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# 13

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## ABSTRACT

Woodchuck (*Marmota monax*) damage to lawns, gardens, orchards, and other agricultural areas is of concern to homeowners and farmers throughout the northeastern region of the United States. Currently, the only effective control methods are live-trapping and relocation, shooting, or lethal trapping. Each of these techniques, though effective, has drawbacks that limit its use in residential areas. Using odors to repel the animals could provide a nonlethal option to help mitigate the vegetation and property damage caused by these animals. For this reason, we studied the repellency of several commonly available odorants to repel woodchucks. Nine different burrow sites were tested during April, May, and June 1995 on the Vassar College campus (Poughkeepsie, NY). Testing occurred in daily 3-hr sessions between the hours of 0700 and 1100 or 1400 and 1900. The two ends of the apparatus were baited with bowls containing approximately 30 g of fresh green peppers. Strips of filter paper containing 0.1 ml of odorant or distilled water were placed at the edges of the bowls. Geranium oil, d-pulegone, coyote (*Canis latrans*) urine, and Deer-Away® were all effective repellents ($P < 0.05$). Cinnamon leaf oil, pennyroyal oil, and Siberian pineneedle oil were not. The data suggest that at least some odorants may be effective in reducing woodchuck damage.

## KEY WORDS

*animal damage control, Marmota monax, New York, odors, repellents, woodchucks*

## INTRODUCTION

Odor avoidance protects potential prey from predators. For example, predator odors are avoided by voles (Fulk 1972, Stoddart 1976, Dickman and Doncaster 1984, Gorman 1984, Sullivan et al. 1988a), ground squirrels (Hennessey and Owings 1978), pocket gophers (Sullivan et al. 1988b), snowshoe hares (Sullivan et al. 1985a), mountain beaver (Epple et al. 1993), woodchucks (Swihart 1991), black-tailed deer (Muller-Schwarze 1972, Melchiors and Leslie 1978, Sullivan et al. 1985b), white-tailed deer (Swihart et al. 1991, Lewison et al. 1993), as well as sheep and cattle (Pfister et al. 1990). The repellent nature of these odors may be mediated by the presence of volatile sulfur compounds likely derived from meat protein digestion (Lewison et al. 1993).

Other naturally occurring odors can signal either unpalatability or toxicity (Launchbaugh et al. 1993). These chemicals are commonly terpenoids, and the available evidence suggests that herbivores are sensitive to these substances and are repelled by them. Our study was designed to investigate the potential abilities of a variety of predator and natural odors as repellents to woodchucks. The development of olfactory repellents of this sort would provide a powerful weapon for the nonlethal control of damage caused by woodchucks.

## STUDY AREA

Testing occurred on the Vassar College campus in upstate New York. We selected 9 burrow sites located in relatively quiet areas of the campus that were no closer than 25 m to one another. The burrows were selected because they provided various levels of cover and a variety of different available food sources. One site was at the foundation of a building, three were near the base of maple (*Acer* spp.) or apple (*Malus* spp.) trees, and five others were located near or under white pine trees (*Pinus strobus*).

## METHODS

Testing was conducted during April, May, and June 1995 in daily 3-hr time blocks between either 0700 and 1100 or 1400 and 1900. All data were recorded using a specially designed apparatus comprised of a 31 x 62 x 124 cm frame that was covered with hardware cloth and stamped aluminum. On each long side, a 31 x 31 cm opening allowed access to the inside of the apparatus. Entry into each end of the apparatus was recorded by Trailmaster TM500 passive infrared detectors.

Testing was preceded by several days of habituation. Initially, the animals were exposed daily to 10 gm of green pepper placed near the burrow opening on each of at least 3 days. When these were being reliably eaten, the woodchucks were then exposed to green peppers in the testing apparatus. When entrance into the apparatus was verified by the infrared detectors, the treatment period began.

For all tests, each end of the apparatus was baited with a 5 x 7 cm pyrex bowl that contained 30 gm of fresh green pepper. A 1 x 5 cm strip of coarse filter paper was attached to each bowl, and 0.1 ml of either one odorant or distilled water was applied to the paper. Each animal received one administration of each odorant/distilled water comparison.

### Candidate Repellents

A total of eight different odorant chemicals were tested. Geranium oil (Hogan Fragrances), pennyroyal oil (Hogan Fragrances), and d-pulegone (International Flavors and Fragrances) were all selected because of reports suggesting insecticidal properties (Walters et al. 1990, Rutledge et al. 1982, Gunderson et al. 1985). Cinnamon leaf oil (Hogan Fragrances) was selected because of its reported fungicidal characteristics (Sinha et al. 1993). Siberian pine-needle oil (Penn Herb Co.), coyote urine (M & M Furs) and Deer-Away were selected for testing because of previous reports of their potency as mammalian repellents (see also other reports in this volume). The remaining odorant chemical, Bobbex (Bobbex Co.), a plant growth stimulant derived from discards of food processing, was selected because previous research suggested that substances derived from mammalian protein might be repellent to herbivores (Lewison et al. 1993).

### Analysis

The number of entries and the amount of green pepper consumption was calculated for each arm of the apparatus in each odorant/distilled water comparison. Two repellency scores were calculated for each test session. Entry and consumption repellency values were determined by subtracting the number of entries or the amount of food consumed on the side baited with distilled water from the relevant value on the side baited with the odorant condition. One-way repeated measure ANOVA's were conducted on these data for primary analysis of the data. Fisher PLSD tests were conducted for post hoc analysis of the data. One additional analysis was conducted on the entry repellency data. The data were separated by habitat to form two groups. The data from these groups were then analyzed by a one-way repeated measures ANOVA.

## RESULTS

Initial analysis indicated that several of the odorants were effective repellents to woodchucks. Overall analysis of the data indicated a significant effect of odorant condition on the number of entries into the apparatus ($F = 7.96$; 7,64 df; $P < 0.001$; Figure 1). Post hoc analyses indicated that geranium oil, d-pulegone, Deer-Away and coyote urine were significantly more repellent than either cinnamon oil or pennyroyal oil ($P<0.05$). Additionally, these analyses indicated that Deer-Away and coyote urine were significantly more repellent than either pine-needle oil or Bobbex ($P<0.05$). Analysis of the consumption data failed to reveal any significant differences among odorant conditions ($F = 0.4$; 7,64 df; $P> 0.05$; Figure 2).

Because of the observations of other investigators suggestmg that pine-needle oil should have repellent qualities, these results were initially a bit disconcerting. However, further analysis suggested a possible reason for the lack of repellency of pine-needle oil in the present experiment. Of the 9 burrow test sites, 4 of the sites were located under deciduous trees or next to the foundation of buildings, while 5 were located near or under pine trees. When the data for entry into the arms of the apparatus for the trials using pine-needle oil were analyzed on a comparative basis for those data derived from burrows under and not under pine trees, it was found that there

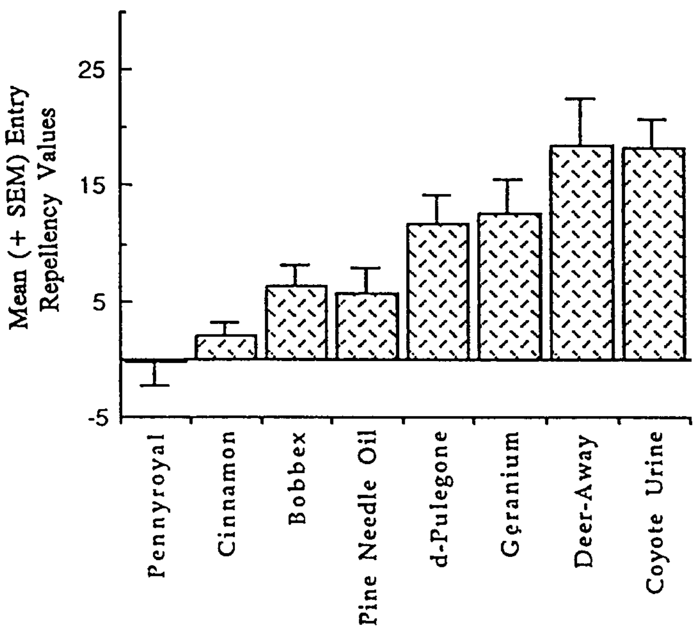


FIGURE 1. Mean woodchuck repellency values for the odorant conditions. Repellency scores were computed by subtracting the number of entries into the control side from the number of entries into the odorant-baited side of the apparatus.

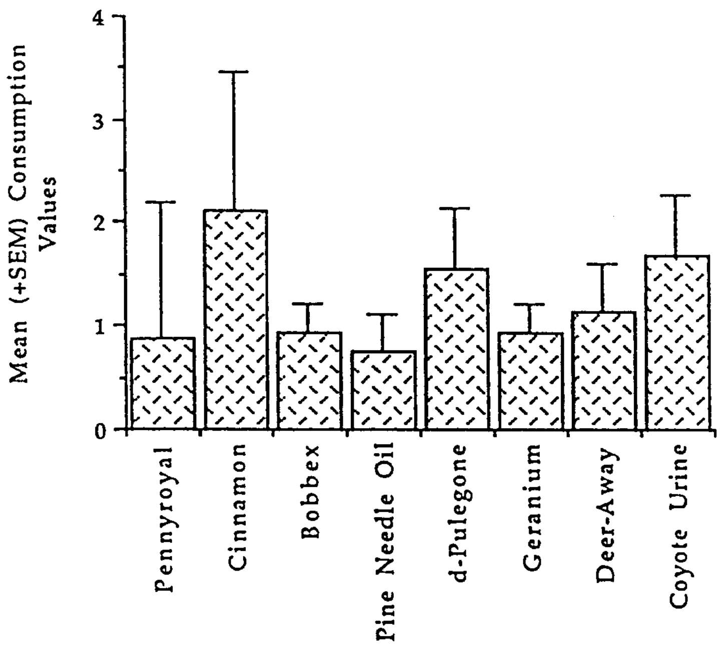


FIGURE 2. Mean woodchuck consumption values for the odorant conditions. Consumption scores were computed by subtracting the amount of stimulus eaten on the control side from the consumption on the odorant-baited side of the apparatus.

was a significant repellency effect of pine-needle oil for only those animals whose burrows were not under pine trees ($F = 7.74$; 1,7 df; $P < 0.05$; Figure 3).

## DISCUSSION AND MANAGEMENT IMPLICATIONS

Several of the candidate odorants were highly repellent to woodchucks. Not surprisingly, given their apparent general repellency to herbivores, Deer-Away and coyote urine markedly reduced the number of entries into the odorant baited arm of the apparatus. These data support the findings of Swihart (1991) that Bobcat (*Lynx rufus*) urine can dramatically reduce woodchuck damage to fruit trees. Our data suggest that this repellency is greater than that of cinnamon, pennyroyal, pine-needle oil, or Bobbex. Geranium and pulegone, though not as effective as Deer-Away and coyote urine, were still more repellent than cinnamon and pennyroyal. The initial very modest effect of pine-needle oil on entries into the odorant-baited arm of the apparatus may have been the result of habituation to the odor by the animals who were continually exposed to this smell at their burrow site. When the data were analyzed in an attempt to address this possibility, we found that animals exposed to the odors of pine trees for extended periods of time showed very little repellency to pine-needle oil. Conversely, those animals not exposed to the odors of pine trees at the burrow site were repelled by pine-needle oil. This suggests that chronic exposure to an odorant has significant effects on the animal's responsiveness to it. This possibility is consistent with the responsiveness of pocket gophers to the odor of pine-needle oil. Epple et al. (this volume) found that in a forced-choice feeding situation, northern pocket gophers (*Thomomys talpoides*) did not respond to pine-needle oil while plains pocket gophers (*Geomys bursarius*) were repelled by the odor. One possible explanation for this difference in responding is that the northern pocket gophers may have been exposed to pine odors and/or feeding on plant parts prior to being captured and brought into the laboratory for testing.

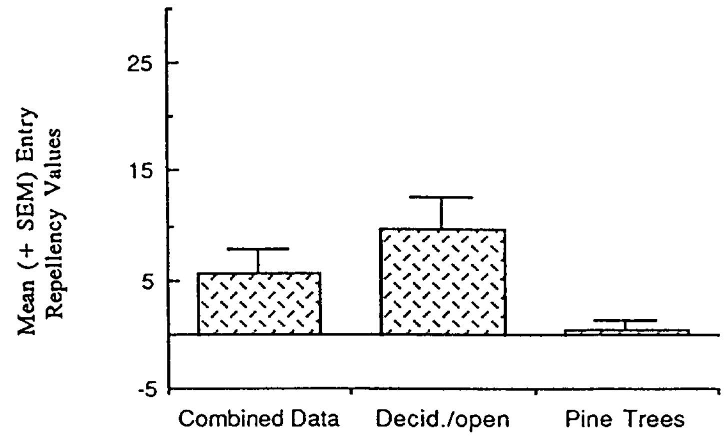


FIGURE 3. Mean woodchuck repellency values for the pine-needle oil test sessions. The left-hand bar is taken directly from Figure 1, while the two right-hand bars depict the mean repellency score of these trials separated by location of the burrow site.

While cautious about extrapolation, we suggest that a variety of chemicals may be effective olfactory repellents for woodchucks. Although, the usefulness of these odors in protecting cultivated plants remains unaddressed at this time, Deer-Away, coyote urine, pulegone, and geranium oil may protect plants from woodchuck damage. Among these substances, our findings with Deer-Away may have the most immediate practical significance, insofar as Deer-Away is already registered as a deer repellent that can be applied to ornamental plantings and nonfood crops.

A variety of issues relevant to this study warrant further investigation. For example, our experiment suggests that habituation may mediate avoidance when animals are continuously exposed to an odorant. Another issue is whether odorants will modify behavior when the odorants are liberally applied to all or most potential foods within a woodchuck's territory. Finally, it is unclear whether odorants can be used to modify burrow use. Studies that explore these questions are currently in progress.

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