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A Dietary Study of big brown (Eptesicus fuscus) and northern bats (Myotis septentrionalis) in Western Kentucky

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A Dietary Study of big brown (*Eptesicus fuscus*) and northern bats (*Myotis septentrionalis*) in Western Kentucky

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DEDICATION

This thesis is dedicated to my mother and sisters
for their unwavering support.

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For his patience and valued advice during my graduate career, I would like to thank Dr. Charles Elliott, my graduate committee chairman, without whom I would not have been able to complete my thesis. I would like to thank Dr. Sherry Harrel and Dr. Paul Cupp, the other members of my committee, as well, for their brilliant instructions and mentoring. A special thanks to Dr. Guenter Shuster for enduring many questions concerning insects. A thank you to the biologists of Copperhead Environmental Consulting for providing samples to my study and giving me terrific field experience. Thank you, as well, to Dr. J. O. Whitaker for performing the physical analysis on my samples, as well as for the personal time given to answer questions about his physical analysis process. A special thanks to my family, friends and coworkers who have ever asked 'Have you finished your thesis yet?' Financial support for this study was provided through a graduate student research grant from the Kentucky Society of Natural History.

ABSTRACT

Knowledge is lacking regarding the dietary habits of northern (*Myotis septentrionalis*) and big brown bats (*Eptesicus fuscus*) in Kentucky. The objective of this study was to determine the prey items consumed by both species at three sites in western Kentucky. Totals of 103 fecal pellet samples from northern bats and 36 fecal pellet samples from big brown bats were collected in 2003 and 2004. Overall prey items found within the samples collected for both species indicated their diets were similar (Sorensen's coefficient; S_s= 0.72); with the most common insect orders being Coleoptera, Lepidoptera, and Hemiptera. Big brown bats consumed a significantly greater amount of the *Chinavia hilaris*, a member of the Hemiptera order, ($P < 0.05$; $z = 8.29$) than did northern bats (35.7 % to 0 %). Northern bats consumed a greater amount of lepidopterans ($z = -6.04$) than did big brown bats (27.1 % to 0.2 %). Adult male ($n = 34$) and adult female ($n = 40$) northern bats consumed similar prey items (S_s= 0.85). Adult male diets of northern ($n = 34$) and big brown bats ($n = 8$), were dissimilar in prey items consumed ($S_s = 0.56$). Adult male northern bats consumed a significantly greater amount of lepidopterans ($z = -3.07$) than did their big brown bat counterparts (27.5 % to 0 %). Adult female diets among northern ($n = 40$) and big brown bats ($n = 5$) had very little similarity in prey items consumed ($S_s = 0.43$). Big brown bat adult females consumed a significantly greater amount of *Chinavia hilaris* (order Hemiptera; $z = 3.61$) than did adult northern bats (0 to 19 %). Northern bat adult females consumed a significantly greater amount of lepidopterans ($z = -2.53$) than did adult female big brown bats (30.6 % to 0.3 %). In general, big brown bats appear to be a "beetle

strategist", typically feeding mainly on hard-bodied insects, particularly beetles (Coleoptera) and true bugs (Hemiptera); while northern bats tend to consume mostly soft-bodied insects like moths (Lepidoptera).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER 1

INTRODUCTION

Insectivorous bats exist within the taxonomic suborder Microchiroptera, feed on a wide variety of insects as well as arthropods (Jones and Rydell 2003), and serve as environmental indicators (Hutson et al. 2001). They depend on a certain combination of environmental factors (both biotic and abiotic) to survive, such as healthy water bodies (lakes, rivers, streams, etc.), mature and dead trees, and natural structures (caves; Hutson et al. 2001). They are also considered to be both ecologically and economically important, consuming many insect pests that may negatively affect agriculture, defoliate trees, or spread infectious diseases (Hutson et al. 2001).

Insectivorous bats have been described as sometimes generalists, hunting and feeding on whatever prey are available (Belwood and Fenton 1976). Whitaker (1994) determined that all insects with the capability of flight "…within cruising distance of the bats' roost…" are potentially available as prey. Within the insectivores, different species of bats are known to use various capture methods, such as aerial hawking (capturing prey "on the wing"), gleaning (taking prey off of the ground or from foliage), and perch hunting (Jones and Rydell 2003). Unlike the big brown bat (*Eptesicus fuscus*) which only employs the aerial hawking method, the northern bat (*Myotis septentrionalis*) has been known to both glean and aerial hawk (Dawson and Ratcliffe 2003), which has the potential to substantially increase the number of species available for consumption.

Understanding the food habits of bats may be one of the most important aspects of bat ecology. It can provide information on population ecology, foraging ecology, home range size and location, nutritional needs, and potential causes of population declines (Kurta and Whitaker 1998). The analysis of dietary data from several species may help determine resource partitioning (Carter et al. 2003, Whitaker 2004) and provide an indirect predictor of how human activity, e.g., logging, mining, agriculture, and urban development, might impact a bat population.

<u>Northern bats</u>

Northern bats (also called Northern Long-eared Bats; *Myotis septentrionalis*) are found mostly in the central and eastern parts of Canada and the midwestern and eastern parts the United States, and are commonly found in all but the western edge of their range (Caceres and Barclay 2000). They have round-tipped long ears with a long, sharp tragus (Myers et al. 2012), as well as a narrow skull and a long rostrum (Caceres and Barclay 2000). Northern bats are approximately 7 to 8 cm in length with a wing span of 23 to 26 cm (Myers et al. 2012); they have a low aspect ratio [Norberg and Rayner 1987; aspect ratio is the length of the wingspan squared divided by the surface area of the wing (Aldridge and Rautenbach 1987; Arita and Fenton 1997; *in* Lacki et al. 2007)] with a moderate wing loading [Norberg and Rayner 1987; wing loading is the mass of the bat divided by its total wing area (Aldridge and Ratenbach 1987; Chruszcz and Barclay 2003; Fenton 1990; Fenton and Bell 1979; Patriquin and Barclay 2003; Saunders and Barclay 1992 *in* Lacki et al. 2007)]. When aspect ratio and wing loading are considered together, flight and habitat use in insectivorous bats can be assessed (Aldridge and Ratenbach 1987; Chruszcz and Barclay 2003; Fenton 1990; Fenton and Bell 1979; Patriquin and Barclay 2003; Saunders and Barclay 1992 *in* Lacki et al. 2007). Northern have a larger wing area and lengthier tail than other equally-sized aerial hawking *Myotis* species which are associated with gleaning (Caceres and Barclay 2000) and are known to forage within intact forests and forest edges (Barclay 1991; Hogberg et al. 2002; Menzel et al. 2002; Nagorson and Brigham 1995; Owen et al. 2004; Patriquin and Barclay 2003; Waldien and Hayes 2001 *in* Lacki et al. 2007).

Northern bats are gleaners, capturing prey directly from the surface of objects, and using echolocation to capture flying moths (Faure et al. 1993, Feldhamer et al. 2009). They may also employ aerial hawking to capture prey (Radcliffe and Dawson 2003). Whitaker (1972) examined the stomach contents of two northern bats from Indiana and reported a preponderance of Reduviidae in one individual (60% by volume; plus 10% Cicadellidae and 30% Ichneumonidae) and mainly Lepidoptera (70%, and 30% Diptera) in the other specimen. The stomach of a male northern bat collected in Indiana contained (by volume) 35% Araneae, 60% adult Lepidoptera, and 5% Diptera (Whitaker and Rissler 1993).

Based on fecal and stomach content analyses, northern bats from four different localities in Missouri and Indiana fed primarily on Lepidoptera (10.4-94.0% of the volume) and to a lesser extent on Coleoptera (0.4-64.0%), Trichoptera (0.0-54.5%), and Diptera (0.0-15.3%; Brack and Whitaker 2001). In a long term study examining the prey selection of 8 species of bats in Indiana captured in the same river floodplain, Whitaker (2004) reported that dipterans were the most abundant (37.5% by volume; 33.7% unidentified, 3.5% Culicidae, <1% Chironomidae) prey item consumed by northern bats. Other major prey consumed included Coleoptera (24.5%; 10.8% Scarabaeidae, 10.1% unidentified, 1.6% Curculionidae, 1.3% *Diabrotica*, <1% Carabidae), Lepidoptera (20.7%), Homoptera (3.9%; Cicadellidae 3.9%, <1% Delphacidae), Hemiptera (3.1%; 2.5% unidentified, <1% Lygaeidae), Hymenoptera (1.2% Ichneumonidae), Trichoptera (2.5% unidentified), Neuroptera (3.9% Hemerobiidae), Araneae (2.0% unidentified), and Ephemeroptera (<1% unidentified).

Burke (2002) examined fecal pellets obtained from northern bats (n=38) captured in the Allegheny Plateau, Allegheny Mountain, and Ridge and Valley physiographical provinces of West Virginia and reported consumption of (excluding unidentified) Lepidoptera (49% by volume), Coleoptera (34%; 6% of which were Scarabaeidae), Diptera (12%; of which 10% and <1% were Tipulidae and Culicidae, respectively), and <1% of Araneae, Homoptera (Cicadellidae), Hymenoptera, and Isoptera. Carter et al. (2003) also collected bats from West Virginia's Allegheny Plateau and Ridge and Valley provinces and reported northern bats primarily consumed Coleoptera (42.3% by volume), Lepidoptera (31.1%), and Diptera (11.5%); with

Trichoptera, Hymenoptera, Homoptera, Hemiptera, and Neuroptera being identified in the diet to a lesser extent, i.e., 6.2%, 5.2%, 2.0%, 1.4%, and <1%, respectively.

Griffith and Gates (1985) investigated the diets of four species of cave-dwelling bats collected in the central Appalachian Mountains of western Maryland. One of the species examined was once understood to be Keen's bat (*Myotis keenii*), but has since been determined to be northern bat. The Keen's and northern bats do not occupy overlapping ranges; therefore any reference to Keen's bat occurring outside of the Pacific Northwest of North America refers to northern bats (Caceres and Barclay 2000). Northern bats (n=42) in Griffith and Gates (1985) study mainly consumed Lepidoptera (95.2% unidentified by occurrence), Coleoptera (78.6%; 66.7% unidentified, 7.1% Scarabaeidae, 4.8% Curculionidae), Neuroptera (54.8%; 12.4% unidentified, 42.4% Hemerobiidae), and Diptera (38.1%; 26.2% unidentified, 4.8% Brachycera/Cyclorrhapha, 2.3% Chironomidae, 4.8% Tipulidae). Insect orders appearing in <12% of the sample were Hymenoptera (11.9%; 9.5% unidentified, 2.4% Braconidae), Homoptera (9.5%; 7.1% Cercopidae, 2.4% Eriosomatidae), Psocoptera (7.1% Psocidae), and Hemiptera (2.4% unidentified).

Feldhamer et al. (2009) assessed the diet of northern bats captured at forested sites throughout southern Illinois. Northern bats consumed mainly Lepidoptera (31.8% by volume), Trichoptera (21.8%), and Araneae (15.6%). Other dietary items included Coleoptera (19.3%; 12.9 unidentified, 2.9% Scarabaeidae, 2.1% Chrysomelidae, 0.8% Carabidae, 0.6% Curculionidae), Diptera (7.9%), Hemiptera (1.9%), Hymenoptera (0.1% Ichneumonidae), Orthoptera (0.2%).

Lacki et al. (2009) determined the food habits of northern bats in the Cumberland Plateau physiographic region of eastern Kentucky. Fecal pellets were collected from bats foraging in areas before (n=6) and after (n=8) prescribed fire. Lepidoptera (62.6%, by volume, preburn vs. 46.4% postburn), Coleoptera (27.8% vs. 35.5%), and Diptera (1.4% vs. 11.0%) were the three most important groups of insect prey, with consumption of dipterans increasing after burning. Other items identified in the diet included Hemiptera (6.1% vs. 5.6%), Hymenoptera (1.4% vs. 0%), Neuroptera (0% vs. 0.2%), and Trichoptera (0.4% vs. 0.2%).

Big brown bats

Big brown bats (*Eptesicus fuscus*) are found throughout most of North and Central America (Kurta and Baker 1990). The species is one of the most common bats in the United States; typically roosting in human dwellings (Barbour and Davis 1969, Agosta 2002). They have a round-tipped ear with a broad tragus (Myers et al. 2012). They are approximately 11 to 13 cm in length with a wing span of around 33 cm (Myers et al. 2012), and have a moderate aspect ratio with low wing loading (Norberg and Rayner 1987 *in* Lacki et al. 2007). Big brown bats are also known to have a keeled calcar and a tail that extends beyond the wing membrane (Kurta and Baker 1990). They have a large, robust skull with heavy, sharp teeth (Myers et al. 2012). Some larger bats are faster than, but not as maneuverable as, smaller bats; which may be why larger bats tend to forage in open, uncluttered habitats; big brown bats forage in riparian forests and forest gaps (Barclay 1991; Hogberg et al. 2002; Menzel et al. 2002; Nagorson and Brigham 1995; Owen et al. 2004; Patriquin and Barclay 2003; Waldien and Hayes 2001 *in* Lacki et al. 2007).

Whitaker (1972) identified food items in the stomachs of 184 big brown bats collected over a 9 year period and discovered a predominance of beetles in the diet. Among the coleopterans (43% by volume), the diet was composed mainly of Carabidae (14.6%), Scarabaeidae (12.4%), and Chrysomelidae (11.5%). Other diet items included Hymenoptera [14%; mainly Formicidae (8.5%) and Ichneumonidae (5.0%)], Hemiptera [10.2%; mainly (9.5%) Pentatomidae], Homoptera [6.7%; mostly Cicadellidae (4.4%) and Reduviidae (1.8%)], Lepidoptera (4.5%), Orthoptera (3.0% Gryllidae), Diptera (2.9%), Trichoptera (1.4%), Hymenoptera (0.5%), and Neuroptera (0.5%).

Griffith and Gates (1985) documented the diet of big brown bats collected in the central Appalachian Mountains of western Maryland. Big brown bats (n=21) consumed Coleoptera (90.5% by occurrence; 76.2% unidentified, 9.5% Curculionidae, 4.8% Scarabaeidae), Hemiptera (71.4% Pentatomidae), Lepidoptera (38.1%), Homoptera (23.8% Cercopidae), and Neuroptera (4.8% Corydalidae).

Whitaker (1995) used guano samples to determine the feeding habits of big brown bats from maternity colonies in Indiana and Illinois. Coleopterans accounted for

73% (by volume) of the overall mean diet [29.6% Scarabaeidae, 28.3% Chrysomelidae (mainly, 28.2%, *Diabrotica*), 10.5% Carabidae, 3.6% unidentified, 1.6% Curculionidae, 0.3% Dytiscidae]. Other items identified in the diet included 9.1% Hemiptera (8.1% Pentatomidae, 0.6% Lygaeidae, 0.4% Miridae), 4.4% Homoptera (4.2% Cicadellidae), 2.1% Diptera (1.1% unidentified, 0.9% Chironomidae, 0.1% Tipulidae), 2.4% Hymenoptera (2.2% Ichneumonidae, 0.2% Formicidae), 1.6% Neuroptera (Hemerobiidae), 4.0% Lepidoptera, and 2.5% Trichoptera.

Burke (2002) examined fecal pellets obtained from big brown bats (n=19) captured in the Allegheny Plateau, Allegheny Mountain, and Ridge and Valley physiographical provinces of West Virginia and reported they consumed mainly Coleoptera (60.8% by volume; 25.3% unidentified, 24.5% Chrysomelidae, 5.5% Scarabaeidae, 5.5% Carabidae) and Hemiptera (29.7% Pentatomidae); along with Lepidoptera (1.6%), Diptera (1.6% Tipulidae), Trichoptera (0.8%), Homoptera (0.8% Cicadellidae), and Acarina (0.3%). Carter et al. (2003) also examined pellets from big brown bats collected in West Virginia's Allegheny Plateau and Ridge and Valley provinces and reported big brown bats mainly consumed Coleoptera (67.5% by volume) and Hemiptera (16.2%). Other prey items consumed included Lepidoptera (5.5%), Homoptera (0.3%), Diptera (1.6%), Hymenoptera (7.5%), and Trichoptera (1.3%).

Agosta and Morton (2003) used fecal analysis to describe the diet of big brown bats from locations in Pennsylvania and western Maryland. Diets were reported individually for the three study sites. Beetles were the major item identified at each study site; comprising 57.5% to 82.4% (percent volume) of the diet. Items identified in the beetle category included Scarabaeidae, Carabidae, Elateridae, and Curculionidae. Other dietary items included Hemiptera (5.6%-19.4%), Orthoptera (0-17.1%), Hymenoptera (2.1%-7.3%, mostly Ichneumonidae and Formicidae), Diptera (3.2%-6.1%, mainly Tipulidae), Neuroptera (0.5%-1.0%, mainly Hemerobiidae), Lepidoptera (3.1%-10.2%), and 'other insects' (<0.1%-2.6%, consisting of Trichoptera, Homoptera, and Plecoptera).

In a long term study examining the prey selection of 8 species of bats from the same location in Indiana, Whitaker (2004) reported big brown bats fed heavily on coleopterans. Beetles accounted for 84.2% (by volume; 12.3% unidentified, 29.6% *Diabrotica*, 21.8% Carabidae, 19.7% Scarabaeidae, 0.5% Curculionidae, 0.3% Dytiscidae) of the diet. Other prey consumed by big brown bats included Homoptera (2.0% Cicadellidae, 0.1% Cercopidae), Hemiptera (6.5% Pentatomidae, 0.2% Lygaeidae, 0.3% Coreidae), Hymenoptera (2.0% Ichneumonidae), Lepidoptera (1.7%), Diptera (0.5% unidentified, 0.2% Tipulidae), Trichoptera (0.2%), Neuroptera (2.0% Hemerobiidae), and Orthoptera (0.1% Gryllidae).

Over half (57.7% by volume) of the overall diet of a colony of big brown bats in Georgia was found to consist of beetles [36.9% Scarabaeidae, 12.1% Carabidae, 5.2% unidentified, 2.9% Curculionidae, 0.4% Chrysomelidae, 0.2% Dytiscidae; Whitaker and

Barnard (2005)]. Additional items identified in the diet included 10.7% Hymenoptera (10% Formicidae, 0.6% Ichneumonidae, 0.1% unidentified), 10.5% Diptera (7.9% Chironomidae, 2.2% unidentified, 0.4% Tipulidae), 8.8% Homoptera (6.4% Cicadellidae, 2.4% Cercopidae), 5.0% Hemiptera (2.0% Pentatomidae, 1.7% Lygaeidae, 0.7% unidentified, 0.5% Thyreocoridae, 0.1% Miridae), 2.8% Lepidoptera, 2.4% Trichoptera, 1.1% Orthoptera (0.8% Gryllidae, 0.3% Blattidae), 0.3% Plecoptera, 0.1% Neuroptera (Hemerobiidae), and 0.1% Ephemeridae.

Feldhamer et al. (2009) collected data on the diet of big brown bats mist netted at 41 forested sites throughout southern Illinois. Big brown bats consumed mainly Coleoptera (71.6% by volume; 41.7% Carabidae, 16.2% Dytiscidae, 8.5% Scarabaeidae, 3.3% Elateridae, 1.9% Curculionidae). Other dietary items included Hemiptera (17.1%; 16.1% Pentatomidae, 1.0% Coreidae), Trichoptera (3.3%), Homoptera (2.1% Diaspididae), Hymenoptera (4.6% Ichneumonidae), Neuroptera (0.1% Hemerobiidae), and Diptera (0.5%)

Regarding the food habits of northern bats and big brown bats in Kentucky, information is largely insufficient. Only one study, to my knowledge, presents dietary information for northern bats living in Kentucky (Lacki et al. 2009), and there are no published accounts documenting the diet of big brown bats in the state. The objective of this study was to determine the prey items consumed by both species in western Kentucky.

CHAPTER 2

STUDY AREA and METHODS

The study encompassed areas within the Crawford-Mammoth Cave Uplands and Outer Bluegrass Interior Plateaus ecoregions of Kentucky (Woods et al. 2002). The Interior Plateau consists of broad plains broken up by separated uplands, knobs, "a few deeply incised master streams," and zones of karst (Woods et al. 2002). Vegetation within the study regions consists of mainly oak (*Quercus*) and hickory (*Carya*) species which comprise a western mesophytic forest [see Jones (2005) for more detailed vegetation descriptions].

In 2003 and 2004, big brown and northern bats were captured in Christian (Bob Overton Cave), Bullitt (Burnheim Forest) and Edmonson (Mammoth Cave) counties, KY, (Figure 1) using mist nets. Mist netting procedures followed guidelines established by the U.S. Fish and Wildlife Service (USFWS 1999). General field protocol called for each bat captured to be identified to species, aged, sexed, weighed, forearm length determined, and placed in a cloth bag until released. Age was determined based on the condition of the epiphyseal growth plate (Lacki and Schwierjohann 2001). Following release, the cloth bag was examined for fecal pellets. If present, pellets were collected and stored in paper envelopes, ultimately drying them. Pellet samples were sent to Dr. J.O. Whitaker at Indiana State University for analysis. The pellet analysis procedure

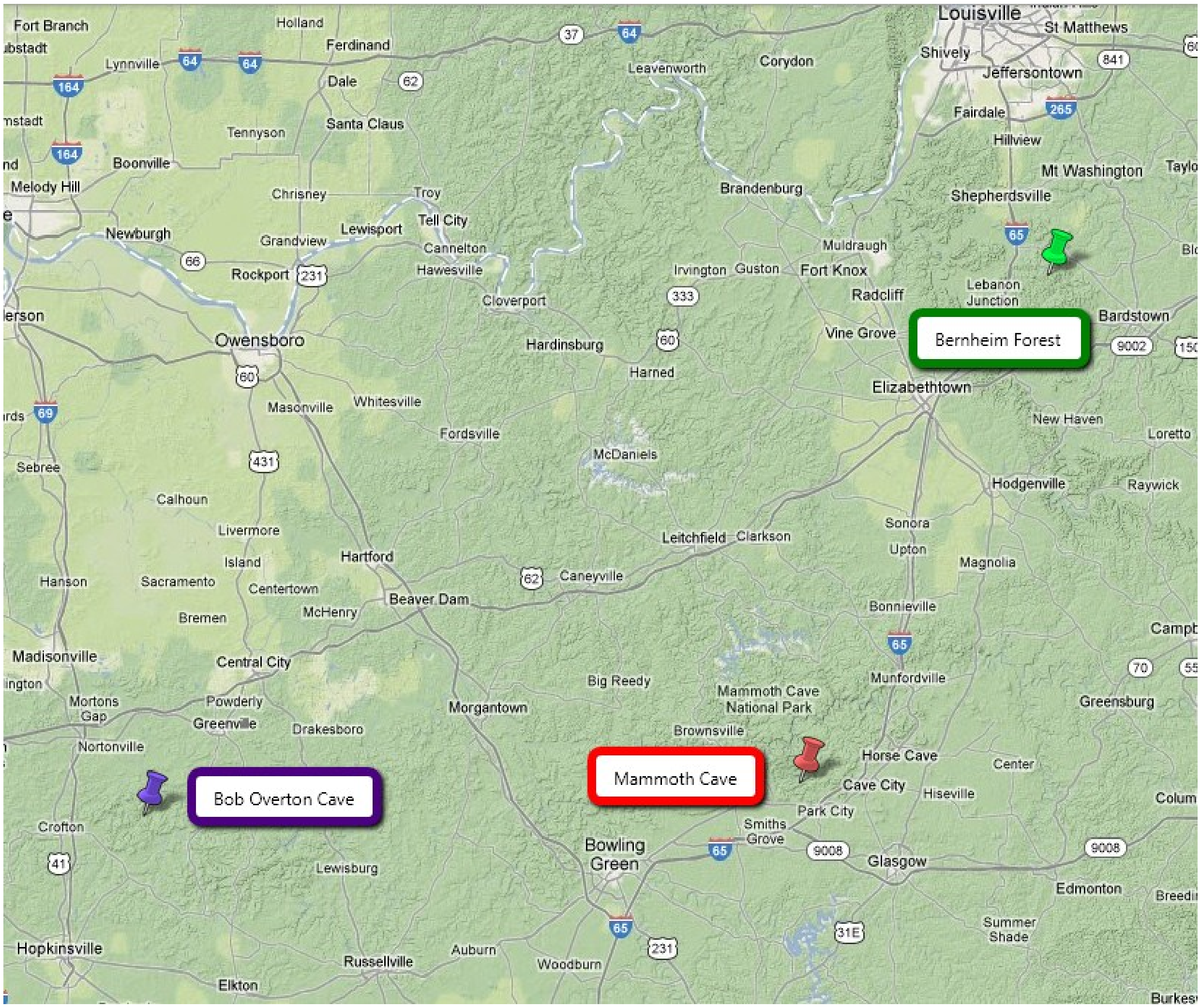

Figure 1: Big brown bats (*Eptesicus fuscus*) and Northern bats (*Myotis septentrionalis*) were captured in Bob Overton Cave, Mammoth Cave, and Burnheim Forest in western Kentucky. Source: http://maps.google.com/maps/ms?msid=211135757924683248504.0004bd46e1e5e7bb9a627&msa=0

involved combining all pellets in an envelope into one sample and teasing the sample apart in a petri dish containing a small amount of alcohol. Food items were identified to the lowest taxonomic level possible and the percentage volume of each item was visually estimated. Data were then summarized and total percentage volumes ([sum of individual volume of food]/ [total volume of all samples] X 100) were calculated to determine the diet of each species (Whitaker 2004).

The similarity between the diets of both species, based on taxonomic orders, families, and genera, where possible, of prey items consumed, was determined using Sorensen's coefficient (S_S) of similarity; 0 being extremely different and 1 being extremely similar (Krebs 1999). The Wilcoxon Rank Sum Test (Ott 1977) was used to determine if there was a significant difference ($P < 0.05$) in diets between the two bat species, and between males and females within a species, based on the percent volume of prey items identified in the diet from the insect orders.

CHAPTER 3

RESULTS

During this study, 36 samples of big brown bats (21 males, 8 females, and 7 unknowns; Table 1) and 103 samples of northern bats (34 males, 40 females, and 29 unknowns; Table 2) were collected over the course of two years. Big brown bats were mist-netted in June (7 samples) and July 2004 (29). Northern bats were mist-netted in June (29 samples), and July 2003 (21); May (11), June (22), July (12), August (2), September (4), and October 2004 (1).

Diets were similar between northern and big brown bats (S_S = 0.72). The most common insect orders found were Coleoptera, Lepidoptera, and Hemiptera (Tables 1 and 2). Concerning coleopterans, there were no significant differences between northern (n = 103) and big brown bats (n = 36) in the unknown coleopterans ($P < 0.05$; z = - 0.67; 23.0% to 20.7%), Scarabaeidae (z = 1.20; 15.2% to 10.3%), *Diabrotica* (z = 1.15; 6.2% to 0.2%), and Carabidae (z = 0.21; 5.5% to 9.4%) consumed. Big brown bats consumed a significantly greater amount of *Chinavia hilaris* (within the order of Hemiptera; z = 8.29; 35.7% to 0.5%) than did northern bats. Northern bats consumed a greater amount of lepidopterans (z = - 6.04; 27.1% to 0.2%) than did big brown bats (Tables 1 and 2).

Adult male (n = 8) and adult female (n = 5) big brown bats consumed similar prey types (S_S = 0.70). There were no significant differences in the amount of unknown

Table 1: Prey in mean percentage volume for 36 big brown bats (*Eptesicus fuscus*) collected in western Kentucky in 2004. Sample size specified in parentheses.

	Male (n=21)				Female (n=8)			Unsexed	All
	Adult n=8	Juvenile n=4	Unaged n=9	All	Adult n=5	Unaged n=3	All	Unaged n=7	n=36
Araneae (spiders)	0.6		2.4	1.3					0.7
Coleoptera (beetles)									
Carabidae (ground beetles)	1.7	20.0	6.4	7.2	2.0		1.3	5.1	5.5
Chrysomelidae (leaf beetles)									
Diabrotica sp. (cucumber beetles, corn rootworms)	9.8			3.7	17.0	19.6	18.0		6.2
Curculionidae (snout, bark beetles)	9.7	7.5	3.6	6.7	11.5	1.7	7.8	0.5	5.7
Cyrtepistomus sp. (broad-nosed weevils)	14.1			5.4	1.5		0.9		3.3
Cyrtepistomus castaneus (Asiatic oak weevil)									
Scarabaeidae (scarab beetles)	19.7	3.8	16.5	15.3	15.7		9.8	21.0	15.2
Unknown	17.8	49.6	11.2	21.0	31.7	15.0	25.4	26.4	23.0
Diptera (flies)						0.8	0.3		0.1
Hemiptera (true bugs)									
Cicadellidae (leafhoppers)			0.2	0.1	0.3		0.2		0.1
Lygaeidae (seed bugs)	2.5			1.0		0.3	0.1	4.3	1.4
Miridae (plant bugs)					1.0		0.6		0.1
Pentatomidae (stink bugs)								12.9	2.5
Chinavia hilaris (green stink bug)	23.5	19.2	58.8	37.8	19.0	61.8	35.0	29.9	35.7
Unknown						0.8	0.3		0.1
Hymenoptera (ants, bees, wasps, sawflies)									
Formicidae (ants)			0.3	0.1					0.1
Ichneumonidae (ichneumonid wasps)	0.6			0.3					0.1
Lepidoptera (moths)			0.7	0.3	0.3		0.2		0.2
Totals	100	100	100	100	100	100	100	100	100

Table 2: Prey in mean percentage volume for 103 northern bats (*Myotis septentrionalis*) collected in western Kentucky in 2003 and 2004. Sample size specified in parentheses.

	Male (n=42)				Female (n=52)				Unsexed (n=9)			All
	Adult n=34	Juv n=5	Unag n=3	All	Adult n=40	Juv n=9	Unag n=2	All	Adult n=7	Juv n=1	Unag n=1	n= 103
Araneae (spiders)	2.6		10.0	2.9	2.8	5.6	17.5	3.8	11.4		20.0	4.0
Coleoptera (beetles)												
Carabidae (ground beetles)	9.9		26.7	9.9	11.5	4.4	12.5	10.1	3.6			9.4
Chrysomelidae (leaf beetles)	1.0			0.8	0.4			0.3				0.5
Diabrotica sp. (cucumber beetles, corn rootworms)	0.6			0.5								0.2
Curculionidae (snout, bark beetles)	5.4		6.7	4.9	4.6		17.5	5.6	7.1			5.3
Cyrtepistomus castaneus (Asiatic oak weevil)	3.4	22.0		5.4	4.8	10.6	5.0	5.7	13.6		40.0	6.4
Scarabaeidae (scarab beetles)	11.8			9.5	8.6	32.8		12.3		20.0		10.3
Unknown	20.0	23.0		18.9	23.9	16.1	10.0	21.9	18.6	50.0	15.0	20.7
Diptera (flies)												
Chironomidae (Midges)	1.8			1.4	0.3			0.2				0.7
Unknown	8.4	24.0	13.3	10.6	6.9	8.9	10.0	7.2		10.0	10.0	8.2
Hemiptera (true bugs)												
Cicadellidae (leafhoppers)	4.0	4.0		3.7	1.0	2.2		1.2	8.6		10.0	2.8
Lygaeidae (seed bugs)	0.1			0.1	0.6			0.5	3.6		5.0	0.6
Chinavia hilaris (green stink bug)						5.6		1.0				0.5
Unknown	0.7		6.7	1.1	2.1	0.6	5.0	1.9	1.4			1.5
Hymenoptera (ants, bees, wasps, sawflies)												
Formicidae (ants)									2.1			0.1
Ichneumonidae (ichneumonid wasps)					0.1	0.6		0.2				0.1
Unknown					0.1			0.1				0.0
Lepidoptera (moths)	27.5	27.0	36.7	28.1	30.6	11.7	20.0	26.5	30.0	20.0		27.1
Neuroptera												
Hemerobiidae (brown lacewings)	2.8			2.3	0.1			0.1				1.0
Orthoptera												
Gryllidea (crickets)					0.3			0.2				0.1
Trichoptera (Caddisflies)						1.1		0.2				0.1
Unknown					1.4		2.5	1.2				0.6
Totals	100	100	100	100	100	100	100	100	100	100	100	100

coleopterans (z = 0.81; 17.8% to 31.7%), Scarabaeidae (z = 0.37; 19.7% to 15.7%), *Cyrtepistomus* (z = 0.59; 0% to 0%), *Diabrotica* (z = 0.59; 9.8% to 17.0%), or *Chinavia hilaris* (within the order of Hemiptera; z = 0.29; 23.5% to 19.0%) consumed (Tables 1 and 2).

Adult male (n = 34) and adult female (n = 40) northern bats also consumed similar prey types (S_S = 0.85). There were no significant differences in the amount of lepidopterans (z = - 0.30; 27.5% to 30.6%), unknown coleopterans (z = - 0.71; 20.0% to 23.9%), Scarabaeidae (z = 0.25; 11.8% to 8.6%), or Carabidae (z = - 0.62; 9.9% to 11.5%) consumed (Tables 1 and 2).

When comparing adult male diets among northern (n = 34) and big brown bats (n = 8), it was found that there was little similarity in prey items consumed (S_S = 0.56). Northern bats consumed a significantly greater amount of lepidopterans (z = - 3.07; 27.5% to 0%) than did big brown bats. There were no significant differences in the amount of unknown coleopterans (z = - 0.86; 20.0% to 17.8%), Scarabaeidae (z = 1.01; 11.8% to 19.7%), *Cyrtepistomus* (z = 1.47; 3.4% to 0%), or Carabidae (z = - 0.46; 9.9% to 1.7%) consumed by both species (Tables 1 and 2).

When comparing adult female diets among northern (n = 40) and big brown bats (n = 5), it was found that there was very little similarity in prey items consumed (S_S = 0.43). Big brown bats consumed a significantly greater amount of *Chinavia hilaris* (within the order of Hemiptera; z = 3.61; 19.0% to 0%) than did northern bats. Northern bats consumed a significantly greater amount of lepidopterans (z = - 2.53; 30.6% to 0.3%). There were no significant differences in the amount of unknown coleopterans (z = 0.25; 23.9% to 31.7%), *Diabrotica* (z = 1.44; 0% to 17.0%), Scarabaeidae (z = 0.52; 8.6% to 15.7%), or Carabidae (z = - 0.56; 11.5% to 2.0%) consumed by female both species (Tables 1 and 2).

CHAPTER 4

DISCUSSION

Researchers documenting the diets of bats have noted that only a small portion of insect fragments actually withstand mastication and digestion (Gould 1955; Whitaker et al. 2009 *in* Kunz and Parsons 2009). Given that most insectivorous bats feed on flying insects, soft-bodied larvae can usually be omitted from the potential pool of prey (Whitaker et al. 2009 *in* Kunz and Parsons 2009). For those bats that feed on soft-bodied adult insects, like moths or midge flies, even less parts remain in fecal material to be recovered for physical analysis (Belwood and Fenton 1976, Rabinowitz and Tuttle 1982, Whitaker et al. 2009 *in* Kunz and Parsons 2009). The problem of bias toward hard-bodied insects often arises when discussing the technique of physical analysis of fecal pellets, although the alternative, culling bats for stomach contents, raises ethical and legal issues (Whitaker et al. 2009 in Kunz and Parsons 2009). However, work by Kunz and Whitaker (1983) indicate physical analysis of bat fecal material is just as accurate as physical analysis of stomach contents.

In general, big brown bats appear to be a “beetle strategist” (Black 1974, Feldhamer et al. 2009), mainly feeding on hard-bodied insects, such as beetles (Coleoptera) and true bugs (Hemiptera). Northern bats tend to also consume soft-bodied insects like moths (Lepidoptera). Freeman (1981) examined the relationship between diet and skull features of a number of species of bats (including *Eptesicus* *fuscus* and *Myotis keenii* = *M. septentrionalis*). She ranked prey on a scale of hardness from 1 (softest; e.g., Trichoptera, Plecoptera, Neuroptera, Diptera) to 5 (hardest; e.g., Coleoptera), and scored bat species based on published diet information. On Freeman's (1981) scale, big brown bats (4.14) which have heavier, more robust, skulls (Kurta and Baker 1990; Myers et al. 2012) took harder prey than northern bats (2.75). A similar trend in prey consumed and prey hardness was noted by Feldhamer et al. (2009) for big brown bats and northern bats in Illinois.

Beetles comprised 58.9% of the overall diet of big brown bats sampled in western Kentucky. Of the beetles identified, scarab beetles made up the largest quantity (15.2%), followed by cucumber beetles (within the *Diabrotica* genus; 6.2%) which are known to be a severe agricultural pest (Whitaker 1995). True bugs accounted for 39.9% of the hemipterans consumed; a major component (35.7%) was green stink bugs (*Chinavia hilaris*; Table 1). Green stink bugs are also known to be agricultural pests (McPherson and McPherson 2000). Based on known skull features, aspect ratio, wing loading, and foraging habits, it is very likely farms, orchards, gardens, and neighboring corridors were utilized as foraging habitat by big brown bats.

Northern bats captured in western Kentucky also fed mainly on beetles (52.7%). They also ate moths (27.1%), and flies (8.8%; Table 2). Of the beetles consumed, most were scarab beetles (10.3%). Northern bats also fed upon Asiatic oak weevils (*Cyrtepistomus castaneus* found within the order Coleoptera; 6.4%) which are a nonnative species that is known as a minor defoliator of several native trees, including oaks (Solomon et al. 2003; Frederick and Gering 2006). A diet dominated by beetles and moths is typical of what has been reported for northern bats within Kentucky (Lacki et al. 2009) and from other areas within its range (Griffith and Gates 1985, Brack and Whitaker 2001, Burke 2002, Carter et al. 2003, Feldhamer et al. 2009). Based on their known physical features and feeding habits, it appears that northern bats hunt under forest canopies and along hedge zones and adjacent corridors.

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