FOOD HABITS OF THE COMMON MUSK TURTLE (*STERNOTHERUS ODORATUS*) IN LENTIC AND LOTIC HABITATS, SPRING LAKE, HAYS COUNTY, TEXAS

THESIS

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

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SUPERVISING PROFESSOR: THOMAS R. SIMPSON

I collected 147 common musk turtles from Spring Lake, San Marcos, Hays County, Texas between April 2008 and February 2009, to examine their dietary habits based on fecal analysis. I collected 70 female and 77 male turtles from lentic and lotic areas of the lake during spring, summer, fall and winter. After voiding their digestive tract contents all turtles were returned to the point of capture. Fecal matter was sorted into five component categories: mollusks, crayfish, insects, plant matter, and other. Five items

per category per sample were identified to the lowest possible taxonomic level, resulting in the identification of 6 types of mollusks, 1 crayfish, 13 insects, 12 plants, and 4 additional taxa. After identification samples were dried and weighed. Mollusk material was the most abundant component of fecal material, followed by crayfish. I performed 3-way ANOVA tests of fecal component categories across three independent variables: habitat, gender and season. The percent weight of mollusks, crayfish and plants showed significant seasonal variation, while the percent weight of insects showed greater variation by habitat. The results of the qualitative identification of food items agree with previous research.

INTRODUCTION

The common musk turtle, *Sternotherus odoratus,* is the northernmost ranging species of the widespread freshwater turtle family Kinosternidae. It inhabits slow moving waters of rivers, ponds, lakes and streams over the eastern portion of the North American continent and in 72 Texas counties. It is small with a narrow, domed carapace and two stripes running down the sides of the head towards the neck. Common musk turtles inhabit heavily vegetated areas with slow currents (Berry, 1975).

Common musk turtles inhabit both lentic and lotic areas of Spring Lake, Hays County, Texas. Differences have previously been documented in the feeding and reproductive habits of common musk turtles in lentic and lotic systems (McPherson and Marion, 1983). This may be a result of differences in the availability of food resources between the systems or competition with other species.

Common musk turtles are chiefly nocturnal (Lagler, 1943; Vermersch, 1992) and omnivorous, feeding on a variety of foods ranging from algae (*Cladophora* sp., *Spirogyra* sp., *Lyngbya* sp.), to snails (*Marisa cornuarletis* and *Hydrobia* sp.), and small vertebrates (tadpoles, frogs and adult fish) (Ernst, 1986). Ford and Moll (2004) described seasonal and sexual differences in common musk turtle diets in Missouri, however detailed and

quantified dietary studies on common musk turtles and how they differ by gender and season in Texas are lacking. Food habit studies need to be done on a local scale because of differences in availability of foods in different geographic areas. Results from one area may not be applicable to another (Rosas-Rosas et al., 2003).

Dietary studies provide basic information to enhance understanding of the ecology of a species and are important prerequisites to developing successful conservation, management and recovery plans (Huygens et al., 2003; Hernandez et al., 2006). Species management and recovery plans depend on knowledge of suitable habitat and distribution of nutritional factors in order to predict the potential distribution of a species (Jones et al., 1998). The quality of nutritional factors within the habitat determine the stability of the breeding population (Mindell et al., 1987), sustainability and the amount of seasonal stress on populations (Madison et al., 2002), and the productivity of an organism or population (Bjorndal, 1985).

Food habits studies lend predictive value to the distribution of the animals in question but also to the floral structure of their habitat (Clark et al., 2001). Birds (Compton et al., 1996; Wutherich et al., 2001), bats and other mammals (Clark et al., 2005), and even turtles (Braun and Brooks, 1987) are important agents of seed dispersal. Understanding the feeding and movement patterns of these seed dispersers enables biogeographers to analyze structural vegetation regimes from a habitat management and conservation standpoint, and allows for the identification of habitat parameters vital to the continued occupation of the species (Ford and Moll, 2004).

A variety of methods are employed to study animal diets. The removal of stomach material by dissection is one of the more reliable ways of obtaining data because foods in

the stomach are often undigested and readily identifiable. This method has been successfully used to study the diets of birds (Day and Byrd, 1989; Falk et al., 1992; Jamieson et al., 2001), deer (Nixon et al., 1970; Weckerly and Nelson 1990), bears (Sato et al., 2000), fish (Hall et al., 1995; Beaudoin et al., 1999), amphisbaenians (Lopez et al., 1991), snakes (Diller and Johnson, 1988) and turtles (Hulse, 1974; Bjorndal, 1985). Stomach flushing does not require sacrificing animals and has been used to study the diets of birds (Gionfriddo et al., 1995; Hess, 1997), small mammals (Wrazen and Svenson, 1979), fish (Culp et al., 1988), lizards (Legler and Sullivan, 1979; Pietruszka, 1981), and turtles (Legler, 1977; Parmenter, 1980; Fields et al., 2003; Seminoff et al., 2002; Caputo and Vogt, 2008).

Less invasive methods of studying animal diets include observational records and analysis of fecal material. Analysis of fecal material is a convenient method to obtain dietary data without causing undue stress to the organism. Fecal studies have been done on bats (Hurst and Lacki, 1997) wildcats including leopards, ocelots and pumas (Johnson et al., 1993; De Villa Meza 2002; Rosas-Rosas et al., 2003), deer and antelope (Koerth et al., 1984; Hodgman et al., 1996), rodents (Karels et al., 2004) and reptiles, including turtles and tortoises (Braun and Brooks, 1987; MacDonald and Mushinsky, 1988; Seminoff et al., 2002; Caputo and Vogt, 2008). In some studies, more items were identified from fecal samples than from samples obtained from stomach contents (Wrazen and Svendson, 1979).

Many individual resident turtles in Spring Lake, including common musk turtles, are marked and currently being used in population studies (Francis Rose, pers. comm.), so fecal analysis is the preferred method of studying food habits. Stomach flushing was

attempted with common musk turtles, but resulted in unacceptable rates of mortality (Thomas Simpson, pers. comm.).

This thesis presents the results of a comparative study of the diets of common musk turtles in the lentic and lotic habitats of Spring Lake. My objectives were to quantify the diet of the common musk turtle in Spring Lake, to determine whether differences exist in the dietary habits of the common musk turtle in lentic and lotic areas of the lake, and to determine whether dietary habits of common musk turtles in Spring Lake vary by gender or season. I also assess whether or not common musk turtle feeding habits in Spring Lake are similar to those previously documented in other portions of their range.

METHODS

Study Site

Spring Lake (Figure 1) was created in 1847 by construction of a dam downstream from the San Marcos Springs system, which is comprised of 200 springs that flow from the Edwards Aquifer in San Marcos, Texas (Stovall et al., 1986; Brune, 2002). This 7.9 ha reservoir (Fields et al., 2003) is the headwaters of the San Marcos River. Sink Creek, an intermittent waterway, empties into Spring Lake through an eastern extension of the lake called the slough, causing periodic localized flooding. Spring Lake, the slough area and the San Marcos River are home to numerous turtle species, including the Texas river cooter (*Pseudemys texana*), red eared slider (*Trachemys scripta elegans*), the spiny softshell (*Apalone spinifera*), the common snapping turtle (*Chelydra serpentina*) and the common musk turtle. Common musk turtles were collected from lentic and lotic areas of the lake (Figure 1).

Sample Collection

I collected 41 common musk turtles during spring (March 2008 – May 2008), 40 during the winter (December 2008 – February 2009), and 33 each during the fall (September 2008 – November 2008), and summer (June 2008 – August 2008). Sixty-eight turtles were collected from the lotic habitat and 79 from the lentic habitat of Spring Lake (Table 1). I used notching codes on the marginal scutes of individuals to determine that no turtles used in my study travelled between habitats.

Figure 1. I collected common musk turtles from the lotic headwaters and from the lentic boardwalk area of Spring Lake.

Table 1. Number of common musk turtles collected from Spring Lake by habitat, gender and season.

	Spring		Summer		Fall		Winter	
	Male	Female	Male	Female	Male	Female	Male	Female
Headwaters (lotic)	7	12	8	4	9	10	6	12
Boardwalk (lentic)	13	9	10	11	8	6	16	6
Total	20	21	18	15	17	16	22	18

I collected common musk turtles from shore with a dip net during 45 minutes before and after dusk. I baited the capture area with a small amount of commercial canned cat food about 10 minutes prior to engaging in capture attempts. After capture, each turtle was placed in a separate 3.8 l bucket with enough water to cover the limbs and base of the shell (Figure 2). Immediately after each evening of collection, I transferred

the buckets of turtles to a laboratory at Texas State University-San Marcos. I rinsed each turtle, then weighed, measured, and determined their gender. I replaced the water in each bucket with fresh, clean water and held the turtles in separate buckets in the laboratory for 48 hours to allow voiding of intestinal contents.

After 48 hours, fecal material was removed from each bucket and immediately stored in 70% ethanol for identification. After sample collection, turtles were released at the site of capture.

Sample Identification

Sample material was sorted and identified in four steps. First, samples were separated into categories including mollusk, crayfish, vegetation (including algae), insects, and "other." The "other" category included everything that could not be placed into any of the preceding four categories, such as non-insect invertebrates, what appeared to be eggs, and unidentifiable material. The five categories from each sample were stored in separate vials and labeled with a sample number and composition for later analysis (Figure 3A).

For identification and quantification, each vial was placed in a 100 x 20 mm petri dish with four lines drawn onto the bottom forming a 30 x 30 mm square (Figure 3B). Items closest to each corner and the mid-point of the square were identified to the lowest taxonomic level possible under a dissecting microscope. After the components of the samples were identified, the contents of each vial was dried and weighed to the nearest 0.0001 gram. To standardize size differences between samples, the percent weight of each component was used in the analysis.

Figure 2. Turtles were captured with dip nets and placed in 3.8 liter buckets with water.

Analysis

Four samples were not included in the analysis because they were physically destroyed prior to being sorted and identified. The raw sample weights for the remaining 143 samples were converted to percent weights to standardize the sample comparisons. To prevent computational errors relating to zero (for example, cannot divide by zero, cannot take the log of zero), fecal weights of 0.0000 were converted to an extremely small nonzero value (0 .00000001).

Because strong correlations would violate the assumptions of a univariate model, Pearson's Product Moment Correlation was calculated to determine the magnitude and direction of association between food items for each of the independent variables (habitat, gender and season) to determine if ANOVA modeling was appropriate for the

dependent variables. To determine if there were any differences across the five dependent variables for the three-way classification variable (season, habitat, gender) a three-way univariate analysis of variance was computed for each category, as appropriate.

A three-way univariate analysis of variance was computed for each measure of fecal composition. Following D'Agostino et al. (1990), normality was determined using Shapiro-Wilk, Fisher's Skewness, Fisher's Kurtosis and D'Agnostino-Peason omni-bus test for Kurtosis were used to determine which of the samples were appropriate for the general linear models (analysis of variance) (see D'Agostino et al., 1990 for a complete description of the selected tests). The Brown-Forsythe test was used to test for homogeneity of group variances.

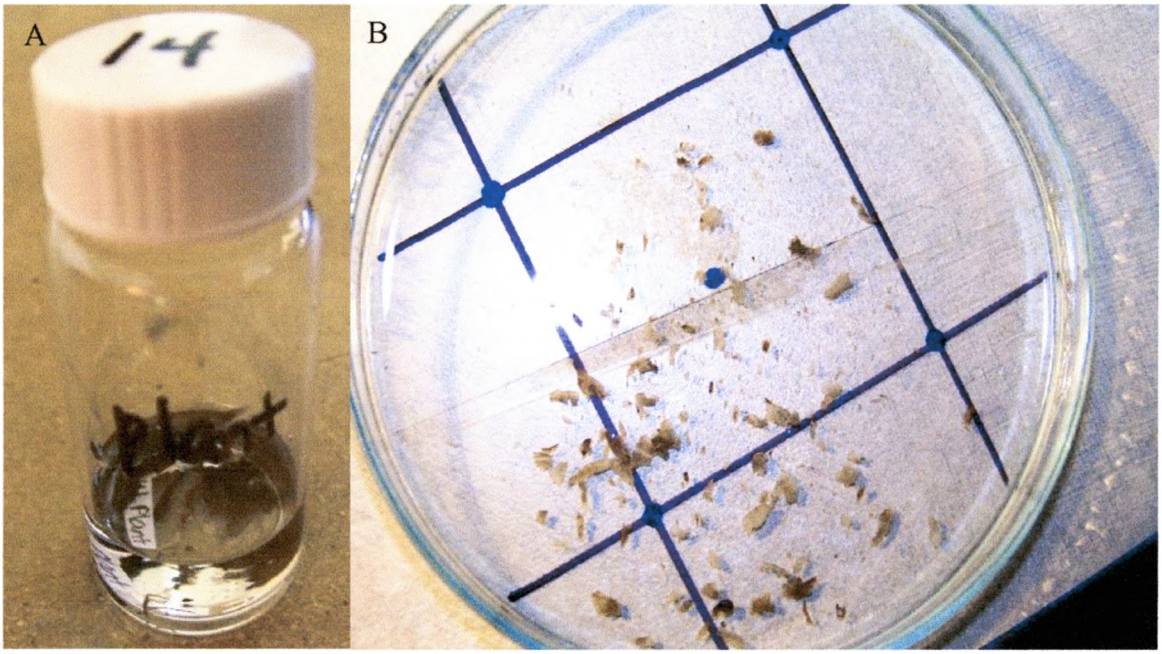


Figure 3. (A) Categorized components of each sample were stored in vials of 70% EtOH and labeled with the sample number and the component type. (B) A petri dish with five points was used to select subsamples from the components of each sample.

RESULTS

I identified 36 taxa including 6 mollusks, 1 crayfish, 13 insects, 12 plants, and 4 taxa in the 'other' category. Mollusks were the most common component in the fecal samples, which occurred in 88% of samples. Crayfish parts were identified in 44% of the samples, insects or insect parts were identified in 46% of the samples and plants were identified in 41% of the samples. Every sample had a portion of material that was classified as 'other.' The most frequently occurring mollusks were snails in the genus *Physa*, and *Gyralus,* which were identified in 57% and 43% of the samples, respectively (Table 2). Photographs of many of the identified taxa are presented in Appendix A.

Normality Assumption

The results of the normality tests indicated that the percent weight of mollusks and 'other' were appropriate for modeling without transformation. Normality tables are presented in Appendix B. The distribution of percent weight values in the crayfish, insect and vegetation categories were transformed according to Stevens (1996).

Table 2. Taxa recorded in 143 samples of common musk turtle fecal material with percent occurrence by season and habitat.

		Spring		Summer		Fall		Winter	
	Classification	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic
Mollusks	*Physa* (Gastropoda: Physidae)	3.4	10.9	2.7	8.2	4.8	10.2	2.0	15.0
	Gyralus (Gastropoda: Planorbidae)	2.7	6.1	0	6.8	4.8	9.5	2.0	10.9
	Pyrgulopsis (Gastropoda: Hydrobiidae)	5.4	3.4	2.0	6.8	4.1	6.1	0.7	8.2
	Sphaeriidae (Mollusca)*	2.0	4.8	0	4.8	0	2.7	0	0
	Marisa cornuarietis (Gastropoda: Prosobranchia)	2.7	2.7	3.4	0	5.4	1.4	3.4	4.1
	Elmia sp. (Gastropoda: Pleuroceridae)	7.5	1.4	6.8	1.4	8.2	0	6.8	0
	Other gastropod material	0.7	0.7	1.4	2.7	2.0	1.4	2.0	0
Total Frequency (%) of Mollusks		24.5	29.9	16.3	30.6	29.3	31.3	17.0	38.1
Crayfish	*Procambarus clarki* (Decapoda: Cambaridae)	7.5	6.8	3.4	7.5	4.8	7.5	1.4	5.4
Insect	Unknown Ephemeroptera	0	0	0	0	0	0.7	0	0.7

Table 2 continued.

	Spring		Summer		Fall		Winter	
Classification	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic
Unknown Odonata	3.4	2.0	0	1.4	1.4	4.1	1.4	6.1
Cordulidae (Odonata)	0	3.4	0	0	0.7	0.7	0.7	2.7
Coenagrionidae (Odonata)	0	1.4	0	0.7	0	0	1.4	0
Unknown Coleoptera	0.7	0	0	0	0.7	0	0	0
Hydrophilidae (Coleoptera)	0	0	0	2.0	0	0	0	0.7
Dytiscidae (Coleoptera)	0	1.4	0.7	0.7	0	0.7	0	0.7
Unknown Hemiptera	0	0.7	0	0	0	0	0	0
Naucoridae (Hemiptera)	0.7	0	0	0	0	0	0	0
Leptoceridae (Trichoptera)	0	0	0	0	0	1.4	0	0.7
Hydropsychidae (Trichoptera)	0	2.0	0.7	5.4	0	1.4	0	0
Aedes albopictus (Diptera: Culicidae)	0	0	0	0	0	0.7	0	0
Sialidae (Neuroptera)	0	0	0	0.7	0	0	0	0
Other insect material	2.0	2.7	0.7	4.1	0	2.0	0.7	4.8

Table 2 continued.

		Spring		Summer		Fall		Winter	
	Classification	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic
	Total Frequency (%) of Insects	6.8	13.6	2.0	15.0	2.7	11.6	4.1	16.3
Plant	*Ceratophyllum demersum* (Ceratophyllales: Ceratophyllaceae)	0.7	6.1	0	2	0	1.4	0	1.4
	Utricularia gibba (Lamiales: Lentibulariaceae)	0.7	1.4	0	0.7	0	0.7	0	0.7
	Lyngbya spp. (Oscillatoriales: Oscillatoriaceae)	0	0.7	0	0.7	3.4	0	2.7	0.7
	Cabomba caroliniana (Nymphaeales: Cabombaceae)	0	0	0	0.7	0.7	0	0	0
	Nuphar advena (Nymphaeales: Nymphaeaceae)	2.0	1.4	0	0.7	0	0.7	0	0
	Myriophyllum heterophyllum (Saxifragales: Haloragiaceae)	1.4	0	0	0.7	0.7	0	0	0
	Vallisneria americana (Alismmatales: Hydrocharitaceae)	0	1.4	0	0	0	0	0	0
	Hydrilla verticillata (Alismatales: Hydrocharitaceae)	0.7	0	0	1.4	0	1.4	0	0
	Leptodictyum (Hypnales: Amblystegiaceae)	0.7	0	1.4	0	1.4	0	0	0
	Spirodela polyrhiza (Aralea: Lemnaceae)	0.7	0	0	0	0	0	0	0

Table 2 continued.

		Spring		Summer		Fall		Winter	
	Classification	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic	Lotic	Lentic
	Taxodium distichum (Pinales: Cupressaceae)	0	0	0.7	0.7	0.7	0	0	0
	Juniperus ashei (Pinales: Cupressaceae)	0	0	0	0.7	0	0.7	0.7	0
	Other plant material	4.8	6.1	1.4	2.7	4.8	1.4	4.1	1.4
Total Frequency (%) of Plants		11.6	18.4	4.1	14.3	12.2	6.1	7.5	4.1
Other	*Placobdella spp.* (Rhynchobdellida: Glossiphoniidae)	0	0.7	1.4	0.7	0	0.7	0.7	0
	Undetermined Ostracod	0	0	0	0.7	0.7	0	0	0
	Hyalella (Amphipoda: Hyalellidae)	0	0	0	1.4	0.7	0	0	0
	Undetermined Acari	0	0	0	0	0	0	0	0
	Other material	14.3	12.9	67.3	14.3	17.7	13.6	15.6	15.6
Total Frequency (%) of Other		14.3	13.6	68.7	17.0	19.0	14.3	16.3	15.6

Homogeneity Assumption

The Brown-Forsythe test was used to test variances within fecal component categories. The hypothesis of equal variances was supported for all categories except 'other' (p = .3086 (mollusks), .3411 (crayfish), .9927 (insects), .2065 (plants), .0273 (others)). The log transformation was applied to the 'others' variable and achieved homogeneity (p = 0.3433).

Independence

Overall, there was a negative relationship between the relative amount (percent weight) of mollusks consumed and the amount of 'other' components consumed. There was little overall correlation between any of the other components (Table 3).

Analysis of Variance

The strong correlation between mollusks and 'other' (r = -0.56) make an ANOVA for the variable 'other' unnecessary because no new information would be gained by adding it to the analysis. ANOVA tests for each of the remaining response variables are adequate because no strong correlations exist among the remaining food items.

For the percent weight of mollusks, a significant main effect was found for the season and habitat interaction. Subsequently, this interaction was also significant for the percent weight of plants. It should be noted that the interaction patterns for each fecal measure match and are inverted by habitat (Figures 4 and 5). Specifically, from spring to summer s increase mollusks in lotic habitats (and decrease in lentic) while plants decrease in lotic (and increase in lentic). From summer to fall, mollusks decrease in lotic habitats (and increase in lentic) while plants increase in lotic (and decrease in lentic). Finally, from fall to winter, both mollusks and plants increase in lotic and lentic habitats. Additionally, for

the percent weight of insects, a significant main effect was found for the season and gender interaction (Figure 6).

Table 3. Intercorrelations between fecal composition measures (Percent Weights) of 143 samples.

Measure	Crayfish	Insect	Plant	Other
Mollusk	-0.43633	-0.04435	-0.24288	-0.56319
Crayfish		-0.07037	-0.09152	-0.20048
Insect			-0.03070	0.00295
Plant				-0.10709

Table 4. Three factor ANOVA for mollusks. Note: *p-value <0.1; **p-value<.01.

Source of variation	DF	Mean squares	F	P
Season	3	0.20772284	2.22	0.0895*
Habitat	1	0.01285056	0.14	0.7118
Gender	1	0.09246124	0.99	0.3225
Season*Habitat	3	0.81323418	8.67	<.0001**
Season*Gender	3	0.01172758	0.13	0.9451
Habitat*Gender	1	0.07111286	0.76	0.3854
Season*Habitat*Gender	3	0.16239776	1.73	0.1637
Error	127	0.0415		

Table 5. Three factor ANOVA for crayfish. Note: *p-value <0.1.

Source of variation	DF	Mean squares	F	P
Season	3	163.3544605	2.37	0.0732*
Habitat	1	10.5271954	0.15	0.6963
Gender	1	6.6102243	0.10	0.7571
Season*Habitat	3	85.5519367	1.24	0.2967
Season*Gender	3	55.4970310	0.81	0.4923
Habitat*Gender	1	0.0007306	0.00	0.9974
Season*Habitat*Gender	3	93.7951820	1.36	0.2570
Error	127	37.6872		

Table 6. Three factor ANOVA for plants. Note: *p-value <0.1.

Source of variation	DF	Mean squares	F	P
Season	3	176.7333622	3.59	0.0156*
Habitat	1	75.2900619	1.53	0.2185
Gender	1	42.0796404	0.85	0.3569
Season*Habitat	3	157.5539788	3.20	0.0256*
Season*Gender	3	57.0314870	1.16	0.3283
Habitat*Gender	1	40.9789610	0.83	0.3633
Season*Habitat*Gender	3	71.3537609	1.45	0.2316
Error	127	28.7310		

Table 7. Three factor ANOVA for insects. Note: *p-value <0.1; **p-value<.01.

Source of variation	DF	Mean squares	F	P
Season	3	58.6625024	1.40	0.2447
Habitat	1	301.5078393	7.22	0.0082**
Gender	1	24.2755302	0.58	0.4474
Season*Habitat	3	48.9492028	1.17	0.3234
Season*Gender	3	96.4102015	2.31	0.0797*
Habitat*Gender	1	32.4638315	0.78	0.3798
Season*Habitat*Gender	3	72.0746898	1.72	0.1652
Error	127	26.5248		

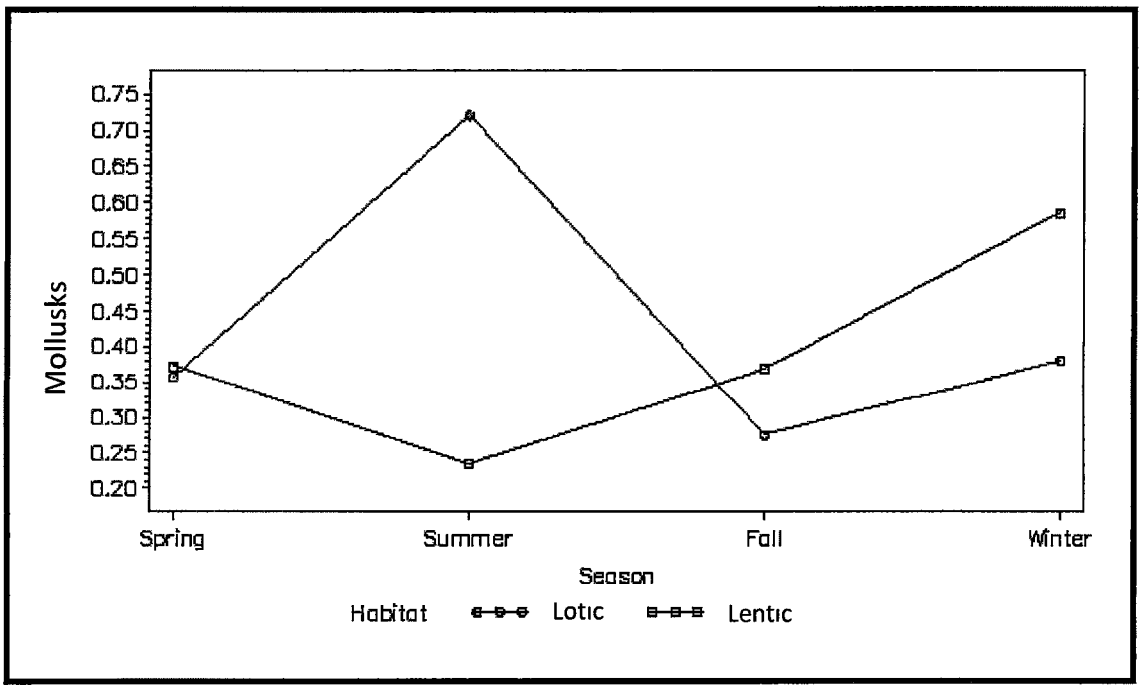


Figure 4. Interaction plot for mollusks (season * habitat).

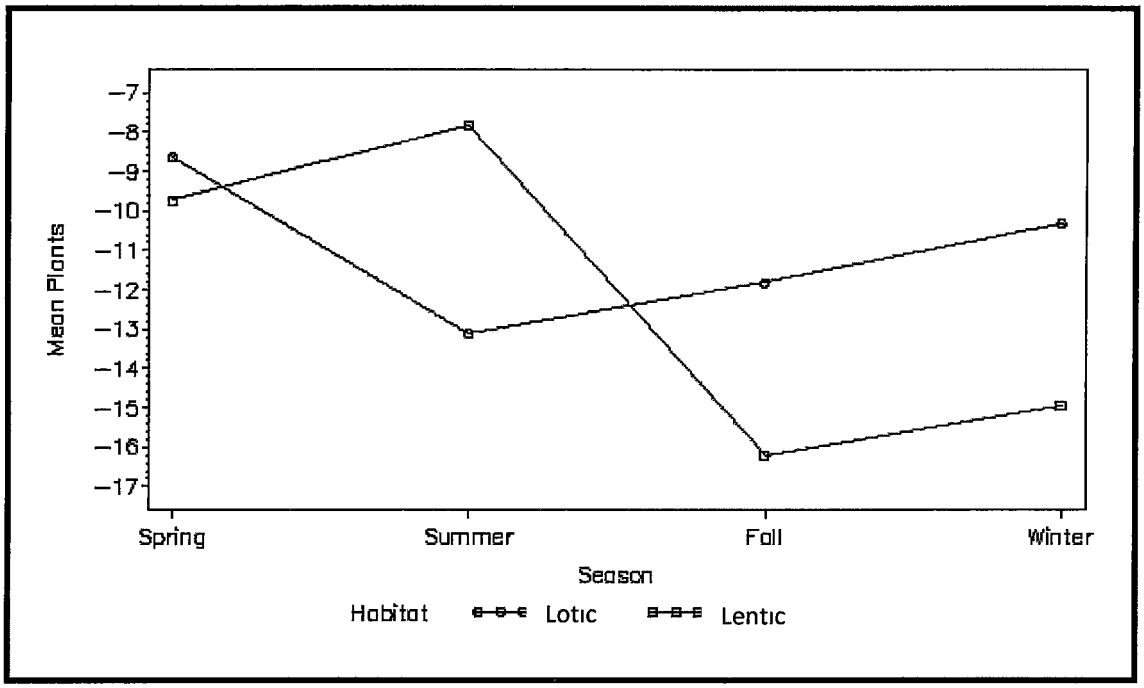


Figure 5. Interaction plot for plants (season * habitat).

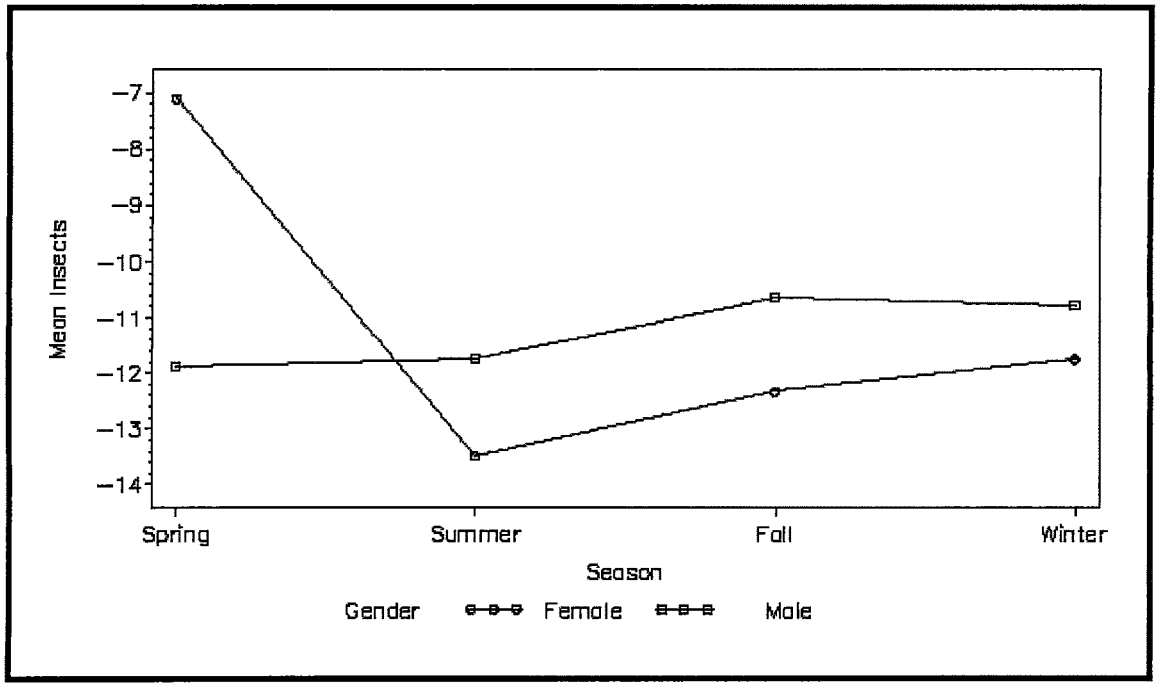


Figure 6. Interaction plot for insects (season * gender).

Fecal Composition of Turtles in Lentic vs. Lotic Habitats

Habitat accounted for a significant portion of the variation in the amount of insects consumed between the two habitats. The frequency of mollusks, crayfish, insects and 'other' was higher in samples from the lentic habitat (Table 2, Figure 7).

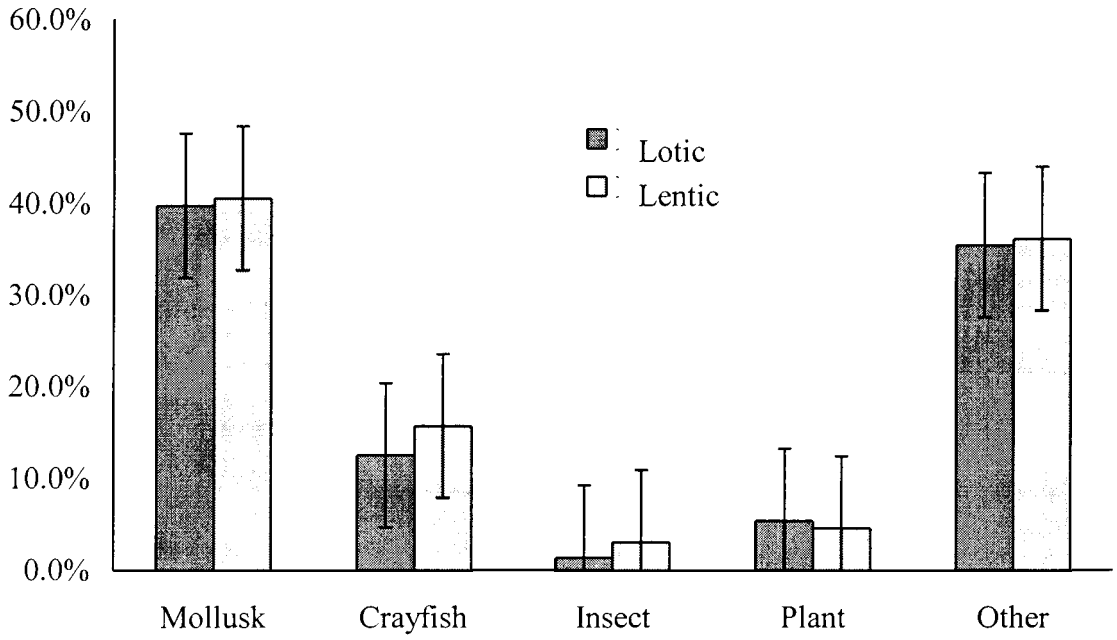


Figure 7. Differences in percent fecal composition of common musk turtles in lentic and lotic habitats.

Fecal Composition Measures of Male and Female Turtles

Table 8 shows frequencies of turtles captured by gender, season and habitat. Chi-square tests of independence revealed that differences in capture rates between genders for each habitat were not significantly different for the spring, summer and fall seasons, but that significantly more males were captured during the winter from the lentic habitat than any other season (Table 9). Female turtle consumed slightly higher average percentages of mollusks and plants and male turtles consumed slightly higher average percentages of mollusks and other (Figure 8).

Table 8. Percentage of males and females captured by season and habitat.

	Spring		Summer		Fall		Winter	
	Male	Female	Male	Female	Male	Female	Male	Female
Headwaters (lotic)	5	8	6	3	6	7	4	8
Boardwalk (lentic)	9	6	7	7	5	4	11	4
Total	14	14	13	10	11	11	15	12

Table 9. Results of Chi-square tests on capture rates of male and female turtles in each season.

Season	X^2	DF	P
Spring	2.019874	1	0.155
Summer	1.521162	1	0.217
Fall	0.308326	1	0.579
Winter	6.207530	1	0.013

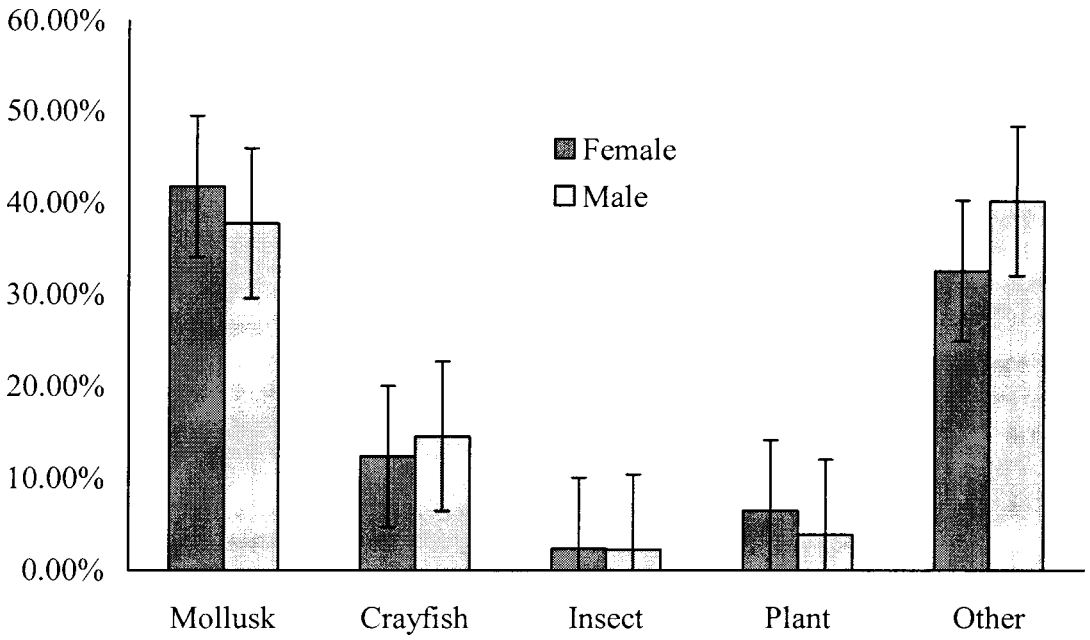


Figure 8. Differences in percent fecal composition of male and female common musk turtles.

Seasonal Variations in Fecal Composition Measures

Mollusks occurred in 54.4% of samples taken in the spring, 46.9% of samples taken in the summer, 60.6% of samples taken in the fall and 55.1% of samples taken in the winter. Crayfish occurred in 6.8 to 14.3% of samples in all seasons, insects occurred in 14.3 to 20.4% of samples in all seasons, and plants occurred in 11.6 to 30% of samples in all seasons (Table 2). The amount of plants consumed varied significantly between habitats (Table 6). There was a higher number of mollusks consumed during the summer and winter, and a higher number of crayfish consumed during the fall and spring (Figure 9).

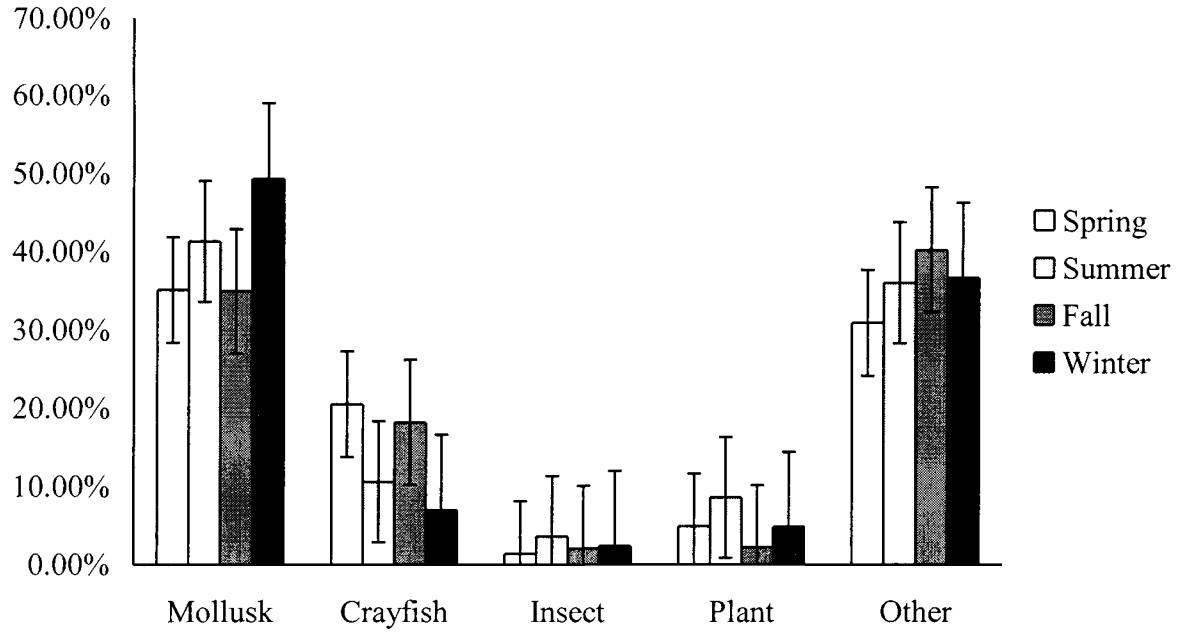


Figure 9. Differences in percent fecal composition of common musk turtle diet by season.

DISCUSSION

It is not surprising that the most commonly counted food items in fecal matter samples from common musk turtles were mollusks, crayfish, and insects due to the persistence of hard parts such as shell and chitinous exoskeleton. Larger shells such as those of the invasive Giant Ramshorn Snail, *Marisa cornuarietis,* were always excreted in fragments, while many smaller shells were excreted intact. Thinner shells with a more fragile structure, such as those of snails in the genus *Physa,* were sometimes broken, but were typically recognizable. Mollusks found in the digestive tracts of common musk turtles in Michigan (Lagler, 1943), were generally crushed beyond recognition.

Both mollusks and insects occurred with a higher frequency in the lentic habitat (Table 2), with a pattern strong enough to be indicative of environmental variation rather than variation in the sampling. Habitat alone accounted for 0.8% difference in the average percentage of mollusks consumed (Figure 7), but habitat combined with seasonal variation showed a difference that was significant, specifically that there was a large increase in the number of mollusks consumed in the summer in the lotic habitat, followed by a decrease in the fall and simultaneous increase in consumption in the lentic habitat (Figure 4). Plant consumption in the lentic habitat dropped significantly from summer to fall, while in the lotic habitat there was a slightly higher percent weight of plants present in fall and winter than in summer samples (Figure 5). Insects occurred at a much lower frequency than mollusks, but the difference in the amount of insects consumed between habitats proved significant (Table 7).

The differential rates of digestion between chitinious, calcareous and cellulose parts probably accounts for some of the variation in the results. Although some studies have been done on differential digestion rates and on the interaction of diet items in turtles (Bjorndal, 1991), no information is available for digestion rates of individual food items in *Sternotherus* sp. If differential digestion rates for common musk turtles were available for this study then the results might have shown less variability between food categories containing hard parts, such as mollusks and crayfish, and those containing mostly soft parts, such as insects and plants. One way to reduce variation introduced by differential digestion rates without having to calculate a digestion coefficient is to obtain food items from the stomachs of the animals prior to digestion, either by dissection or stomach flushing.

Although this study employed only fecal analysis and did not attempt to correct for differential rates of digestion among food items, the results did not disagree with studies that employed other methods of dietary analysis for the common musk turtle (Lagler, 1943; Ford and Moll, 2004). Common musk turtles are typically described as omnivores and scavengers (Mahmoud, 1969), both designations were supported by my study. Common musk turtles actively hunt for food such as snails and insects (referred to by Ernst (1986) as the peer and probe method) and I observed them actively attacking crayfish, but they also scavenge on carcasses of dead animals (Ernst, 1986). One sample was made up almost entirely of mammal fur and skin, and another contained bird feathers.

Only two juveniles were captured (Mitchell, 1988 only captured 7% juveniles out of 107 turtles, so this is not uncommon), so an analysis of diet variation with age was not

possible. It is possible that the dietary tendencies of common musk turtles change over the course of their lives, such as in *Pseudemys* and *Graptemys* species (Clark and Gibbons, 1969; Moll 1976), this possibility should be explored more in depth with future research.

Some Chelonians are agents of seed dispersal, which may explain patterns in riparian vegetation (Ford and Moll, 2004). Seeds have been identified in the fecal matter of snapping turtles, box turtles, and tortoises (Lagler, 1943; Braun and Brooks, 1987), however Lagler (1943) noted that seeds were crushed after passing through the digestive tract of the common musk turtles. *Nuphar advena* seeds identified in fecal samples from common musk turtles in Spring Lake were identifiable, but had also been crushed. It is possible that larger Chelonians may pass seeds without mechanical damage and are better suited to seed dispersal.

There was not a significant difference in the amount of plant matter measured in common musk turtle fecal material between the lentic and lotic areas of Spring Lake. This analysis, however, did not take into account possible differences in species composition of the samples or of the environment itself. The percent weight of mollusks, insects and 'other' was different between the two habitats, indicating perhaps that resources differ between the habitats. Because the differences only occurred in non-vegetative categories, it is possible that the vegetative composition is similar but the habitat differences affect the community composition of the rest of the food resources available to the turtles. Lindeman (1996) postulated that differences observed in two populations of Painted Turtle, *Chrysemys picta,* in different habitats were due to the

differential availability of chironomid larvae in the two environments in which the populations were found.

Ford and Moll (2004) found that seasonality affected the sex ratio of their captures. There were more males than females captured during the winter portion of my study, but caution should be used when interpreting this because of the relatively low sample size (22 males, 18 females). Seasonal trends may be more apparent in northern latitudes where the water temperature changes throughout the year.

Season did, however, have a significant effect on the percent weight of mollusk, crayfish and plant categories (Tables 4, 5 and 7). These seasonal feeding trends were also apparent for the insect category as a season by gender interaction, with females consuming significantly more insects than males in the spring season (Figure 6).

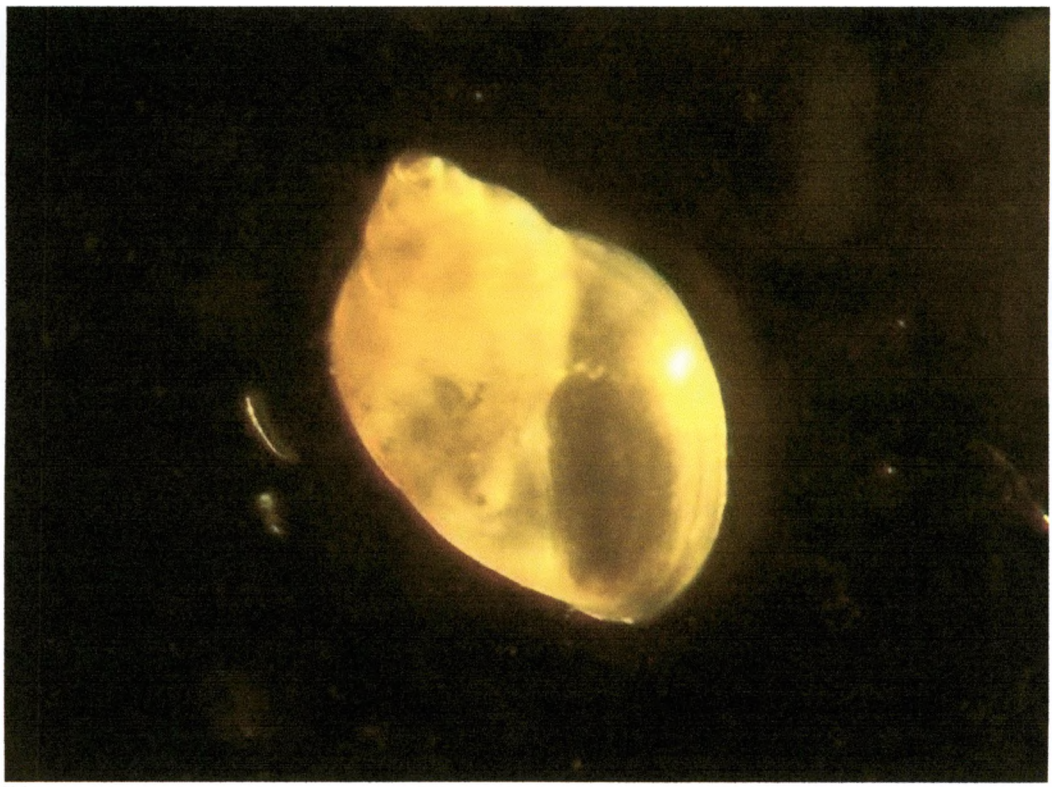
One reason for the shift in feeding trends of females in the spring might be that invertebrates provide more protein and energy than plants, algae and detritus (Bowen, 1995). Mollusks and crayfish have more hard, indigestible parts than insects. Perhaps turtles can gain more energy from eating insects because the chitinous exoskeleton of insects occupies less space in turtle digestive tracts. There would be more digestible, usable food there per unit volume with insects than for mollusks and crayfish.

The results of this study largely agreed with past dietary analyses of common musk turtles, most of which noted algae, seeds, plants, crayfish, mollusks, insects and other invertebrates and scavenged materials in the stomach, gut and fecal material (Lagler, 1943; Ford and Moll, 2004). Based on the results of this study, fecal analysis is an appropriate method of quantifying the diet of common musk turtles, and the diet of

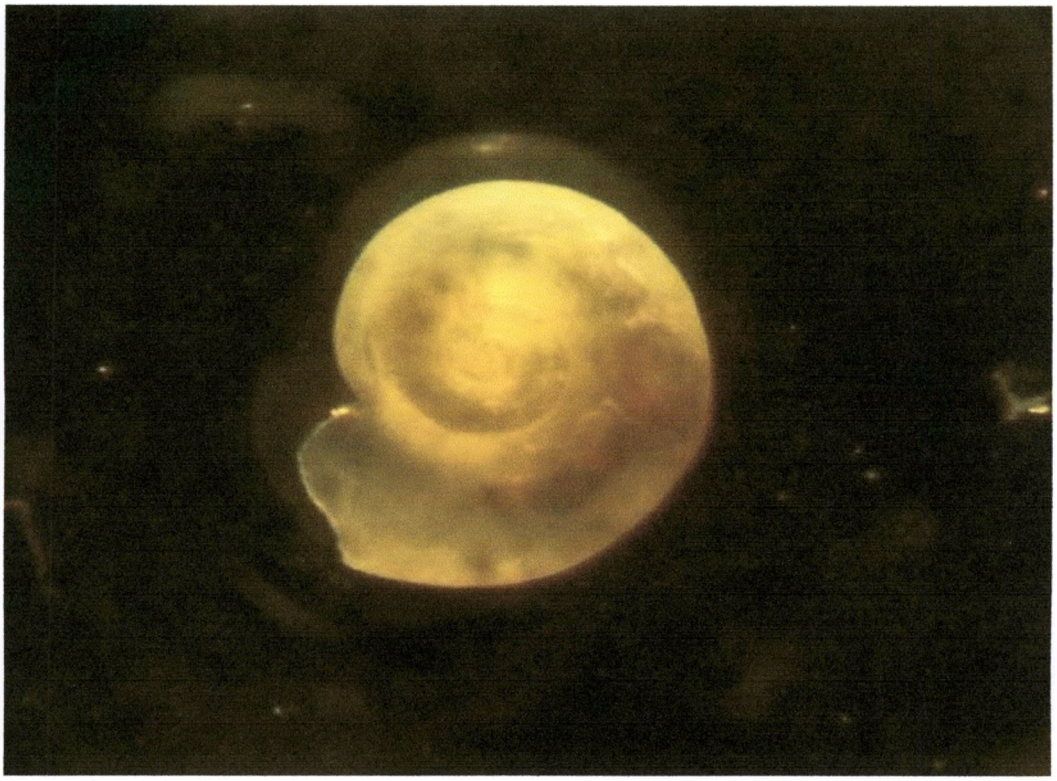
common musk turtles in Spring Lake is consistent with that in other portions of their range.

APPENDIX A

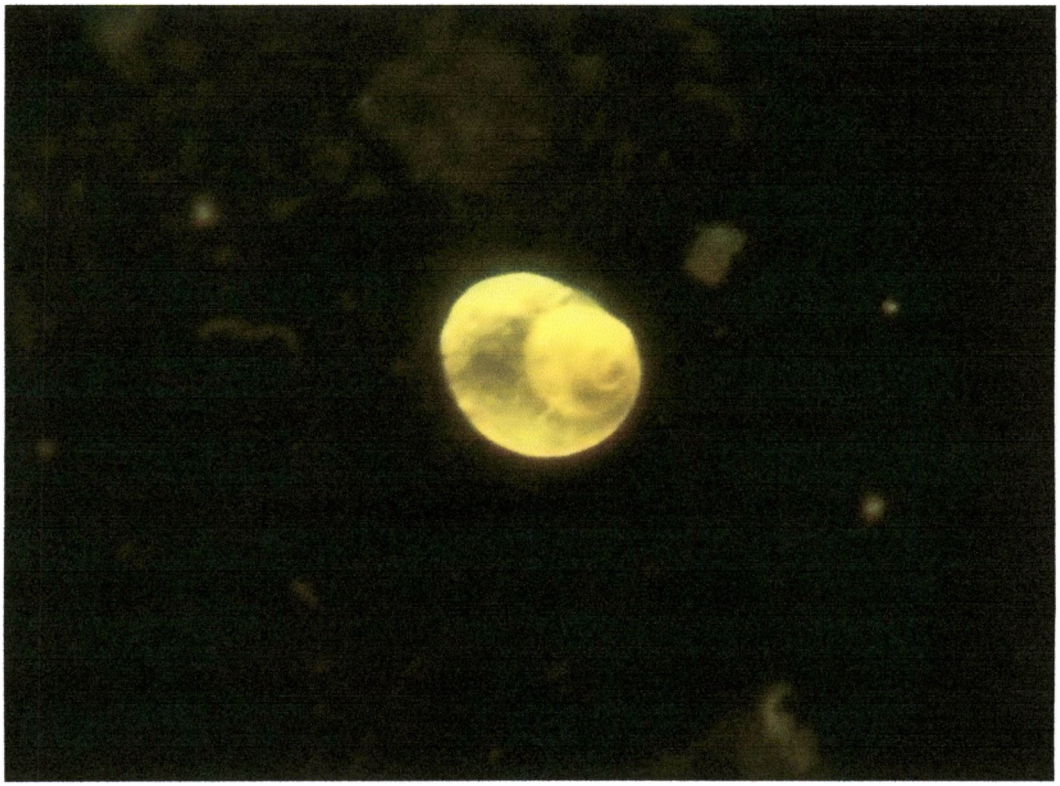
Photographs of selected taxa from fecal samples of common musk turtles from Spring Lake and the San Marcos River, San Marcos, Hays County, Texas.



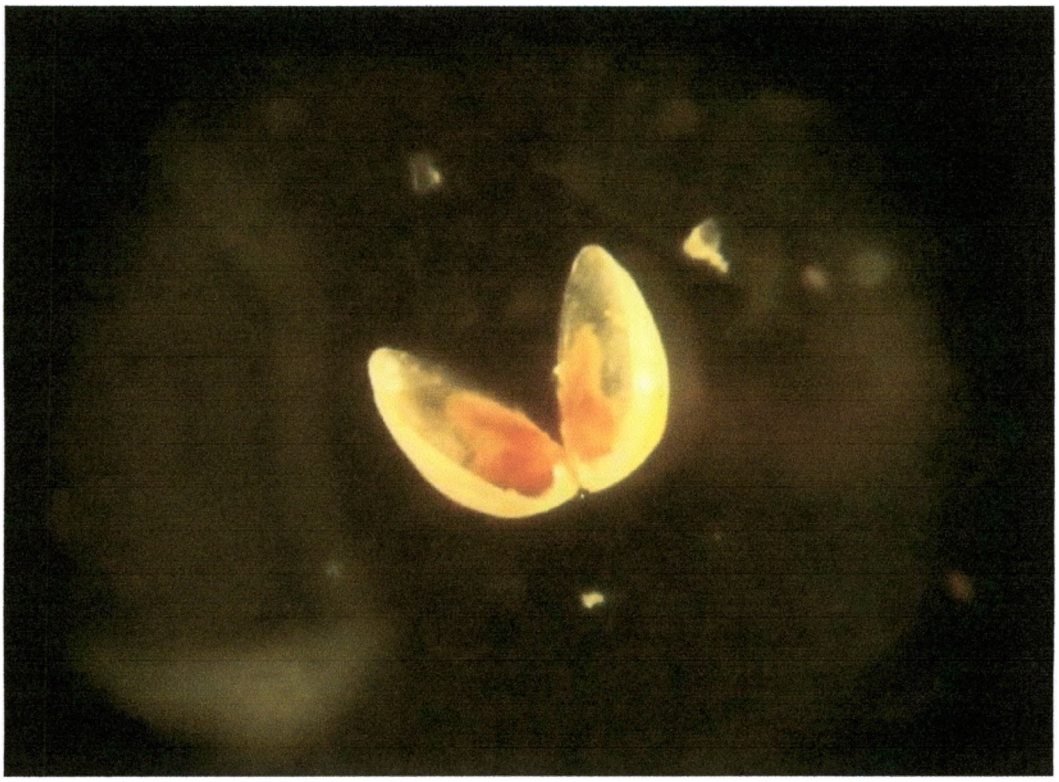
Physa sp.



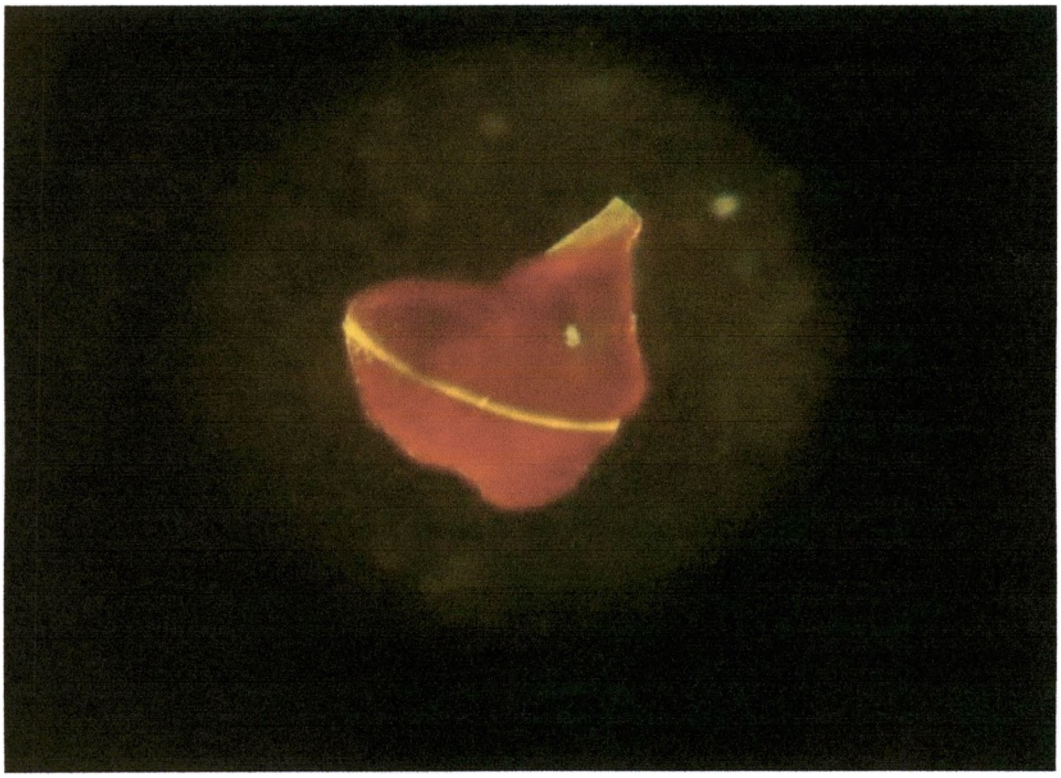
Gyraulus sp.



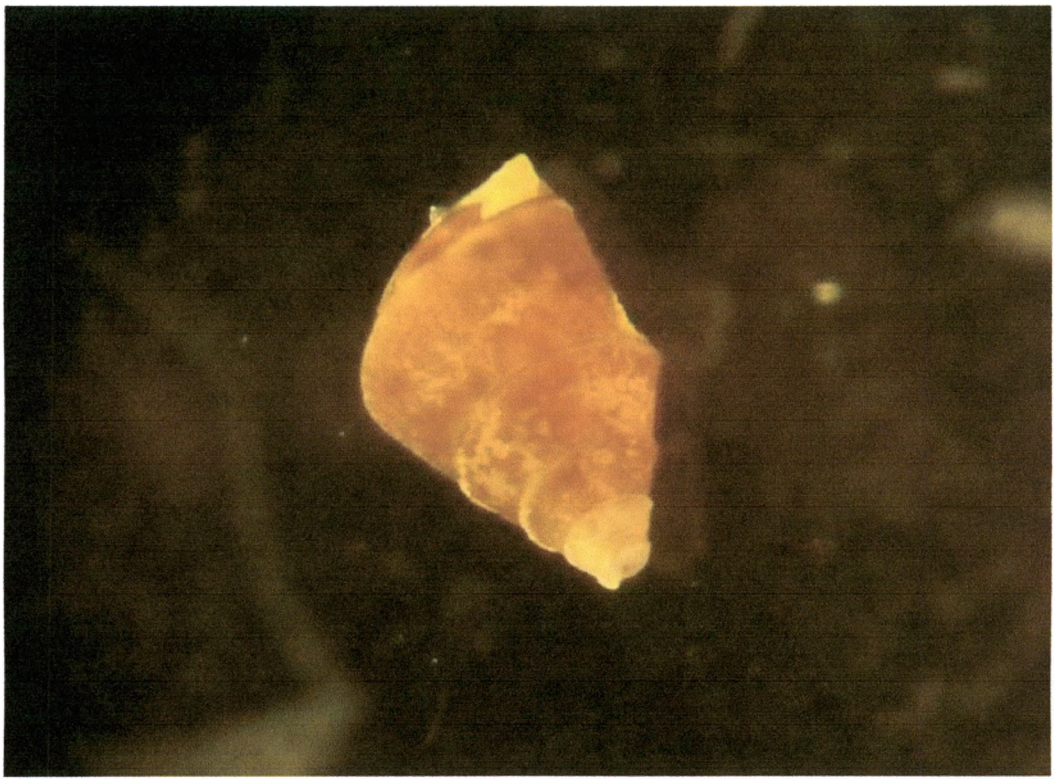
Pyrgulopsis sp.



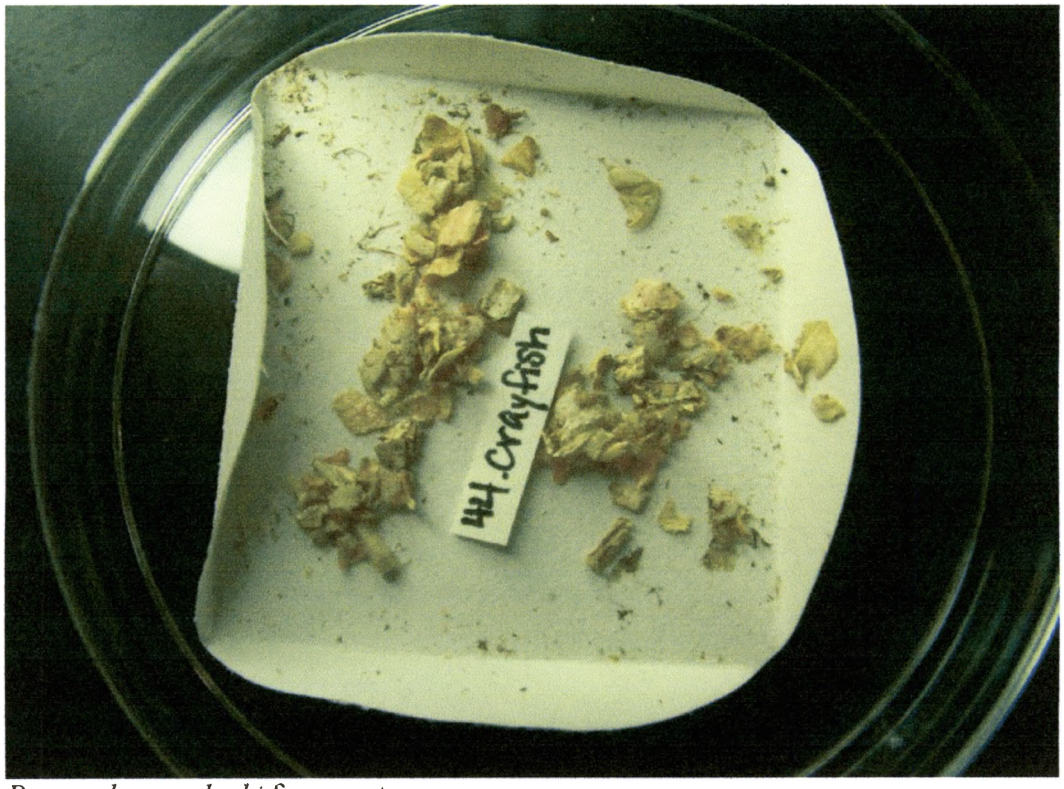
Sphaeriidae



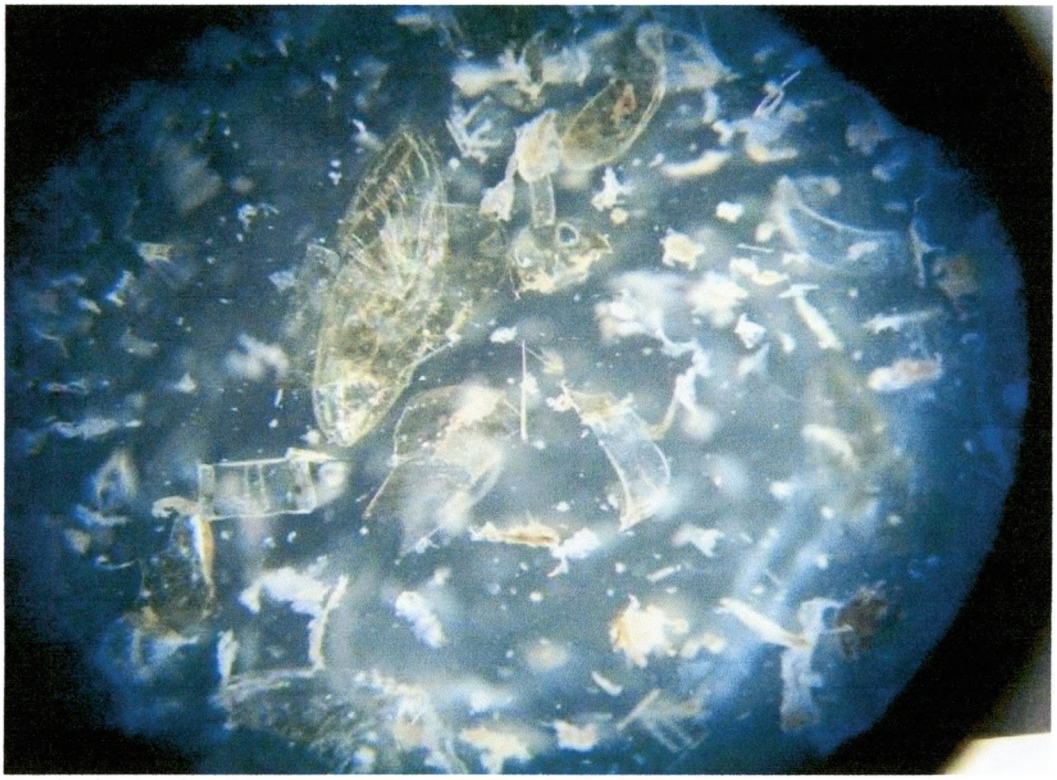
Marisa cornuarietis



Elmia sp.



Procambarus clarki fragments



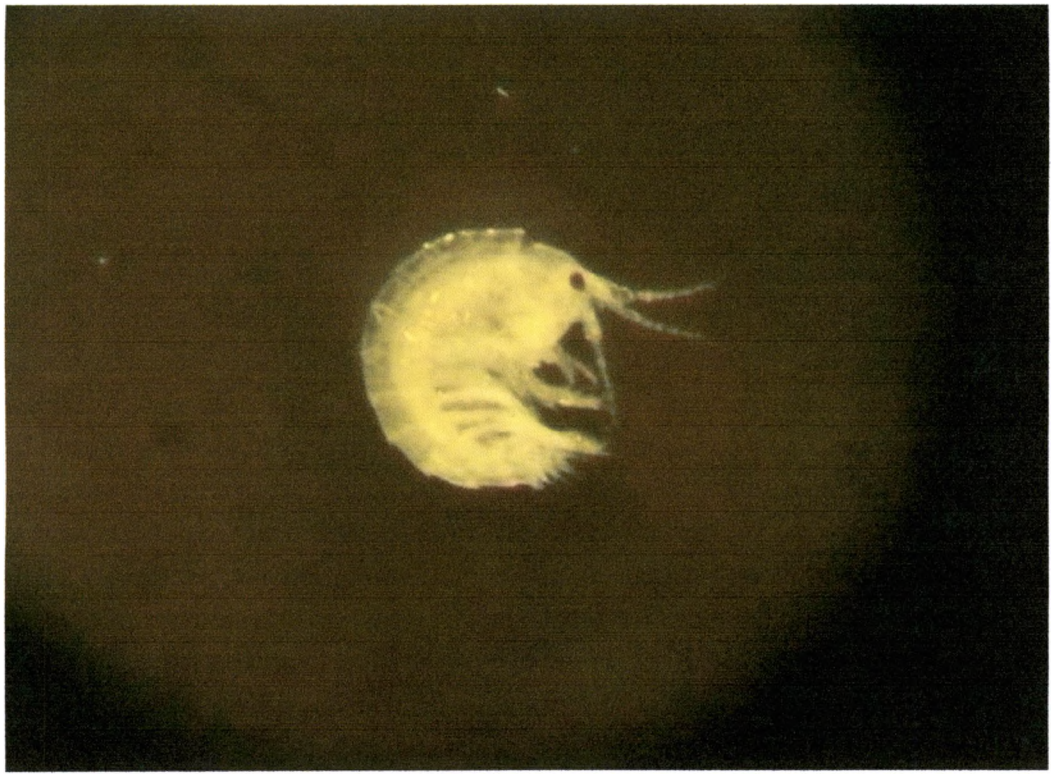
Typical sample of insect material

Odonata nymph

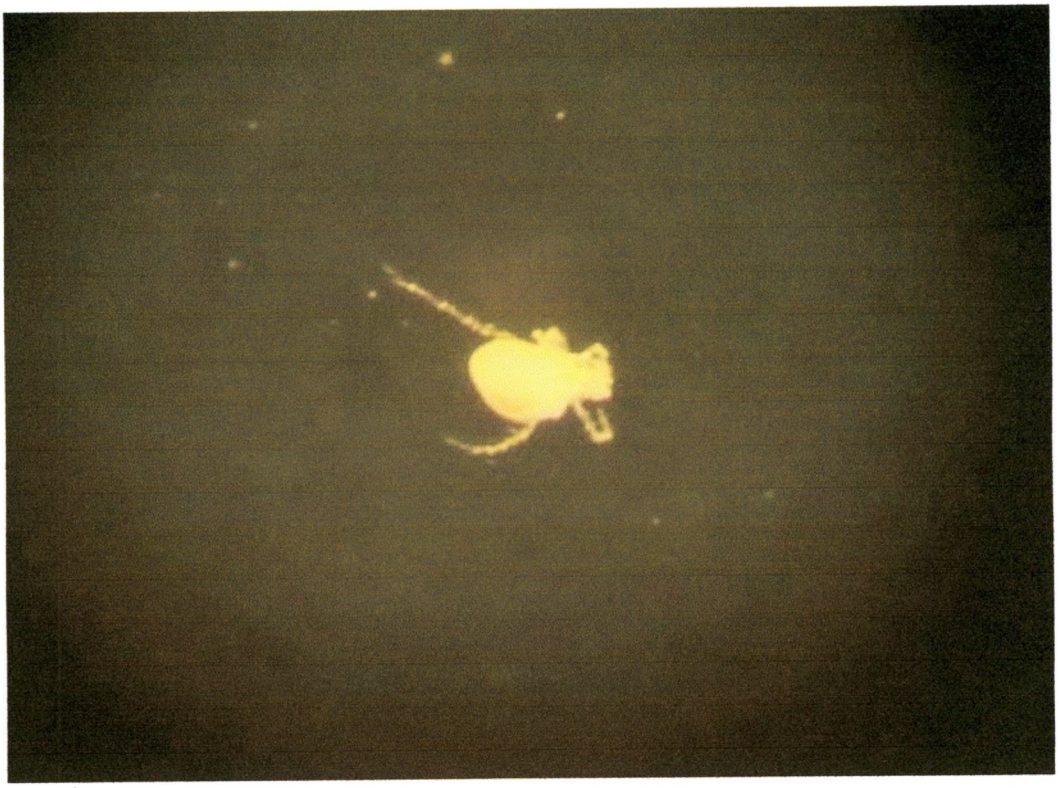
Coleoptera parts

Coleoptera

Plant material (bark)



Hyalella sp.



Acari

APPENDIX B

P-values for univariate normality tests[1].

Mollusks.

	Variable				Test			
Measure	Season	Habitat	Gender	n	1	2	3	4
Mollusks	Spring	Lotic	Female	12	0.0069	0.0653	0.0732	0.1725
			Male	7	0.5631	--	0.2459	--
		Lentic	Female	9	0.385	0.4272	0.4662	0.5595
			Male	13	0.0039	0.124	0.407	0.2172
	Summer	Lotic	Female	4	0.1619	--	0.0166	--
			Male	8	0.3139	0.5085	0.2912	0.4604
		Lentic	Female	9	0.4393	0.7049	0.2035	0.4146
			Male	10	0.0074	0.1655	0.4275	0.2791
	Fall	Lotic	Female	8	0.0064	0.1066	0.9213	0.2708
			Male	9	0.0016	0.0555	0.6747	0.1452
		Lentic	Female	6	0.0970	--	0.3043	--
			Male	8	0.1867	0.1589	0.7714	0.3554
	Winter	Lotic	Female	12	0.0038	0.9950	0.0004	0.0019
			Male	6	0.1893	--	0.1747	--
		Lentic	Female	6	0.1695	--	0.4545	--
			Male	16	0.0667	0.0800	0.5172	0.1751

Crayfish.

	Variable				Test			
Measure	Season	Habitat	Gender	n	1	2	3	4
Crayfish	Spring	Lotic	Female	12	0.0011	0.0691	0.8264	0.1871
			Male	7	0.0012	--	0.6916	--
		Lentic	Female	9	0.0006	0.0047	0.0170	0.0011
			Male	13	0.0026	0.3177	0.0613	0.1054
	Summer	Lotic	Female	4	--	--	--	--
			Male	8	0.0315	0.1801	0.7333	0.3842
		Lentic	Female	9	0.0119	0.0423	0.2258	0.0611
			Male	10	0.0029	0.0162	0.0735	0.0112
	Fall	Lotic	Female	8	0.0035	0.0380	0.3210	0.0710
			Male	9	0.0001	0.0002	0.0007	0
		Lentic	Female	6	0.0156	--	0.5531	--
			Male	8	0.0032	0.0409	0.3703	0.0829
	Winter	Lotic	Female	12	0.0001	0	0.0001	0.0019
			Male	6	0.0001	--	0.0076	--
		Lentic	Female	6	0.0023	--	0.2783	--
			Male	16	0.0001	0.0496	0.6781	0.1336

Insects.

	Variable				Test			
Measure	Season	Habitat	Gender	n	1	2	3	4
Insect	Spring	Lotic	Female	12	0.0001	0.0001	0.0005	0
			Male	7	0.0001	--	0.0031	--
		Lentic	Female	9	0.0164	0.0207	0.0844	0.0155
			Male	13	0.0001	0.0001	0.0006	0
	Summer	Lotic	Female	4	0.0012	--	0.0111	--
			Male	8	0.0001	0.0004	0.0014	0
		Lentic	Female	9	0.0001	0.0219	0.3583	0.0475
			Male	10	0.0348	0.0435	0.1357	0.0428
	Fall	Lotic	Female	8	0.0007	0.0054	0.0172	0.0012
			Male	9	0.0001	0.0002	0.0007	0
		Lentic	Female	6	0.0001	--	0.0076	--
			Male	8	0.0035	0.0113	0.0455	0.0055
	Winter	Lotic	Female	12	0.0001	0.0002	0.0014	0
			Male	6	0.0001	--	0.0076	--
		Lentic	Female	6	0.0378	--	0.6305	--
			Male	16	0.0001	0	0.0001	0

Plants.

	Variable				Test			
Measure	Season	Habitat	Gender	n	1	2	3	4
Plant	Spring	Lotic	Female	12	0.0001	0.0001	0.0005	0
			Male	7	0.0002	--	0.0093	--
		Lentic	Female	9	0.0003	0.0334	0.4761	0.0807
			Male	13	0.0001	0.0001	0.0005	0
	Summer	Lotic	Female	4	--	--	--	--
			Male	8	0.0001	0.0007	0.0025	0
		Lentic	Female	9	0.0007	0.0125	0.1064	0.0120
			Male	10	0.0003	0.0033	0.0183	0.0008
	Fall	Lotic	Female	8	0.0001	0.0006	0.0023	0
			Male	9	0.0001	0.0002	0.0008	0
		Lentic	Female	6	0.0001	--	0.0076	--
			Male	8	--	--	--	--
	Winter	Lotic	Female	12	0.0001	0.0001	0.0006	0
			Male	6	0.0001	--	0.0076	--
		Lentic	Female	6	0.0004	--	0.0135	--
			Male	16	0.0001	0	0	0

Other.

	Variable				Test			
Measure	Season	Habitat	Gender	n	1	2	3	4
Other								
	Spring	Lotic	Female	12	0.0363	0.0541	0.3216	0.0958
			Male	7	0.2491	--	0.4763	--
		Lentic	Female	9	0.2123	0.2239	0.9434	0.4761
			Male	13	0.0349	0.1016	0.9854	0.2618
	Summer	Lotic	Female	4	0.5604	--	0.0332	--
			Male	8	0.7307	0.3352	0.9965	0.6285
		Lentic	Female	9	0.9328	0.7331	0.8968	0.9356
			Male	10	0.9653	0.8156	0.8810	0.9623
	Fall	Lotic	Female	8	0.3781	0.5858	0.3938	0.5993
			Male	9	0.0463	0.4906	0.1082	0.2171
		Lentic	Female	6	0.4221	--	0.3749	--
			Male	8	0.3981	0.6488	0.2167	0.4203
	Winter	Lotic	Female	12	0.0203	0.2596	0.1982	0.2315
			Male	6	0.5403	--	0.5802	--
		Lentic	Female	6	0.4535	--	0.3089	--
			Male	16	0.0976	0.3032	0.8705	0.5

[1] Bonferroni adjusted alpha level = 0.0125 = (.05/4)
Tests: 1=Shapiro-Wilk 2= Fisher's Skewness (transformed) 3=Fisher's Kurtosis (transformed) 4=D'Agostino-Pearson Omnibus Kurtosis

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VITA

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