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The stripping of bark by eastern gray squirrels *(Sciurus carolinensis)* is a serious problem in England with 50 to 100% of the trees damaged in some locations (Shorten 1957). The economic consequences of such damage have resulted in much research (Kenward 1982, 1983; Kenward and Parish 1986); squirrel-induced damage to trees also occurs in North America (Allen 1943, Brenneman 1954) but is rarely of the magnitude observed in England. At least 10 hypotheses (reviewed by Kenward 1983) have been suggested to account for bark-stripping damage including: 1) reduction of tooth wear; 2) uncontrolled gnawing reflex; 3) source of nesting material; 4) water, 5) genetic mutation; 6) scent-marking; 7) displacement activity related to agonistic behaviors; 8) trace nutrient deficiency; 9) sap as an emergency food; and 10) sap as a preferred food. However, only hypotheses 6 through 10 appear to have merit (Kenward 1983).

Gray squirrels in England regularly visited marking points to chip bark and sometimes urinate which suggests that some bark removal is related to scent marking (Taylor 1968, 1977). Many ground squirrels (Halpin 1985) and tree squirrels (Benson 1980, Ferron 1983) scent mark using oral glands. Fox squirrels *(S. niger)* frequently bite the substrate prior to scent marking (Benson 1980). Although squirrels do ingest bark and cambium (Packard 1956), some bark removal is related to scent-marking activities (Taylor 1969, 1977). Scent marking, including the rubbing of oral glands on a substrate and occasional urination at traditional marking points, is an almost exclusively adult male activity that occurs throughout the year (J. L. Koprowski, unpubl. data). Damage in urban areas may be highly visible, unappealing, and intolerable to residents. Herein, I report the characteristics of scent-marking points and discuss the extent of bark removal by fox and eastern gray squirrels at marking points with reference to preferred timber size classes in an urban parkland.

STUDY AREA AND METHODS

The study area was a 4.2 ha woodlot at the University of Kansas, Lawrence, Kansas, in a wide draw along a north-facing slope (elevation range, 282.9 m to 303.0 m) and delineated by buildings, roadways, and parking areas. The canopy of 319 trees was dominated by mature black walnut *(Juglans nigra).* Fourteen species of trees (*/. nigra, Quercus palustris, Q. velutina, Q. borealis, Morns rubra, M. alba, Celtis occidentalis, Ulmus rubra, U. americana, Populus deltoides, Cornus floridana, Catalpa bignonoides, Crataegus* sp., and *Gymnocladus dioica)* provided a diversity of food sources. Provisioning by humans was never observed. Water was available in 6 storm drains. The shrub layer was absent;

the ground cover was mowed grass. Squirrels were trapped and marked with uniquely numbered ear tags and freeze marks from May 1986 to May 1990 as part of a study on the social organization of fox squirrels and eastern gray squirrels; squirrel densities exceeded 8 squirrels/ha from 1986 to 1989 (Koprowski 1991).

Trees were surveyed in November 1986 to detect marking points. Marking points were easily distinguished by grooves from incisors and sometimes discoloration (Taylor 1968); binoculars were used to search for marking points in the canopy. In May 1989, all trees were examined to determine temporal persistence of marking points and to measure marking point characteristics. The orientation of each marking point was categorized as north, south, east, or west. Height was measured from the lowest point of the marking site. Maximum width, maximum length, and maximum depth were measured for each marking point. The area of the wound was obtained using a 1 cm transparent grid overlay. Frequencies were compared using G-tests. The Bonferroni Z-test methods of Marcum and Loftsgaarden (1980) were used to compare the expected and observed proportions when examining the susceptibility of tree species to be marked. Student's Mests were used to compare means. Means + 1 SD are presented in the text.

RESULTS

Marking Site Characteristics

Forty-four scent marks were located on 39 trees (12.2% of all trees) yielding a density of 8.6 marks/ha. Most marks (88.6% of 44 sites) were located just aboveground (64.7 + 46.5 cm) and were frequently oriented to the south (N = 2, S = 23, E = 6, W = 6; G = 25.4, 3 df, P < 0.05). Sites were sometimes located on existing wounds (36.4% of 44 sites). Marking sites were traditional with 92.3% of the 39 marking points from 1986 still active in 1989 and only 1 new marking point recorded. However, damage to trees appeared minimal. The area of damage was variable and sometimes large (309 ± 349 cm^2; range =15 to 1871 cm^2; but, marks were generally superficial and only penetrated 1.19 + 0.85 cm into the outer bark. Complete bark removal resulting in slight exposure of the vascular cambium occurred in 11.4% of 44 instances and was restricted to <5 cm^2 in 4 of 5 cases.

Tree Susceptibility.

Scent marks were distributed unequally among timber size classes (Table 1; G = 16.6, 8 df, P < 0.01); only 1 tree with a diameter breast height (DBH) <40 cm had marking points. The DBH of marked trees (62 + 22 cm) was greater *it* = 8.66, P < 0.05) than the DBH of unmarked trees (35 + 17 cm).

Table 1. The distribution of scent marks of tree squirrels by timber size class.

DBH[a] class (cm)	Stems available	%of stems marked
10- 19	62	1.6
20-29	63	0
30-39	51	0
40-49	52	21.2
50-59	35	14.3
60-69	27	37.0
70-79	13	23.1
>80	10	60.0

"Diameter breast height (DBH).

Table 2. The distribution of scent marks among trees with >10 stems greater than 39 cm diameter breast height (DBH). Values in () are proportions of column totals. Expected values are calculated using the percent composition of each species among stems >39 cm DBH.

Species	Number of Stems with Marks: Observed	Number of Stems with Marks: Expected	Bonferroni Z-test Confidence Interval
Black Walnut	17 (0.68) 5	11.7 (0.47)	-0.105, -0.317[a]
Catalpa	(0.20) 2	3.6 (0.14)	0.029, -0.145
Hackberry	(0.08) 1	2.6(0.11)	0.383, -0.031
Pines	(0.04) 0	2.6 (0.10)	0.107, 0.009
Oaks	(0.00)	4.3 (0.17)	0.262, 0.084

[a]When confidence intervals include 0, the observed and expected proportions do not differ significantly.

The 5 tree species that had at least 10 stems >40 cm on the study area were used to examine the differential susceptibility of tree species to scent-marking activities (Table 2). Although the sample sizes were small and only represent a subset of the available species, the location of marking sites was not independent of tree species. Scent marks were located more frequently than expected on black walnut, as frequently as expected on catalpa and hackberry, and less frequently than expected on pines and oaks. I examined an additional 30 pines and oaks adjacent to the study area to ascertain if the apparent avoidance was an artifact of small sample sizes; however, none of the additional pines or oaks were used as scent marks. Care must be taken in extrapolating these data to other areas and tree species. For instance, species with fewer stems on the study area were also used heavily; the only 2 cottonwoods and locusts were each marked.

DISCUSSION

Although I have observed scent marks throughout the range of eastern gray and fox squirrels, the damage is rarely attributed to squirrels. Some characteristics of marking sites should permit their easy identification. Squirrels appear to preferentially gnaw and strip certain tree species; some oaks and pines appear to be avoided while other species are apparently more palatable or have bark characteristics that are conducive to scent deposition such as *Acer* sp., *Fagus sylvatica,* and *Juglans nigra* (Shorten 1957, Rowe and Gill 1985, this study). Marking points are traditional and used in all months (Taylor 1977; J. L. Koprowski, unpubl. data). Taylor (1968) believed that some tree wounds resulted from squirrel marking activities over many years. If marking points are used over many generations, older trees with large DBH are expected to be marked most frequently as I observed. In England, marking points were located under limbs or between root buttresses or other protected areas which may promote scent longevity (Taylor 1968). The crest of a hill and university buildings protected my study area from south winds while strong north winds were funneled up the wide draw. Perhaps due to the strong north winds, most trees also lean slightly to the south. The frequent placement of marking points on the south side (usually the leeward and underside) of trees in this study may promote maximum scent longevity. The protected location of marking points, impressions from incisors, tree species, as well as dampness, odor, and discoloration of exposed bark due to oral gland secretions and urine permit the marking points of tree squirrels to be distinguished from damage due to lagomorphs or lawn maintenance equipment.

Two types of bark damage are reported and potentially confused in the literature. Squirrels completely remove bark over large areas, sometimes girdling and killing trees (Allen 1943, Brenneman 1954, Kenward 1983); these large scale removals appear related to phloem content of trees (Kenward and Parish 1986). Bark removal over small portions of trees that are frequently visited by adult squirrels is related to social organization and not nutrient acquisition (Taylor 1968,1977; J. L. Koprowski unpubl. data). Management strategies for these 2 types of damage will likely differ as do their biological functions.

Solutions to the extensive bark removal problems experienced in England will likely involve selective breeding of trees to decrease palatability as well as population control using contraceptives, habitat management, and removal trapping (Kenward 1983, Kenward and Parish 1986). Scent marks, however, appeared to cause minimal damage to trees and rarely penetrated deep into the bark. Although the consequences of this damage such as the susceptibility of marked trees to disease and insect infestation require further study (Abbott et al. 1977, Kenward 1983), a major problem created by marking points is likely the aesthetics of the site when found on large shade trees near homes.

Damage due to scent marking will not likely be controlled with same measures derived to combat large scale bark removal unless scent marks originate as very localized feedings by squirrels. The application of a registered oral deterrent such as thiram (Jackson 1983) may be the only necessary action. Swihart (1991) found thiram to be ineffective in deterring the scent-marking behavior of another sciurid, the woodchuck *(Marmota monax);* however, the urine of a predator was an effective deterrent. Research needs to focus on effective deterrents for tree squirrels, perhaps examining the effectiveness of the urine of mammalian predators including domestic dogs and cats. Trapping to remove "problem" animals will not be effective because many individuals are likely involved and marks are soon found by ingressing squirrels (Taylor 1977, pers. obs.). Denying squirrels access by placing aluminum flashing above and below isolated marks may prevent continued use of certain sites. However, because this damage appears to be a consequence of the social system of tree squirrels, squirrels may shift to another tree or to another portion of the same tree.

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