and appeared wilted; roots grew in some cases but mortality and decay of branch roots was very evident.

In the ammonium toxicity experiment, 100% mortality occurred at concentrations > 84 ppm N ($NH^+_4$) within three weeks, but seedlings growing in all concentrations of $NO^+_3$ and $NH_4NO_3$ grew better than seedlings remaining in germination flats.

## CONCLUSIONS

Although the presence of excess free $NH^+_4$ in plant cells is believed to be toxic, there is limited direct information on the character of this effect. While $NH^+_4$ toxicity was suspected in our three-week-old seedlings, the possible low concentrations of carbohydrate (organic acids) in very young seedlings may have been responsible for complete mortality at ≧ 84 ppm $NH^+_4$, since there is some evidence for the influence of carbohydrates on $NH^+_4$ metabolism (McKee 1962) to nontoxic organic nitrogen compounds.

Several authors have investigated the effects of different levels of nitrogen on the growth of tulip poplar, although none compared types of nitrogen fertilizers. Ammonium has been used successfully as a nitrogen source in field fertilization experiments. Ike (1962) and Farmer et al. (1970) found that seedling growth approximately doubled in the first five years by using diammonium phosphate (36.7 kg N/ha) and ammonium nitrate (102 kg N/ha), respectively, and Finn and White (1966) found that 20-year-old slow growing trees doubled in growth in response to an undefined mixed fertilizer containing approximately one-half of the nitrogen as urea formaldehyde (61.7 kg N/ha). Nitrification rates were not taken into consideration in any of these studies, so the actual ionic form of nitrogen absorbed was not defined. However, Cummings (1941) found no response of one-year-old tulip poplar seedlings to $NH_4SO_4$ (55 kg N/ha) in acidic, sterile, strip mine spoil banks. Under such soil conditions, nitrification rates would be slow, and most nitrogen may have remained in the $NH^+_4$ form. In addition, seedlings were small (20-30 cm tall) and would not have had much carbohydrate reserve.

Within limits, the data from this study can be extrapolated to natural forest ecosystems. Seedling growth with $NO^-_3$ compared favorably to that observed with the balanced N-source ($NH_4NO_3$) at a pH found on optimum sites. In contrast, negligible tree growth occurred with $NH^+_4$. The favorable growth response to ammonium fertilizers in fertilizer trials in the past may have been due to nitrification of ammonium to nitrate. Our results provide evidence that either $NH^+_4$ or $NO^-_3$ can be absorbed by tulip poplar seedlings and that seedlings can utilize both $NO^-_3$ and mixed forms of nitrogen. Mature trees with greater carbohydrate reserves may be able to assimilate nitrogen in the $NH^+_4$ form alone. However, the apparent greater growth using a balanced nitrogen source should be taken into consideration in tulip poplar fertilization efforts, especially in establishing seedlings or in soils expected to be low in nitrifying capability.

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FIG. 1. *Cumulative increase in terminal shoot leaf area for tulip poplar growing in different nitrogen solutions.*

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# FOOD HABITS OF BOBCATS IN EASTERN TENNESSEE

JAY D. STORY, WILLIAM J. GALBRAITH, and J. THOMAS KITCHINGS
*Oak Ridge National Laboratory*
*Oak Ridge, Tennessee 37830*

## ABSTRACT

Food habits of bobcats (*Lynx rufus*) in eastern Tennessee were determined from analyzing 176 scat samples collected on the Oak Ridge National Environmental Research Park. Remains of cottontail rabbits (*Sylvilagus floridanus*) were the most frequently occurring food item. White-tailed deer (*Odocoileus virginianus*) and pine vole (*Microtus pinetorum*) remains also were found frequently in samples. Data obtained from this study indicated that food preferences for bobcats in eastern Tennessee are similar to those in other southeastern states where the habitat is similar to the Oak Ridge area and somewhat different from those with significantly different habitat.

## INTRODUCTION

In December, 1978 a study of the food habits of bobcats (*Lynx rufus*) was begun on the Department of Energy's Oak Ridge Reservation. The primary objective of this study was to learn more about the ecological relationship between the bobcat and other mammalian species on the Reservation, particularly those species which were important to the bobcat as prey. Interest in the status of the bobcat on the Reservation has stemmed from a need to know more of the habits of this animal and to monitor the effects of anthropogenic activities on these habits. This note documents the food habits of eastern Tennessee bobcats as determined from the analysis of 176 scats collected on the DOE Reservation between December 1978 and June 1980.

## STUDY AREA

The DOE Oak Ridge Reservation is a 15,000-ha tract of land that includes the 5500 ha Oak Ridge National Environmental Research Park. It encompasses parts of both Roane and Anderson counties, Tennessee, and is located 24.1 km west of Knoxville, Tennessee. Southern, eastern, and western boundaries are formed by the Tennessee Valley Authority's Melton Hill and Watts Bar reservoirs along the Clinch River. The northern boundary is formed by the City of Oak Ridge, Tennessee. The Reservation is predominantly oak (Quercus sp.) and hickory (*Carya* sp.) with some elements of the mixed mesophytic association commonly found in the adjacent Cumberland Mountains (Kitchings and Story, 1978).

## METHODS

Bobcat scats were collected primarily along gravel backroads on the Reservation year-round. Bobcat scats were identified by (1) characteristic odor; (2) presence of tightly compacted hair, teeth, and pieces of bone; and the absence of seeds and many insects or insect parts (Pollack 1951). Scats collected from 16 September through 15 March were designated as fall-winter and those collected from 16 March through 15 September were spring-summer. Samples were washed through number 10, 20, and 100 USA Standard Testing Sieves; contents of the number 100 sieve consisted of fine hairs and other unidentifiable debris and were discarded, while contents of the number 10 and 20 sieves were separated into (1) a hair sample and (2) bone, teeth, and other hard parts. These samples were dried in a small freeze-drying unit for periods ranging from overnight to several days. The samples were examined using a 10X hand lens, a binocular dissecting scope (7X magnification), and a compound microscope (100X and 430X magnification). For contents identification, keys to hairs of mammals were used (Mathiak, 1938; Stains, 1958), but mammal skin and skull collections were also heavily utilized. All scat samples are stored in the Environmental Sciences Division at Oak Ridge National Laboratory for reference.

## RESULTS

Insect parts were found occasionally in scats but were not treated as a food item. Common dog ticks (*Dermacentor variabilis*) were commonly found in spring-summer samples, occurring as early as 5 May and as late as 25 September. One bot fly larva (*Cuterebra* sp.) was recovered from a June 1979 sample which also contained rabbit and groundhog hair. Grass (*Festuca* sp.) was not included in the table of scat contents, but it was present in many of the scats, usually in an unaltered form.

The frequency of occurrence of various prey species remains found in the scat samples is summarized in Table 1. The most important prey species listed in decreasing order of frequency of occurrence were cottontail rabbits (*Sylvilagus floridanus*), pine voles (*Microtus pinetorum*), white-tailed deer (*Odocoileus virgininus*) small bird (unidentified), opossum *Didelphis marsupialis*), and ground hog (*Marmota monax*). As Table 1 shows, a variety of other mammal species was found less frequently than those above, and reptile remains were found in one sample. Although bobcat hair was found in 12.5% of the samples, this species was not included in the table of prey species, since in all samples but one the amount of hair found was indicative of grooming. One sample contained a large quantity of bobcat hair that suggested cannabalism, but no bobcat claws, teeth, or identifiable bone parts were found in this sample.

TABLE 1. *Frequency of prey species found in 176 bobcat scats collected during spring-summer and fall-winter 1979 and spring-summer 1980.*

| Prey species | % frequency[a] Spring-summer 1979[b] (n = 40) | Fall-winter 1979[c] (n = 102) | Spring-summer 1980[b] (n = 34) | Average for all season (n = 176) |
|---|---|---|---|---|
| *Sylvilagus floridanus* | 62 | 50 | 41 | 51.1 |
| *Microtus pinetorum* | 28 | 31 | 15 | 27.3 |
| *Odocoileus virginianus* | 25 | 13 | 18 | 16.5 |
| *Didelphis marsupialis* | 8 | 20 | 12 | 15.3 |
| Birds (unidentified) | 15 | 12 | 15 | 13.1 |
| *Marmota monax* | 15 | 7 | 18 | 10.7 |
| *Sigmodon hispidus* | 8 | 9 | 6 | 8.0 |
| *Sciurus carolinensis* | 3 | 8 | 3 | 5.7 |
| *Ondatra zibethica* | | 10 | | 5.7 |
| Unidentified mice | 5 | 7 | 3 | 5.7 |
| *Blarina brevicauda* | | | 9 | 5.1 |
| *Mephitis mephitis* | 10 | 4 | 3 | 5.1 |
| *Tamias striatus* | 3 | 1 | 18 | 4.5 |
| *Glaucomys volans* | | 2 | 12 | 3.4 |
| *Procyon lotor* | | 1 | 9 | 2.3 |
| *Peromyscus leucopus* | 2 | 1 | | 1.1 |
| *Scalopus aquaticus* | 2 | | | 0.6 |
| *Reithrodontomys humulis* | | 1 | | 0.6 |
| *Mustela vison* | | 1 | | 0.6 |
| Snakes (nonpoisonous) | 2 | | | 0.6 |

[a] Determined by presence-absence of prey species in scat sample.
[b] 16 March 15-September 1979 and 1980.
[c] 16 September-15 March 1979.

## Discussion

Data acquired in this study indicated that food preferences for bobcats on the Oak Ridge Reservation were similar to those found in some other southeastern studies. The cottontail rabbit was the most frequently occurring species in bobcat scats on the Oak Ridge area as it was in food studies in North Carolina and Virginia (Progulske, 1955), Alabama (Davis, 1955), Arkansas (Fritts and Sealander, 1978), and Tennessee (Buttrey 1974). However, in studies in South Carolina (Kight 1962) and Alabama (Miller and Speake 1978) the cotton rat was the most frequently occurring food item, and the cottontail rabbit was second in frequency in both studies. The frequency of the rabbit in the Oak Ridge study decreased, however, from spring-summer 1979 through the 1980 spring-summer period, possibly reflecting a reduction in the rabbit population on the Reservation during this time.

Pine voles, which were second in frequency of occurrence (27.3%) in the Reservation samples, appeared with about equal frequency in the spring-summer and fall-winter samples, and then during the 1980 spring-summer period their frequency dropped to about half that found in either of the two preceding seasons. It may be noteworthy to consider the small size of the pine vole (a large adult male may weigh only 25-30 g in this area) in relation to the amount of energy assimilated by the bobcat ingesting a vole. As was pointed out by Rosenzweig (1966), there is a tendency for predators to specialize in killing prey of a particular size, bobcats usually taking prey in the 150 g to 55 kg range. While the appearance of smaller rodents in the bobcat's diet might be due to chance encounter (Leopold 1933), it seems unlikely that the high frequency of occurrence of the small vole found in our study (27.3%) and Buttrey's (1974) study (22.4%) could be attributed to chance encounter. Rather, the data make it seem more likely that (1) the bobcat has developed a very successful and efficient technique for capturing these small animals or (2) the voles are simply easy prey to capture. Miller and Speake (1978) pointed out that a predator would not be very successful if it expended more energy in the capture of a small prey than was obtained by its assimilation.

White-tailed deer represent an important food source for Reservation bobcats, occurring in 16.5% of the scats. Other studies (Fritts and Sealander, 1978; Buttrey, 1974; Marston, 1942; Young, 1958; Rollings, 1945; Jones and Smith, 1979) have identified white-tailed deer as a food item of bobcats, but as Buttrey (1974) pointed out, evidence of deer occurred most often during the fall-winter period, leading him to suspect that bobcats were taking advantage of deer carcasses resulting from illegal kills (poaching) and hunter losses during big game hunts. Occurrence of deer remains in the Oak Ridge Reservation scats has not followed the seasonal pattern observed by Buttrey (1974) and others; rather, Reservation bobcats appear to be utilizing deer on a year-round basis with evidence that fawns are being taken in spring and summer. There have never been legal deer hunts on the Reservation, but poached deer and those dying after being injured by vehicles may provide some of the deer remains we are seeing in scats. While we have seen no direct evidence that Reservation bobcats are preying on deer, our data indicate a higher utilization of deer by bobcats in the spring-summer than in the fall-winter period, and since fawns are born during the spring and summer months, they may represent an attractive and relatively easy-to-take prey for the bobcat. We did note that in five of six spring-summer 1979 samples the deer hair examined appeared to have come from very young animals.

The opossum occurred in 15.3% of the Reservation scat samples, and in each of the three sampling periods the frequency was higher than was reported in any of several other studies. Miller and Speake (1978) found opossum occuring in 5.5% of the scats in their Alabama study, and Progulske (1955) found opossum in only 5.2% of the Virginia and North Carolina bobcat scats, stomach, and intestinal tract samples in his southern Appalachian study. Buttery (1974) reported no opossum remains in his Tennessee bobcat scats but did find 13.3% occurrence in the bobcat stomach contents he examined. Pollack (1951) found no opossum remains in the stomachs and intestines of the New England bobcats he studied, and Rollings (1945) reported no evidence of opossum in any of the 50 Minnesota bobcat stomachs examined in that study.

Small bird parts appeared in 13.1% of the Oak Ridge scats, and their occurrence was quite consistent through the seasonal sampling. This compares closely to the 14.7% found by Buttrey (1974); Miller and Speake (1978) found 15.1% of their Alabama bobcat scats to contain bird parts, and Progulske (1955), in his southern Appalachian study, reported unidentified birds in 6.9% of the samples he examined.



Groundhog or woodchuck (*Marmota monax*) appeared in 10.7% of our samples, more frequently in the spring-summer than in the fall-winter. Since this species hibernates a good portion of the fall-winter period in eastern Tennessee, the seasonality of occurrence is not unexpected. Buttrey (1974) also found evidence of groundhog in his samples, but he found only one occurrence in each of two seasonal periods. Miller and Speake (1978) reported no groundhog remains in their samples, but this is not surprising since their study in southern Alabama was outside the range of this species. Progulske (1955) found groundhog in 6.3% of his southern Appalachian bobcat scats, but the seasonality in occurrence that we observed was not noted in Progulske's study.

Two bobcat-groundhog encounters have been observed and both observations were made in the same general area. The first occurred about 6:30 p.m. on a June evening when a bobcat was seen carrying a medium-sized groundhog by the back of the neck with the groundhog still struggling. The second observation also occurred on a June evening about the same time of day and involved a bobcat, an adult groundhog, and what appeared to be a juvenile groundhog. The adult groundhog was apparently trying to prevent the bobcat from getting to the smaller groundhog. Although the adult groundhog's aggressiveness caused the bobcat to back up several feet in a few short moves, the bobcat would sit down after each move and just watch the two groundhogs. After about 15-20 minutes of this activity, the small groundhog made a dash for a ditch; as soon as it was in the ditch, the bobcat jumped over the adult groundhog, bounded to the ditch and attacked the small animal. The bobcat immobilized the young groundhog with a bite to the back of the head.

Although cotton rats (*Sigmodon hispidus*) were utilized consistently through the sampling periods of our study, they were found in only 8% of the samples. Buttrey (1974) found no cotton rat remains in the scats in his Tennessee study, and no cotton rat remains were reported in the southern Appalachian study (Progulske 1955). However, in the south Alabama study (Miller and Speake 1978) and the South Carolina study (Kight 1962) the cotton rat was the most frequently appearing food item. Habitat differences probably account for the cotton rat being taken relatively infrequently in the Oak Ridge area while it appears to be a very important part of the diet of South Carolina and south Alabama bobcats. In both the Alabama and South Carolina studies a more open, old-field-type habitat occurred over large parts of the study areas; the Oak Ridge Reservation, on the other hand, has little old field habitat and much forested land, so we would not expect to find an abundance of cotton rats except in localized areas.

Gray squirrel (*Sciurus carolinensis*) was not taken frequently (5.7%) but the seasonal pattern of occurrence, higher in fall-winter than in spring-summer, was similar to that found by Buttrey (1974). As Buttrey (1974) pointed out, this species may be taken more often in the fall-winter simply because during this time squirrels are on the ground more and may be easier prey for the bobcat. Squirrels were relatively important to the bobcats in the Tennessee wildlife management area where Buttrey conducted his study, since they occurred in 10.2% of his bobcat samples, and Progulske (1955) found this species in 24.9% of his southern Appalachian samples, making it second only to the cottontail rabbit in frequency. In Alabama (Miller and Speaek 1978) the gray squirrel occurred in only 5% of the samples.

The muskrat (*Ondatra zibethica*) occurred in 5.7% of our samples, the same frequency as gray squirrel and unidentified mice. This species was not reported in the Alabama study (Miller and Speake 1978), the earlier Tennessee study (Buttrey 1974), or the southern Appalachian study (Progulske 1955) although it would be expected to occur in all three of the areas. The fact that we found muskrat in such a low percentage of our samples leads us to believe this species is low on the preference list of bobcats, especially considering the abundance of muskrat sign in and around the ponds, lakes, and streams of the Oak Ridge Reservation.

The shorttailed shrew (*Blarina brevicauda*) and striped skunk (*Mephitis mephitis*) occurred with equal frequency (5.1%) in our study; Buttrey (1974) also found striped skunk (4.1%) in his Tennessee study, but he saw no shorttailed shrew remains. The southern Appalachian study (Progulske, 1955) reported only 0.4% occurrence of unidentified shrew remains and 1.3% occurrence of striped skunk. The Albama study (Miller and Speake 1978) reported no skunk remains in any samples, but the least shrew (*Cryptotis parva*) and the shorttailed shrew appeared in a small number of samples. Miller and Speaks (1978) considered neither the frequency nor the volume of shrews to be appreciable, but they did consider the presence of shrews to be noteworthy because of previous reports that mammalian predators would kill but not eat these animals due to their disagreeable taste.

We found the eastern chipmunk (*Tamias striatus*) in 4.5% of our samples, and the majority of scats containing chipmunk remains was collected during the spring-summer period. The low frequency of chipmunk in the fall-winter sample is probably the result of this species hibernating during this period. Buttrey (1974) found no chipmunk remains in his Tennessee study, though the species is known to occur in his study area. In Alabama Miller and Speake (1978) found chipmunk occurring in 2.3% of their scat samples, and Progulske (1955) found the chipmunk in 3.0% of the samples from the southern Appalachian area. In none of the southeastern studies, however, does it appear that the chipmunk represents an important component in the bobcat's diet.

The southern flying squirrel (*Glaucomys volans*) occurred in 3.4% of the Oak Ridge bobcat scats, and Progulske (1955) reported only 2.6% in the southern Appalachian samples he examined. This species was not found by Milller and Speake (1978) in Alabama scats, nor by Buttrey (1974) in his Tennessee study.

Raccoon (*Procyon lotor*) was found in 2.3% of the Reservation bobcat scats, and this level of occurrence compares closely with the 2.1% reported by Progulske (1955) for his southern Appalachian study. Buttrey (1974) found no evidence of raccoon in his Tennessee study, and while Miller and Speake (1978) found the raccoon relatively abundant on their study areas, evidence of raccoon occurred in only 0.7% of their bobcat stomach samples.

We found little indication that Reservation bobcats were preying on mice of the genus *Peromyscus* (1.1% frequency), but Buttrey, on the other hand, found this genus occurring in 18.4% of his samples. Progulske (1955) found *Peromyscus* in 2.6% of his Appalachian samples and Miller and Speake (1978) found 1.5% and 3.7% occurrence in their Alabama bobcat intestines and scats, respectively. Perhaps one explanation of the high frequency of *Peromyscus,* a very small prey species, in Buttrey's (1974) Tennessee study is that it acts as a buffer food for the bobcat during times when game animals are more difficult to obtain (Progulske 1955). There is also the possibility that, as we mentioned in discussing voles as prey, the bobcats in Buttrey's study area had perfected a quite successful technique for hunting *Peromyscus* species.

Table 1 lists four prey items each of which was found only once (0.6%) in our study; these were the eastern mole (*Scalopus aquaticus*), harvest mouse (*Reithrodontomys humulis*), mink (*Mustela vision*), and an unidentified snake. None of these four food items was reported as occurring with as high as 1.0% frequency in the other southeastern studies mentioned above. These prey species would best fit into the "chance encounter" category on the bobcat food list.

Grass (*Festuca* sp.) was not included in the table of scat contents, but it was present in many scats, usually in an unaltered form. Buttrey (1974) reported grass in 12.2% of his samples and postulated that it may have been ingested as a purgative, since it passed through the digestive tract without being digested. Miller and Speake (1978) reported grass in 66% of their Alabama bobcat scats; they felt that this grass had been ingested accidentally or perhaps as a purgative. Progulske (1955) reported grasses in 3.4% of his southern Appalachian samples but did not discuss the significance of this occurrence. Rollings (1945) mentioned finding grass and white cedar leaves in a high percentage of bobcat stomachs in Minnesota, and he observed that in " . . . specimens shot or choked quickly by snares it was obvious that the grass and leaves were not trap debris; they were taken intentionally or were ingested with deer offal frequently encountered in the woods." We do not believe the grass found in Oak Ridge scats was ingested for nutritional reasons, but the fact that some scats were composed almost entirely of fresh, green grass left little doubt that the grass had been ingested intentionally rather than by accident.

This study has enabled us to put into better perspective the relationship of the bobcat to many sympatric species on the Oak Ridge Reservation. Understanding the food habits of this top level predator will enhance our ability to assess effects that might be brought about by man's activities here on the Reservation. Also, as a result of this study, we are now better prepared to monitor and document any major changes in Reservation bobcats' food habits; one potential change we will be watching for is increased utilization of white-tailed deer in the diet. A rapidly increasing white-tailed deer population on the Reservation (Kitchings and Story 1980) provides the potential for a major shift in food preference, especially during periods when rabbit and vole populations might be experiencing population crashes.

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Gus Tomlinson

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