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# Diets of Bats in West Virginia

Theresa Sydney Burke
biosyd@hotmail.com

# DIETS OF BATS IN WEST VIRGINIA

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# ABSTRACT


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Little work has been conducted concerning feeding ecology of bats, and only 2 studies have been done in West Virginia. West Virginia is a prime location for the study of bats because 12 species are reported in the state. To increase knowledge of food habits of bats inhabiting West Virginia, fecal samples of 7 species were examined: Virginia Big-eared Bat (*Corynorhinus townsendii virginianus*), Rafinesquii's Big-eared Bat (*Corynorhinus rafinesquii*), Big Brown Bat (*Eptesicus fuscus*), Red Bat (*Lasiurus borealis*), Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), and Eastern Pipistrelle (*Pipistrellus subflavus*). Collections of samples were made in the eastern mountainous area, the Ohio Valley area, and the New River Gorge area. Biologists with WV Division of Natural Resources (DNR) Nongame Program conducting bat surveys during the 2000 and 2001 summer field seasons (15 May to 15 Aug.) collected the samples used. Fecal pellets were teased apart in petri dishes and insect remains were identified to the lowest taxonomic level possible. After identification, volume and frequency percentages were calculated to estimate major food sources of the bats. With knowledge of diets and feeding ecology, it is possible to make inferences that may be useful in conservation of bats in West Virginia.

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I think that Ralph Waldo Emerson sums up all the work put into a thesis best: "Sometimes a scream is better than a thesis."

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# CHAPTER I

## Introduction

There are nearly 1,000 species of bats known to occur on the earth, and these comprise nearly one-quarter of all mammalian species (Wilson and Reeder 1993). More than half of American bats are in severe decline or already listed as endangered (Harvey et al. 1999). There are 45 bat species in the United States. Of these 45 species, 6 are considered endangered by the U.S. Fish & Wildlife Service (FWS), and 20 additional species are considered to be of special concern (Harvey et al. 1999). This designation means bat numbers are declining and special management is required to preclude further losses.

Bats inhabit most temperate and tropical regions of both hemispheres but are absent from certain remote, oceanic islands. Bats compose the order Chiroptera, which is subdivided into 2 suborders, Megachiroptera and Microchiroptera. Only microchiropterans inhabit West Virginia, and all of these particular species are insectivorous. In North America, little is known about feeding habits of insectivorous bats (Kunz 1974). An insubstantial amount of data has been collected, especially in West Virginia. Only two studies have been carried out concerning diet in the state, one in 1933 (Hamilton) and another in 1993 (Sample and Whitmore).

Twelve species of bats have been reported in West Virginia, 2 of which are listed as federally endangered by the U.S. FWS. These are the Indiana Myotis (*Myotis sodalist* Miller and Allen) and Virginia Big-eared Bat (*Corynorhinus townsendii virginianus*

Cooper). Also found in West Virginia are three other *Myotis* species: Little Brown Myotis (*Myotis lucifugus* LeConte), Northern Myotis (*Myotis septentrionalis* Trouessart), and Small-footed Myotis (*Myotis leibii* Audubon and Bachman). The Silver-haired Bat (*Lasionycteris noctivagans* Peters), Eastern Pipistrelle (*Pipistrellus subflavus* F. Cuvier), and Big Brown Bat (*Eptesicus fuscus* Beauvois) are found here as well. Two *Lasiurus* species are included: the Red Bat (*Lasiurus borealis* Müller) and the Hoary Bat (*Lasiurus cinereus* Beauvois), plus the Evening Bat (*Nycticeius humeralis* Rafinesque) and Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii* ). Most of these bats are residents, while the Silver-haired Bat, Evening Bat, and the Hoary Bat are migrants.

Understanding the vital roles of bats, which leads to progress in management and conservation, is seriously impeded by lack of knowledge. The inclusion of bat habitat requirements in forest management plans is sparse because information about roosting and foraging habitat preferences is lacking (Vonhof and Barclay 1996). In order to gain this knowledge, which is crucial for protecting threatened and endangered species, it is essential to document the full range of variability in dietary and other requirements (Best et al. 1997). Conservation of bats requires knowledge of their ecology; therefore, studies of food habits is justified in adding to the whole ecological picture (Easterla and Whitaker 1972).

Dietary information of insectivorous bats can be gathered by analysis of stomach content and fecal pellets. Stomach content analysis has been supported in the past because insects remain partially intact (Ross 1967). This method of study is very destructive to bats and impractical when studying threatened or endangered species. Analysis of bat feces is preferred because it does not require sacrificing bats (Belwood and Fenton 1976). Fecal analysis is feasible because the sclerotized or hardened exoskeleton of insects is not entirely digested as it passes through the digestive tract of the bat (Warner 1985).

The reliability of fecal pellet versus stomach content analysis has been questioned. For example, Belwood and Fenton (1976) and Rabinowitz and Tuttle (1982) reported difficulty in identifying Ephemeroptera (mayflies) in bat fecal samples. However, Anthony and Kunz (1977), Lacki et al. (1995), and Swift et al. (1985) reported success in correct identification of prey items, including mayflies, using fecal pellet analysis. In 1983, Kunz and Whitaker showed that fecal analysis can produce satisfactory estimates of food eaten by insectivorous bats. They did this by capturing Little Brown Myotis bats and holding them separately in small cloth cages until individuals voided any feces that remained in their digestive tracts from previous feedings. They were then fed insects and returned to individual cages for 20 hours until fecal samples were collected. J.O. Whitaker (1983) analyzed fecal material without previous knowledge of which insects were fed to the bats. The results showed that the four most used food items, by percent volume and frequency, recovered in the feces were the same as those in the diet. This test of fecal analysis is the first to establish that the method can yield reasonable estimates of food eaten by insectivorous bats, while pointing out some amount of “error” is to be expected. An example would be that softer food, such as mayflies, would likely yield fewer undigested parts.

# CHAPTER II

## Description of Collection Sites

The location of West Virginia is unique because it is the only state to lie completely within the Appalachian Mountain region. It has a higher mean elevation than any state in the eastern United States, 1,654 ft (Lee et al. 1973). West Virginia also has 78% of its land covered in forest. Three National Forest lands exist in the state, with one of these encompassing just under 1,000,000 acres. Mountains cover most of West Virginia; however, climate and type of vegetation are very diverse. Lee et al. (1973) call attention to the fact that the land rises from nearly 500 feet at the western border to more than 4,000 feet at the highest ridge of the Allegheny Mountains, and decreases to less than 300 feet at the eastern border. These elevational differences are primary factors of varying habitat types and variety of flora and fauna present.

Climate in West Virginia is established by its geographic location and topography (USGS 2002). West Virginia is located in the eastern United States, with latitude of 37º12' to 40º38'N and longitude of 77º43' to 82º39'W. At this location, mostly westerly winds sweep across the state. These winds are influenced by cold northern and warm southern air currents that can produce a substantial amount of precipitation (Lee et al. 1977). A rain shadow effect is created by the Allegheny Mountains. Higher amounts of precipitation to the west of the mountains and lower amounts to the east are due to prevailing winds rising and cooling over the mountains. Therefore, while the mountains receive the most rainfall, the western edge of the state receives more precipitation than the eastern panhandle.

Five physiographical provinces are present in West Virginia, with 3 major regions: the Allegheny Plateau in the west and north, the Allegheny Mountains running from the southwest through the northeast, and the Ridge and Valley province located east of the Allegheny Front. Collection sites in Tyler and Wayne counties are included in the Allegheny Plateau region (Figure 1). This area covers the western part of the state and is relatively flat with regions of open and developed areas and moderate amounts of forest cover. Bat fecal samples were also collected in Randolph County and the western edges of Pendleton, Pocahontas, and Greenbrier counties, which lie within the Allegheny Mountains. This mountainous region is mainly rural and has the highest percentage of forest cover of the 3 regions. Another collection site included the eastern areas of these counties and Jefferson County, all located in the Ridge and Valley Province. The Ridge and Valley Province is characterized by ridges formed by folded and faulted rocks composed largely of limestone and interspersed with broad valleys. This is where most of the state's limestone outcrops occur and where many of its caves are located.

# CHAPTER III

## Materials and Methods

Species used for this study were determined by the availability of adequate fecal samples. A minimum of 15 to 20 pellets must be obtained from a species in order to gain informative results (Whitaker 1988; Hurst and Lacki 1997). The sample sizes I used in this study range from 19 to 70 pellets for each species.

Samples were obtained from seven counties across the state: Greenbrier, Jefferson, Pendleton, Pocahontas, Randolph, Tyler, and Wayne counties (Figure 1). Biologists with the WV Division of Natural Resources (DNR) Nongame Program conducting bat surveys during the 2000 and 2001 summer field seasons (15 May to 15 Aug.) collected the samples used. Fecal samples were obtained from bats captured in mist nets and others from cave sites. After removal from nets and identification, bats were held in cloth or paper bags for 2 hours or more. Bats should be captured for food habits analysis near the time of foraging due to rapid digestion and defecation rate (Whitaker 1988). Food passes through the gut as rapidly as 35-170 minutes for the Little Brown Myotis (Buchler 1975) and 90-130 minutes for the Big Brown Bat (Lukens et al. 1971). It was shown by Warner (1985) that most feces were voided in the first hour of captivity, and bats rarely defecated after being held for more than 2 hours. Collections from cave sites were made from the cave floor after identification of roosting bat species. Fecal pellets in this study were stored dry until analyzed.

Fecal samples were analyzed using techniques similar to those of Anthony and Kunz (1977), Black (1974), Ross (1967), and Whitaker (1988). These methods have changed very little since Ross' work in 1967. I trained with Dr. John O. Whitaker, Jr. of Indiana State University, a prominent researcher in this field, to learn the technique of food habit analysis. To isolate identifiable insect remains, each fecal pellet was placed singly in a petri dish, carefully teased apart in a thin layer of 70% ethyl alcohol, and examined under a dissecting microscope. Volume percentages for each food item were estimated visually for each pellet; items were sorted by distinguishing or diagnostic characters into piles of each food type (Whitaker 1988).

The percentages of volume and frequency for each sample were calculated as follows:

$$\text{Percentage volume} = \frac{\text{sum of individual volumes for each food type}}{\text{sum of all volumes for all foods (100 X number of pellets)}}$$

$$\text{Percentage frequency} = \frac{\text{number of pellets in which individual food type was found}}{\text{total number of pellets examined}}$$

Prey items were identified to order and often family by using several insect guides: Borror et al. (1992), Borror and White (1970), Dillon and Dillon (1972), Klots and Klots (1971), Holland (1968), and Jaques (1951). Identification of food items was also determined by comparison of characteristic parts to a reference collection of whole insects and known portions of the insects (e.g. wings, legs, head capsules) mounted on microscope slides. To make this collection, I obtained insects, positively identified them taxonomically, and looked for microscopically identifying characters. After mounting individual pieces of the insect on a slide, fragments found in fecal material could be compared to the reference collection under a dissecting microscope. A list of insects found in this study is in Table 1. Some examples of insect fragments that were identified are moth scales (Figure 2), a midge eye (Figure 3), a beak from a true bug (Figure 4), and a beetle leg (Figure 5).

Dietary overlap was calculated using a similarity index:

$$D = (1.0 - 0.5\sum|Px,i - Py,i|)x100$$

where D is the percentage of overlap and $Px,i$ and $Py,i$ are proportions of the percent volume of each food item identified in species x and those identified in species y (Holomuzki 1980, Rathcke 1976, Schoener 1970). The percent volume data for each are presented in Tables 3 through 9. Twenty-one comparisons representing all possible combinations of species pairs were made, and percentage overlap was calculated (Table 11). One hundred percent overlap indicates complete similarity, while zero percent would indicate complete dissimilarity.

# CHAPTER IV

## Results

Food items (Table 1) from fecal pellets of 7 bat species found in West Virginia (Table 2) were examined. Estimates of the volume percentage of each food item in each pellet were made; the percent volume is an indication of abundance of each kind of food in the diet of a species. Because bats chew their food into small pieces, visual estimates of the amount of each food type must be made; the small amount of sample precludes use of volumetric measurements (Whitaker 2001; Kunz and Whitaker 1983). Percent frequency was used to show how often the bats took each prey item. Dietary data presented as percent volume and percent frequency facilitate comparisons with other studies (Korschgen 1970).

### *Corynorhinus townsendii virginianus*

Forty fecal pellets from Virginia Big-eared Bats, one of 2 cave-dwelling species in this study, were examined. Moths were the dominant food, forming 90% of the total food and occurring in 100% of the pellets (Table 3). Coleoptera was the second most abundant prey order identified, composing 6% of total volume. Four orders of insects (moths, beetles, caddisflies, and true flies) and one non-insect group (order Araneae, the spiders) were found in Virginia Big-eared Bat feces, but moths were by far the most abundant food item (Figure 6).

*Corynorhinus rafinesquii*

This is the second cave-dwelling species studied. Of 30 pellets I examined, diets of the 2 West Virginia *Corynorhinus* species were nearly the same, with most food items for *C. rafinesquii*, 66%, being moths (Figure 7). Rafinesque's Big-eared Bats had a greater concentration of beetles included in the diet, making up a combined volume percentage of 34% of food items and found frequently (Table 4).

*Eptesicus fuscus*

Nineteen Big Brown Bat fecal pellets were examined. Pentatomids, a family of hemipterans or true bugs, were in 84% of the pellets (Table 5) and were also abundant food items with 29% volume. Beetles made up the next 4 highest volume percentages: unidentified coleopterans, chrysomelids, scarabids, and carabids; grouped together, beetles formed 61% of the diet (Figure 8). In addition, there was a fair amount of variation in the diet of the Big Brown Bat with 10 prey items identified in feces.

*Lasiurus borealis*

Of 43 fecal pellets of Red Bats studied, moths were the most abundant dietary item, with 55% volume and 74% frequency (Table 6). Beetles and leaf hoppers were food items next in abundance at 28% and 9% volume, respectively (Figure 9). The diet exhibited a good deal of variation, with 11 prey items identified.

*Myotis lucifugus*

My data show that in West Virginia, Little Brown Myotis eats mostly moths, with a 37% volume (Figure 10). Moths were the most abundant food item and showed a 91% frequency, but many other types of food were consumed (Table 7). Little Brown Myotis also had a diet with much variation in 32 fecal pellets examined, consisting of 15 different prey items.

*Myotis septentrionalis*

Of 38 Northern Myotis fecal pellets I examined, moths were the main dietary component, 49% volume and 92% frequency (Table 8). Beetles were found to be the second most abundant prey item, 28% volume, and true flies were the next major dietary component, 10% volume, (Figure 11). Both *Myotis* species in this study were found to eat a variety of insects. Eleven prey items were identified from the Northern Myotis.

*Pipistrellus subflavus*

Moths were the most abundant prey item for the Eastern Pipistrelle, with 35% volume (Table 9). In 70 pellets examined, however, true bugs and true flies were the foods most frequently eaten, 79% and 58% respectively. These foods were found often in the feces, but made up less of the volume than moths (Figure 12).

## CHAPTER V

### Discussion

Studies of feeding aspects of West Virginia bats are feasible because they are insectivorous. Because insects contain sclerotized pieces that are relatively indigestible, informative estimates of prey items can be gathered from fecal pellets (Whitaker and Lawhead 1992). Also, since bats have such a rapid rate of digestion, food passes quickly through the digestive tract and pieces of sclerotized exoskeleton remain mostly intact (Whitaker 1988). Therefore, even though bats exhibit a great amount of mastication, or chewing of prey items, identification is possible.

The Virginia Big-eared Bat, *C. townsendii virginianus*, is a relict subspecies of the Western Big-eared Bat. Due to small population sizes, restricted range, and vulnerability to human disturbance, this subspecies was placed on the U.S. FWS's Endangered Species List in 1979 (Bagley 1984). Thus, study of the ecology of this species, especially food habits, is crucial. Most information concerning Virginia Big-eared Bat food habits is drawn or inferred from the more common western subspecies. It was shown by Ross (1967) and

Whitaker et al. (1977, 1981) that moths were the main dietary items taken by the western subspecies. Moths were the dominant food in my study of Virginia Big-eared Bats, by percentage volume and frequency. These findings are consistent with those previously reported by Sample and Whitmore (1993) and Whitaker (1997).

Food habits of both *Corynorhinus* species in my study are similar; less information is available about the diet of Rafinesque's Big-eared Bat. Clark (1991) found from investigations in North Carolina that moths typically averaged 90% of any fecal pellet. In Kentucky, moths were also found to be the food item of greatest abundance in *C. rafinesquii* by Hurst and Lacki (1997). In agreement with these studies, both cave-roosting species in West Virginia are moth specialists, with the only other well-represented dietary component being beetles.

Another moth specialist found in West Virginia is the Red Bat, *L. borealis*. Unlike other moth specialists, these bats are solitary, mostly using small shrubs or trees as roost sites (Shump and Shump 1982). My results are concordant with those of Hickey et al. (1996) and Whitaker et al. (1997), who also found that Red Bats in other areas feed primarily on moths. In fact, Red Bats are not selective since they will take moths from different families and from different size classes (Hickey et al. 1996). Therefore, while Red Bats are moth specialists, they tend to generalize within the order Lepidoptera.

Of 7 bats studied, the widely distributed *M. lucifugus* (Little Brown Myotis) exhibited the most dietary variation. The Little Brown Myotis has been described as "a selective opportunist" in reference to feeding because of this variation in feeding habits (Fenton and

Morris 1976). The most frequent additions to the diet were: midges, caddisflies, moths, leaf hoppers, flies, and beetles (Whitaker and Lawhead 1992). I found moths to be most abundant and frequent in the diet. In this study, the Little Brown Myotis preyed upon a variety of insects, but ate mostly one type of insect that was probably locally abundant in the foraging area at time of feeding. This is typical feeding behavior for this species: the Little Brown Myotis concentrated on mayflies in New York (Buchler 1976), true flies in Ontario (Belwood and Fenton 1976), and ants and true flies in the Appalachians (Griffith and Gates 1985).

Little published information exists on the diet of *M. septentrionalis* (Brack and Whitaker 2001). While most insectivorous bats are known to capture prey in the air (Norberg and Rayner 1987), Northern Myotis has been considered a gleaner (Faure et al. 1993), meaning this species is capable of taking insects from leaves or other surfaces. Even though some food may be acquired by gleaning, many prey items are flying insects. The Northern Myotis is known to eat small insects, particularly moths, and to a lesser extent beetles and flies (Brack and Whitaker 2001). The main food items taken by this species in West Virginia were moths, consisting of nearly half the diet. This diet was similar to those of the Red Bat and Little Brown Myotis, with 80% and 78% diet overlap, respectively (Table 11).

Moths were found to be prey items of greatest volume for the Eastern Pipistrelle, but other insects such as true bugs and true flies were consumed more frequently. Eastern Pipistrelles are known to eat mostly small moths, beetles, and leaf hoppers in the central

Appalachians, mainly western Maryland (Griffith and Gates 1985). Eastern Pipistrelles are small bats with a total length of 77-89 mm (Davis 1959*a*), which gives some insight as to why their prey generally consists of small insects ranging from 4 to 10 mm in length (Ross 1967).

Foraging habitat for Big Brown Bats, *E. fuscus,* is non-specific; this species shows no preference for differing habitats (Kurta and Baker 1990). This variation is found not only in foraging habitat, but in dietary items as well: 10 different foods were found in the feces. Foraging habitat, however, does not always predict what diet a forager will select under uncontrolled conditions (Hamilton and Barclay 1998). Although there a is fair amount of foraging and dietary variation, analysis of samples in this study shows that Big Brown Bats concentrate on two insect orders: Coleoptera (beetles) and Hemiptera (true bugs). Hamilton et al. (1996) and Whitaker (1997) also showed beetles and true bugs to be the 2 major prey types for Big Brown Bats. These bats exhibited a diet unlike other bats in this study, with less than 40% of the diet overlapping with any other species (Table 11). The ability of Big Brown Bats to be the only species in the state to exploit a certain group of insects may largely account for their success.

Although mist-netting was mostly used to obtain fresh feces, samples from the *Corynorhinus* species were collected from cave sites. The Virginia Big-eared Bat samples were taken from caves located in Pendleton County. Findings from 2 locations, Cave Mountain Cave and Minor Rexrode Cave, were in accordance with other reported findings for this species. Samples from a third location (Schoolhouse Cave), however, yielded an unexpectedly high amount of beetles in the diet, 43% (Table 10). On follow-up of this anomaly, collectors recognized that these samples were collected at the cave entrance where Big Brown Bats, *E. fuscus*, were also roosting. This would explain high beetle content found in fecal material. These samples were eliminated from data of the Virginia Big-eared Bat because I could not be certain that fecal samples taken were from this species. It is imperative, when collecting bat fecal material from cave sites, to be completely positive on identification of the bat species roosting in that cave. Once accurate identification is made, cave samples can be a reliable source of data.

Most insectivorous bats are food generalists, exhibiting a variety of prey items in diets (Anthony and Kunz 1977). An adaptive strategy is dietary flexibility, in which individuals will eat mostly one type of insect that is locally and seasonally abundant. For example, Big Brown Bats have consumed mainly beetles in southeastern Alberta, Canada (Hamilton and Barclay 1998) and mostly beetles and true bugs in the central Appalachians (Griffith and Gates 1985). This suggests that some bats, especially Big Brown Bats and the 2 *Myotis* species, are opportunists, "exploiting local insect faunas to their best advantage by preying upon the most abundant and diverse insect taxa within the appropriate size range" (Anthony and Kunz 1977).

Prey items taken by insectivorous bats are dependent on 2 things: availability of food and selectivity by the predator (Whitaker 1994). The general method of assessing whether feeding is carried out opportunistically or selectively is to collect insects available to bats and to make a comparison to prey actually taken (Buchler 1976). Accurate assessment of food available to predators, especially insectivorous bats, may not be truly representative due to biases of conventional methods; nearly every kind of insect gathering technique possesses a bias (Kunz 1988). Whitaker (1994) states that since insectivorous bats must select food from available insects, there exists a balance between availability and selectivity of food. Because several bat species may forage in the same area, it is to their benefit to partition food supply. Hickey et al. (1996) studied 2 *Lasiurus* species inhabiting the same area to determine if resource partitioning was occurring. They did in fact partition resources, which suggests the 2 closely related and sympatric species are minimizing competition. This relationship has not only been studied between species, but also within a species, such as between adults and juveniles (Hamilton and Barclay 1998; Rolseth et al. 1994; Warner 1985). Adults and juveniles usually feed on different prey items. This may be due to lack of experience on the juvenile's part (Rolseth et al. 1994), or to minimize competition. There is not sufficient data to assess this aspect of resource partitioning in my study, but further investigation would be informative.

According to Findley (1993), foraging sites, as well as food, are potentially limiting factors that may affect community structure and the entire niche a species fills. Food availability for insectivorous bats depends on insects in the foraging area, and insect populations fluctuate with season, habitat availability, or amount of precipitation. General productivity of all orders of insects favored by bats was highest in the wetter months (Black 1974). The season, as well as precipitation for that year, dictates size and type of insect populations available to bats. The rain shadow effect causing differing amounts of precipitation across West Virginia would also cause insect populations to vary from location to location throughout the state, which in turn may cause bat populations to vary. With more insect variability, bats with greater diet flexibility would have a survival advantage.

Another factor affecting insect populations, thus possibly indirectly affecting bat populations, is presence of pesticides in the environment. The gypsy moth, *Lymantria dispar*, is one of North America's most devastating forest pests. In order to slow spread of this pest and in turn to reduce the extent of defoliation, pesticides such as diflubezuron (Dimilin) are used (USFS 1990). This pesticide is primarily effective against immature or larval insects in general, but residues in concentrations large enough to be considered lethal to many insects have been detected up to 7 weeks after application (Robertson and Boelter 1979). Because moths comprise a major part of the diets of West Virginia bats, the effectiveness of Dimilin in reducing both target and non-target moth populations is likely detrimental to bat species in the state (Sample 1991). This is only one example of a pesticide used to stop the spread of an insect, but other biological and chemical pesticides are used without knowledge of ramifications to non-target species.

More dietary information about bats is needed for conservation of these mammals in West Virginia. The 2 studies completed in the state (Hamilton 1933; Sample and Whitmore 1993) include information on only 2 species: the Big Brown Bat and the Virginia Big-eared Bat. My findings are consistent with theirs. In general, dietary information has not been recorded for some species and is sparse for others.

It would be useful to find better ways to study availability and diversity of foods for insectivorous bats as correlated with prey actually taken. Also, broader investigation of food partitioning would be helpful in determining how several insectivorous bat species forage in the same area. An increased number of collection sites will provide broader knowledge about dietary variation across diverse habitats in West Virginia. Such studies, and teaming with entomologists to investigate habitat requirements of prey species, will support better conservation management for West Virginia bats.

# CHAPTER VI

## Conclusions

Understanding vital needs of bats, which leads to progress in management and conservation, is seriously impeded by lack of knowledge. Information about bat habitat can be acquired by study of feeding habits; foraging strategies can be revealed through dietary information (Vaughn 1997). Without sacrifice of bats, reasonable estimates of foods consumed by bats are derived from fecal pellet analysis (Whitaker and Lawhead 1992). New information concerning feeding habits of 7 bat species inhabiting West Virginia has been recorded and is available to foresters and biologists with responsibility for conservation and management.

This study has identified major food items for 7 of 12 bat species inhabiting West Virginia. Findings are similar and in agreement with other studies of feeding habits in eastern North America. Five species, Big-eared bats (2), Myotis bats (2), and *Lasiurus borealis*, depend heavily on moths and are considered specialists, while Big Brown Bat and Eastern Pipistrelle are generalists. These species tend to be most successful due to dietary flexibility and capability of adapting to a variety of prey.

West Virginia, with its diverse Appalachian terrains and elevations, its large chiropteran community, and rural environment, is a suitable place to study feeding ecology of bats. More information is needed about prey availability as well as which foods are taken by bats. These studies, coupled with data provided by entomologists on prey habitat requirements, should be used to further bat conservation efforts in West Virginia.

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## Appendix

Figure 1. Map of West Virginia, showing counties with location of collecting stations.

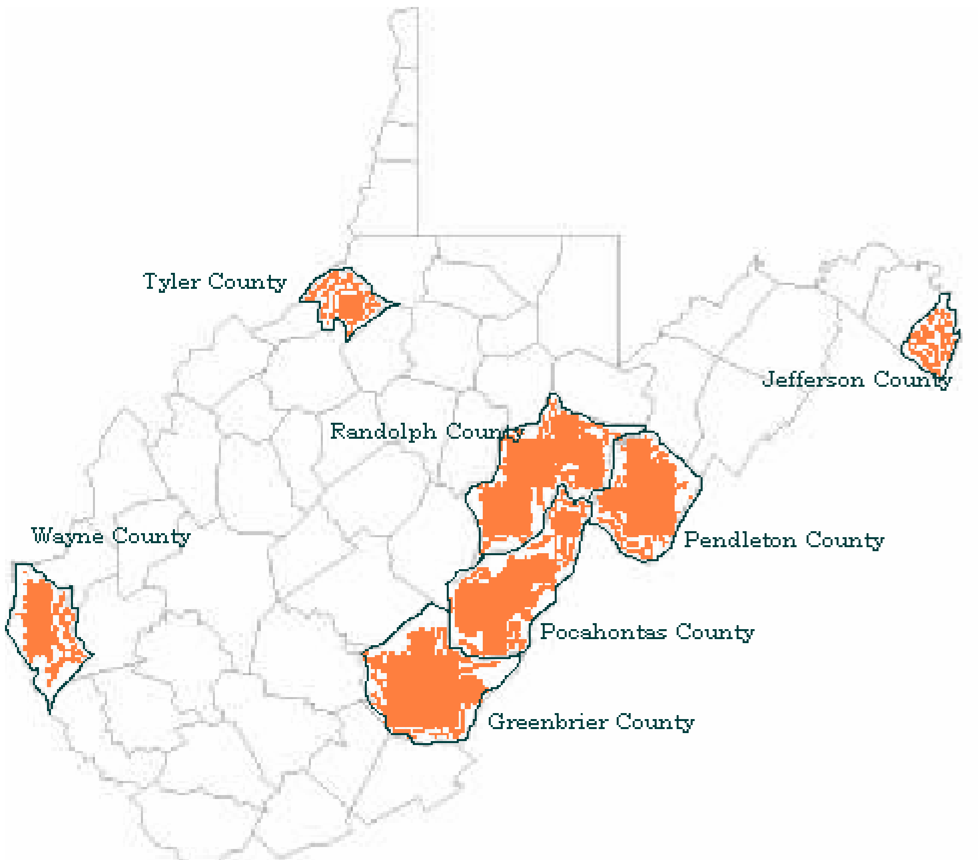

Table 1. Food items identified by fecal analysis.

| Scientific Name (Orders) | Common Name |
|---|---|
| Acarina | mites |
| Araneae | spiders |
| Coleoptera | beetles |
| Diptera | true flies |
| Hemiptera | true bugs |
| Homoptera | cicada, hoppers, and aphids |
| Hymenoptera | wasps, ants, and bees |
| Isoptera | termites |
| Lepidoptera | moths and butterflies |
| Trichoptera | caddisflies |

Figure 2. Lepidopteran scales.

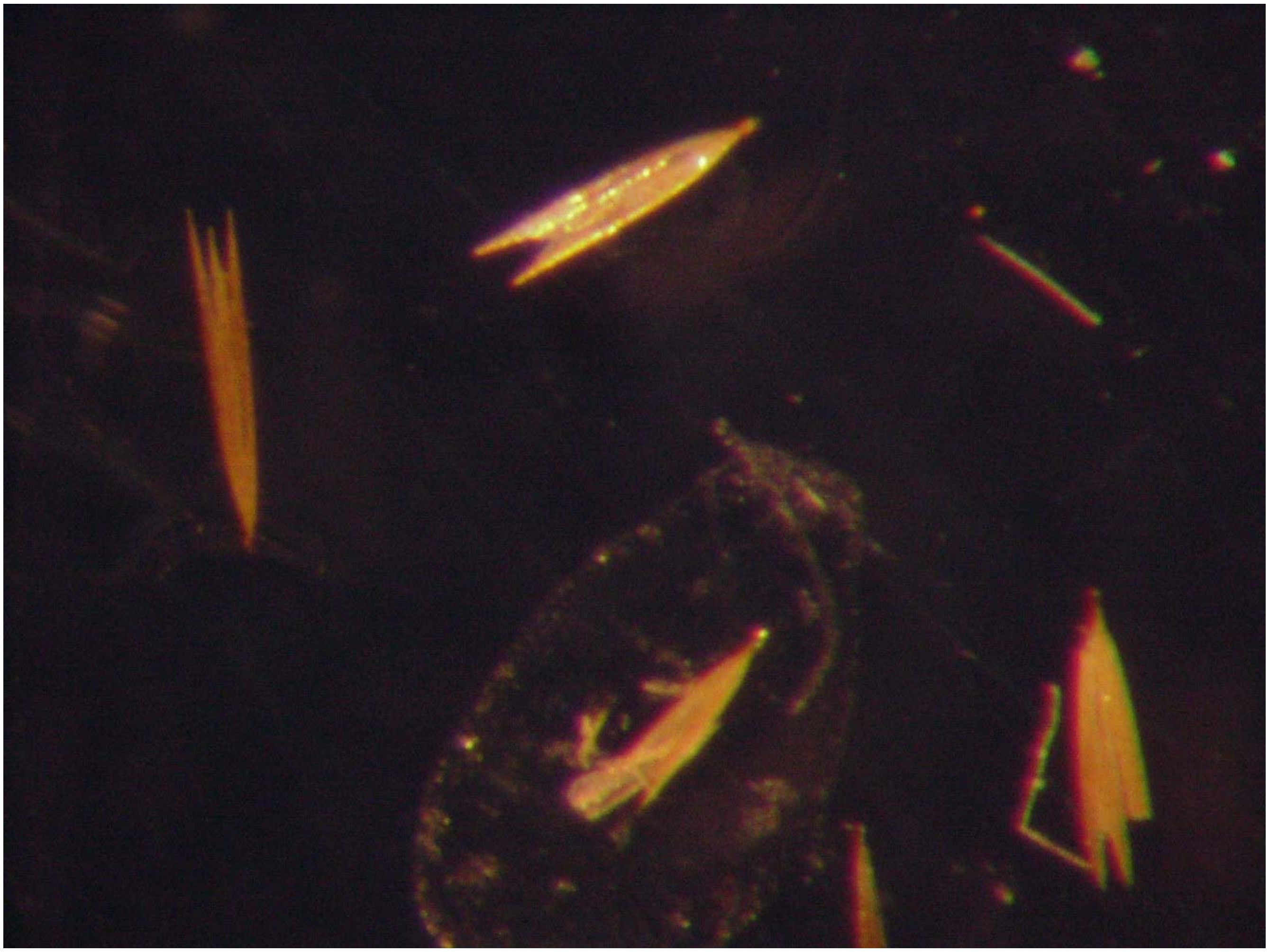

Figure 3. Dipteran eye.

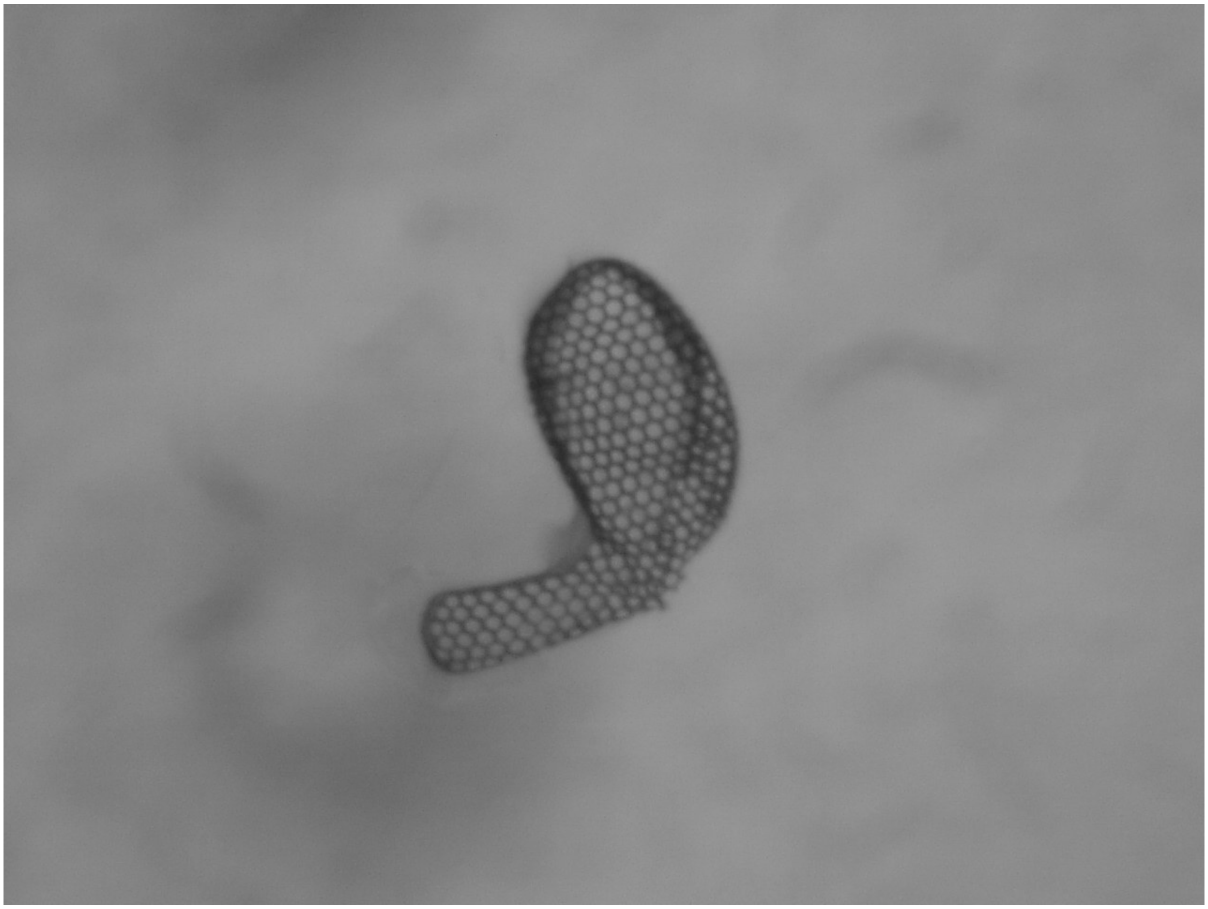

Figure 4. Hemipteran beak.

Figure 5. Coleopteran leg.

Table 2. Bat species included in the study.

| Species | Sample Size (Number of fecal pellets examined) |
|---|---|
| *Corynorhinus townsendii virginianus* | 70 |
| *Corynorhinus rafinesquii* | 30 |
| *Eptesicus fuscus* | 19 |
| *Lasiurus borealis* | 43 |
| *Myotis lucifugus* | 32 |
| *Myotis septentrionalis* | 38 |
| *Pipistrellus subflavus* | 19 |

Table 3. *Corynorhinus townsendii virginianus*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 89.5 | 100.0 |
| Coleoptera | 3.1 | 12.5 |
| Scarabaeidae (Coleoptera) | 3.1 | 12.5 |
| Unknown | 2.3 | 22.5 |
| Plant Material | 2.1 | 7.5 |
| Araneae | 0.4 | 7.5 |
| Trichoptera | 0.3 | 2.5 |
| Diptera | 0.1 | 2.5 |

Figure 6. *Corynorhinus townsendii virginianus*: percent volume of food items.

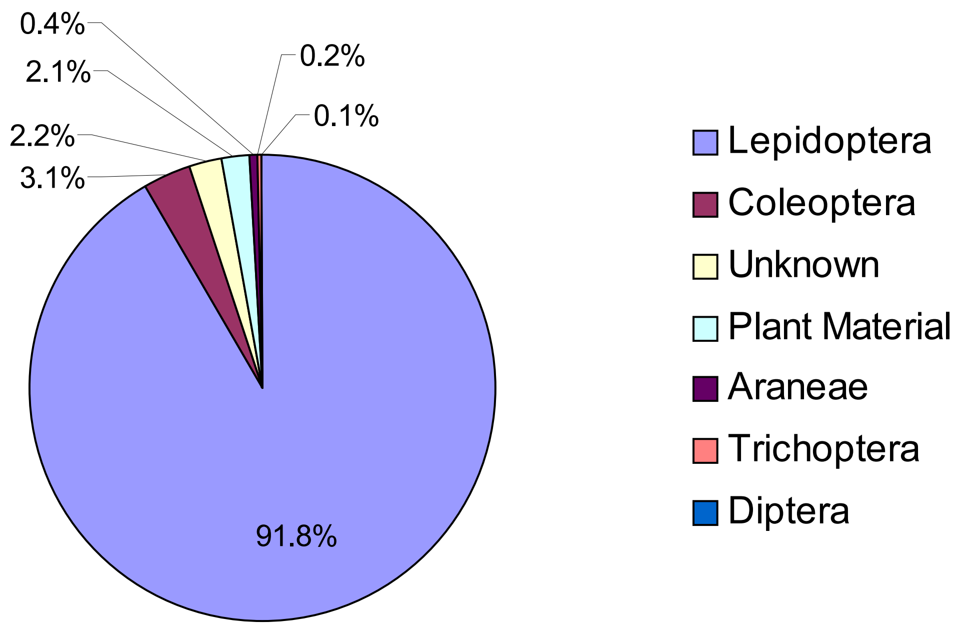

Figure 7. *Corynorhinus rafinesquii*: percent volume of food items.

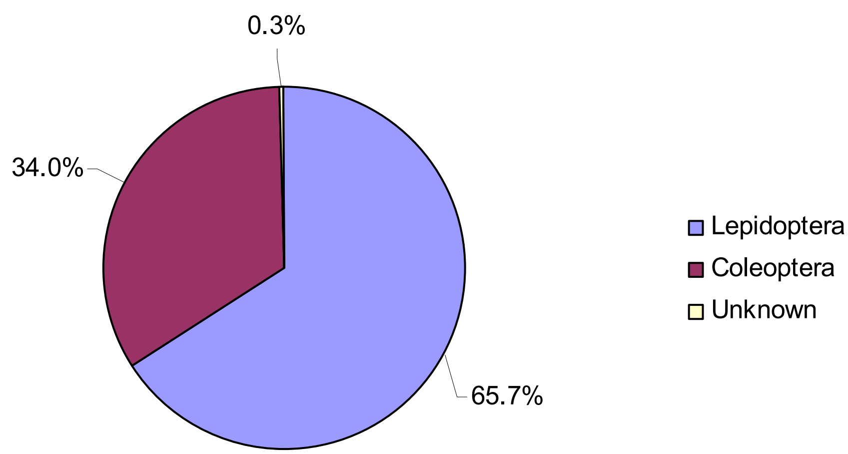

Table 4. *Corynorhinus rafinesquii*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 65.7 | 76.7 |
| Scarabaeidae (Coleoptera) | 20.0 | 66.7 |
| Coleoptera, unidentified | 14.0 | 46.7 |
| Unknown | 0.3 | 0.01 |

Table 5. *Eptesicus fuscus*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Pentatomidae (Hemiptera) | 29.7 | 84.2 |
| Coleoptera, unidentified | 25.3 | 42.1 |
| Chrysomelidae (Coleoptera) | 24.5 | 47.4 |
| Scarabaeidae (Coleoptera) | 5.5 | 10.5 |
| Carabidae (Coleoptera) | 5.5 | 15.8 |
| Unknown | 4.5 | 47.4 |
| Lepidoptera | 1.6 | 15.8 |
| Tipulidae (Diptera) | 1.6 | 15.8 |
| Trichoptera | 0.8 | 5.3 |
| Cicadellidae (Homoptera) | 0.8 | 5.3 |
| Acarina | 0.3 | 5.3 |

Figure 8. *Eptesicus fuscus*: percent volume of food items.

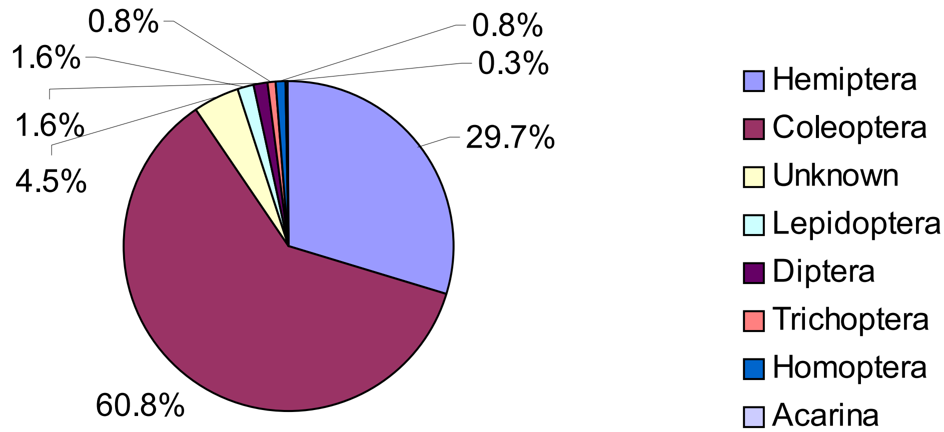

Table 6. *Lasiurus borealis*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 55.3 | 74.4 |
| Scarabaeidae (Coleoptera) | 17.1 | 46.5 |
| Coleoptera, unidentified | 11.2 | 32.6 |
| Cicadellidae (Homoptera) | 9.1 | 27.9 |
| Trichoptera | 4.1 | 32.6 |
| Unknown | 1.6 | 20.9 |
| Chrysomelidae (Coleoptera) | 0.7 | 4.7 |
| Pentatomidae (Hemiptera) | 0.4 | 7.0 |
| Isoptera | 0.4 | 7.0 |
| Araneae | 0.1 | 2.3 |
| Hemiptera, unidentified | 0.1 | 2.3 |

Figure 9. *Lasiurus borealis*: percent volume of food items.

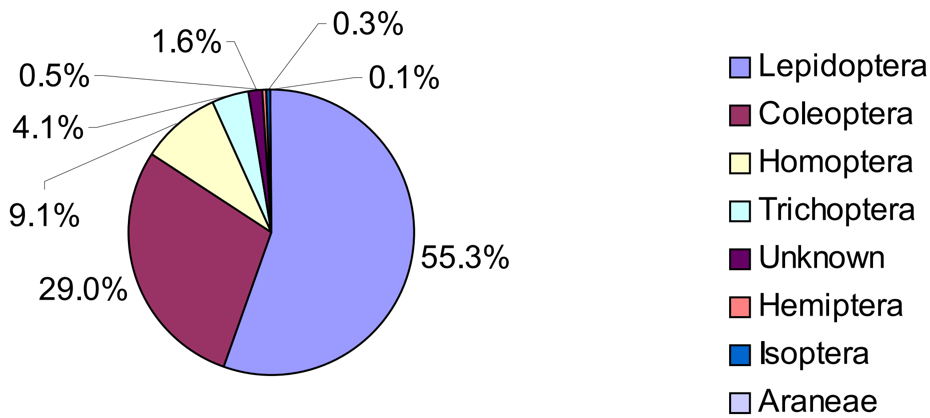

Figure 10. *Myotis lucifugus*: percent volume of food items.

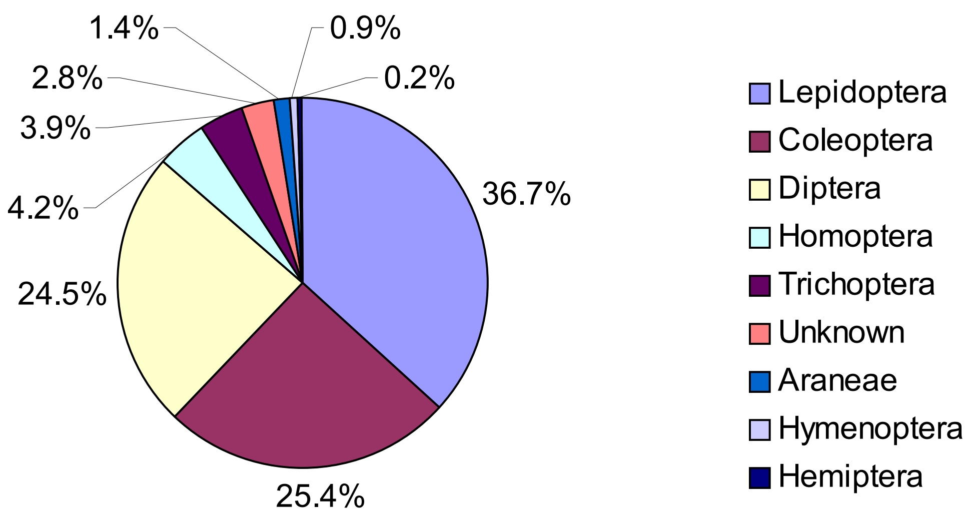

Table 7. *Myotis lucifugus*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 36.7 | 90.6 |
| Coleoptera, unidentified | 12.9 | 50.0 |
| Scarabaeidae (Coleoptera) | 10.4 | 28.1 |
| Diptera | 9.6 | 40.6 |
| Tipulidae (Diptera) | 9.1 | 34.4 |
| Chironomidae (Diptera) | 5.0 | 9.4 |
| Cicadellidae (Homoptera) | 4.2 | 15.6 |
| Trichoptera | 3.9 | 15.6 |
| Unknown | 2.8 | 37.5 |
| Carabidae (Coleoptera) | 1.6 | 6.3 |
| Araneae | 1.4 | 15.6 |
| Formicidae (Hymenoptera) | 0.9 | 3.1 |
| Culicidae (Diptera) | 0.8 | 3.1 |
| Chrysomelidae (Coleoptera) | 0.5 | 3.1 |
| Hemiptera | 0.2 | 3.1 |

Table 8. *Myotis septentrionalis*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 48.8 | 92.1 |
| Coleoptera, unidentified | 28.2 | 71.1 |
| Tipulidae (Diptera) | 10.1 | 52.6 |
| Scarabaeidae (Coleoptera) | 6.1 | 7.9 |
| Diptera, unidentified | 2.9 | 21.1 |
| Unknown | 1.5 | 15.8 |
| Culicidae (Diptera) | 0.7 | 7.9 |
| Araneae | 0.7 | 7.9 |
| Cicadellidae (Homoptera) | 0.5 | 5.3 |
| Hymenoptera | 0.4 | 2.6 |
| Isoptera | 0.3 | 2.6 |

Figure 11. *Myotis septentrionalis*: percent volume of food items.

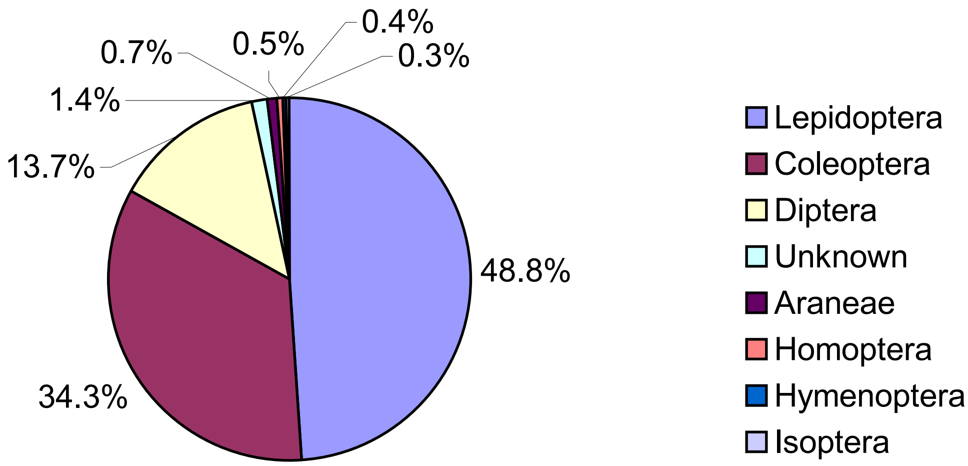

Table 9. *Pipistrellus subflavus*: percent volume, frequency of food items.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 35.0 | 47.4 |
| Hemiptera | 24.5 | 78.9 |
| Hymenoptera | 21.1 | 31.6 |
| Tipulidae (Diptera) | 11.1 | 57.9 |
| Cicadellidae (Homoptera) | 5.8 | 10.5 |
| Unknown | 1.1 | 10.5 |
| Diptera, unidentified | 1.1 | 10.5 |
| Trichoptera | 0.5 | 5.3 |

Figure 12. *Pipistrellus subflavus*: percent volume of food items.

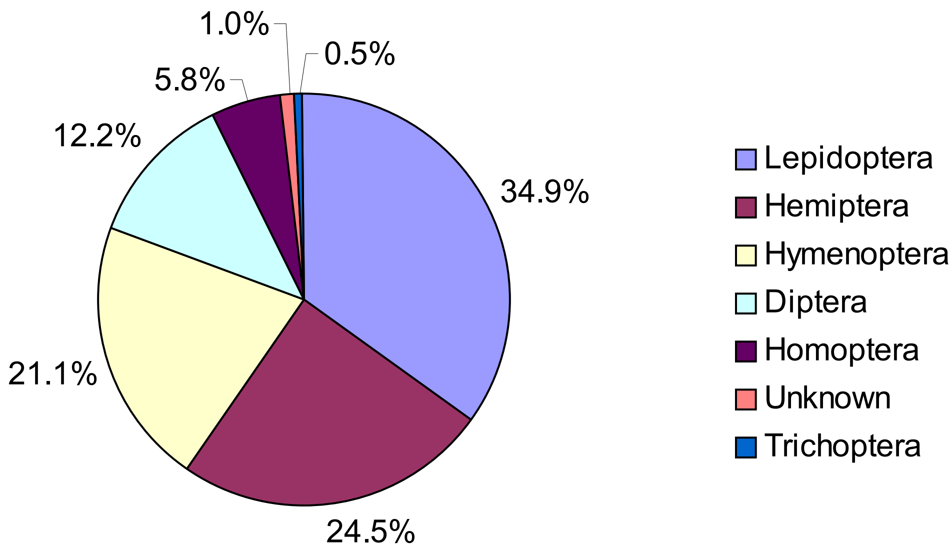

Table 10. *Corynorhinus townsendii virginianus*: percent volume, frequency of food items at Schoolhouse Cave, Pendleton County.

| Food item | Percent Volume | Percent Frequency |
|---|---|---|
| Lepidoptera | 40.7 | 53.3 |
| Coleoptera, unidentified | 36.2 | 43.3 |
| Hemiptera | 10.7 | 23.3 |
| Scarabaeidae (Coleoptera) | 6.3 | 10.0 |
| Unknown | 2.5 | 40.0 |
| Araneae | 2.5 | 13.3 |
| Hymenoptera | 0.7 | 10.0 |
| Diptera | 0.5 | 6.7 |

Table 11. Percentage of dietary overlap.

| | *C.t.v.* | *C.r.* | *E.f.* | *L.b.* | *M.l.* | *M.s.* |
|---|---|---|---|---|---|---|
| *C.townsendii virginianus* | --- | | | | | |
| *C. rafinesquii* | 88.7 | --- | | | | |
| *E. fuscus* | 6.9 | 15.9 | --- | | | |
| *L. borealis* | 60.0 | 69.6 | 34.2 | --- | | |
| *M. lucifugus* | 42.4 | 51.0 | 36.5 | 68.3 | --- | |
| *M. septentrionalis* | 53.4 | 63.1 | 39.4 | 80.1 | 78.4 | --- |
| *P. subflavus* | 35.9 | 35.2 | 29.9 | 42.7 | 54.0 | 49.0 |