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# A TWO YEAR STUDY OF THE PHYSICAL AND ECONOMIC IMPACT OF VOLES (Microtus montanus) ON MIXED MATURITY APPLE (Malus spp.) ORCHARDS IN THE PACIFIC NORTHWESTERN UNITED STATES

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# A TWO YEAR STUDY OF THE PHYSICAL AND ECONOMIC IMPACT OF VOLES (Microtus montanus) ON MIXED MATURITY APPLE (Malus spp.) ORCHARDS IN THE PACIFIC NORTHWESTERN UNITED STATES

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ABSTRACT: The physical impact of voles in agriculture and forestry has been duly noted by many researchers around the world. The economic impact of the various species, however, has not received much attention other than to note that losses from these animals can be substantial when population levels become high. This study assesses the economic impact of an extremely high population of Microtus montanus (mountain voles) in a large apple (Malus sp.) orchard in northcentral Washington State (U.S.A.) over a two-year period. In this study, 200 trees were harvested, weighed, graded, and compared by the amount of visual damage that could be seen above the soil surface. These values were then compared with cash values received by growers for the season. Production was decreased a weighted average of 36% (31 % for red delicious and 53% for golden delicious) or $3036/ac. ($7500/ha.) during the first year. In the second year, production increased 3.2 fold but still did not reach that of the control orchard. If 30% of the orchards in the state were to suffer the same level of infestation, over $137 million/year could be lost because of poor management and control programs.

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"Small mammals, especially rodents, with their self-sharpening incisors and phenomenal capacity to increase in numbers, take a toll of man's provisions all over the globe" (Myllymaki, 1979; p. 239).

The litany of animal impacts, particularly for rodents, is long-longer than the time or space afforded here for a complete review. Elton (1942) and Myllymaki (1979), in their reviews, bring the overall problem into focus. As these and other reviewers indicate, information on the physical impact of rodents is common. Not so for economic impacts. In the rare instances where economic impacts are reported, the data are generally generated from visual estimates or historical interviews and summaries. For example, Ryszkowski et al. (1973) and Wolf (1977) estimated alfalfa losses by Microtus arvalis and M- guentheri. but did not state how the data were developed. Johnson etal. (1982) reported on corn losses, but did not detail the economic impact. Neither did Sullivan et al. (1987) in summarizing the interviews with orchardists in western Canada.

Attempts at estimating general economic impacts have been made by several researchers. For example, Myllymaki (1977) felt that the M- agrestis and M- guentheri caused about $100 million in crop losses between the mid 1950's and 1970's. Wieland (in Myllymaki 1979) reported a S3 million loss with the destruction of 600,000 apple trees in a single year. These losses, however, were conservative. The cost of a new tree was the only economic factor considered. Lost revenues and replanting costs were not accounted for in the report.

Vole damage and losses have not been well documented (Laidlaw 1981). Vole activity is easy to identify. The animal is well known for its open holes, packed runways, and clippings. Vole damage, however, is difficult to evaluate. Damage is often recorded by the number of severely damaged trunks or dead trees. Yet M- pennsvlvanicus and M- pinetorum arc known root feeders (Poche and Sharp 1985). Recent evidence shows that M.- montanus have similar feeding behavior not only at one, but at four different levels above and below the soil surface (Askham unpubl.).

The potential for substantial economic losses to Pacific Northwestern United States agriculture is quite large. For example in the state of Washington over 160,000ac. (65,000 ha.) are currently under apple production in the Yakima and Wenatchee valleys. If, according to Sullivan etal.'s (1987) estimates, 30 to 50% of these orchards are infested with voles and approximately S445.34/ac. ($1100/ha.) in damages are sustained (Laidlaw 1981), then approximately S21 to S36 million is lost per year. These estimates, however, do not present an accurate picture. First, because they arc based on assumptions. Second, because they are based on interviews, which can be subjective. And finally, because no production and replacement cost data have been used.

To resolve these problems and develop some baseline data for future studies, an indepth multi-year analysis of an infested orchard was undertaken. The objective of the study was to assess the impact of control prescriptions and measure the effect of an extremely high population of mountain voles (M. montanus) on apple fruit quantity, size, replacement costs, and economic losses.

## MATERIALS AND METHODS

The study was limited to three randomly selected 10 ac. (4.05 ha.) blocks within a 500 ac. (203 ha.) block of 'red delicious' and 'golden delicious' (Malus domestica) apples along the Columbia River in north-central Washington State (U.S.A.). Vole population levels were first assessed to determine the activity, abundance, and possible numbers of animals present.

The presence or absence of voles was determined by using the Activity Index (AI) developed by Byers (1975). Abundance was derived by expanding the AI to calculate the Feeding Index (FI). FI's were developed by placing each apple slice into one of five categories (Table 1). The number of apples in each category is then multiplied by their category class (e.g., 5 apples in the 4th category = 20), added together, and then divided by the total number of observations. The formula for these calculations is:

$$FI = \frac{E(xi\ fi)}{fi.}$$

When used in conjunction with the AI, the FI provides a means by which population increases or decreases can, over time, be measured. The FI can be used, as well, as a predictive index for orchard understory vegetation management (Table 1).

Table 1. Use of the Feeding Index (FI) to Determine Population Rank and Treatment Recommendations for Vole Control in Apple Orchards.

| Category Value | Feeding Activity (% of apple slice consumed) | Population Ranking | FI Rank | Treatment Recommendations |
|---|---|---|---|---|
| 0 | None | | 0 | None - Continue monitoring |
| 1 | <25 | Low | <1.0 | Spray herbicides within rows. Mow twice weekly between rows. Treat isolated colonies with rodenticides. |
| 2 | 25-50 | Moderate | 1.0-1.99 | Same as above, Increase number of mowings/month. |
| 3 | 50-75 | High | 2.0-2.99 | Broadcast application of rodenticides after cover vegetation has been mown. |
| 4 | >75 | Severe | 3.0-4.0 | Emergency treatment. Cover and forage removal required. Multiple rodenticide treatment required. |

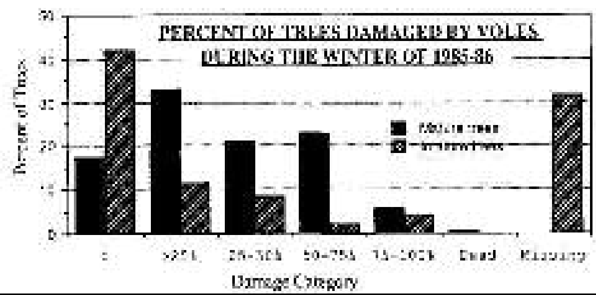
The AI's and FI's were developed by visually assessing the amount of pulp eaten from each of 25 apple slices placed in two 1/2 ac. (1/4 ha.) plots on each treatment site (Godfrey and Askham 1986). Vole numbers were estimated by counting the number of active burrow openings within a 1 -m area. Samples were taken from ten randomly selected plots. A Population Index (PI) was developed to provided a quick estimate for the entire orchard with the following formula:

$$PI = \underline{(Exi)\ (A)}$$

where Exi = sum of the number of holes/plot,
fi = number of plots, A = area,
xh = average number of excavated holes per active animal.

Every tree within the three blocks was rated for the amount of feeding seen above the soil surface. Each tree was placed in one of six categories (Fig. 1): no visual damage; 0-25% of the bark circumference removed; 25 to 50% removed; 50 to 75% removed; 75 to 100% removed; or the tree was dead. Each tree was also placed in one of two sub-categories: immature (non-bearing) or mature (bearing).

Fig. 1.




In late September and early October of 1986, five trees from both varieties were randomly selected from each of the first five damage classes within each block (total =150 trees). These trees were harvested, weighed, sorted, and graded to U.S. Department of Agriculture standards (Figs. 2 & 3). A base 1986 price, received by the grower at the packing house door, was added to each size class and weight to calculate the gross production values for each variety each year. The following year packing records from the sorting sheds was used to develop a two-year production profile.

Prior to 1986, understory vegetation management had been limited to once-a-month mowings between the rows. No herbicide sprays were used. In April, 1986, the grass under the tree canopies was treated with an herbicide spray. During May, all of the dead vegetation, including prior years accumulations, was raked from beneath the trees, pulverized and scattered with the remaining vegetation between the rows that was mown twice each month.

## RESULTS

Vole activity was extremely high between October, 1985 and March, 1986. The AI on the apple slices ranged between 94 and 100% in each of the six population assessment blocks. The FI (an indication of the number of animals feeding in a given area over time) ranged from 2.35 to 3.16 (Table 1; Scale - 0 to 4.0). In stable populations of 30 to 80 animals/ac. (74 to 200/ha.) outside the orchard, FI's ranged from 0.44 to 0.88 during the same time period. The RPI developed from other studies (Askham unpubl.) and applied to this trial indicates that about 1700 voles/ac. (about 4200/ha) were active prior to the assessment.

This extensive infestation damaged over 82% of all bearing trees and 57% of all immature trees (Fig. ^.Approximately 77 % of the mature trees and 22% of the immature trees had 25 to 75% of the bark removed from the main stem. Only 61% of the mature and 4% of the immature trees were completely girdled at the time of the survey. Damage was severe enough that 151 trees (3%) in the three treatment sites were replaced the following year. The remainder were bridge grafted.

By October, approximately 98% of the vole population had been eliminated by changing the orchard's understory vegetation management program. Follow up studies and rodenticide trials conducted on the remaining resident pockets during the next seven months did not alter these results.

<u>First year fruit production</u>

During the 1986 growing season, the entire orchard produced 3,049 bins (2,896,550 lbs.) of red delicious and 2,987 bins (2,541,937 lbs.) of golden delicious apples; an average of 6.04 bins (5436 lbs.) per acre. An analysis of the harvested fruit shows extreme weight variation between that from undamaged trees during the prior 15 years (control) and damaged trees. No significant production differences (p = .001) were found between damage classes nor was there a correlation between damage and increased or decreased productivity.

During this growing season, the red delicious produced an average of 21% fewer pounds of apples per tree in the infected blocks than in the non-infected block (Fig 2). The goldens produced an average of 51 % less per tree (Fig. 3).

In addition to less fruit, a greater quantity of smaller fruits was produced as well. Reds produced 85% and the goldens produced 35% fewer premium size apples (88 or more apples per 421b. [20.25 kg] box) than the controls. The goldens produced an average of 42% fewer pounds of medium size fruit (apples/box) but the reds produced about as much for the first two size classes and more (42%) for the lower class. The same was found for the peelers and juice classes (2.5 to 2.25 in or 5.72 to 6.35 cm) where the damaged reds produced 3 times more, and the goldens produced 2.5 times less than the controls.

The significance of these changes is intensified when prices are computed for each of the yields. When data from non-infected orchards arc used to calculate gross revenues, a fully stocked mature orchard in the Wcnatchcc valley could

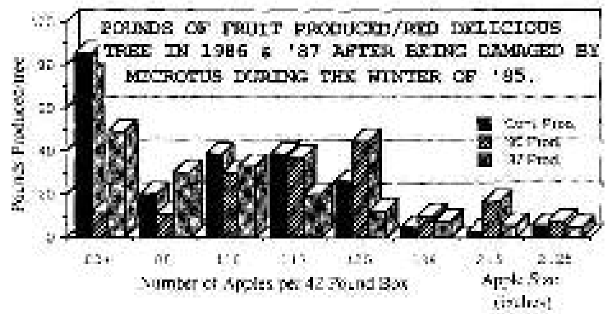



Fig .2.

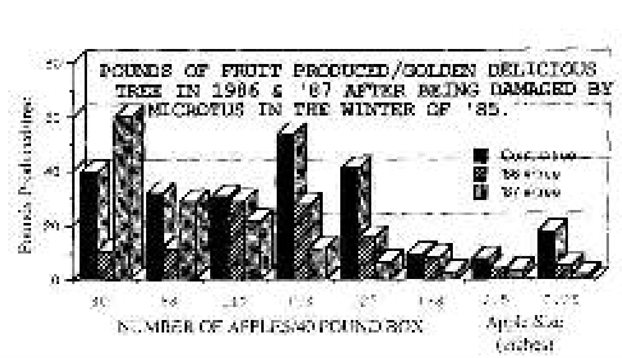



Fig. 3.

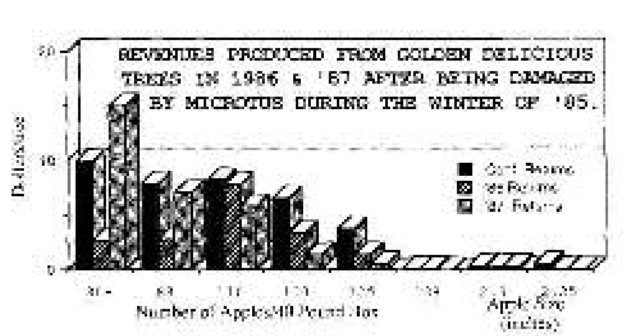



Fig. 4.

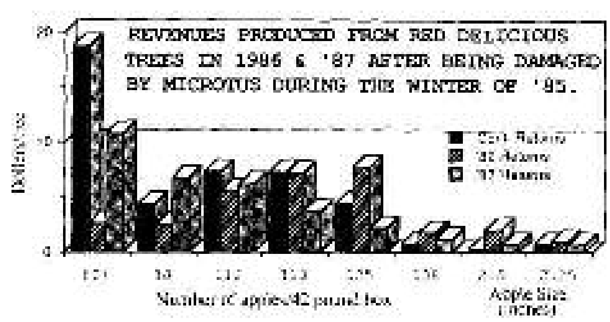



Fig. 5.

produce about S9,900/ac. ($24,500/ha.) in 1986. With 15% of the orchard being replaced with new plantings, this value drops to $8,5OO/ac. ($21,000/ha).

The impact of a high vole population reduced the first year's total cash yields by almost 36% ($3042/ac. or $7500/ha). Returns were reduced by 53% ($10001/ac; $2500/ac.) for goldens (Fig. 4) and 31% ($2041/ac.;$5000/ha) for reds (Fig. 5). The 1985 cost of replacing the orchard projected a S1,033/ac. ($2550/ha.) expense during the next five years (if 10% of the damaged trees were replaced the first year). Only 32% of the stock, however, was replaced for an estimated cost of S310/ac. ($765/ha.). Projected production losses, assuming a 20% production improvement/tree/year during the next five years, were calculated to exceed S100,000/ac. ($249,000 ha.) or well over $50 million for the entire orchard. The grower limited the replacements to 31% of the orchard. The remainder were in-arch bridge grafted. Replacement costs for the first year amounted to approximately $310/ac. ($765/ha.). Grafting costs were another $ 177 for a total of $487/ac. ($1203/ha.). If no additional trees are replaced, replacement costs for the five years between the vole infestation and full production of the orchard is achieved should reach $2400/ac. ($5900/ha.). Second Year Production

One year after the voles had been eliminated from the orchard, total fruit production increased 3.3 fold. During 1987, 9,896 bins (9,401,200 lbs) of reds and 9,926 bins (8,446,628 lbs.) of goldens were produced in the same orchard. This was a respective increase of 124.74 bins (li8,503 lbs) and 138.78 bins (118,113 lbs.) per acre.

The first year's production of fruit resembled a bell-shaped curve for both varieties. A high percentage (65.5%) of medium-sized apples (110, 113 and 138's) rather than large (80's) and premium (88+'s) or small (125 or smaller) were produced during the growing season. One year after the voles had been eliminated from the orchard, the golden's production resembled a flattened "J" shaped curve with a high proportion (67%) of the fruit distributed in the large and premium grades (Figure 3). Goldens produced approximately 19% more fruit during the second year, but 41% less than the controls. The reds produced 4% less total fruit in the second year; 27% less than the control. Fruit sizes, however, improved with more large and premium grades produced, as well as fewer in the medium, and small classes (Fig. 2).

Revenues for the second year improved. Holding prices constant at the 1987 level, income per tree improved 38% for the goldens and 6% for the reds. This was still 19% (for the golds) and 27% (for the reds) below those calculated for the control.

## DISCUSSION

This study shows that the physical and economic impact of voles in red and golden delicious apple trees in the Pacific Northwestern United States can be severe and costly. It also indicates that vole population levels can reach extremely high numbers.

The voles were found to eat anything that was green: grass, trees and their roots. Root feeding was found to be substantial. In the analysis of variance performed on the first year's production, no significant differences were found between trees with little or no above-ground damage and trees with varying amounts of above-ground damage. Trees from this sample were pulled and the root systems compared. It was found that all of the trees had been severely damaged below the soil surface, even those that were not girdled.

The removal of vegetative cover and the judicious use of rodenticides effectively eliminated this problem. The resident vole population was decreased by about 98% (from a high of approximately 1700animals/ac. [4200/ha.]) while the surrounding populations grew. The continued use of herbicide sprays, cleanings, frequent mowings and spot rodenticide treatments during the second year prevented a further reinfestation.

The economic impact of the heavy vole infestation was, and will continue to be, extensive. Production losses for the orchard were a little over $3042/ac. ($7500/ha.) or an average of 36% of the cash value for the entire crop during the first year. Replacement costs were expected to be about SI 034/ac. ($2550/ha.). However, by replacing only 3% of the orchard, along with bridge grafting, costs were lowered to $487/ac. (S1203/ha.). Hence, the combined production losses and replacement costs amounted to a little over S35OO/ac. ($8600/ha.).

Fruit production, and subsequently income, improved substantially during the second year. Most of the improvement was noted in the production of large and premium grade apples and was most pronounced in the goldens. This variety produced 18% more fruit during the second year but the cash value for the crop improved 38%. The reds production and cash value only improved 4% and 6%, respectively. While showing a major improvement over the previous year, the goldens were still 19% and the reds 27% below their full productivity potentials. Total production losses and replacement costs averaged about $2,600/ac. (S6430/ha.) for the second year.

## SUMMARY

The data from this study show that the physical and economic effect of heavy infestations of one vole species, M-montanus. is much greater than previous estimates would indicate.

Three population assessment techniques were used to establish infestation levels. The first, following Byer's work (1975), established the presence or absence of the target species. This procedure was labeled the AI or activity index. This procedure was found to be inadequate, however, for assessing the relative abundance of animals in a given area during high population periods. The development of the FI (feeding index), when used with the AI, provided a means for assessing the increase or decrease of a population. Excavations of subterranean chambers were used to assess the impact of the Microtus beneath the soil surface, and helped established a RPI (Relative Population Index) by which numbers of animals within a given area could be estimated without the use of extensive trapping programs.

These procedures, along with the data collected by harvesting individual apple trees that had suffered different degrees of damage in a large orchard, and compared with data developed from non-damaged orchards, provided enough information to assess the economic impact of the voles for two years. These data showed that approximately 83% of the trees had been damaged above ground. The excavations, along with the production data statistical analysis, indicate that all of the trees suffered some form of subterranean trauma during the preceding year. The effect of this trauma was that about 36% less fruit was produced. When replacement costs were included in the analysis, an average of $35OO/ac. ($7645/ha.) was lost the first year. These combined losses were 7.9 times higher than those estimated by Laidlaw and many fold those estimated by Wieland.

During the second year, total fruit production increased about 3.2 fold. Most of this increase was noted in the larger and premium grade fruit and was reflected in the total return per tree. This increase, however, still did not equal that from non-infested orchards. Losses for the second year were about $2,600/ac. ($6430/ha.). Total losses for the two year period were about $6,100/ac. ($15,000/ha.)orabout$3 millionfor the entire orchard.

The long-term impacts will continue to be assessed for the next three years. As with most research, more questions seen to have been raised than answered. Hopefully, additional data will be developed from other orchards in different parts of the world. Only then will the true impact of voles be understood.

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