ABSTRACT

MICROTINE DAMAGE IN MICHIGAN APPLE ORCHARDS

By

Craig Steven Killian

The object of this study was to provide an estimate of the financial losses caused in Michigan's apple orchards by members of the genus Microtus, and, if possible, to discover some of the factors affecting the amount of damage. Information was collected from apple growers and from direct observation of 1,520 Michigan apple trees.

Data was collected concerning the winters of 1972-73 and 1973-74. Both of these years were characterized by relatively low populations of microtine rodents in Michigan.

Mice, presumably microtines, were most frequently named as the most destructive pest. Deer and rabbits were ranked second and third respectively. Mice appear to be most destructive in the southern half of the apple growing region.

Damage rates were greatest for newly planted trees and decreased as trees aged. By the age of ten, apple trees attain minimum damage rates.

Ninety-seven percent of Michigan's apple growing acreage is treated with rodenticide or other rodent damage preventatives at an annual average cost of $166,400. In spite of such control measures, however, microtines are responsible for a minimum annual loss of $322,500 from damaged trees.

Contrary to expectations, damage rates were not lowest

in the cleanest orchards. Elimination of undergrowth had no significant effect on the amount of microtine damage.

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By

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INTRODUCTION

Many species of the genus *Microtus* are considered agricultural pests. The European field vole, *Microtus agrestis* has caused significant damage to pine plantations, apple orchards, nurseries, and field crops such as sugar beets, hay, and oats. Kanervo and Myllymaki (1971) report that during 1954 to 1966 *M. agrestis* caused an estimated $40,860,000 damage in Finland alone.

California and Nevada suffered from unusually dense populations of microtine rodents during the early 1960's which caused heavy damage to fruit trees, and field crops such as alfalfa and sugar beets (Anon. 1964). This extreme damage occurred in spite of heavy applications of rodenticide. In some cases, fallow fields were virtually stripped of standing vegetation under snow cover (Foster 1965).

In eastern and midwestern United States there are three species of the genus *Microtus* which are of concern. These species are the field vole, *M. pennsylvanicus*, the prairie vole, *M. ochrogaster*, and the pine vole, *M. pinetorum*. All three species occur in Michigan.

The pine vole is a common inhabitant of orchards in New York, Pennsylvania, Ohio, Indiana, Virginia and the Carolinas. In these regions it can cause serious destruction in orchards by girdling and cutting roots and underground portions of the stem (Davis 1943). In spite of the fact that *M. pinetorum* is known to feed heavily on the bark and roots of apple trees, few estimates have been made of the economic impact of this species due to its highly subterranean habits. Scattered reports prove the occurrence of the pine vole in Michigan (Burt 1957) but nowhere in the state does it appear abundant.

The prairie vole, _M_. _ochrogaster_ may be locally abundant, but is concentrated primarily in Cass, Berrien, and Van Buren counties in the southwest corner of Michigan. Biologically, _M_. _ochrogaster_ is very similar to the meadow vole, _M_. _pennsylvanicus_; thus, these two species will not be differentiated in this report.

The meadow vole, _M_. _pennsylvanicus_ is the species of primary importance to Michigan apple growers since it is established throughout the state. Like the European field vole, _M_. _pennsylvanicus_ becomes extremely destructive during the peak phase of its demographic cycle. During 1938 and 1942 _M_. _pennsylvanicus_ destroyed approximately 50% of the Scotch and Douglas Pine seedlings planted in a reforestation project in New York (Littlefield, Schoonmaker, and Cook 1946).

While reports of heavy damage are common (Littlefield, Schoonmaker, and Cook 1946, Hayne 1950, Biser 1967) few attempts have been made to assess the economic damage caused by _M_. _pennsylvanicus_ or similar species.

In this study, I have estimated the economic impact of the field vole, _M_. _pennsylvanicus_ upon Michigan's apple growing industry. The extreme fluctuations in densities of vole populations create difficulties in estimating and controlling their impact. Application rates of appropriate pesticides and other associated control procedures, such as mowing, clean cultivation and use of herbicides, which may be efficient at low densities may be ineffective when dealing with population densities of 150 or more animals per acre which may be attained during peak years (Krebs 1973). Conversely, application rates and procedures which are warranted during peak years may represent wasted insurance during periods of low densities. In an industry with a small profit margin, savings of several dollars per acre would be a significant benefit to the grower.

PROCEDURES

Data for this research were gathered by three different methods. A questionnaire was sent to 118 apple growers in the state of Michigan. Growers were identified through the Apple Pest Management Program at Michigan State University. The questionnaire requested information on the size of the orchard, varieties and ages of trees, current and past mammal control procedures, costs and effectiveness of control procedures, estimated annual loss due to small mammals, estimated value of trees of various ages, past experiences, and related topics. A sample questionnaire is included in Appendix A.

Following questionnaire returns, personal interviews were conducted with 14 orchard owners. The purpose of these interviews was to gain insight into topics which received poor response on the returned questionnaires, and to give orchard owners a better chance to express their opinions and experiences.

In the spring of 1974 a field survey was conducted with the cooperation of the Apple Pest Management Program personnel. Field scouts were instructed in the appearance of damage inflicted by microtines. Each scout was then provided with a data sheet for each 10 acre orchard block which was to be inspected. In each block the scouts selected 10 trees at random. At each of the 10 trees scouts recorded the variety of tree, percent of the circumference which exhibited girdling by Microtus sp., diameter of the tree at ground level, distance from the tree to the nearest visible runway, and the depth of the litter layer. Scouts also indicated whether or not vegetative manipulations had been practiced under the trees or between rows of trees. The vegetative manipulations which were considered included the use of herbicides, mowing, and clean cultivation. In addition, scouts indicated whether or not there was any corn at the base of the tree (corn is the standard vector of zinc phosphide, currently the major rodenticide used in Michigan orchards), location of the orchard block and trapping success from a related program. A sample data form is shown in Appendix A.

RESULTS

Forty-seven of the 118 questionnaires were returned for analysis. Mice (presumably Microtus sp.) were most often named as the most destructive pest in Michigan orchards (Table 1). Deer ranked a close second while rabbits were third. In many cases growers indicated more than one species for question 29. In these cases the species were considered equally

TABLE 1. Response to Question 29 "What species of mammal do you feel is the most damaging in your orchard(s)?"

Pest	No. of times Recorded	% of Responses
Mice	28	45.9%
Deer	21	34.4
Rabbits	6	9.8
Woodchuck	3	4.9
Raccoons	1	1.6
Subterranean rodents	1	1.6
Birds	1	1.6
Total	61	99.8

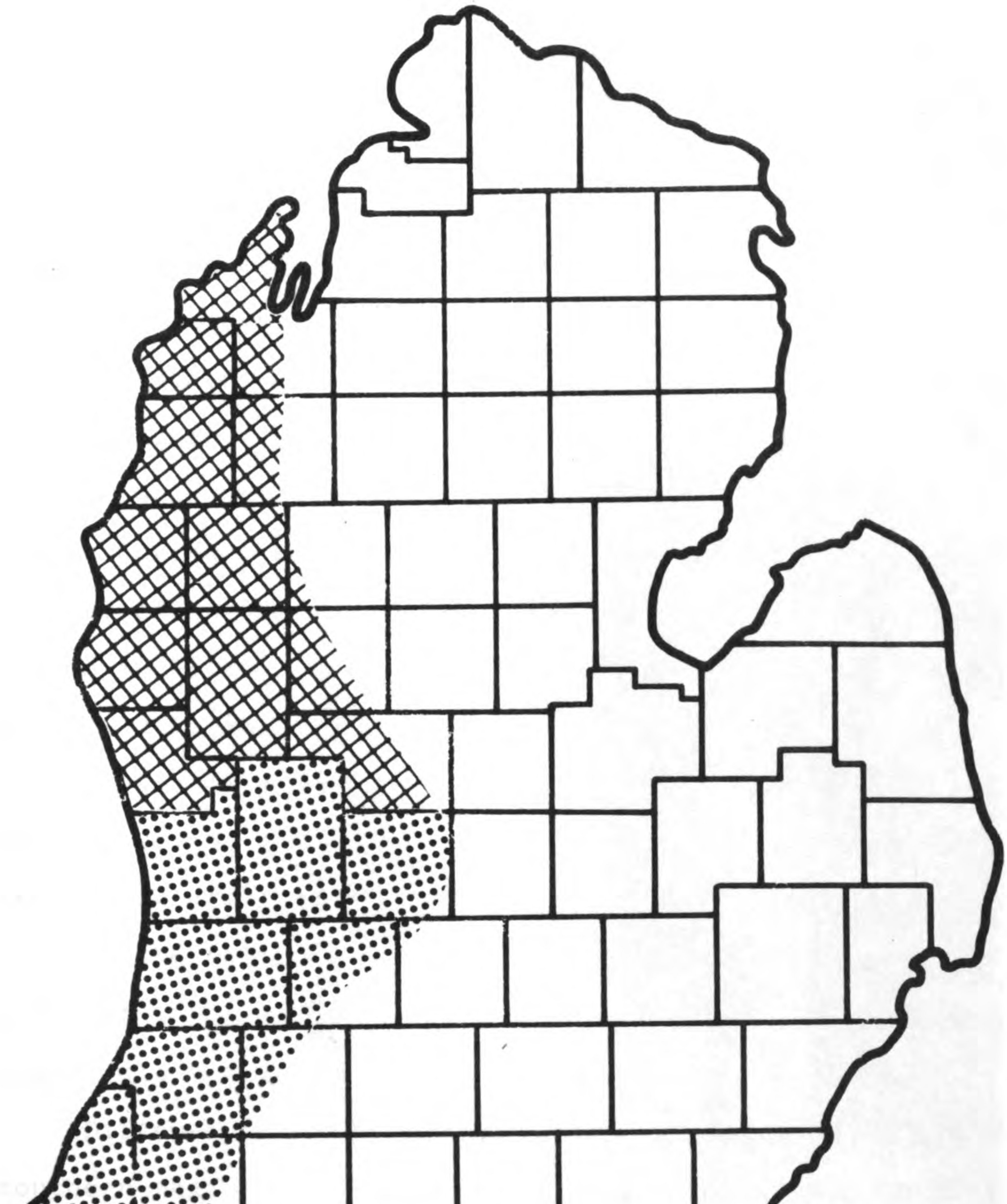
destructive and a single response was accorded to each.

Deer appeared most often as the most destructive mammal in the more northern reaches of Michigan's fruit growing region, while only a few growers from the southern region indicated that deer were the most destructive mammal. In the southern regions, mice were the most destructive mammal as indicated by grower responses.

References to subterranean rodents may indicate the activity of _M_. _pinetorum_ or of ground squirrels (_Spermophilus tridecemlineatus_). Several growers indicated a belief that pine voles were present in their orchards. However, of several hundred mice trapped by field scouts of the Apple Pest Management Program in the last two years, there have been no specimens of _M_. _pinetorum_. I conclude, therefore, that the pine vole is not causing substantial damage in Michigan orchards.

The majority of Michigan orchard owners feel that mice are a significant pest in their apple orchards. There is, however, a significant difference in the opinions of the orchard owners when the state is divided into northern and southern regions (Figure 1). In the northern portion of the fruit growing region 28.6% of respondents felt that mice currently were a serious pest in their orchards and an additional 21.4% qualified their response with such phrases as "at times" or "moderately",etc. In the southern portion of the state 66.7% of the respondents indicated they considered mice to be a serious pest and an additional 3.3% qualified their response. The difference is statistically significant

FIGURE 1. Michigan's Lower Peninsula with major apple producing region indicated. Southern region (stipled) demonstrated most severe damage rates.



($\chi^2 = 7.05$ df = 5 $0.05 > p > 0.01$).

Data collected by field scouts of the Apple Pest Management Program supports this trend. In southern counties, 1.5% of 960 trees examined exhibited damage by Microtus sp. while only 0.9% of 560 trees in the northern region had been damaged. The difference, however, is not statistically significant ($\chi^2 = 1.22$ df = 3 $0.9 > p > 0.5$) and I have therefore used the state-wide mean of 1.3% in my analyses.

The increased concern with mice among orchard growers in the southern half of the state is also reflected in the cost of control programs. The median per acre cost of vole control programs in the southern half of the state is $3.00. In the northern regions the median cost is $1.75 per acre. Because of the larger number of responses from the southern region $3.00 per acre is also the state median. Median values are utilized rather than mean values because the responses were skewed strongly towards higher costs. These figures, however, are generally conservative since in many cases interviews disclosed the fact that growers indicated only the cost of the poisoned grain. Other growers included operating costs of vehicles and wages. Many who treated their own orchards did not include their own wages.

Differences in the responses received from northern and southern regions do not necessarily indicate inherent differences between the regions. They may simply indicate that during recent years vole populations were at different stages of their demographic cycle in the two regions. To test this possibility growers were asked to rate damage during the winter of 1972-73 as being light, average, or severe. However, there was no significant difference between the two regions ($\chi^2 = 5.74$ df = 5 $0.5 > p > 0.1$). Overall, 76.4% of the growers rated the winter of 1972-73 as a year of light damage; only 5.3% rated it as a year of heavy damage. The remaining 18.3% rated the year as one of average damage.

Table 2 summarizes the various control procedures reported on the questionnaires. When the number of orchard owners responding is weighted by the amount of acreage each has devoted to apple orchards approximately 97.6% of Michigan's 56,600 acres of bearing age apple trees are treated with rodenticide at an average annual cost of $166,400. This figure is conservative for a number of reasons. First, the 56,600 acres of trees represents only those trees which are commercially productive. Another contributing factor is the rising cost of gasoline, labor, and poisoned grain. Only two growers reported that they practice no small mammal control in their orchards. In addition to the application of zinc phosphide treated grain, the majority of Michigan apple growers eliminate or reduce ground vegetation in their orchards through clean cultivation, mowing and/or the use of herbicides. While this practice is usually aimed at reducing competition for water between the trees and the ground cover, most growers indicated that they believed part of this cost should be assessed to their rodent control program. This again raises the total cost of rodent control within the state. However, no attempt was made to determine what portion of this cost would be applicable to rodent control.

TABLE 2. Current rodent control procedures in Michigan apple orchards.

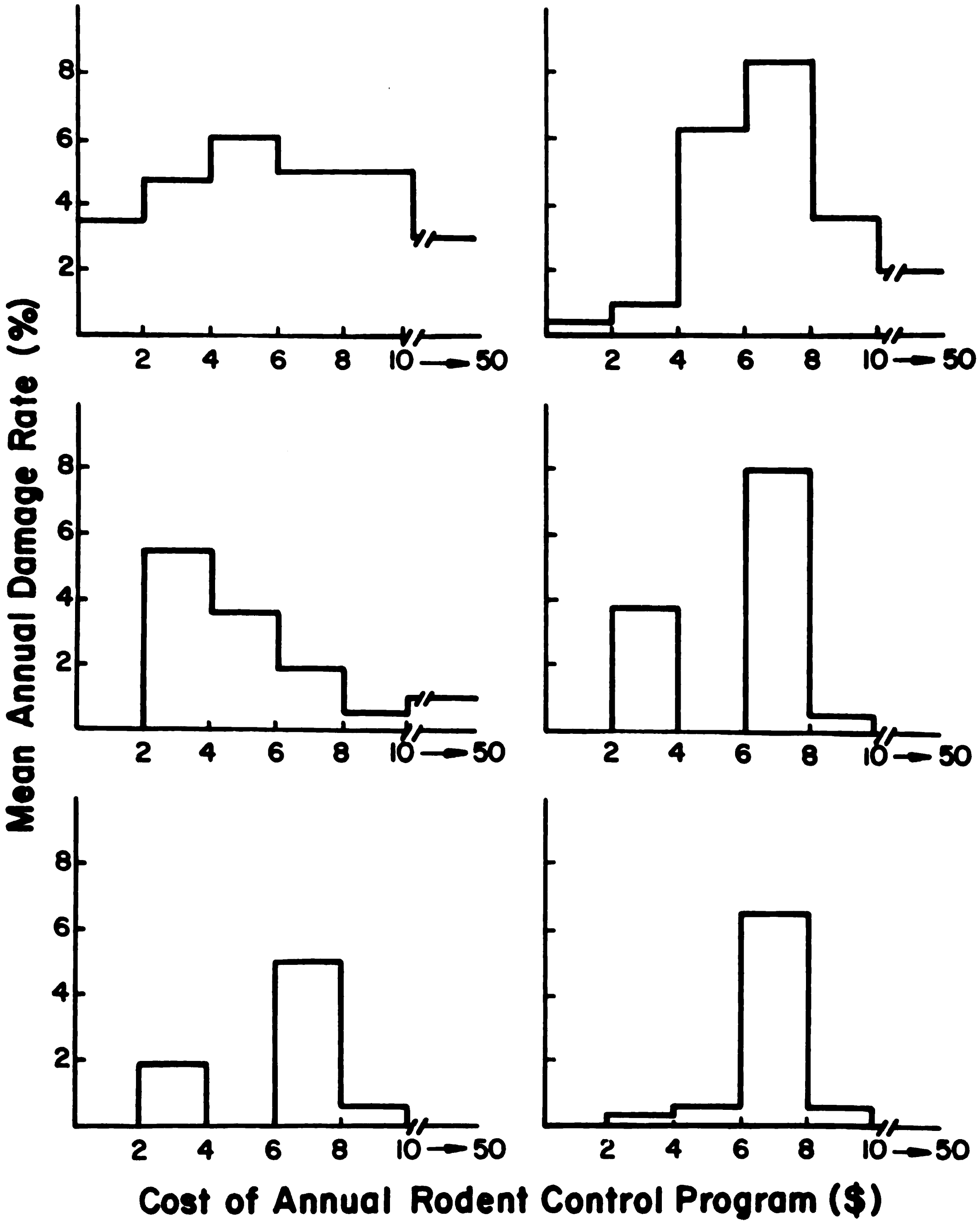
Control Procedure	No. of Responses	% of Responses
Zinc phosphide on corn	12	25.0%
Bait (unspecified)	29	60.4
Bait and guards	2	4.2
Guards	1	2.1
Unspecified	2	4.2
None	2	4.2
Total	48	100.1

When questioned about the effectiveness of their entire rodent control program 75.6% indicated that they felt it was effective or better. Only 24.4% of the growers who responded indicated that they felt it was less than effective. In spite of the differences in costs between the northern and southern portions of the fruit growing regions there was no significant difference in the growers' opinion of control efficacy. Six orchard owners who returned questionnaires did not express an opinion on this subject.

Comparisons were made between amount of money spent on rodent control programs and the reported damage rate in the associated orchards. Histograms of damage rates versus control costs for each age group exhibit an initial segment of low damage rates with low control costs followed by peak damage rates at intermediate expenditures. Further increases in control costs provide reduced damage rates (Figure 2). It appears that those growers who believe they have low damage rates maintain relatively low key, inexpensive rodent control programs. Conversely, those growers who spend large amounts of money on rodent control have relatively low average annual damage rates. Peak damage rates for trees in each age category occurred at intermediate control costs. Even at an estimated annual expenditure of $50.00 per acre for rodent control programs, the estimated annual damage rate is as much as 3% of newly planted trees and 1% for trees 6 to 10 years old.

With only one exception growers indicated that the annual damage rate decreases with increasing age of the tree. However, most growers indicated damage rates only for the age

FIGURE 2. Relationship between annual damage rate and cost of annual rodent control program for each of the six age categories considered.


Mean Annual Damage Rate (%)
2
4
6
8
2
4
6
8
10
50
Cost of Annual Rodent Control Program ($)

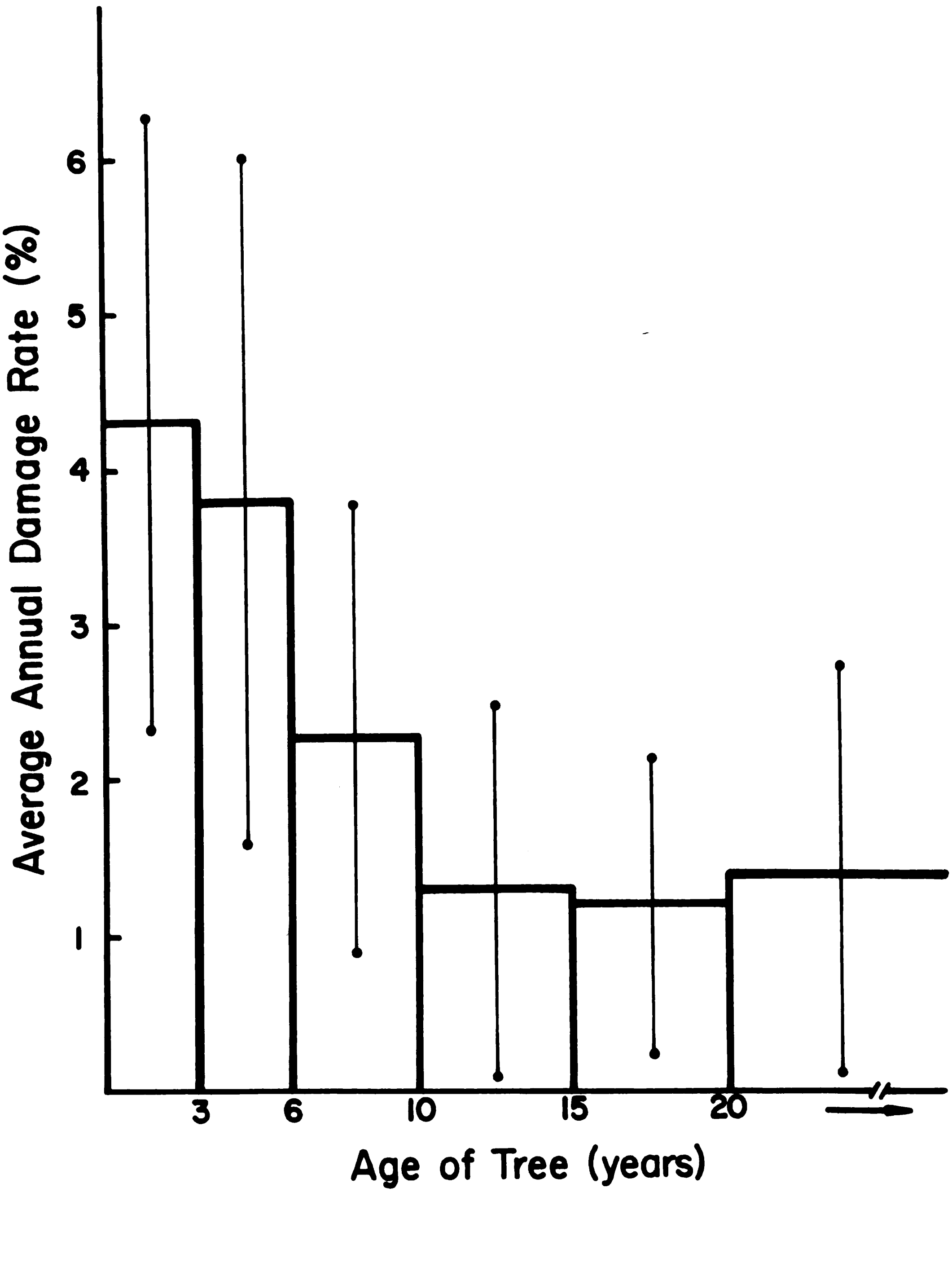
classes presently in their orchards. Estimates of damage rates for the first five age classes indicate that damage rates decrease as trees grow older (Figure 3). The only exception to this tendency occurs among trees greater than twenty years of age. The sixth age class (greater than 20 years) had a mean damage rate which was slightly higher (but not statistically significant) than the two preceding age classes. Beyond approximately ten years of age, apple trees are relatively free from microtine attack. Newly planted trees in the whip stage are approximately three times as likely to be damaged as trees ten years old or older.

The damage rate of 1.0% to 1.5% for mature trees as determined from the questionnaires was compared to the information received from the Apple Pest Management field scouts. This latter source indicated a damage rate of 1.3% (±0.01) for individual 10 acre orchard blocks. A total of 1,520 trees were examined and recorded.

It is interesting to note that all damaged trees were restricted to 12 growers. One grower who had 5 ten acre blocks inspected by the Apple Pest Management field scouts had 14% of inspected trees damaged by <u>Microtus</u> <u>sp</u>. during the previous winter. Growers with multiple blocks tended to have similar damage levels in all blocks. Of 38 growers with more than one block only two exhibited damage in any block while 36 had no visible damage in any block. One grower had one tree damaged in 4 of 5 blocks.

Mowing, herbicides and clean cultivation have long been considered effective means of reducing microtine populations

FIGURE 3. Histogram indicating the relationship between the age of a Michigan apple tree and its chance of being attacked by <u>Microtus sp</u>.



Average Annual Damage Rate (%)
1
2
3
4
5
6
3
6
10
15
20
Age of Tree (years)

through the destruction of suitable habitat (Elton 1951, Holm, Gilbert and Haltvick 1959). These procedures appear to be of dubious value in reducing damage to apple trees. While reducing or eliminating ground cover under the trees significantly reduced the number of trees which had visible runways within their driplines there was no decrease in the number of trees which were damaged. Trees which received no vegetative manipulations around their base (192 total) showed no evidence of damage while of the 1,308 trees examined which had been treated to reduce grasses and herbs, 20 received some amount of visible damage.

While there was no significant difference between these two categories ($\chi^2 = 2.91$ df = 3 $0.5 > p > 0.1$) these results are contrary to my a priori expectations. It was felt that orchards in which ground vegetation had been reduced would exhibit lesser damage rates (Littlefield, Schoonmaker, and Cook 1946). Many growers also felt that elimination of ground cover was an important aspect of their rodent control program. The lack of a significant difference, however, may prove to be of considerable import to growers as the elimination of vegetative control would represent a savings of several dollars per acre.

Mice do not seem to prefer any particular variety of apple tree despite growers' indications of a slight preference for the red delicious variety. Contingency table analysis indicated no significant difference in damage levels among the varieties examined.

Question 18 on the questionnaire concerned growers' estimates of their expenses and losses incurred because of small mammal damage, including not only the cost of rodent control programs, but also damage in the form of girdled or partially girdled trees and the resulting loss in production. The mean response weighted by acreage was $5.31 per acre per year. There was no significant difference between the northern and southern regions in the state. State-wide, this figure indicates a loss of approximately $301,000. I suspect, however, that growers' estimates are low. In many cases, the answer to question 18 indicated a loss which was less than the amount spent on rodent control alone. Furthermore, many growers ignore the fact that damaged trees may produce a reduced crop, preferring to ignore fruit that never developed rather than to estimate its potential value.

DISCUSSION

Microtines are a significant pest throughout the major apple growing region of Michigan. The region south of and including Muskegon county may incur slightly more damage than the more northern regions.

Microtines seem to prefer young apple trees to mature trees. This preference, however, is not absolute and approximately 1.3% of Michigan's mature apple trees are damaged by voles annually.

Economic losses due to microtine damage are difficult to estimate for several reasons. Beside the fact that damage rates vary from year to year, the effect of observed damage to the tree's trunk on apple production has never been ascertained except in the extreme case where complete girdling causes the death of the tree.

Even in the case of complete girdling, trees are often saved by bridge grafts. Many growers, however, prefer to remove such trees and replace them. Furthermore, some growers remove all developing fruit from extensively damaged trees to redirect the trees' energy budget.

Small amounts of girdling probably have no significant effect on apple production. However, such injury may facilitate the infection of the tree by other factors.

Since little data is available on the effect of physical damage to the tree's trunk on apple production, a series of "best estimates" have been made based on information obtained during interviews with orchard owners. When a tree is girdled on less than 10% of its circumference, there is little or no decrease in production. However, when a tree is girdled over 80% or more of its circumference, bridge grafts are usually required to prevent the death of the tree. At this point, production is usually temporarily halted either through the inability of the tree to produce fruit or the action of removing developing fruit. Little information is available on the effect of intermediate amounts of damage but for the sake of simplicity the relationship is taken as linear between these two points.

Furthermore, little information is available on the effect of damage during subsequent years. Again, estimates were based on information gathered during interviews. For any amount of damage it was assumed that recovery takes approximately two years and that any decrease in production caused by girdling is halved during the second year. This may not be entirely accurate for trees which sustain only small amounts of damage or for trees which are severely damaged but I feel it is the most appropriate estimate based on available information. A graphic explanation of these effects is given in Figure 4A and 4B. This estimate probably understates the effect of microtine damage on apple production since trees which are severely girdled are apt to require more than two years to fully recover, if they recover at all.

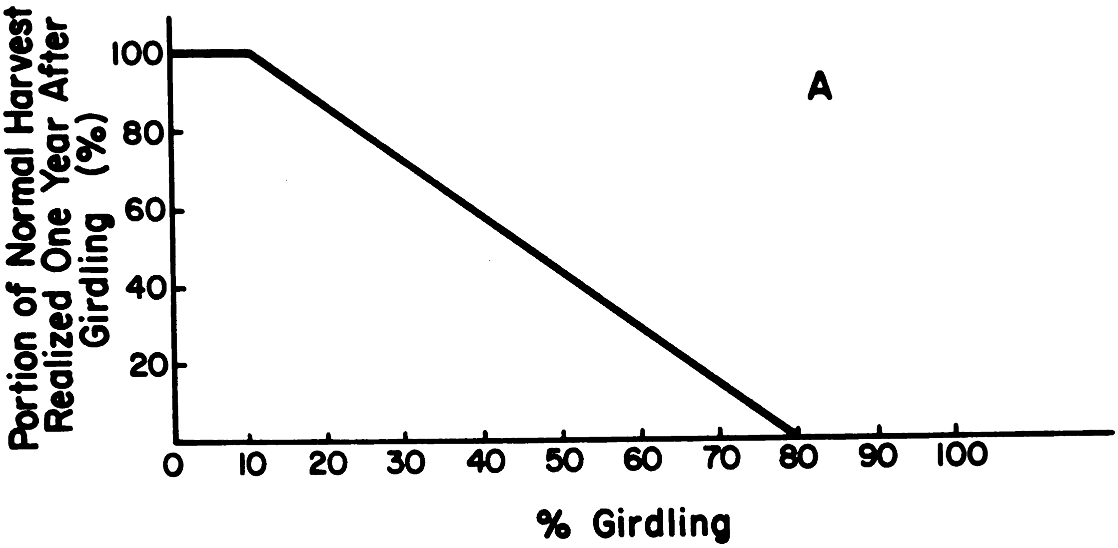
Applying these estimates to the data collected by field scouts, 0.86% of Michigan's apple trees of bearing age were damaged sufficiently during the winter of 1973-74 to reduce production. Of the trees which were damaged, including trees damaged less than 10%, the mean portion of the circumference which was girdled was 31%. According to the damage/harvest schedule developed earlier, the average harvest reduction on damaged trees would thus be 28% during the harvest season following the damage and 14% during the second harvest subsequent to the damage.

By multiplying the appropriate annual damage rate of 1.3% by 3,170,000, the number of trees of bearing age, I have calculated that in the winter of 1973-74, approximately 41,210 Michigan apple trees of bearing age were damaged by microtines.

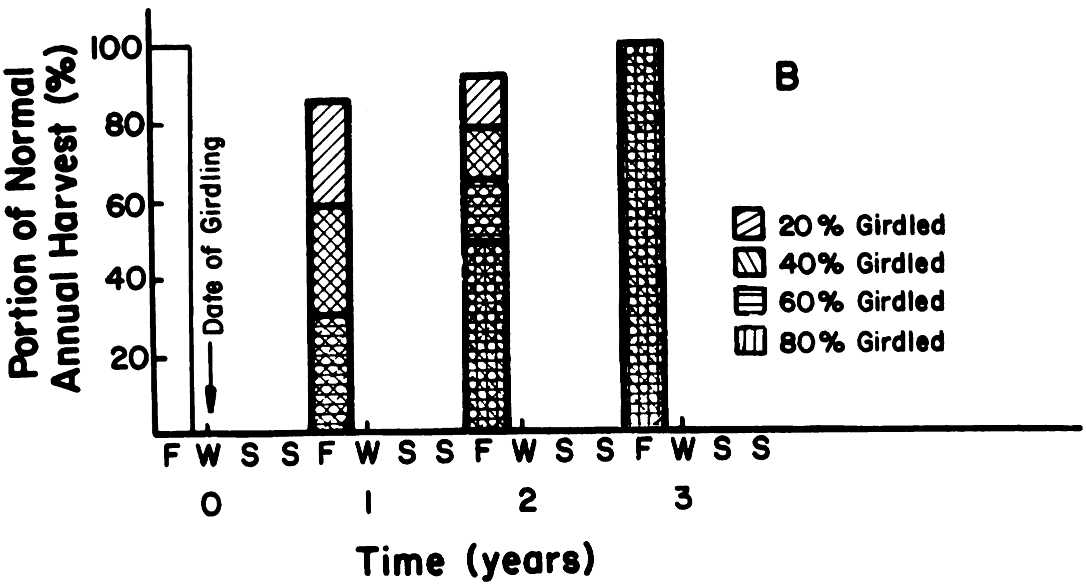
An average Michigan apple tree of bearing age produced 221 pounds of apples in 1972 (Anon. 1973). In 1972 then, the harvestable apple crop in Michigan was reduced by an

FIGURE 4A. Effects of various amounts of girdling on harvest during first harvest season after girdling.

FIGURE 4B. Effect of various amounts of girdling on production of an average Michigan apple tree during successive years following girdling.



A
Portion of Normal Harvest Realized One Year After Girdling (%)
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
% Girdling



B
Portion of Normal Annual Harvest (%)
100
80
60
40
20
Date of Girdling
20% Girdled
40% Girdled
60% Girdled
80% Girdled
F W S S F W S S F W S S F W S S
0
1
2
3
Time (years)

estimated 3,825,112 pounds (Number damaged trees X lbs. harvest/tree X reduction of harvest during first season after damage X 1.5) with a market value of $146,500. This is an average of $2.58 per acre of producing trees and is incurred in spite of prevailing control techniques.

Younger trees, however, bear the brunt of the damage. To protect these trees many growers provide additional protection to new orchards in the form of clean cultivation, wire or aluminum collars around the base of the trees, or the eradication of all undergrowth through complete herbicide treatment. Young trees, however, are seldom repaired by bridge grafting in the case of severe damage, as it is usually easier and cheaper to replace them. Assuming that there are equal numbers of trees planted every year and that an orchard has an average life expectancy of approximately 50 to 60 years (from personal interviews) approximately 57,600 new apple trees are planted in the state every year. This figure is probably somewhat low because of the recent trend towards high density dwarf trees. Thus, while the total acreage planted to apples in Michigan remains essentially constant, the number of trees planted every year is increasing. Using the damage rates indicated by the growers and their estimates of the value of trees at various ages, it is possible to estimate the financial loss which growers suffer before their trees are old enough to produce fruit commercially as

$$\text{Loss} = \sum_{\iota=1}^{10} \begin{pmatrix}\text{number of trees} \\ \text{aged } \iota \text{ years}\end{pmatrix} \cdot \begin{pmatrix}\text{damage rate among} \\ \text{trees aged } \iota \text{ years}\end{pmatrix} \cdot \begin{pmatrix}\text{value of a} \\ \text{tree aged } \iota\end{pmatrix}.$$

Using the appropriate values I have estimated the loss to be $175,797. This figure assumes that all damaged trees are destroyed and subsequently replaced. If destroyed trees are not immediately replaced the loss is higher since subsequent production is lost. In this case, it becomes much more difficult to estimate the loss as many of the maintenance tasks such as trimming, harvesting, spraying, etc., need not be continued while others such as mowing are often performed. In order to be consistent with other estimates of financial costs, I will continue to use a minimum estimate.

Thus, in spite of better than $166,400 spent on the control of microtines in Michigan orchards, they continue to inflict a minimum of $322,290 worth of annual damage in Michigan. It is important to note that these damage estimates were based on the winter of 1972-73 and 1973-74 which were both conceded to be relatively light years in terms of microtine populations. While no estimate of the state-wide damage rates during years of high microtine densities were possible during this research, extrapolation of a few isolated orchards which suffered unusually high damage rates indicates that damage levels can go considerably higher. One grower in the southern portion of the state suffered relatively severe damage during the winter of 1973-74. Of 50 trees examined 7 exhibited girdling for a damage rate of 14%. Similarly, another grower indicated that during the winter of 1972-73, 250 of 30,000 trees were damaged severely enough to require bridge grafting. While it is difficult to extrapolate on such limited information, microtine densities are well known to vary as much as two orders of magnitude from years of low density to periods of peak densities. Thus, the damage rate during years of peak microtine populations may easily be increased to five to ten times as much as my data indicate.

The increased damage rate among young trees bears further consideration. While the total cost of the damage to young trees is considerably less than the value of the decreased production estimated to result from girdling damage to older trees, the current trend towards dwarf fruit trees may increase this figure. Dwarf fruit trees start bearing earlier and also stop producing at a commercially profitable rate at earlier ages. As older orchards are replaced by dwarf trees, a larger portion of Michigan's apple trees will be under ten years of age and therefore, subject to higher damage rates.

The effects of manipulating ground vegetation were surprising. The initial purpose of recording the type of clearing used was to determine whether the use of herbicides produced a significantly lower damage rate than just mowing. The lack of a significant difference (and the trend towards lower damage rates in orchards where no weed control was practiced) is, in itself, biologically important since mowing and herbicide treatments are generally considered to be destructive to good microtine habitat (Elton 1951). Microtines may move into the orchards during the winter, after the application of poisoned baits, under the cover of a snow blanket and utilize the trees as a food source where no other vegetation is available.

An alternative explanation may be that growers with a previous history of little damage from microtines do not feel the need to mow or spray in their orchards. Further research on this question is warranted since if the first explanation is valid, it may be possible to reduce the costs of weed control in orchards as well as microtine damage. An added benefit would be the decreased use of unselective herbicides. Competition between trees and ground vegetation, however, may warrant continued use of herbicides, particularly early in the summer when apples are first developing on the tree.

Growers felt that current control procedures are generally effective. During the interviews, however, I learned that zinc phosphide is applied to the corn with either an oil or paraffin base. While the corn treated with oil is generally less expensive, if application of the orchards is followed by rainy weather, the zinc phosphide may be washed from the corn or become detoxified. This may account for the fact that several growers indicated that periods of severe mouse damage are often associated with rainy weather.

SUMMARY

Of 52 orchard owners responding to the questionnaire and/or contacted for a personal interview, a majority considered rodents to be significant pests in their orchards. Ninety-seven percent of the apple producing acreage covered in this survey was treated with poison bait, presumably zinc phosphide.

The median cost to apply zinc phosphide treated corn to orchards was $3.00 per acre. State-wide, the projected annual cost of applying poison bait to commercial apple orchards is in excess of $166,400. This cost is based on the acreage of mature trees. The cost of rodent control in younger orchards is higher than in mature orchards because of increased protection usually given to new trees.

In spite of the rodent control procedures currently being used in Michigan apple orchards, damage still occurs. Responses to questionnaires indicated that growers estimated a 4% damage rate among trees three years old or younger. This damage rate declines until the tree reaches an age of approximately ten years at which time the average annual damage rate was estimated to be 1.3%. These data agree closely with data collected by field scouts during the spring of 1974. Information gathered on 1,520 apple trees in the state indicated a damage rate of 1.3% among mature trees. This was in a year of apparent low microtine density.

Based on estimates of the effect of girdling on a tree's production of apples, the yearly harvest loss attributable to microtines is approximately 3,825,000 pounds. At an average value of 3.82 cents per pound as determined by the Michigan Department of Agriculture, this can be converted to a minimum annual loss of $146,500 due to Microtus sp. Following peak years apple production may be reduced by as much as $732,500 or more.

In addition to the loss due to decreased production, microtines also cause the death of trees. Damage of this severity is relatively infrequent among mature trees, and when it does occur, it is often repaired by bridge grafting. In younger orchards, however, microtines can destroy a significant number of trees. Estimates based on responses to the questionnaire indicate that field voles may cause $176,000 annual damage among young apple trees.

Based on my estimates, microtines are responsible for a minimum annual cost of approximately $489,000 in Michigan apple orchards. This estimate includes the minimum estimates of the costs of rodent control, the value of lost production due to girdled trees, and the value of destroyed trees less than 10 years old (Figure 5).

The damages may well be greater than this during years of peak populations. Estimates based on two growers who sustained higher than average damage rates indicate that in peak microtine years, damage levels may be increased five to tenfold.

Zinc phosphide appears to be an effective means of rodent control under suitable weather conditions. The efficacy, however, is difficult to determine from my data. Dimmick (1972) reported that both 1.0% and 1.5% applications of zinc phosphide on oat groats were significantly effective in reducing populations of *M. ochrogaster* and *M. pinetorum* in Tennessee. Dry weather following application appears necessary for adequate control. Severe damage during peak years often occurs in spite of the use of rodenticides.

The effect of eliminating or reducing ground vegetation in orchards bears further study. While the purpose of herbicides is to reduce competition for ground water, in view of

FIGURE 5. Partitioning of annual expenses which Michigan apple growers sustain due to microtine rodents.

recent evidence that permitting ground cover is beneficial in attaining biological control of European Red Mites (Croft and McGoraty 1973), and the evidence that I have gathered which indicates that girdling damage is most prevalent in orchards where ground cover was eliminated, it may be more beneficial to the apple grower to permit grasses and herbs to grow under his trees.

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APPENDICES

APPENDIX A

SAMPLE QUESTIONNAIRE

1. Do you have fruit trees other than apples? __________
   If yes, please list the number of trees of each type and the number of acres devoted to each.

Kind	Acres	# Trees
__________	__________	__________
__________	__________	__________
__________	__________	__________
__________	__________	__________
__________	__________	__________

2. How many acres of apple trees do you presently manage?

   ____

3. How many apple trees do you presently manage? ________

4. Do you have more than one variety of apple tree in your orchard? __________
   If yes, list the number of trees of each variety and the number of acres devoted to each.

Variety	Acres	# Trees
________	________	________
________	________	________
________	________	________
________	________	________
________	________	________
________	________	________
________	________	________

SAMPLE QUESTIONNAIRE - continued

5. Are all of your trees the same age? __________
   If yes, how old? __________
   If no, please list the number of trees and acres in each age category.

	0-3	3-6	6-10	10-15	15-20	>20
# Trees	___	___	____	_____	_____	____
# Acres	___	___	____	_____	_____	____

6. Estimate the net worth of a tree in each of the above age categories.

	0-3	3-6	6-10	10-15	15-20	>20
$	___	___	____	_____	_____	____

7. Are small mammals a pest problem in your orchard currently? __________ in the past? __________

8. Do you practice small mammal pest control in your orchard? __________
   If yes, how often?
   semi-annually? __________ dates____ ____
   annually ______________ date ____
   as required _____________

9. How much does this method cost per acre? __________

10. What procedures have you used in the past? __________

    currently __________________

11. In your opinion, how effective is the method of small mammal pest control which you are currently using?

    very effective _____ effective _____ moderately effective _____ of little value _____

SAMPLE QUESTIONNAIRE - continued

12. Do you eliminate ground vegetation in your orchard(s) either thru the use of herbicides or by plowing? _____
If yes, directly under the tree? _____ how ___________
between rows of trees? _______ how ___________

13. Do you feel that small rodents are damaging any particular variety(ies) of tree? __________
If yes, which variety or varieties?

________, ________, ________, ________, ________.

14. Do you feel that dwarf trees are more susceptible to small mammal damage than larger stocks? __________

15. Estimate the percentage of trees in each age category which are damaged by small mammals during an average year.

0-3	3-6	6-10	10-15	15-20	>20
___%	___%	____%	_____%	_____%	____%

16. Do you practice different small mammal control methods in newly established orchards? __________
If yes, what methods? ______________________________

17. What portion of your resources (time and money) is devoted to controlling:

time		money	
pests of all kinds	____	pests of all kinds	____
small mammals only	____	small mammals only	____

(Note: include maintenance and depreciation on equipment)

18. Estimate the amount of money you lose each year to pests of all kinds _____ small mammals only _____.
(Be sure to include money spent on pest control)

SAMPLE QUESTIONNAIRE - continued

19. If a tree is damaged seriously enough to require a bridge graft, by what proportion is its productivity reduced during the following years? ___________

20. What % of your trees require bridge grafts during an average year? ___________

21. Of the small mammal damage incurred during the course of a year what % occurs during each season?

spring ____% summer ____% fall ____% winter____%

22. Do you feel that high levels of small mammal damage are associated with any particular climatic conditions? ___

If yes, what conditions? ______________________________

23. Are there any sections of your orchard which suffer excessive small mammal damage more consistently than other areas? ___________

24. Do your records indicate the severity of small mammal damage which occurred in your orchard during the last 10 years? ___________

If yes, please list

1963	1964	1965	1966	1967	1968
_____	_____	_____	_____	_____	_____
1969	1970	1971	1972	1973	
_____	_____	_____	_____	_____	

25. Rate the severity of small mammal damage in your orchard during the year preceding the '73 harvest season.

heavy _____ average _____ light _____

SAMPLE QUESTIONNAIRE - continued

26. In your experience, when did you suffer the greatest damage by small mammals?

    year _____ amount in % of trees damaged __________

    amount in $ __________

27. Did you practice small mammal pest control at the time?

    __________ If yes, what method? __________

28. Do you consider large mammals such as deer to be pests in your orchards? __________

29. What species of mammal do you feel is the most damaging in your orchard(s)?

30. Do you hunt wild species in or around your orchards?

    deer _____ rabbits _____ pheasants _____

    grouse _____ squirrels _____

31. What effect does your entire pest control operation have on these animals?

32. Would you be willing to participate in a program designed to reduce this problem? __________

33. Do you feel a descriptive brochure on the small mammals found in Michigan orchards would be helpful to you? ___

34. At the present time, what information regarding small mammals would be most helpful to your operation?

SAMPLE QUESTIONNAIRE - continued

35. Please add any comments you feel would be useful to our survey of small mammal damage in Michigan orchards.

Return to:
Walt Conley
Dept. Fisheries & Wildlife
Michigan State University
East Lansing, MI 48824

Variety (if known)											
Tree #	1	2	3	4	5	6	7	8	9	10	
% Girdling	%	%	%	%	%	%	%	%	%	%	
Distance from Trunk to Nearest Runway	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
Diameter of Trunk	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
Evidence of Cracked corn at Base of Tree											(Yes or No)
Was Ground Around Base of Tree Sprayed with Herbicide											"
Grass Mowed											"
Soil Tilled or Disced Between Rows											"
Depth of Litter Layer on Ground											"

Orchard Owner________________________ County__________

Have you trapped mice in this Orchard? __________
If Yes, how many Microtus did you catch? __________
(NOTE: Microtus are dark grizzled brown on top with short ears, tail, and legs)
How many trap nights did you spend? __________
(NOTE: Trapnights = # traps x # nights they were set)

APPENDIX B

TABLE B1. Varieties of trees examined by field scouts.

Variety of Tree	No. Examined	No. Injured	% Injured
Red Delicious	398	9	2.3%
Jonathan	314	4	1.3
Macintosh	113	1	0.9
Greening	47	1	2.1
Grimes	10	0	0.0
Golden Delicious	95	2	2.1
Rome	97	1	1.0
Ida Red	26	1	3.8
Hyslop Crab	10	0	0.0
Spy	55	0	0.0
Courtland	6	0	0.0
Stamen	1	1	100.0
Wealthey	6	0	0.0
Winesap	27	0	0.0
Wolf River	1	0	0.0
Yellow Transparent	1	0	0.0
Fenton	4	0	0.0
Macoun	2	0	0.0
William's Early Red	1	0	0.0
Delicious (unspecified)	20	0	0.0

TABLE B2. Contingency table data for Question 7 "Are mice a serious problem in your orchards?" versus region (χ^2 = 7.05 df = 5 0.5 > p > 0.1).

		NORTH	SOUTH	TOTALS
YES	OBSERVED	4	20	24
	EXPECTED	7.64	16.36	
	χ^2	1.73	.81	
SOME	OBSERVED	3	1	4
	EXPECTED	1.27	2.73	
	χ^2	2.36	1.10	
NO	OBSERVED	7	9	16
	EXPECTED	5.09	10.91	
	χ^2	.72	.33	
TOTALS		14	30	44

TABLE B3. Contingency table analysis comparing severity of damage during winter of 1972-73 as determined from the questionnaires versus geographical area. There was no significant difference (χ^2 = 1.58 df = 5 0.975 > p > 0.900).

		NORTH	SOUTH	TOTALS
LIGHT	OBSERVED	9	20	
	EXPECTED	7.63	21.37	29
	χ^2	0.24	0.09	
MEDIUM	OBSERVED	1	6	
	EXPECTED	1.84	5.16	7
	χ^2	0.39	0.14	
HEAVY	OBSERVED	0	2	
	EXPECTED	0.53	1.47	2
	χ^2	0.53	0.19	
TOTALS		10	28	38

TABLE B4. Contingency table analysis of damage rates between orchards where grass cover occurred and orchards where it was eliminated. Data was collected by Apple Pest Management field scouts ($\chi^2 = 2.91$ df = 3 $0.5 > p > 0.1$).

		GRASS COVER	NO GRASS COVER	TOTALS
DAMAGED	OBSERVED	0	20	
	EXPECTED	2.53	17.47	20
	χ^2	2.53	0.35	
NOT DAMAGED	OBSERVED	192	1,308	
	EXPECTED	189.47	1,310.53	1,500
	χ^2	0.03	0.00	
TOTALS		192	1,328	1,520