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Abstract. A province-wide evaluation of the amount, distribution, source and control of damage to Ontario apple trees was initiated. Data were obtained from 280 responses to a questionnaire distributed to growers across Ontario, and from trap censuses in three widely separated areas. Meadow voles (*Microtus pennsylvanicus*) damaged or destroyed 8,423 trees in our questionnaire sample and other mammals damaged another 10,307 trees. No relationship was found between application of rodenticide and levels of damage, but rodenticide-treated baits sharply reduced numbers of voles on our trap plots. Orchards with high levels of damage were on average only one-third as large as the average orchard in our total sample. All damage by voles appeared to be caused by meadow voles and no pine voles (*M. pinetorum*) were found. Numbers of voles varied greatly among our three study areas. Future work will concentrate on factors causing high levels of damage and on the relationship between dispersal of voles and the effects of rodenticide treatment.

Introduction

In Ontario, there has been very little systematic research into the amount and control of damage caused by herbivorous mammals in apple orchards, despite abundant evidence from growers that this damage is extensive and costly (Brooks and Schwarzkopf 1981). In 1981, Ontario growers sought to support a research program that would determine the amount of damage caused by voles and that would develop more economical and effective control measures than those that exist now.

In September 1981, we initiated a four-year research program. The objectives of the first phase of this research were:

1. To identify the mammalian species causing damage to Ontario fruit trees.
2. To quantify the extent of mammalian pest damage in Ontario.
3. To assess the nature and effectiveness of current management and control practices.
4. Using trapping techniques, to estimate densities of voles in orchards in three areas of the province.

From information obtained during this initial phase, we have formulated research plans directed toward the long-term goals of the project. Specifically, these goals are to develop recommendations to advise growers on cost and labor-efficient methods to reduce tree damage by rodents and, within these constraints, to recommend methods that minimize the use of toxicants in control.

Methods and Materials

1. Questionnaire

In September 1981, questionnaires were distributed by mail to 1100 apple growers in Ontario. These questionnaires provided information on: (a) tree composition (i.e., number, age, variety, etc.) and size of the orchard; (b) methods (i.e., timing, and frequency of use of herbicides, rodenticides, mowing, cultivation, etc.) of habitat management and rodent pest control used by growers; (c) amount of damage inflicted on trees by mammalian pests; and (d) general location of the orchard, depth of winter snow cover and other factors.

Returned questionnaires (280) were allocated to four regions (Fig. 1).

A. Lake Erie = all counties bordering on Lake Erie

B. Central Ontario = all counties from Lambton to York

C. Georgian Bay = counties of Grey, Simcoe and Wellington

D. Eastern Ontario = all counties east of York.

2. Trapping Programs

Standard live-trapping and snap-trapping techniques (Davis 1956, Krebs et al. 1969, Renzulli et al. 1980, Stockrahm et al. 1981, Webster and Brooks 1981) were used to identify rodent species resident in apple orchards and to estimate population levels of these species. Trap grids were established in orchards in Haldimand-Norfolk municipality, Grey County, and Prince Edward County (Fig. 1). The study orchards were selected because they had experienced damage by voles in previous years. Sampling was conducted in such widely dispersed trap grids, because the Ontario Pesticides Advisory Committee (OPAC) expressed interest in determining whether it would be feasible to estimate vole levels across apple growing areas of Ontario on the basis of samples from a single grid.

Four 0.21-ha live-trap grids were established in each of the three sample areas. Trapping commenced in early September and ended in mid-December. Each area was trapped throughout four consecutive 24-h periods on three occasions (Cycles 1, 2, and 3), giving a total of 12 days and 12 nights trapping on each study grid. Baited Sherman live traps were set at each grid marker with 5 m between markers. Traps were locked open for 24 h before each four-day Cycle began. Captured animals were marked with numbered ear tags, weighed, sexed and released. Reproductive activity was also noted.

Five 0.21-ha grids were established on the three areas for snap-

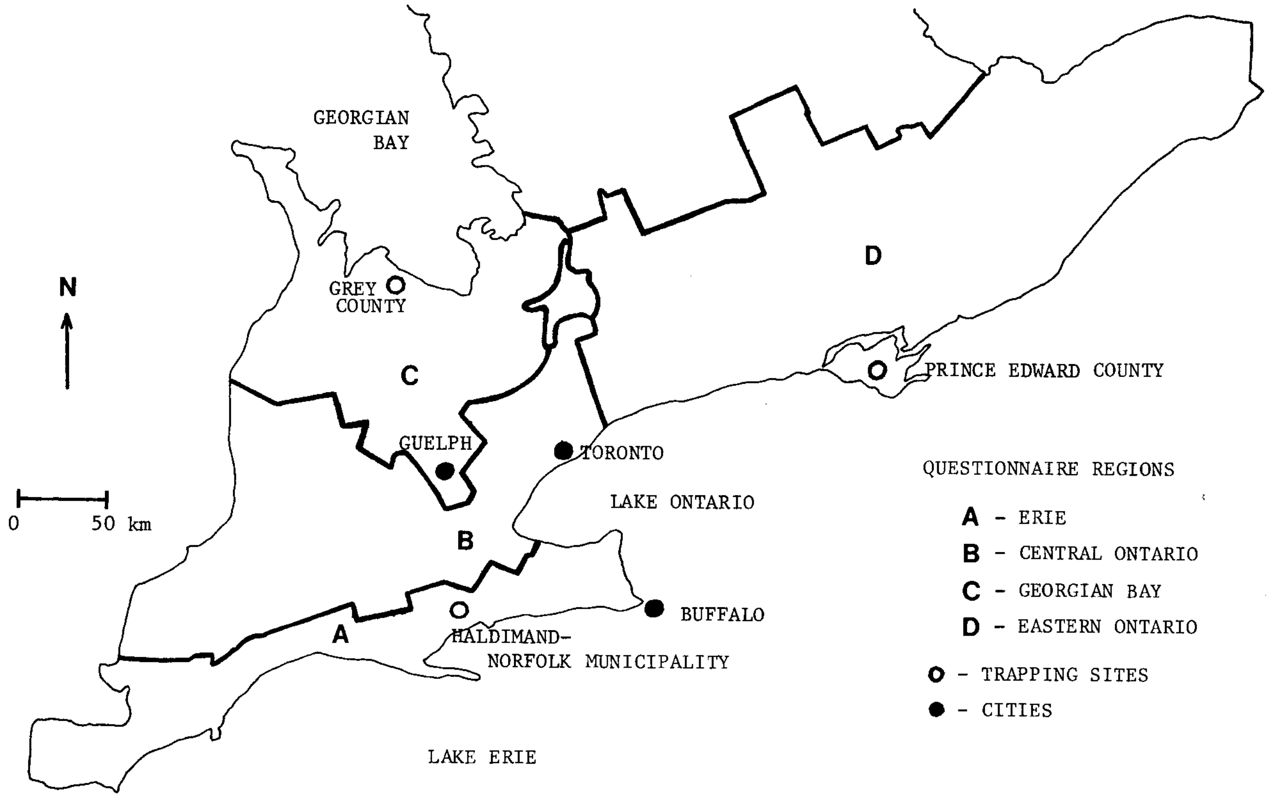

Figure 1. Questionnaire regions and trapping locations in southern Ontario.

trap sampling. Snap trapping was conducted twice: Session 1 occurred between live-trap Cycles 1 and 2; and Session 2 occurred between live-trap Cycles 2 and 3. Snap trap plots were sampled over two consecutive 24-h periods in each session.

Results and Discussion

The data from 280 questionnaires are summarized in Table 1 to show the per cent of apple trees damaged across Ontario in the winter of 1980-81. Overall, mammals destroyed or damaged 1.9% of 991,000 trees on our response sample. Therefore, in the average Ontario orchard of 3500 trees, about 70 trees were damaged by rodents, hares or deer in the 1980-81 winter. As our sample represented about 25% of Ontario apple growers, we estimated that mammals damaged 75,316 trees in winter.

Table 1. The percentage of apple trees damaged by vertebrate pests in Ontario in 1980 - 81.+

	Region				
	Lake Erie Niagara	Central Ontario	Georgian Bay	Eastern Ontario	Ontario Total
Total % apple trees damaged	1.57	2.34	2.51	2.85	2.28
By Voles	0.68	0.78	1.13	0.98	0.85 (0-100)*
Hare	0.58	0.32	0.80	0.25	0.45 (0-40)
Deer	0.29	1.03	0.53	0.35	0.59 (0-60)
Other++	0.02	0.21	0.05	1.27	0.38 (0-30)

* Range of values in parentheses.
\+ Figures based on responses from 280 questionnaires.
++ Most damage in this category is from winter kill but a few trees were damaged by groundhogs (*Marmota monax*).

Voles damaged 0.85% (8423) of the trees in our sample (Table 1). Highest levels of vole damage occurred in Georgian Bay and Eastern Ontario. In previous years, growers in these regions have reported greater problems than have growers in the Lake Erie or Central Ontario regions.

Deer (*Odocoileus virginianus*) browsed on 0.59% (5847) of the trees and inflicted heaviest damage in Central Ontario (Table 1), where deer numbers are relatively high. Lagomorphs damaged 0.45% (4460) of all trees and had their greatest effect in the Georgian Bay region

(Table 1). Most of the "other" damage (Table 1) was caused by extreme cold in the winter of 1980-81. This problem was most severe in Eastern Ontario (Table 1).

Zinc phosphide-treated baits were applied to orchards by 86.7% of the growers in our sample. In these orchards, voles damaged 0.80% of the trees (Table 2). In 21 orchards treated with Ramik Brown, 1.20% of the trees were damaged; whereas the 17 orchards not treated with rodenticide experienced the lowest damage levels (0.30%).

Table 2. The percentage of apple trees damaged by meadow voles (Microtus pennsylvanicus) in orchards treated or not treated with rodenticide.

	Region				
	Lake Erie Niagara	Central Ontario	Georgian Bay	Eastern Ontario	Ontario Total
Rodenticide program					
Zinc phosphide	0.67(72)*	0.80(77)	1.20(34)	0.75(59)	0.80
Ramik brown	5.52 (3)	0.51 (3)	1.03 (7)	1.46 (8)	1.20
No rodenticide	0.30 (9)	0.00 (1)	0.00 (2)	0.52 (5)	0.30

* Number of orchards in parentheses.

The average number of trees in orchards not treated with rodenticides was only one-third (1187 trees)of the number of trees in the average orchard was 3542 trees in our entire questionnaire sample. Many of the growers who did not apply rodenticides indicated that they did not do so because they had no history of rodent damage. Some of these orchards were surrounded by cultivated or urban areas.

To isolate factors associated with high levels of damage, we looked next only at those orchards (N = 38) with more than 2.5% of their trees damaged by voles (Table 3). An average of 11.5% of trees were damaged in these orchards, more than ten times the Ontario average (Table 3). The mean number of trees in these orchards was only 1428, compared to the average of 3542 for all the orchards sampled by our questionnaire. Twenty-six of the 38 "high damage" orchards were treated with zinc phosphide baits, yet they still had 13.8% of their trees damaged by voles.

Table 3. The percentage of apple trees damaged by meadow voles (Microtus pennsylvanicus) in orchards with more than 2.5% of trees damaged.

	Region				
	Lake Erie Niagara	Central Ontario	Georgian Bay	Eastern Ontario	Ontario Total
% Trees damaged (> 2.5% damaged)	10.5(10)*	17.8(8)	11.9(7)	9.6(13)	11.5(38)
Mean number trees/orchard (> 2.5% damaged)	1978	938	1553	1239	1428
Mean number trees/orchard	3190(84)	4140(81)	3738(42)	3160(72)	3542(280)

* Number of orchards in parentheses.

These results indicated that orchard size may be an important factor in reported levels of damage. Small orchards seemed to suffer very little damage (e.g. those described above that had not been treated with rodenticide) or a substantial and costly level of damage. There are three possible explanations for the latter case.

1. As smaller orchards have a higher perimeter/ area ratio, a given rate of immigration of voles would lead to a higher level of damage.
2. Many small orchards may be located in areas of low-intensity agriculture, and therefore, may be surrounded by old fields, pastures, etc. that maintain high numbers of voles. This hypothesis is related to the first one.
3. Small orchards may be more likely to have inexperienced (recent) or inefficient owners as compared to large operations.

In 1982, we will attempt to ascertain which of these possibilities is the most likely reason for the observed high levels of damage by visiting the orchards and by a revised and expanded questionnaire.

Meadow voles, deer mice (Peromyscus maniculatus) and short-tailed shrews (Blarina brevicauda) were the only species of small mammals captured in live traps. No pine voles (Microtus pinetorum) were taken even though this species has been trapped in the Haldimand-Norfolk region (Peterson 1966). In Prince Edward County, meadow voles were numerous in Cycles 1 and 2 (88 and 72 voles/ha), but they declined to low levels (7.1 voles/ha) in Cycle 3, after zinc phosphoride treated baits were applied to the plots between cycles 2 and 3 (Table 4). A similar decline was observed in Haldimand-Norfolk when rodenticide was applied between Cycles 1 and 2 (Table 4). In Grey County, an area with a history of high levels of reported vole damage, densities of meadow voles remained low throughout the study. Numbers of *Peromyscus* were low in all sampling areas except in Haldimand-Norfolk during the first cycle. No conclusions could be inferred regarding effects of rodenticide application on numbers of this species.

Table 4. The number of meadow voles (*Microtus pennsylvanicus*) per ha live trapped in Southern Ontario apple orchards.

	Grey County	Haldimand-Norfolk	Prince Edward County
Cycle			
1	10.7(3.6)*	36.9(16.7)	88.0(2.4)
2	11.9(3.6)	9.5 (2.4)	72.6 (0)
3	6.0 (0)	4.8 (1.2)	7.1 (0)

* Numbers in parentheses refer to the number of deer mice (*Peromyscus maniculatus*) per ha.

Results from the snap-trap plots indicated that densities of meadow voles were low in all areas and in both sessions, except for Session 1 in Prince Edward County (Table 5). However, numbers in Session 1 in Haldimand-Norfolk may have been underestimated owing to inclement weather during the trapping session.

Table 5. The number of meadow voles (*Microtus pennsylvanicus*) snap trapped in Southern Ontario.

	Grey County	Haldimand-Norfolk	Prince Edward County
Session			
1	1.0*	3.8	50.5
2	1.0	9.5	6.7

* Number of meadow voles per ha.

Overall, these results indicate that numbers of meadow voles are not similar in orchards throughout the apple growing regions of Ontario.

This is not surprising. In addition, it appears that applications of zinc phosphide-treated baits do cause significant reductions of numbers of resident voles. However, this effect may be only temporary as evidenced by the high levels of damage that occur annually in Grey and Prince Edward Counties despite zinc phosphide treatments. Because of this and because smaller orchards often have the highest levels of damage, we suggest that voles may emigrate into orchards after the rodenticide has been consumed by the resident population or otherwise lost its effectiveness. If significant dispersal takes place in winter, as appears sometimes to be the case (Brooks and Webster in press), then high levels of damage by voles could occur over winter even though few voles were present in the orchard in late fall and early winter.

It appears that movements of voles into treated orchards may make fall applications of rodenticide relatively ineffectual in control of damage to trees. Development of a control program to prevent damage by voles over winter will require an understanding of the extent and timing of these movements. To this end, we will use radiotelemetry (e.g., Pagano and Madison 1981, Webster and Brooks 1981) to monitor movements, particularly during late fall and early winter after rodenticide application. As carried out at present, rodenticide control measures have only a short-term effectiveness and show little relationship to levels of overwinter damage caused by voles.

Questionnaires provide an economical means to obtain information over a large area. In 1982, we will update and reorganize our questionnaire to evaluate more specific questions that have arisen from our 1981 effort. In particular, we will examine those orchards subject to heavy damage in 1980-81 and add questions pertaining to grower attitudes and degree of flexibility in altering their cultural practices. We also plan to investigate effects of habitat manipulation on numbers of voles (Steele 1977) using enclosures and various cultural practices. Finally, we will disseminate information useful to growers both to enhance their understanding of the overall problem, and to assist them in developing control programs that are more effective and economical.

Summary: Over the winter of 1980-81, mammals damaged about 2% of apple trees in Ontario orchards. Highest damage was suffered by smaller operations and although rodenticides were effective over the short term, application of these toxins bore no discernible relationship to levels of damage over the entire winter. Overall, populations of meadow voles in fall 1981 were at low levels. There was no evidence that pine voles were causing damage in Ontario. Future studies will concentrate on defining other factors associated with high levels of damage.

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