FOOD HABITS OF NUTRIA (*MYOCASTOR COYPUS*) AT SPRING LAKE, HAYS COUNTY, TEXAS

THESIS

Presented to the Graduate Council of
Southwest Texas State University
in Partial Fulfillment of
the Requirements

For the Degree

Master of SCIENCE

By

Kathleen Towns, B.A.

San Marcos, Texas
May 2002

ACKNOWLEDGMENTS

I thank Dr. Randy Simpson for being a patient, enthusiastic advisor. I thank Dr. Richard Manning for his help with nutria collections and for his love for birds. I thank Dr. Francis Rose for his support, encouragement, and sense of humor. I thank all the members of my committee for being such great teachers and for their love of biology. I thank Dr. Jim Ott for his help with nutria collections and for never letting one get away.

I am grateful to my fellow SWT students for their help on this project. I thank Cris Hein, Todd Swannack, and Janie Nelan for their help with vegetation surveys and nutria collections. I thank Minnette Marr and Karl Hagenbuch for their help with plant identification.

I thank David Shore for his work creating the map of Spring Lake. I thank my family for their support and encouragement, in particular Jeannine for all the babysitting. I thank Zach for being so patient during my endless hours at the computer. Most of all I thank my husband, Tim, for everything.

This thesis was submitted on April 4, 2002.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

ABSTRACT

FOOD HABITS OF NUTRIA (*MYOCASTOR COYPUS*)

AT SPRING LAKE, HAYS COUNTY, TEXAS

by

Kathleen Towns
Southwest Texas State University
May 2002

Supervising Professor: Thomas R. Simpson

I investigated the food habits of nutria at Spring Lake from 1998 to 2000 using microhistological analysis of stomach contents. Forty-four nutria were collected during the year. Vegetation surveys were conducted at Spring Lake using the Daubenmire technique to estimate aquatic macrophyte cover. The availability of aquatic macrophytes at Spring Lake was compared with aquatic macrophyte use by nutria to determine if they fed selectively. Three plant species comprised the bulk of the diet: coontail (*Ceratophyllum demersum*), hydrilla (*Hydrilla verticillata*), and fanwort (*Cabomba caroliniana*). Results of Chi-square analysis with related confidence intervals suggest that nutria ate coontail and fanwort more than expected and hydrilla less than expected.

INTRODUCTION

The nutria (*Myocastor coypus*) is a large, semi-aquatic rodent native to the southern half of South America (Gosling and Baker 1991). Nutria have been an important fur resource in South America since the 1800s, and were introduced to North America by fur farmers as early as 1899 (Evans 1970). They were well established in the United States by the 1920s to 1930s. Many fur farm nutria were released into the wild after the market for their fur decreased in the 1940s (Evans 1970). Populations on the Gulf Coast of Texas may have originated from escapees of E. A. McIlhenney's fur farm on Avery Island, Louisiana. Floods caused by a hurricane in 1940 led to the escape of many animals, and feral populations spread west of Port Arthur, Texas, by 1946 (Simpson 1980). A decline in the demand for nutria fur led to their promotion as "weed cutters," and the animals were moved inland in Texas by landowners who wanted to clear weed-choked ponds and streams. Nutria are now widespread in the eastern 2/3 of the state (Davis and Schmidly 1994).

Nutria are regarded as pests where they damage agricultural crops, contribute to marsh fragmentation and loss, and disturb natural plant communities. It has also been suggested that they may compete with waterfowl or muskrats for food (Woods et al. 1992, Davis and Schmidly 1994). Damage to crops by nutria was reported in Louisiana (Evans 1970), Texas (Swank and

Petrides 1954, Evans 1970), Britain (Gosling et al. 1988), and France (Abbas 1991). In Texas, the main damage occurs in rice fields on the Gulf coast. The problem is not that the animals eat large numbers of rice plants, but that their burrows damage levees, leading to water loss in the fields (Evans 1970). In a study of nutria food habits in Chile, researchers found that nutria did not damage crops near the study site, and suggested that damage to cultivated crops would not occur where there are other plants available for food (Murua et al. 1981).

Damage to marshes has been widely documented in Louisiana (Harris and Webert 1962, Evans 1970, Johnson and Foote 1997, Ford and Grace 1998, Carter et al. 1999). Harris and Webert (1962) found that, while nutria had a large impact on big cordgrass (*Spartina cynosuroides*), they did not have a major effect on marsh vegetation as a whole and did not create extensive bare areas. Later studies (Johnson and Foote 1997, Carter et al. 1999) reported that nutria reduced aboveground biomass by digging for roots and rhizomes, leading to marsh fragmentation and erosion. Ford and Grace (1998) reported that when nutria harvest decreased, there was a substantial increase in wetland loss rates. Nutria also had an impact on swamps in Louisiana by inhibiting regeneration of bald cypress (*Taxodium distichum*) (Wilsey et al. 1991).

Few studies have addressed competition between nutria and other animals. Swank and Petrides (1954) suggested that, where they are sympatric, nutria may compete with muskrats for food. However, Evans (1970) suggested that competition for food between nutria and muskrats was minimal. In Maryland, the principal foods for nutria and muskrats were different (Willner et al. 1979).

Davis and Schmidly (1994) reported that nutria may destroy vegetation that is important to both muskrats and waterfowl. In East Texas, Simpson (1980) found that nutria ate plants that were important to waterfowl, but they also ate plants that are considered undesirable for waterfowl management.

Information on food habits is essential to understand the natural history of an animal. Food habits studies not only provide information about an animal's needs, but also about the potential for competitive interactions among sympatric species (Litvaitis 2000). Competitive interactions are of special interest when trying to determine how the presence of an introduced species might affect native species in the community. Methods for investigating the food habits of animals include direct observation, feeding site surveys, and examination of feces or stomach contents. The method employed depends on the animal and the level of accuracy desired. Stomach contents studies are more accurate than other methods, and they have the advantage that differences between sex or age groups may by investigated (Litvaitis 2000). The main drawback of stomach contents studies is that usually the animal must be sacrificed (Cooperrider 1986). This does not present a problem in the present case, as nutria are considered to be an exotic undesirable species at Spring Lake.

Previous studies addressing nutria food habits were done in Texas (Swank and Petrides 1954, Simpson 1980), Louisiana (Atwood 1950, Warkentin 1968, Shirley et al. 1981, Wilsey et al. 1991), North Carolina (Milne and Quay 1966), and Maryland (Willner et al. 1979). Studies outside the United States were done in Argentina (Borgnia et al. 2000), Chile (Murua et al. 1981), and

France (Abbas 1991). Studies that took place before 1970 used direct observation or feeding site surveys to determine the diet of nutria. Later studies used the microscopic examination of stomach contents or fecal pellets to identify the plants eaten. Most of the previous studies took place in freshwater or brackish marsh environments. My study differs from these in that I studied nutria in a large, spring-fed lake with little emergent vegetation. Vegetation surveys were conducted in the field to determine availability of food items. Availability of aquatic macrophytes at the study site was compared with the proportion of those species in the stomach contents to determine if nutria are selective feeders.

The objectives of this study were 1) to describe the food habits of nutria at Spring Lake and 2) to determine if nutria are feeding selectively by comparing aquatic macrophyte use to availability at the study site.

MATERIALS AND METHODS

Study Site

This study took place at Spring Lake, San Marcos, Hays County, Texas. The lake is an 8 ha, spring-fed reservoir that forms the headwaters of the San Marcos River (Figure 1). The lake was formed in the 1840s by the construction of a dam that is located approximately 650 m downstream from the main springs (Seaman 1997). For descriptive purposes, Spring Lake will be divided into the main lake and the slough.

The main lake is the center of a former amusement park. Southwest Texas State University acquired the property in 1994, and the emphasis is now on education and research (Seaman 1997). The eastern shoreline of the upper region, from the main springs to about 350 m downstream, is partly curbed in concrete and is dominated by buildings, docks and walkways of Aquarena Center. Glass-bottomed boats still operate from this area. Remnants of the former park include a submarine theater and underwater fountain system (Aguirre 1999). The western shoreline of the upper region is narrow, covered with elephant ear (*Colocasia esculenta*), and rises to a steep hillside. Water depths in this area reach more than 6 meters (Aguirre 1999). The lower region of the main lake, from the dam upstream to the point at which the slough joins the lake, is shallower than the upper region and is characterized by thick growths of

N

0 50 100 150 200 Meters

Figure 1. Spring Lake, Hays County, Texas.

Created by: David Shore, April 2002
Source: 1m DOQQ, 01/28/95
San Marcos North SE
UTM zone 14, NAD83

hydrilla (*Hydrilla verticillata*), coontail (*Ceratophyllum demersum*), and water milfoil (*Myriophyllum* spp.). Dense stands of elephant ear grow along the western shoreline. The eastern shoreline has very little emergent vegetation, but free-floating plants such as water fern (*Azolla caroliniana*), floating fern (*Ceratopteris thalictroides*), and duckweed (*Lemna minor, Spirodela polyrhiza*) are found in sheltered areas. Water from the lake empties into the San Marcos River over two man-made spillways, located approximately 650 m downstream from the main springs (Aguirre 1999).

The slough is a backwater area bordered by a golf course and softball fields. Water lettuce (*Pistia stratiotes*), water fern, and duckweed are present in sheltered areas along the shoreline. Much of the submersed and floating-leaf vegetation, including hydrilla, water milfoil, and spatterdock (*Nuphar luteum*), was scoured from the bottom of the slough during the flood of October 1998. Water hyacinth (*Eichhornia crassipes*) and other free-floating plants were also removed by the flood at this time. Vegetation in the slough continued to recover during the period of this study.

Aquatic macrophytes at Spring Lake include both native and introduced species. Common native species are coontail, Carolina fanwort (*Cabomba caroliniana*), cone-spur bladderwort (*Utricularia gibba*), variable-leaved milfoil (*Myriophyllum heterophyllum*), and delta arrowhead (*Sagittaria platyphylla*). The most widespread introduced plant is hydrilla. Other introduced species include floating fern, Eurasian water milfoil (*Myriophyllum spicatum*), elephant ear, and water hyacinth.

Nutria Collection

A total of 44 nutria were collected from August 1998 to January 2000 (IACUC #1030). Sex was determined by examination of external genitalia (Willner et al. 1979). Animals with hind foot length < 110 mm were classified as juveniles, and those with hind foot length ≥ 110 mm were classified as adults (Adams 1956). Nutria were grouped by season, with 9 animals collected for the fall, 17 for the winter, 5 for the spring, and 13 for the summer. The stomach contents were removed and placed in 10% formalin for later microscopic analysis.

Stomach Contents Analysis

Percent composition of aquatic macrophytes in the stomachs was determined through microhistological analysis. First, stomach contents were washed through a 35 mesh (0.5 mm) sieve to rinse out formalin and to remove the smallest unidentifiable plant fragments. Next, the rinsed material was dispersed in a dissecting tray in the manner described by Seaman (1997). A small sample of the stomach contents was placed on each microscope slide. The material was cleared as described by Litvaitis et al. (1996). A few drops of Hertwig's solution were placed on each slide and mixed with the stomach contents. The slide was heated over a Bunsen burner until most of the solution evaporated. A drop of Hoyer's solution was placed on the slide and covered with a 22 mm x 22 mm cover slip. Twenty slide preparations were made from the contents of each stomach. Five fields of view on each slide were picked randomly by rolling two twenty-sided dice and moving the microscope stage accordingly. Each field was examined at 100x, and the epidermal fragment closest to the pointer identified to species. Epidermal characteristics were used in species identification because the epidermis is most resistant to digestion and it contains diagnostic characteristics (Baumgartner and Martin 1939, Dusi 1949, Sparks and Malechek 1968, Litvaitis et al. 1996). Characteristics that were helpful in identification included cell size and shape, stomata, trichomes, and glands, as well as the general pattern of cells (Baumgartner and Martin 1939, Litvaitis et al. 1996). Reference slides were used to help with identification of epidermal fragments.

Reference Slides

Reference slides of the leaves and stems of the plants found in Spring Lake were made to aid in identification of the epidermal fragments in the stomach contents. The epidermis was removed from the leaf or stem by scraping away the underlying material with a razor blade. The piece of epidermis was inverted onto a slide, and then cleared with Hertwig's solution and mounted with Hoyer's solution in the same manner as the stomach contents slide preparations. Reference slides were made of both the upper and lower epidermis. In cases where it was difficult to remove the epidermis by scraping, leaves and stems were blended in an electric household blender with water. Small samples of the resulting plant fragments were placed on slides, and then cleared and mounted as above. Photomicrographs were taken of the reference slides to aid in comparison with the stomach contents slides.

Vegetation Survey

Vegetation surveys of Spring Lake were conducted quarterly from February1999 to November 1999. Percent cover was estimated for each plant species using the Daubenmire method (Daubenmire 1959). A modified Daubenmire frame of 20 cm by 100 cm (0.2 m^2) was used. Twelve transects were located every 100 m along the shoreline of the main lake and the slough. A calibrated rope was stretched across the water at each transect location, and coverage was estimated for each plant species at 5 m intervals. A total of 145 quadrats was used to estimate coverage.

Aquatic Macrophyte Use

Aquatic macrophyte use was defined as percent composition of each plant species found in the stomach contents. Percent composition was determined through microhistological analysis and was calculated in the same manner as Simpson (1980). The number of epidermal fragments counted for each species was divided by the total number of epidermal fragments observed (100 for each stomach) and then multiplied by 100. The percent of stomachs containing a given species was calculated as the number of stomachs in which that species occurred, divided by the total number of stomachs containing aquatic macrophytes, multiplied by 100.

I considered a plant as a principal food item if it comprised ≥ 10% of the diet and was found in ≥ 50% of the stomachs. A chi-square goodness of fit test was used to test for differences in use of principal food items by sex and by age.

Feeding Selectivity

According to Johnson (1980), usage is selective if components are used disproportionately to their availability. In order to determine if nutria are selective feeders, the proportion of each aquatic macrophyte species in the stomach contents was compared to its availability at Spring Lake. The method used was that suggested by Krebs (1999) and Manly et al. (1993).

Usage for each plant species was defined as the proportion of that species in the stomach contents. This proportion was estimated through microhistological analysis of the stomach contents, as described above. Availability for each plant species was calculated as described by Krebs (1999, and personal comm. Oct. 26, 2001). Availability was defined as m_i/M where m_i = the number of observations of available plant species i, and M = the total number of observations of availability = $\sum m_i$ (Krebs 1999). The number of observations for each available plant species (m_i) was counted as the number of quadrats in which the plant made up more than 5% of the cover. M was the sum of the observations for all species (Krebs, personal comm. Oct. 26, 2001).

A log-likelihood chi-square test was performed (Manly et al. 1993) to test the null hypothesis that usage of aquatic macrophytes does not differ from their availability at Spring Lake. Confidence intervals were constructed for the proportion of each species found in the stomach contents (observed use) to determine whether that species was used significantly more or less than its availability in the environment. Availability reflects "expected" use if no selection occurs. A Bonferroni z-statistic was used to calculate the simultaneous confidence intervals (Neu et al. 1974). This scaled down the significance level for each estimate so that an overall significance level of α=0.05 could be maintained (Neu et al. 1974, Alldredge and Ratti 1992, Manly et al. 1993). To maintain a 95% "family" of confidence intervals, α was corrected to 0.0033 to reflect the individual confidence intervals constructed for 15 aquatic macrophyte species. Calculations were based on figures for yearly, or total, use and availability.

RESULTS

Aquatic Macrophyte Cover at Spring Lake

Percent cover of aquatic macrophytes at Spring Lake was estimated quarterly. Overall percent cover for each plant species for the year was estimated by averaging the cover values obtained for each season (Table 1, Figure 2). The species with the greatest overall coverage was hydrilla (40.5% cover, 55.1% of the total aquatic macrophyte community). Muskgrass (*Chara* sp.) was found only in the slough (8.4% cover, 10.4% of the total aquatic macrophyte community). Coontail, a free-floating native species, was also abundant (8.1% cover, 11.3% of the total aquatic macrophyte community).

Other submersed plants were present in smaller amounts. Two species of water milfoil, one native (*Myriophyllum heterophyllum*), and one introduced (*Myriophyllum spicatum*), had a combined percent cover of 3.9 and comprised 5.4% of the aquatic macrophyte community. Fanwort (2.0% cover, 2.6% of the aquatic macrophyte community) was found scattered throughout the lake and slough, usually mixed with other submersed species. Delta arrowhead (1.4% cover, 1.9% of the aquatic macrophyte community) was present in the upper region of the main lake and in the area where the slough joins the main lake. East Indian hygrophila (*Hygrophila polysperma*) had a cover value of 0.7% and comprised 1.0% of the aquatic macrophyte community.

Table 1. Percent cover of aquatic macrophytes at Spring Lake, Hays County, Texas during 1999.

Plant Species	Winter	Spring	Summer	Fall	Total
Azolla caroliniana	0.0	0.2	0.1	1.4	0.4
Cabomba caroliniana	0.9	1.4	3.7	1.8	2.0
Ceratophyllum demersum	8.7	4.1	8.8	10.9	8.1
Ceratopteris thalictroides	0.5	0.2	0.9	0.7	0.6
Chara sp.	0.0	9.9	9.3	14.2	8.4
Colocasia esculenta	2.9	2.0	2.0	2.1	2.3
Duckweed	0.7	0.6	0.7	0.7	0.7
Eichhornia crassipes	0.2	0.1	0.0	0.0	0.1
Filamentous algae	1.1	1.1	0.1	2.7	1.3
Hydrilla verticillata	33.0	51.9	36.9	40.1	40.5
Hygrophila polysperma	1.2	0.2	0.5	0.9	0.7
Myriophyllum spp.	4.9	2.6	2.3	5.7	3.9
Pistia stratiotes	0.7	1.3	1.4	0.3	0.9
Sagittaria platyphylla	1.6	0.2	2.0	1.7	1.4
Utricularia gibba	0.3	1.9	8.7	0.8	2.9
Substrate	42.2	21.2	22.0	15.3	25.2

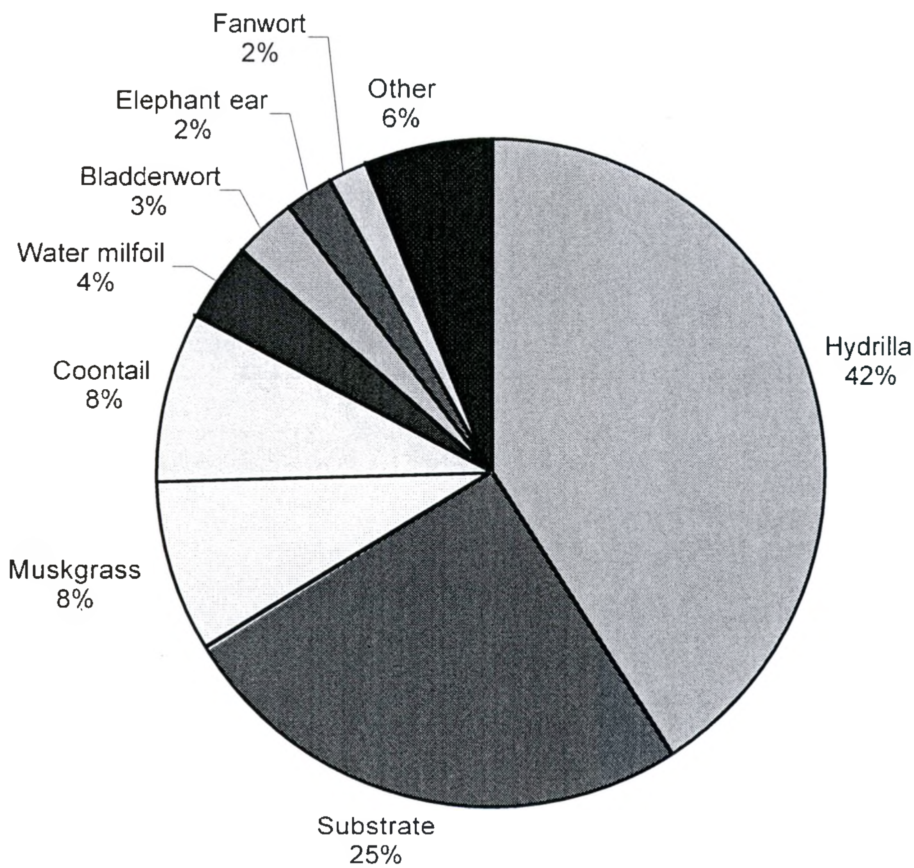

Figure 2. Yearly percent cover of aquatic macrophytes at Spring Lake, Hays County, Texas during 1999.

Small free-floating plants were found along the shoreline and in other sheltered areas. These included water fern, small duckweed (*Lemna minor*), giant duckweed (*Spirodela polyrhiza*), and water meal (*Wolffia papulifera*). Their combined cover was 1.1%, and they comprised 1.4% of the total aquatic macrophyte community. Larger free-floating plants also occurred in sheltered areas, including floating fern (0.6% cover, 0.8% of the aquatic macrophyte community), water hyacinth (0.1% cover, 0.1% of the aquatic macrophyte community), and water lettuce (0.9% cover, 1.3% of the aquatic macrophyte community).

Bladderwort (2.9% cover, 3.8% of the aquatic macrophyte community) was found mainly in the slough, and often was mixed with filamentous algae (1.3% cover, 1.7% of the aquatic macrophyte community). Filamentous algae also coated other macrophytes in the main lake, especially hydrilla and water milfoil. Elephant ear (2.3% cover, 3.2% of the aquatic macrophyte community) grew along the shoreline, particularly the western shore of the main lake.

Some aquatic macrophyte species present at Spring Lake were not measured in the vegetation survey because they did not occur along the line transects. Common cattail (*Typha latifolia*) grew in a relatively small stand at the northern shore of the lower slough. Red ludwigia (*Ludwigia repens*) occurred in small amounts in the lower region of the main lake, and also was found mixed with hydrilla in the lower region of the slough. Spatterdock occurred mainly in the slough, although a few plants were found in the main lake.

Bare substrate and open water comprised 25.2% of the total cover for the year. The cover value for bare substrate was highest for the slough in winter (68.3%). The flood of October 1998 scoured most of the submersed vegetation from this area, and much of the bottom was still bare when the winter vegetation survey was conducted in February. The bare substrate cover value for the slough decreased in each of the following seasons, with 35.9% in the spring, 21.0% in the summer, and 15.3% in the fall.

There was little seasonal variation in the coverage and composition for most aquatic macrophytes at Spring Lake. Muskgrass was not present in the winter survey, but this was attributed to the flood mentioned above, and not to seasonal variation. Three species showed some seasonal variation. Bladderwort was much more abundant in the summer (8.7% cover, 11.2% of the aquatic macrophyte community) than in other seasons. Fanwort was also more abundant in the summer (3.7% cover, 4.8% of the aquatic macrophyte community). Coontail was less abundant in the spring (4.1% cover, 5.3% of the aquatic macrophyte community) than in other seasons.

Aquatic Macrophyte Use

Five species of aquatic macrophytes comprised more than 90% of the annual diet of nutria (Table 2, Figure 3). Coontail was present in the greatest amount (39.3%), followed by hydrilla (26.0%), fanwort (17.4%), elephant ear (6.0%), and water milfoil (4.2%). Four species of aquatic macrophytes were present in smaller amounts in the stomach contents. Water hyacinth comprised

Table 2. Annual diet of nutria collected from Spring Lake.

Plant Species	Percent Composition in the Diet	Percent of Stomachs Containing Plant Species
Bacopa monnieri	0.2	2.3
Cabomba caroliniana	17.4	58.1
Ceratophyllum demersum	39.3	74.4
Ceratopteris thalictroides	2.6	11.6
Colocasia esculenta	6.0	25.6
Eichhornia crassipes	2.9	9.3
Hydrilla verticillata	26.0	79.1
Ludwigia repens	1.3	7.0
Myriophyllum spp.	4.2	18.6

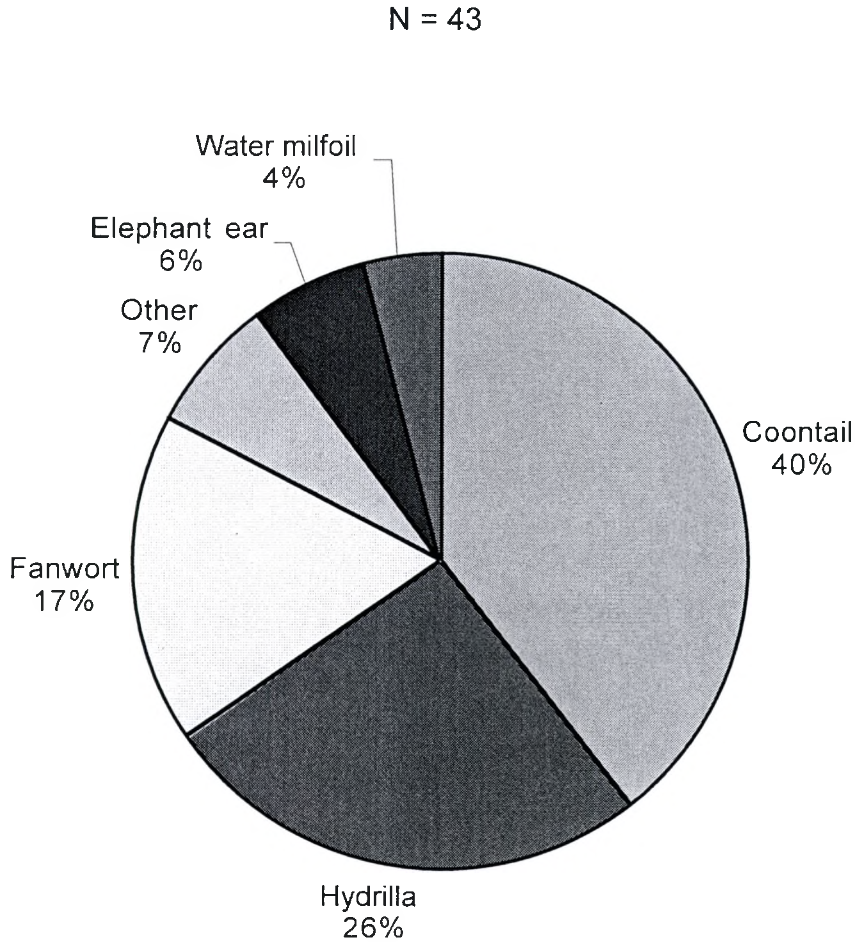

Figure 3. Percent composition of aquatic macrophytes in the yearly diet of nutria at Spring Lake.

2.9% of the diet. It was found in 9.3% of the stomachs, with 62.1% coming from one stomach. Floating fern comprised 2.6% of the diet. It was found in 11.6% of the stomachs, with 81.3% coming from one stomach. Red ludwigia comprised 1.3% of the diet. It was found in 7.0% of the stomachs, with 68.5% coming from one stomach. Smooth water hyssop (*Bacopa monnieri*) was found in only one stomach and made up 0.2% of the diet.

There was some seasonal variation in the percent composition of food items in the diet, but the principal food items remained the same. Three plants, coontail, hydrilla, and fanwort, were important in every season. They comprised 73.6% of the winter diet, 100% of the spring diet, 84.0% of the summer diet, and 90.4% of the fall diet (Table 3).

The winter sample consisted of 17 stomachs and included the following aquatic macrophytes: coontail (42.9%), hydrilla (19.5%), elephant ear (12.5%), fanwort (11.2%), water milfoil (10.2%), water hyacinth (2.8%), smooth water hyssop (0.6%), and floating fern (0.2%). Smooth water hyssop and floating fern were each present in only one stomach in the sample.

The spring sample consisted of 4 stomachs and included the following aquatic macrophytes: coontail (56.5%), hydrilla (38.3%), and fanwort (5.3%).

The summer sample consisted of 13 stomachs and included the following aquatic macrophytes: hydrilla (32.9%), coontail (32.8%), fanwort (18.3%), floating fern (8.4%), red ludwigia (4.2%), and elephant ear (3.4%).

The fall sample consisted of 9 stomachs and included the following aquatic macrophytes: coontail (34.3%), fanwort (33.2%), hydrilla (22.9%), water

Table 3. Percent composition of aquatic macrophytes in the diet of nutria collected from Spring Lake.

Plant Species	Winter N = 17	Spring N = 4	Summer N = 13	Fall N = 9	Total N = 43
Bacopa monnieri	0.6	0.0	0.0	0.0	0.2
Cabomba caroliniana	11.2	5.3	18.3	33.2	17.4
Ceratophyllum demersum	42.9	56.5	32.8	34.3	39.3
Ceratopteris thalictroides	0.2	0.0	8.4	0.0	2.6
Colocasia esculenta	12.5	0.0	3.4	0.1	6.0
Eichhornia crassipes	2.8	0.0	0.0	8.6	2.9
Hydrilla verticillata	19.5	38.3	32.9	22.9	26.0
Ludwigia repens	0.0	0.0	4.2	0.0	1.3
Myriophyllum spp.	10.2	0.0	0.0	0.9	4.2

hyacinth (8.6%), and water milfoil (0.9%). Water hyacinth and water milfoil were each present in only one stomach in the sample.

There was no statistical difference in use of principal food items by sex ($\chi^2 = 6.721$, $p > 0.05$). Fanwort, coontail, and hydrilla each were consumed in similar amounts. There was a difference in use of principal food items by age class ($\chi^2 = 27.055$, $p < 0.001$). Coontail was consumed much less by juveniles (20.2%) than adults (53.1%). Fanwort and hydrilla were consumed in similar amounts.

Aquatic Macrophyte Selection

Aquatic macrophyte use by nutria was compared to availability to determine if nutria fed selectively. Chi-squared analysis showed that the proportion of aquatic macrophytes in the diet differed significantly from the proportion available at Spring Lake ($\chi^2 = 102.6$, $p < 0.001$) (Table 4, Figure 4). The null hypothesis that use does not differ from availability was rejected.

Confidence intervals on observed use indicated which plants were selected based on their availability. Plants with availability values that were not included in the confidence intervals for observed use were used significantly more or significantly less than expected. Plants with availability values that fell within the confidence intervals were used within their expected ranges.

Fanwort and coontail each were used significantly more than expected based on their availability in the environment. Both had availability values that

Table 4. Proportion of aquatic macrophytes in the diet of nutria compared to the proportion available at Spring Lake. Hypothesis of proportional use was rejected ($\chi^2 = 102.6$, $p < 0.001$).

Plant Species	Expected Use (Availability)	Observed Use (In Diet)	95% Confidence Interval on Observed Use	Used More (M) or Less (L) Than Expected
Cabomba caroliniana	0.0400	0.1768	$0.0639 < p < 0.2897$	M
Ceratophyllum demersum	0.1514	0.3994	$0.2545 < p < 0.5443$	M
Ceratopteris thalictroides	0.0100	0.0264	$0.0000 < p < 0.0739$	–
Colocasia esculenta	0.0286	0.0610	$0.0000 < p < 0.1318$	–
Eichhornia crassipes	0.0043	0.0295	$0.0000 < p < 0.0795$	–
Hydrilla verticillata	0.4471	0.2642	$0.1337 < p < 0.3947$	L
Myriophyllum spp.	0.1029	0.0427	$0.0000 < p < 0.1025$	L

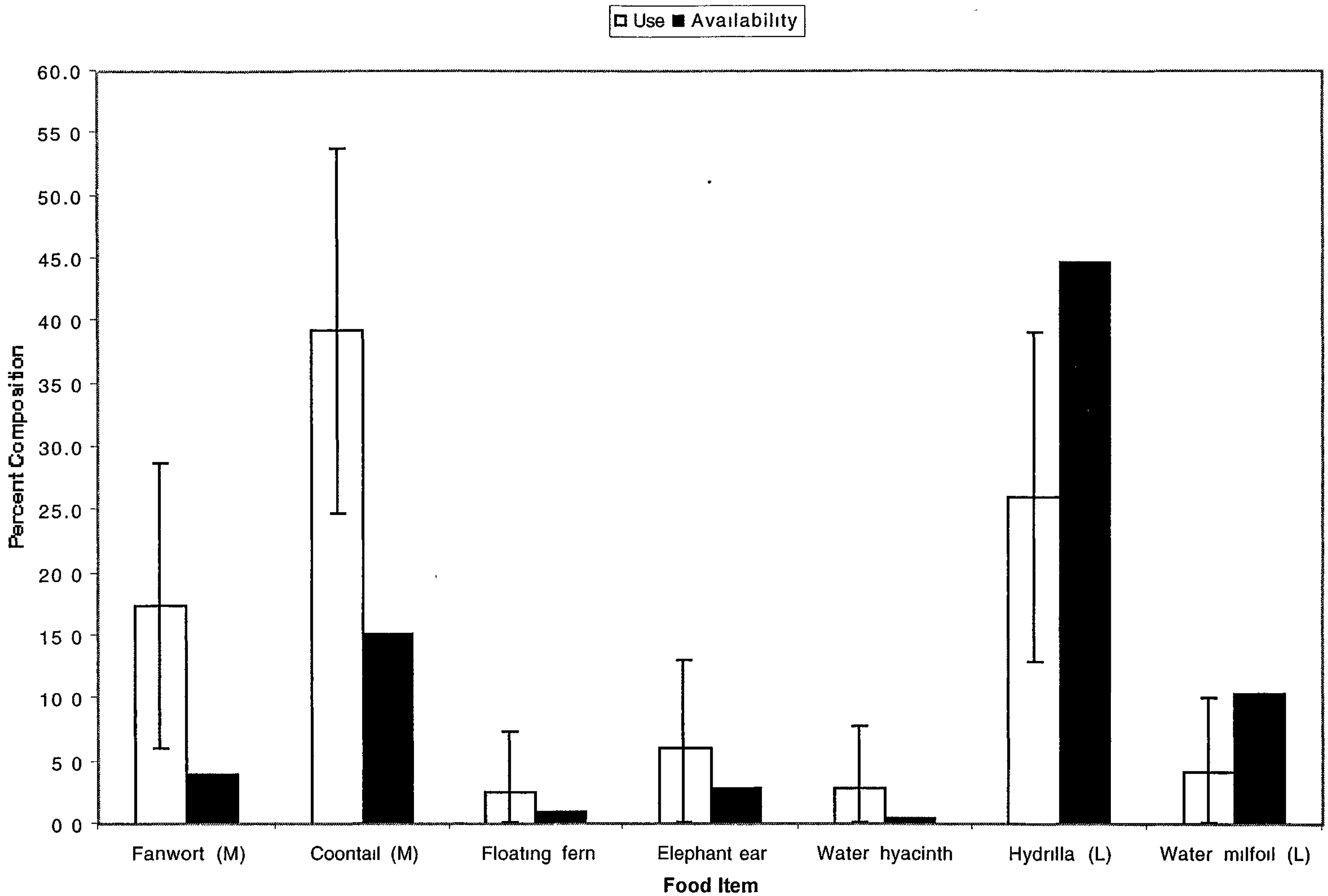

Figure 4. Comparison of use to availability of aquatic macrophytes. Error bars represent 95% confidence intervals with a Bonferroni correction to the z-statistic. Plant species eaten more (M) or less (L) than expected are indicated.

were below the lower confidence limit on observed use. Aquatic macrophytes that were consumed as expected based on their availability included elephant ear, floating fern, and water hyacinth. Each of these species had availability values that fell within the confidence intervals for observed use. Hydrilla was used significantly less than expected. It had an availability value above the upper confidence limit on observed use. Use of water milfoil was slightly less than expected. It had an availability value that was slightly above the upper confidence limit (Table 4, Figure 4).

Two aquatic macrophyte species each had an expected use of ≥ 5%, but were not present in the stomach contents. Muskgrass had an expected use of 8.9%, and bladderwort had an expected use of 5.3%. These plants were included in the calculations because they were considered potential food items, even though no fragments were found in the stomach contents. Murua et al. (1981) found muskgrass in the diet of nutria in Chile. Milne and Quay (1966) and Shirley et al. (1981) found bladderwort in nutria diets in North Carolina and Louisiana, respectively.

DISCUSSION

Nutria Food Habits

According to Cooperrider (1986), most herbivores are opportunistic in nature. Food habits of a species may vary with geographic location and time. Nutria thrive in areas where they have been introduced (Evans 1970, Gosling and Baker 1991), and they eat a wide variety of plants. In a given location, however, nutria diets tend to be dominated by only a few plants (Willner et al. 1979, Murua et al. 1981, Wilsey et al. 1991, Borgnia et al. 2000). Willner et al. (1979) found that one species of rush (*Scirpus olneyi*) made up almost 80% of the annual diet. Borgnia et al. (2000) reported a diet dominated by spikesedge (*Eleocharis bonariensis*) in the winter and duckweed in the summer. Duckweed also dominated the diet of nutria in a study in Louisiana (Wilsey et al. 1991).

The yearly diet of nutria at Spring Lake was dominated by 3 species of aquatic macrophytes. Coontail was the most important food item, comprising 39.3% of the diet and occurring in 74.4% of the stomachs. Hydrilla was also an important food item. It comprised 26.0% of the diet and was found in 79.1% of the stomachs. Fanwort comprised 17.4% of the diet and was found in 58.1% of the stomachs. Each of the other plants in the diet were present in less than 30% of the stomachs, and comprised < 7% of the diet.

Nutria did consume a few terrestrial plants, but these comprised only a small portion (< 5%) of the overall diet. Milne and Quay (1966) reported that nutria rarely fed on land in places where submerged and floating vegetation was available. Borgnia et al. (2000) also found that the probability of plant use decreased exponentially with distance from water.

Swank and Petrides (1954) found that common cattail was a favored food of nutria, and that they ate few other plants where cattail was available. However, it was not found in the stomach contents of nutria at Spring Lake. There was no evidence of nutria feeding activity in the stand of cattails located in the slough.

Seasonal variation in food habits was reported in previous studies (Atwood 1950, Willner et al. 1979, Murua et al. 1981, Shirley et al. 1981, Abbas 1991, Wilsey et al. 1991, Borgnia et al. 2000). My study found no seasonal variation in which plants were most important in the diet. Further comparisons of seasonal food habits cannot be made because of small sample sizes, which ranged from a low of 4 stomachs in the spring to a high of 17 in the winter. However, the diet of nutria at Spring Lake probably would not vary as much as diets in areas with large amounts of emergent vegetation. Milne and Quay (1966) reported that the greatest change in diet was a result of emergent vegetation dying off in the winter. Nutria at Spring Lake ate mostly submersed and free-floating plants, which are not vulnerable to freezing in winter.

Use of principal food items did not differ by sex, but did differ by age class. Juveniles consumed less coontail than adults. Fanwort and hydrilla were consumed in similar amounts. Further investigation into the difference between adult and juvenile food habits is needed.

Aquatic Macrophyte Selection

Selection and preference are terms that are sometimes used interchangeably in food habits studies, but it is important to distinguish between the two. According to Johnson (1980), selection is the process of choosing a resource, and preference is the likelihood of a resource being chosen if offered on an equal basis with others. Usage is selective if resources are used disproportionately to their availability.

Nutria at Spring Lake were selective in their feeding. Coontail and fanwort each were consumed significantly more than expected based on their availability. Hydrilla was consumed significantly less than expected based on its availability. All other plants were consumed within their expected ranges. Previous studies also reported selective feeding by nutria (Willner et al. 1979, Shirley et al. 1981, Wilsey et al. 1991, Borgnia et al. 2000).

The two aquatic macrophytes that were consumed more than expected are native species. Fanwort also was selected by the Texas River Cooter (*Pseudemys texana*) in Seaman's (1997) study on their food habits. The fact that nutria selected the same species is of interest because of the potential competition between the two animals. Coontail also was consumed by these turtles, but not out of proportion to its availability at Spring Lake (Seaman 1997).

Hydrilla, an introduced species, was the most abundant plant in the lake and was an important food item for nutria. Although hydrilla was important in the diet, it was consumed significantly less than expected based on its availability. This supports the view that, as a means of removing undesirable vegetation, nutria have only limited value (Evans 1970, Davis and Schmidly 1994). Further studies are needed to determine how nutria impact native plants and animals at Spring Lake.

LITERATURE CITED

Abbas, A. 1991. Feeding strategy of coypu (*Myocastor coypus*) in central western France. Journal of Zoology, 224:385–401.

Adams, W. H., Jr. 1956. The nutria in coastal Louisiana. Proceedings of the Louisiana Academy of Sciences, 19:28–41.

Aguirre, P. 1999. Space use patterns of the common snapping turtle, *Chelydra serpentina serpentina*, at the headwaters of the San Marcos River, Hays County, Texas [MS Thesis]. San Marcos (TX): Southwest Texas State University. 38 p.

Alldredge, J. R. and J. T. Ratti. 1992. Further comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management, 56(1):1–9.

Atwood, E. A. 1950. Life history studies of nutria, or coypu, in coastal Louisiana. Journal of Wildlife Management, 14(3):249–265.

Baumgartner, L. L. and A. C. Martin. 1939. Plant histology as an aid in squirrel food-habit studies. Journal of Wildlife Management, 3(3):266–268.

Borgnia, M., M. L. Galante, and M. H. Cassini. 2000. Diet of the coypu (nutria, *Myocastor coypus*) in agro-systems of Argentinean pampas. Journal of Wildlife Management, 64(2):354–361.

Carter, J., A. L. Foote, and L. A. Johnson-Randall. 1999. Modeling the effects of nutria (*Myocastor coypus*) on wetland loss. Wetlands, 19(1):209–219.

Cooperrider, A. Y. 1986. Food habits. In: Cooperrider, A. Y., R. J. Boyd, and H. R. Stuart, editors. Inventory and monitoring of wildlife habitat. Denver, CO: U.S. Bureau of Land Management. p 699–710.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science, 33(1):43–64.

Davis, W. B. and D. J. Schmidly. 1994. The Mammals of Texas. Austin, TX: Texas Parks and Wildlife Press. 338 p.

Dusi, J. L. 1949. Methods for the determination of food habits by plant microtechniques and histology and their application to cottontail rabbit food habits. Journal of Wildlife Management, 13(3):295–298.

Evans, J. 1970. About nutria and their control. Bureau of Sport Fisheries and Wildlife. Resource Publication no. 86. 65 p.

Ford, M. A. and J. B. Grace. 1998. Effects of vertebrate herbivores on soil processes, plant biomass, litter accumulation and soil elevation changes in a coastal marsh. Journal of Ecology, 86:974–982.

Gosling, L. M. and S. J. Baker. 1991. Family Myocastoridae. In: Corbet, G. B. and S. Harris, editors. The handbook of British mammals. Oxford: Blackwell Scientific Publications. p 267–275.

Gosling, L. M., S. J. Baker, and C. N. Clarke. 1988. An attempt to remove coypus (*Myocastor coypus*) from a wetland habitat in East Anglia. Journal of Applied Ecology, 25:49–62.

Harris, V. T. and F. Webert. 1962. Nutria feeding activity and its effect on marsh vegetation in southwestern Louisiana. U. S. Dept. Interior, Fish and Wildl. Serv., Special Scientific Rept., Wildl. No. 64. 53 p.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology, 61(1):65–71.

Johnson, L. A. and A. L. Foote. 1997. Vertebrate herbivory in managed coastal wetlands: a manipulative experiment. Aquatic Botany, 59:17–32.

Krebs, C. J. 1999. Ecological methodology. 2nd ed. Menlo Park (CA): Addison-Wesley Educational Publishers, Inc. 620 p.

Litvaitis, J. A. 2000. Investigating food habits of terrestrial vertebrates. In: Boitani, L. and T. K. Fuller, editors. Research techniques in animal ecology. New York: Columbia University Press. p 165–190.

Litvaitis, J. A., K. Titus, and E. M. Anderson. 1996. Measuring vertebrate use of terrestrial habitats and foods. In: Bookhout, T. A., editor. Research and management techniques for wildlife and habitats. 5th ed. Bethesda, MD: The Wildlife Society, Inc. p 254–274.

Manly, B., L. McDonald, and D. Thomas. 1993. Resource selection by animals. London: Chapman and Hall. 172 p.

Milne, R. C. and T. L. Quay. 1966. The foods and feeding habits of the nutria on Hatteras Island, North Carolina. Proc. Ann. Conf. Southeastern Assoc. Game and Fish Comm. 20:112–123.

Murua, R., O. Neumann, and I. Dropelmann. 1981. Food habits of *Myocastor coypus* in Chile. In: Chapman, J. A. and D. Pursley, editors. Worldwide furbearer conference proceedings. Frostburg (MD): p 544–558.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management, 38(3):541–545.

Seaman, J. R. 1997. Food habits of the Texas river cooter (*Pseudemys texana*) at Spring Lake, Hays County, Texas [MS thesis]. San Marcos (TX): Southwest Texas State University. 57 p.

Shirley, M. G., R. H. Chabreck, and G. Linscombe. 1981. Foods of nutria in fresh marshes of southeastern Louisiana. In: Chapman, J. A. and D. Pursley, editors. Worldwide furbearer conference proceedings. Frostburg (MD): p 517–530.

Simpson, T. R. 1980. The influence of nutria on aquatic vegetation and waterfowl in east Texas [dissertation]. College Station (TX): Texas A&M University. 55 p.

Sparks, D. R. and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. Journal of Range Management, 21:264–265.

Swank, W. G. and G. A. Petrides. 1954. Establishment and food habits of the nutria in Texas. Ecology, 35(2):172–176.

Warkentin, M. J. 1968. Observations on the behavior and ecology of the nutria in Louisiana. Tulane Studies in Zoology and Botany, 15:10–17.

Willner, G. R., J. A. Chapman, and D. Pursley. 1979. Reproduction, physiological responses, food habits, and abundance of nutria on Maryland marshes. Wildlife Monographs, No. 65. 43 p.

Wilsey, B. J., R. H. Chabreck, and R. G. Linscombe. 1991. Variation in nutria diets in selected freshwater forested wetlands of Louisiana. Wetlands, 11(2):263–278.

Woods, C. A., L. Contreras, G. Willner-Chapman, and H. P. Whidden. 1992. Myocastor coypus. Mammalian Species, No. 398. p 1–8.

VITA

Kathleen Towns was born in Fort Worth, Texas on January 1, 1968. She is the daughter of Ralph and Cora Towns. After high school she attended the University of Texas at Austin, where she received a Bachelor of Arts in geography in 1992. In 1997, she entered the graduate program in biology at Southwest Texas State University in San Marcos, Texas. While at Southwest Texas State University she worked as an instructional assistant for Vertebrate Natural History. She is a member of Tri-Beta Biological Honor Society.

Permanent address: 1082 River Trail

Seguin, Texas 78155

This thesis was typed by Kathleen Towns.