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MODIFYING SCENT-MARKING BEHAVIOR TO REDUCE WOODCHUCK DAMAGE TO FRUIT TREES¹

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Abstract. Woodchucks (*Marmota monax*) damage fruit trees by gnawing on main stems during scent marking, a behavior unrelated to feeding. I tested whether damage could be reduced by providing alternative sites for scent marking or by applying predator odor to trees. Nearly all hardwood stakes supplied as alternative sites for scent marking were used, and the elapsed time from activation of a burrow until onset of damage to an adjacent tree was significantly greater for sites with stakes. However, the mean level of damage to trees was not significantly reduced. Impregnating hardwood stakes with sodium chloride increased their use as gnawing sites relative to untreated stakes, presumably due to dietary sodium deficits incurred by woodchucks during spring. Use of NaCl-treated stakes did not reduce damage to adjacent trees, however. Application of a predator odor, bobcat urine, as a topical spray reduced mean levels of gnawing by 98.3% relative to untreated trees, and placement of bobcat urine in capillary tubes at the bases of trees also resulted in significant reductions in damage over a 3-mo period.

Key words: bobcat; chemical communication; *Lynx rufus*; *Marmota monax*; olfaction; orchard; predator urine; repellent; scent marking; sodium; wildlife damage; woodchuck.

INTRODUCTION

Woodchucks (*Marmota monax*) are medium-sized (3–6 kg), semi-fossorial sciurids that inhabit agricultural areas throughout the eastern United States and Canada (Hall 1981). In orchards, woodchucks can be serious pests; apple growers in New York estimated that 3.5% of young trees and 1.2% of older trees incurred woodchuck damage each year (Phillips et al. 1987). Woodchucks damage fruit trees by excavating burrows near trees, which can aerate roots excessively, and by gnawing on the main stem, which can reduce growth rates and increase the likelihood of pathogenic infection or death (Byers 1984, Swihart and Conover 1988). Attempts to reduce damage typically rely on population reduction, but rapid colonization of areas by non-residents, plus increased birthrates and juvenile survival, work against a long-term reduction in numbers (Davis et al. 1964, Byers 1984, Swihart and Conover 1988).

The effects of control techniques with a biological basis should generally be longer lasting than nonbiological or anthropogenic ones (Shumake 1977, Sullivan and Crump 1984). Here, I report on tests to determine whether gnawing damage by woodchucks in orchards can be reduced by modifying their behavior and/or activity near susceptible trees. Three ecologically oriented techniques were tested for their ability to reduce damage: provision of scent stations; application of sodium to increase use of scent stations; and application of predator urine.

Gnawing by woodchucks occurs primarily during spring in Connecticut and apparently is unrelated to feeding; cambial tissue commonly is found on the ground around damaged trees, gnawing has been noted on >25 species of woody plants, and dead trees and fenceposts also are gnawed (R. K. Swihart, *personal observation*). Rather, gnawing seems to be associated with scent-marking behavior (Ouellet and Ferron 1988). Woodchucks have multilobular apocrine sudoriferous glands in the oral angle that are capable of producing a pungent odor (Walro et al. 1983). Muzzle-rubbing in woodchucks is similar to the scent-marking behavior of other ground squirrels (Halpin 1984) and has been observed in captive (Hébert and Prescott 1983) and free-ranging (Ouellet and Ferron 1988) woodchucks, with peaks in scent marking occurring during the spring breeding season (Hébert and Prescott 1983). Ouellet and Ferron (1988) demonstrated that there was a significant probability of transition from gnawing to muzzle rubbing. They hypothesized that gnawing facilitated deposition and retention of scent on wooden substrates. Although the ability of woodchucks to discriminate among conspecific odors has not yet been demonstrated, intraspecific chemical communication is plausible given its widespread occurrence in other species of ground squirrels (e.g., Harris and Murie 1982, reviewed in Halpin 1984).

If gnawing damage is related to scent marking, provision of alternative marking sites could reduce damage to trees. One problem with this approach is that woodchucks may preferentially mark a tree because of visual cues and residual scent from earlier marking episodes as well as neophobic responses to the new

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marking site (Stoddart 1980, Ouellet and Ferron 1988). Thus, an attractant to encourage inspection and use of the alternative marking site may improve the technique's effectiveness. Numerous herbivorous mammals incur dietary sodium deficiencies (reviewed in Robbins 1983), and sources of sodium are actively sought during periods of deficiency (e.g., Blair-West et al. 1968, Botkin et al. 1973, Weeks and Kirkpatrick 1976). Weeks and Kirkpatrick (1978) showed that woodchucks in sodium-poor environments actively seek this mineral; free-ranging individuals preferentially gnawed on wooden stakes containing sodium relative to stakes containing magnesium, calcium, or potassium. Thus, sodium may serve as an attractant to encourage use of alternative marking sites.

Several species of mammalian predators occur sympatrically with woodchucks in eastern North America, including red fox, *Vulpes vulpes* (Hamilton 1934), coyote, *Canis latrans* (Parker 1986), bobcat, *Lynx rufus* (Progulski 1955), badger, *Taxidea taxus* (Lee and Funderburg 1982), and black bear, *Ursus americanus* (Lee and Funderburg 1982). Interspecific odor recognition is well developed between many species of predator and prey (Stoddart 1980), and the behavior of naive prey in the presence of predator odors suggests that recognition of such odors may have a genetic component (Müller-Schwarze 1972, Hennessy and Owings 1978). Predator odors are capable of modifying the behavior and activity of prey species (e.g., Fulk 1972, Hennessy and Owings 1978, Stoddart 1980, Sullivan and Crump 1986a, Sullivan et al. 1988b). In particular, several studies have demonstrated the ability of predator odors to deter feeding by mammalian herbivores (Müller-Schwarze 1972, 1983, Sullivan and Crump 1984, 1986b, Melchior and Leslie 1985, Sullivan et al. 1985a, b, Sullivan 1986, Sullivan et al. 1988a, b).

I tested whether (1) alternative scent-marking stations would reduce gnawing by woodchucks on fruit trees, (2) addition of sodium to alternative marking stations would enhance their effectiveness, and (3) application of predator urine to fruit trees would reduce gnawing (and presumably scent marking). The effectiveness of these techniques was also compared to results obtained using tetramethylthiuram disulfide (thiram), a commercial repellent of rabbits (*Sylvilagus*) and deer (*Odocoileus*).

METHODS

Experiments were conducted in commercial apple orchards in Southington and Middlefield, Connecticut, USA, from mid-February to mid-May. This period largely encompasses the time from emergence of adults from hibernation until the emergence of juveniles from natal burrows (Snyder and Christian 1960, Snyder et al. 1961). It also corresponds to the period of peak scent-marking activity (Hébert and Prescott 1983, R. K. Swihart, *personal observation*). Two orchards in

Southington were used in experiments in 1988, and a third orchard in Middlefield was added in 1989.

Ouellet and Ferron (1988) noted that 96% of all scent marking by woodchucks took place within 6 m of a burrow. Thus, I examined the effect of various treatments on gnawing damage to the fruit tree closest to the main entrance of a burrow. Orchards were surveyed for burrows in the spring and summer preceding an experiment, and the location of each burrow was mapped. Each burrow was marked with numbered flagging and classified as either active or inactive on the basis of freshly excavated soil, capture or sighting of a woodchuck at the burrow entrance, or use of the burrow by radio-collared individuals (Swihart and Conover 1988, Swihart 1989). Only burrows classified as active during a survey and occurring within 3 m of a young fruit tree (<15 cm basal diameter) were used in experiments the following year; these are subsequently referred to as experimental burrows.

Burrows in the orchards exhibited an aggregated dispersion pattern, with edaphic and topographic features apparently important in determining burrow location (see Merriam 1971, Swihart 1989). I assigned treatments to experimental burrows to ensure that treatments were represented approximately equally within any given aggregation. However, burrows within an aggregation typically did not occur in multiples of the number of treatments, and some experimental burrows were not activated by woodchucks during the study period. Hence, sample sizes among treatments was unequal.

In 1988, experiments were conducted using three treatments. Only the tree closest to an experimental burrow was monitored, unless two trees were an equal distance from the burrow. To test whether alternative scent-marking stations could reduce gnawing damage, two 3 × 3.5 × 120 cm hardwood stakes were driven into the ground <1.5 m from the main entrance of an experimental burrow ($N = 30$) in mid-February. To test whether application of predator urine could reduce damage, 3–5 mL of undiluted bobcat urine (Hoosier Trapper Supply, Greenwood, Indiana) was sprayed at approximately weekly intervals on the lower 75 cm of the fruit tree nearest to an experimental burrow ($N = 36$). I also tested whether a single application of a 20% solution of thiram (Chew-Not, Nott, Pleasant Valley, New York) was effective in reducing gnawing when painted on the lower 75 cm of a tree in mid-February ($N = 28$). Other experimental burrows with untreated trees served as a control ($N = 38$).

In 1989, tests were replicated for each of the treatments examined in 1988, with the exception that only one hardwood stake was placed at an experimental burrow as an alternative scent-marking site. In addition, I tested whether sodium increased the attractiveness of alternative scent-marking sites. A separate group of hardwood stakes was soaked for 4 d in a 1:10 solution of NaCl and water. After air-drying for 2 d,

sodium-soaked stakes were then presented at experimental burrows ($N = 17$) in the same manner as unsoaked stakes.

To determine whether small quantities of predator odor could affect gnawing behavior of woodchucks, trees adjacent to experimental burrows ($N = 21$) were equipped with bobcat urine in capillary tubes in mid-February 1989. Initially, capillary tubes (inside diameter = 1.12 mm, length = 5 cm) were filled with 0.2 mL of urine using a syringe and 19-gauge needle, one end of the tubes was sealed with wax, and the other end was left unsealed to permit gradual escape of the bobcat odor. Two capillary tubes were then attached with duct tape to the base of a tree on opposite sides. However, subfreezing temperatures in February resulted in dislodging of wax plugs. Consequently, additional tubes were filled with urine, flame-sealed at one end, and used to replace wax-plugged tubes on 10 March 1989.

Experimental burrows were monitored for woodchuck activity by checking the burrow entrance for fresh signs of excavation at approximately weekly intervals, and associated trees (and hardwood stakes for the scent station and sodium treatments) were checked for gnawing damage. Gnawing damage to trees was measured as square centimetres of surface area of bark removed. Use of hardwood stakes as scent-marking sites was determined by the presence of mud deposited during muzzle rubbing and/or the odor of oral gland secretions. An estimate of the magnitude of damage was recorded within a week of its first occurrence at each experimental burrow, and final estimates of damage were recorded in mid-May at the termination of the experiment. In addition, hardwood stakes were collected, and the surface area of a stake that was subjected to scent marking was estimated by calculating the area of the stake over which mud deposition had occurred. In 1989 a qualitative assessment was made of gnawing damage to stakes by recording whether damage was absent, slight ($< 1 \text{ cm}^3$ of a stake removed by gnawing), moderate ($1\text{--}10 \text{ cm}^3$ removed), or severe ($> 10 \text{ cm}^3$ removed).

Burrows that remained inactive and received no damage were omitted from subsequent statistical analysis. Preliminary tests indicated that mean levels of damage in 1988 were comparable to 1989 levels for each treatment as well as the control ($P > .05$ for all tests); hence, data were pooled across years for tests of unsoaked hardwood stakes, bobcat urine (spray), and thiram. Because experiments with sodium-soaked stakes and urine-filled capillary tubes were conducted only in 1989, only data for 1989 control sites were used in analyses of these treatments. Nonparametric Mann-Whitney tests (Conover 1980: 215) with one-tailed comparisons were used to determine whether the extent of gnawing differed for treated vs. untreated sites. A Kruskal-Wallis nonparametric ANOVA was used to test for differences among treatments in the mean

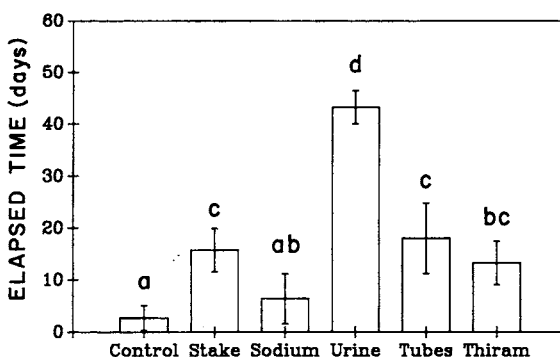


FIG. 1. Elapsed time (days) between activation of a burrow and onset of gnawing damage to adjacent fruit trees by woodchucks for each of five treatments and an untreated control (means $\pm$ SE). Treatments were as described in Fig. 2 legend. Treatment means were unequal ($P < .001$, Kruskal-Wallis nonparametric ANOVA); treatments with different letters differ ($P < .05$).

elapsed time between activation of a burrow and onset of gnawing, with differences between each treatment and the control assessed using multiple pairwise comparisons (Conover 1980: 231).

RESULTS

Alternative scent-marking stations

All but one (97%) of the unsoaked hardwood stakes provided at active experimental burrows were scent marked by woodchucks. The elapsed time from activation of a burrow until the onset of damage to its associated tree was greater at trees adjacent to unsoaked stakes than at untreated trees ($P < .005$, Fig. 1). However, damage to trees adjacent to these stakes ($\bar{X} \pm \text{SE}$, $19.4 \pm 3.8 \text{ cm}^2$, Fig. 2) was not reduced significantly relative to untreated trees ($24.2 \pm 5.2 \text{ cm}^2$, $P = .30$, Fig. 2).

Sodium as an attractant

Woodchucks scent marked on all but one (94%) of the sodium-soaked stakes at active burrows. The extent of scent marking on sodium-soaked stakes ($299.4 \pm 48.7 \text{ cm}^2$) did not significantly exceed marking on unsoaked stakes ($225.2 \pm 48.4 \text{ cm}^2$) in 1989 ($P = .12$). However, there was a tendency for woodchucks to gnaw sodium-soaked stakes more severely than unsoaked stakes; of stakes incurring gnawing damage, a marginally significant increase in the extent of gnawing occurred ($P = .087$). In addition, 5 of the 17 (29%) sodium-soaked stakes were severely damaged, including 3 that were gnawed into two pieces, whereas none of the unsoaked stakes ($N = 11$) was severely damaged.

The mean elapsed time from activation of a burrow until onset of damage did not differ from that observed at untreated sites ($P > .25$, Fig. 1). Further, damage to fruit trees adjacent to sodium-soaked stakes ($29.5 \pm 6.1 \text{ cm}^2$, Fig. 2) did not differ significantly from untreated trees ($25.1 \pm 4.4 \text{ cm}^2$, $P > .50$).

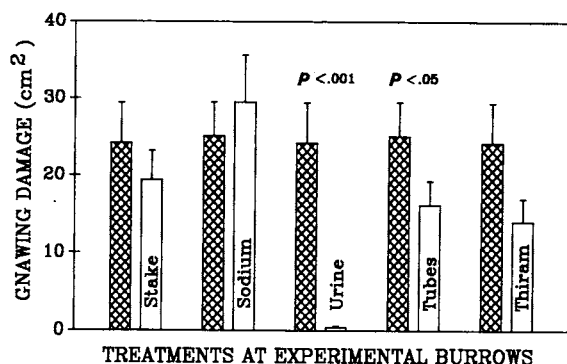


FIG. 2. Levels of gnawing damage by woodchucks to experimental fruit trees in Connecticut orchards (□) vs. untreated trees (▨). Data are means + SE. Damage was assessed for trees < 3 m from burrows and receiving one of the following treatments: hardwood stake (Stake); hardwood stake soaked in a solution of NaCl (Sodium); bobcat urine applied as a topical spray (Urine) or dispensed in capillary tubes (Tubes); and tetramethylthiuram disulfide (Thiram).

Bobcat urine

Only four trees (11%) sprayed with bobcat urine were damaged by woodchucks. The elapsed time between activation and onset of damage at a particular burrow was greater near sprayed trees (Fig. 1) than near untreated trees ($P < .0005$). Damage to sprayed trees averaged 0.4 ± 0.2 cm² (Fig. 2), a value significantly less than for untreated trees ($P < .0001$).

A significant delay occurred in the mean elapsed time between activation of a burrow and damage of a tree equipped with urine-filled capillary tubes relative to untreated sites ($P < .001$, Fig. 1). In addition, mean damage to trees treated with urine-filled capillary tubes in 1989 (16.2 ± 3.1 cm², Fig. 2) was less than to untreated trees ($P = .04$).

Thiram

The elapsed time from activation of a burrow until initiation of damage to an adjacent tree also was delayed by use of thiram relative to untreated trees ($P < .025$, Fig. 1). However, damage to trees painted with thiram (14.0 ± 3.0 cm², Fig. 2) was not significantly less than to untreated trees ($P = .08$).

DISCUSSION

Provision of scent stations

Chemically mediated communication among mammals is well documented (e.g., Stoddart 1980, Halpin 1986), and olfactory communication appears well developed in many species of ground-dwelling sciurids, including woodchucks (Halpin 1984). Hébert and Prescott (1983) concluded that scent marking by a woodchuck could provide conspecifics with information regarding the reproductive or dominance status of the marker, or it could serve to familiarize an individual

with its environment. Because scent marking usually occurred near a burrow and increased in frequency following movements between burrows or sightings of conspecifics, Ouellet and Ferron (1988) concluded that marking probably was used to advertise occupancy of a burrow.

In the present study, alternative stations for scent marking were used to a considerable extent by woodchucks, and the presence of alternative sites slowed the rate at which adjacent trees were damaged (Fig. 1). The total mean damage due to gnawing was not reduced, however (Fig. 2). Many of the trees at experimental burrows had incurred gnawing damage in years prior to the study, and it is possible that residual odor or visual markers on the trees contributed to their continued use as scent stations even in the presence of alternative sites. Halpin (1984) suggested that gnawing may provide a visual cue for location of marking sites, and Ouellet and Ferron (1988) and Hébert and Prescott (1983) noted that woodchucks repeatedly scent marked at stations used by other individuals. In established orchards, then, increasing the effectiveness of alternative marking sites may depend on reducing the relative attractiveness of fruit trees. Application of a repellent compound on trees is one possibility. Also, the attractiveness of alternative sites may be enhanced by "priming" them with natural secretions or synthetic derivatives of the active compounds produced by the oral gland of woodchucks (see Shumake 1977).

Sodium apparently functioned as an attractant in the present study; gnawing damage to sodium-soaked stakes generally was more severe than to unsoaked stakes. Sodium drive often peaks in female mammals during gestation and lactation (Robbins 1983). In woodchucks, this time also corresponds to the spring period during which herbaceous vegetation often contains excessive amounts of water and potassium, both of which may reduce sodium retention in mammals (Weeks and Kirkpatrick 1976, 1978, Smith et al. 1978). Woodchucks actively seek sources of sodium during spring; Weeks and Kirkpatrick (1978) observed licking of residual salt from roads and use of natural mineral deposits, and Fraser (1979) observed feeding on sodium-rich aquatic plants, an atypical food (Hamilton 1934).

Despite their attraction to stakes soaked in sodium, woodchucks did not reduce their gnawing on adjacent fruit trees (Fig. 2). Although stakes provided a suitable substrate for scent marking, the presence of sodium may actually have reduced the effectiveness of stakes as alternative sites for marking by altering the context in which woodchucks perceived them. That is, stakes became primarily sodium sources instead of marking sites.

The repellency of bobcat urine

Bobcat urine reduced gnawing damage to fruit trees by 98% (Fig. 2). Its effectiveness was reduced when presented in capillary tubes rather than as a topical

spray, suggesting that the amount of urine was important. Urine in capillary tubes declined in effectiveness as the study progressed, indicating that evaporation or dilution of the urine occurred. Sullivan and Crump (1984), Sullivan et al. (1985a), and Sullivan (1986) also noted that evaporative loss, aging, and low initial concentration of predator urine resulted in reduced repellency.

Woodchucks in this study avoided marking fruit trees sprayed with bobcat urine for as long as 93 d. Further, habituation did not seem to occur, even though many animals in the populations studied were exposed to the urine in consecutive years. The geographic ranges of bobcats and woodchucks overlap extensively (Hall 1981), and although the evolutionary significance of bobcats as predators on woodchucks is unknown, bobcats prey upon woodchucks (Rollings 1945, Pollack 1951, Progulske 1955, Fox and Fox 1982) and other sciurids (Gashwiler et al. 1960, Parker and Smith 1983); the detection of a bobcat elicits alarm calling in marmots (Lee and Funderburg 1982). Innate responses to odors of sympatric predators should not habituate (Müller-Schwarze 1974). And although cultural transmission of behavioral responses to predator odors is possible in social mammals or species with an extended period of parental care, other forms of learned responses likely would result in lowered survival. Genetic control of avoidance behavior toward the scents of sympatric predators has been demonstrated for black-tailed deer (*Odocoileus hemionus columbianus*, Müller-Schwarze 1972) and voles (*Microtus arvalis*, Gorman 1984), and responses of California ground squirrels (*Spermophilus beecheyi*) toward odors of snakes likely have a genetic component (Hennessy and Owings 1978).

An alternative explanation for the repellency of bobcat urine to woodchucks is that its odor may interfere with the effective transmission of chemical messages conveyed by scent marking. If so, pungent novel odors or odors of nonpredator species should exhibit similar repellent properties. My intent was to test the effectiveness of techniques with a sound ecological basis; hence, I did not test novel or nonpredator odors. However, work by other researchers indicates that odors without some biological basis for avoidance are not as effective. For instance, Gorman (1984) demonstrated that of three prey species tested, two, *Microtus arvalis* and *M. agrestis*, reduced their movements and actively avoided areas marked with scent from the anal gland of a predator (stoat, *Mustela erminea*), whereas no avoidance occurred in response to odor from the anal gland of a nonpredator (guinea pig, *Cavia porcellus*). Similarly, feeding by snowshoe hares (*Lepus americanus*) and black-tailed deer was suppressed by odors of native felid, canid, and mustelid predators but not by novel odors such as ammonia or 2-methylbutyric acid (Sullivan et al. 1985a, b). Studies with black-tailed deer and snowshoe hares also indicate that odors of sympatric predators are more effective than odors

of predators with allopatric distributions (Müller-Schwarze 1972, Sullivan et al. 1985a).

Stress- or fear-provoking odors are gaining increasing attention from applied ecologists and wildlife managers because of their ability to modify prey behavior (Shumake 1977). Previous studies have tested the ability of predator odors to deter feeding by mammalian herbivores such as snowshoe hares (Sullivan and Crump 1984, 1986b, Sullivan et al. 1985a, Sullivan 1986), black-tailed deer (Müller-Schwarze 1972, Sullivan et al. 1985b), voles (*Microtus pennsylvanicus* and *M. montanus*, Sullivan et al. 1988a), and pocket gophers (*Thomomys talpoides*, Sullivan et al. 1988b). Predator odors have succeeded in reducing feeding damage in field trials by 60–100% for time periods ranging from 1 to 4 mo (Sullivan and Crump 1984, Sullivan 1986, Sullivan et al. 1988a). My findings indicate that long-term protection of agricultural crops can also be attained by the use of predator odors in certain situations where behaviors other than feeding are involved. Identification, synthesis, and incorporation of the repellent components in predator urine into slow-release devices are required to enhance the practicality of this control technique (Sullivan and Crump 1984, 1986, Sullivan et al. 1988a).

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