2007. Proceedings of the Indiana Academy of Science (116):196–199

FOOD HABITS OF MAMMALS DURING AN EMERGENCE OF 17-YEAR CICADAS (HEMIPTERA: CICADIDAE: *MAGICICADA* SPP.)

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ABSTRACT. We examined the diet of nine species of mammals in Vigo and Clay Co. Indiana during an emergence of 17-year cicadas (Cicadidae; *Magicicada* spp.) in May and June of 2004. Small mammals were snap-trapped, and larger mammals were collected dead along roadways. During the emergence, cicadas constituted over 51% (by volume) of the diet of short-tailed shrews (*Blarina brevicauda*) and raccoons (*Procyon lotor*), while the opossum (*Didelphis virginiana*), white-footed mouse (*Peromyscus leucopus*) and eastern chipmunk (*Tamias striatus*) consumed periodical cicadas in lesser amounts.

Keywords: diet, foraging, Indiana, *Peromyscus,* resource pulse

Resource pulses (*i.e.,* episodic periods of superabundance), such as the emergence of 17-year cicadas (hereafter termed cicada), have recently gained attention as factors that can have widespread effects on ecological communities (Ostfeld & Keesing 2000; Yang 2004). For instance, the emergence of cicadas can influence the population dynamics of avian (Anderson 1977; Strehl & White 1986; Koenig & Liebhold 2005) and mammalian species (Krohne et al. 1991). During spring of 2004, Brood X of the 17-year cicada (Hemiptera: *Magicicada cassini, M. septendecim* and *M. septendecula*) emerged across the middle-latitudes of the eastern United States. Cicadas are characterized by large size, slow flight, a general lack of anti-predator behavior (Karban 1982; Steward et al. 1988) and high density (up to 3 million/ha; Dybas & Davis 1962). These characteristics should make cicadas easily obtainable prey and have led to the hypothesis that the synchronized emergence of cicadas evolved as a means of predator swamping (Karban 1982; Williams et al. 1993). Cicadas are abundant along woodland edges and should be an easily obtainable food source for many terrestrial mammals. Given that cicadas are common both in trees and along the ground, we expected a variety of insectivorous and omnivorous mammals to feed on cicadas. In addition, the high density of cicadas may allow foraging rodents to minimize time spent foraging and therefore reduce their risk of predation (Lima & Dill 1990).

A wide variety of birds feed on cicadas (Howard 1937; Leonard 1964; Karban 1982; Strehl & White 1986; Stephen et al. 1990), but there has been little investigation of mammalian foraging on cicadas. Although there have been several studies on the diet of mammals in Indiana during non-cicada years (e.g. Whitaker 1966; Whitaker & Mumford 1972a, 1972b), few studies have assessed the impact of cicada emergence on the diet of mammals. The few previous studies have found that cicadas are consumed by the white-footed mouse (*Peromyscus leucopus*), short-tailed shrew (*Blarina brevicauda*) and prairie vole (*Microtus ochrogaster*; Hahus & Smith 1990; Krohne et al. 1991). The objective of our study was to assess the diet of mammals in west-central Indiana during a cicada emergence.

METHODS

Small mammals were collected in a grassy field along the edge of a mature 16.2 ha woodlot approximately 2 km NW of Brazil, Clay County, Indiana, from 21 May to 10 June 2004. The woodlot is predominantly composed of tulip tree (*Liriodendron tulipifera*)

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and a variety of oak (*Quercus* spp.) and hickory (*Carya* spp.) trees. During the emergence, there were numerous cicadas in trees, shrubs, and on the ground both within and along the woodlot. Small mammals were captured using snap-traps baited with peanut butter and rolled oats. Larger mammals (squirrels, opossum, raccoons, and eastern moles) were collected dead along roadways in Clay and Vigo counties, Indiana, in areas where cicadas were abundant.

Stomachs were removed and placed in a Petri dish filled with ethanol. Food items were identified using a reference collection of cicada remains and keys in Whitaker (1988) and Arnett (2000). The percent volume of each prey type was visually estimated and the total percent volume for each prey type was calculated using the methods in Whitaker (1988).

RESULTS

Although all samples were small, six of the nine mammal species we collected had fed upon cicadas (Table 1). Cicadas constituted over 51% (by volume) of the diet of short-tailed shrews and raccoons (*Procyon lotor*) and were present in 66.7% and 77.3% of individuals, respectively. Cicadas were less common in the diet of the opossum (*Didelphis virginiana*), white-footed mouse, eastern mole (*Scalopus aquaticus*) and eastern chipmunk (*Tamias striatus*). The prairie vole, woodland vole (*Microtus pinetorum*), and fox squirrel (*Sciurus niger*) did not contain any cicada remains in their stomachs.

DISCUSSION

Several species of mammals consumed cicadas, but none fed on cicadas to the exclusion of other prey. Many of the cicadas were unavailable to foraging non-arboreal mammals since cicada nymphs crawl toward the nearest tree trunk upon emergence (Dybas & Lloyd 1974) and adult cicadas spend most of their life in the tree canopy (Williams & Simon 1995). However, during the time of our trapping, many cicadas were readily available on the ground both within and along the edge of the woodlot. The lack of complete specialization on cicadas may relate to the availability of non-cicada prey or the importance of complementary resources in the diet.

The northern short-tailed shrew feeds primarily on invertebrates, especially earthworms and gastropods (Whitaker & Mumford 1972a; Mumford & Whitaker 1982). Despite the fact that northern short-tailed shrews often forage below ground (George et al. 1986), cicadas were a common component of their diet. Earthworms were also common in the diet during the emergence, but cicadas were the most prevalent food. Similar to our results, Hahus & Smith (1990) and Krohne et al. (1991) found that northern short-tailed shrews feed on cicadas.

Although eastern moles feed primarily on invertebrates (Whitaker & Schmeltz 1974; Mumford & Whitaker 1982), cicadas were not common in their diet, likely due to the fossorial habits of moles. Although we found no evidence of cicada nymphs or adults in the stomachs of moles, it is possible that moles fed on cicada nymphs prior to the nymphs emergence from the ground. Eastern moles feed on beetle larvae (Hartman et al. 2000) and it has been hypothesized that subterranean foraging by moles may influence cicada populations (Lloyd & Dybas 1966). Similar to Hahus & Smith (1990), we found that white-footed mice fed upon cicadas. Given the omnivorous foraging habits of white-footed mice and their preference for forested habitats (Barry & Francq 1980), the presence of cicadas in the diet was expected.

Raccoons are opportunistic foragers, (Mumford & Whitaker 1982) so the large number of cicadas in their diet is not surprising. Eastern chipmunks are predominantly herbivorous and granivorous (Mumford & Whitaker 1982); however, we expected chipmunks to forage on cicadas. The scarcity of cicada remains in our study likely reflects the small number of individuals examined, rather than an avoidance of cicadas by foraging chipmunks. Fox squirrels generally feed on mast (Mumford & Whitaker 1982), and none of the individuals we examined had eaten cicadas; however, both gray and fox squirrels were observed eating cicadas (J. Whitaker, pers. obs.). Prairie and woodland voles are primarily herbivorous (Mumford & Whitaker 1982) and did not feed on cicadas during this study. Hahus and Smith (1990) reported that prairie voles fed upon cicadas, but they constituted less than 2% of the diet in their study.

ACKNOWLEDGMENTS

We thank J. Boyles, V. Brack, D. Sparks and M. Storm for comments on the manu-

Table 1.—Number of individuals sampled and percent volume of each food type in the diet of mammals during an emergence of periodical cicadas (*Magicicada* spp.) in Vigo County and Clay County, Indiana, 2004.

Prey Type	*Blarina brevicauda*	*Didelphis virginiana*	*Microtus ochrogaster*	*Microtus pinetorum*	*Peromyscus leucopus*	*Procyon lotor*	*Scalopus aquaticus*	*Sciurus niger*	*Tamias striatus*
Sample size (n):	10	1	4	2	3	6	6	2	4
Animalia	100.0	40.0	0.0	0.0	25.0	80.9	98.3	0.0	11.6
Bird	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Earthworm	41.0	0.0	0.0	0.0	0.0	15.0	70.5	0.0	0.0
Mollusk	0.0	0.0	0.0	0.0	0.0	6.7	16.7	0.0	0.0
Arthropoda	59.0	25.0	0.0	0.0	25.0	59.2	11.1	0.0	11.6
Arachnida	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Crayfish	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insecta	59.0	15.0	0.0	0.0	25.0	58.4	11.1	0.0	11.6
Unidentified insect	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
Carabidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5
Coleoptera	2.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
Diptera	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Formicidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Insect larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Lepidoptera	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0
Magicicada	53.0	15.0	0.0	0.0	25.0	51.7	5.0	0.0	3.8
Plantae	0.0	60.0	100.0	100.0	75.0	19.2	1.7	100.0	88.8
Blackberry	0.0	0.0	0.0	0.0	26.7	0.0	0.0	0.0	0.0
Fruit	0.0	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0
Mast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	65.0
Mulberry	0.0	60.0	0.0	0.0	0.0	16.7	0.0	75.0	23.8
Seeds	0.0	0.0	0.0	0.0	23.3	0.0	0.0	0.0	0.0
Vegetation	0.0	0.0	100.0	100.0	0.0	2.5	1.7	0.0	0.0

script. This project was approved by the Indiana State University Institutional Animal Care and Use Committee.

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Manuscript received 14 June 2007, revised 10 August 2007.