive survey of vegetation in Spring Lake (Williams et al. 2011) indicated 51 aquatic macrophytes were present in Spring Lake. My line transects encountered only 23 species. Pale yellow iris and eel grass are newly introduced plants to the lake and were first recorded in 2009 (Williams et al. 2011). Though the vegetation in Spring Lake is noted to have little seasonal variation, Carolina fanwort, coontail, and cone-spur bladderwort are prone to some degree of fluctuation (Towns 2002).

**Aquatic Macrophyte Selectivity**

I determined aquatic macrophyte selectivity by comparing availability of plants in

Spring Lake to the amount of each species consumed by Texas river cooters (Manly et al. 2002). I used five aquatic macrophytes comprising 91% of the diet in the analysis. These primary food items included filamentous algae, Carolina fanwort, coontail, and watermilfoil spp. The free-floating vegetation and other vegetation were analyzed collectively in their categories.

The null hypothesis for the log-likelihood chi-square (Nue et al. 1974, Manly et al. 2002) test was that Texas rivers cooters used the aquatic macrophytes in exact proportion to their availability in Spring Lake. My analysis did not support the null hypothesis ($\chi^2 = 3{,}412.4$, df = 6, $p < 0.001$), (Table 4).

I calculated confidence intervals to estimate each aquatic macrophyte's proportional use (Manly et al. 2002). If the expected proportion of vegetation was within the range of the confidence interval, then it was consumed within its expected proportion (Nue et al. 1974). I calculated a Bonferroni's correction to compensate for the number of categories analyzed in the chi- square ($1-\alpha / 2k$). I identified seven available resource categories; the corrected $\alpha$ was 0.004, which decreased the probability of making a type 1 error.

The confidence intervals for Carolina fanwort and filamentous algae indicated that these two aquatic macrophytes were consumed in greater proportion compared to the availability of the vegetation in the lake. Watermilfoil spp. were consumed within the expected proportion. Coontail was consumed less than expected based on availability implying that coontail was avoided.

I calculated Manly's alpha preference index for each of the six primary food items as a secondary method to estimate selectivity or avoidance. Filamentous algae (0.045

Table 4. Percent composition of aquatic macrophytes in Spring Lake and in the fall-winter diet of *P. texana* with chi-square intervals for 2011 ($\chi^2 = 3412.4$, df= 6, p<0.001).

| Aquatic Macrophyte | Percent Composition of Plants in Lake | Percent Composition of Plants in Diet | 95% Confidence Interval (Diet) $\alpha$= 0.004 |
|---|---|---|---|
| Coontail | 0.384 | 0.160 | 0.116 > p > 0.204 |
| **Carolina Fanwort** | 0.127 | 0.287 | 0.247 > p > 0.328 |
| Watermilfoil spp. | 0.120 | 0.155 | 0.111 > p > 0.199 |
| **Filamentous algae** | 0.117 | 0.388 | 0.351 > p > 0.426 |
| Free-floating plants | 0.131 | 0.002 | ---- |
| Other plants | 0.121 | 0.007 | ---- |

Names in bold indicate plants that were significantly selected for by Texas river cooters.

index value) and Carolina fanwort had the highest index values (0.29), indicating that Texas river cooters actively selected these plants. Watermilfoil spp. (0.17 index value) was eaten at a slightly higher proportion than it was found in the environment. Coontail (0.06 index value), Delta arrowhead (0.02 index value) and cone-spur bladderwort (0.01 index value) were not selected for based on their available proportion in the lake. Selection on Florida elodea was not estimated due to lack of data on its availability within the lake.

**Comparison of Diet Composition**

I identified 12 aquatic macrophytes in the stomach contents. Seven of these ten were found by Seaman (1997, Table 5). This greater number of species in my study is in part due to the separation of watermilfoil spp. into two species. To better compare my results to those of Seaman (1997), the two watermilfoil species' percent compositions were combined. Unknown vegetation comprised 0.75% of the diet in 2011 when flushed and fecal samples were combined. In 1997, unknown vegetation comprised 2.1% of the diet. In 2011, 43.8% of the stomachs had at least one hit that was unidentifiable. In 1997, 21.2% of stomachs had at least one hit that was recorded as unidentifiable. Four aquatic macrophytes comprised 91% of the diet (n=32). Filamentous algae (36.2%), Carolina fanwort (26.8%), coontail (14.9%), and watermilfoil spp. (14.5%). Seaman (1997) recorded a diet composition 91% (n=33) dominated by Florida elodea (33.5%), Carolina fanwort (24.5%), coontail (13.4%), and watermilfoil spp. (20.2%). The largest difference is between the minute percentage of Florida elodea (2%) in the 2011 diets in comparison to the 33.5% dominance in 1997. It was the highest percentage consumed in 1997. Filamentous algae (36.2%) had the highest percentage consumed in 2011. In 1997, algae comprised 4% of the diet and 51% was collected from one individual.

Two other aquatic macrophytes, delta arrowhead (1997 = 0.7%, 2011 = 0.56%) and cone-spur bladderwort (1997 = 0.2%, 2011 = 0.13%), were similarly found in small percentages in both studies.

Leaves were the primary plant part found in the stomach contents in both studies. They comprised 94.9% of the stomach contents in this study. However, they only comprised 64.7% of the 1997 study. Stems comprised 0.91% of the diet. Both studies involved one individual influencing this percentage considerably. For example, in this study 38% of the stems collected were from one individual. In the 1997 study all Florida elodea stems were collected from one individual.

**Comparison of Percent Cover and Composition**

Spring Lake has endured three major floods, management maintenance, and restoration efforts. The composition of the lake was notably different than in 1997, which inspired this study (Table 6). Coontail was the overall dominant species in coverage (2.98 ha). Seaman (1997) recorded Florida elodea as the overall dominant species in coverage of the lake (2.1 ha).

Seaman (1997) combined the estimates of the two watermilfoil spp. in her summarized results. Therefore, I combined the estimates in order to make a fluent comparison. Coontail (22.43% cover, 37.71% composition of aquatic macrophyte composition), Carolina fanwort (7.42% cover, 12.94% of aquatic macrophyte composition), Watermilfoil spp. (7% cover, 12.28% composition of aquatic macrophyte composition), and filamentous algae (6.83% cover, 11% of the aquatic macrophyte composition) account for 43% of the estimated lake cover in 2010 surveys. In 1997,

Table 5. Comparison of percent composition of aquatic macrophytes in the seasonal diet of *Pseudemys texana* collected in 1997 (Seaman 1997) and 2011 in Spring Lake, Hays County, Texas.

| Aquatic Macrophyte | 1997 Percent Composition in Diet | 2011 Percent Composition in Diet | Percent Change |
|---|---|---|---|
| Filamentous algae | 4.4 | 36.2* | +31.8 |
| Cedar elm | 0.0 | 3.4 | +3.4 |
| Carolina fanwort | 24.5* | 26.8* | +2.3 |
| Coontail | 13.4* | 14.9* | +1.5 |
| Common water hyacinth | 0.0 | 0.1 | +0.1 |
| Creeping primrose willow | 0.0 | 0.1 | +0.1 |
| Insects | 0.6 | 0.6 | 0.0 |
| Delta arrowhead | 0.7 | 0.6 | -0.1 |
| Cone-spur bladderwort | 0.2 | 0.1 | -0.1 |
| Watermilfoil spp. | 20.2* | 14.5* | -5.7 |
| Florida elodea | 33.5* | 2.0 | -31.5 |
| | | | |
| Unknown | 2.1 | 0.8 | -1.3 |
| Other | 0.4 | 0.0 | -0.4 |

* = primary food item (made up >10% of the diet and was found in > 50% of the diet samples.

Florida elodea (26.59% cover, 34.73% composition of aquatic macrophyte composition), coontail (9.15% cover, 11.03% composition of aquatic macrophyte composition), Carolina fanwort (3.54% cover, 3.99% composition of aquatic macrophyte composition) and watermilfoil spp. (9.78% cover, 13.53% composition of aquatic macrophyte composition) made up 49% of the estimated cover of the lake in 1997.

**Comparison of Selectivity**

In 2011, six aquatic macrophytes were analyzed in the diet of Texas river cooters to determine selectivity using Manly's alpha index and confidence intervals (Nue et al. 1974, Table 7). These included filamentous algae (0.45 index value), Carolina fanwort (0.31 index value), watermilfoil spp. (0.17 index value), coontail (0.06 index value), delta arrowhead (0.02 index value), and cone-spur bladderwort (0.01 index value). Filamentous algae, Carolina fanwort and watermilfoil scores indicated selectivity. Seaman's (1997) study resulted in the selectivity of only one aquatic macrophyte, Carolina fanwort (0.593 index value). Watermilfoil spp. (0.145 index value) were consumed at in a slightly higher proportion to its availability in Spring Lake during 1997. Coontail (0.118 index value) and Florida elodea (0.094 index value) were important food items but were not selected for in the lake. Filamentous algae had an index value of 0.002 index value. This indicated that it was avoided.

Table 6. Comparison of the percent composition of aquatic macrophytes in Spring Lake, Hays County in 1997 (Seaman 1997) and 2011.

| Aquatic Macrophyte | 1997 Percent Composition | 2011 Percent Composition | Percent Change |
|---|---|---|---|
| Coontail | 11.03 | 37.71 | +26.68 |
| Carolina fanwort | 3.99 | 12.94 | +8.95 |
| Muskgrass sp. | 0.00 | 2.35 | +2.35 |
| Delta arrowhead | 5.16 | 5.05 | -0.11 |
| Indian swampweed | 0.40 | 0.17 | -0.23 |
| Filamentous algae | 12.26 | 11.97 | -0.29 |
| Watermilfoil spp. | 13.53 | 12.28 | -1.25 |
| Common water hyacinth | 2.42 | 0.24 | -2.18 |
| Cone-spur bladderwort | 8.02 | 1.90 | -6.12 |
| Florida elodea | 34.73 | 0.00 | -34.73 |

Table 7. Comparison of Manly's alpha preference index scores for aquatic macrophytes during 2011 and 1997 (Seaman 1997) in Spring Lake, Hays County.

| Common Name | 1997 Manly's alpha 1/m = 0.125 | 2011 Manly's alpha 1/m = 0.143 |
|---|---|---|
| Carolina fanwort | **0.593** | **0.31** |
| Watermilfoil species | **0.145** | **0.17** |
| Coontail | 0.118 | 0.06 |
| Florida elodea | 0.094 | ---- |
| Delta arrowhead | 0.013 | 0.02 |
| Cone-spur bladderwort | 0.002 | 0.01 |
| Filamentous algae | 0.002 | **0.45** |

Numbers in bold indicated vegetation that was actively selected for based on its availability in Spring Lake, Hays County, TX.

# DISCUSSION

## 2011 Fall Winter Food Habits

The Texas river cooters in Spring Lake were primarily herbivorous with only 0.63% of the diet consisting of Amphipods. I found 12 species of aquatic macrophytes in the stomach contents of 32 Texas river cooters during the fall-winter of 2010 to 2011. Four of these aquatic macrophytes made up over 90% of the diet: filamentous algae (36%), Carolina fanwort (27%), coontail (15%), and Eurasian watermilfoil (13%). The turtles are selectively foraging for filamentous algae, Carolina fanwort and watermilfoil species in the lake. Some discrepancy was shown between the confidence interval and Manly's alpha index ratio for the watermilfoil species. The confidence interval was within its expected range while the Manly's alpha index indicated selectivity for this plant group. Therefore, I concluded that this plant was not actively selected in the lake.

## Changes in Food Habits and Availability from 1997 to 2011

The composition and availability of resources for Texas river cooters has changed in Spring Lake since Seaman's (1997) study that was conducted from October 1996 to March 1997. Four plant taxa comprised over 90% of the diet composition in 1997 and 2011. Texas river cooters have adjusted their dietary responses to the modified availabilities. Coontail increased by 27% in the composition of the lake since 1997; however it increased only by 2% in the diet. It was not actively selected for in the lake in 1997 or 2011. Florida elodea decreased by 32% less in the diet and decreased 35% in the vegetative composition of the lake since 1997. Filamentous algae increased by 32% in the diet and decreased by 0.3% in the vegetative composition of the lake by 2011. The other primary food items varied from 1-6% since 1997. The reduction of Florida elodea was attributed to the series of floods (Towns 2002).

**Management Implications**

Habitat changes affect the availability of resources. An understanding of different wildlife responses to such changes is crucial to implementing effective management strategies. The Spring Lake population of Texas river cooters is shielded from extensive habitat fragmentation, intensive poaching, and excessive pollution because of numerous federally protected species, which also are found in the lake. This provides a rare opportunity to record and analyze habitat changes and wildlife response through time in an environment. This is optimal in comparison to short studies in different geographical locations. There can be extensive geographical variation when pertaining to reptiles and amphibians. Therefore, results are limited to that population and should be considered with caution rather than as factual.

## APPENDICES

Appendix 1. List of first documented occurrences of native and introduced aquatic macrophytes.

| Years First Recorded | Common Name | Scientific Name |
|---|---|---|
| 1930 | Mosquito fern | *Azolla caroliniana* |
| 2009 | Creeping spot flower | *Acmella oppositifolia* |
| 2009 | Alligator weed | *Alternanther philoxeroides* |
| 1930 | Water moss | *Amblystegium riparium* |
| 2009 | Brushy bluestem | *Andropogon glomeratus* |
| 2009 | Coastal water hyssop | *Bacopa monnieri* |
| 2009 | False nettle | *Boehmeria cylindric* |
| 1940 | Carolina fanwort | *Cabomba caroliniana* |
| 2009 | Red canna | *Canna hybrid* |
| 2009 | Ravenfood sedge | *Carex crus-corvi* |
| 2009 | Buttonbush | *Cephalanthus occidentalis* |
| 1930 | Coontail/ Hornwort | *Ceratophyllum demersum* |
| 1975 | Watersprite | *Ceratopteris thalictroides* |
| 2002 | Muskgrass | *Chara* spp. |
| (1901) | Elephant's ear | *Colocasia esculenta* |
| 1973 | Common water hyacinth | *Eichhornia crassipes* |
| 2009 | Spikerush | *Eleocharis montevidensis* |
| 2009 | Horsetail rush | *Equisetum hyemale* |
| 1975 | Verticillate pennywort | *Hydrocotyle verticillata var. triradiata* |
| 2009 | Pennywort | *Hydrocotyle umbellata* |
| (1940)1997 | Florida elodea | *Hydrilla verticillata* |
| 1997 | Indian swampweed | *Hygrophilla polysperma* |
| 2009 | Pale yellow iris | *Iris psuedacoris* |
| 1975 | Texas rush | *Juncus texanus* |
| 2009 | Water willow | *Justinia americana* |
| 2009 | Frogfruit | *Lippia nodiflora* |
| 1930 | Common duckweed | *Lemna minor* |
| 1975 | Primrose willow | *Ludwigia octovalvis* |
| 1940,2002 | Creeping primrose willow | *Ludwigia repens (natans)* |
| 2009 | Waterclover | *Marilea macropoda* |

Appendix 1, continued. List of first documented occurrences of native and introduced aquatic macrophytes.

| Year Recorded | Common Name | Scientific Name |
|---|---|---|
| 1975 | Parrot feather watermilfoil | *Myriophyllum brasiliense* |
| 2002 | Eurasian watermilfoil | *Myriophyllum spicatum* |
| 1930 | Twoleaf watermilfoil | *Myriophyllum heterophyllum* |
| 1930 | Southern naiad | *Najas guadalupensis* |
| (1930)1975 | Spatterdock | *Nuphar luteum* |
| 2009 | Water cress | *Nasturtium officinale* |
| 1930 | Water lettuce | *Pistia stratiotes* |
| 2009 | Cursed buttercup | *Ranunculus scleratus* |
| 1930 | Slender riccia | *Riccia fluitans* |
| 1930 | Delta arrowhead | *Sagittaria platyphylla* |
| 2009 | Great bulrush | *Schoenoplectus tabernaemontani* |
| 1930 | Giant duckweed/ Common duckmeat | *Spirodela polyrhiza* |
| 2009 | Great bulrush | *Schoenoplectus tabernaemontani* |
| 2009 | Canadian germander | *Teucrium canadense* |
| 1930 | Broadleaf cattail | *Typha latifolia* |
| (1930) | Cone-spur bladderwort | *Utricularia gibba* |
| 1940 | European eelgrass | *Vallisneria spiralis* |
| 1930 | Common watermeal | *Wolffia papulifera* |
| 1930 | Texas wildrice | *Zizania texana* |
| 1930 | Southern wildrice | *Zizaniopsis miliacea* |

Years in ( ) indicate a report of a similar species but could have been a misidentification.

(Watkins 1930, Devall 1940, Bruchmiller 1973, Seaman 1997, Towns 2002, Williams et al. 2011)

Appendix 2. Number of *Pseudemys texana* collected and flushed from January to March 2011.

| | Dip-net | | Basking Trap | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Caught | 30 | 22 | 7 | 9 |
| Recaptured | 0 | 1 | 1 | 0 |
| Flushed | 23 | 19 | 1 | 2 |
| Sample | 10 | 3 | 2 | 0 |

I started effectively dip-netting at night in early January 2011. The basking traps were set in place and daytime dip-netting began during the middle of February. They were placed in locations where high densities of *P. texana* were observed. The spray-painted carapaces reduced the recapture rate. Female flush success rate was around 16%. This could possibly be due to life history traits before they begin the nesting process. However, Seaman (1997) had a 77% female flush success rate.

As noted in the Seaman (1997) paper, males were more easily accessible than females during the dip-netting sessions at night. As the season progressed towards the end of February, females became more active during the day near dense beds of *Chara* sp. This time frame accounted for 87% of the dip-net females.

Appendix 3. Paired t-test of lake vegetation data from 1997 (Seaman 1997) and 2010.

| Vegetation | 1997 Total Vegetation Averages | 2010 Total Vegetation Averages |
|---|---|---|
| Carolina fanwort | 66.98 | 352.29 |
| Cone-spur bladderwort | 118.49 | 51.57 |
| Coontail | 208.96 | 1065.48 |
| Creeping primrose willow | 0.00 | 44.65 |
| Delta arrowhead | 109.35 | 136.97 |
| Duckweed | 12.18 | 178.89 |
| Elephant ear | 13.04 | 2.62 |
| Filamentous Algae | 211.47 | 324.70 |
| Florida elodea | 613.72 | 0.00 |
| Indian swampweed | 3.75 | 4.71 |
| Mosquito fern | 12.13 | 2.46 |
| Muskgrass | 0.00 | 63.78 |
| Pennywort | 0.00 | 3.86 |
| Slender riccia | 15.83 | 93.63 |
| Southern naiad | 0.00 | 0.46 |
| Spatterdock | 0.36 | 72.91 |
| Water hyacinth | 35.57 | 6.63 |
| Water lettuce | 0.81 | 26.63 |
| Watermilfoil spp. | 206.22 | 333.13 |
| Water moss | 16.67 | 0.00 |
| Watersprite | 1.61 | 8.49 |
| Water willow | 0.00 | 0.48 |

A paired t-test was conducted to test the null hypothesis that the lake's vegetative composition did not differ significantly since 1997 (Seaman 1997). The sum of the transect averages for each plant species was used in the analysis ($t = -0.501$, $df = 22$, p-value = 0.621). The results indicated that the overall vegetative composition of the lake was similar in 1997 and 2010. However, the 1997 survey data was incomplete, and this project was focused on the changes in primary food resources for the turtles. Among these food items, Florida elodea made up the majority of the diet (32%) in 1997. By

2011, it was not found along any transects. Qualitatively, the availability of the primary food resources has changed while the overall composition of the lake is not statistically different. This project was focused on evaluating the dietary trends in this absence of a primary food source. Therefore, no further inquiry into the overall change in the lake was pursued.

Appendix 4. Cummulative comparison of the vegetation composition of Spring Lake.

| Common Name | 1997 (Seaman 1997) % Composition | 1999 (Towns 2002) % Composition | 2010 % Composition |
|---|---|---|---|
| Carolina fanwort | 3.99 | 2.60 | 12.94 |
| Common water hyacinth | 2.42 | 0.10 | 0.24 |
| Coontail | 11.03 | 11.30 | 37.71 |
| Indian swampweed | 0.40 | 1.00 | 0.17 |
| Florida elodea | 34.73 | 55.10 | 0.00 |
| Watermilfoil spp. | 13.53 | 3.90 | 12.28 |
| Delta arrowhead | 5.16 | 1.90 | 5.05 |
| Muskgrass | 0.00 | 10.40 | 2.35 |
| Creeping primrose willow | 0.00 | 0.00 | 1.64 |
| Moss | 0.56 | 0.00 | 0.00 |
| Mosquito fern | 0.67 | 0.80 | 0.09 |
| Watersprite | 0.68 | 0.00 | 0.01 |
| Water lettuce | 0.04 | 1.30 | 0.98 |
| Slender riccia | 0.26 | 0.00 | 3.45 |
| Cone-spur bladderwort | 8.02 | 3.80 | 1.90 |
| Duckweed | 0.96 | 1.40 | 5.95 |
| Spatterdock | 0.20 | 0.00 | 2.69 |
| Elephant’s Ear | 0.10 | 3.20 | 0.31 |
| Filamentous algae | 12.26 | 1.70 | 11.97 |
| Pennywort | 0.00 | 0.00 | 0.14 |
| Water willow | 0.00 | 0.00 | 0.02 |
| Southern naiad | 0.00 | 0.00 | 0.02 |

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# VITA

Vanessa Piña was born in Houston, Texas, on March 26, 1986, the daughter of Sally and Conroy Piña. She graduated from North Shore Senior High in 2004 in the top 10%. She received a bachelor of science in Ecology, Evolution, and Behavior from the University of Texas in 2009. She began studying the wildlife ecology at Texas State University-San Marcos in the spring of 2010. She conducted research on the dietary trends of *Pseudemys texana* in Spring Lake, Hays County, Texas. She graduated with her master's degree in wildlife ecology in the spring of 2012.


Permanent Address: 12548 Wethersby Way,

Austin, Texas 78753


This thesis was typed by Vanessa Piña.