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Diet And Activity Patterns of Five Bat Species in North-Central Kansas

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DIET AND ACTIVITY PATTERNS OF FIVE BAT SPECIES IN NORTH-CENTRAL KANSAS

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ABSTRACT

My study focuses on six bat species that occur in north-central Kansas. Although each species is widely distributed, information about their diet and activity patterns is lacking, especially within Kansas. Increased knowledge about bat species in Kansas can provide a baseline for future studies and conservation efforts for the species included in my study; big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis)*, hoary bat *(Lasiurus cinereus)*, northern myotis *(Myotis septentrionalis)*, evening bat *(Nycticeius humeralis)*, and tricolored bats (*Perimyotis subflavus*) were captured and fecal samples were examined for diet diversity.

I captured bats in mist nets in the Kansas counties of Ellis, Rooks, and Trego from April through October of 2015 and 2016, when temperate bats are most active. Each captured bat was detained to collect a comprehensive fecal sample, which was used to determine diet. I captured 272 bats during 2015, from which 217 fecal samples were collected and captured 333 bats during 2016, of which 241 produced samples.

Within the fecal samples, 6 orders of insect were identified: Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Orthoptera. Results showed significant differences in diet between bat species within the state of Kansas, specifically between big brown bat and eastern red bat and between eastern red bat and evening bat for consumption of coleopterans. Big brown bat consumed more coleopterans and eastern red bat consumed more lepidopterans. Significant differences also occurred between eastern red bat and evening bat for consumption of lepidopterans, with eastern red bat consuming more lepidopterans. Activity patterns significantly differed between bat species, specifically between big brown and eastern red bats and between big brown and evening bats. Big brown bat was most often captured at an average of 2.45 hours after sunset, evening bat at an average of 1.67, and eastern red at an average of 1.66 hours after sunset. Sample sizes for both hoary bat and northern myotis were too low to draw firm conclusions relative to prey in their diets. All bat species peaked in activity between 1 and 3 hours after sunset.

Keywords: bats, biodiversity, diet, *Eptesicus fuscus*, insects, Kansas, *Lasiurus borealis*, *Lasiurus cinereus*, *Myotis septentrionalis*, *Nycticeius humeralis*, *Perimyotis subflavus*

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PREFACE

This thesis is written in the style of the Journal of Mammalogy, to which a portion will be submitted for publication.

INTRODUCTION

Maintaining biodiversity is essential to sustaining functional ecosystems (Williams-Guillén et al. 2008), which can be valued in a variety of ways. Other than natural value, ecosystems can be given an economic value. Economically, nature can benefit humans through producing goods, offering intrinsic value, maintaining genetic diversity for future genetic use, and providing services essential to life (e.g., pollination or water purification) (Daily et al. 2000).

Bats are essential components in the elaborate framework of our ecosystems (Kunz et al. 2011). They provide stabilizing ecosystem services of pollination, seed dispersal, and crop pest reduction that are irreplaceable and invaluable (Bernard and Fenton 2002). Because of their different trophic levels, acting as both prey and predator, insectivorous bats could be used as indicator species of ecosystem health for both long- and short-term effects of multiple anthropogenic actions such as: climate change, deterioration of water quality, agricultural intensification, loss and fragmentation of forests, disease, and pesticide use (Jones et al. 2009). The order Chiroptera is diverse and widespread, with over 1,300 species described (Fenton and Simmons 2014). However, bat populations are facing serious declines around the world due to habitat loss (Agosta 2002) and disease (Frick et al. 2010). As bat populations decline, so do the benefits humans receive from their ecosystem services.

Insectivorous bats are of particular conservation interest because they are responsible for top-down maintenance of native and human-generated insect populations, which can damage both native habitat and crops (Kalka et al. 2008; Kunz et al. 2011). Pest insect species cause substantial damage to resources used by humans for food, fiber, and timber. Many of these pests are reduced by natural predators (Cleveland et al. 2006), including bats. Loss of natural pest control services could have important economic, environmental, and human health consequences (Daily 1997). For example, the Mexican free-tailed bat (*Tadarida brasiliensis*) is estimated to consume two-thirds of its body mass every night, with much of its diet consisting of arthropods that are considered pests (Kunz et al. 1995). The economic value of bat pest control in agricultural settings typically has two components: (1) the crop value that would have been lost in the absence of bats and (2) the avoided additional cost of pesticide use (Cleveland et al. 2006). Economic value of pest control by bats in agriculture and their pest control services in cotton crops alone is estimated conservatively at $3.7 billion per year in the United States (Boyles et al. 2011). Crop pests known to be consumed by bats include cucumber beetles (Coleoptera), June bugs (Coleoptera), corn earworm moths (Lepidoptera), cotton bollworm moths (Lepidoptera), tobacco budworm moths (Lepidoptera), and Jerusalem crickets (Orthoptera) (Whitaker 1995; Lee and McCracken 2005). These insects are agricultural pests on crops such as corn, cotton, and potatoes (Whitaker 1993; Cleveland et al. 2006).

To gain a better understanding of the role of bats in their environment, we can study the diet, activity, habitat use, species-specific echolocation calls, and morphology of bats. Because ecological interactions are exceedingly complex, ecomorphology, defined as "the study of relationships between morphology and ecological behavior", is often used as a proxy to study their interactions (Findley 1993). Trends indicate that "bats showing similar adaptations in wing morphology and foraging style revealed similar associations with structural forest parameters" (Jung et al. 2012). Feeding habitat for insectivorous bats might include, but is not limited to: riparian areas, swamp, forest, cropland, and ecotones between cropland and forest fragments (e.g., Fleming et al. 1972; Estrada and Coates-Estrada 2002). Larger bats, with greater wing loading, are less maneuverable and specialize in open habitat foraging (Brigham et al. 1997). Smaller, more maneuverable, bats forage and glean in areas with dense understory vegetation and closed canopies (Jung et al. 2012).

Differences in bat ecomorphology could lead to inter- and intraspecific partitioning of time and food resources. Morphology and echolocation call characteristics vary between bat species, and therefore, might be used to predict habitat use and foraging areas by species (Aldridge and Rautenbach 1987). Prey size consumed by each bat species also varies in relation to their ecomorphology (Aldridge and Rautenbach 1987). In arid environments, bat species use the same water sources, but at different times, which might facilitate their coexistence by using time as a resource (Adams and Thibault 2006).

Knowledge of interactions, activity, and diets of bats will inform conservation decisions. Results of my research should provide critical information for policy makers, managers, and the public to protect this unique group of animals, especially the now federally threatened *Myotis septentrionalis* (listed 2 April 2015), from further losses. In Kansas, there is a lack of data regarding activity patterns and resource use by bats. Only two studies have been conducted on bat diet in Kansas (Phillips 1966; Marquardt 2005). I studied the diets and temporal interactions of five species of insectivorous bats in Kansas: big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis),* hoary bat *(Lasiurus cinereus)*, northern myotis *(Myotis septentrionalis),* and evening bat *(Nycticeius humeralis)*. I hypothesized the diet of these bats varied within their activity patterns. My findings provide insight into ecology of Kansas bats.

MATERIALS AND METHODS

Study Sites

My research was conducted in seven counties in Kansas: Ellis, Linn, Miami, Phillips, Rooks, Russell, and Trego. Acoustic sampling took place in all seven counties and I successfully collected samples in three north-central counties: Ellis, Rooks, and Trego. Multiple locations were sampled from each county, all with different management strategies and different levels of human disturbance. My research was one of multiple projects attempting to collect data relative to northern myotis within the state of Kansas. Because this was the target species, all sampling focused on capturing the one species and my study used the bycatch to determine diet and activity patterns of bats.

Mist Netting

My project was approved by the Fort Hays State University Institutional Animal Care and Use Committee (protocol number 15-0002 Appendix 1). Mist netting occurred in April through October of 2015 and 2016, with acoustic data being collected during 2016.

In 2015 and 2016, mist nets were set at a total of 93 sites determined to be suitable habitat for the northern myotis. Suitable habitat was defined as being near limestone bluffs and the presence of trees and a water source, with flyways being an ideal component to aid in sampling to maximize captures. Flyways could be overhanging trees or tall river banks that create a corridor that guides bats into the mist nets when moving to a water source. The overall goal of the northern myotis project was to maximize captures by using standardized sampling within particular habitat characteristics.

I used 38mm mesh bat mist nets (Avinet) that were 6, 9, or 12 m long. Depending on the habitat structure of an individual site, I used either multiple single-high nets or a single triple-high net. My study encompassed 231 net hours across 139 nights of mist netting, with a net night being a single net or multiple nets stacked in a single location.

Bats were removed from the nets, time of capture was recorded, and bats subsequently were detained to collect additional data for each individual, including: species, age (juvenile or adult), sex, reproductive status (males: testes descended or non-descended; females: lactating, post-lactating, pregnant, or non-reproductive), mass (g), and lengths of the ear, tragus, hindfoot, forearm, body, and tail (mm). Age was determined by examining the phalangeal bones of the bats. I used level of ossification of the bones categorized them as either juveniles, if there was no epiphyseal-diaphyseal fusion, or adults, if there was epiphyseal-diaphyseal fusion (Brunet-Rossinni and Wilkinson 2009). Reproductive status for males and females was inspected visually; females also were palpated for pregnancy. Males were categorized as having descended or non-descended testes. If females had bare nipples, they were tested for lactation. If no milk was expressed, they were categorized as post-lactating. Non-pregnant females with nipples that were not bare were categorized as non-reproductive. Mass (g) was measured by using a 50 g Pesola spring scale. Body measurements (mm) were taken with a field ruler. In 2016, bats were marked by placing a 2.9 mm aluminum alloy lipped band from Porzana Ltd. (East Sussex, United Kingdom) with a unique identifier (FHSM0001-FHSM9999) on their right forearm.

During each night of mist netting, environmental data were collected. Records in 2015 included moon phase, humidity, percent cloud cover, time of sunset, wind speed at time of sunset (mph), and temperature (°F). In 2016, additional measurements were taken in every 30 minutes while mist nets were open by using a Kestrel 3000. Wind chill (°F), relative humidity (%), heat index (°F), and dew point (°F) were measured.

Sample Collection

Acoustic Sampling-- Song Meter SM3Bat acoustic detectors from Wildlife Acoustics with an omnidirectional SMM-U1 model microphone were used for acoustic sampling during the 2016 season. Kaleidoscope software version 3.4.0 was used to analyze acoustic data. Detectors were set near the net each time mist nets were set. Detectors were also used to aid in mist netting site selection. Because my study was part of a larger study focusing on northern myotis, if calls from the genus *Myotis* were not recorded at a site, netting would not take place at that site. Calls were used at the taxonomic level of genus for *Myotis* because acoustic detectors cannot reliably distinguish between *Myotis* calls, as they are very similar. Latitude and longitude (decimal degrees), accuracy of the GPS, GPS brand and model, start time, end time, and start and end dates were recorded for each sampling site.

Fecal Sample Collection--In 2015, captured bats were detained in individual cloth bags for a minimum of 30 minutes and a maximum of 3 hours. This time frame was based on food retention time, or how long it takes for food to pass through the digestive tract, of bats of similar body size (Roswag et al. 2012). In 2016, bats were detained in wax cups. After each bat was released, fecal pellets were removed from the container in which the bats were detained. In 2015, samples were stored in small plastic bags with a zip seal and frozen. All samples were transferred to vials containing 60% ethanol at a later date and remained frozen until analyzed. In 2016, fecal samples immediately were placed into vials containing 60% ethanol and frozen until analyzed.

Dietary Analyses

All fecal pellets collected were examined under a dissecting microscope to determine dietary components of the bats. I visually identified insect fragments within the fecal samples to order. I used dichotomous keys to aid in the identification of insect fragments (Sheil et al. 1997; Whitaker et al. 2009). The most common fragment types within the samples were tarsi, antennae, and wing membranes.

Each vial of pellets had only an identification number and season of capture written on its lid and vials were chosen at random to avoid any bias in content identification. After selection, the contents of the vials were emptied into disposable aluminum weigh dishes and fecal samples were dried in an oven for 2 hours at 100°C. Each dish was labelled with the identification number and season of capture of the individual bat. I collected and analyzed 458 fecal samples. Recaptures were treated as separate events, because no bat was caught twice in one night. As I went through each sample, I recorded the order and percent composition of the fragments within the sample. Percent composition was visually assessed.

Samples were also collected from *Perimyotis subflavus* at a single location in four visits to Russell County, Kansas during September and October of 2016. These samples were collected from bats roosting in a cave-like structure during the day between noon and 13:00. Because these samples did not have a corresponding activity pattern, they were not used in this study. Contents of these samples were variable and included five orders of insect (Table 1).

Statistical Analyses

Bat capture data were grouped by species, age, and sex for analyses to determine if there were differences between these groups. There were 17 different groups (Table 2). To compare diet and activity patterns between these groups, I conducted a multiple response permutation procedure (MRPP), a nonparametric multiple analysis of variance (MANOVA), because these groupings did not have normal distributions. MRPP detects if differences occur between and among groups, but does not detect where differences occur. To identify which variables differed, I used Kruskal-Wallis tests. If the Kruskal-Wallis produced significant results, it was followed by Tukey's Honest Significant Difference (Tukey's HSD) test to determine between which groups the differences occurred. Species, age, and sex were grouped to test against the other variables. These variables included capture time converted to hours after sunset (HASS) and proportions of dietary components: Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Orthoptera. Because the dietary components were recorded as proportions, I used Euclidean distance in the tests. All statistics were conducted in R version 3.3.1 and a significance level of 0.05 was used for all tests.

RESULTS

Dietary components and proportions of each varied for each bat species. Coleoptera were prey items of all bat species, being most common in evening bat and least common in hoary bat diets. Coleoptera were also the most common component in the diet of northern myotis (Fig. 1). The proportions of dipterans within the bat diets were highly variable, with two of the five species consuming none (Fig. 2). Hemipterans occurred in the diet of all five bat species with the highest proportion in the diet of the hoary bat (Fig. 3). Hymenoptera were a rare component of any bat's diet, but were most common in the diet of the evening bat(Fig. 4). Lepidopterans were common in the diet of all five bat species (Fig. 5). Orthoptera were consumed only by five individuals, four of which were the evening bat (Fig. 6). Mean proportions of dietary components differed for each bat species, with Coleoptera having the highest mean proportion for four of the five bat species (Table 3).

The grouped MRPP produced significant results (δ=0.3377, n=458, p=0.001), and produced significant results from the Kruskal-Wallis for Coleoptera (χ^2=35.275, df =17, p = 5.72^{-3}), Lepidoptera (χ^2=62.226, df =17, p = 4.49^{-7}), Diptera (χ^2=34.532, df =17, p = 7.16^{-3}), Orthoptera (χ^2=37.447, df =17, p = 2.93^{-3}), and HASS (χ^2=57.073, df =17, p = 3.17^{-6}). However, the Tukey's HSD tests that followed could not determine between which groups differences occurred for any variable except HASS, likely because groupings made sample sizes too low. HASS significantly differed between big brown bat adult females and evening bat adult females, big brown bat adult males and evening bat adult females, and big brown bat adult females and evening bat adult males (Table 4).

Because of low sample sizes, the species-age-sex groupings did not produce highly meaningful results, I separated species, age, and sex to run against diet and activity (HASS) variables. The majority of variables did not meet the normality assumption of MANOVA, so I again used MRPP to test for differences between and among groups. “Species” was the only variable that resulted in a significant difference (δ=0.3443, n=458, p=0.001).

When tested against species, Coleoptera (χ^2=19.56, df =4, p=7.67^{-4}), Lepidoptera (χ^2=37.304, df =4, p=1.56^{-7}), and HASS (χ^2=35.584, df =4, p=3.53^{-7}) produced significant results with the Kruskal-Wallis. The Tukey’s HSD on species and Coleoptera showed differences between big brown bat and eastern red bat and between eastern red bat and evening bat. The Tukey’s HSD on species and Lepidoptera showed a difference between eastern red and evening. The Tukey’s HSD showed differences between big brown bat and eastern red bat and between big brown bat and evening bat in their activity patterns (Table 5). Based on these results, I speculate that big brown bat consumed coleopterans most often, eastern red bat consumed lepidopterans most often, and evening bat acted as a generalist when it occurred with either big brown or eastern red bats.

DISCUSSION

I hypothesized that there would be a relationship between diet and activity patterns between species because each species possesses unique characteristics to allow for exploitation of resources that should reduce competition. Based on the results of my study, I reject my null hypothesis and retain my alternate hypothesis. This relationship between diet and activity was supported in the most commonly captured species. There was not an evident relationship between diet and activity patterns for all species. However, my analyses probably had low power because of smaller sample sizes for some species than others. If the sample size had been larger, relationships between diet and activity might have been apparent for more species.

A relationship between diet and activity patterns was clear when comparing big brown and eastern red and the coleopteran dietary component and HASS. Big brown bat is known to be a beetle strategist (Freeman 1981; Agosta 2002). According to the literature, eastern red bat consumes primarily lepidopterans (Whitaker 1972; Clare et al. 2009). Because big brown bat and eastern red bat were significantly different in their activity patterns (HASS) as well as the use of Coleoptera as a prey item, I suspect that they either partitioned their times of activity to avoid competition or were competitors in the past and the partitioning was a result of past competition. Unfortunately, past competition is a hypothesis that is difficult to demonstrate (Connell 1980).

Diet

Evening bat feeds on a variety of prey items (Feldhamer et al. 2009; Whitaker and Clem 1992), but consumes low numbers of Lepidopterans (Feldhamer et al. 2009), unlike eastern red bat (Whitaker 1972; Clare et al. 2009). This difference was supported by my results, so there could be consistency in diet at the level of order for these bat species in multiple states.

Groupings-- Although results of the MRPP and some of the Kruskal-Wallis tests were significant, the Tukey'sHSD was not able to determine where these differences occurred. As mentioned, this was likely because of small sample sizes. Some species (eastern red bat, hoary bat, and northern myotis) had low capture numbers and grouping them by species-age-sex reduced the sample size for each group. Because four dietary components had significant results (Table 6), I know that there were some differences in diet between these groups. I speculate that the differences occurred between the big brown, eastern red, and evening bats because these species had the largest sample sizes. To determine between which groups these differences occurred, a larger sample size would be needed.

Separated Variables--Big brown bat consumed more coleopterans than eastern red and evening bats, and eastern red bat consumed more lepidopterans than big brown and evening bats. At every site eastern red bat was captured, evening bat was also captured. However, not everywhere evening bat was captured was eastern red bat captured. As previously mentioned, big brown bat specializes on beetles and eastern red bat typically consumes moths. Evening bat seemed to be a generalist, so perhaps evening bat was able to use a different prey source if eastern red bat was monopolizing the moths where evening and eastern red bats occurred in the same community and foraged at the same time. This is supported in my data in that when eastern red bat and evening bat occurred together, evening bat generally consumed more coleopterans and hemipterans and eastern red bat usually consumed lepidopterans. From the dietary components, Hemiptera and Hymenoptera were marginally significant (χ^2=7.89, df =4, p=0.09, χ^2=8.88, df =4, p=0.06, respectively), meaning that with a larger sample size I might have been able to detect differences within these prey types between bat species.

Activity Patterns

Groupings-- The significant results obtained from the tests run on the groupings were differences in HASS between big brown bat and evening bat. There were differences between the sexes of these species also, with big brown bat females being captured in a narrower time frame than evening bat females, big brown bat males later in the evening than evening bat females, and big brown bat females earlier than evening bat males (Table 7). However, the differences were only between adults. Female Mexican free-tailed bat maternity colonies emerge earlier than males (Lee and McCracken 2001), possibly leading to different diets due to different insect emergence times. The difference between sexes in my study was seen in adults, possibly because my sampling periods included the maternity season and the subsequently altered activity times. This could potentially confound my data because sampling took place before, during, and after maternity season.

Separated Variables--Big brown bat and evening bat differed in their capture times, as did big brown and eastern red bats. Big brown bat was captured at a mean of 2.45 HASS, evening bat at a mean of 1.67, and eastern red bat at a mean of 1.66 HASS. The difference in HASS between big brown and evening bats and between big brown and eastern red bats could be because of different dietary components emerging at different times and bat specialization for particular prey types. The similar capture times and different prey items for eastern red and evening bats could support my hypothesis that evening bat was able to switch to a prey source other than moths if eastern red bat was monopolizing this resource. Further studies related to diet, foraging sites, and insect emergence patterns would be needed to be certain.

FUTURE RESEARCH

If I were to continue this research, there are some additions and changes I would make. First, I would be very interested to see if there are seasonal dietary changes at the individual level within the bat populations in Kansas. This would require multiple recaptures of individuals throughout the year. Second, I would want to make comparisons between age, sex, and reproductive status to see if there is any change in diet throughout life stages. I speculate that this is possible for nutritional purposes and might be supported by my results. This also would require recapture of individuals throughout the year. Third, I think concurrent studies of insect activity and foraging locations would be informative. This could potentially allow for bat dietary components to be identified to a lower taxonomic level and help to determine if diet is a cause or an effect of activity patterns. In addition, it would be interesting to study predators of bats and how they might affect emergence times of bats (Jones and Rydell 1994). Fourth, DNA/PCR techniques could be used to identify prey items (Clare et al. 2009). This technique is not yet reliable, but has the potential to be very beneficial for ecological studies such as mine. Fifth, my study could have benefitted from repeated sampling in the same locations to see if there was seasonal variation or variation between years of diet and activity patterns. There was some overlap in location between 2015 and 2016, but because this was one portion of a larger study and my study was based on bycatch, there was little repeatability between seasons. The addition of these components would help us achieve a better understanding of the observed bat diet and activity patterns of bats within the state of Kansas.

My results provide a foundation of knowledge regarding the bats of north-central Kansas which can be built upon in future studies. Each species captured had peak activity between 1 and 3 hours after sunset (Fig.7, Fig. 8). Future studies can use their time more efficiently if looking only for presence/absence of species at a location. Understanding that each species has unique dietary needs and activity patterns also can guide conservation decisions for this declining group of organisms. Each species would need a conservation plan based not only on habitat requirements for bats, but its prey and prey availability. Maintaining bat populations is essential if we are to retain the services they provide.

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TABLES

Table 1.-- Diet of *Perimyotis subflavus*. All individuals were captured during the day from a cave in north-central Kansas. Dates of capture ranged from 20 September 2016 to 9 October 2016.

Sex	ID	Coleoptera	Lepidoptera	Hemiptera	Diptera	Neuroptera	Total	Notes
F	0280II	60	0	0	0	40	100	
F	0289II	0	70	0	30	0	100	
F	0296II	40	0	60	0	0	100	
F	0305II	0	100	0	0	0	100	half sand half scales
F	0309II	0	100	0	0	0	100	80 percent sand
F	0317II	0	0	0	0	0	0	completely sand
M	0274II	45	25	30	0	0	100	
M	0277II	0	0	35	65	0	100	
M	0282II	100	0	0	0	0	100	
M	0284II	50	0	0	0	50	100	
M	0285II	0	0	0	0	100	100	
M	0293II	40	40	0	20	0	100	
M	0293IIRecap	0	0	85	15	0	100	
M	0308II	0	0	100	0	0	100	

Table 2.-- Bat sample sizes of grouped variables run with a Multi-response Permutation Procedure. Group code represented by species code followed by age and sex. All samples were collected from north-central Kansas during 2015 and 2016.

Group	**n**
EPFU/AD/F	30
EPFU/AD/M	26
EPFU/JUV/F	15
EPFU/JUV/M	7
LABO/AD/F	9
LABO/AD/M	2
LABO/JUV/F	5
LABO/JUV/M	2
LACI/AD/F	2
LACI/AD/M	1
LACI/JUV/F	2
LACI/JUV/M	1
MYSE/AD/M	7
NYHU/AD/F	210
NYHU/AD/M	9
NYHU/JUV/F	78
NYHU/JUV/M	52

*Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Age: AD = adult, JUV = juvenile

Sex: M = male, F = female

Table 3.-- Mean proportions of dietary components for each bat species from north-central Kansas during 2015 and 2016 rounded to the nearest hundredth. Species are listed by scientific name and sample sizes (n) represent the number of each bat species whose diet was analyzed. Standard deviation is from the overall mean of each dietary component.

	n	Coleoptera	Diptera	Hemiptera	Hymenoptera	Lepidoptera	Orthoptera
Eptesicus fuscus	78	0.64	0.01	0.21	0.01	0.12	0
Lasiurus borealis	19	0.36	0.1	0.17	0	0.36	0.01
Lasiurus cinereus	6	0.25	0	0.41	0	0.29	0
Myotis septentrionalis	7	0.42	0	0.21	0	0.37	0
Nycticeius humeralis	348	0.59	0.03	0.29	0.01	0.07	0.01
Standard Deviation	458	0.3179	0.095	0.3	0.0752	0.1987	0.056

Table 4.-- Significant differences in activity patterns of bats from north-central Kansas during 2015 and 2016 from Tukey's HSD from capture time converted to hours after sunset. Categories are grouped by common name of bat followed by age (adult or juvenile) and sex (male or female).

Group Comparison	**Observed Difference**	**Critical Difference**
BIG BROWN/AD/F : EVENING/AD/F	101.502381	92.82184
BIG BROWN/AD/M : EVENING/AD/F	129.160073	98.87227
BIG BROWN/AD/M : EVENING/AD/M	196.891026	183.92507

Table 5.-- Tukey's HSD results with significant differences between bat species from north-central Kansas during 2015 and 2016 for dietary components and capture times converted to hours after sunset (HASS) to represent activity patterns..

Species Comparison	BIG BROWN-EASTERN RED	EASTERN RED-EVENING	EASTERN RED-EVENING	BIG BROWN-EASTERN RED	BIG BROWN-EVENING
Variable	Coleoptera	Coleoptera	Lepidoptera	HASS	HASS
Observed Difference	114.53779	94.68776	115.877949	96.5161943	98.0268568
Critical Difference	95.05126	87.53116	87.53116	95.05126	46.54403

Table 6.-- Significant results from Kruskal-Wallis on dietary groupings for bats from north-central Kansas during 2015 and 2016

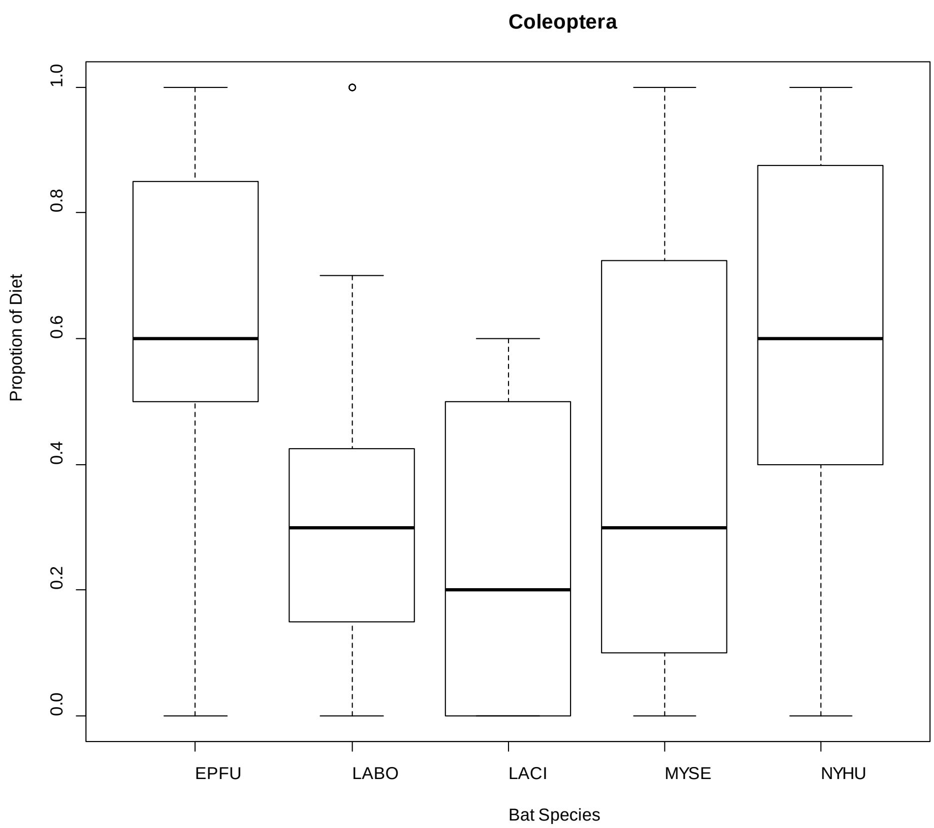
Dietary Component	**χ2**	**df**	**p-value**
Coleoptera	35.275	17	5.7 $^{-3}$
Lepidoptera	62.226	17	4.49 $^{-7}$
Diptera	34.532	17	7.16 $^{-3}$
Orthoptera	37.447	17	2.93 $^{-3}$

Table 7. Capture times converted to hours after sunset of adult bats in north-central Kansas during 2015 and 2016. These groupings showed significant differences in activity patterns converted to hours after sunset (HASS).

HASS	Big brown female	Big brown male	Evening female	Evening male
0-0.99	2	2	45	3
1-1.99	14	7	113	6
2-2.99	8	5	35	0
3-3.99	5	10	8	0
4-4.99	1	1	5	0
5-5.99	0	1	1	0
Total	30	26	207	9

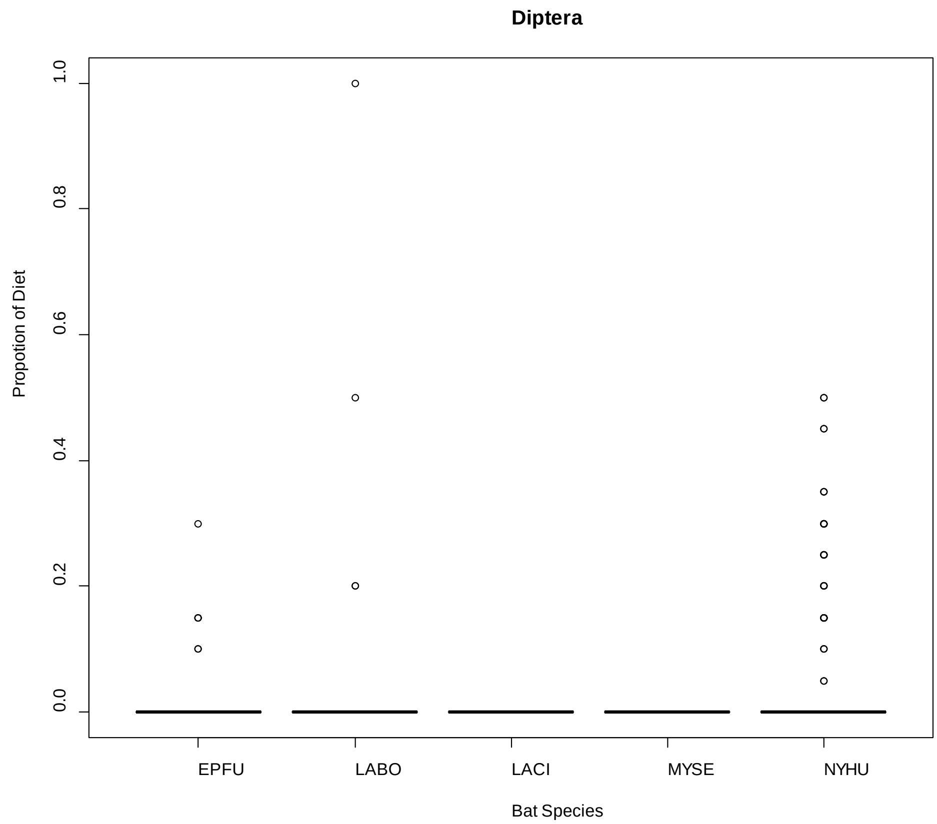
FIGURES

Fig 1.--Proportion of Coleoptera within the diet of each bat species from north-central Kansas during 2015 and 2016.



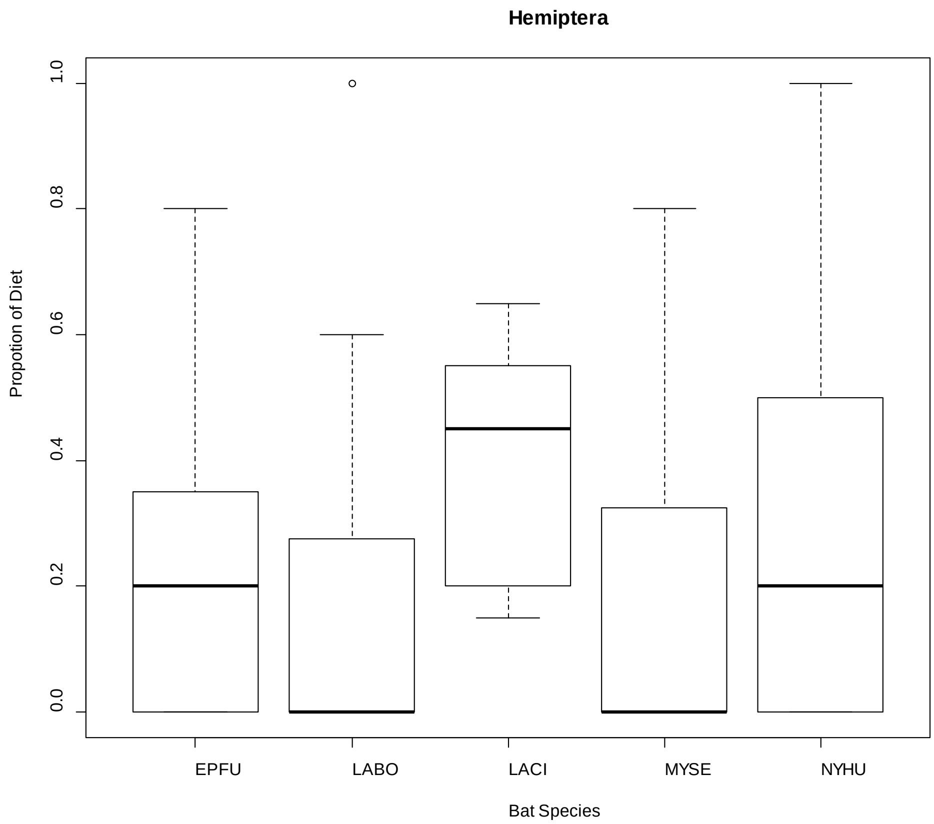
*Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Fig 2.--Proportion of Diptera within the diet of each bat species from north-central Kansas during 2015 and 2016.



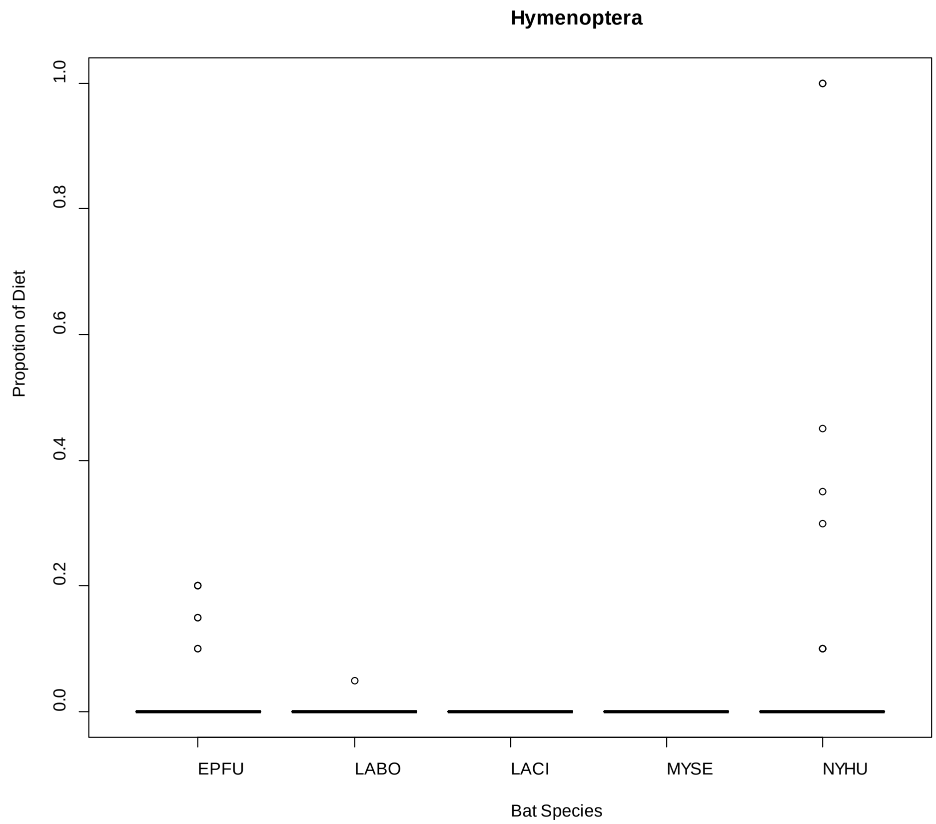
* Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Fig 3.--Proportion of Hemiptera within the diet of each bat species from north-central Kansas during 2015 and 2016.



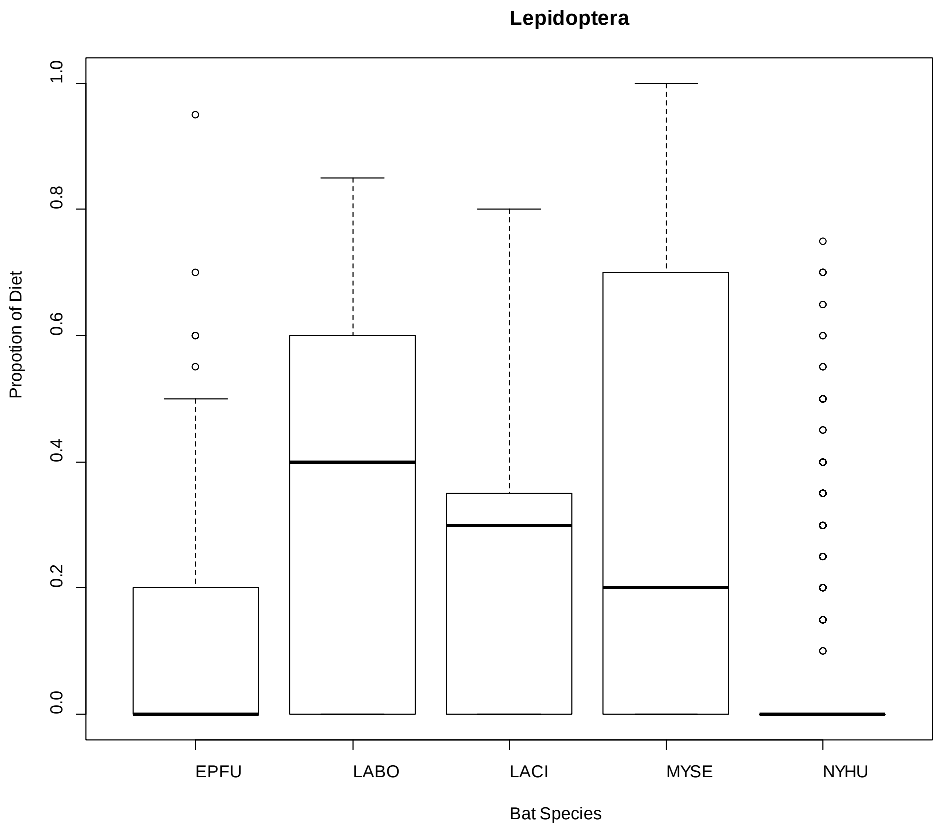
* Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Fig 4.--Proportion of Hymenoptera within the diet of each bat species from north-central Kansas during 2015 and 2016.



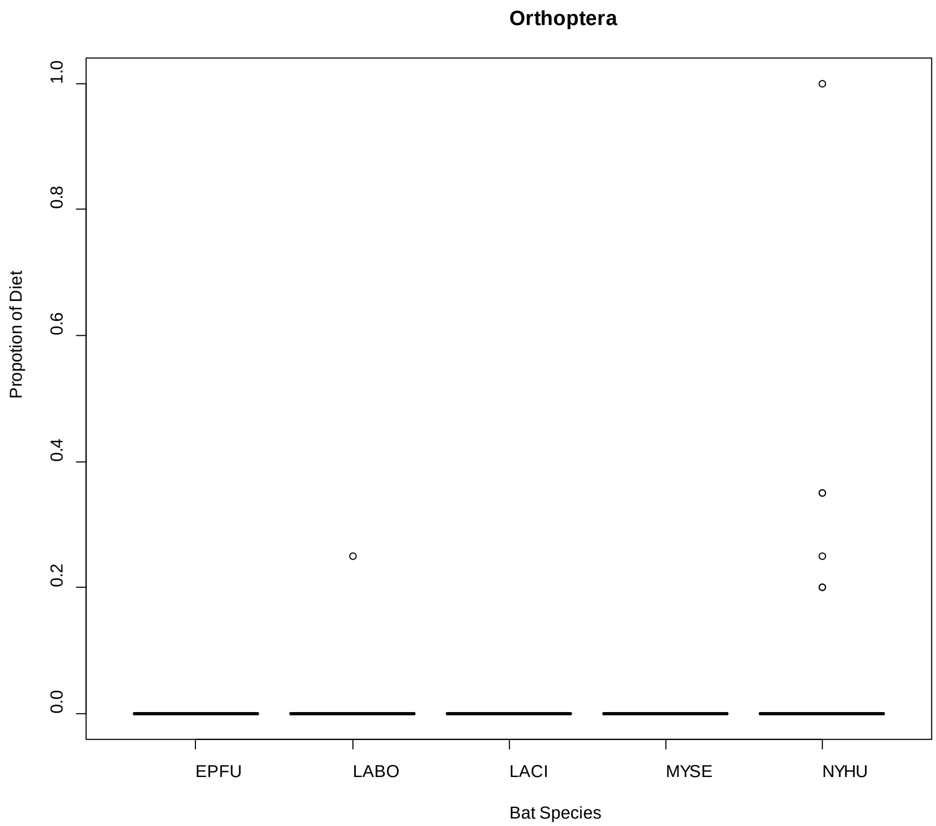
* Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Fig 5.--Proportion of Lepidoptera within the diet of each bat species from north-central Kansas during 2015 and 2016.



* Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Fig 6.--Proportion of Orthoptera within the diet of each bat species from north-central Kansas during 2015 and 2016.



* Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

Fig 7.-- All bat capture times from 2015 and 2016 combined and converted to hours after sunset. Bats were captured in north-central Kansas from April through October of both years. This graph represents frequency of captures in 30 minute increments.

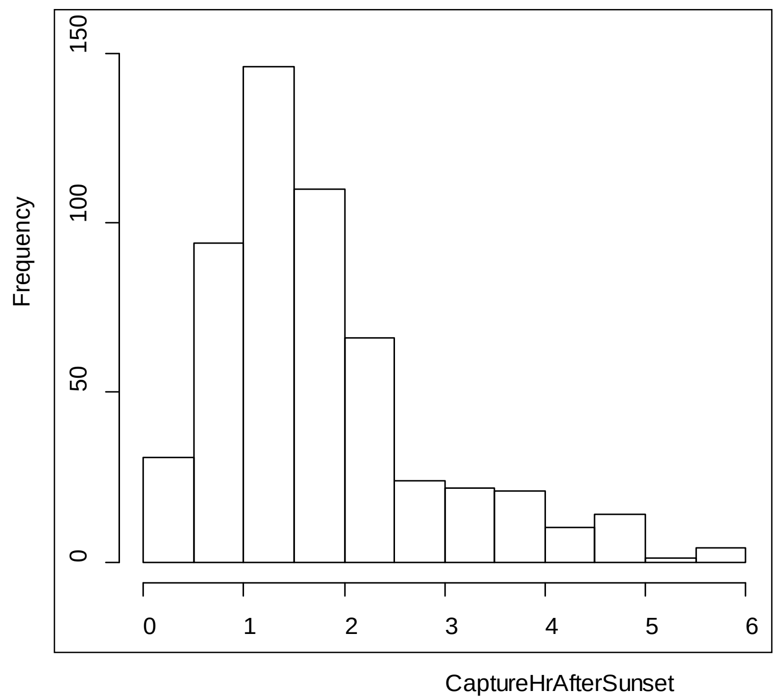
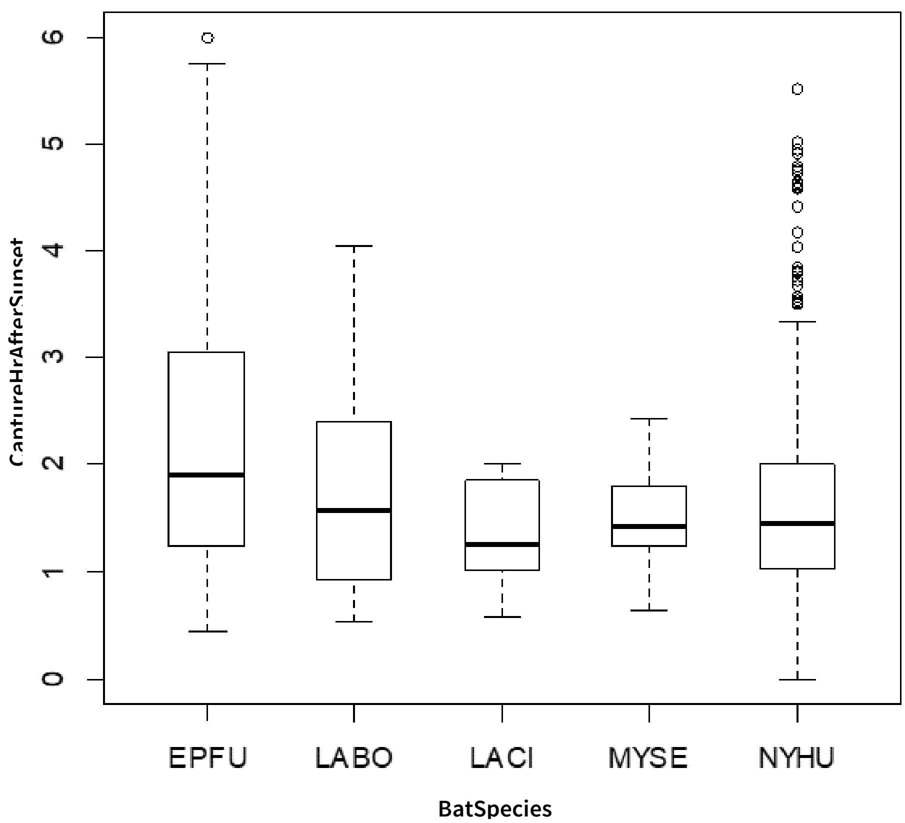


Fig 8.-- Capture times of bats from north-central Kansas from April through October of 2015 and 2016 separated by species. All bat species, represented by species codes, peaked in capture times at water sources between one and three hours after sunset.



* Species Codes: EPFU = big brown, LABO = eastern red, LACI = hoary, MYSE = northern myotis, NYHU = evening

APPENDIX

Appendix 1.--Institutional Care and Use Committee approval.

FORT HAYS STATE UNIVERSITY
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GRADUATE SCHOOL

Institutional Animal Care and Use Committee

To: Elmer Finck

From: Y. Kobayashi, Institutional Animal Use and Care Committee Chair Y. K.

Re: IACUC protocol (15-0002) titled: titled *Roost site characterization and distribution of the Northern Long-eared bat (Myotis septentrionalis) in Kansas.*

January 9, 2015

The Institutional Animal Care and Use Committee administrator has reviewed your revised IACUC protocol application titled titled *Roost site characterization and distribution of the Northern Long-eared bat (Myotis septentrionalis) in Kansas,* and determined it to be:

In compliance with all USDA and PHS regulations and requirements and approved

This approval is for the number and species of animals you listed in the protocol. Your approval will be in effect until January 8, 2018.

Please note that the IACUC is required to review and approve, prior to initiation, proposed modifications to an approved protocol.

All approved research protocols must be updated annually, and must be reviewed by the IACUC every three years. All teaching activities using vertebrate animals are reviewed annually.

IACUC approved activities may be subject to further review and approval by university officials; however, those officials may not approve an activity involving the care and use of animals if it has not been approved by the IACUC.

The Principal Investigator is responsible for following federal guidelines and university policies and procedures regarding the care and use of animals.

Please feel free to contact me if there are any questions or concerns regarding the committee's decision on your IACUC protocol.

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