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FOOD HABITS OF GRAY FOXES *(UROCYON CINEREOARGENTEUS)* AND RED FOXES *(VULPES VULPES)* IN EAST TENNESSEE

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ABSTRACT

One–hundred and seventy fox scats were collected for food habit analysis between September 1986 and September 1987 on the Oak Ridge Reservation in east Tennessee. To avoid bias, no distinction was attempted between scats of gray *(Urocyon cinereoargenteus)* and red *(Vulpes vulpes)* foxes, however concurrent trapping indicated a population of 3:1, respectively. Analysis revealed that plant foods were most highly represented, followed by invertebrate and vertebrate prey. Proportions of these three categories utilized were not evenly distributed between months and were probably dictated by availability. Biological seasons were determined by statistical detection of dietary shifts between the three food categories. Vertebrate prey, predominantly rabbits and rodents, comprised 67.0% of winter (January–April) dry weight (66.6% occurrence); arthropods, predominantly 17–year locusts, comprised 96.1% of spring (May) dry weight (100.0% occurrence); plant material, predominantly persimmon, cherry, blackberry and squaw–root, comprised 92.9% of summer–fall (June–December) dry weight (100.0% occurrence). Foxes may switch dietary trophic level depending on seasonal food availability.

INTRODUCTION

Numerous studies of fox food habits indicate the opportunistic and omnivorous nature of these carnivores (e.g. Nelson 1933; Errington 1935; Kozicky 1943; Glover 1949; Scott 1955; Wood *et al.* 1958; Trapp and Hallberg 1975; Trapp 1978; King 1981; Hockman and Chapman 1983). Most studies show that food availability and abundance play a major role in diet composition. Seasonal analysis suggests dietary emphasis on mammals in the winter, while arthropods (especially orthopterans) and plant materials become important dietary components in summer and autumn months. Knowledge of seasonal food habits is important in assessing the biological needs of a species. It is also of importance in understanding habitat use, and the relationship between dietary trophic level and home range size (Gittleman and Harvey 1982) within a species.

Nonbiological determination of "season" allows for error in interpretation and comparison of seasonal food habits. For example, Hockman and Chapman (1983) title "autumn" September-November and "winter" December–February in the Appalachian and Piedmont provinces of Maryland; Wood *et al.* (1958) refer to April–September as "summer" and October–March as "winter" in Georgia; Scott (1955) titles "winter" January–March in Iowa; Nelson (1933) titles "winter" December–March in Virginia; Kozicky (1943) refers to September–November as "late summer and early fall;" Ashby (1974) contrasts fall and winter combined, with spring and summer combined. Other studies do not specify seasons except by vague reference (e.g. Glover 1949; Yoho and Henry 1972). Determination of seasons would be more meaningful by statistical detection of significant dietary shifts, and grouping months of similar food habit into biological seasons. It is the purpose of this study to document the food habits of foxes in east Tennessee, and to suggest seasonal differences in the exploitation of different food sources based on availability.

STUDY AREA

The study area was located within the National Environmental Research Park (NERP), on the Department of Energy Oak Ridge Reservation approximately 28 km west of Knoxville, Tennessee. The study area lies between approximately 84° 16' to 84° 21' west longitude and 35° 56' to 35° 58' north latitude.

The NERP contains a diversity of vegetation community types, including both natural and managed yellow pine forests, eastern red cedar barrens, oak–hickory forests, bottomland hardwood forests, old fields, as well as developed areas. The Tennessee Valley Authority's Melton Hill Reservoir and Watts Barr Lake, which border the reservation on the west, south and east, and numerous streams and springs throughout the area provide an abundance of wetland habitat and water for a variety of wildlife species.

The geology of the reservation is characteristic of the Southern Appalachian Ridge and Valley province. Parallel, southwest–northeast–oriented ridges separated by valleys (elevation ranging from 226 to 413 m above sea level) lend additional diversity to the landscape.

Methods and Materials

A total of 170 fox scats were randomly collected along infrequently used roads throughout the study area in all months between September 1986 and September 1987. The area sampled was great enough to ensure that samples were representative of several animals (based on concurrently documented home range sizes and locations, and those noted in the literature). In addition, the sampling area encompassed a variety of habitat (food source) types to eliminate the possibility of habitat–biased samples. Sample size per month varied from 3 to 21 (mean=14.17). Scats were identified by shape, size, odor and their characteristic prominent location. To avoid bias, no attempt was made to distinguish between scats of gray *(Urocyon cinereoargenteus)* and red *(Vulpes vulpes)* foxes, however concurrent trapping indicated a population of 3:1, respectively. Each scat was collected in a plastic bag; date and location were recorded. Only fresh scats (estimated at less than one week old) were collected to ensure accurate representation of monthly food habits.

Specimens were prepared for analysis following the methods of Scott (1941): each scat was soaked in warm water to soften, then washed through two sieves (no's. 10 and 35) over a glass beaker to catch any important material which might occasionally pass through. The remaining material was air dried. All items were hand separated and analyzed with the assistance of a magnifying glass and/or binocular microscope (12–15x).

Seeds were identified according to Martin and Barkley (1961) and verified with a personal collection of known seeds or the extensive seed collection of Paul and Hazel Delcourt (University of Tennessee). Bones and bone fragments were identified by zooarchaeologist Lynn Snyder (Anthropology Department, University of Tennessee) using comparative faunal materials from the vertebrate osteological collection maintained by the Department of Anthropology, University of Tennessee, Knoxville. Additional dental formulae were taken from Hall (1981). Hairs were identified by comparison with reference materials. Arthropods were identified to order using a Petersons guide (Borror and White, 1970), numerous 4–H guides, and the reference collection at the Entomology Department, University of Tennessee, Knoxville.

Food types were recorded as percentage frequency of occurrence (number of scats in which a food item or food category was found), and percentage dry weight. Animal weight included bones, teeth and/or hair if present. Plant weight included seeds, fruit skins and flesh, and grass. To maximize time efficiency and reduce error involved in minute weights of individual invertebrates, the weight of all invertebrates per scat was combined. Therefore only percentage occurrence is recorded for individual invertebrate orders.

For statistical comparison, each food type was categorized as plant, invertebrate or vertebrate. The mean weight for each food category was plotted by month. While different food types may be differentially assimilated during the digestion process, these differences may be assumed to remain constant in all months. Therefore, significant changes in the representation of the three food categories over time is assumed to indicate a corresponding change in the consumption of these categories by foxes.

Data were examined for normal distribution and homogeneity of variance. An (ANOVA) (SAS Inst., Inc. 1985), with Tukey's studentized range test, was run for each month to test for significant differences in dry weight among the three food categories. Each month was then compared against all other months to test whether the relative proportions of plant, vertebrate or invertebrate dry weight were significantly ($p>0.05$) different from other months. Similar months (containing a significantly greater proportion of a given food category, or containing no significant differences) were pooled (as "seasons") for statistical contrast against other "seasons." In this manner three biological seasons were determined based on fox food habits.

Results and Discussion

A total of 52 food taxa were identified from all scats (Table 1). Twenty–four identified plant taxa comprised 78.6% of the total annual dry weight, and occurred in 89.4% of the scats. Persimmon *(Diospyros virginiana)* was the most highly represented plant food, accounting for 43.4% of dry weight, and occurring in 41.8% of the scats. Black cherry *(Prunus serotina)* (20.2% wt; 12.9% occurrence) blackberry (*Rubus* sp.) (4.0% wt; 10.6% occurrence) and squaw–root *(Conopholis americana)* (6.3% wt; 4.7% occurrence) were well represented fruit items. Twelve invertebrate orders comprised 13.0% of total annual scat content by dry weight (74.7% occurrence). Coleopterans (57.6% occurrence), orthopterans (42.4% occurrence) and homopterans (18.8% occurrence) occurred most often.

Vertebrate material comprised only 8.4% of the total annual dry weight, occurring in 37.7% of the scats. Annu-

Table 1. Contents of 170 fox scats in east Tennessee, 1986-1987.

Food Item	Percentage Dry Weight	Percentage Occurrence
ANGIOSPERMAE	78.58	89.41
Diospyros virginiana (persimmon)	43.43	41.76
Prunus serotina (cherry)	20.18	12.94
Rubus sp. (blackberry)	3.96	10.59
Conopholis americana (squaw root)	6.32	4.71
Vitis sp. (grape)	0.26	3.53
Morus rubra (mulberry)	1.95	2.94
Quercus sp. (oak)	0.07	2.94
Rhamnus caroliniana (buckthorn)	0.11	2.94
Cornus florida (dogwood)	0.11	1.76
Parthenocissus quinquefolia (VA creeper)	0.35	1.18
Vitis rotundifolia (muscadine)	0.08	1.18
Phytolacca americana (pokeweed)	0.02	1.18
Cercis canadensis (redbud)	0.01	1.18
Acer sp. (maple)	Trace	1.18
Eleagnus sp. (silverberry)	0.02	0.59
Leguminosae	0.06	0.59
Compositae	0.01	0.59
Cornus amomum (dogwood)	Trace	0.59
Nyssa sp. (gum)	0.03	0.59
Rhus radicans (poison ivy)	0.02	0.59
Prunus americana (plum)	0.09	0.59
Carya sp. (hickory)	0.01	0.59
Pyrus sp. (pear)	0.01	0.59
Gramineae sp.	0.94	24.70
INVERTEBRATA	13.00	74.71
Coleoptera		57.64
Orthoptera		42.35
Homoptera		18.82
Coleopteran larvae		7.06
Hymenoptera		3.53
Hemiptera		2.35
Lepidoptera (cocoon)		1.18
Lepidoptera (caterpillar)		1.18
(continued)		
Annelida		1.18
Ephemeroptera		1.76
Diplopoda		0.59
Copopoda		0.59
Isopoda		0.59
Gastropoda		1.18
Unidentified		2.94
VERTEBRATA	8.42	37.65
(MAMMALIA)	7.58	19.42
Sylvilagus floridanus (cottontail rabbit)	4.03	7.06
Odocoileus virginianus (whitetail deer)	1.71	4.70
Peromyscus sp. (mouse)	0.18	3.53
Microtus pinetorum (pine vole)	0.43	2.94
Marmota monax (woodchuck)	0.79	1.76
Tamias striatus (chipmunk)	0.13	1.18
Sigmodon hispidus (cotton rat)	Trace	0.59
Mephitis mephitis (striped skunk)	Trace	0.59
Lasiurus sp. (bat)	0.01	0.59
Myotis sp. (bat)	0.03	0.59
Blarina brevicauda (shorttailed shrew)	Trace	0.59
Unknown	0.27	4.11
(AVES)	0.38	5.88
(AMPHIBIA)	0.32	2.35
Plethodontidae	0.17	1.76
Rana sp. (frog)	0.15	0.59
(OSTEICHTHYES)	0.01	1.18
Micropterus sp. (bass)	0.01	0.59
Unknown sp.	Trace	0.59
(REPTILIA)	0.13	0.59
Colubridae	0.13	0.59
UNKNOWN	0.15	8.23

ally, mammals (11 identified species) were most highly represented, comprising 7.6% of the total annual vertebrate dry weight, and occurring in 19.4% of the scats. Rabbit *(Sylvilagus floridanus)* and white-tailed deer (probably carrion from road kills) were the most highly represented vertebrate items by percentage dry weight and percentage occurrence. Also of interest was the occurrence of two bats: *Myotis* sp. in February, and *Lasiurus* sp. in December. Bird remains occurred in 5.9% of scats (0.4% weight); none were identified to specific taxa. Amphibians (2.4% occurrence), fish (1.2% occurrence) and reptiles (0.6% occurrence) occurred infrequently in fox scats.

Distribution of food categories (plant, invertebrate and vertebrate) was not uniform between months (Figure 1). Analysis of variance with Tukey's studentized range test revealed no significant differences between dry weights of food categories in January (n=3; p=0.4666), February (n=18; p=0.1165), March (n=13; p=0.0760) and April (n=8; p=0.3249). Vertebrate dry weight comprised 86.7% of mean total weight for January, and 69.1%, 67.7%, and 56.0% for February, March and April, respectively. Large variance in vertebrate dry weight between scats, possibly due to erratic food (animal prey) availability, may have obscured detection of significant differences for these months. January–April were grouped despite this, since they were also the only four months where no significant differences among the three food categories were detected. Dry vertebrate weight for January–April was contrasted against other months; a significant difference (n=42; p=.0001) was detected, indicating that significantly more vertebrate than plant or invertebrate material was consumed by foxes between January–April, 1987 than in other months. Hence, January–April are referred to as "winter," where vertebrates were the predominant dietary component.

Arthropods comprised a significantly greater portion of total dry weight than vertebrate or plant material in May only (n=16; p=0.0001). A contrast between invertebrate dry weight in May versus other months revealed a highly significant difference (n=16; p=0.0001). Therefore, May alone is referred to as "spring," where invertebrates were the predominant dietary component represented in scats.

Plant material comprised a significantly greater portion of total dry weight than vertebrate or invertebrate components in June (n=11; p=0.0001), July (n=11; p=0.001), August (n=13; p=0.0001; September (n=21; p=0.0001), October (n=18; p=0.0001). November (n=18; p=0.0001) and December (n=20; p=0.0001). A contrast of dry plant–material weight for June–December versus other months revealed a highly significant difference (n=112; p=0.0001). Therefore, June–December is referred to as "summer–fall," where plants were the predominant dietary component represented in scats.

Distribution of food categories (plant, invertebrate and vertebrate) and food items within a category was not uniform among the three seasons (Figure 2). Vertebrate

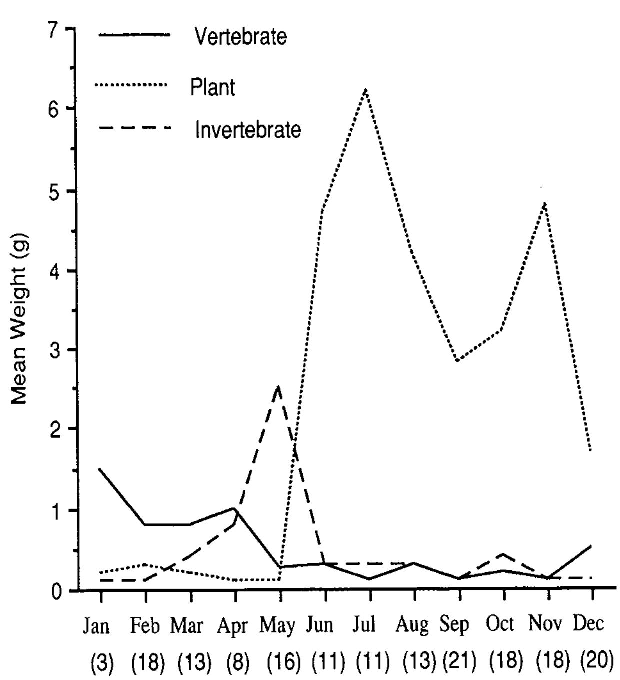

Figure 1. Mean monthly dry weights of Plant, Invertebrate and Vertebrate Material in Fox Scats, East Tennessee, September 1986-August, 1987. Sample sizes in parentheses.

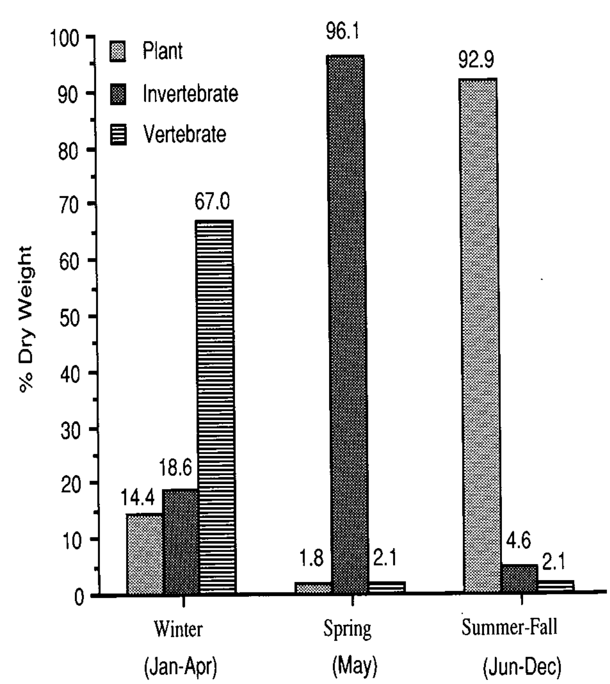

Figure 2. Winter (n=42), Spring (n=16) and Summer-Fall (n=112) Comparison of Percentage Dry Weight of Plant, Invertebrate and Vertebrate Material in Fox Scats, East Tennessee, September 1986-August 1987.

material comprised 67.0% of total winter dry weight and occurred in 66.6% of winter scats, while arthropods comprised only 18.5% dry weight (57.1% occurrence) and plant material 14.4% (59.5% occurrence) (n=42). Vertebrate material comprised over 2.2 times the expected vertebrate winter dry weight (where "expected" is defined as even distribution of weight among all months) while only 5% of expected plant, and 40% of expected invertebrate weight occurred during winter. Rabbit and white–tailed deer (probably carrion) were the most highly represented animal food items in the winter season, followed by *Peromyscus* sp. and pine voles. Ashby (1974) also found these four species to be the most common mammalian genera in east Tennessee gray fox diets. Coleopterans were the most frequently occurring invertebrates, while persimmon and acorn were the most highly represented fruit items during winter.

Invertebrate material comprised 96.1% of total dry weight in spring (100% occurrence) while vertebrate material comprised only 2.1% dry weight (18.8% occurrence) and plant material 1.8% dry weight (93.8% occurrence) (n=16) (Figure 2). Invertebrate material comprised over 6.8 times the expected invertebrate spring dry weight, while only 2% of expected plant, and 23% of expected vertebrate weight occurred during spring. The predominance of homopteran insect material in May scats coincided with the peak emergence of the 17–year locust *(Magicicada* sp.). This presented a unique case, perhaps overly emphasizing or artificially suggesting a dietary shift toward invertebrate prey in spring. Coleopterans and orthopterans also occurred frequently. Squaw–root was the most highly represented plant item in spring; the only spring animal prey included one snake (Colubridae) and a chipmunk *(Tamias striatus).*

Plant material comprised 92.9% of the total summer–fall food weight (100% occurrence), while invertebrate material comprised only 4.6% (77.7% occurrence) and vertebrate material only 2.5% dry weight (29.5% occurrence) (n=112) (Figure 2). Plant material comprised over 1.6 times the expected plant summer–fall dry weight, while only 42% of expected vertebrate, and 51% of expected invertebrate weight occurred during this season. Utilization of fruit species shifted over the six summer–fall months. Squaw–root comprised the bulk of June plant weight and percent frequency of occurrence, but was present only in small quantities in all remaining summer–fall months. Blackberry was highly represented from June–August; black cherry in July and August, and persimmon from September–December. Coleopterans, orthopterans and homopterans were most highly represented invertebrate food items, and rabbit and bird were the most highly represented vertebrate dietary items in the summer–fall season.

Such striking shifts between dietary trophic levels have not been reported for foxes, although opportunistic use of seasonally available foods is often noted. Non–biological separation of seasons, and reporting methodologies could obscure dramatic shifts in dietary trophic level which might occur.

Trapp (1978) reported a predominance of fruit in the gray fox autumn diet in Utah, but the proportion of mammal and/or arthropod food items was also of some importance. While mammals comprised a large proportion of winter gray fox diet, so did fruit. Arthropods were prevalent in the spring and summer diet, but not to the virtual exclusion of plant or animal food categories. Availability of invertebrates, however, was probably lower than in this instance, where 17–year locusts were superabundant. Similarly, Wood *et al.* (1958) noted that rabbits, rodents and birds comprised 71% by volume of the winter (October–March) diet, and 44% of the summer (April–September) diet in north Florida, south Georgia and South Carolina. Insects accounted for 41% of summer, and 8% of winter volume. Ashby (1974) reported that mammals occurred in 74.7% of the fall–winter diet and 86.3% of the spring–summer diet, although the occurrence of insects and vegetative matter increased in spring–summer by 27.7% and 33.9% respectively. Nearly exclusive reliance upon a single food category was not as apparent in these studies as in the current study.

In contrast, Yearsley and Samuel (1980) noted that gray fox scats in October were composed almost entirely of autumn olive (*Eleagnus* sp.) in West Virginia. Hamilton *et al.* (1937) reported that some red fox scats were comprised of almost 100% fruits and berries in late summer and early fall in Massachusetts. Nelson (1933) and Errington (1935) reported a high incidence of animal material in winter gray fox stomachs in Virginia and the mid–west, respectively. Stomach analyses from 59 red and four gray foxes revealed nearly exclusive utilization of vertebrate prey, especially rodents, rabbits and chickens, during two winters in Wisconsin (Richards and Hine 1953). These authors also reported fox scats, collected during early summer, composed almost entirely of May beetle pupae (*Phyllophaga* sp.). As in the current study, these studies suggest opportunistic utilization of food sources by foxes. Errington (1935) suggested that fox food habits seem to be heavily dependent on prey availability, but noted that small mammals appear to be a year–round food staple, while other dietary items may fluctuate according to seasonal availability, weather, prey vulnerability, and experience of individual foxes.

Yoho and Henry (1972), studying gray fox diets in the Appalachian mountains of east Tennessee, reported the reverse trend from that observed in the current study. Cottontails were represented more frequently in stomachs collected in summer (n=17) than winter (n=7); they suggested that peak production of young cottontails in summer might account for their increased occurrence in the diet. Predation on small mammals was similar in both seasons, but decreased in summer for birds. They also reported less vegetation consumption in summer than winter, although large quantities of debris eaten by trapped animals precluded analysis of plant foods. This may also have precluded an objective analysis of fox stomach contents. Higher elevation, decreased habitat diversity (hence food availability) and small sample size might account for some of the contrast in findings with the current study. Richards and Hine (1953) also reported high use of vertebrate prey by red and gray foxes between April and July, 1948, in Wisconsin. However, these data were based solely on collection of prey remains from dens, hence does not accurately represent total fox food habits during these months.

This study confirmed the opportunistic feeding habits of foxes, and suggested that vertebrate prey was significantly exploited only in the absence of plants and invertebrates, which are presumed to be more easily acquired food sources when seasonally available. The emergence of 17–year locusts may have artificially emphasized invertebrate food utilization in spring. Nonetheless, opportunistic shifts in dietary habits according to food availability (which appears to correspond to seasons), is demonstrated. Observed seasonal shifts in dietary trophic level could be of significance in other aspects of fox biology and management.

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