# UC Agriculture & Natural Resources
## Proceedings of the Vertebrate Pest Conference

**Title**

Predator odors and their potential role in managing pest rodents and rabbits

**Permalink**

**Journal**

**ISSN**

**Authors**

Sullivan, Thomas P.
Sullivan, Druscilla S.
Crump, Douglas R.
et al.

**Publication Date**

# PREDATOR ODORS AND THEIR POTENTIAL ROLE IN MANAGING PEST RODENTS AND RABBITS

**THOMAS P. SULLIVAN** and **DRUSCILLA S. SULLIVAN**, Applied Mammal Research Institute and Mammal Pest Management Ltd., 23523 47th Avenue, R.R. No. 7, Langley, British Columbia, Canada V3A 4R1.

**DOUGLAS R. CRUMP**, Chemistry Division, Department of Scientific and Industrial Research, Private Bag, Petone, New Zealand.

**HAL WEISER** and **ELISABETH A. DIXON**, Department of Chemistry, University of Calgary, Calgary, Alberta, Canada T2N 1N4.

ABSTRACT: The snowshoe hare (Lepus americanus), several species of voles (Microtus spp.), the northern pocket gopher (Thomomys talpoides), and the red squirrel (Tamiasciurus hudsonicus) cause serious damage to forest plantations and stands (and voles and pocket gophers in tree fruit orchards) by their feeding activities. Certain synthetic predator odors are reviewed which have produced significant avoidance responses in these pest species and reduced damage to crop trees on an experimental basis. In addition, the specific study reported in this paper was designed to assess the influence of predator odors on population density and survival of montane vole (M. montanus) populations in natural grassland habitat. Vole populations declined significantly in three consecutive winters on an area (and also on a replicated area in the third winter) treated with predator odors. These declines were caused by significantly lower survival in the treatment than control populations. Concurrent feeding damage to young apple trees was significantly reduced on the treatment area. We suggest that the predator odors may have attracted additional predators to the study area thereby increasing predation, as well as perhaps inducing behavioral-physiological stress in the vole populations. This technique could be implemented in forest plantations and tree fruit orchards as a means to disrupt resident vole populations and protect crop trees from damage.

## INTRODUCTION

Several species of rodents and lagomorphs inflict serious feeding damage to forest and agricultural crops in North America and many other parts of the world. These mammal pests feed on the bark, vascular tissues, and roots of trees in fruit orchards and coniferous/deciduous forest plantations, as well as vegetable, grain, and forage crops in cultivated fields.

In particular, regeneration of coniferous forests is hampered by seedling destruction by the snowshoe hare (Lepus americanus) (Aldous and Aldous 1944, Black et al. 1979, Sullivan and Moses 1986), various species of voles (Microtus spp.) (see review by Green 1978), the northern pocket gopher (Thomomys talpoides) (Barnes 1973, Barnes et al. 1982, Crouch 1982), and the red squirrel (Tamiasciurus hudsonicus) (Sullivan and Sullivan 1982). Snowshoe hares fluctuate dramatically in abundance with peak populations every 9 to 10 years (Keith 1963). Voles tend to fluctuate in regular cycles of abundance every 2 to 5 years (Krebs and Myers 1974). Hares and voles may feed intensively on deciduous and coniferous tree seedlings during periods of high population density. Pocket gophers tend to have an annual cycle of abundance with the potential for feeding damage to occur every year. Red squirrel populations appear to fluctuate in accordance with available cone crops, with high numbers leading to debarking of trees in young stands in central B.C. and Alberta (Sullivan 1987). Feeding damage to tree fruit

orchards by voles and pocket gophers is also a serious problem in eastern (Davis 1976, Byers 1984, 1985) and western North America (Sullivan et al. 1987).

The use of toxicants (poison baits) has been the principal method to deal with this problem. This technique may be temporarily effective and is usually the only method available in most problem areas. However, the application of poison has four major disadvantages: (1) resiliency of target species to repopulate poisoned areas, (2) development of resistance to bait formulations; (3) poor bait acceptance, and (4) hazard to non-target species. An alternative technique to keep these pests from feeding on crops is needed if food and fibre production are to be maintained and perhaps expanded in the future.

The use of synthetic predator odors as area repellents has considerable potential for protection of forest and agricultural crops. Certain predator odors originating from feces, urine, or scent (anal) gland secretions, elicit a "fear" response when detected by prey species. To date, on an experimental basis, synthetic predator odors as repellents have produced significant avoidance responses in several pest species and reduced damage to forest and agricultural crops (Sullivan and Crump 1984, 1986a, 1986b, Sullivan et al. 1988a, 1988b). Experimental results for hares, voles, pocket gophers, and red squirrels are summarized in Fig. 1. Larger-scale trials are currently in progress in forest plantations

(snowshoe hare) and apple orchards (pocket gophers).

| Pest species | Synthetic constituents | Avoidance response | Reduction in damage | Duration |
|---|---|---|---|---|
| Snowshoe hare | Weasel | - | YES | OVERWINTER |
| | Red fox | - | YES | PEN |
| Montane and meadow voles | Weasel | YES | YES | OVERWINTER |
| | Red fox | YES | YES | OVERWINTER |
| Pocket gopher | Weasel | YES | - | OVERWINTER |
| Red squirrel | Weasel | YES | - | SCREENING |
| | Red fox | YES | - | SCREENING |

Fig. 1. Review of the avoidance responses and reduction in damage for the snowshoe hare, montane and meadow voles, northern pocket gopher, and red squirrel when exposed to synthetic predator odors from the weasel and red fox. Details of these studies are given in Sullivan and Crump (1984, 1986a, 1986b) and Sullivan et al. (1988a, 1988b). Those for the red squirrel are in Sullivan et al. (unpubl.).

Certain predator odors presumably have kairomonal properties by inducing a "fear" response in the pest (prey) species. Synthetic compounds from the anal-gland secretion of the ferret (Mustela furo) and urine of the red fox (Vulpes vulpes) have been used experimentally as means of individual recognition and to mark territories (Whitten et al. 1980, Clapperton et al. 1988, Clapperton and Minot 1988). Thus, it is possible that additional predators may be attracted to the repellent odors which they assume other members of their species have deposited as territory or other behavioral marks. As such, an increased number of predators would enhance the rodent repellent strategy by direct predation on rodents, and reinforcement of the avoidance response by those rodents which have detected the odor and are actively avoiding the protected area. Therefore, could these odors be used to attract predators, thereby reducing the population density (and survival) of a pest species on a given area?

This paper reports on a study designed to assess the influence of synthetic predator odors on the population density and survival of montane vole (M. montanus) populations in natural grassland habitat.

METHODS
Study area
This study was conducted at the Agriculture Canada Research Station, Summerland, B.C., Canada, during the period July 1983 to May 1986. Control and treatment study areas were located in old field grassland habitat composed mainly of crested wheatgrass (Agropyron cristatum), bluegrass (Poa spp.), quackgrass (A. repens), and smooth brome (Bromus inermis) and were separated by 3 km. Each area was approximately 5 ha of grassland with some sagebrush (Ar-temisia spp.), serviceberry (Amelanchier alnifolia), snowberry (Symphoricarpos albus), and knapweed (Centaurea spp.) in surrounding areas. The climate is semi-arid and so the study areas were irrigated at 3-week intervals during summer months to maintain a suitable habitat for voles. Deer mice (Peromyscus maniculatus) also occupied this habitat in substantial abundance. Yellow pine chipmunks (Eutamias amoenus) and Great Basin pocket mice (Perognathus parvus) also were present but in minor abundance and were captured infrequently.

Vole populations
Voles were sampled on 1-ha checkerboard grids (7 x 7) with two Longworth live-traps at each station. Separate control and treatment grids were sampled in the first two experiments and one control and two treatment grids were monitored in a third experiment.

Traps were baited with whole oats, peanut butter, and carrot; coarse brown cotton was supplied as bedding. Traps were set on day 1, checked on the morning and afternoon of day 2 and morning of day 3, and then locked open between trapping periods. All voles captured were ear-tagged with serially numbered tags, breeding condition noted, weighed on Pesola spring balances, and point of capture recorded. These populations were monitored at 3-week intervals in spring, summer, and fall, and at 4-week or irregular (depending on weather conditions) intervals in winter.

Populations were enumerated by minimum number known to be alive (MNA) at each trapping period (Krebs 1966). This technique counts all animals actually captured and those not captured but known to be alive due to subsequent capture. MNA provides sufficiently accurate enumeration of a population when trappability (susceptibility to capture) is 70% or higher (Hilborn et al. 1976), and this level was achieved in this study. Minimum survival rates were calculated per 21-day periods, and reflect disappearance of voles from the trappable population. Thus, both mortality and emigration were included in these survival estimates.

Predator odor compounds
Anal-gland compounds from the stoat or short-tailed weasel (M. erminea), 2-propylthietane and 3-propyl-1,2-dithiolane, were prepared according to Crump (1978, 1980, 1982). These two compounds were mixed in a 1:1 ratio for all 3 experiments. The principal active component from fox feces, 2,5-dihydro-2,4,5-trimethylthiazoline, was prepared as described in Sullivan et al. (1988a). Purity of synthesized compounds ranged from 95% to 98%. The 2,5-dihydro-2,4,5-trimethylthiazoline and stoat mixture were each dispensed in 140-ul capillary tubes (75 mm in length). The capillary tubes protected the compounds from adverse weather conditions, controlled the release of the odors, and maintained the respective odor around the base of apple trees. One capillary tube was attached to each tree by a plastic twist-tie. Approximately 30 mg of the 2,5-dihydro-2,4,5-trimethylthiazoline (neat) or stoat mixture was placed in a given capillary tube using a 1-ml microsyringe with 20-gauge

needle. Empty capillary tubes were attached to trees in the control area to complete the design of a given experiment.

## Experimental design

Table 1 outlines the design of the three experiments. One-year-old crabapple (Malus spp.) trees were systematically planted on control and treatment sampling grids prior to each experiment. These trees provided: (1) placement of the predator odor compounds so as to permeate throughout the treatment study area, and (2) an assessment of overwinter feeding damage by voles.

Table 1. Design of experiments A, B, and C testing the influence of predator odor compounds on vole population density and survival. Sample size (n) in parentheses is number of capillary tubes attached to apple trees on treatment grids. 2-PT (2-propylthietane); 3-PDIT (3-propyl-1,2-dithiolane); TTH (2,5-dihydro-2,4,5-trimethylthiazoline).

| Experiment | Period | Predator odor compounds | |
| | | Treatment-1 (n) | Treatment-2 (n) |
| --- | --- | --- | --- |
| A | 11/11/83 to 3/2/84 | 2-PT+3-PDIT (48) | - |
| B | 10/26/84 to 3/30/85 | 2-PT+3-PDIT (48) + TTH (48) | - |
| C | 10/27/85 to 3/31/86 | 2-PT+3-PDIT (42) + TTH (42) | 2-PT+3-PDIT (48) + TTH (48) |

## RESULTS
### Experiment A

The responses of vole populations to predator odors in terms of changes in density and survival are illustrated in Fig. 2. Comparable numbers of voles occurred on the control and treatment grids during a period of population increase prior to the start of experiment A. However, after placement of the predator odor in the field in October 1983, the treatment population declined by 30%, increased, and then declined to 43 voles/ha before increasing again in the early spring of 1984. The control population did not behave in this manner, but reached a peak of 117 voles/ha, declined to 85 voles/ha, and then increased in the summer and fall of 1984. Survival of voles was significantly lower in the treatment than control population during this period. The two periods of increase after sharp declines in the treatment population were due to recruitment of new voles, which presumably reflected resiliency to depopulation as discussed by Sullivan (1986). This latter response was not surprising since the vole populations were at or near peak density during 1983 and 1984. After removal of the predator odor in March, both populations returned to comparable levels by late September 1984.

### Experiment B

Again, after placement of predator odors in the field in experiment B, the treatment population declined from 89 to 41 voles/ha (Fig. 2). The control population also declined but at a much slower rate. At the completion of this experiment in March 1985, the treatment population had 27 voles/ha and the control 62 voles/ha. Vole survival was significantly lower in the treatment (0.38) than control (0.74). The treatment population increased dramatically in May, which again may have been a result of surplus voles colonizing available habitat. This increase was short-lived with a subsequent decline and yet another increase; an oscillation which was also recorded in the spring and summer of 1984.

### Experiment C

As indicated in Table 1, predator odors were placed on two treatment grids in experiment C. These three populations tended to be at comparable levels in October 1985, at the start of the experiment, and continued this similarity into December (Fig. 2). Both treatment populations then declined while the control increased during February and March 1986. Low densities of 14 to 19 voles/ha were recorded for the treatment populations, whereas the control was at > 50 voles/ha. Again, voles survived significantly better in the control (0.86) than in either treatment population (0.74 and 0.57).

### Feeding damage to trees

In experiment A, the proportion of apple trees attacked by voles on the control grid was 95.8% with 83.3% girdled (Fig. 3). These results were significantly higher than on the treatment where 34.8% of trees were attacked and 19.6% girdled (see Sullivan et al. 1988a). A similar pattern occurred in experiment B where 62.5% of trees were attacked and 25.0% girdled on the control grid, compared with no damage recorded to trees on the treatment (Fig. 3). There were presumably not enough voles to attack trees on either control or treatment grids during the 1985-86 overwinter period of experiment C.
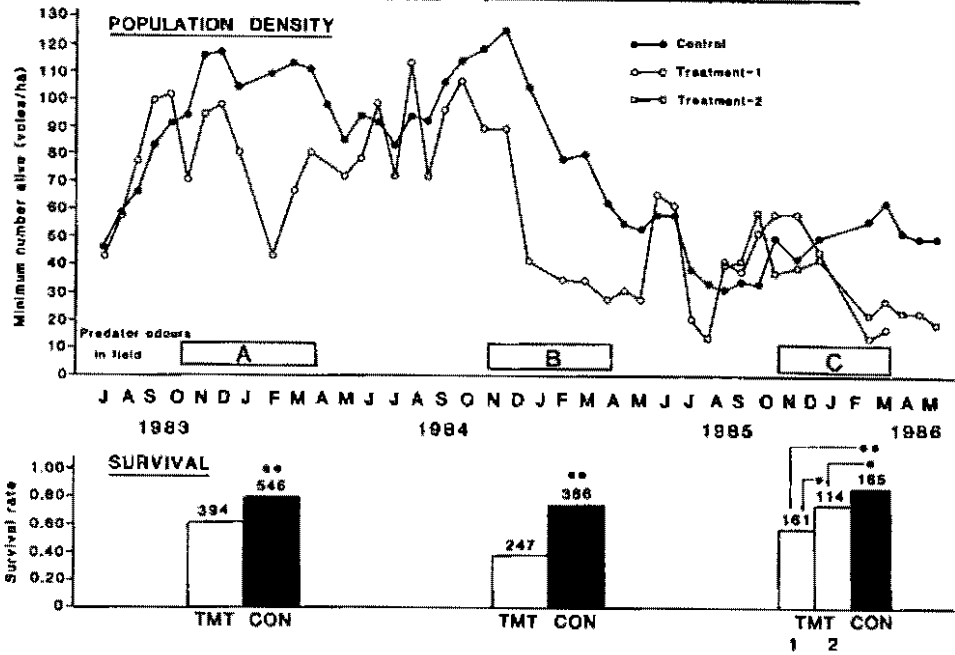
## DISCUSSION

Clearly, populations of the montane vole declined significantly in three consecutive winters on areas treated with synthetic predator odors. These declines were related to poor survival of voles. Since survival reflects disappearance (mortality and dispersal) from the trappable population, voles may have emigrated from the treatment area to avoid the predator odors and potential increase in numbers of predators (e.g., stoats, foxes, coyotes). Voles may also have died from behavioral or physiological stress induced by the odors, or succumbed to an influx of predators. Measurements of relative levels of predators on control and treatment areas in these experiments would certainly have been a valuable addition to the study.

Sampling grids located in adjacent territory to the 5-ha treatment study area did not have an influx of marked voles which may have dispersed away from the predator odors. This observation, and the poor survival of voles and signifi-

147

Fig. 2. Population density and survival of montane voles on control and treatment areas during 1983 to 1986. Three experiments (A,B, and C) placing synthetic predator odors in the field were conducted during the overwinter periods. Survival estimates were made during experiments (TMT-treatment; CON-control). Sample size above each histogram. **p<0.01; *p<0.05; significant difference by chi-square.

## PREDATOR ODORS and FEEDING DAMAGE TO TREES

EXPERIMENT A (1983-84)

EXPERIMENT B (1984-85)
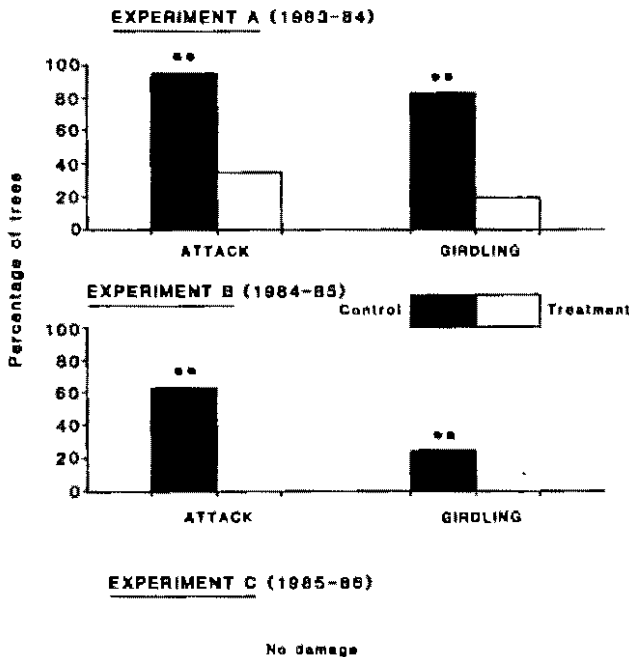
Control ▮▮ Treatment

EXPERIMENT C (1985-86)

No damage

Fig. 3. Percentage of trees attacked and girdled by vole feeding activity during overwinter periods. **p<0.01; significant difference by chi-square.

cant protection of trees on the treatment area, strongly suggest that the predator odors did cause considerable mortality in the vole populations.

It has generally been concluded that predators do not cause the decline in cyclic populations of microtine rodents, but they are capable of maintaining rodent populations at low densities for some time thereafter (see reviews by Erlinge 1975, Sullivan and Sullivan 1980). In particular, Erlinge (1975) has reviewed the reasons for the failure of predators to prevent outbreaks of rodents and how this relates to the use of predators in biological control programs. For example, the introduction of a natural predator such as the stoat might be a strategy to artificially reduce vole density. In this regard, introduction of weasels for control of voles in coniferous forest was not successful (Sullivan and Sullivan 1980). The principle of introducing weasels and related predators to a given area for reducing vole populations has two serious drawbacks: (1) the dispersal of predators away from the target population; and (2) the inability to keep an area devoid of voles during peak periods.

The results of our study and those of Whitten et al. (1980), Clapperton et al. (1988), and Clapperton and Minot (1988) suggest that synthetic predator odors could be used to attract and perhaps maintain predators in a given area. This technique could be implemented during overwinter damage periods as was done in our study. Alternatively, predator odors could be used on a year-round basis to prevent vole population buildups since predators appear capable of maintaining voles at low densities. Future experiments should assess the influence of long-term use of predator odors on vole and perhaps other rodent pest populations.

As summarized in Fig. 4, predator odors may be attached directly to crop trees or broadcast over a general area where vole populations are a pest problem. The combination of an avoidance response (Sullivan et al. 1988a) and depressed population density and survival should result in a significant degree of crop protection. Approximate costs of this technique may range from $100-$200 per ha depending on number of point sources of predator odor required.
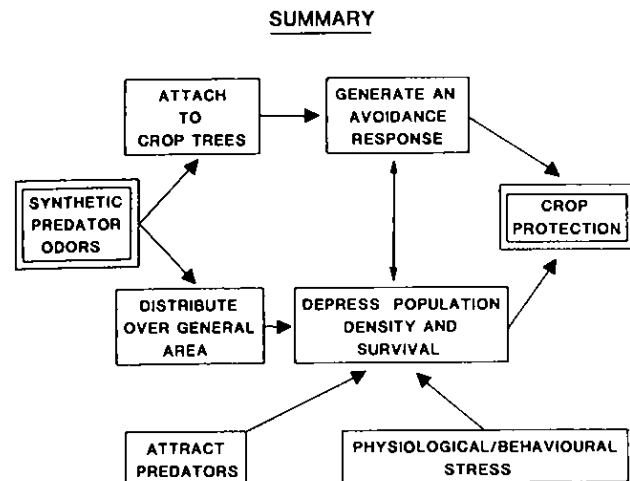
SUMMARY



Fig. 4. Summary of the use of synthetic predator odors to disrupt vole populations and protect crop trees from feeding damage.

ACKNOWLEDGMENTS

LITERATURE CITED

ALDOUS, C.M. and S.E. ALDOUS. 1944. The snowshoe hare - a serious enemy of forest plantations. J. For. 42:88-94.

BARNES, V.G. 1973. Pocket gophers and reforestation in the Pacific Northwest: a problem analysis. USDI Fish and Wildlife Service. Special Scientific Report No. 155.

BARNES, V.G., R.M. ANTHONY, J. EVANS, and G.D. LINDSEY. 1982. Evaluation of zinc phosphide bait for pocket gopher control on forest land. pp. 219-225. In: Proc. Tenth Vert. Pest Conf., Monterey, California, University of California, Davis.

BLACK, H.C., E. DIMOCK, J. EVANS, and J. ROCHELLE. 1979. Animal damage to coniferous plantations in Oregon and Washington - Part I. A survey, 1963-1975. For. Res. Lab., Oregon State Univ., Res. Bull. No. 25.

BYERS, R.E. 1984. Control and management of vertebrate pests in deciduous orchards of the eastern United States.

Horticul. Rev. 6:253-285.

BYERS, R.E. 1985. Management and control. pp. 621-646. In: Biology of New World Microtus. R.H. Tamarin (ed.). Special Publication No. 8. Amer. Soc. of Mammal.

CLAPPERTON, B.K., and E.O. MINOT. 1988. An olfactory recognition system in the ferret (Mustela furo L.) (Carnivora: Mustelidae). II. Behavioral evidence. J. Chem. Ecol. (In Press).

CLAPPERTON, B.K., E.O. MINOT, and D.R. CRUMP. 1988. Scent lures from the anal sac secretions of the ferret Mustela furo L. J. Chem. Ecol. (In press).

CROUCH, G.L. 1982. Pocket gophers and reforestation on western forests. J. For. 80: 662-664.

CRUMP, D.R. 1978. 2-Propylthietane, the major malodorous substance from the anal gland of the stoat. Tetrahedron Lett. 1978: 5233-5234.

CRUMP, D.R. 1980. Thietanes and dithiolanes from the anal gland of the stoat (Mustela erminea). J. Chem. Ecol. 6: 341-347.

CRUMP, D.R. 1982. Synthesis of (2S)-2-propylthietane. Aust. J. Chem. 35: 1945-1948.

DAVIS, D.E. 1976. Management of pine voles. pp. 270-275. In: Proc. Seventh Vert. Pest Conf., Monterey, California. University of California, Davis.

ERLINGE, S. 1975. Predation as a control factor of small rodent populations. pp. 195-199. In: Biocontrol of rodents, L. Hansson and B. Nilsson (eds.). Swedish Natural Science Research Council, Stockholm.

GREEN, J.E. 1978. Techniques for the control of small mammal damage to plants: a review. Alberta Oil Sands Environmental Research Program. Project VE 7.1.1.

HILBORN, R., J.A. REDFIELD, and C.J. KREBS. 1976. On the reliability of enumeration for mark and recapture census of voles. Can. J. Zool. 54:1019-1024.

KEITH, L.B. 1963. Wildlife's ten year cycle. University of Wisconsin Press, Madison.

KREBS, C.J. 1966. Demographic changes in fluctuating populations of Microtus californicus. Ecol. Monogr. 36: 239-273.

KREBS, C.J. and J.H. MYERS. 1974. Population cycles in small mammals. Adv. Ecol. Res. 8: 267-399.

SULLIVAN, T.P. 1986. Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: Control of Mammal Pests, C.G.J. Richards and T.Y. Ku (eds.). Taylor and Francis Ltd., London. Supplement No. 1 to Tropical Pest Management 32: 69-82.

SULLIVAN, T.P. 1987. Red squirrel population dynamics and feeding damage in juvenile stands of lodgepole pine. Min. of Forests and Lands, Victoria, B.C. FRDA Report 019 (In press).

SULLIVAN, T.P. and D.R. CRUMP. 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. and D.R. CRUMP. 1986a. Feeding responses of snowshoe hares (Lepus americanus) to

volatile constituents of red fox (Vulpes vulpes) urine. J. Chem. Ecol. 12: 729-739.

SULLIVAN, T.P. and D.R. CRUMP. 1986b. Avoidance response of pocket gophers (Thomomys talpoides) to mustelid anal gland compounds. pp. 519-531. In: D. Duvall, D. Muller-Schwarze, and R.M. Silverstein (eds.). Chemical Signals in Vertebrates IV. Plenum Press, New York.

SULLIVAN, T.P. and R.A. MOSES. 1986. Demographic and feeding responses of a snowshoe hare population to habitat alteration. J. Appl. Ecol. 23: 53-63.

SULLIVAN, T.P. and D.S. SULLIVAN. 1980. The use of weasels for natural control of mouse and vole populations in a coastal coniferous forest. Oecologia 47: 125-129.

SULLIVAN, T.P. and D.S. SULLIVAN. 1982. Barking damage by snowshoe hares and red squirrels in lodgepole pine stands in central British Columbia. Can. J. For. Res. 12: 443-448.

SULLIVAN, T.P., D.R. CRUMP, and D.S. SULLIVAN. 1988a. The use of predator odor repellents to reduce feeding damage by herbivores. III. Montane (Microtus montanus) and meadow (M. pennsylvanicus) voles. J. Chem. Ecol. 14: 363-377.

SULLIVAN, T.P., D.R. CRUMP, and D.S. SULLIVAN. 1988b. The use of predator odor repellents to reduce feeding damage by herbivores. IV. Northern pocket gophers (Thomomys talpoides). J. Chem. Ecol. 14: 379-389.

SULLIVAN, T.P., J.A. KREBS, and H.A. KLUGE. 1987. Survey of mammal damage to tree fruit orchards in the Okanagan Valley of British Columbia. Northwest Sci. 61: 23-31.

WHITTEN, W.K., M.C. WILSON, S.R. WILSON, J.W. JORGENSON, M. NOVOTNY, and M. CARMACK. 1980. Induction of marking behavior in wild red foxes (Vulpes vulpes L.) by synthetic urinary constituents. J. Chem. Ecol. 6: 49-55.