

Effectiveness of predator odors as gray squirrel repellents

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Abstract: The ability of gray squirrels (*Sciurus carolinensis*) to discriminate between different predator odors and the use of predator odors to deter gray squirrels from foraging on plants have not been previously investigated. To test the hypothesis that predator scent decreases foraging, I investigated the effect of such scent on consumption of butternuts (*Juglans cinerea*) in the field. Results showed that (i) red fox (*Vulpes vulpes*) scent was significantly more effective than either a control or human scent; (ii) raccoon (*Procyon lotor*) scent was significantly more effective than white-tailed deer (*Odocoileus virginianus*) scent (but only after 7–9 h); (iii) red fox scent was not significantly more effective than raccoon scent; and (iv) human scent was not significantly more effective than the control. The utility of predator odors in controlling damage by gray squirrels should be explored.

Résumé : La capacité des Écureuils gris (*Sciurus carolinensis*) à reconnaître les odeurs de différents prédateurs et l'utilisation de ces odeurs pour éloigner les Écureuils gris et les empêcher de se nourrir d'espèces données de plantes n'ont jamais été étudiées. J'ai éprouvé l'hypothèse selon laquelle l'odeur d'un prédateur diminue l'activité alimentaire en examinant l'effet d'une telle odeur sur la consommation de noyers cendrés (*Juglans cinerea*) en nature. Les résultats indiquent (i) que l'odeur du Renard roux (*Vulpes vulpes*) est significativement plus efficace que l'odeur témoin ou que l'odeur humaine, (ii) que l'odeur du Raton-laveur (*Procyon lotor*) est significativement plus efficace que celle du Cerf de Virginie (*Odocoileus virginianus*) (mais seulement après 7–9 h, (iii) que l'odeur du Renard roux n'est pas plus efficace que celle du Raton-laveur et (iv) que l'odeur humaine n'est pas significativement plus efficace que l'odeur témoin. L'utilité des odeurs de prédateurs pour contrer les dommages causés par l'Écureuil gris vaut la peine d'être exploitée.

[Traduit par la Rédaction]

Introduction

Many prey species have the ability to assess their risk of being preyed upon. Predator avoidance is associated with costs such as a reduction in feeding rates and breeding opportunities (Lima 1985; Lima and Dill 1990). Prey may reduce these costs by assessing the risk of a predator being present from its odor. Avoidance of predator odor can be either species-specific (e.g., Swihart 1991) or general (e.g., Nolte et al. 1994). Furthermore, some prey learn to respond only to predators that are actively dangerous (Dickman 1992). Recognition of (and response to) predator odors by prey is of adaptive significance because it reduces predation risk.

Mammalian pests such as rodents cause conflict with man by spreading disease to both humans and livestock, spoiling stored food, and damaging buildings, trees, and crops (Gurney et al. 1999). Tree squirrels gnaw ears of growing corn and the bark of trees (Kenward 1983). Western gray squirrels (*Sciurus griseus*) have caused serious losses to timber production in Jackson County, Oregon (Baldwin et al. 1986). Gray squirrel (*Sciurus carolinensis*) damage has also been

reported to American chestnut (*Castanea dentata*) in West Virginia (Brooks 1922) and sugar maple (*Acer saccharum*) in Connecticut (Britton 1933), Michigan (Brenneman 1954), and Minnesota (Irving and Beer 1943). Gray squirrels have also been reported to pose a serious problem to commercial foresters in Britain (Rowe 1984; Rowe and Gill 1985; Gurnell 1987). Squirrels may also gnaw through the insulation on electricity cables, dig up bulbs, corms, and newly sown seeds, eat ripe fruit, and damage plastic bird netting (Gurnell 1987). Gray squirrels often annoy people by nesting in attics or between walls and by raiding gardens and bird feeders (Nowak 1999).

Chemical repellents such as Squirrel-Away™ are now being marketed in stores for the general public's use against squirrels. However, the above-mentioned conflicts could possibly be reduced by using predator odors as repellents (e.g., Merkens et al. 1991). The use of predator odors to deter gray squirrels from eating butternuts (*Juglans cinerea*) has not been investigated, nor the ability of gray squirrels to discriminate between different predator odors.

Three species known to prey on gray squirrels in United States are the red fox (*Vulpes vulpes*), the raccoon (*Procyon lotor*) (Whitaker 1996), and man by hunting (Nowak 1999). Gray squirrels should therefore avoid the scent of these three species.

In this study I investigated 3 different predator odors (human, red fox, and raccoon) as repellents of gray squirrels. To test the hypothesis that predator scent decreases foraging, I designed a study to investigate the effect of such scent on butternut consumption in the field. I tested the following predictions: (i) red fox scent would be more effective than a

Received January 15, 2001. Accepted July 10, 2001.
Published on the NRC Research Press Web site at
<http://cjfas.nrc.ca> on September 12, 2001.

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control (no scent); (ii) red fox scent would be more effective than human scent; (iii) human scent would be more effective than a control; and (iv) raccoon scent would be more effective than scent from a non-predator (white-tailed deer, *Odocoileus virginianus*).

Materials and methods

I conducted my study in Oakwood Cemetery (a green space) in Syracuse, New York. During the period of my study in October 2000, I observed both a raccoon and a red fox in the cemetery, as well as a white-tailed deer. No recent estimates of the gray squirrel population exist for my study area. However, during a 10-min walk through the cemetery on October 1, a distance of 0.5 mi (1 mi = 1.609 km), I observed >27 different gray squirrels.

The samples of red fox scent (natural red fox urine from the Wildlife Research Center, Inc., 1050 McKinley Street, Anoka, MN 55303, U.S.A.), raccoon scent (The Primetime[®] Luring system, raccoon urine, 6000 Huntington Court NE, Cedar Rapids, IA 52402, U.S.A.), and white-tailed deer scent (Whitetail Maniac 155, doe in heat urine with tarsal gland, Roger Raglin Products, Box 55175, Tulsa, OK 74155, U.S.A.) used in these experiments were bought from a hunting store. The red fox urine was collected from adult foxes fed meat. The human urine was collected from the author, who ate meat the day before the urine was collected. The butternuts were collected from a butternut tree 16 mi from the study site.

I tested my hypothesis by using a three- or two-sample choice test. In the first experiment I constructed 3 experimental circles (ECs): a control circle (no scent), a red fox scent circle, and a human scent circle. In the second experiment I constructed 2 ECs: a raccoon scent circle and a white-tailed deer scent circle. The circles were constructed approximately 0.5 m apart near a tree or a tombstone. I randomly selected 5 butternuts for each circle and randomized the placement of each EC by lot before each trial to control for side preference. Then I placed quilted cotton squares (5.5 cm long and 5 cm wide; CVS, Woonsocket, RI 02895, U.S.A.) in the middle of each circle with a small stick and applied 5 mL of scent material to the cotton squares. I applied scent to the cotton squares but not to the butternuts because I wanted to test the effect of smell only, i.e., I wanted to exclude taste. To prevent contamination with human odor, I wore clean plastic gloves when constructing the ECs.

I carried out the first experiment on the morning (9:00–10:00 a.m.) of October 7 and 9, when 23 different experimental trials were conducted. The second experiment was carried out between 8:00 and 9:30 a.m. on October 30, when 20 trials were conducted. Since gray squirrels are diurnal (Thompson 1977; Hougart and Flyger 1981) and because I wanted to exclude possible responses by nocturnal animals, I recorded the response to the ECs after 2–4 h and after 7–9 h to elucidate a possible habituation effect. No rainfall occurred during the field experiments.

I gave an EC an index value of 1 when squirrels removed 1 butternut, 2 when 2 butternuts were removed, and so on up to a maximum score of 5. After measuring response intensity at the ECs, I removed the remaining butternuts and cotton squares. Activity at the ECs that could be attributed to other diurnal mammal species such as the chipmunk (*Tamias striatus*) was assumed to be unlikely because of the size of the butternuts. No other squirrel species were present in my study area. I therefore assumed that the only vertebrate feeding on the butternuts was the gray squirrel.

Home ranges of gray squirrels overlap extensively and territoriality is not evident, but adults may defend a core area in the fall (Koprowski 1994). Doeble and McGinnes (1973) reported home range sizes of 0.53 and 0.40 ha for males and females, respectively, in Virginia. However, Nowak (1999) reported that a gray squirrel may spend most of its life in a home range of less than 0.5 ha. I

therefore carried out the different trials >0.5 ha apart to increase the possibility that different animals responded in each trial. This was done to avoid pseudoreplication (e.g., Hurlbert 1984). However, several individuals may have responded during a specific trial.

I used the non-parametric Friedman's test for within-subject effects (related samples) to compare the numbers of butternuts removed from the 3 related ECs (Siegel and Castellan 1988). Thereafter I checked for differences in response between scents (red fox vs. control, red fox vs. human, and human vs. control) by using the non-parametric Wilcoxon's signed-ranks test for matched samples (Siegel and Castellan 1988). A Wilcoxon's signed-ranks test was also used to check for differences in response to the raccoon scent and the non-predator scent (white-tailed deer) (Siegel and Castellan 1988). I checked for differences in response to scent for between-subject effects (red fox vs. raccoon) by using a Mann-Whitney *U* test for independent samples. All tests were two-tailed and all mean values are shown with standard deviations. *P* values less than 0.05 were considered significant. Data analyses were performed with the statistical package SPSS version 10.0.

Results

Red fox scent vs. human scent vs. control (no scent)

The numbers of butternuts removed by the gray squirrels differed significantly between the 3 ECs, both after 2–4 h ($\chi^2 = 7.8$, *df* = 2, *p* = 0.020) and after 7–9 h ($\chi^2 = 11.3$, *df* = 2, *p* = 0.004) (Fig. 1). The results after 2–4 h showed that the red fox scent was significantly more effective than both the control (no scent) ($Z = -2.1$, *p* = 0.037) and the human scent ($Z = -2.0$, *p* = 0.044). However, the human scent was not significantly more effective than the control ($Z = 0.1$, *p* = 0.943). The results after 7–9 h showed that the red fox scent was significantly more effective than both the control (no scent) ($Z = -2.7$, *p* = 0.006) and the human scent ($Z = -2.9$, *p* = 0.003). However, the human scent was not significantly more effective than the control ($Z = 0.77$, *p* = 0.442).

Raccoon scent vs. non-predator scent (white-tailed deer)

The results after 2–4 h showed that the raccoon scent was not significantly more effective than the scent from the non-predator (white-tailed deer) ($Z = -1.9$, *p* = 0.061) (Fig. 2). However, the results after 7–9 h showed that the raccoon scent was significantly more effective than the scent from the non-predator (white-tailed deer) ($Z = -2.4$, *p* = 0.017) (Fig. 2).

Red fox scent vs. raccoon scent

The red fox scent was not significantly more effective than the scent from raccoon after 2–4 h ($Z = 1.3$, *p* = 0.208) or after 7–9 h ($Z = -1.7$, *p* = 0.088).

Discussion

My results support the hypothesis that predator scent decreases foraging by gray squirrels. The red fox scent was significantly more effective than both the human scent and the control, and the raccoon scent was significantly more effective than the scent from a non-predator (white-tailed deer) (but only after 7–9 h). These findings are in accordance with my first, second, and fourth predictions. They indicate that the gray squirrel is able to distinguish between different predator odors, and between the odors of a predator and a non-predator. This conclusion is supported by the fact

Fig. 1. Numbers of butternuts removed by gray squirrels (*Sciurus carolinensis*) from 3 different experimental circles (ECs) after 2–4 h (note that only 18 of the 23 trials were checked) and after 7–9 h in Oakwood cemetery in Syracuse, New York, during October 2000. The top and bottom of the boxes are drawn at the lower and upper quartiles (interquartile range), respectively. The box is divided at the median. The vertical line is drawn from the largest (top) and smallest (bottom) observations within 1.5 interquartile ranges. The open circle denotes a value more than 1.5 box lengths from the 75th percentile (outlier) (Norusis 1993). Numbers below the *x* axis show the number of trials carried out.

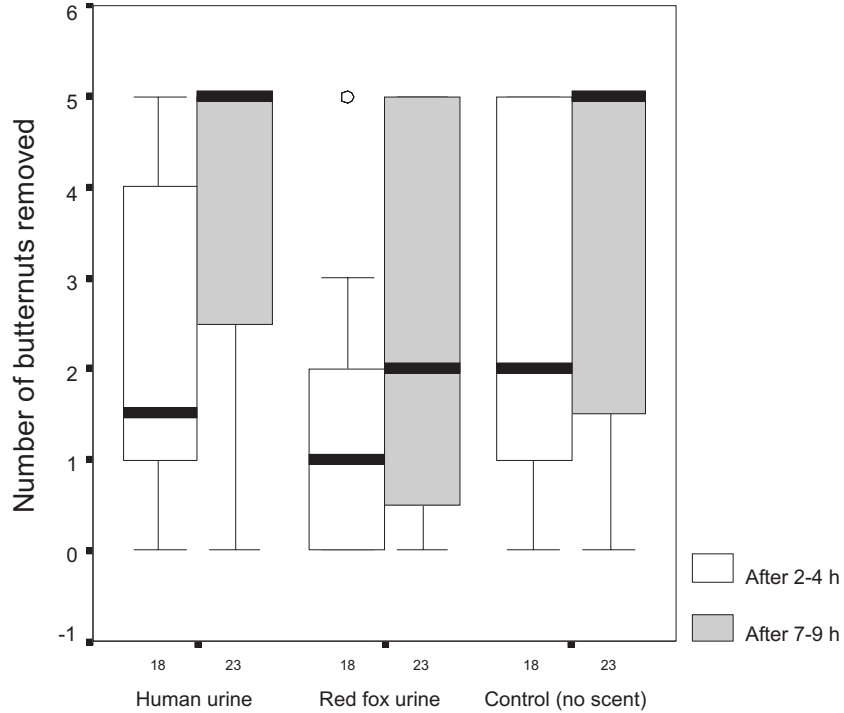
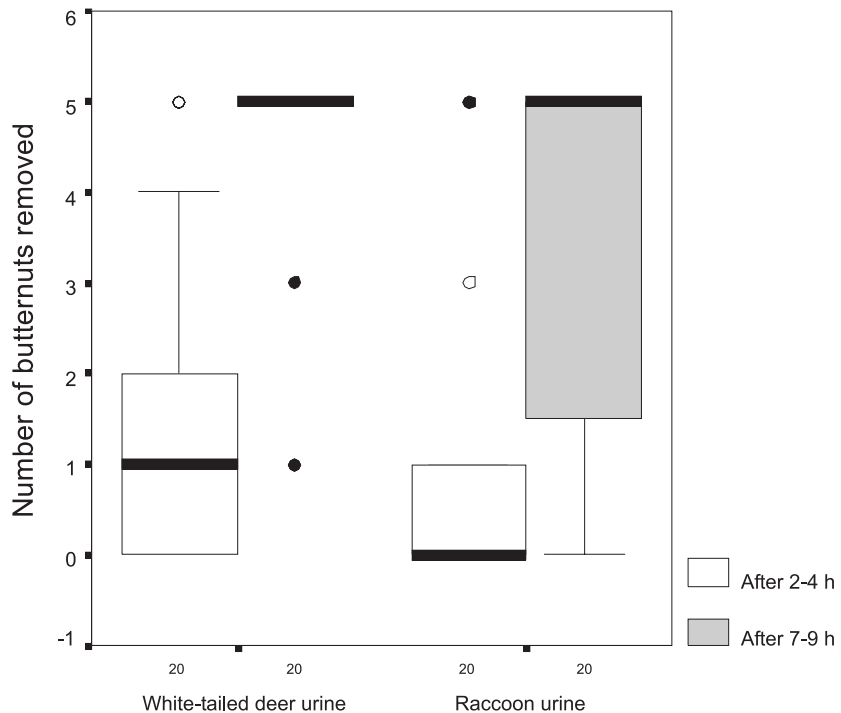


Fig. 2. Numbers of butternuts removed by gray squirrels from 2 different ECs after 2–4 h and after 7–9 h in Oakwood cemetery in Syracuse, New York, during October 2000. Open circles denote values more than 1.5 box lengths from the 75th percentile (outliers) and solid circles denote values more than 3 box lengths from the 75th percentile (extreme values). Numbers below the *x* axis show the number of trials carried out.



that a gray squirrel (gray morph) was observed to jump backwards when it sniffed the cotton square with the red fox scent but not when it sniffed the human scent. On the next visit it clearly avoided the circle with red fox scent and removed butternuts from the other circles instead. This happened twice (personal observation). Thus, the red fox scent probably elicited a "fear" response, resulting in avoidance of the butternuts. However, another possible interpretation is that the red fox and raccoon scents inhibited feeding by gray squirrels more because of the "foul" smell than because of predator recognition. Indeed, the gray squirrels ate other butternuts near the red fox and raccoon scent ECs.

However, my third prediction, that human scent would be significantly more effective than a control (no scent), was not supported. This may be due to the squirrels' familiarity with human scent. The cemetery is used as a recreation area and no hunting is allowed. Humans also provide gray squirrels with food (personal observation). Gray squirrels may therefore have habituated to human scent. However, Rosell and Czech (2000) showed that human scent had a significantly stronger effect than three controls in decreasing foraging by Eurasian beaver (*Castor fiber*) during fall.

The effectiveness of predator odors as natural repellents may depend on such factors as the geographic distribution of predator and prey, the duration of their geographic association, and cultural transmission of predator responses among prey (Swihart 1991). An innate response by prey to a predator cue such as odor is likely to occur if prey and predator have coexisted over evolutionary time (e.g., Barreto and Macdonald 1999). However, research with house mice (*Mus musculus*) conducted on an island with no predatory mammals showed that reaction to predator odor (cat, *Felis catus*, and red fox) may disappear after a certain number of generations (Dickman 1992), and is therefore not passed on genetically. Jędrzejewski et al. (1993) showed that bank voles (*Clethrionomys glareolus*) exhibited a diversified response to seven species of predators. Different antipredator behaviors of voles towards various predatory mammals seemed to be adaptations for protection against their modes of hunting. There was a significant positive correlation between the antipredation abilities of voles and the degree of mammalian predators' specialization on that species (Jędrzejewski et al. 1993). Further studies need to be carried out to elucidate whether the responses by gray squirrels to the red fox and raccoon scents are innate or learned.

My results may have some practical implications. One implication may be that predator odors could reduce damage to human interests such as gnawing ears of growing corn and the bark of trees, providing a humane, environmentally acceptable substance that can be used to manage wild gray squirrel populations. In field trials, predator odors have succeeded in reducing feeding damage caused by a few species by 60–100% for periods ranging from 1 to 5 months (Sullivan and Crump 1984; Sullivan 1986; Sullivan et al. 1988; Swihart 1991). However, no repellent is likely to provide total protection. Nevertheless, red fox and raccoon scents could reduce damage by gray squirrels during periods when trees are most vulnerable, e.g., May to July in England (see Kenward and Parish 1986) and between mid-February and April in Oregon (see Baldwin et al. 1986). Preventing gray squirrels from raiding gardens and bird feeders may also be possible,

at least for a short period when it is most necessary. However, the main mammalian predators of squirrels are martens (*Martes martes* and *Martes americana*) and the fisher (*Martes pennanti*) (Gurnell 1987). Therefore, further tests should investigate the effectiveness of marten and fisher scents as gray squirrel repellents, as well as the duration of effectiveness of different predator-odor repellents.

Acknowledgements

I thank Randi Pettersen for excellent help in the field, Dietland Müller-Schwarze, Howard Parker, André Tanguay, and Larry W. Van Druff for valuable discussions and (or) comments on an earlier draft of the manuscript, and André Tanguay for providing me with butternuts and scent samples.

References

- Baldwin, R.J., Howard, W.E., and Marsh, R.E. 1986. Debarking of conifers by western gray squirrel (*Sciurus griseus*). In Supplement to tropical pests management. Edited by C. Richards. Taylor and Francis, London.
- Barreto, G.R., and Macdonald, D.W. 1999. The response of water voles, *Arvicola terrestris*, to the odours of predators. *Anim. Behav.* **57**: 1107–1112.
- Brenneman, W.S. 1954. Tree damage by squirrels: silviculturally significant? *J. For.* **52**: 604.
- Britton, W.E. 1933. Injury to trees by squirrels. In Proceedings of the 9th Natural Shade Tree Conference, New York Botanical Garden, New York. pp. 85–91.
- Brooks, F.E. 1922. Note on a feeding habit of the grey squirrel. *J. Mammal.* **4**: 257–258.
- Dickman, C.R. 1992. Predation and habitat shift in the house mouse, *Mus domesticus*. *Ecology*, **73**: 313–322.
- Dooble, J.H., and McGinnes, B.S. 1973. Home ranges and activity of a gray squirrel population. *J. Wildl. Manag.* **38**: 860–867.
- Gorman, M.L. 1984. The responses of prey to stoat (*Mustela erminea*) scent. *J. Zool.* (1965–1984), **202**: 419–423.
- Gurnell, J. 1987. The natural history of squirrels. Facts on File Publications, New York.
- Gurney, J.E., Watkins, R.W., Dunsford, G.E., and Cowan, D.P. 1999. Modification of exploratory behavior by house mice (*Mus domesticus*) in response to fox fecal odor. In Advances in chemical signals in vertebrates. Edited by R.E. Johnston, D. Müller-Schwarze, and P.W. Sorensen. Kluwer Academic/Plenum Publishers, New York. pp. 633–640.
- Hougart, B., and Flyger, V. 1981. Activity patterns of radio-tracked squirrels. *Trans. Northeast Sect. Wildl. Soc.* **38**: 11–16.
- Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecol. Monogr.* **54**: 187–211.
- Irving, F.D., and Beer, J.R. 1943. A six year study of sugar maple bark stripping by gray squirrels in Minnesota oak maple stand. *J. For.* **61**: 508–511.
- Jędrzejewski, W., Rychlik, L., and Jędrzejewska, B. 1993. Responses of bank voles to odours of seven species of predators: experimental data and their relevance to natural predator–vole relationships. *Oikos*, **68**: 251–257.
- Kenward, R.E. 1983. The causes of damage by red and grey squirrels. *Mammal Rev.* **13**: 159–166.
- Kenward, R.E., and Parish, T. 1986. Bark stripping by grey squirrels. *J. Zool. Ser. B*, **210**: 473–481.
- Koprowski, J.L. 1994. *Sciurus carolinensis*. *Mamm. Species No.* 480.

- Lima, S.L. 1985. Maximizing feeding efficiency and minimizing time exposed to predators, a trade-off in the black-capped chickadee. *Oecologia*, **66**: 60–67.
- Lima, S.L., and Dill, L.M. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. *Can. J. Zool.* **68**: 619–640.
- Merkens, M., Harestad, A.S., and Sullivan, T. 1991. Cover and efficacy of predator-based repellents for Townsend's vole, *Microtus townsendii*. *J. Chem. Ecol.* **17**: 401–412.
- Nolte, D.L., Mason, J.R., Epple, G., Aronov, E., and Campbell, D.L. 1994. Why are predator urines aversive to prey? *J. Chem. Ecol.* **20**: 1505–1516.
- Norusis, M.J. 1993. SPSS base system user's guide, release 6.0. SPSS, Inc., Chicago.
- Nowak, R.M. 1999. Walker's mammals of the world. 6th ed. Vol. II. The John Hopkins University Press, Baltimore and London.
- Rosell, F., and Czech, A. 2000. Responses of foraging Eurasian beaver *Castor fiber* to predator odours. *Wildl. Biol.* **6**: 13–21.
- Rowe, J. 1984. Grey squirrel (*Sciurus carolinensis*) bark-stripping damage to broadleaved trees in southern Britain up to 1983. *Q. J. For.* **78**: 231–236.
- Rowe, J., and Gill, R.M.A. 1985. The susceptibility of tree species to bark-stripping damage by grey squirrels (*Sciurus carolinensis*) in England and Wales. *Q. J. For.* **79**: 183–190.
- Siegel, S., and Castellan, N.J., Jr. 1988. Nonparametric statistics for the behavioural sciences. 2nd ed. McGraw-Hill, New York.
- Sullivan, T.P. 1986. Influence of wolverine (*Gulo gulo*) odor on feeding behavior of snowshoe hares (*Lepus americanus*). *J. Mammal.* **67**: 385–388.
- Sullivan, T.P., and Crump, D.R. 1984. Influence of mustelid scent-gland compounds on suppression of feeding by snowshoe hares (*Lepus americanus*). *J. Chem. Ecol.* **10**: 1809–1821.
- Sullivan, T.P., Crump, D.R., and Sullivan, D.S. 1988. Use of predator odors as repellents to reduce feeding damage by herbivores. III. Montane and meadow voles (*Microtus montanus* and *Microtus pennsylvanicus*). *J. Chem. Ecol.* **14**: 363–377.
- Swihart, R.K. 1991. Modifying scent marking behavior to reduce woodchuck damage to fruit trees. *Ecol. Appl.* **1**: 98–103.
- Thompson, D.C. 1977. Diurnal and seasonal activity of the grey squirrel (*Sciurus carolinensis*). *Can. J. Zool.* **55**: 1185–1189.
- Whitaker, J.O., Jr. 1996. National Audubon Society field guide to North American mammals. Alfred A. Knopf, New York.