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Diet of the *Myotis sodalis* (Indiana Bat) at an Urban/Rural Interface

Nicole M. Tuttle[1], David P. Benson[1], and Dale W. Sparks[2,*]

Abstract - We conducted a study of the diet of the federally endangered Indiana bat (*Myotis sodalis*) at an urban/rural interface near Indianapolis International Airport in summer 2004. We used two 1-m^2 quadrats covered with window screening to collect guano under a known roost tree. We then examined 20 fecal pellets/week until the bats abandoned the roost (i.e., 13 weeks). The most common orders of insects eaten were: Lepidoptera (35.3% volume, 84.6% frequency), Diptera (27.9%, 73.2%), Coleoptera (16.9%, 62.9%), and Hymenoptera (10.9%, 45.9%). Components of the diet at the ordinal level varied significantly over time. Despite the developed nature of the site, the diet consisted of the same components reported in earlier studies.

Introduction

A colony of federally-endangered *Myotis sodalis* Miller and Allen (Indiana bats) near Indianapolis International Airport (the airport, hereafter) has been studied since 1994 (Whitaker et al. 2004). The area surrounding the airport is rapidly developing, and thus offers a unique opportunity to examine responses of bats to urbanization (Duchamp et al. 2004, Sparks et al. 1998, Whitaker et al. 2004). Radio-telemetry studies of Indiana bats foraging near the airport indicate that highly developed areas such as suburbs and strip malls surrounding this site are seldom used by Indiana bats (Sparks et al. 2005a). Instead, this species appears to restrict foraging to less urbanized habitat consisting of a patchwork of forest fragments separated by agricultural fields and grasslands. These areas are associated with the East Fork of White Lick Creek, and are being managed by the Indianapolis Airport Authority in an effort to preserve this colony. This effort is hampered, however, by a lack of knowledge about how bats respond to urbanization (Sparks et al. 1998, 2005a). We are unsure why Indiana bats avoid highly developed areas, but hypothesize these areas provide little suitable food. Objectives of this study were to 1) determine the diet of Indiana bats at the Indianapolis Airport, and 2) compare these results to the diet of the Indiana bat in more rural landscapes, especially nearby portions of rural Indiana (Sparks et al. 2005b).

Methods and Materials

This study was conducted by obtaining guano from two 1-m^2 quadrats covered with window mesh beneath a single roost tree during the 13-week

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period beginning on 24 May and ending on 20 August 2004 when the roost was abandoned. We chose to exclusively use guano from this tree for three reasons. First, this tree was used by five radio-tagged Indiana bats during the summers of 2002 and 2003, making it the most consistently used roost tree at the study area. Second, the best data available indicates this tree is only used by Indiana bats, unlike several other roosts we could have chosen. None of the seven other species of bats that have been radio-tracked at the airport have roosted in this tree (Duchamp et al 2004, Everson 2005, Sparks 2003, Whitaker et al. 2004). We specifically avoided obtaining guano from artificial roosts that are used by four species including Indiana bats (Ritzi et al. 2005, Whitaker et al. 2006). Third, little under-story vegetation was present between roosts in this tree used by Indiana bats and the ground, which both maximized the amount of guano collected, and increased the likelihood the guano we collected was fresh.

Fecal analysis is known to provide a reasonable estimate of diet in insectivorous bats and does not require sacrificing animals (Whitaker 1988). As such, it is the only practical technique for determining diet of this endangered species. Fecal pellets were stored in plastic bags and frozen until examination. We examined a randomly-selected subsample of 20 pellets each week using established techniques (Murray and Kurta 2002, Whitaker 1988), except for 2 occasions where we analyzed more pellets (22 pellets for the week of 30 May and 38 pellets for the week of 11 June). Each fecal pellet was placed in a Petri dish, covered in 75% ethanol, dissected, and examined under a 10–30-power zoom dissecting microscope. Insect remains were identified to the lowest possible taxonomic level (usually family). Each insect type was visually estimated as the percent of the total pellet volume. We present results as both percent volume (average percent of a prey item making up each pellet) and percent frequency (the percent of pellets that contained a food item).

Following Whitaker (1988), we used a series of univariate ANOVAs followed by Student-Neuman-Keuls multiple range tests to compare arcsine transformed percent volumes for Lepidoptera, Diptera, Coleoptera, and Hymenoptera across weeks. All statistical analyses were conducted in SPSS 10.0 with an overall rejection level of $\alpha = 0.05$.

Results

We documented the presence of 9 orders and 26 families of arthropods in the diet (Table 1). Included were 5 pest species: *Diabrotica undecimpunctata* Barber (spotted cucumber beetle), *Cyrtepistomus castaneus* (Roelofs) (Asiatic oak weevil), *Acrosternum hilare* (Say) (green stink bug), mosquitoes (Family: Culicidae), and *Mayetolia destructor* (Say) (Hessian fly). The overall diet was dominated by moths (37.3% by volume, 84.6% by frequency), flies (27.9%, 73.2%), beetles (16.9%, 62.9%), and wasps/ants (10.9%, 45.9%), and was similar to diets (Fig. 1) reported in earlier studies conducted in more rural areas of Indiana (Belwood 1979,

Table 1. Food eaten by Indiana bat (*Myotis sodalis*) at a roost in Hendricks County, IN, during summer 2004. Totals for higher-level taxa are found in parentheses.

Food eaten	% by volume	% frequency
Arthopoda (total)	100.0	100.0
Insecta (total)	(99.9)	(100.0)
Lepidoptera (total)	(37.3)	(84.6)
Diptera (total)	(27.9)	(73.2)
Unknown Diptera	22.7	57.9
Nematocera (total)	(4.4)	(17.1)
Unknown Nematocera	0.6	2.9
Chironomidae	1.8	5.6
Culicidae	1.0	4.3
Tipulidae	1.0	5.7
Sciaridae	0.1	1.1
Cedciomyiidae (total)	(< 0.1)	(0.4)
Mayetiola destructor	< 0.1	0.4
Brachycera (total)	(0.9)	(7.5)
Muscoidea	0.5	6.8
Assilidae	0.4	0.7
Coleoptera (total)	(16.9)	(62.9)
Unknown Coleoptera	1.6	16.4
Cucurlionidae(total)	(10.6)	(34.3)
Unknown Cucurlionidae	2.9	11.1
Cyrtepistomus castaneus	7.7	23.2
Chrysomelidae (total)	(1.3)	(6.8)
Unknown Chrysomelidae	0.2	2.9
Diabrotica undecimpunctata	1.1	3.9
Chrysochus auratus (Fabricius)	0.5	12.5
Carabidae	2.3	5.0
Scarabaeidae (total)	0.8	1.4
Hymenoptera (total)	(10.9)	(45.9)
Unknown Hymenoptera	4.5	21.1
Chalcidoidea	0.4	0.7
Ichneumonidae	5.0	20.7
Braconidae	0.1	1.1
Formicidae	0.9	4.3
Homoptera (total)	(2.0)	(20.1)
Cicadellidae	1.8	17.9
Delphacidae	0.2	1.8
Flatidae	< 0.1	0.4
Trichoptera (total)	(1.6)	(8.2)
Hemiptera (total)	(0.9)	(11.0)
Unknown Hemiptera	0.3	3.2
Lygaeidae	0.5	6.4
Pentatomidae (total)	(0.1)	(1.4)
Acrosternum hilare	0.1	1.4
Neuroptera (total)	(0.5)	(3.1)
Chrysopidae	< 0.1	0.4
Hemerobiidae	0.5	2.9
Unidentified insect (total)	(1.6)	(5.4)
Arachnida (total)	(0.1)	(2.5)
Araneae	0.1	2.1
Acari	< 0.1	0.4

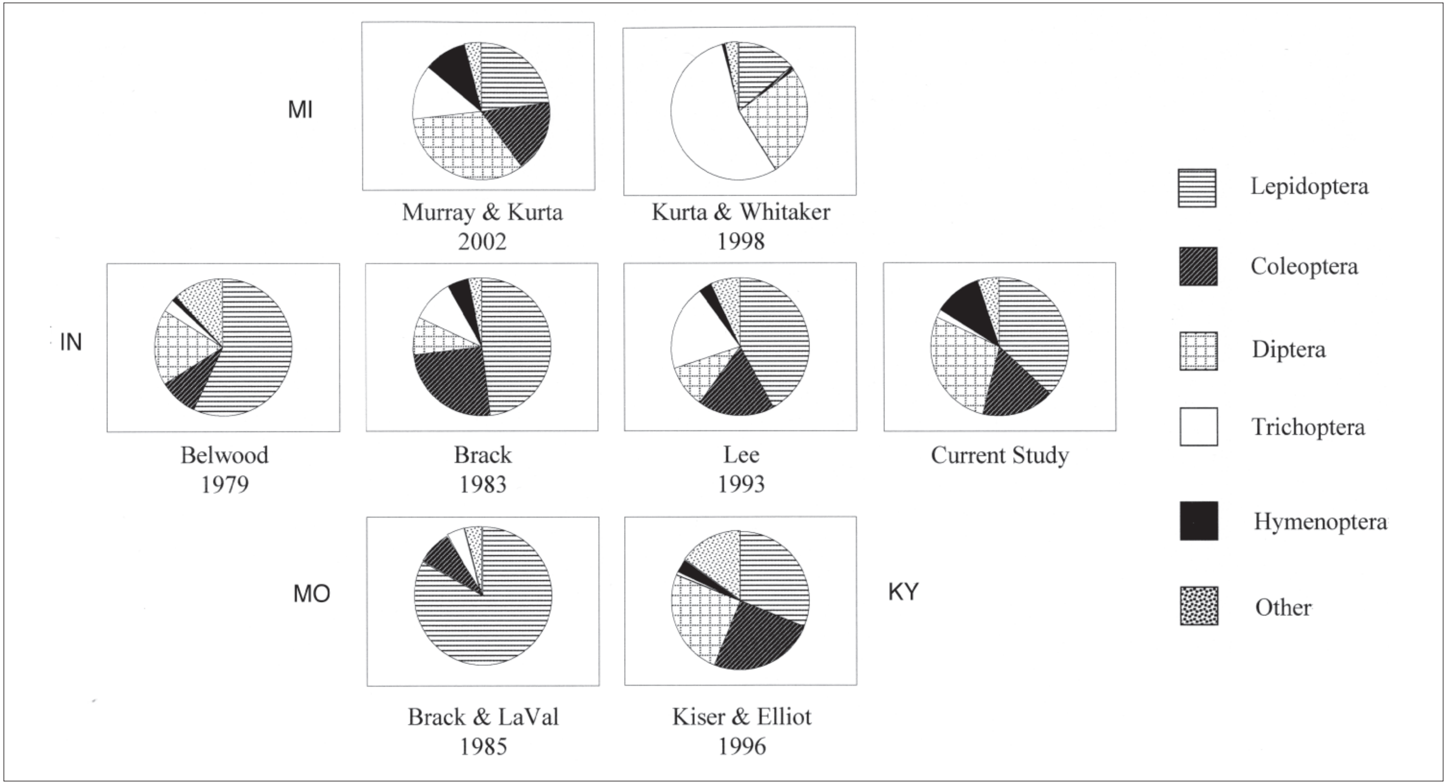

Figure 1. Comparison of diet across the range of Indiana bat (*Myotis sodalis*) for studies in which diets for more than 20 Indiana bats were included in the analyses. States are abbreviated by postal codes (MI = Michigan, IN = Indiana, MO = Missouri, and KY = Kentucky).

Brack 1983, Lee 1993), Kentucky (Kiser and Elliot 1996), and Michigan (Murray and Kurta 2002). Diet at the Indianapolis Airport was least similar to those reported from bats captured just prior to hibernation in Missouri (Brack and LaVal 1985) and at the northern extreme of the range in Michigan (Kurta and Whitaker 1998).

We found significant variation over the summer in proportions of lepidopterans ($F_{12,267} = 4.91$, $P < 0.001$), dipterans ($F_{12,267} = 4.90$, $P < 0.001$), coleopterans ($F_{12,267} = 4.91$, $P < 0.001$), and hymenopterans ($F_{12,267} = 4.91$, $P < 0.001$) in the diet (Fig. 2). Lepidopteran consumption peaked in June at 66.5% by volume, but were less than 20% of the diet during 3 other weeks. Diptera were almost absent from the diet in late July and then became increasingly important in August. Coleopterans, particularly Asiatic oak weevils, were the primary food at the beginning of August. Hymenopterans were typically a small proportion of the diet except during the week of 29 June, when they were only slightly less common than dipterans.

Discussion

Previous studies have recorded significant variation in the diet of Indiana bats across the range of the species, within single colonies through one or more seasons, between reproductive classes, and even between different parts of the night (see review by Murray and Kurta 2002). Similar to previous studies, the diet near Indianapolis shifts several times throughout the maternity season. These fluctuations in diet probably reflect differences in insect availability and changes in diet selection during the course of the maternity season. Barclay and Brigham (1994) suggested members of the genus *Myotis*

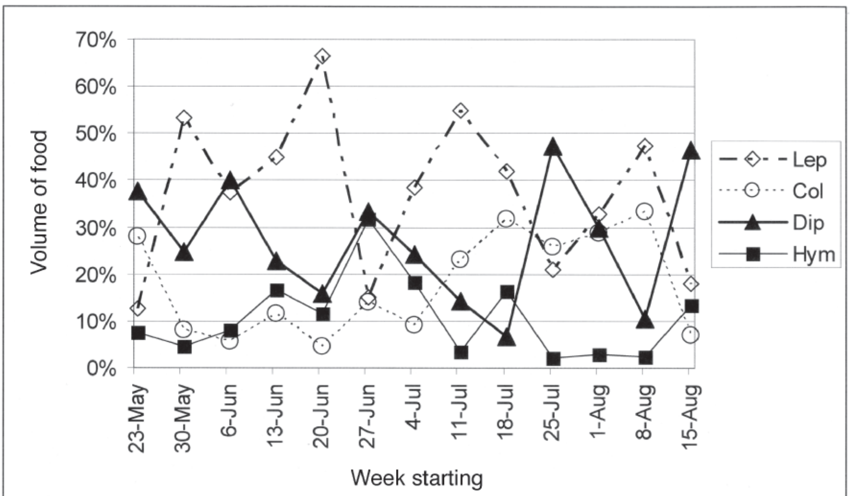

Figure 2. Variation in percent-volume of food items consumed by Indiana bats at the Indianapolis International Airport during 2004. Lep = Lepidoptera, Col = Coleoptera, Dip = Diptera, and Hym = Hymenoptera.

have difficulty in distinguishing between insect types because the bats have rapid flight speeds and short echolocation ranges. If so, *Myotis* spp. should have difficulty in selecting particular prey types. Conversely, several studies (Belwood 1979, Brack and LaVal 1985, Lee 1993) suggest Indiana bats consume some insects disproportionate to their abundance. These observations suggest bats are capable of selecting prey items, but as noted by Whitaker (1995), selection of prey occurs at multiple scales and bats may select prey items in part by modifying where they forage.

Despite these differences, it is also important to note that diet of Indiana bats is composed of the same components throughout the range of the bat (Sparks et al. 2005b). In the current as well as all previous studies, diets were dominated by a combination of moths, beetles, flies, caddisflies, and hymenopterans (Belwood 1979; Brack 1983; Brack and LaVal 1985; Kiser and Elliot 1996; Kurta and Whitaker 1998; Lee 1993; Whitaker 1972, 2004). When more than 20 Indiana bats were examined, > 50% of the diet consists of moths, true flies, and beetles (Fig. 1; Sparks et al 2005b), except at the northern extreme of the range (Kurta and Whitaker 1998) where caddisflies are particularly important. Thus, the diet of Indiana bat consists primarily of five orders of insects.

Previous authors rarely identified food items below the ordinal scale, but when such identification are made Asiatic oak weevils (Brack 1983, Brack and Whitaker 2004, Kiser and Elliot 1996), spotted cucumber beetles (Brack and Whitaker 2004, Kiser and Elliot 1996), ichneumon wasps (Kiser and Elliot 1996, Kurta and Whitaker 1998, Whitaker 1972), scarab beetles (Kurta and Whitaker 1998, Whitaker 1972), and ants (Kiser and Elliot 1996, Kurta and Whitaker 1998, Whitaker 1972) are all frequently reported.

Five of the insects we recorded in the diet of Indiana bats at the airport are pests. The most prevalent of these was the Asiatic oak weevil (7.7% by volume, 23.2% by frequency), which was often consumed in late July. Throughout our study, bats irregularly consumed mosquitoes (1.0% by volume, 4.3% by frequency), spotted cucumber beetles (1.1% by volume, 3.9% by frequency), and green stink bugs (0.1% by volume, 1.4% by frequency). We were surprised to find a wing of a Hessian fly (a pest of wheat) in one sample because wheat is uncommon in the area. Most authors do not identify dipterans below ordinal level, so this agricultural pest may have been overlooked in previous studies. We suspect that in future studies, many other pest species will be detected in the diet of Indiana bats.

Indiana bats near Indianapolis Airport ate many of the same foods as do bats in less-developed areas and forage in similar habitats (Sparks et al. 2005b). At present, properties conserved by Indianapolis Airport are providing foods similar to those consumed in more rural areas, but telemetry studies at Indianapolis Airport (Sparks et al. 2005a,b) indicate Indiana bats avoid highly developed lands. Thus, we suspect conservation efforts aimed at these bats must focus on maintaining appropriate foraging habitat. Indiana bats at this site frequently forage on privately-owned parcels surrounding the conservation lands, and many of these are being developed for commercial or residential use. Thus, we remain concerned that development surrounding this site will eventually negatively impact these bats by removing the remaining viable foraging habitat. As such, examining the types and quantities of insects available within these areas remains an important future project.

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