February 1978

Proceedings of the Second Eastern Pine and Meadow Vole Symposium

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Beltsville, Maryland
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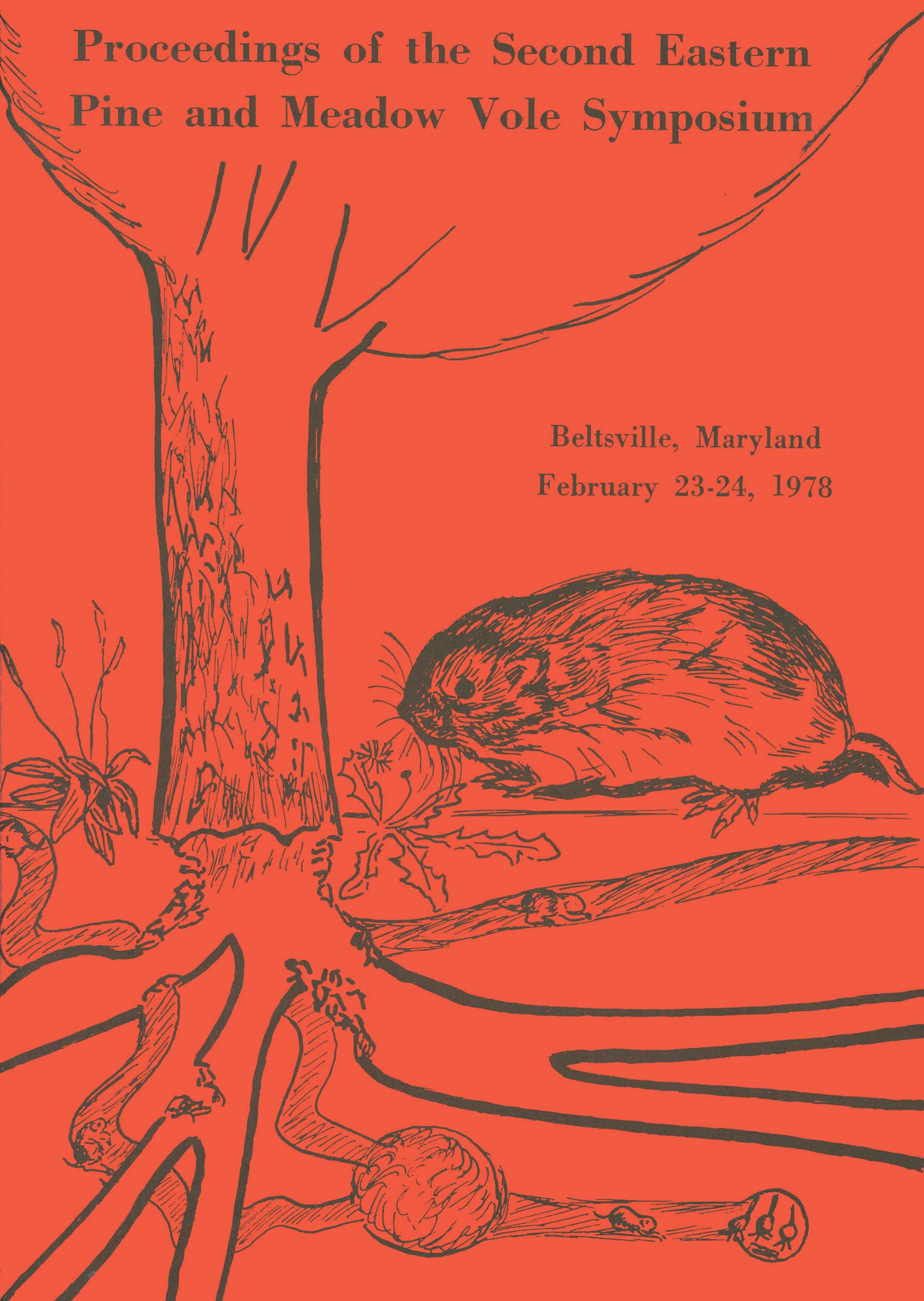

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SECOND EASTERN PINE AND

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EDITOR

ROSS E. BYERS

1978

CONTENTS

Editor's note: The papers in the Proceedings appear as originally written.

HIGHLIGHTS OF THE SECOND EASTERN FINE AND MEADOW VOLE SYMPOSIUM

The Second Eastern Pine and Meadow Vole Symposium met at Beltsville, Maryland, February 23-24, 1978, to discuss various solutions to the serious damage caused by these rodents to fruit trees in the Eastern United States. Fruit growers, local, state, and federal research and extension specialists from many universities, Environmental Protection Agency, U. S. Department of Agriculture, U. S. Department of Interior, and the chemical industry participated in the program.

The purpose of the second symposium was to focus attention on one of the most serious cultural problems facing the fruit industry, to stimulate research, and to seek funds for a national pine vole damage control program. A number of universities reported their work on various aspects of the problem; but because of the lack of funding, the scope and intensity of coordinated research efforts was felt to be greatly needed.

The removal of Endrin by New York State in 1971 provided a classic example of serious farm losses caused by the irresponsible removal of a minor use pesticide with no planned alternate control measure. Since the Hudson Valley was on the northern most border of the pine vole range and because Endrin was being used until 1970, only approximately 7 orchards involving 600-700 acres were known to be infested. By 1977 the vole had enlarged its range to 30 orchards involving 4,200 acres (Warren Smith, personal communication).

In the center of the geographic range (Virginia and West Virginia) the problem had become most acute in the period 1965-1970 because Endrin had been used on an annual basis for about 10 years and Endrin resistant strains developed. Ten years have now passed since the first resistant strains were found. At this time (1978) Endrin resistance is widespread in the Cumberland-Shenandoah apple region. Therefore, we expect that Endrin will be only a temporary control agent for the margin areas where Endrin has had more limited usage on less than an annual basis. State by state labels for Chlorophacinone baits and ground sprays and Diphacinone baits are now the only cleared alternatives to Endrin. Research on two promising new anticoagulants Brodifacoum and Bromadiolone was reported.

A nationally funded coordinated research program was discussed at a night session. The USDI personnel presented a 1.3 million dollar "add-on" appropriation proposal to their budget designed for both inhouse and contract research. This "add on" proposal was approved in early May by the Interior sub-committee. By early June it had passed the full committee on Interior. The House and Senate must yet act on the full Interior Bill, but it is not likely the pine vole research money would be altered after approval by the sub and full committees. In addition soon after the symposium, a tentative National Pine Vole Advisory Council was appointed by a number of State Horticulture Societies. This list of individuals appear to have the knowledge and expertise to assist in the development of a coordinated balanced research program as federal funding becomes available.

Proceedings of the First Symposium ($3.00) and Second Symposium ($7.00) provide the most up-to-date information on pine and meadow vole control research and should be of value to growers and research personnel alike. For Symposium copies make checks payable to Dr. Ross E. Byers, and mail requests to Dr. Ross E. Byers, Associate Professor of Horticulture, VPI & State University, Winchester Fruit Research Laboratory, 2500 Valley Avenue, Winchester, VA 22601.

PROGRESS REPORT TO THE SECOND PINE MOUSE SYMPOSIUM ON CONTROL MEASURES BY NEW YORK GROWERS

Steve Clark
Fruit Grower
Milton, NY 12547

In the past year, The Pine Mouse Action Committee of the North Eastern Fruit Council, mounted a successful campaign to secure a state label for endrin. This was a temporary state label for special use in pine vole infested orchards. Warren Smith, Extension Agent, will explain in more detail how this was done and what restrictions were imposed. To most of you, this may not seem like we made much progress, but this is the first time a persistant chemical has been returned to the active list. We feel the endrin will give us the needed vole control in orchards until we can mount a serious research effort for the development of an economical, integrated control program.

The motivation to request a state label for endrin came from two areas:

First, from grower comments at the first symposium in Winchester, VA. Last year, we came to the conclusion that endrin was the only currently available control method in which there was any confidence. New York growers were the only ones who had a serious vole problem and could not use endrin.

Our second motivation came when the snow cover melted in March of last year. Many growers discovered unprecendeted damage levels where alternative control measures had been used. Most growers made tarpaper baiting stations and applied either Rozol or Ramik pellets for control. A few of the worst orchards suffered complete damage to 60% of the trees with an additional 25%-30% of the trees being partially girdled. The continue effacacy of these methods was in serious doubt.

The Pine Mouse Action Committee then requested the Bureau of Pesticides to make a risk-benefit analysis of the situation as a basis for issuing a state label for endrin. An orchard tour was conducted and because of the damage they agreed to hold a public hearing and make a decision for granting state label based on the testimony. After two public hearings, we did receive a strict, temporary state label for endrin use.

The grower response to renewed use of endrin was very enthusiastic. We felt that endrin would be effective because vole populations had not been exposed to it for so many years.

The most common method of application was by air-blast sprayer, although some growers did use pressure sprayers. To make them more effective, most air-blast sprayers were modified with shieldsto direct the air to the ground under the drip line.

Because of the restrictive nature of the label, there were several state inspectors in the field checking applicators to make sure safety procedures were being followed. All applicators were required to wear rubber suits, boots, gloves, and face masks during application. The inspectors did stop a few growers from spraying until the applicator was wearing the protective equipment.

Through Cornell University, The Pine Mouse Action Committee is also submitting a proposal for research funding to the U.S. Department of Interior. We have had support for this proposal from state industry groups, as well as some of our neighboring states in the Northeast who also harbor vole populations.

Several growers are also cooperating with Jay McAninch, a wildlife biologist with the Cary Arboretum. Our aim is to record and evaluate several factors in the orchard pine vole ecosystem to determine which of these factors are significant to high vole populations. We will then try to manipulate the significant factors to discourage reinfestation in the endrin eradicated areas. We will also be evaluating different mowing techniques and some different orchard grass covers.

These growers will also attempt to encourage predator species such as the kestrel hawk and short tailed weasels. Perch sites will be placed in the orchard with nesting boxes attached to encourage these hawks to use the orchard as a home site--hunting area. To induce higher populations of short tailed weasels, we will be building denning sites adjacent to the orchard.

We are optimistic that with adequate funding from U.S.D.I. and selection of talented researchers, we can develop and test theories leading to an integrated control program in 3-5 years.

A GROWER'S VIEW OF VOLE CONTROL METHODS

R. N. Barber - Apple Grower
R. N. Barber Orchards
Waynesville, North Carolina 28786

Barber Orchards has been an operating orchard since 1903. Our number one problem as far as pests are concerned has been the loss of trees due to mice -- pine and meadow vole.

In the 20's, 30's, and 40's, we consistently lost from 300 to 500 trees per year, even though we were putting out and using every known conventional bait station and bait known to the various states growing apples in a commercial way. We used poisoned oats, wheat, chufers, peanuts and apples which we placed in the runs and holes, as well as under one yard squares of tar paper, in glass containers and under sawmill slabs.

In spite of all our actual losses of dead trees, we were using bridge grafts and approach grafts to as many as 2,000 trees per year to help cut our losses. We were using all available labor to do this and often went as late as July doing this. This damage to the root systems lowered our production as much as 20 percent and increased our labor costs by a similar figure or even higher; in addition to the cost of buying new trees to replace trees of all ages, in most cases only 2 to 8 year old trees.

We have written, received and followed the advice of commercial orchardists in every apple growing state. But, our mainstay has been the research of Dr. Frank Horsfall of Virginia, who has practically devoted his lifetime to perfecting the control of mice in orchards.

At the present time, we are following a practice of a winter spray of Endrin, plus a spring and late summer baiting of poison grain. In other words, we are not eliminating field mice, only partly controlling them. We still have damage to the root system of our trees and lose some trees each year. A complete eradication is, we feel, impossible; but any control measure less than that now practiced would in a matter of years destroy our orchards.

North Carolina is now producing over 8 million bushels of apples per year in commercial orchards. It would be impossible for North Carolina to produce this volume without the control of mice. The production of this state has gone up nearly 300 percent since Endrin became available as a control; it could not have been attained otherwise. North Carolina now has trees in the ground and coming into production which will boost production to approximately 10 million bushels. To eliminate the poisoning of mice would spell the death knell of the apple industry in North Carolina and would result in millions of dollars of loss to commercial orchardists. It would also cost so much to produce apples, the public could not buy them.

To argue that poisoning of mice in orchards kills wildlife or is dangerous is unrealistic and unfounded. I live in a house surrounded by apple trees planted as close as 30 feet to my house. I have grown children and grandchildren who play under these trees. This house was built by my Father when I was four years old and I am now 71 and still living in this house. There are 15 other houses in our orchards surrounded by apple trees. As many as 5 generations have been raised in these houses. No child or wildlife has been poisoned.

There are no less than 20 species of birds that build their nests and raise their young in our orchards. These include quail, doves, cardinals, tohees, wrens, juncos, titmice, nuthatches, catbirds, mockingbirds, grackles, blue jays, bluebirds, sparrows, woodpeckers, flickers to mention a few. Squirrels also raise their young within twenty feet of my house and all species of birds frequent my bird feeders during snows or when food is scarce.

According to published statistics, there are now greater numbers of most species of wildlife in the United States than when Columbus discovered America. There are exceptions, of course: the carrier pigeon, the condor, the whooping crane and the buffalo. This, in spite of a well-fed 220 million people and with agricultural exports amounting to 24 billion dollars in 1977.

The facts are, the United States is now the breadbasket of the world due to the scientific use of chemicals, fertilizers and the control of destructive pests. Every American farmer now produces food for about 56 people,many who know nothing of the methods of producing and harvesting food. I read nearly every word of about 14 agricultural publications in order to stay abreast of the latest scientific production.

I believe in the preservation of wildlife and like all farmers and orchard people, I have given liberally to the National Wildlife Federation. In fact, I still have a certificate presented from this organization.

The farm population of the United States and of North Carolina are the greatest protectors of wildlife. They have been isolated by the methods employed by the so-called protectors who produce no food nor fibre and some would expect every farmer's property to be a game preserve for their exploits. The same people who seek to preserve wildlife are the same ones who would destroy it for lack of food. The animals in our forests are dependent on the surplus of food, the healthy forests and grasses which are controlled by people and chemicals.

Pine mice and meadow mice are rodents and pests to all people who produce food. They are pests of far greater magnitude than rats that can be caught in traps and can be poisoned. Any view to the contrary will only be voiced by people who have never produced food or their jobs are dependent on their arbitrary views.

I have many birds and squirrels at my home just to say that I love and protect wildlife as does every farmer and I am one.

At the present, we have no proven substitute for Endrin. If production of food is to be maintained at our present volume and price, Endrin is our only solution until a better means of control is established and proven. We will be only too happy to use any better method of control.

R. N. Barber

R. N. Barber & Company

A GROWER'S EXPERIENCE IN PINE MICE CONTROL - 1973 THROUGH 1977

Philip Glaize
Fred L. Glaize Orchards
304 N. Cameron St., Winchester, VA 22601

By 1973 Endrin in Virginia was proving ineffective. Mice were resistant to Endrin in Most orchards.

Dr. Horsfall had started work with Chlorophacione (C.P.N.) just prior to 1973 and Virginia had cleared it for experimental use.

In November we purchased a considerable amount of the first that was manufactured.

The first C.P.N. that was applied at the recommended rate of .2 lbs. per acre was very effective. The weather was fairly warm and according to our checks we had 90 percent control.

Unfortunately, part of our C.P.N. separated due to a bad formulation and we could not complete the job.

In 1974, with new material we again sprayed, however, the weather was colder and I believe the mice were feeding further underground because our control was only 60%.

In 1975 we decided to disc and hand bait using zinc phosphide with mixed results.

In 1976 I decided to try Endrin again after a layoff of 4 or 5 years. This turned out to be disastrous. We wasted a lot of money, got no control, and had to spend the winter with a crew of women hand baiting with Rozol. The hand baiting, where done thoroughly, proved very effective.

In 1977 we tried spraying again with Chlorophacione in November. The weather was bad with a lot of rain. This could have been part of the reason for our lack of control and only 65% effectiveness.

We have been putting our shingles, one between each tree or every other tree and they have proven a very effective place to hand bait whereever we have runs. It is necessary to move some to spots where we can find fresh runs.

Whether a grower sprays, discs, or uses hand bait it is very important to keep check stations and have a reliable person run checks with sliced apples and bait continuously.

At one time I thought C.P.N. was the answer, now it seems we are still a long way from finding a satisfactory and economical solution to pine mice control.

There has been some discussion about the use of various root stocks as mice seem to have a preference for certain varieties. This should be researched.

THE HUDSON VALLEY'S EXPERIENCE SECURING ENDRIN FOR USE IN 1977

Warren H. Smith
Cooperative Extension Agent
Fruit Industry
Hudson Valley Laboratory
Highland, NY 12528

The year 1977 was eventful for Hudson Valley fruit growers who are troubled by pine voles. In March when the snows melted it was clearly evident that serious vole damage to area orchards had taken place and immediate action was necessary to eradicate this menace. Cooperative Extension played a major leadership role organizing grower committee activities, and the North Eastern Fruit Council, a newly formed grower group, represented the industry during these activities. Steve Clark, a Milton, New York fruit grower, was chosen as chairman of the North Eastern Fruit Council grower action committee.

Our first move was to alert the New York State Department of Agriculture and Markets (NYSDAM) and the Department of Environmental Conservation (DEC) of the seriousness of the situation and explain to them what our needs were. Because of the seriousness of the problem and the need for immediate control in the fall, securing Endrin for use was our primary goal. At the same time we were also interested in stimulating a more vigorous research program than what was presently being funded.

Mr. Burel Lane, Director of Plant Industries with the NYSDAM, became a good friend and assisted us as we prepared our case. Numerous preparatory meetings were held and considerable homework done. Finally a tour of damaged orchards and to our surprise an E.P.A. RPAR hearing was scheduled. The tour was arranged to compliment the impact of the hearing. One interesting side-light concerning the involvement of the E.P.A. is that we were petitioning the DEC to remove Endrin from its restricted useage list and were surprised to learn of E.P.A.'s interest in our problem when Endrin is federally labelled. We learned of E.P.A.'s involvement only a few days before the hearing was to be held and frantically began alerting others in neighboring states who we thought were interested in the future of Endrin. This hearing, we were told, was to be one of only two hearings that E.P.A. planned to hold as part of their RPAR investigation of Endrin; in other words, the future of Endrin label was at stake. The response was tremendous and people as far away as North Carolina testified. Many of these people are here today.

Our New York presentation at the hearing was designed to emphasize the damage and economic impact done by the pine voles. We were fortunate to have on our team several experts who were able to access this impact.

Mrs. Karen Pearson who spoke last year at this Symposium on her Master Thesis, "Some Economic Aspects of Pine Vole Damage in Apple Orchards of New York State", was asked to up-date her survey work done for her thesis and also to do a detailed survey of several orchards that were severely damaged last winter. This information was presented at the hearing. Also, Mr. Ralph Lawrence, Regional Extension Specialist in Fruit Farm Management and Marketing for Eastern New York, was asked to take Mrs. Pearson's survey results and develop a hearing presentation that would look at the economic impact of the pine vole to those orchards that were damaged. I would like to quote a paragraph from Mr. Lawrence's testimony. This excerpt will give you an idea of the type of economic information Mr. Lawrence was able to present to E.P.A. I believe this type of information was very meaningful and impacted greatly on their investigation.

> "Block I on Farm A in Dutchess County is a 15 year old Tydeman's Red block. The orchard run price received for the apples from this block in 1976 was $5.40 per bushel. The computation done here assumes an average price of $4.00 per bushel. This block currently shows 59% of the trees 100% girdled. This reduces the yield from 517 bushels per acre to 212 bushels per acre, and results in an annual loss of income of $946 per acre after deducting growing and harvesting expenses. Over a ten year period the net present value of that permanent loss is $6,348 per acre. In spite of the fact that without pine vole damage this orchard and the following orchards would be a viable economic units for more than 10 more years, I have limited the analysis to 10 years, assuming that a replacement orchard could be approaching full production by then.
>
> Block II on Farm A is an 18 year old Red Delicious block. Using an average orchard run price of $3.50 per bushel rather than the $5.00 actually received this year, the annual net loss is $1,128 per acre. The net present value of this loss over a ten year period is $7,569 per acre."

The orchard tour that proceeded the Endrin hearing was very important to our plan of attack. We felt that we had to show to what extent pine vole can damage and were damaging our orchards. Seeing is believing was never more true than that day in those many orchards we visited with freshly girdled trees. We even went so far as to remove trees so that girdled trunks and roots could be more closely examined. One of these tree stumps was presented as evidence at the following day's hearing. My feeling is that this orchard tour did our case as much good as the presentation made at the hearing. We had small buses for transportation and enough growers on the tour so that no visitors were left "unattended".

The DEC representatives were present on the tour and at the E.P.A. hearing, however, they were not able to accept the E.P.A. hearing as official for State purposes, therefore, the State set-up its own hearing for early August. This was an abbreviated hearing and merely a formality to satisfy State requirements.

Our homework had been done and presented at both Federal and State hearings and it was now a matter of waiting for a decision from the DEC. E.P.A.'s decision was hoped for before the State had to make its own independent decision, but as the hour got close all E.P.A. was saying was that it was continuing to review the data. Word from E.P.A. was that their review of the hearing data was favorable. The State waited until the zero hour, but finally made a decision in favor of the fruit industry. The announcement read and I quote,

> "Thursday, September 22, 1977
>
> Commissioner of Environmental Conservation Peter A. Berle today announced that he has approved a highly restricted, one-time use of Endrin this fall as a 'stopgap measure' to combat pine voles, a major threat to the $18 million apple industry in the lower Hudson Valley.
>
> Commissioner Berle set the following restrictions upon the use of Endrin:
>
> --Use is being permitted only for the fall of 1977.
> --Use only in orchards with obvious pine vole damage and not as a preventative.
> --Applicants must attend an approved training session on the use of Endrin before applying for a permit, pass a written examination and be certified as competent to use restricted pesticides.
> --Endrin be applied only after the area to be treated has been harvested, including the collection of drops."

This was a very difficult and courageous decision for Commissioner Berle to make. One particular incident made it even more difficult since the department was threatened by a suit from the State's Audubon Society if it allowed the use of Endrin. But, other than this threat, and thats all it turned out to be, there was no other public outcry against the one time use of Endrin under these restricted conditions. One or two local papers including the New York Times carried challenging articles, but no serious consequences were felt. Even at the hearings little was heard from Environmental and Save The Earth Groups. One or two groups were present at the hearings and they did express concern about the use of Endrin, but they were sympathetic about the vole problem and agreed something had to be done. Endrin seemed to be the only stopgap measure that would work to solve the immediate problem.

These groups including the Ulster County Federated Sportman's Club, plus Commissioner Berle in his Endrin Release Statement have all said that the real solution to the vole problem lies not with Endrin, but with research to find a long term environmentally safe control program. Hopefully this symposium today will help stimulate greater funding, so we can get on with this needed research.

The DEC in an effort to increase the knowledge base concerning the environmental impact of such pesticides as Endrin, undertook an ambitious monitoring program. Samples before, after, and at future dates of treatment were taken and will be taken of water, soil, soil organisms, orchard plant life, fish, and wildlife. To date, results of this monitoring program are not available. Apparently, there has been a delay with the analytical work, but once this monitoring program report is published it should provide extremely interesting information and have a far reaching impact on our future thinking.

Throughout this presentation, I have indicated that we in New York, like you, are very interested in encouraging more research. In New York the College of Agriculture and Life Sciences has agreed to support a full-time wildlife control technician to be located at the Hudson Valley Lab. We are also hopeful that a full-time wildlife biologist can be hired to also work at the Lab. Funding for the biologist position is still in question. Possibly federal funds, USDA or USDI, can be secured to aid in support of this position. This is what we in New York are working towards. At any rate, we are aggressively moving forward with respect to more research work, and we have the support of Cornell, the Geneva Experiment Station, the NYSDAM, and DEC. We are optimistic that this Symposium will add support to our efforts and that next year we can introduce two new pine vole research people from New York to the Symposium group here today.

Matters of Concern in Rodent Control in Pennsylvania Orchards

C. M. Ritter
The Pennsylvania State University

Rodent control -- both meadow and pine -- has been and continues to be a matter of major concern in all Pennsylvania orchards. Insect and disease problems are vexing but largely seasonal and comparatively easy to correct. Rodent damage, at best, is a dibilitating factor in tree growth and fruit production. At worst, it is terminal so far as tree life is concerned.

As matter of record, Pennsylvania's extension orchard specialists have stressed mouse (vole) control in our printed recommendations for over 40 years. The problem has been present in orchards for as long as the orchards have existed. However, it seems that it did not reach really serious economic levels until the time that the practice of pasturing livestock -- horses, cattle, hogs -- was discontinued.

At present, Pennsylvania's pomology extension recommendations for mouse (vole) control are two-pronged. We stress both the physical and chemical methods to be used to gain some degree of control.

The recommended practices are listed below:

Sod Control: Discing, or the use of herbicides, to keep a 4 to 5 foot band of bare ground on each side of the tree row and periodic mowing, sufficient to keep the sod at a 3 to 6 inch height, is emphasized. Since the mice are rather timid animals, it appears that they do not find a short-sod habitat inviting.

Crown-Trunk Protection: At the time of planting, we recommend that one to two bushels of crushed limestone (quarry fill grade is excellent) be placed around the trunk of the new tree. The rock is placed so that it forms a mound 4 to 6 inches high around the trunk. We recommend also that a hardware clothe guard be placed around the trunk. We believe the hardware clothe to be superior to the spiral plastic guard. The wire guard is constructed from a piece 15 by 18 inches formed into a circle with the 18-inch dimension as the length of the tube.

Rodenticide materials and baits: Pennsylvania's pomology extension recommendations currently include the use of zinc phosphide baits (0.92-2.0%), chlorophacinone (both dry baits and liquid forms), and diphacinone baits. We also include specific information concerning safe, proper use of endrine for orchard mouse control.

We have tried not to depend entirely on one system to control the vole situation. Rather we believe that the physical control measures -- crushed rock, mowing and wire trunk guards -- should be the primary control measures and that the chemical baits and sprays should be considered as materials to be used in handling crisis situations.

In any event, we do believe that the chemical control measures must be continued in federal registration to provide the fruit grower with a sufficient array of control measures to control the meadow and pine mouse (vole) problems.

THE MEADOW, PRAIRIE, AND PINE VOLE PROBLEM IN OHIO

Charles L. McGriff
District Field Assistant
U. S. Fish and Wildlife Service
Animal Damage Control
Columbus, Ohio

Fruit growers, nurserymen, and Christmas tree growers in Ohio suffer economic loss each year if tree-girdling mice are present and not controlled. Unfortunately, in Ohio as elsewhere we have no practical method for arriving at the total value of loss from mouse damage. The grower's reports of losses are merely estimates.

Populations of meadow, prairie, and pine voles are present in Ohio, with pine voles most common in the Southern part. It is essential that the grower identify the species present, because control methods differ, and the same materials are not equally effective for all species.

The control material most widely used in Ohio has been, and still is, zinc phosphide. In the late 1950's and early 1960's experiments with endrin were conducted. This chemical never has been widely accepted, because of grower reports of fish kills in their ponds, and the death of rabbits and quail. The U. S. Fish and Wildlife Service has never recommended endrin for mouse control. Zinc phosphide apple cubes and grain baits are recommended for control of all three species of tree-girdling mice in Ohio.

It has been our experience that meadow and prairie mice are easier to control than pine mice. Zinc phosphide-treated apple cubes and grain baits have given good control when broadcast for meadow and prairie mice, but grain baits are a must for pine mouse control. For pine mice, the grain bait should be applied by hand trail baiting or by a trail builder machine, not broadcast. Hand trail baiting is an expensive, time consuming job, and needs to be done by dependable and well-trained personnel. The trail builder machine is fast and makes a nice burrow when soil moisture conditions are correct, but has never been a popular tool in the hilly terrain of Southern Ohio because soil moisture often is deficient in the fall when baiting normally is done.

Since the early 1970's cultural practices have become a part of our mouse control recommendations. Control of ground vegetation by mowing between the trees and the destruction of vegetation in a three or four foot radius around the tree trunk with chemical weed killers have discouraged mice from using this area. Tree guards are helpful in reducing summer and early fall damage. Cultural practices have definite limitations, especially when prairie and pine voles are present. The destruction of surface cover may have little or no effect on their underground activities.

Growers in Ohio feel zinc phosphide baits are not the complete answer to mouse control, even though these have been the universal baits for the past twenty years. They have been effective in meadow mouse control, but for prairie and pine mice do not meet grower expectations. We need a control tool that is environmentally safe, easy to apply, economical to use, and will do a good job on all three species. We need a method for accurately determining damage to orchards, nurseries, and Christmas tree plantings. Above all, we need to develop an educational program that will reach more growers.

THE PINE VOLE - MONITORING & RESEARCH EFFORTS

by

Burel H. Lane, Director
Division of Plant Industry
New York State Department of Agriculture & Markets
Albany, New York 12235

The fruit industry is an important segment of New York's agricultural economy generating over 100 million dollars of farm income annually. Of the 66,740 acres of apples in the state, four counties of the lower Hudson River Valley incorporate 20,680 acres or approximately 30% of New York's apple acreage.

This viable fruit area is now in jeopardy due to severe tree damage by the meadow mouse, *Microtus pennsylvanicus*, and pine vole, *Pitymys pinetorium*. These rodents have caused very serious economic loss to many growers in this important fruit area of our state. During the last six years, pine voles have spread from a relatively few farms to over 4,000 acres of infestation, thereby threatening a fruit industry in the area averaging an annual farm cash income in excess of $18,000,000.

Prior to 1971, growers could use Endrin as well as other pesticides for the control of rodent populations in the orchards. There was little reported economic damage up to that time. On January 1, 1971, the New York State Department of Environmental Conservation issued an order totally prohibiting the use of Endrin in the state. As a result, growers had no effective rodenticides as Zinc Phosphide treated corn and bait did not control pine vole populations. The anticoagulant rodenticide, Chlorophacinon, was tried in both a spray and bait form. In 1975 and 1976 another anticoagulant, Diphacinon, was also used in control efforts. During both seasons the control obtained was very erratic.

On August 11, 1977, the New York State Department of Environmental Conservation held an informational hearing to solicit comments and information relevant to the risks and benefits associated with the use of Endrin in orchards for pine vole control. After reviewing the hearing record, Commissioner Peter Berle, on September 22, 1977, announced that he had approved a highly restricted, one time use of Endrin as a "stopgap measure" to combat pine voles in the lower Hudson River Valley.

Commissioner Berle set the following restrictions upon use of Endrin:

- Use is permitted only for the fall of 1977.
- Use only in orchards with obvious pine vole damage and not as a preventive.
- Applicant must attend an approved training session on the use of Endrin before applying for a permit, pass a written examination and be certified as competent to use restricted pesticides.
- Endrin be applied only after the area to be treated has been harvested, including the collection of drops.

Consideration of the requested use of Endrin in New York was a classic example in which potential risks to non-target organisms and the environment must be carefully balanced against benefits obtained in reducing severe economic losses to an important industry. Local, state and national environmental groups expressed their opposition to the proposal to again permit use of the material.

Commissioner Berle, in announcing his decision, stated that any subsequent use of Endrin would be approved only after careful review of the control program with regard to Endrin's efficacy, its effects on non-target organisms and the environment in general. In other words, a monitoring program must be implemented to obtain this essential information on which to base any decision for future use of Endrin in New York. At the same time he indicated that it was absolutely essential that the College of Agriculture and Life Sciences at Cornell, the New York State Department of Agriculture and Markets, the United States Department of Agriculture, and/or the United States Department of Interior cooperate to develop a comprehensive research effort which would result in a long-term control program more effective and more acceptable than the use of Endrin.

In an effort to support Commissioner Berle and comply with his request, our Department, in cooperation with the Department of Environmental Conservation, has implemented a monitoring program in the fruit area where Endrin was applied. The objectives are:

- to determine effectiveness of the Endrin application on pine vole control.
- to determine effects of Endrin usage on non-target organisms within and surrounding the area.

- to determine changes in Endrin residue levels in organisms within and bordering the Endrin treatment area.

- to determine the time and extent of movement of Endrin from the application site.

- to determine changes in water quality related to Endrin usage.

Samples of soil, water and appropriate species of wildlife, fish and aquatic organisms from and adjacent to the treated orchards will be collected and analyzed for residue levels. Collection periods will include pre-treatment, post-treatment, post-snow melt and one year post-treatment. Our Department has made a commitment with a projected 257 man-days of expense allocated to monitoring and field sample collection. An estimated 500 to 600 samples will be analyzed in our laboratory for residue levels. The combined cost for field monitoring and laboratory analysis will be in excess of $59,000. Data accumulated from this effort is considered vital in adequately evaluating any continued use of Endrin in pine vole control in our state. This data will also be available and utilized in the expanded research effort by the College of Agriculture and Life Sciences at Cornell.

On our part, we are also aware of the potential toxicity and residual life of Endrin. We agree that use of the material should not be permitted any longer than absolutely necessary. The only real solution lies in research to develop biological or cultural control methods and alternate environmentally acceptable pesticides - an integrated pest management program. The College of Agriculture and Life Sciences at Cornell has recently increased funds available for expanded research on pine vole control in the Hudson Valley fruit area. However, this effort alone is not adequate to find a satisfactory solution to the problems.

We assume that fruit areas in other states are experiencing similar tree damage from the orchard mouse and pine vole. Undoubtedly research efforts are also occurring in other states with the basic objective of finding a safe, effective, selective, economical, and environmentally acceptable rodent control technique. While having a unity of purpose, at best such efforts by individual states currently lack proper coordination and direction of research effort.

On September 28, 1977, the prestigious National Association of State Departments of Agriculture adopted a resolution requesting research funding to develop new pest control materials and/or cultural methods to reduce pine vole damage in orchards. A copy of the resolution is attached. It requests the United States Department of Interior, Bureau of Fish and Wildlife Services, to assign high priority to a request for research funding. This agency has the responsibility for wildlife resources. It has the capability to conduct and coordinate a broadly based research program for orchard rodent control. It could conduct in-house research and contract for complementary research with State Universities and research organizations.

A research field station in the northeast, in an area where there are severe pine vole problems, is absolutely essential. To date, research efforts have been very limited and fragmented with little evident progress in a solution to the problem. Currently in New York there is an annual increase in damage to orchard fruit trees with no effective environmentally acceptable, pine vole control materials or methods. Undoubtedly, orchards in other eastern states are experiencing similar losses. We request that the Department of Interior recognize this severe orchard problem and immediately initiate an emergency research program to alleviate damage to fruit crops by meadow mice and pine voles.

February 22, 1978

NATIONAL ASSOCIATION OF STATE DEPARTMENTS OF AGRICULTURE

Policy No. PI-12

PINE VOLE DAMAGE IN ORCHARDS

The pine mouse or pine vole, Pitmys pinetorum, a recognized serious pest of fruit trees, is present in increasing population in orchards of the eastern United States. This rodent causes severe economic loss to the grower through girdling of roots and trees with resulting loss of vigor, productivity and eventual death of both young and mature trees. There is currently no registered environmentally acceptable pesticide material which effectively reduces orchard pine vole populations.

RESOLVED, that the National Association of State Departments of Agriculture in convention in Bedford, New Hampshire, September 28, 1977, requests the United States Department of Interior, Fish and Wildlife Services, to assign high priority to a request for research funding todiscover and develop new pest control materials and/or cultural methods to reduce pine vole damage to trees in fruit orchards.

PRELIMINARY BENEFIT ANALYSIS OF ENDRIN USE ON APPLE ORCHARDS

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This article summarizes the Preliminary Benefit Analysis of Endrin Use on Apple Orchards of September, 1977. The analysis was prepared to be an input to the risk/benefit decision by the Administrator of EPA as to the continued registration of endrin under FIFRA, as amended. A notice of rebuttable presumption against registration (RPAR) of endrin was issued in the Federal Register on July 27, 1976. If the data on human health and or environmental risks cited in the RPAR are not rebutted and risks outweigh benefits, the Administrator may announce intent to cancel the apple orchard registrations of endrin. This report analyzes the benefits obtained from the use of endrin on apple orchards, as mandated by FIFRA.

Background and Analysis Methodology

Endrin is applied as a postharvest ground spray to control pine and meadow voles in many areas of the East and Northwest. Current endrin use on apple orchards is estimated at about 84,000 pounds active ingredient per year applied to about 58,100 acres (11.2% of total domestic apple acreage). In the nine states in which endrin is extensively used for vole control (Georgia, South Carolina, North Carolina, Virginia, West Virginia, Maryland, Pennsylvania, Washington, Idaho), the acreage treated with endrin represents 26.5% of total acres in commercial apple production.

Pine and meadow voles are considered to be the most important threat to establishing and maintaining economic levels of apple production in both the Eastern and Western apple-producing areas of the U.S. Projections of economic losses incurred by orchardists due to tree loss and/or reduced fruit yield and quality resulting from vole damage are difficult to quantify, for two main reasons: 1) damage rates vary from year to year depending upon natural and induced changes in vole populations, weather patterns, etc., and 2) it is difficult to attribute tree mortality and production losses solely to vole damage in many instances, since factors such as winter damage, drought, insects, diseases, and mechanical injury must also be considered.

Forecasts of future orchard damage by voles would require accurate information on natural changes in populations, effectiveness of alternative control techniques, susceptability of orchards by location, likelihood of adoption of alternative control techniques by growers, and other factors which influence the severity and extent of tree injury by voles. In the absence of such information, estimates of orchard damage under alternative systems must be based on the expert opinions of horticulturists and others knowledgeable in the area of orchard vole damage and control. In 1974, Byers estimated the impact of pine vole damage upon apple production in the East and Midwest at $40,000,000 annually (Byers, 1974).

A recent survey of apple experts conducted by the U.S.Department of

Agriculture found that, in the Eastern states, a 10% annual rate of loss in production is anticipated if endrin is unavailable for vole control. In the Western apple states a 5% loss in production was projected under the same circumstances.[1/] The survey did not provide information based on the effectiveness of chlorophacinone (CPN) or diphacinone (DPN) relative to endrin and the sole Federally registered alternative, zinc phosphide. This analysis provides estimates of the impact of the potential cancellation of endrin for use on apple orchards under two settings: 1) that growers utilize only zinc phosphide with a resulting 6.66% annual weighted average loss in apple production, and 2) that growers utilize CPN or DPN in conjunction with herbicides and/or intensive cultural practices and achieve control leading to losses equivalent to 50% of those incurred under a zinc phosphide program (3.33% annual weighted average loss in production). Although quantitative evidence does not exist which supports either assumption, a significant number of field trials have been performed using CPN and DPN which support the assumption that the efficacy of these materials exceeds that of zinc phosphide and approaches that of endrin when conscientiously applied (Byers, 1975,1975a; Byers and Young, 1975; Byers, Young, and Neely, 1976). Inherent to this methodology is the assumption that endrin is the most effective material in the orchards where it is now used.

The analysis uses a composite acre approach to assess the impact of the cancellation of endrin upon the value of fresh and process apple production on the affected acreage. Per acre production values decline in successive years based on the projected losses for the two alternative control programs. A weighted average nonharvest production cost of $1,079 per acre was developed based on data provided by economists in Eastern and Western states. Harvest costs were assumed to approximate 11% of the per acre value of production.

Since the impacts incurred by endrin users will include both losses in value of production and higher expenditures for alternative control measures, per acre production costs were adjusted to include the additional costs of control using either the zinc phosphide or CPN-DPN-cultural measures programs.

Summary of Findings

The results of the economic impact analysis resulting from the potential cancellation of endrin for use on apple orchards indicates that endrin users who adopt a zinc phosphide control program would incur total reductions in value of fresh apple production equal to $19,479,000 during the initial three year period after cancellation of endrin. Process apple reductions are estimated at $1,960,000 during the same period. The value of fresh apple production on the average affected acre would decrease by $382 per year (15.3%) during the three year period. The value of process apple production on a typical acre treated with zinc phosphide would decline by about $76 per year (7.4%) at the end of the initial three year period following cancellation of endrin.

Growers (former endrin users) who adopt a CPN-DPN-herbicides-cultural methods program are expected to incur value reductions in fresh and process apple production after the first three years following cancellation of $9,777,000 and $879,000, respectively. This type of program would

1/ These projections represent losses over and above that rate of tree loss (up to 3% per year) usually anticipated by the grower due to all causes-i.e., voles, insects, diseases, winter damage, drought, mechanical injury, etc.

lead to a reduction in value of production at the user level of $193 per year (7.7%) on an affected acre producing fresh apples after three years. A typical acre producing process apples in affected areas would have a loss in value of production equivalent to $34 per year (3.3%) at the end of three years.

Under a zinc phosphide control program, current endrin users would incur losses in net returns equal to $19,110,000 after three years, while non-users of endrin would experience increased net returns of $51,323,000 after three years due to higher apple prices caused by the losses in the endrin use areas. Under a CPN-DPN-herbicides-cultural methods program, the aggregate impacts upon users and non-users of endrin would be approximately one-half the magnitude projected under a zinc phosphide program. Current endrin users adopting CPN, DPN, herbicides, and increased cultural control methods would experience a loss in net returns of $9,479,000 over the initial three year period. Non-users of endrin would receive an aggregate increase in net revenues of $25,773,000 over the same period, again as a result of higher apple prices caused by losses in the endrin use areas.

The impacts projected in this analysis are subject to several important limitations. Both alternative programs assume the availability of adequate labor to properly bait orchards. This assumption is subject to question and must be carefully scrutinized when dealing with assessing the feasibility of endrin alternatives. It was also assumed that apple production would remain constant in the non-endrin use areas for the period analyzed. However, higher market prices caused by losses in endrin use areas would probably stimulate intensive production practices and increased planting in non-use areas. Although the production effects of new plantings would not be felt for several years, intensified production practices would likely result in rather immediate impacts. However, the extent of such effects cannot be predetermined with reliability.

Another limitation concerns the effect of output reductions upon market prices and revenues. The revenue and net return streams developed in the analysis are based on the assumption that the price elasticities of demand for fresh and process apples used in the analysis are representative for the first three year period after cancellation. It is likely that the production reductions projected to occur if endrin is cancelled would change the price elasticities of demand for apples, thereby leading to corresponding changes in revenues. Expected changes in price elasticities of demand suggest that both the losses in user revenues and gains in non-user revenues would decline over time. Unfortunately, data is not available to evaluate the elasticity responses of the various apple categories to supply reductions, which could then be used to project future revenue streams. For this reason, the analysis is limited to a short, three-year time horizon. For these and other reasons, projections of economic impacts to periods beyond the years evaluated in this analysis would be inappropriate.

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SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
ENDRIN USE ON APPLE ORCHARDS

A. USE: Endrin use as postharvest spray on apple orchards.

B. MAJOR PESTS CONTROLLED: Pine voles, meadow voles.

C. ALTERNATIVES:

Major registered chemicals:

RPAR: none
Non-RPAR: Federal registrations: zinc phosphide
State registrations: chlorophacinone (CPN), diphacinone (DPN)

State/Federal recommendations:

Number of apple states (out of 20) recommending: endrin-6; zinc phosphide-13; CPN-2; DPN-3; strychnine-2; herbicides-6; trunk guards-5; mowing/cultivation-11.

Non-chemical controls:

Cultural practices (mowing, cultivation, trunk guards) and non-rodenticide chemicals (herbicides) are used to destroy the food sources and habitat of voles and to directly protect the trees.

Efficacy of alternatives:

In areas where endrin is still used (probably due to lack of development of resistant vole populations) it is the most effective material available.

Comparative performance:

According to state contacts, use of zinc phosphide on acreage now treated with endrin will lead to a 6.66% weighted average loss in production per year on the affected acreage. An analysis was also completed under the assumption that the use of CPN, DPN, herbicides and cultural practices would result in 50% of the losses in production expected under a zinc phosphide program (3.33% annual weighted loss).

Comparative costs:

Control measure	treatment cost/acre
endrin 1.6 EC ground spray	$16.40
CPN 0.4 conc. ground spray	37.40
CPN 0.005% pellets	17.45
DPN 0.005% pellets	16.95
Zn_2P_3 corn-oat bait	14.55
cultivation + herbicide (paraquat)	35.84
cultivation	26.84
herbicide (paraquat)	15.65
herbicides (simazine + paraquat)	24.40

Seasonal control programs generally include two or more of the methods listed. Trapping and trunk guards are also used. Current endrin users face a maximum seasonal control cost increase of $93 per acre (an 8.6% increase in per acre nonharvest production costs). The average Zn_2P_3 and average CPN-DPN-herbicides-cultural methods programs would increase per acre seasonal control costs (relative to the average cost of endrin control programs) by $18 (1.67% of nonharvest production costs) and $21 (1.95% of nonharvest production costs), respectively.

Conclusion:

Loss of endrin for orchard vole control will increase production costs and reduce apple production on the acreage currently treated with endrin. Available alternatives do not provide adequate control in areas subject to consistently high levels of infestation and damage.

D. EXTENT OF USE:

Active ingredient applied and acres treated:

State	Acres treated/year	Pounds a.i. applied/year
Georgia	500	1,200
South Carolina	900	2,200
North Carolina	5,000	12,000
Virginia	4,000	9,600
West Virginia	5,500	13,200
Maryland	900	2,200
Pennsylvania	10,400	25,000
Washington	30,200	18,100
Idaho	700	400
Total	58,100	84,000

E. ECONOMIC IMPACTS: Analysis limited to initial three years following an endrin cancellation.

User:

		Estimated Change in Net Returns per acre	total
Assuming current endrin users adopt Zn_2P_3 programs:	User	-$246	-$19,110,000
	Non-user	+$113	+$51,323,000
Assuming current endrin users adopt CPN-DPN-herbicides-cultural methods programs:	User	-$123	-$ 9,479,000
	Non-user	+$ 57	+$25,773,000

Market:

		Estimated Change in Value of U.S. Production farm level	retail level
Assuming current endrin users adopt Zn_2P_3 programs:	Fresh apples	+$ 4,965,000	-$7,815,000
	Process apples	+$12,868,000	----
Assuming current endrin users adopt CPN-DPN-herbicides-cultural methods programs:	Fresh apples	+$ 1,575,000	-$3,962,000
	Process apples	+$ 6,555,000	----

F. SOCIAL/COMMUNITY IMPACTS: Not investigated in depth. However, loss in grower income and reduced marketings in affected areas likely to have an adverse effect on economy in localized areas.

G. LIMITATIONS OF ANALYSIS:

1. Apple production assumed to remain constant in non-endrin use areas.
2. To minimize effects of diverse orchard situations and management practices, a composite acre approach was used.
3. No quantitatively-based estimates of loss under the alternative programs were available. The crop loss estimate under the Zn_2P_3 program provided state personnel. Losses under the CPN-DPN-herbicides-cultural methods programs represent an assumption by the analyst based on limited field test data.
4. Long-term grower and industry economic impacts could not be developed due to a lack of supply-price response data. Analysis limited to three years following cancellation.
5. No data available to quantify effects of endrin withdrawal upon fruit grades in affected and unaffected areas.

H. PRINCIPAL ANALYST AND DATE:

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Office of Pesticide Programs
U.S. Environmental Protection Agency
September 1977

RESEARCH FUNDING

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The purpose of this paper is to review the past trends in funding agricultural research and focus on the current situation and offer suggestions for ways that we might help ourselves in the funding crisis that seemingly gets worse each year.

All of you are well aware that there has been a shift from a rural-farm orientation to an urban orientation and that particularly since 1950 there has been a shift of public concern and support away from agriculture to other societal problems. Perhaps the successes achieved by the land grant colleges, experiment stations and the United States Department of Agriculture have been our undoing. The high productivity per man hour in agriculture as compared to other industries and the low cost and bountiful supply of high quality food is taken for granted by the majority of our society. This attitude is particularly damaging to research funding at a time when there is a plethora of well-intentioned programs competing for appropriated dollars during this period of inflation when the purchasing power of the dollars that we do have decreases every year.

Actually total federal and non-federal funds for agricultural research has increased at an average annual rate of 8.7 percent since 1955. In addition to rising inflation affecting our costs of supplies and equipment we have faced spiraling costs in salaries, matching funds for fringe benefits and now drastic increases in the Social Security tax. Earmarking funds for research on certain commodities has reduced the administrators flexibility in shifting funds to meet changing priorities.

The other side of the coin, however, which has led to our discouragement as scientists and administrators in agricultural research is the rapid increases in support for other areas of science accompanied by a drastic decline in the proportion of the total research funds going into agriculture. It is not that we object to the development of other areas of scientific endeavor but that at this time of diminishing values of the dollar we have a real need to share in this several fold increase. Our present feelings are that we are excluded from meaningful increases. The Executive budget recently submitted to Congress demonstrates the point. Even at a time when it appears that food will be in short supply world wide and that foreign sales of agricultural commodities are one of the main means of easing the balance of payments situation we still cannot generate enthusiasm for agriculture research.

Where have we failed and what alternatives do we have? It is obvious that agricultural research scientists and agriculture producers have been about their main business to the exclusion and even disdain of engaging in public relations and being active in the political process. We simply must influence the thinking and attitudes of the general public. We have not gotten the point across that research for the continued high production of food crops at economical prices under changing conditions must be a continuous process. Our spokesmen have been active on our behalf for several years but it should be a concern of each of us. Seek opportunities to present your message to local civic groups. Do not overlook youth groups as they are tomorrow's voters. Even members of our commodity groups should be reminded of the need for research. They need urging to express their concerns to the congressional representatives. You researchers have done an excellent job in calling attention to the special problems in pine vole control and the extensive destruction of which the rodent is capable. The apple eating public in general is ignorant of this as well as other production problems. Thus educating and influencing the attitudes of the general public still remains. To summarize this section - get involved and involve your growers in education and the political process at all levels.

On the generation of funds let us take a look at project preparation. At the working scientists' level it is understandable that much attention is given to stating objectives clearly and giving details of the methodology to be employed including statistical analysis of the data. Not enough emphasis is given to the benefits to be derived from the research or any discussion of the possible cost/benefit ratio that could be expected. The rate of return from current and additional investments in production agriculture research for apples is estimated to be 36 percent whereas the overall average rate in the economy of the United States is 15 percent. The returns from research expressed as dollars wherever possible are particularly appropriate in the progress report on the CRIS forms. These figures are combined and perhaps may influence OMB in their considerations.

It may be time to spend more effort with state legislators to increase research funds for agriculture. A few states have had some success recently in spite of the tremendous competition for tax dollars. Enlist the aid of urban representatives. Most reasonable people will respond favorably to a well-presented, factual and logical proposal that involves food commodities, a daily necessity. We are going to need the support of the urban group for any gains in research funding for the future. In project proposals and progress reports ultimate benefits to the consumers must be prominently defined.

Another source of funding, which at VPI & SU is of great importance since nearly one-third of the College of Agriculture and Life Sciences' operating budget is generated from this source, are grants. Many of you have learned that you must expect many rejections for each success and that you must keep submitting proposals. A grant to be truly beneficial must supplement your ongoing research program. An effort to identify and talk to the grants program administrator will be time well spent. Formulate critical questions in advance, be tenacious and obtain your answers but remember these are very busy people. Enlarge your vision in your grantsmanship effort. Develop cooperative proposals whenever possible as it should strengthen the proposal for all concerned. Again let me remind you to keep the ultimate consumer goal in mind and the dollar benefit of the research in relation to its cost.

In summary we seem to be in a crisis in funding agriculture research. We seem to be dealing with a public who takes their "food and fiber" blessings for granted. We have made some progress in Congress, e.g., the National Agriculture Research, Extension and Teaching Policy Act of 1977, which emphasizes research needs. We must maintain our integrity and organization, keep active in the political processes and when events occur that shift the tides even the least bit in our favor we will be ready to act as a group and achieve a better response for our requests for increased research funding.

RESEARCH NEEDS: PINE VOLE DEPREDATIONS

G. K. LaVoie and H. P. Tietjen

Pine voles {Pitymys pinetorum (Audubon and Bachman), or Microtus pinetorum (LeConte)} are pests of significant economic importance to orchardists in several eastern and northeastern states. The purpose of this report is to selectively review the status of pine vole research from the control, biological, ecological, and behavioral aspects, and to recommend the research needed to develop effective, economical, and safe programs for controlling this problem.

THE PINE VOLE PROBLEM

Pine voles are causing an estimated annual $50 million loss in apple production in eastern and northeastern U.S. These animals are considered by many orchardists to be the most serious animal pest in orchards. No other pest-caused agricultural problem is driving orchardists out of business. On several farms in New York State, more than 75 percent of the trees have been killed by pine voles.

Direct loss in New York alone is estimated at $12 million annually. McCue (1977) estimated the reduction in apple production in Virginia for the period 1973-75 at $11 million annually. These estimates probably are conservative. Apple growers, extension specialists, researchers, and industry organizations have described significant losses of apple trees and reduced vigor in damaged trees throughout the range of the pine vole (Pearson 1977, Smith 1977, Kolbe 1977, McCue 1977, Clark 1977, Butler 1977, Showalter 1977, Lowe 1977, Barber 1977, Ferguson 1977).

Damage to food crops by pine voles was noted over 100 years ago by Kennicott (1857). Hamilton (1935) estimated that orchard mice (Microtus spp.) caused a $500,000 annual loss to fruit trees in New York, and he reported a similar figure for Connecticut. Garlough (1944) described an orchard near Charleston, West Virginia, in which one thousand 18-year-old trees were killed by pine voles.

Pine vole damage to apple trees is usually confined to subsurface root destruction in contrast to surface trunk girdling by meadow voles (Microtus pennsylvanicus). Larger roots are frequently completely stripped of bark and cambium while smaller roots are entirely cut away.

HISTORICAL REVIEW

Taxonomy and Distribution. One member of the genus Microtus, subgenus Pitymys, occurs in the United States. The subgenus contains two species and six subspecies. Only two of these subspecies, M. p. pinetorum and M. p. scalopsoides are considered within the scope of this report. The former occurs from Virginia south to Georgia and Alabama and west to Illinois. The latter occurs from Virginia north into New England, west into Iowa, and thence south to Kentucky (Hall and Kelson 1959).

Reproduction. The literature clearly defines a relatively low reproductive potential for pine voles. Embryo counts from numerous studies indicate a mean litter size of approximately two with a maximum of four (Hamilton 1935, Richmond and Roslund 1949, Gifford and Whitehead 1951, Roberts and Early 1952, Horsfall 1963, Miller and Getz 1969, Paul 1970). The breeding season appears continuous from about February to October-November throughout the range of the pine vole (Hamilton 1935, Benton 1955, Miller and Getz 1969, Paul 1970). The annual peak in breeding activity occurs in September-October. Recent evidence provided by Horsfall (1963) and Richmond et al. (1977) indicates females were pregnant each month of the year. Thus, it appears that the duration of the breeding season may be controlled by geographic and physiographic influences and other environmental factors. Paul (1970) reported a potential of up to 12.5 litters female/year. The gestation period for captive females is approximately 24 days (Kirkpatrick and Valentine 1970).

Population Structure. Pine vole sex ratios have been reported as 1:1, and during the summer months 45 percent of the population consists of subadults and young (Miller and Getz 1969, Paul 1970). Extreme variations in both ratios were noted depending on population density, reproductive activity, and time of year.

Longevity. The low survival time for pine voles is described by Richmond and Roslund (1949), Gifford and Whitehead (1951), Roberts and Early (1952), Conner (1960), 1966), and Gentry (1968). Miller and Getz (1969) show that only about 19 percent of males and females were recaptured 2 months after their first capture. Hayne (1977), in his projection of survival rates over time, suggests that a population of pine voles would be eliminated (reduced to 1 percent of its original size) in about 330 days--assuming no recruitment. The average and maximum survival times shown by Miller and Getz (1969) was 2-6 months and 12 months, respectively, similar to those described by Burt (1940) and Stickel and Warbach (1960).

Population Cycles and Fluctuations. Pine vole populations have been described as cyclic, but there have been few long-term studies specifically designed to study this phenomenon and the published data are somewhat contradictory. Hamilton (1935, 1938) cites three instances where pine vole populations drastically decreased or increased during periods of 2-5 years. He attributed these fluctuations to cyclic behavior. Benton (1955), however, found no evidence of cyclic tendencies during his study. Annual fluctuations in population density are described by Benton (1955), Gentry (1968), Miller and Getz (1969), Paul (1970) and Gettle (1975). Population density varied widely within and between specific locales and appeared to be related to interactions between environmental conditions and intrinsic factors. For example, Gettle (1975) found that pine vole populations in Pennsylvania were highest but less mobile in the fall and lowest and more mobile in the spring.

Population Density. Accurate estimates of pine voles per unit area in orchards are difficult to project because habitat factors (topography, soil type, soil moisture) can have a significant impact on distribution. Horsfall (1951, 1964) estimated vole density at close to 80 per acre (approximately 2 per tree) in a heavily infested orchard in Virginia. Hamilton (1938) estimated populations as high as 200-300 per acre in an apple orchard in New York. Population densities in non-orchard or natural habitats (mixed woodlands) are normally significantly less than that found in-orchard (Stickel and Warbach 1960). Thus, it appears that the orchard environment provides pine voles an optimum habitat with maximum carrying capacity. A single burrow system normally provides space for one to three pine voles, although Byers (1977) found extremes of up to 22 voles per tree in Virginia. Byers also observed that under serious damage situations it was not uncommon to find up to 10 percent of the trees harboring eight or more pine voles.

Habitat (orchard only). Pine voles are basically fossorial. Burrows, 1 to 2 inches in diameter, are generally very shallow, usually no more than 3 or 4 inches deep but occasionally may attain a depth of a foot or more. The deeper zones of the burrow system are usually confined to the tree trunk area. Nests and food caches are usually found in these deep systems (Byers 1977). Surface and subsurface runways are usually confined within the dripline of individual trees. On the surface, the presence of pine voles is indicated by trails, partial tunnels, mounds of soil at the terminals of active burrows, vertical and near horizontal burrow openings, and, all too frequently, dead or dying apple trees.

Movement and Activity Patterns. Studies of pine vole movements have centered around home range and daily movement patterns. Horsfall (1956) noted 1/4 acre as a maximum home range in Virginia apple orchards, but considered the average much smaller. Fitch (1958) reported that 70 percent of the pine vole recaptures occurred within 10 yards of previous captures. Stickel and Warbach (1960), in a woodland habitat, recorded movements of less than 40 yards for 14 of 16 pine voles captured four or more times. Miller and Getz (1969) noted the average maximum diameter of home ranges (greatest distance between captures corrected for trap spacing) as 32.7 to 33.7 meters for females and males, respectively. Paul (1970) observed that the home range and movement of pine voles was related to tree spacing with colonies of mice occupying a one to four tree area intrarow. This observation was expanded on by Sullivan (1977) who found that an average of about 40 percent of the pine voles were captured in more than one row of trees, and 13 percent in more than two rows with linear, intrarow movements of up to 120 feet.

While pine voles spend a considerable time underground, they are easily trapped from surface runways. Activity periods are about equally divided between day and night but are subject to modifications related to extrinsic conditions (Miller and Getz 1969, Paul 1970).

Limiting Habitat Factors. Hardy (1945) found that soil texture had a distinct effect on the local distribution of mammals, especially the burrowing or fossorial forms. Although opinions vary, a consensus indicates that soil type (light soils and humus), rather than the composition and density of the vegetative understory, is the most important factor in determining the occurrence and distribution of pine voles (Hansen 1946, Jameson 1949, Neill and Boyles 1955, Foreman 1956, Paul 1970). Studies by Fisher (1976) suggest that pine voles require soils with greater than 35 percent gravel, 20 percent clay and 25-48 percent sand.

Miller and Getz (1969) concluded that the distribution of pine voles was essentially restricted to moist, well drained sites. Paul (1970) also explored the possibility that soil moisture was a critical factor in site selection by pine voles, i.e., areas where trap success was high during wet periods yielded poor trap response during the dry season. Benton (1955) and Paul (1970) attributed this low trap success to vertical downward migration. However, it is possible that natural mortality and/or lateral migration might also have occurred.

Food Habits Preferences and Nutrition. The literature on pine vole food habits dates back over 100 years; however, to the present day, few if any long-term studies have been conducted to develop a comprehensive picture of inter-intra-orchard diets, preferences, nutrition and seasonal variation in the diet. Initial investigations (Audubon and Bachman 1851) mentioned peanuts and seeds of grama grass (Bouteloua spp.) as dietary components. Underground plant parts are frequently mentioned as preferred foods (Quick and Butler 1885, Hahn 1908, Schmidt 1931). Perhaps the first reference to bark damage was noted by Kennecott (1857). While some authors felt that pine voles fed mainly on succulent roots and tubers (Hamilton 1938), more recent additions to the literature show that diet is more variable, including both above- and below-ground plant parts. Indications of opportunistic feeding were described by Gifford and Whitehead (1951) who reported voles with stained abdominal walls from eating pikeberries, while the flesh of another group of voles smelled strongly of wild onion (Allium spp). Benton (1955) stated "the orchard pine mouse appears to subsist largely on grass roots and stems during the summer, fruit and seeds during the fall, and bark, roots and possibly stored food during the winter." Benton also reported that the normal diet contained only small amounts of animal matter, yet Sim (1934) found that voles readily accepted larvae of Japanese beetle (Popillia japonica). Various sources indicate that apple tree roots are not a preferred food. Kirkpatrick and Noffsinger (1977) found that pine voles feed primarily on above ground vegetation (grasses and forbs) and feed on roots only when other foods are in short supply. They found some root (apple tree) fragments in the stomachs throughout most of the year but larger amounts (7 to 14 percent of the identifiable epidermal material) were found only during the January-March period. This observation tends to isolate the winter months as the major period of apple tree damage by pine voles.

Evidence of food caching by pine voles is conflicting, but most authors tend to agree that pine voles cache rootstocks, stems, and leaves in both orchard and natural habitats.

Recent studies by Noffsinger (1976) and Estep et al. (1977) indicate that well-managed orchards provide pine vole populations with an ideal habitat from the standpoint of nutrition. They found that while body fat levels were not consistently different between managed and abandoned orchards, there was a marked decline in fat stores during the autumn months in abandoned orchards. The dry weights and percent digestible energy of the stomach contents were markedly lower in voles from abandoned orchards, especially during the early autumn.

Behavior. Basic and applied studies of pine vole behavior are almost nonexistent. A sampling from the literature shows that all behavioral research is keyed to two phenomena--inter-species associations (Fitch 1958, Calhoun 1959, 1964, Paul 1970) and intra-species antagonism (Kimball 1972).

CONTROL METHODS

Little effort was expended to develop ways and means to control pine voles (or damage) until 1934 when the U.S. Fish and Wildlife Service initiated a program to evaluate toxicants, baits and baiting techniques. Much time and effort has been spent on this avenue of research by the Federal government and other agencies and groups with few efforts made to gain a better understanding of the pine vole/orchard problem. In recent years the initiative for basic and applied research and the development and evaluation of new control methods has shifted from the USFWS (DWRC) to other agencies, primarily state universities and Cooperative Wildlife Research Units in the problem area.

Many publications detail ways and means of controlling pine voles with poison baits, most utilizing materials such as zinc phosphide, chlorophacinone (Rozol) and diphacinone (Ramik Brown) on either grain or cubed apple carriers (O'Neal 1977, Byers 1977). When properly carried out, these methods can be effective, offering temporary relief (Tietjen 1969, Byers 1977). However, field trials employing these agents indicate that, while they are effective if used on a consistent basis, they all suffer from certain common weaknesses--(1) time-cost economics, (2) lack of trained and dedicated applicators, and (3) inherent use limitations (if applied mechanically). These shortcomings restrict general acceptance and use of toxic baits in many areas.

The development of endrin as an area spray for controlling pine voles (Horsfall 1954, 1956) has also received much publicity--at least 95 publications dealing directly with the pros and cons of its use in orchards and conifer plantations. The technique has met with questionable success. Hayne (1970) concluded that endrin ground spray for the control of pine voles . . . "may on occasion reduce activity in orchards." The reasons for the failure of endrin under certain conditions are not readily apparent; however, both endrin resistance in some populations (Webb and Horsfall 1967, Byers 1977) and the characteristics of the vegetative ground cover (Webb and Horsfall 1969) have an impact on the effectiveness of this contact toxicant. Horsfall further speculated that the occurrence and abundance of pine voles is regulated by ground cover type, and that endrin spray treatment is ineffective in heavy grass cover because grasses are not a preferred food. Additional difficulties with endrin may be encountered in the form of residues on fruit and hazards to nontarget species. Numerous recommendations against its use in orchards appear in the literature (Eadie 1957, Hamilton 1966, Small 1958, Fitzwater 1953, MacNay 1965). In spite of the many problems associated with the use of endrin, many growers feel it provides their main (and only) line of defense against pine vole damage and it is still used in some apple growing regions during the dormant season. However, the future of endrin is in doubt since it is under Rebuttable Presumption Against Registration by the EPA (Markley 1977), and other methods of control are urgently needed.

New control techniques have been under evaluation in recent years and include the use of anticoagulant-treated baits (e.g., chlorophacinone {Rozol}, diphacinone {Ramick Brown}, ICI 581, and LM 637), anticoagulant area sprays, selected herbicides to eliminate preferred foods (Byers 1977, Young 1977), and various cultural techniques modifying orchard flora to destroy or enhance vole habitat (e.g., establishment of buffer foods).

RESEARCH NEEDS

Vital quantitative information about the pine vole problem is lacking because past research has emphasized chemical control. The long-heard contention by some orchardists and scientists that research need only provide an effective chemical to kill pine voles has in recent years been largely replaced by the recognition that the pine vole problem may be very amenable to nonchemical control methods. Only within the past few years has the Service provided funds to universities for studies on the ecology of the pine vole problem. These studies, though limited in scope, suggest that nonchemical control methods may be very promising.

The limited and disrupted distribution of pine voles, both seasonally and geographically, indicates that this species is not readily adaptable to a wide range of habitat types or conditions. If there are certain factors that are limiting the occurrence and abundance of pine voles, and they can be detected, we may be able to exploit this knowledge to adversely affect pine vole populations by manipulating their habitat. Future pine vole research, therefore, should be broad in scope and include studies of the economics of damage, pine vole biology, physiology, behavior, movements, and habitat requirements, as well as the development of control methods.

Economics of Damage/Damage Assessment

Economic data on the impact of pine vole damage to apple orchards are incomplete; however, we do know that pine voles are causing intolerable losses to orchardists. Current loss figures probably are conservative, since they are based primarily on the costs of tree replacement and do not reflect declining yields from vole-damaged trees over the several years prior to replacement. This lack of quantitative damage data is due to inadequate techniques for measuring declining yields resulting from subterranean damage to tree roots. The development of a technique to assess damage prior to replacement, possibly by physio-electric measurement of tree vigor, is needed. Such damage assessment data would provide: (1) more reliable estimates of losses, (2) a basis for determining cost-benefit ratios of new control methods, (3) a method by which the orchardist and researcher could determine the extent of infestation within an orchard before extensive tree loss occurs, and (4) a measure of efficacy of experimental and currently used methods of pine vole damage control.

Ecology

Pine Vole/Meadow Vole Relationship. Because pine and meadow voles often occupy the same orchards, the relationships between the two species is of particular interest. Field studies are needed to determine what occurs when one of these species is eliminated from an orchard. Data are needed on the interactions between pine and meadow voles and on the changes in the numbers and distribution of these species that may occur throughout the year. Without knowledge of the interdependencies of these species, control measures may result in an even greater problem by improving the habitat for the surviving species. For example, the control of meadow voles in some orchards may have resulted in more severe pine vole problems.

Habitat. Research findings indicate that cultural practices, soil type (e.g., amounts of clay, gravel, sand, and humus), and composition of understory vegetation are correlated with the occurrence and distribution of pine voles. The occurrence of pine voles also has been observed to be virtually restricted to active apple orchards, and that their numbers are greatly reduced or they are absent in abandoned orchards. Comparative inter- and intra-orchard studies are needed to better define vole habitat requirements. Such information may provide clues to ways of reducing pine vole populations.

Food Habits. The meager data available about pine vole food habits indicates that pine vole density declines in orchards treated for several years with herbicides. Grasses, when available, constitute the bulk of the vole diet. The dependency on grasses also may be the cause of a decline or disappearance of pine voles in abandoned orchards, which generally exhibit increased forb density and a decrease in grasses. The relationship between high pine vole densities and the ratio of grasses to forbs required to maintain these high population levels is not clear and requires study. Studies of vole food habits and the effects of herbicides on orchard vegetation are needed in a wide variety of orchards with diverse vegetative composition and cultural practices. Such research has good potential for producing low-cost control methods.

Distribution of Voles in Orchards. The distribution of pine voles and associated vertebrate fauna in orchard habitat is not well documented. For example, pine and meadow voles do not usually inhabit the basal area of the same tree. Knowing the distribution of both species in orchards, together with damage and population data, would provide a basis for optimizing control techniques.

Behavior and Physiology

We are handicapped by our lack of knowledge about the behavior and physiology of pine voles. The limited habitat and fossorial existence of pine voles indicates a finely tuned physiological-behavioral order. The disturbance of this order could result in a reduction of this pest species. Sensory systems, such as olfaction, perhaps in relation to reproduction or the identification of foods or of other inhabitants within the community, would seem to offer a reasonable starting point for such investigations. The sporadic activity of voles may be cued by environmental factors. The identification of these behavioral cues may show that they are amenable to disruption. This area of inquiry is so broad and unexplored that virtually any point of investigation could lead to the development of control methods.

Movements

Seasonal. Although daily movements and home ranges have been fairly well determined, seasonal movements have not been investigated. Theories regarding the vertical and horizontal movement of pine voles in response to climatic stresses (summer and winter) are speculative. However, it seeems reasonable that extremes in soil moisture/ temperature, and climatic conditions could be important in initiating movements. Data on the influence of climatically induced stress and its resulting effects on the pine vole, whether it be movement, mortality, or other behavior, will yield valuable knowledge about the periods of greatest vulnerability to control.

Immigration/Emigration. We do not know the extent and distances involved in vole immigration and emigration into and from stable (noncontrolled populations, areas where populations are suppressed, or areas adjacent to suppressed areas. The inter- and intra-behavior between pine vole residents and immigrants is not known. Knowledge of movements and associated behavior would provide data for determining the frequency of application of control methods and for determining the need for either separate or simultaneous control of pine voles and/or meadow voles.

Population Dynamics

Population Density/Damage Potential. Orchards have been observed where high vole populations do not cause significant damage. Conversely, in other orchards, major problems have been caused by only a few animals. Studies are needed, therefore, to determine the relationship between pine vole densities and the amount of vole damage at various seasons of the year.

Cyclic Patterns. Some investigators attribute a cyclic population pattern to pine voles, as is common to other microtine rodents. This basic aspect of pine vole biology is of intense interest in the development of control methods because if this species is predictably cyclic, we could predict damage trends and thus optimize control strategies.

Reproduction. Data are needed on pine vole reproduction potential in various habitat types. This research is essential if we are to be able to determine factors that affect reproductive potential and the long-term efficacy of new control methods.

Mortality. Knowledge of natural mortality rates in pine vole populations is needed to aid in the development and evaluation of control strategies. Further, this information would be of value in developing population models having a predictive value in the development and application of control methods. The limited literature on pine vole longevity indicates that only about 20 percent of a population lives longer than 4 months. If this short life span is truly representative of the species, it may be possible to identify and utilize causative agents within the environment to adversely affect vole life span.

Repopulation. Recovery of pine vole populations after successful reductional control may result from accelerated reproduction in the residual population, and also, in part, to invasion from adjacent areas. This little-known aspect of pine vole population dynamics should be studied in order to evaluate proposed control methods.

Control Methods Development

Cultural Practices. Most investigators concur that pine vole density decreases when orchards are abandoned. Observations also show that pine voles do not occur in some active orchards, but will occur in large numbers in adjacent active orchards. These observations suggest the possibility that certain cultural practices are detrimental to vole populations. Although the gathering and interpretation of these data would be a formidable task, it is essential that it be done.

Physical Barriers. The most economically expedient control, in some rodent damage situations, has been to physically restrict access to the depredating species. This might involve installing voleproof exclosures around the perimeters of orchards. Physical barriers may offer complete and economical protection over an extended period, and, as such, are a control technique to be explored.

Chemical Control Agents. In view of problems associated with direct chemical, e.g., hazards to nontarget species, high registration costs, chemicals may be the least promising approach for controlling pine vole damage. The history of the Service's role in pine vole research has followed a single basic course consisting generally of the development of lethal baits. This approach has been only marginally successful. Chemical control research should not receive undue emphasis but should be an essential part of an overall research program. Research on chemicals should be broadened to include studies of the physiology of target species to determine if physiological uniqueness is present that could be exploited in the development of highly selective chemical stressing agents.

EPA Registration

The development of a new chemical control agent to meet EPA registration requirements currently costs from $4 to $6 million per chemical. In view of these enormous costs, and the fact that such chemicals have a limited market and produce little profit for the chemical industry, most of the future costs of chemical development must be borne by the FWS.

PROJECT REQUIREMENTS

The proposed research should be planned and implemented so that the various components are of high priority and will comprise a balanced and integrated research program. Research should be identified that would seem to offer the most direct route to problem solving, and that would yield data relevant to the entire program. Once priorities are set, research documentation should be prepared for each major area of research--problem definition, ecology, behavior and physiology, population dynamics and control methods development. The scope of the program will permit simultaneous research on each major area of interest and provide ample funds for Service pertinent contract research. The primary goal should be the development of species-specific integrated control programs that can be used throughout the range of the pine vole.

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1976 IPOMS VOLE RESULTS

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ABSTRACT: This is a preliminary report on the vole portions of an interdisciplinary study of integrated pest and orchard management systems (IPOMS) in North Carolina. Vole trapping results of winter 1976-77 in 46 orchards are reported and compared to vegetational and chemical measurements made in the same orchards the previous summer.

INTRODUCTION: IPOMS is an acronym representing an interdisciplinary project of the North Carolina Agricultural Experiment Station entitled "Integrated Pest and Orchard Management Systems for Apples in North Carolina." This project unites the efforts of specialists in a number of different disciplines in a joint study. The project is at present in the data-gathering phase with the first records made in 1976. The study of voles in orchards is a relatively small part of the whole study.

One unique and valuable characteristic of the study is that the orchard blocks and the trees within these blocks, were selected at random; therefore we have an unbiased sample of orchards of a county.

A second important characteristic of the study is its breadth, as illustrated here where data from voles are compared with those gathered on the same orchards and the same trees by weed scientists (vegetative records), horticulturists (leaf analyses), soil scientists (soil analyses) and plant pathologists (tree death analyses). All of these data, and more, are being recorded on the same sites; this would not be possible if done solely for the purpose of investigating relationships to vole populations.

This report covers the vole trapping and the dead tree survey of the winter of 1976-77 and the vole signs, vegetational, and chemical records of the summer of 1976. Results are tentative in that only a single season is involved.

METHODS: Selection of study sites. The orchards where the study is being carried out were selected at random from aerial photographs covering Henderson County, North Carolina. First, all areas of orchard were divided into smaller pieces of land of suitable size (less than about 25 acres, mostly less than 8 acres), marked on the aerial photographs, numbered and listed. From this list a sample was drawn at random, and these portions of orchards were visited on the ground. Each was divided into subareas, one of which was chosen at random as the sample area (block). Within each such block, 8 to 18 study trees were chosen at random, averaging about 10 per block. Management practices are being studied in the orchard block that contains the sample area.

The study depends upon grower cooperation. Initially, 41 of the 60 randomly chosen sample areas belonged to growers who chose to cooperate. Absentee and changing ownership was an important reason for failure to cooperate. By-and-large we feel that the IPOMS project is based upon a sample that is just about as close to random as it is practical to achieve with operating orchards.

In addition to the random sample, eight other cooperating orchards are included in the study.

Trapping. Live traps were set in the sample blocks near each sample tree, with one trap at each of the adjacent trees in the same row as the sample tree and one trap at each of the two closest trees in the adjacent rows. Thus 4 traps were set for each sample tree but none was set immediately beneath the sample tree (to avoid disturbing the sample tree's vegetation). After traps were set, they were visited at 24 and 48 hours, and then removed. Live animals were marked and released; dead voles were examined for embryos. Trapping was completed in November and December. In data represented here a total of 2,119 traps were set twice (one trap was missing) near 530 sample trees in 48 sample blocks. Because one trap was missing and a number were sprung without capturing an animal, the effective total number functioning and able to capture an animal was 2,067 per setting (instead of 2,119) counting each tripped trap as one-half effective. Estimated population numbers are stated as per functioning trap (or per tree since there was one trap per tree).

Population estimates. Populations were estimated by calculating a capture probability for trapped animals. There are two estimates:

1. $p_1 = \dfrac{C_{12}}{C_1}$

2. $p_2 = \dfrac{C_{12}}{C_2}$

where C_{12} = animals captured both periods

C_1 = animals marked and released alive at the first trapping

C_2 = all animals captured at the second trapping

The mean value is:

$$\bar{p} = \frac{C_{12}}{2}\left(\frac{1}{C_1} + \frac{1}{C_2}\right) .$$

The expected value for total number captured is:

$$E(C_T) = P(2p - p^2).$$

From this, I estimated $\hat{P}$ as:

$$\hat{P} = \frac{C_T}{2p - p^2} .$$

Records of adult males, adult females and all immatures were examined for evidence of a difference in the proportion of live marked releases the first night, recaptured the second night. No significant difference was found by x^2 test, and records were pooled. These pooled records were used to estimate capture probability and the expansion factor for estimating the total population. This factor is the reciprocal of $2p - p^2$; this was multiplied by the total number of individuals captured to estimate the population number.

Vole signs. At the same time the notes on the vegetation of the orchard floor were recorded, signs of vole presence and activity were made. These signs are calculated as a "local frequency," here called tree frequency, by scoring 1 for each of the 20 plots where vole signs occurred, and dividing the sum of these scores for one tree by 20. This tree frequency is then averaged over all the sample trees in the block.

The only vegetational data examined for relationship to vole signs or numbers were those for percent bare ground, height of dominant vegetation, thatch depth, and number of plant species; average block values were used here.

Leaf analyses. Vole numbers were also compared to average growing season leaf content of a series of 11 plant nutrients, separately in simple regression and in multiple regression. The hypothesis here was that vole numbers may reflect the nutrient condition of an orchard; it is commonly stated that voles are easier to find in orchards that are heavily fertilized.

Soil analyses. Vole numbers were compared to average surface soil content of plant nutrients, using regression methods.

Dead tree survey. Dr. Turner Sutton and Bill Sullivan pulled and examined all 324 dead trees in 35 orchard blocks during the winter of 1976-77. For each dead tree, they made a judgement as to the principal cause of death, whether disease, vole injury or other factors. Whether lethal vole injury was caused by pine voles or meadow voles was judged primarily by the location of injury on the root system, whether above or below the ground level, with some weight given to signs of current activity.

RESULTS: Species captured. The 1976 live-trapping made a total of 442 captures of small mammals of 8 species; most of these were of pine voles (Table 1).

Table 1. Results of live-trapping in 48 IPOMS orchards in the winter of 1976-77

Species	No. of captures	
Pine vole	336	(311 individuals)
Meadow vole	40	(36 individuals)
Short-tailed shrew	52	
Deer mouse	2	
House mouse	1	
Jumping mouse	4	
Norway rat	4	
Cotton rat	3	
Total Captures	442	

Prevalence of voles. In the 48 orchard blocks trapped, voles of either species were captured in 34 blocks (Table 2) with pine voles in 32 (66.7%), meadow voles in 12 (25.0%) and neither species in 14 (29.2%).

Pine vs. meadow voles. It has been reported that one species of vole drives out the other. This question was examined in two ways, as to prevalence and as to correlation of numbers; neither method supported the idea of much influence of one species on the other.

Table 2. Species prevalence (presence or absence) of voles in 48 IPOMS orchards, winter 1976-77

		Meadow Vole		
		Present	Absent	Total
Pine Vole	Present	10	22	32
	Absent	2	14	16
	Total	12	36	48

Based on the overall prevalence of each species (Table 2) the expected numbers of orchard blocks containing both species would be 8 (instead of 10 as observed) and containing neither species, 12 (instead of 14 as observed). These deviations are within expected sampling variation and thus there is no evidence here of any association (negative or positive) between the two species of voles.

Next the estimated population numbers (Table 3) were examined for any relationship from orchard to orchard. A linear regression of meadow vole numbers on pine vole numbers showed a weakly significant relationship ($n = 48$; $R^2 = 0.071$; $p = 0.07$). The intercept was +0.048 and the slope +0.036.

Populations of voles. The capture probabilities and expansion factors were estimated from the trapping records as shown in Table 3.

Table 3. Capture probabilities and expansion factors, winter 1976-77, IPOMS vole live-trapping

Species	Capture probability p	$2p-p^2$	Factor = reciprocal of $2p-p^2$
Pine vole	.07820	.1503	6.654
Meadow vole	.1053	.1994	5.014

Although the calculated capture probability for the meadow vole was about one-third greater than that for the pine vole, the difference was not statistically significant by chi-square test.

The estimated numbers of voles per tree are shown in Table 4, separately for the two species.

Population numbers are highly variable from orchard to orchard, representing many low and relatively few high values (Table 4). A better idea of the distribution is presented by a calculation using log-transformed data ($x = \log_{10}(x' + 0.1)$). Here for pine voles the geometric mean is 0.35 mice per tree, with 2 standard deviation (95%) limits of 0.02 and 5.2 mice per tree; with meadow voles the geometric mean is 0.04 mice per tree with 2 standard deviation limits of 0.01 and 0.14 mice per tree. For the total of both species the geometric mean is 0.40 with 2 standard deviations ranging from 0.03 to 5.9 voles per tree. These values refer to orchard block averages, each based on a number of trees per block (average 45); values based upon single trees would be more variable.

Table 4. Estimated number of voles per tree in 48 IPOMS sample blocks winter 1976-77

Block	Pine Vole	Meadow Vole	Block	Pine Vole	Meadow Vole	Block	Pine Vole	Meadow Vole
1	0.9	0.0	17	0.3	0.0	34	0.3	0.1
2	2.3	0.0	18	0.0	0.0	35	2.0	0.0
3	3.0	0.0	19	0.0	0.0	36	0.7	0.1
4	0.0	0.0	20	0.0	0.0	37	0.2	0.1
5	3.6	0.1	21	1.6	1.0	38	0.0	0.0
6	2.9	0.0	22	0.2	0.0	39	1.0	0.6
7	1.2	0.0	23	0.1	0.0	40	0.0	0.0
8	0.0	0.0	24	1.5	0.0	41	0.0	0.0
9	0.2	0.0	25	0.4	0.3	42	1.2	0.0
10	0.4	0.0	26	2.4	0.0	43	0.5	0.0
11	3.4	0.0	27	2.9	0.0	44	0.3	0.0
12	0.1	0.1	28	2.9	0.0	45	0.0	0.0
13	0.0	0.0	29	0.2	0.0	46	0.3	0.0
14	0.0	0.0	30	1.5	0.0	47	0.0	0.0
15	0.2	0.3	31	0.0	0.2	48	0.0	0.0
16	7.9	0.6	32	0.0	0.5	49	0.0	0.0

Arithmetic Mean ± dev.: Pine vole 0.97 ± 1.49; Meadow vole 0.08 ± 0.20

Summer vole signs and winter vole numbers. A practical question is how well winter vole populations can be predicted from the summer signs of vole activity. This was examined by a linear regression of total vole numbers (sum of pine and meadow voles) on tree frequency, which is the index of summer vole activity. The data used are shown in Table 5, along with the values for number of voles "predicted" from tree frequency. The linear regression established on 46 points was highly significant ($p = .0001$) accounting for a moderate fraction of the variability ($R^2 = 0.57$; see Table 6). The predicting equation is: Vole number = 0.3 + 16.3 (tree frequency). Inspection of Table 5 shows that while some "predictions" were quite close, others missed by important margins.

One point (block no. 16) stands out as the highest value for both summer signs and winter numbers; a natural question is whether this value is responsible alone for the apparent relationship. When this point is excluded, a linear regression based on the remaining 45 points shows a highly significant relationship ($p = .003$) although with less of the variability accounted for ($R^2 = 0.18$). The predicting equation here is: Vole number = 0.5 + 10.2 (tree frequency).

Table 5. Tree frequency of activity in summer 1976, subsequent vole numbers in winter 1976-77, and vole number "predicted" by the regression on summer activity, in 46 IPOMS orchard blocks

Block	Tree Freq.	Vole Nos. Obs.	Vole Nos. Pred.	Block	Tree Freq.	Vole Nos. Obs.	Vole Nos. Pred.	Block	Tree Freq.	Vole Nos. Obs.	Vole Nos. Pred.
1	0.062	0.9	1.3	18	0.115	0.0	2.2	35	0.030	2.0	0.8
2	0.092	2.3	1.8	19	0.050	0.0	1.1	36	0.000	0.8	0.3
3	0.125	3.0	2.4	20	0.040	0.0	1.0	37	0.015	0.3	0.6
4	0.039	0.0	1.0	21	0.000	2.6	0.3	38	0.000	0.0	0.3
5	0.111	3.7	2.1	22	0.040	0.2	1.0	39	0.009	1.6	0.5
6	0.123	2.9	2.3	23	0.000	0.1	0.3	40	0.000	0.0	0.3
7	0.041	1.2	1.0	24	0.086	1.5	1.7	41	0.000	0.0	0.3
8	0.000	0.0	0.3	25	0.000	0.7	0.3	42	0.012	1.2	0.5
9	0.000	0.2	0.3	26	0.141	2.4	2.6	43	0.059	0.5	1.3
10	0.000	0.4	0.3	27	0.000	2.9	0.3	44	0.196	0.3	3.5
11	0.066	3.4	1.4	28	0.085	2.9	1.7	45	0.000	0.0	0.3
12	0.043	0.2	1.0	29	0.0125	0.2	0.5	46	0.012	0.3	0.5
13	0.000	0.0	0.3	30	0.056	1.5	1.2	47	0.000	0.0	0.3
14	0.000	0.0	0.3	31	0.044	0.2	1.0	48	0.000	0.0	0.3
16	0.414	8.5	7.1	32	0.000	0.5	0.3				
17	0.010	0.3	0.5	33	0.000	0.0	0.3				

Summer vegetational characteristics and winter vole numbers. Vole numbers were examined as to regression on the gross vegetational characteristics of percent bare ground, height of dominant vegetation and thatch depth. None of these regressions accounted for an appreciable fraction of the variability (Table 6).

Table 6. Regressions of vole numbers in winter on gross vegetational characteristics of the previous summer (including tree frequency) IPOMS 1976-77 trapping data from 46 orchard blocks

Independent Variable	Intercept	Slope	R^2	Statistical Significance
Tree frequency	0.324	16.345	0.57	$p = 0.0001$
Percent bare ground	1.646	-0.033	0.03	$p = 0.30$
Height dominant veg.	0.908	0.024	0.02	$p = 0.46$
Thatch depth	0.549	0.549	0.02	$p = 0.39$

Summer vegetational characteristics and summer vole signs. Tree frequency was examined as to regression on the gross vegetational characteristics: percent bare ground, height of dominant vegetation, depth of thatch and number of species of plants. This comparison was based on 46 blocks. Results (Table 7) showed a highly significant relationship with thatch depth and suggested a possible relationship with percent bare ground, though in neither case was any large proportion of the variability accounted for.

Table 7. Regressions of vole signs as tree frequency on gross vegetational characteristics recorded at the same time in the summer of 1976, in 46 IPOMS orchard blocks

Independent Variable	Intercept	Slope	R^2	Statistical Significance
Percent bare ground	0.063	-0.00167	0.06	$p = 0.09$
Height dominant veg.	0.024	0.00126	0.03	$p = 0.28$
Thatch depth	-0.035	0.056	0.17	$p = 0.004$
No. plant species	0.110	-0.023	0.04	$p = 0.19$

Summer leaf analyses and winter vole numbers. Linear regressions of vole numbers on summer leaf analyses failed to reveal any statistically significant relationship (Table 8). The closest to significance was with phosphorus ($p = 0.19$). A stepwise regression (maximum R^2 option) failed to improve the relationship appreciably with up to 6 variables. Thus no evidence was found of any reliable relationship between leaf content of 11 plant nutrients and vole numbers the following winter.

Table 8. Regressions of winter vole numbers on leaf analyses for 11 plant nutrients in previous growing season, 1976 IPOMS data from 48 orchard blocks

Independent Variable	Intercept	Slope	R^2	Statistical Significance
N	3.028	-0.896	0.01	$p = 0.40$
P	2.852	-10.143	0.04	$p = 0.19$
K	0.018	0.598	0.02	$p = 0.33$
Ca	2.047	-0.921	0.02	$p = 0.34$
Mg	-0.408	4.238	0.02	$p = 0.28$
Na	0.357	10.536	0.02	$p = 0.34$
Fe	1.750	-0.009	0.02	$p = 0.33$
Mn	1.367	-0.002	0.03	$p = 0.26$
Zn	1.082	0.0005	0.001	$p = 0.84$
Cu	1.705	-0.147	0.02	$p = 0.33$
B	0.828	0.004	0.002	$p = 0.78$

Summer soil analyses and winter vole numbers. Linear regressions of vole numbers on summer soil analyses failed to reveal any statistically significant relationship (Table 9). The closest to significance were with sulphur and potassium ($p = 0.28$). A stepwise regression (maximum R^2 option) failed to improve the relationship. Thus no evidence was found of any reliable relationship between soil analyses and vole numbers the following winter.

Table 9. Regressions of winter vole numbers on soil analyses for 10 plant nutrients and 6 other characteristics in the previous growing season, 1976 IPOMS data from 47 orchard blocks

Independent Variable	Intercept	Slope	R^2	Statistical Significance
N	0.987	0.147	0.006	p = 0.58
P	1.383	-0.003	0.02	p = 0.40
K	0.182	2.686	0.02	p = 0.28
Ca	1.343	-0.072	0.005	p = 0.63
Mg	0.505	0.633	0.02	p = 0.37
Na	1.438	-4.682	0.01	p = 0.54
Mn	1.094	-0.002	0.0002	p = 0.92
Cu	1.206	-0.030	0.01	p = 0.46
Zn	1.348	-0.035	0.02	p = 0.39
S	1.656	-0.029	0.02	p = 0.28
Weight Volume	1.139	-0.086	0.00004	p = 0.97
Organic Matter	1.202	-0.048	0.001	p = 0.86
Soluble Salts	0.560	5.255	0.005	p = 0.63
pH	-0.016	0.188	0.003	p = 0.71
Acidity	1.427	-0.195	0.006	p = 0.61
CaMgKNa	1.149	-0.018	0.0005	p = 0.88

Voles as causes of tree death. The 324 trees pulled and examined by the dead tree survey in 35 orchard blocks constituted 1.37 percent of trees in these blocks. It is not known for how many years these trees have accumulated in these orchards; presumably the period is greater than one year and therefore this figure sets an upper limit on annual tree mortality.

In principal suspected causes of death, voles ranked first, closely followed by disease (Table 10). It must be recognized that the causes assigned were probably not independent; death may have resulted from the combined action of several factors. But as a first approximation, these data suggest that losses by tree death are below 1.4 percent per year, and losses by voles, below 0.6 percent per year. This accounting does not allow for losses to voles from reduced vigor and fruit production over the years before tree death.

DISCUSSION AND CONCLUSIONS: Voles dominate the small mammal fauna of Henderson County orchards, with pine voles about eight times as numerous as meadow voles. This trapping program found voles in about 70 percent of the orchards; considering the small fraction of each orchard covered and the clustered nature of vole distribution, animals of one or both species are probably present in almost all orchards of this region. There was no evidence of antagonism to be found in the trapping records.

Table 10. Causes of death of apple trees as judged by an experienced 2-man team; all dead trees in 35 IPOMS orchard blocks, winter 1976-77

Cause of death		No. Trees		Percent	
Pine voles		122		37.7	
Meadow voles		22		6.8	
Total voles			144		44.5
Disease			131		40.4
Other identified causes			39		12.0
Unknown causes			10		3.1
	Total		324		100.0

The capture probability of voles, as measured here, appears to be about 8 percent in a 24-hour setting of traps. This value refers to the set of 4 traps, even though the population estimates are stated per single tree (trap). This means that in two days this trap setting pattern seems to capture about one-sixth of the animals presumed to be resident.

The mean estimated population of all voles was 1.05 per tree (or 4.2 voles for the 5 tree diamond-shaped area centered on a sample tree). Populations were highly variable from orchard to orchard; considering total voles the two standard deviation range either side of the geometric mean of 0.40 voles per tree included a span of about 15-fold in either direction (this refers to block mean values).

Winter vole numbers may be predicted fairly well from the signs of vole activity at the same orchard location the previous summer. It is not yet clear whether this association is close enough to provide useful predictive ability. The test used here was the most favorable for demonstrating an association. At least, the association suggests that the data may be measuring the same thing. Vegetational characteristics associated with summer vole signs and measured at the same time showed no relation to winter vole numbers, although thatch depth was correlated with summer vole signs. This somewhat contradictory finding may only mean that a well-developed thatch preserves runways, once they are established.

There was no measurable association between vole numbers in winter with the values for leaf analysis of 11 plant nutrients in the previous growing season, or with measurements of soil characteristics (including analyses of 10 plant nutrients).

The dead tree survey showed voles to be a relative important cause of tree death compared to other factors, but the suggested values for tree mortality rate seem to be less than some reports from growers. On the other hand, this survey took no account of trees that are off-color and obviously dying, and thus a continuing reminder to the grower that trees are being killed.

AN EXPERIMENTAL COMPARISON OF VOLE CONTROL METHODS

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This is a description of a new relatively long-term study of pine vole control under the North Carolina Agricultural Experiment Station. The objective is to evaluate on an experimental basis, the principal methods used to control vole populations and damage in apple orchards.

THE PROBLEM: Usually, practical control measures to reduce damage by pine voles have been limited to use of rodenticides, applied either in bait form or as a ground spray. On the other hand, some workers have maintained that removing the surface vegetation by cultivation and use of herbicides can provide either complete protection, or a general reduction in level of hazard. Such claims have been supported by observational studies. Control of voles by habitat manipulation would have certain advantages over the use of rodenticides; it would be environmentally more acceptable, reduce for the orchard worker the dangers in application of poisons for vole control, and possibly be less costly. We feel that there is need for a formal test on a relatively long-term basis, to explore how effective the practice of habitat manipulation may be in reducing vole damage and population levels.

THE EXPERIMENTAL PLAN: This experiment compares methods of reducing damage by voles either by use of rodenticides, or by habitat alterations, or by a combination of the two, through use of a randomized block design.

The field study areas, or blocks, are eight orchards in Henderson County, North Carolina. Each block contains four plots of approximately 2.5 acres each selected to be as nearly comparable as possible within that orchard. Data are recorded on a central area of about 0.9 acres. The remaining area outside of this central portion is a boundary or buffer zone that receives the same treatment. In most of the plots the trees range in age 8-18 years, and were planted at about 120 trees per acre. Figure 1 shows an idealized plot layout.

Within any one block, the four plots were randomly assigned treatments at the beginning of the experiment. The four treatments are grower option, rodenticide only, clean culture only, and combination of rodenticide and clean culture. Treatments are to be repeated over a number of years on the originally assigned plot.

The grower plot will serve as the closest thing to a control; whatever the grower does or does not do will be recorded as the treatment.

The rodenticide plot will receive a routine fall application of a rodenticide considered currently to be most desirable. We may be working with more than one rodenticide at a time but will use only one in any given plot.

The clean culture plot is to be maintained with clean ground under the trees, using cultivation and herbicides. Mowing will be done as we feel it is needed and standard herbicide applications will be made. We are not testing new herbicides.

The combination plot is under clean culture with rodenticides used here only when inspection shows that they are needed.

The equipment and materials used in field treatments are those used by growers. This equipment includes tractor, sprayers, sickle bar, bush hog and hedging blades such as are part of most orchard operations. Our records of time, materials and equipment used will provide cost figures for the treatments; we recognize this measurement of cost as important.

Results will be measured several ways. The number of damaged trees would be the most convincing variable in terms of usefulness of the treatment but we doubt that we have enough trees in our plots to distinguish any moderate difference between treatments as to the rate of tree damage and death. Vole activity, recorded both by probing for runways and by using the apple sign test, is being measured routinely at least three timings per year, in early fall, winter and summer. Vegetational cover is being measured once a year in mid-August as percent cover of grass, forbes and vines and as mean height under the trees and in the middles.

Analysis of the vole population by live-trapping, mark, and recapture is being undertaken at least twice per year, before and after the normal time for applying rodenticides in the fall. We are still considering two possibilities as to exact method. In the past we have used live-trapping in a grid pattern to determine survival rates but this method does not provide population estimates; at worst that method can be used. Second, however, we are currently developing a method for estimating population density as well as survival; this will be the method of choice if it provides sufficient information. In this second method the traps are set in cross lines (see Fig. 1) with trap numbers greatly reduced. As a result we will have a lower number of animals caught as compared to the grid method applied to the same plot. Breeding status and age will be recorded each time an animal is trapped.

Grower cooperation is essential to this type of investigation and we are fortunate in having good working relationships. Our association with the grower must remain voluntary on both sides; in two (rodenticide only and clean culture only) of the four plots in a block the grower has yielded to us, to a fractional degree, temporary control of his land, but clearly we cannot expect him to maintain this relationship contrary to his better judgement. On the other two plots, either the grower retains complete control, or the treatment (combination plot) applied is the best possible and its use is beneficial to him.

Although this study has a high manpower requirement, we are continuing to work with our IPOMS group on a study of integrated management of orchards.

As opportunity arises and time permits, we will continue with short-term field and laboratory tests on a one-treatment basis to answer practical questions about methods of application for labeled materials and provide ratings of efficacy for new materials as they are developed.

Trap locations within a plot

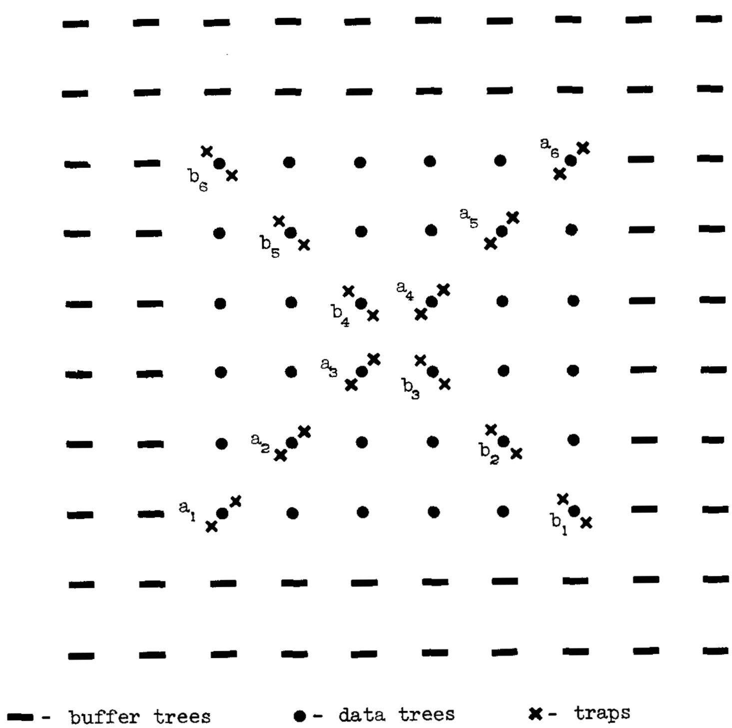

Fig. 1. Generalized view of a single plot, showing central trees where data are recorded, and buffer trees; treatments are applied over both the central data zone and the buffer zone.

EFFICACY DATA FOR BAITS PREPARED AS CANDIDATE ORCHARD VOLE CONTROL AGENTS

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I believe this audience is already well aware of the dilemma in New York State. We have suffered extensive damage from orchard mice over the past three years in New York with some growers losing their entire operation. The pine vole, Pitymys pinetorum, has assumed an important role as an orchard pest and in eastern New York easily surpasses the related meadow vole, Microtus pennsylvanicus as a significant orchard pest. A recent grower-funded economic survey, initiated by this Unit, and reported in a paper by Pearson and Forshey (1978) points up the severity of losses thru reduced quality and quantity of the apple crop.

Apparently, there is no quick or satisfactory answer to our problem in New York. We have tested a wide variety of experimental toxicants as well as certain ones that are available commercially. None of these materials has proved satisfactory in the hands of the growers nor have they been completely reliable in all of our experimental trials.

Today we would like to discuss results obtained from laboratory and field research conducted from 1975-1977 in the Hudson Valley of southeastern New York State. In making these preliminary results available for the public record we must face the inadvertant problem created for the grower, the supplier, the chemical company and even the research biologist that may occur when one reports findings of high efficacy for a mediocre or faulty product or low efficacy for a potentially sound chemical/management procedure.

Beginning in 1975 with financial support from the growers, chemical industry, the U.S. Department of the Interior and the college at Cornell we began an intensive screening program of several baits and bait preparations available to us. Our approach to screening a wide variety of candidate materials was to first test these in a laboratory situation with captive voles and ultimately categorize the effectiveness of the various combinations of toxicants and bait preparations into three general levels of efficacy (Table 1). We then proposed to take the materials and bait preparations that were most effective or showed considerable promise into the field and test them under field conditions on wild pine voles. The third step was to select from these preliminary field trials the three or four most promising treatments and expand the testing effort on these materials to a larger scale that included plots up to 3 acres in size and as many as 150 trees. From Table 1 we recognize that efficacy data obtained in laboratory testing is not the only reliable determinant of what should be examined further in a field situation. We did however, have initial concerns about acceptance of several baits that we had treated with a chemical toxicant and these notions needed evaluation first in a laboratory. Table 1 indicates those treatments which were judged to be most effective, only moderately effective or not effective in the laboratory cage environment. In most

TABLE 1. TREATMENTS WHICH WERE EFFECTIVE OR MODERATELY EFFECTIVE IN LABORATORY TESTING VERSUS THOSE NOT EFFECTIVE.

I. EFFECTIVE			
	ROZOL	MINERAL OIL	APPLES*
	ROZOL	MINERAL OIL	PEANUTS*
	ROZOL	TRACKING POWDER	APPLES*
	ROZOL	PARAFFINIZED PELLETS (LARGE)*	
II. MODERATELY EFFECTIVE			
	ROZOL	TRACKING POWDER	
III. NOT EFFECTIVE			
	ROZOL	MINERAL OIL	APPLES (LOW CONCENTRATION)
	ROZOL	MINERAL OIL	PEANUTS (LOW CONCENTRATION)
	ROZOL	TRACKING POWDER	PEANUTS
	ROZOL	PARAFFINIZED PELLETS (SMALL)	
	ROZOL	PARAFFINIZED BLOCK	
	RAMIK	PELLETS (SMALL)*	
	RAMIK	PELLETS (LARGE)*	
	ZnP_3		APPLES*
	ZnP_3		PEANUTS

*SELECTED FOR FIELD TESTING

instances an effective bait was one that killed 80% or more of the 10-15 voles within 5 days. Several of the Rozol preparations when applied to apples and raw peanuts were quite effective especially at higher concentrations. Among the many bait preparations judged not effective in the laboratory, the lack of efficacy was due in most cases to the failure of the voles to consume the toxic baits.

Table 2 lists the variety of materials and bait preparations that were taken into the orchard for testing. Included in these tests were

TABLE 2. MATERIALS SELECTED FOR FIELD TESTING.

ROZOL	MINERAL OIL	APPLES
ROZOL	MINERAL OIL	PEANUTS
ROZOL	TRACKING POWDER	APPLES
ROZOL	PARAFFINIZED PELLETS (LARGE)	
RAMIK	PELLETS (LARGE)	
RAMIK	PELLETS (SMALL)	
TETRACYCLINE (DMCT)		APPLES
ZnP_3		APPLES

four preparations of Rozol (chlorophacinone), two preparations of Ramik (diphacinone), one preparation of a broad spectrum antibiotic (tetracycline) that was intended as a marker substance due to its affinity for coloring the teeth and bones of mammals with a fluorescent material

(Crier 1970). And, finally, zinc phosphide powder applied to sliced apples. These seven candidate baits and the tetracycline were field tested in the following manner. An orchard block of 12 rows by 15 trees per row with a high infestation of pine voles was selected for testing. Each candidate material was then tested in a single row that included from 13-15 trees. Vole activity at each of the trees was determined by placing an apple slice under a tar paper cover and reexaming the apple slice after 24 hours (activity index). The post treatment evaluation of candidate materials was carried out in the same way with the addition of a trapping effort that consisted of two traps per tree checked for three days and nights.

The results obtained from this preliminary field screening were very encouraging. The initial activity index in most of the rows was 80% or more (Table 3). The post treatment evaluations that began either two or

TABLE 3. EFFECT OF HAND PLACEMENT OF LABORATORY AND COMMERCIALLY PREPARED BAITS ON PINE VOLES. THEW ORCHARD, ORANGE COUNTY, N.Y.

TREATMENT (1.)	# TREES PER ROW (2.)	PRETREATMENT % ACTIVITY	POST-TREATMENT TRAPOUT (#VOLES/ROW)	DATE
CONTROL	13	84.6	4	10/4 - 10/7/75
RAMIK LARGE	14	100	3	"
RAMIK SMALL	15	93.3	4	"
ROZOL	15	86.6	0	"
CONTROL	13	100	10	9/21 - 9/24/75
ZNP3 APPLE	15	60	1	"
TETRACYCLINE APPLE	15	86.6	1	"
ROZOL TRACKING PD. APPLE	13	100	1	"
ROZOL PEANUTS	15	80	0	"
ROZOL APPLE	14	100	3	"
CONTROL	15	93.3	14	9/9 - 9/12

(1.) ALL TREATMENTS STARTED SEPT. 9, 1975.
(2.) ACTIVITY DETERMINED AT 1 STATION PER TREE.

three weeks after treatment indicate a drastic reduction in the number of voles in each of the test rows. We recognize that this was a preliminary field screening of these materials and that we did not have sufficient buffer rows associated with each of the treatments. Nevertheless, there appeared to be a nearly complete decimation of the voles from all rows subjected to a toxic treatment. Two of the three control rows designated in this orchard maintained a high population of voles at the time of post treatment evaluation. Because buffer rows were inadequate in these tests it is possible that the voles in the third control row moved out of that row and into other rows where animals presumably had been killed by the toxic baits.

From this preliminary field test of the several baits we selected for further testing either those that were most promising as control agents or that were available to us from the supplier. These included Ramik (diphacinone) small pellets, applied at two concentrations; Rozol (chlorophacinone) both small and large pellets and Rozol prepared as a ground spray and tested on 7 plots. In addition to these rozol prepared as a ground spray was tested on five separate orchard plots.

Figure 1 shows a typical orchard block that was selected for the testing of each candidate material. A section of orchard including a

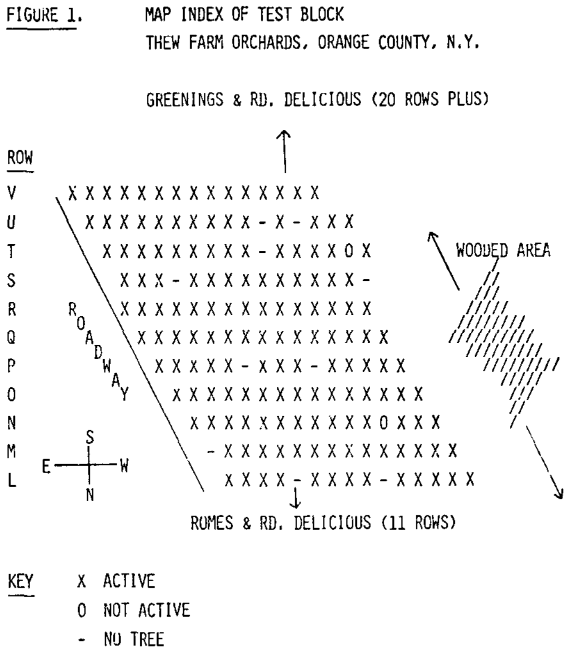

Fig. 1. Typical orchard block selected for field testing of candidate control agents.

block of trees approximately ten rows by 15 trees was treated with a single candidate preparation. Two pretreatment indices of vole activity were recorded before any test materials were applied. A plot within the 150 tree boundary with at least two buffer rows on each side and six buffer trees at the end of each row was apple indexed at two, three and five weeks post treatment. At the end of the five-week index each of the plots was trapped for three days with two traps per tree to remove remaining voles.

The most promising of all the candidate materials tested was ground-sprayed Rozol. This product seemed quite desirable from the standpoint that it could be mixed with water and applied to the orchard floor with a conventional speed-sprayer which practically all of the orchard owners possess. Unfortunately, Figs. 2 and 3 which show results from the seven separate orchards treated with the ground spray do not bear out the potential of this candidate material. In six of seven applications of Rozol as a ground spray the material was applied as recommended and allowed to dry on the vegetation for at least two days prior to any rainfall. In the seventh (Plot E) a light rain began approximately 2 hours after application. The rain continued unabated for the next 24 hours with a total rainfall during that period of 1.6 inches. As present we have no explanation for the apparent discrepancy or wide range of variation in the results obtained from this material. In plot G (Fig. 3) ground sprayed Rozol appeared to reduce the vole activity at

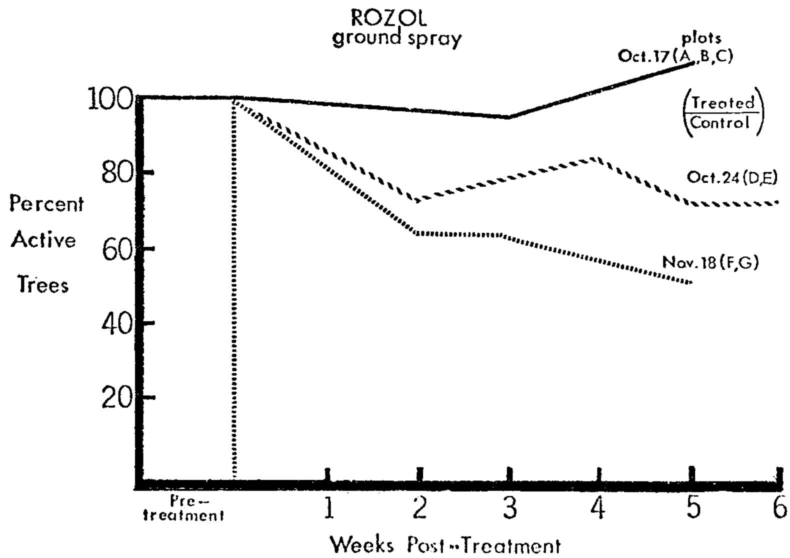

Fig. 2. Pine vole activity before and after treatment with ground sprayed Rozol.

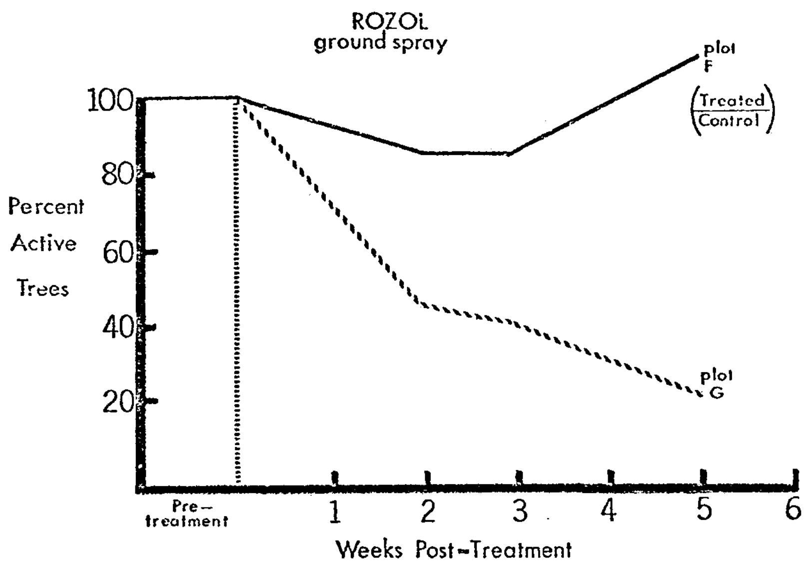

Fig. 3. Disparity in activity data following treatment with ground sprayed Rozol on paired plots treated on the same dates.

two weeks post treatment to approximately 50% of the initial activity index. At five weeks post treatment vole activity was reduced even further down to the 20% range. Spray plots A, B, C and F show absolutely no reduction in vole activity post treatment. The slight increase in activity above 100% is accounted for by the fact that activity in these plots is expressed as a percent of the activity in control plots of a similar size. Vole activity in plots D and E was reduced only moderately. At the end of two weeks the combined activity for the two plots was approximately 80% and at the end of five weeks the activity had declined to only 70% of the initial activity. On the basis of these results we conclude that ground sprayed Rozol is not a reliable control procedure when applied at concentrations recommended by the manufacturer in the conventional speed spraying apparatus.

Rozol incorporated into baits that could be hand-placed in the vole burrows or under tar paper bait stations was somewhat more effective. In four test plots selected and handled as previously described, Rozol pellets containing .005% chlorophacinone and packaged in small cellophane packets as well as larger pellets with the same concentration of active ingredient showed a reduction in vole activity after one week (Fig. 4).

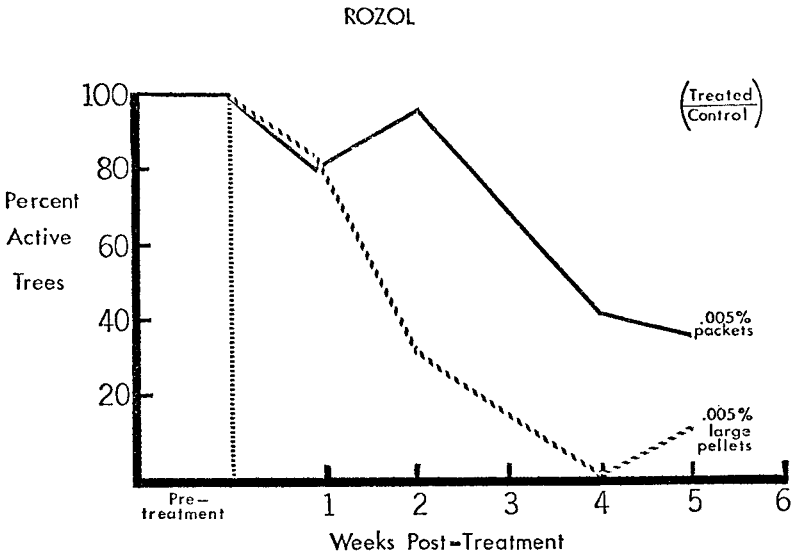

Fig. 4. Activity indices of plots treated with commercially prepared baits.

At two weeks there was some disparity in results but by four weeks both the Rozol packets and the Rozol large pellets had substantially reduced the vole activity in the orchards to 10 and 40% of the initial activity index. Activity indices run at five weeks post treatment indicated a continuing low level of vole activity.

In yet another orchard two formulations of Rozol small pellets were tested in orchards that had extremely high pine vole infestations and the results were even more promising. At the end of one week vole activity in both of these orchards had been reduced to less than 40% of initial activity. The decline in vole activity as measured by the activity index continued through the second, fourth and into the fifth week where vole activity approached 20% (Fig. 5). Here, as in other figures, activity in treated orchards is expressed as a percent of control activity.

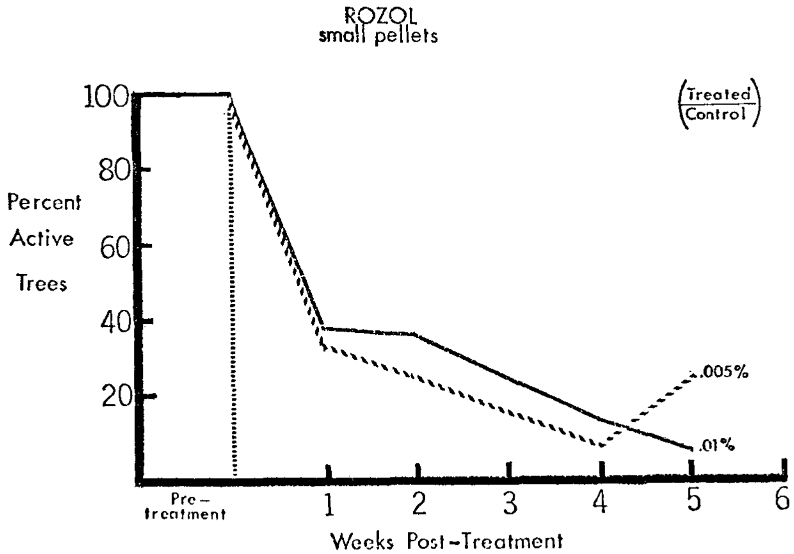

Fig. 5. Activity indices of plots treated with commercially prepared baits.

Figure 6 presents results from testing of Ramik (diphacinone) incorporated in small pellets and applied at the rate of 20 lbs. per acre in a single treatment, 10 lbs. per acre in a single treatment, and 10 lbs. per acre plus a second treatment of 10 lbs. per acre (10+10). Our interpretation of these results is that the 10+10 application is the most effective of the three application rates tested in this experiment.

The results presented here are encouraging but fail to point clearly to a control procedure that can be recommended for all orchardists in New York. Laboratory and field tests of these candidate materials confirm for us that control of pine voles can be achieved but to do so requires labor intensive and costly procedures. The testing procedures that we used were laborious and painstaking and likely cannot or would not be duplicated by the commercial grower. It is indeed unfortunate that ground-sprayed Rozol did not show clearcut efficacy. The apple growers are practically wedded to the speed spraying apparatus as a management procedure. The development of a rodent control material that could be applied with a speed sprayer would be a very practical end to achieve.

Currently we are funded by the U.S. Department of Interior and the College of Agriculture and Life Sciences at Cornell to pursue alternative control research. We anticipate additional funding from the

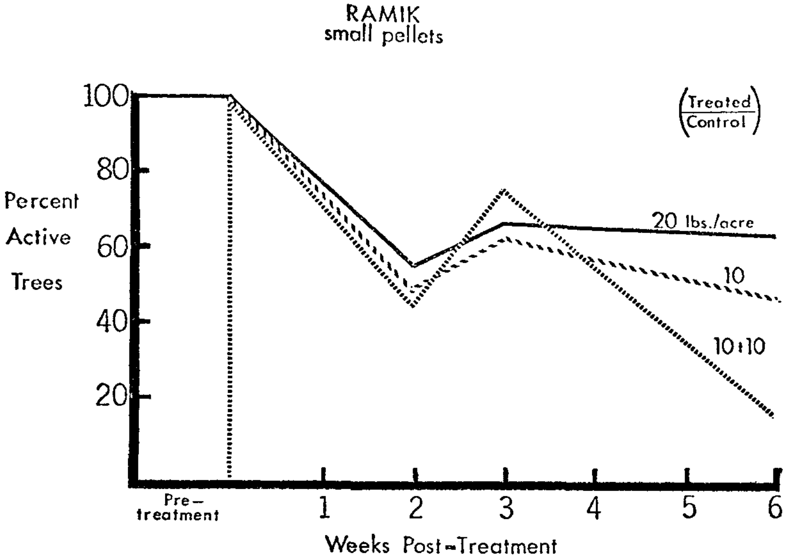

Fig. 6. Activity indices of three plots treated with commercially prepared baits.

Department of Interior and perhaps from the college. At present we are participating in an effort to monitor the efficacy of ground-sprayed endrin which was applied to many of the orchards in the Hudson Valley in the fall of 1977. Endrin was released to the growers for mouse control on an emergency basis this past fall because of the substantial increase in pine vole damage and the lack of other kinds of adequate rodent control procedures. We have recently added a research technician to our staff who will be stationed at the Highland Fruit Lab and will spend full time assisting in the design and completion of research work aimed at pine mouse control. Our research unit is approximately 150 miles from the key damage area so we are pleased to add a research person who can be located near the heart of the problem. In the coming year we expect to be in a position to test any new control chemicals or management procedures which show possibility in managing orchard rodent pests. Currently we are working with ideas that involve vegetation management of the orchard floor. It appears that the orchardist in managing for an abundant and high quality apple crop is inadvertantly encouraging reproduction and survival of the pine vole. Through vegetation management or habitat manipulation there is a possibility of achieving a type of biological control that not only will alleviate the problem but perhaps point the way to inexpensive and more efficient methods for managing the orchard environment. Details of our work presented at this meeting that appear to be relevent to the planning or pursuit of a research project are available from the New York Cooperative Wildlife Research Unit. You may review copies of our data, field procedures and analytical methods simply by writing to the authors at the New York Cooperative Wildlife Research Unit, Department of Natural Resources, Cornell University, Ithaca, N.Y. 14853.

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RECENT VOLE RESEARCH IN NEW YORK'S HUDSON VALLEY

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During fall, 1977, four potential chemical methods for controlling pine voles (Pitymys pinetorum) were evaluated on 12, one hectare plots in three apple orchards in the lower Hudson River valley. Each plot consisted of 45 trees. Three plots were treated with endrin, applied at the recommended rate of 1.5 lbs. per acre; two were treated with 2% technical Vacor (RH 787), applied in an unpelletized meal formulation at a rate of 60-70 gms per tree; two received 10% Vacor in an egg-sugar mix (marketed for human consumption as "Marshmallow Fluff") applied at the rate of 5-10 grams per tree; two received Vydate, a systemic nematocide highly toxic to rodents, at the maximum recommended rate of 15 lbs/acre; and three served as controls. Prior to treatment, all plots were sampled by live trapping and use of an apple index to determine the presence and abundance of pine voles and meadow voles (Microtus pennslyvanicus).

Following treatment on November 16-18, the plots were re-examined on the 6th, 12th, and 30th days post-treatment. Vydate and Vacor (unpelletized and in Fluff) provided little or no control. Endrin was effective on one plot (80% of the trees active before treatment were inactive following treatment) but achieved only partial or no control on the other two plots. Further post-treatment surveys of these plots will be carried out during spring, 1978.

In a second study, pine vole distribution and abundance in abandoned orchards was investigated. We and others have noted that if an orchard is abandoned pine voles rapidly disappear and meadow voles become more abundant as the grass grows longer providing the cover they require. Furthermore, in active orchards we rarely find pine voles and meadow voles coexisting in close proximity. These observations coupled with other preliminary evidence suggest that in habitats providing the food and cover requirements of both species, meadow voles, which are nearly twice as large as pine voles, may be able to exclude pine voles. If this is true it might be possible to manage active orchards in order to favor the immigration of meadow voles, a species posing considerably less threat to apple trees than pine voles.

A first step in evaluating the use of meadow voles to control pine voles was to determine whether pine voles actually do decline in abandoned orchards. Five abandoned orchards were trapped for pine voles. For each orchard there was evidence that pine voles had been present prior to the orchard's abandonment. This evidence consisted of subsurface girdling of trees, remnants of subsurface tunnel systems, and information supplied by growers. No pine voles were found in any of the orchards; all contained numerous meadow voles. Further investigations of the possibility of using meadow voles and habitat manipulation to control pine voles will be conducted during 1978.

PINE VOLE CONTROL STUDIES IN VIRGINIA - 1977

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ABSTRACT: Hand placed baits of Rozol (Chlorophacinone, CPN), Ramik-Brown (Diphacinone, DPN), and Talon (Brodifacoum, BFC) gave excellent control of pine voles in 1977. Vacor (RH 787) did not give adequate control when a meal preparation was hand placed at 10 lbs/A.

Talon and Rozol broadcast at 25 and 22 lbs/A, respectively, gave 100% and 96% control of pine voles. Five lbs/A of hand placed Talon gave equivalent control. A second broadcast experiment of LM 637, Rozol and Talon at 15 lbs/A each was followed by rain the next day but gave 21%, 66%, and 93% control, respectively.

Ground cover spray of BFC at 5.1 g/ha (or 7.5 g/treated ha) was insufficient for good control and higher rates would be required. A deodorized kerosene formulation of CPN plus a sticker was compared to the Xylene-formulation presently used by the industry for ground cover sprays. Relatively poor control was obtained with both formulations.

INTRODUCTION: The performance of new ground sprays and baits for pine vole control need year to year evaluation under field conditions so that a good understanding of many environmental variables, resistance development, and product quality control will result in more reliable recommendations.

Any damage control method, must meet certain criteria before it can be implemented, such as: 1) economically practical, 2) elimination of damage under most orchard and weather conditions, 3) rapid treatment of large acreages with a minimum of labor power, and equipment, 4) minimum hazard to non-target species, 5) clearance by government agencies if the method is under federal or state control.

Toxic baits and ground sprays have met, to a certain extent, all of the above criteria in the past, and remain the best possible control method for the immediate future. However, any method which would eliminate the need for government clearance will be of great value to the fruit industry.

We have studied rootstock resistance (2) and cultural changes (3) as well as other alternatives to toxic chemicals. Since these methods have not adequately met the first 3 criteria, they will be covered in other papers.

METHODS AND MATERIALS FOR PINE VOLE EXPERIMENTS: Evaluation of pine vole control plots was determined using methods previously described (1,5,6). Randomized complete block designs were used in pine vole experiments which were statistically analyzed. Orchards used for experiments in Table 1, Table 2, Table 3, Table 4, Table 5, and Table 6 had approx. 38, 38, 36, 60, 60, and 80 trees/acre, respectively. All plantings were mature orchards in the vicinity of Winchester, Virginia in the age range of 25-40 years. All experiments utilized 24 sites per plot with 2 sites/tree, except one experiment (Table 6). In this experiment, the 24 sites per plot were established with 1 site/tree.

In addition to pine vole studies, a meadow vole experiment was conducted near Vincennes, Indiana, in a 3-year-old orchard planted 10 ft X 20 ft. The trees were cultivated 2 m wide in a tree line strip the previous spring and summer causing voles to reside in the middles. The orchard block consisted of 48 tree rows crossected by 2 crossroads at 28 tree intervals. Each plot consisted of 7 rows wide (6 middles) X 28 trees long. Twenty four sites were established per plot on top of the soil, about 3 ft from the trunk, adjacent to the cultivated strip and in a meadow vole runway at each of 24 interior trees which were in the center row of each plot. Since the voles might invade adjoining plots in a longitudinal fashion, because of the nature of the cultivated strips, plots were not arranged in a standard experimental design. Rather, plots were arranged so that treatments were joined on the end by the same treatment so that invasions of voles would be a remote possibility. Therefore, plots 1-3; 4-6; 7-9; 10-12; 16-18; 19-20; and 22-23 were treated with the same broadcast treatments (Table 1). Plots 13, 14, and 15 were treated with a single hand placed application of Ramik, Rozol, and Talon, respectively, on November 12. In addition, to identify the species, plot #13 was trapped October 21-26 and 37 meadow voles were caught. By November 3, meadow voles from border rows of plot #13 sufficiently invaded this plot so that it could be treated on November 12.

RESULTS OF PINE VOLE EXPERIMENTS: Hand placement of Ramik-Brown, Rozol, and Talon in a heavy pine vole population gave excellent control (Table 1). The treatments were applied just prior to a misty and light rain period which could have greatly affected control. Baits were placed in runways under shingles and excellent control was achieved. Talon at 5 lbs/A appeared to be the most effective treatment but statistical differences between the 3 materials were not detectable.

In the same orchard, two plots of Vacor 2% meal bait was not adequate to control pine voles (Table 2). Previous experiments with pelletized Vacor also has failed to give adequate control (1,3). However, a number of experiments with a 1% apple cube bait have given outstanding control (1,3,4). I therefore believe that a more acceptable formulation will be required.

Since broadcast treatments of anticoagulant bait may greatly reduce application costs, skilled labor requirements, reduce total treatment time of large acreages, and may reduce hazards to non-target species, Talon and Rozol were applied with a commercial fertilizer spreader to the tree line strip (Table 3). Application rates are expressed as lbs/acre of orchard. Since only 2/3 of the orchard floor was actually treated in these experiments, the rate/treated area (tree line strip) was 50% greater than that listed in the table. Outstanding control was achieved with the broadcast treatments of Talon and Rozol. This orchard had been previously treated with anticoagulants for 3 years and Ramik-Brown in two hand placed applications gave excellent control.

Table 1. Effect of hand placed anticoagulant baits on pine vole activity and population treated Oct. 14, 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Oct 13	% Activity[z] Oct 21	% Activity[z] Oct 28	Voles/plot (Oct 30-Nov 4)	Voles/site	% Control
Control	3	--	--	83 a[y]	80 a	72 a	47 a	2.54 a	0
Ramik-Brown 0.005% DPN	3	11.2	10	79 a	27 b	11 b	3 b	0.14 b	94
Rozol 0.005% CPN	3	11.2	10	80 a	23 b	15 b	3 b	0.14 b	94
Talon 0.005% BFC	3	5.6	5	83 a	20 b	1 b	0.3 b	0.01 b	99

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

Table 2. Effect of Vacor on pine vole activity treated Oct. 21, 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Oct 21	% Activity[z] Oct 28	Voles/plot (Oct 30-Nov 4)	Voles/site	% Control
Control	2	--	--	76	67	40	1.65	0
Vacor 2% RH 787	2	11.2	10	83.5	46	13	0.55	67

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

Table 3. Effect of broadcast and hand placed anticoagulants on pine vole activity and populations 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	Date treated	% Activity[z] Oct 28	% Activity[z] Nov 29	% Activity[z] Dec 2	Voles/plot (Dec 6-13)	Voles/site	% Control
Control	3	--	--	--	93 a[y]	63 a	72 a	18 a	0.75 a	0
Talon-Hand placed	3	5.6	5	Nov 11	90 a	10 bc	7 bc	1 b	0.04 b	95
Talon-Broadcast	3	28	25	Nov 11	93 a	14 bc	7 bc	0 b	0.00 b	100
Rozol-Broadcast 0.005% CPN	3	26	22	Nov 11	93 a	8 c	0 c	1 b	0.03 b	96
Ramik-Hand placed 0.005% DPN	3	11.2 11.2	10 10	Nov 9 Nov 18	94 a	26 b	15 b	2 b	0.07 b	91

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

Table 4. Effect of Brodifacoum ground-cover spray on pine vole activity and population treated Nov. 15, 1977.

Treatment	No. of plots	Rate g/ha	% Activity[z] Nov 11	% Activity[z] Dec 2	Voles/plot (Dec 6-13)	Voles/site	% Control
Control	1	-	96	75	21	0.88	0
BFC	1	1	100	88	31	1.29	-
BFC	1	2.5	100	86	26	1.08	-
BFC	1	5.1	100	63	11	0.46	48

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunks were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

Ground spray applications of Brodifacoum (BFC) and Chlorophacinone (CPN) were conducted in the same orchard block (Table 4 and 5). Plots used for the Brodifacoum experiment (Table 4) were probably more uniform and heavier in population than in the Chlorophacinone experiment (Table 5). The CPN formulations were applied on November 14 and the BFC on November 15, 1977. Mist and rain occurred November 17 and 18, 1977, and much of the next two weeks were also wet. The BFC at 5.1 g/ha (0.01 lbs/A) was approximately equivalent to CPN at 0.22 g/ha (0.2 lbs/A).

Broadcast treatments of LM 637, Rozol, and Talon were applied December 13, 1977 just before a rainy period on December 14, 1977 (Table 6). Examination of bait in the plots on December 15 indicated that the bait had become very wet and appeared to be unacceptable to the voles. In spite of the severe weather conditions the Talon performed pretty well and the Rozol did not. A wide variation in activity existed between plots with both the Rozol (83%, 83% and 0%) and Talon (42, 0, 8). This great variation is probably related to differences in activity of voles in various sections of the orchard during the first 24 hour period which may have been due to terrain, tunnel system development (surface vs deep), or ground cover differences. In any case, the broadcasting of pelletted bait is probably much more dependent on good weather conditions for vole activity in the upper runway systems, than hand placement in runs and holes. With hand placement, large quantities of bait may be found by the voles and relocated in the first 24 hours. Broadcast baits may not be found as quickly by animals and sufficient quantities must be sought out and accumulated before weathering occurs.

The broadcast bait method has many advantages over hand placement of bait and/or ground cover sprays. Broadcasting of bait is more rapid, requires less costly equipment, less labor, easier calibration and may be less costly.

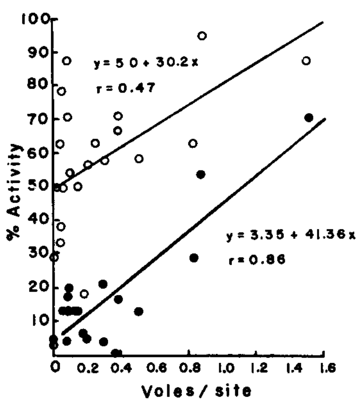

Figure 1. Linear regression of % active sites (o) and highly active sites (●) on voles/site in 23 plots.

Table 5. Effect of Chlorophacinone ground-cover sprays on pine vole activity and populations treated Nov. 14, 1977.

Treatment	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Nov 11	% Activity[z] Dec 2	Voles/plot (Dec 6-13)	Voles/ site	% Control
Control	3	--	--	83 a[y]	68 a	15.3 a	0.64 a	0
CPN-Xylene formulation	3	0.22	0.20	87 a	31 b	4.6 b	0.19 b	70
CPN-Deodorized Kerosene formulation Witco (775) 1/2 pt/100 gal.	3	0.22	0.20	83 a	38 b	7.6 b	0.32 b	50

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

Table 6. Effect of broadcast anticoagulant baits on pine vole activity treated Dec. 13, 1977.

Treatment[w]	No. of plots	Rate kg/ha	Rate lbs/A	% Activity[z] Dec 2	% Activity[z] Dec 30	Estimated[x] Voles/site	% Control
Control	3	--	--	96 a[y]	88 a	1.65	0
LM 637	3	16.8	15	92 a	79 a	1.30	21
Rozol-CPN	3	16.8	15	92 a	55 ab	0.73	66
Talon-BFC	3	16.8	15	92 a	17 b	0.12	93

[z] Apples placed in 2 holes or runs 5-15 cm below the soil surface on opposite sides of the tree trunk were examined 24 hrs. after placement. Percent activity refers to all sites with vole tooth marks on the apple.

[y] Mean separation, within columns by Duncan's multiple range test, 5%.

[x] Vole population was estimated from regression curve from 1975 and 1976 data (Byers 1978).

[w] Rain occurred on Dec. 14 which caused all baits to deteriorate.

MEADOW VOLE EXPERIMENT: The apple activity test, used in pine vole studies (1,2), was adapted for use on meadow voles (Figure 1, Table 7). An apple with a 3-4 cm slice removed from the apple was placed in a runway and covered with a shingle. After 24 hours the apples were checked for vole tooth marks and recorded as highly or slightly active Percent high activity referred to the percent of apples having a portion larger than a semisphere of 2.5 cm (approx 2.5 g) removed by the voles. Percent activity referred to percent of apples with vole tooth marks. Only % high activity should be presented (Table 7) since it is much better correlated to the vole populations at trap out ($r = 0.87$, $y = 3.35 + 41.36 x$, Figure 1) than % activity ($r = 0.47$, $y = 50 + 30.2 x$, Figure 1). The quadratic regressions were not significant. I believe the reason % activity was not well correlated was because meadow voles are known to range over a large area and will feed to some extent at each monitor site. Therefore, % activity readings for meadow voles may be unusually high even though very low populations actually exist. Since % high activity was dependent on consumption of at least 2.5 g of apple at each site, a better correlation with population was obtained. In addition, I believe weights of apple consumption may give a better correlation with population than this estimate; however, weighing each apple may not be practical when large numbers of plots and sites are to be evaluated. The number of sites per hectare acre may also be important to standardize, since populations of meadow voles may overlap a number of monitor sites. However, this may be difficult because of the great variation in tree numbers per ha, and orchard design from experiment to experiment. In previous pine vole experiments, two sites per tree were established when tree populations were below 70 trees per acre, and one site per tree above about 80 trees per acre (1). This site spacing we believe has allowed population overlap of approx 2 monitor sites in a 24 hour period. Meadow vole overlap may involve many more sites when they are closely spaced; and even a very small population in the vicinity of a monitor site may be detected. In addition, dropped apples in bearing orchard experiments would probably lower visitation and feeding at monitor sites and thus different correlations would be expected compared to a non-bearing orchard situation.

The first 13.4 kg/ha (12 lb/A) broadcast treatment (October) appeared to reduce the % high activity in all of the treated plots, however, a heavy population still appeared to be present as indicated from activity records of November 3 and November 10. For this reason, a second application of baits was applied November 12 at the same rate per acre; untreated plots 13, 14, and 15 were treated November 12 by hand placing baits in runways at the rates indicated (Table 7).

A greater effect from the second application was suspected and may have been the result of a number of low temperature freezes occurring between the first application and the second application and/or the possible accumulation of anticoagulant in the animals. The single hand placed applications of DPN, CPN, and BFC appeared to have given excellent control. However, trail baiting for meadow voles may not be advisable unless sites are covered with some type of site cover to reduce hazard to dogs, cats or other non-target species. This type hazard is much less for pine voles since baits are placed in underground holes and runways and are removed by voles to underground caches.

Table 7. Effect of anticoagulant baits on meadow vole activity and populations.

Treatment	Plot No.		% High activity[zx] Oct 20	Nov 3	Nov 10	Nov 26	Voles/plot[z] (Dec 1-5,1977)	Voles/site[zy] (Dec 1-5,1977)	% Vole control[z]
Control - no treatment	1		83	83	83	71	36	1.50	-
	2		42	42	58	29	20	0.83	-
	3		50	79	71	54	19	0.79	-
		AV	58	68	71	51	25 ± 16	1.04 ± 0.63	0.0
		UL	92	97	90	83			
		LL	21	28	48	19			
Ramik-Brown (DPN)	4		29	29	29	4	6	0.25	77
Broadcast	5		63	33	21	7	9	0.38	65
13.4 kg/ha Oct 22	6		79	21	25	0	9	0.38	65
13.4 kg/ha Nov 12	22		29	33	29	5	4	0.19	82
	23		59	29	53	6	3	0.18	83
		AV	52	29	31	6	6.2 ± 2.6	0.28 ± 0.09	74
		UL	73	34	43	13			83
		LL	30	25	21	1			66
Rozol (CPN)	10		67	42	25	17	2	0.08	93
Broadcast	11		58	63	54	13	2	0.08	93
13.4 kg/ha Oct 22	12		67	42	67	0	3	0.13	88
13.4 kg/ha Nov 12	19		88	29	33	13	1	0.04	96
	20		67	17	42	13	12	0.50	53
	21		46	13	33	13	2	0.08	93
		AV	66	34	42	12	3.7 ± 3.4	0.15 ± 0.14	86
		UL	78	50	55	18			97
		LL	55	18	28	4			76
Talon (BFC)	7		79	29	21	4	0	0.00	100
Broadcast	8		29	25	38	13	1	0.04	96
13.4 kg/ha Oct 22	9		29	29	13	4	1	0.04	96
13.4 kg/ha Nov 12	16		33	8	25	0	0	0.00	100
	17		43	24	57	19	2	0.09	92
	18		83	42	54	21	6	0.25	77
		AV	49	26	35	10	1.7 ± 1.9	0.07 ± 0.08	93
		UL	72	36	48	17			100
		LL	28	15	19	2			88
Hand Placed									
Ramik-Brown (DPN) 11.2 kg/ha Nov 12	13[w]		38	38	21	4	3	0.14	87
Rozol (DPN) 11.2 kg/ha Nov 12	14		38	54	54	13	3	0.14	87
Talon (BFC) 5.4 kg/ha Nov 12	15		33	42	29	0	0	0.00	100

[z] Confidence interval, 90%, determined within columns within treatments. Percent data was transformed to arc sin before upper (UL) and lower (LL) limits were determined.

[y] One site was established per tree by placing an apple in an active runway and covering with a shingle. All plots contained 24 sites except plots 22, 23, and 17 which had 21, 17, and 21 sites, respectively.

[x] Refers to the % of sites having apple consumption greater than a semi-sphere of 2.5 cm.

[w] Plot #13 was dead trapped Oct 21-26 and 37 meadow voles were caught. Invasion from border rows was sufficient by Nov 3 to use as a test plot on Nov 12.

Table 8. Penned pine voles treated with a ground cover spray of Chlorophacinone (CPN) at 0.3 lbs/treated area.

Treatment[x]	Mortality after 14 days
Experiment # 1	
CPN sprayed grass[y] + unsprayed soil	6/8
CPN sprayed soil[z] + unsprayed grass	4/8
Experiment # 2	
CPN sprayed soil[z] + CPN sprayed grass[y]	10/10
No treatment	3/10

[z] Pine voles were allowed to establish runway systems under boards in pens. Boards were removed and trail systems sprayed and boards replaced prior to introduction of animals 1 hour after spraying.

[y] Orchard grass was sprayed in an orchard, allowed to dry, dug, and placed in the feeder box.

[x] Feeders, water bottles, and apples were supplied in addition to grass.

PENNED PINE VOLE EXPERIMENT: Two 3/8 inch hardware cloth wire enclosures were made for testing groundcover spray effects on pine vole populations. Pens were 9 ft X 3.3 ft each and extended 1.5 ft below and 2.5 ft above the soil surface. Animals were allowed 10 days or more to establish tunnels and acclimate to feeding box, water, apples, etc. Voles were live trapped over a 2 day period prior to treatment and returned 1 hour after treatment. During the acclimation period voles did not get along well and some loss was always experienced. The loss of 3 animals in the untreated control over a 14 day period tended to negate these tests (Table 8). However, it did appear in the first experiment that spraying the runways was about as effective as spraying the grass only. In the second experiment all animals were killed when soil and orchard grass were sprayed. I was not happy with the losses of animals in these penned experiments, and some method changes would be necessary to obtain good results. These preliminary results suggest however that contamination of both the runway system and the food supply is important to get the toxicant to the animal as was suggested by Horsfall in 1956 (7).

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TANK TEST METHOD FOR DETERMINING ROOTSTOCK RESISTANCE TO PINE VOLE ATTACK

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ABSTRACT: Pine vole attack of one-year-old stem tissue of clones representing many hybrid and other species revealed 5 cultivars apparently less susceptible to damage when compared to Golden Delicious stems. Fusca seemed to be least attacked along with 74R5M9-62, PI 286613, N.Y. 11928, and Hall.

INTRODUCTION: Several methods of pine vole control have been used by growers in the Central-Eastern United States. For the past 15-20 years Endrin was used as a ground spray to control pine voles (4 & 5). However, where Endrin has been continuously used for over 10 years, resistant strains of mice have developed thus decreasing its effectiveness (2). In recent years anticoagulant baits have been used to control these resistant voles.

The development of new and effective rodenticides, that are also environmentally safe, has been an expensive and long term project. Many chemical companies faced with tighter federal registration laws and increased expenses are becoming more reluctant to invest money in the development of rodenticides (6).

Cultural management practices have not proven adequate for controlling the pine vole problem,& are expensive in terms of labor, energy, and machinery. Even though combinations of cultural and toxicant control methods have been found to be effective for vole control (2), the additional expense for cultural changes may be questionable.

New methods must be developed to control vole damage during periods when the grower cannot bait or spray (ie under snow). The development of rootstocks resistant to damage could greatly reduce the severity of the vole problem. Some rootstocks have been observed by Horticulturists to have vole damage differences. We have developed a screening technique for potentially resistant rootstocks.

MATERIALS & METHODS: Most of the cultivars used in these experiments were provided by Dr. Cummins at the Geneva Research Station in Geneva, N.Y. The material was collected and shipped while still fully dormant during the winter months (January - March) of 1977 and 1978 to

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Winchester, Va. Golden Delicious scions collected in the Winchester area, were used in a paired comparison tank test with the wood sent from Geneva.

The animals were adult pine voles trapped in the Winchester area and some juveniles raised in cages. Twenty mice were selected for each experiment, however, by the end of the period some animals were usually killed (2-5) in fighting. The tank was 6 feet in diameter with a circular partition in the center, 4 ft in diameter. Six inches of sandy loam soil mixed with oak bark mulch was put in the tank. The animals were then placed in the tank center partitioned area. In 1977, burlap strips were offered for bedding and in 1978 orchard grass and natural ground cover was used. The tank was insulated to keep the temperature at 20 $\pm$ 2° C. It was also covered and kept in total darkness. The animals were offered water and commercial rat food ("Lab-Blox", Allied Mills, Inc., Chicago, Illinois) continuously throughout all experiments. There were 19 single-stem replications with the wood arranged in blocks equally spaced in the outer 12 inch circumference of the tank. The stems were placed in 4 inch floral tubes containing water to prevent the material from drying during the test. The wood ranged from 0.15 - 1.01 cm in diameter and 15-17 cm long taken from 1 year-old-wood. The floral tube was placed in the soil allowing approximately 10 cm of the stem to remain above ground and exposed to the voles. The holes in the partition were opened to allow the animals access to the wood. They were exposed to the wood for varying lengths of time, mostly 72 and 96 hrs. After this period the wood was removed and rated by a 0-4 damage rating: 0 = no damage, 1 = less than half girdled, 2 = 1/2 girdled or more, 3 = completely girdled, 4 = cut into at least two pieces (3), and a subjective measure of the % bark removed was also recorded.

RESULTS AND DISCUSSION: The rootstock Fusca has been rejected by the voles in 2 test years (1977, 1978, Table 1 and 2). A Japanese rootstock M. X sublobata PI 286613, Hall, and N.Y. 11928 also turned out significant in 1977 (Table 1).

Varying diameters of the wood was found to influence test results. This problem was reduced with the extraction of the diameter covarient in 1977 (Table 1) and eliminated by the use of paired comparison testing with similar diameter wood in 1978 (Table 2).

We felt the tank test used in the 1977 and 1978 experiments had certain advantages to caged trials (1) such as: 1) pine voles were placed in a more natural environment, 2) animal to animal variation was removed because all wood in an experiment was subject to exposure to all animals in the tank, 3) less wood is used, 4) more varieties and types can be tested at one time. The paired comparison testing in the 1978 trials removed to a large degree problems with the diameter factor and is the preferred method at this time.

Table 1. Damage to apple rootstock stems by pine voles in a 72 hr. tank trial, using 'Golden Delicious' as a standard.

Rootstock	Adjusted Damage (%)[y]		Adjusted Damage Rating (0-4)[x]	
PI 286613	14	a[z]	1.1	a
NY 11928	15	a	1.2	a
Hall	18	ab	1.4	ab
Fusca	26	ab	1.7	abc
PK 14	35	bc	2.1	bcd
Golden Delicious (f)[w]	44	c	2.4	cd
Rink 752	46	c	2.5	d
Control	47	c	2.5	d
Parwar	50	c	2.6	d

[z] Mean separation, within columns by Duncan's multiple range test, 5%.

[y] Percentage arc sin transformed means presented were adjusted for wood diameter covarient. Percentages were an estimation of bark stripped from stem pieces.

[x] Damage rating: 0 = no damage, 1 = less than 1/2 girdled, 2 = 1/2 girdled or more, 3 = completely girdled, 4 = cut into at least two pieces. Means presented were adjusted for wood diameter covarient.

[w] Golden Delicious stems were allowed to absorb a 50:1 formaldehyde: water solution from the cut base for 72 hrs.

Table 2. Damage to apple rootstock stems by pine voles in a 96 hr. tank trial, using 'Golden Delicious' apple as a standard in paired comparison.

	Diameter			Damage (%)[z]			Damage Rating (0-4)[y]		
Rootstock	Rootstock	Golden Delicious		Rootstock	Golden Delicious		Rootstock	Golden Delicious	
74R5M9-14	.148	.150	ns	15	23	ns	1.5	2.2	*
74R5M9-56	.082	.087	**	32	79	**	2.1	3.5	**
Rob-5	.127	.126	ns	18	45	*	1.7	2.7	**
74R5M9-62	.133	.135	ns	7	22	**	1.2	2.2	**
74R5M9-57	.142	.143	ns	69	30	++	2.6	2.2	+
74R5M9-89	.115	.114	ns	41	55	ns	2.2	2.7	*
Fusca	.111	.112	ns	5	48	**	1.1	2.5	**
Parwar	.170	.171	ns	59	18	++	2.3	1.7	+

*,** Plant material was less susceptible to pine vole attack in comparison with Golden Delicious, t test at 5% and 1%.

+,++ Plant material was more susceptible to pine vole attack in comparison with Golden Delicious, t test at 5% and 1%.

[z] Estimated percentage of bark stripped from stem pieces.

[y] Damage rating: 0 = no damage, 1 = less than 1/2 girdled, 2 = 1/2 girdled or more, 3 = completely girdled, 4 = cut into at least two pieces.

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HERBACEOUS COVER SPRAY OF CHLOROPHACINONE FOR MEADOW MICE CONTROL IN APPLE ORCHARDS

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ABSTRACT: Very effective control of the short-tailed meadow mice (Microtus spp.) was obtained by means of grass and weed spraying in two orchards with Chlorophacinone. This toxin was applied in one orchard with a boom-type tractor sprayer and in another orchard with a hand-gun nozzle operated from the tractor manually. The anti-coagulant rodenticide in each orchard was mixed in spray tanks at the rate of one pint per 100 gallons water. Spray was directed to an area two feet on each side of apple tree rows applying six pints of the concentrate per treated acre. A five-foot strip of dense grassy area bordering the orchards was also sprayed to prevent mouse invasion. We found no injurious affect to wildlife or domestic animals that were in the vacinity of orchards following toxicant treatment.

INTRODUCTION: The short-tailed meadow mouse causes considerabe damage to fruit trees throughout the orchard regions of Washington. Mice gnaw and peel the bark from trunks and roots of trees at or just below the ground line. Mouse injury can weaken trees while also serving as points of infection of various root rot diseases. When severly girdled, the trees die unless bridge-grafted.

This species of mice is medium-size, stout (1.5-2.0 ounces) with small, black, beadlike eyes and small, fur-covered ears. An important designating feature is its short tail (1/3 of head and body length) which is covered with hair. The feet do not have black guard hairs.

We find very significant differences in the palitability of fruit tree bark to the short-tailed meadow mice. Young apple trees are preferred over all over fruits. Pear is much less acceptable than apple, but preferred over stone fruits. Peach and, in some instances, cherry trees can be attacked while apricot, plum and prune are rarely fed on.

The volume of bark and trunk is important. In contrast to large, mature trees, a young tree has only a limited amount of bark, and a few mice can readily girdle. Meadow mice prefer the relatively soft and susceptible young or inner bark. Thus, older trees with heavy, thick bark are less susceptible to serious injury or loss.

HABITAT: In orchards, mice runways tend to be concentrated more heavily under the drip line of the trees. In hedge-row plantings, they extend up and down the row. Nests are often located near or close to the trunk of the tree. Rarely are the various colonies well-distributed in or near the orchard. They are more common or frequent where the soil is deep, fertile, well covered with grass and weeds and well drained. Activity is evident by small piles of brownish droppings and short grass clippings scattered along the path under the canopy of the cover. The freshness of these droppings and clippings is indicative of recent activity. How closely the vegetation along the sides of these paths is clipped as well as the width of the path is a fair indication of the presence of mice and population numbers.

The failure to find evidence of much activity in these runways requires some interpretation. This may be the result of a heavy mouse kill, or indication that mice have abandoned the area or path. Regardless, once established, this network may be readily re-invaded and worked.

The meadow mouse in Washington orchards lives in an environment just below or above the soil surface. Here it forms an extensive network of runways. It feeds on the succulent stems and roots of grasses, legumes, and weeds above these paths. It nests just below the soil surface, in dense cover, often at the base of trees where there is little disturbance and good protection from its natural enemies: hawks, owls, shrikes, snakes, badgers, coyotes and skunks.

Its enormous appetite combined with prolific breeding causes much of the problem. Each mouse may eat its weight in forage daily. It can produce as many as eight to ten litters per year with an average of six and up to eleven young per litter. The new females become sexually mature and can begin breeding at just four weeks of age.

We observe that mouse populations are eradic both within and between years. Their number is lowest in the spring and highest in the fall. Peaks in population occur approximately every four years in Washington state. These peaks and the ability to multiply so rapidly have often been misinterpreted as a migration of heavy mouse populations into the orchard. While such migrations do occur, they are usually of only limited distance from around or within the orchard.

SELECTION OF PLOTS: Two five-year-old semi-dwarfed apply orchards with mice activity were selected for Chlorophacinone plot establishment. Both sites were located on well drained, very fine silt loam soils with a sloping topography. Each orchard block had a dense strip of grass and weed cover (annual and perennials) around trees. Between tree row, summer beating had been maintained from eight to ten inches from trees.

Orchard "A" had a heavy amount of mice activity -- network of runways and holes in ground between rows and around trees while orchard "B" had only moderate activity of mice.

	Orchard "A"	Orchard "B"
Tree Spacing	10' X 20' (218 trees/A)	10' X 20' (218 trees/A)
Root stock	Malling Merton 106	Malling VII
Varieties	Red & Golden Delicious	Red & Golden Delicious
Irrigation	Sprinkler - overhead	Rill
Ground cover - % grass	85	50
- % b.leaf	15	50
Ave. ht. ground cover around tree	14 inches	26 inches

DETERMINING MICE POPULATIONS: Three methods were used to determine the activity and population of mice in the two orchards before treatment: (1) observation on both sides of tree rows to determine presence of active recent surface trails, holes, grass clippings and fresh droppings in forage ground cover. (2) placement of thirty 5/8-inch pealed slices of apples in active runways or holes. Twenty-four hours later, apple slices were checked for mice tooth markings and recorded and, finally, (3) placement of thirty wooden snap-type mouse traps baited with apple slices (one per tree) near active run trails or holes in ground. Traps were checked daily for following three days, re-baited and re-set when necessary. Thirty trees were used per orchard plot. Results were as follows:

Method:	Orchard "A"	Orchard "B"
(1) Observation	26 trails, 7 holes, 14 piles grass clippings, 4 dropping piles	8 trails, 2 holes, 4 piles grass clippings, 1 dropping pile
(2) Apple slices chewed on	28	11
(3) Mice trapped	17	6

TOXICANT: To the knowledge of the writer, this is the first test plots to be established in tree fruit orchards within the state of Washington to employ Chlorophacinone 2-/(p-chloraphenyl) phenylaceryl/-1,3-Indandione (contains 0.40 pounds chlorophacinone per gallon) as a herbaceous cover spray for the control of short-tailed meadow mice.

The toxicant was sprayed on ground forage in six acres of orchard "A" with a handgun nozzle operated manually from tractor. Orchard "B" used tractor equipped with spray boom. The anti-coagulant rodenticide in each orchard was mixed in spray tanks at the rate of one pint per 100 gallons water. Spray was directed to the ground forage area two feet on each side of apple tree rows applying six pints of the concentrate per treated acre. A five-foot strip of dense grass and weedy area bordering the orchards was also sprayed to prevent mouse invasion.

Treatments were made in early November on a clear day, no wind and temperatures near 50°F.

RESULTS FOLLOWING TOXICANT TREATMENT: New 30 tree plot sites were selected within treated areas of orchards skipping three rows over from "check plot" and four trees down. Using same procedure as described in "Determining Mice Population", results were:

Table #1 EFFECT OF CPN GROUND SPRAY ON MEADOW MICE ACTIVITY

Days From Treatment-CPN Spray	Orchard "A"	Orchard "A" Check*	Orchard "B"	Orchard "B" Check*
	Apple Slices Chewed On			
8	2	11	0	4
18	0	-	0	-
28	0	-	0	-
	Mice Trapped			
29	0		0	
30	0		0	
31	0		0	

* Apple slices were placed in the checks 8 days following treatment, but not subsequently.

EVALUATION AND DISCUSSION: The two cooperating orchardists, who have had considerable experience with short-tailed meadow mice problems, and the writer are enthusiastic with the mice killing effect of the toxicant. Results following treatment show that mice populations were reduced even below what is considered a safe level in Washington tree fruit orchards. No mice activity was observed in the orchards following the melting of a six-inch snow cover in early January.

There are presently three rodenticides labeled for use in Washington orchards: (1) zinc phosphide, a poison used to mix with various kinds of baits; (2) Ramik Brown, a pellet bait incorporating the anti-coagulant diphacinone; and, (3) Endrin, a chlorinated hydrocarbon insecticide used in spraying the orchard floor and/or borders for long-term control.

Where the application of rodenticides has been our principle means of controlling mice, there are other practices we feel which may be used to reduce the hazzard of extensive short-tailed meadow mouse damage to trees. These are important because even the loss or weakening of a few trees in a planting can be very costly in loss production. Mouse damage can occur in our orchards at almost any time during the year.

Maintaining an area free of vegetation around each tree can greatly reduce the hazzard. Mice do not nest in or like to cross ground where there is no ground cover.

Mechanical guards can be constructed to encircle young trees. These can be wire guards of one-half inch hardware cloth cut to 18 inches square and closed with simple hog rings around a loose collar about six inches in diameter around the tree. Plastic guards also are made available for this purpose.

Mechanically cutting up the sod cover is another method which can be used to reduce mouse populations. This breaks up runways and disturbes the mouse population.

REPRODUCTIVE PATTERNS IN THE PINE VOLE

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ABSTRACT: Reproductive potential in the pine vole is low compared with other small rodents including other species of voles. Age of maturity is late. Males do not reach puberty before 51 days and females before 77 days. Estrus and ovulation are not spontaneous but tend to be induced by mature males. Gestation is long (24 days). Litter sizes are small (2.8 young weaned per female). Litters are produced less frequently because, although females mate and conceive within 3 days of parturition, prolonged gestation insures a minimum of 24-27 days between litters. Only dominant females in a group carry litters to term regardless of the age of other females in the group. Life span is short and crowding delays reproductive maturity thereby reducing potential for large population increases.

INTRODUCTION: Highlights of the first Eastern Pine and Meadow Vole Symposium noted that a serious pine vole problem exists and that much research will be required to find the real solution to the problem. Control is now exercised through the use of toxicants. However, in New York State environmentalists and wild life groups who were opposed to the use of pesticides succeeded in prohibiting Endrin in 1971. Without Endrin the pine vole problem worsened and last fall as a "stop-gap measure" the Commissioner of the Department of Environmental Conservation lifted the ban temporarily. The lifting of the ban brought many protests but the Commissioner clearly had no choice. The apple crop was in danger and at that point in our understanding of the pine vole, poisoning offered the only consistently reliable means of control. But there may be other ways of limiting pine vole populations. I hereby present my findings on reproductive patterns in the pine vole in the hope that thorough understanding of the life cycle of this animal may suggest other safer means for restricting its growth.

Problems faced by the apple growers notwithstanding, the pine vole has a low reproductive potential compared with other voles. Age of maturity is late. Estrus is sporadic and occurs infrequently in the absence of mature males. Gestation is long effectively increasing the length of time between successive litters and thereby limiting the number of litters during a reproductive season. Litter sizes are small. Only dominant females reproduce which limits numbers of fecund females. Crowding has a deleterious effect upon reproduction. Life span is short and population numbers are self restricting.

REPRODUCTIVE PATTERNS: Age of Reproductive Maturity. Both male and female pine voles matured at a later age than other voles. The earliest age for males was 7 weeks 3 days (51 days) and for females 11 weeks (77 days).

To test age of puberty, twelve young males were paired with females of known maturity. The age at which they were able to sire a litter was noted. All males were successful in siring litters between the ages of 51 and 77 days (Figure 1). As a further check of sexual maturity, histological sections of testes from developing males were examined microscopically. They showed that production of mature sperm did not begin until the age of 6-7 weeks. By 8 weeks all testes examined showed mature sperm. Table 1 compares age of maturity of pine vole males with 2 other common vole species.

Female puberty was determined in a similar fashion. Twenty three experimental females were placed with fertile males for a period of 24 weeks. The age at which each was able to conceive and carry a litter to term was noted. Twenty one of the 23 were successful in conceiving a litter between the ages of 11 weeks and 24 weeks (Figure 1). By 15 weeks more than half (13 of 21) had matured. An examination of histological sections from ovaries of 8-10 week old animals revealed they were submature. Some contained tertiary ovarian follicles but none had preovulatory follicles or corpora lutea. On the other hand, 89% of 12 week old females had ovaries with preovulatory follicles and corpora lutea indicating

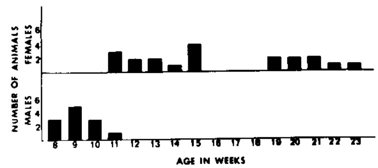

Figure 1. Age at which males successfully sired a litter and females conceived and carried a litter to term.

Table 1. Age at which males of three species of vole sired a first litter

Animal	Age of Maturity in Days	Investigator
M. ochrogaster	35+	Richmond and Stehn (1976)
M. pennsylvanicus	35	Hamilton (1941)
M. pinetorum	51+	Schadler (1977)

+ Laboratory Populations

they had mated and ovulated or were in readiness to ovulate. Table 2. compares age of maturity of pine vole females with other species of voles.

Estrus. Female pine voles did not show estrous cycles comparable to those of laboratory rats and mice. Vaginal smears indicated that all stages of estrus (proestrus, estrus, metestrus and diestrus) occurred in voles but periods were sporadic and often did not occur in the absence of mature males.

Estrus was studied for 28 consecutive days in 10 mature females housed adjacent to mature males in the same cage but separated by a wire barrier to prevent mating. No patterns of cyclicity occurred. Periods of estrus varied from 1 day to 22 days and were separated by periods of diestrus lasting for a minimum of 1 day and a maximum of 9 days.

Males had a profound effect upon estrus. In my experiment 29 diestrus females housed in isolation were placed with mature males.

Table 2. Age at which females of five species of vole conceived a first litter

Animal	Age of Maturity in Days	Investigator
M. ochrogaster	40 40+	Fitch (1957) Richmond & Stehn (1976)
M. pennsylvanicus	25-28	Hamilton (1941)
M. agrestis	21+	Chitty (1966)
Clethrionomys glareolus	32+	Peters & Clarke (1974)
M. pinetorum	77+	Schadler (1977)

+ Laboratory Populations

Twenty four of the 29 reacted by entering estrus by the 5th day (Table 3). Vaginal smears showed the presence of sperm in all estrous animals indicating all females had mated.

Table 3. Number of females in diestrus (N=29) on day zero which showed estrous smears within five days

	Day Number				
	1	2	3	4	5
Number Females	0	0	14	8	2

Mating. Pine vole females were promiscuous and mated during estrus with any available male. The above evidence indicated that the presence of mature males induced females to go into estrus and mate. For this reason a large number of litters can be sired by a single male.

Ovulation. Ovulation was also male induced. In my colony no ovulation occurred without mating. Histological examination of ovaries and Fallopian tubes revealed that ovulation was completed and the ovum in the duct within 24 hours after coitus. This finding concurs with that reported by Kirkpatrick and Valentine.

Gestation. Gestation was 24 days which is long compared with other voles. In my laboratory only one litter out of several hundred was recorded as having been delivered in less than 24 days. These animals were born in 23 days. However, all infants died immediately suggesting they may have been born prematurely. Kirkpatrick and Valentine also noted a 24 day gestation. Table 4 compares gestation in pine voles with that in other voles.

Intervals Between Litters. The majority of healthy pine vole females produced a new litter every 24-25 days (Figure 2). Females showed immediate post partum estrus and all but a few conceived within 4 days. Those not conceiving immediately usually did not become pregnant for many days or weeks.

Litter Size. Litters were small. The average number of animals born in 150 litters and the number that survived to weaning are presented in Table 5. In the laboratory, females averaged 3.11 young born per litter. However, not all survived and the number reduced to 2.75 at weaning.

Table 4.* Length of gestation and litter size in the genus *Microtus* as determined in the laboratory

Species	Gestation (days)	Litter (range)	Size (mean)	References
arvalis	19-21	N.D.	N.D.	Reichstein, 1964
agrestis	19.7	2-8	4.7	Bread, 1969
californicus	N.D.	1-9	4.7	Colvin and Colvin, 1970
longicaudis	N.D.	N.D.	4.0	Colvin and Colvin, 1970
montanus	N.D.	3-9	6.0	Colvin and Colvin, 1970
"	21	N.D.	4.7	Pinter and Negus, 1965
ochrogaster	21-23	1-8	3.8	Richmond and Conaway, 1969
"	N.D.	1-7	3.9	Colvin and Colvin, 1970
oeconomus	20-21	N.D.	N.D.	Asdell, 1964
oregoni	N.D.	1-6	3.8	Colvin and Colvin, 1970
pennsylvanicus	21	N.D.	N.D.	Lee et al., 1970
"	N.D.	2-8	5.5	Colvin and Colvin, 1970
pinetorum	24-25	N.D.	1.8	Kirkpatrick and Valentine, 1970
"	24	1-6	2.8	Schadler, 1977

* All data except Schadler (1977) excerpted from a review article by Hasler (1975).

Female pine voles have only 4 mammae which precluded large litters.

As might be expected, the survival of litters in the wild is less than that in the laboratory. Field researchers reported 2.0-2.2 young per female. For comparison of litter sizes in the pine voles with that of other voles see Table 4.

SOCIAL FACTORS AND REPRODUCTION: Effects of Crowding. Pine vole reproductive potential was significantly reduced when animals were crowded. Placement of more than 10 newly weaned voles in an enclosure

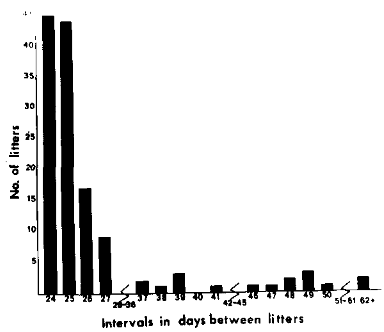

Figure 2. Intervals in days between 132 litters born to permanently paired breeding stock.

(in this case 20 gallon aquaria) resulted in lack of of sexual maturation and no reproduction. Microscopic examination of histological sections of gonads from 12 week old crowded animals (normal ovaries and testes are typically mature at that time) showed incomplete gametogenesis and abnormal appearing gonads.

Table 5. Litter size at birth and at weaning

Number in litter	1	2	3	4	5	6
Number of litters	8	33	62	33	10	4
Total number of animals in each litter size category*	8	66	186	132	50	24
Number surviving to weaning+	8	62	158	110	31	20

*Mean 3.11 ± 0.09
+Mean 2.75 ± 0.09

Effect of Dominant Female on Reproduction. Only dominant females reproduced. In compatible groups of animals with several females reproduction was limited to the dominant animals.

This was demonstrated in one of my experiments which called for freely growing colonies. A freely growing colony is originated by a single reproductive pair. Any young that are produced are not removed at weaning but are allowed to remain in the parent pen. The colonies were maintained for 11 months until they ceased growing at which time all females were 14 weeks of age or older. Only the dominant females reproduced. These females were the founding mothers and in one cage one member of the first litter born to the colony. None of the other females was fertile.

DISCUSSION AND CONCLUSION: Conclusions drawn from laboratory studies about reproduction in the wild may be risky. However, it is probably safe to assume that late age of maturation, induced estrus and ovulation, 24 day gestation and 24-27 day intervals between litters are comparable. We know litter sizes do not differ much. Three different researchers reported litters of 2-2.2 animals per female in the wild compared with 2.75 young raised in the safety of our laboratory.

Evaluation of effects of pine vole social organization upon fertility is probably a bit riskier. However, let us assume that in wild populations crowding does repress fertility. Let us also suppose that reproduction is restricted to the dominant female in any social group. Both conditions have been widely reported for other small rodents and they probably occur in the wild in pine voles also.

Field researchers tell us that pine voles live in social groups or colonies that may number as many as 16 animals. If social factors do indeed affect reproduction, an orchard population may possess only a limited number of fecund females. Because a single male can mate with any number of females, population size depends upon the number of fertile females.

Clearly we are not talking about a large number of reproducing animals in a highly fertile species. Pine voles do not evidence dramatic population explosions and declines as do many other voles. In addition they are short lived. Hayne calculated survival rate for 3 months (when large numbers of females should be coming into sexual maturity) to be 29%. By 5 months the rate decreased to 13% and only 1% lived 1 year. The life cycle of an animal with a low reproductive potential and a short life span has vulnerable points. Perhaps the next stage in the control effort on the pine vole should concentrate on those vulnerable points.

PROGRESS IN DEVELOPING A MICROTUS EFFICACY TEST METHOD FOR REGISTRATION PURPOSES

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The purpose of this presentation is to document the progress that is being made in the development of a Microtus rodenticide efficacy test method. When finished the method will satisfy EPA requirements for a laboratory alternate diet bioassay. We have been working on the method for 2 to 3 years.

One of the biggest problems has been in attempting to combine both meadow and pine voles in a single method. Also the method should be applicable for Microtus toxicants designed to be applied at many use sites in the entire 50 states.

In California and Western States Microtus depradation can be severe in alfalfa, barley and other grain fields, truck crops such as brussel sprouts and potatoes. On the east coast vole damage is severe but not limited to orchards. The EPA apple orchards in Beltsville are heavily girdled by voles and several trees decline and die each year. To make matters worse Microtus are carriers of many diseases, the most important being tularemia.

Therefore designing a laboratory test method that will reveal the efficacy of a vole toxicant in all these use sites has been very difficult. I would like to briefly describe the method as it is at this time. In short the state of the art.

The apparatus used to test the voles are screened bottom all-metal cages. It has been our experience that many vole species cannot be grouped together and therefore all of them are individually caged. In one group tank test with 20 meadow voles (Microtus pennsylvanicus) with no toxicant present and commercial rodent feed offered ad lib. 7 individuals died. We attribute the deaths to fighting and cannibalism.

Laboratory temperature should be about 20 to 25^{o} C and there should be 12 hours of artificial light per day. Water is available to the voles at all times.

The rodenticide-treated bait and the standard field rodent diet are offered to test voles in separate containers on opposite sides of the cage. There is more than enough food in each cup to supply the daily food requirements.

The standard field rodent challenge diet is composed of 50 percent (by weight) rolled oat groats, and 50 percent commercial rodent laboratory chow. The commercial rodent food was not palatable enough by its self to realistically create a challenge with the poison bait. The field rodent diet is not as palatable as the diet used to challenge commensal rodents.

An untreated control (check) group of 20 animals is required and is offered only the field rodent diet. If more than 10% of control voles die the entire test is voided. Food consumption is not recorded for the control animals.

The test vole consumption of both poison bait and challenge diet is determined daily and returned to starting weight by addition of the given food. Every day the quantity of food consumed by each vole is recorded. Recordings should be made at the same time each day. Weighing accuracy shall be to at least the nearest half-gram. The Animal Biology Laboratory weighs all rodenticide products to the nearest tenth of a gram. Spilled rodenticide and challenge diet are recovered and weighed to establish exact food consumption data. When the food spillage has gotten wet it must be dried to original moisture content before weighing.

The position of the vole toxicant and the standard field rodent diet containers must be reversed every day to reduce any feeding position bias of the animals. There must be a free choice between the rodenticide and the challenge diet. The voles must not be stressed unduly from noise or human disturbance. The Animal Biology Laboratory maintains all test rodents in a room separate from its main laboratory to reduce stress to the test subjects.

The length of the test period is 3 days for acute (single-dose) rodenticides and 15 days for anticoagulants. Dead voles are removed daily. All rodenticides are removed at the end of the test period leaving only the standard field rodent bait. No further weighing of food consumption is required.

Observation is maintained on surviving voles for 5 days following the test period. Any deaths encountered during this time period is attributed to the rodenticide. Some toxicants may require up to a 10 day post observation period. Sound rational for this extended post-test observation period would have to be presented. It is possible some of the potent anticoagulants tested for 3 days could justify a 10 day post-test period.

A vole toxicant (either single or multidose) would be considered satisfactory if a minimum of 90 percent mortality of test animals is obtained. Vole baits with exceptional safety characteristics to humans and other nontarget animals with a high degree of usefulness in special control situations may have a parameter of efficacy reduced to 80 percent.

Some of the problems encountered by the Animal Biology Laboratory in using this method are: 1. Mortality in control animals, 2. lack of a suitable nest container in each cage, 3. food dish may inhibit easy access to rodenticide and challenge diet, and 4. lack of a large uninterrupted supply of voles.

The Animal Biology Laboratory has or will in the near future test the following listed active ingredients in various concentrations on pine and meadow voles:

1. Strychnine Alkaloid
2. Warfarin
3. Sodium Fluoroacetate
4. brodifacoum
5. Zinc Phosphide
6. diphacinone
7. chlorophacinone
8. DLP-787

The use of generic or brand names does not imply endorsement by the Federal government. Finally, I would like to acknowledge the cooperation of Dr. Ross Byers in the development of this test method.

AN ECOLOGICAL FRAMEWORK FOR VOLE MANAGEMENT

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A great deal of past pine vole (Microtus pinetorum) and meadow vole (Microtus pennsylvanicus) research has focused upon toxicants as a means of population control. The advent of more and more environmental restrictions on chemical uses and toxicant resistance in target populations has created endless research in this area of vole control techniques. The application of wildlife management principles through biological and cultural techniques could serve as a sound foundation upon which to build a vole control program.

Many growers and research personnel have noticed lower damage levels when even a few vegetative or environmental components of the orchard habitat have been altered. Horsfall, in several papers, advocated the cultivation of various forbs as primary food sources for voles (Horsfall, 1972a; Horsfall, 1972b; Horsfall et. al, 1974). This cultural technique provided an alternative food source for potentially damaging voles that consume apple bark and roots. Perhaps the greatest gain in maintaining forbs was the ingestion of ground sprayed toxicants by higher numbers of damaging voles. While forbs may deter voles from feeding on trees, they also maintain a favorable habitat for continuous vole populations and hence create an ever-present damage potential.

The work of Byers and Young (1974) with the Smitty tree hoe has been an advancement in the concept of destruction of vole habitat. The tree hoe has been successful in lowering vole population levels by the disruption of burrowing systems vital to the animal's existence.

At this symposium last year several speakers felt cultural management, encouragement of predators, and various other natural strategies held promise as more long-term control solutions. Young felt great possibilities for good control resulted from herbicide bands along tree rows. Alternatively Conley and Killian felt the elimination of current weed control practices would lower damage levels. Techniques to change the plant species composition on the orchard floor to reduce available digestible energy supplies in summer and autumn and increase supplies during winter were suggested by Kirkpatrick and Noffsinger. Anthony found soil texture regulated the distribution of pine voles in Pennsylvania orchards. Even with the efforts of these studies there still remains a multitude of environmental factors that have not been examined.

An ecological yet practical approach to the management of any wildlife species is to assay its population size or density per unit area then attempt to quantify the multitude of factors vital to the existence of the species in question. If management means control, as in the case of damaging voles, then techniques to create undesirable or marginal habitats would be essential. Once known, the variety of factors most correlated with higher vole densities should be disrupted or altered while those factors correlated with low vole densities should be the primary elements in the development of cultural techniques.

A Case Study

The application of the concepts described above was undertaken at the Cary Arboretum during the summer of 1977. Seven 3-4 ha. open field habitats were chosen as simple systems to test the responses of voles to various cultural management practices. All but one field had been frequently mowed in past years and supported vegetation such as bluegrasses (Poa spp.), bromegrasses (Bromus spp.), timothy (Phleum pratense), clove (Trifolium spp.), and plantain (Plantago spp.).

Field 430 was chosen as a more natural small mammal habitat having been last disturbed in late 1975. Vegetation in this field consisted of some brome grasses, plantain, goldenrod (Solidago spp.), sheep sorrel (Rumex acetosella), cinquefoil (Potentilla spp.), and bedstraw (Galium mallugo).

Field 177 was mowed with a sicklebar mower in late autumn, 1976. Grass height was 50-60 cm and the site was left unaltered during 1977. Field 544 was treated identical to 177 but was mowed with a rotary brush-hog mower. Field 312 was sicklebar mowed in May, 1977 when grass height was 25-30 cm. Field 223 was also mowed in May but with the rotary mower. Field 225 was mowed with the rotary mower in early June and again in mid-July when grass height at each mowing was 30-40 cm. Field 870 was mowed and baled into hay in early June and again in mid-July. The mowing techniques were designed to provide variations in ground litter, and vegetation density.

In August a .81 ha. grid was established within each field and live-trapped for seven days. The following seven days, live and snap traps were used to remove animals from eight, 110 m assessment lines that emanated from the original grid center. Density estimates were developed using the Lincoln index, the regression techniques of Smith et al. (1971), and a modification of a Lincoln index regression using integration procedures (Swift and Steinhorst, 1976).

Quantitative measures of vegetation density and ground litter depth were taken at 68 stations within the .81 ha. grid and averaged for the entire grid. Ground litter depth was found using a centimeter ruler and vegetation density at 0-25 cm, 0-1 m, and 1-2 m strata was measured with density boards (MacArthur and MacArthur, 1961; Birch, 1977). Plant species data was not analyzed since a previous study found vegetation taxa was not strongly correlated with vole densities (McAninch and Harder, 1977).

Our results established ground litter depth as a key factor in meadow vole densities. (Table 1). A regression relationship over the seven sites found ground litter accounting for .92 of the variation in vole densities. (Fig. 1). Vegetation density at the three strata measured did not account for appreciable portions of the variation in vole densities. Our conclusions for management practices to control voles in this simple system were to use mowing techniques that left little or no ground litter. Although haying was used in this study, fields with numerous seedlings would make this technique impractical. We have considered using flail choppers which finely chop cuttings and a bumper mower which is comparable to our rotary mower but able to clear vegetation to the base of the seedling. In addition our program for next summer will determine the frequency and type of mowing needed to keep ground litter low without becoming inefficient from the standpoint of

Table 1. Data summary of vole densities and vegetation parameters collected during August, 1977.

Field	Vole Density (ha)	Ground Litter Depth (cm)	Vegetation Density (percent) 0-25 cm	0-1 m	1-2 m
177	112	4.34	.65	.65	0
544	85	3.51	.95	.68	.01
312	69	2.87	.35	.20	0
223	62	2.85	.57	.42	0
225	42	1.38	.43	.26	0
430	33	1.34	.48	.37	.06
870	10	1.30	.45	.34	0

man-hours involved.

Conclusions

Several conclusions from this study reinforce the basis for an ecological framework for vole management. The first is the underestimation of the effects of predation on vole populations. Field 430, the natural, less disrupted site, produced three short-tailed weasels (Mustela erminea) during our live-trapping period. Fitzgerald (1977) found short-tailed weasel diets were 98.1 percent voles. Even when vole densities were low, weasels continued to select voles in spite of increasing scarcity. Several of our study areas were bordered by stone rows and dead fallen timber that probably served as denning sites of

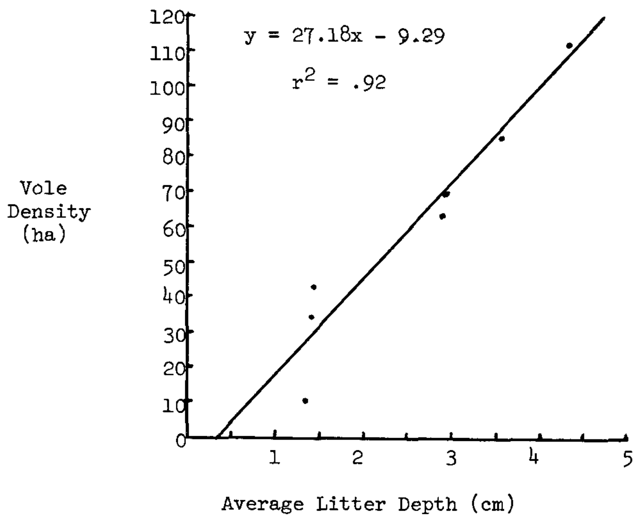

Fig. 1. Regression relation of vole density and average litter depth.

weasels. Vole consumption by resident weasels could be considerable as demonstrated by a captive female at our lab who consumed 1.2 voles per day during the summer months.

Reducing ground litter likely allows heavier predation pressure not only by weasels but also foxes, snakes, vagrant house cats, and avian predators such as kestrels and red-tailed hawks. Providing adequate denning, nesting, and perching sites likely would encourage predators to take up residence and become a natural component of a vole control program.

The second noticeable product of our cultural practices was the change in site factors. In fields where vole densities were low, soil compaction was greater probably due to less soil moisture, less ground cover, and the impact of mowing equipment. Minimal ground cover likely exposed voles to more extreme summer heat and winter cold. Reduction of ground litter also returned less humus to the soil which in combination with dryness and compaction would make burrowing more difficult. In essence, cultural practices can make life fairly difficult for meadow voles.

Due to the complexities of the orchard environment, the extrapolation of our results would mean many more factors have to be quantified and correlated to vole densities. These might include vegetation density, ground litter depth, soil moisture, soil density, soil texture, fertilizer rates, light intensity beneath the tree canopy, vegetation taxa, and many other parameters. Those factors highly correlated with low vole densities should become useful management tools while techniques to disrupt or alter factors correlated with high vole densities should be promoted. Development of the techniques to discourage voles would be tempered by the need for maximizing fruit production and limited by unchangeable factors tied to the physiography of the block. The degree to which additional controls such as toxicants are necessary would be dependent upon the relationship between vole densities and damage levels. Estimation techniques such as those described in this study or documented by Overton (1969), Eberhart (1969), and Jolly (1965), would provide reliable estimates of vole densities. Using these estimates as validation, research programs need to develop simple, rapid, and accurate techniques for evaluating vole densities each autumn. Once known, the success of control strategies could be established. When populations have reached the lowest levels possible under a conscientious cultural management system, the economic and ecological ramifications of toxicants as controls could be better evaluated and justified.

In New York's lower Hudson Valley region, growers were granted the use of Endrin in 1977 after a six year ban. Adverse publicity has been rampant in regional newspapers and among civic organizations. Few people understand that inadequate research monies and consequently research programs have not provided growers with sound, long-term control strategies. An increase in federal and state funds in conjunction with research programs oriented within an ecological framework for vole management should be the ultimate goal.

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COMPARISON OF PINE VOLE POPULATIONS IN A MAINTAINED AND AN ABANDONED ORCHARD

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Before more effective and reliable control methods for pine vole populations can be developed, it is essential to increase our knowledge of the pine vole's basic biology and ecology. Former research conducted by Estep et al (1978) and Noffsinger (1976) has demonstrated distinct differences in food habits, physiological condition and reproductive activity of pine voles in active and abandoned orchards. A summary of their findings is presented in Kirkpatrick and Noffsinger (1977). Results from these studies has promoted an interest to more completely define population characteristics of pine voles in these two orchard types. In this manner, it will be possible to enhance our knowledge of this species' response and adaptability to habitats of different vegetative composition, structure and type. Utilizing capture-recapture techniques, we have undertaken a study to examine population structure, density, and movement of pine voles in a maintained and an abandoned orchard. The two orchards are the same ones where Noffsinger (1976) previously collected voles in September 1974 through July 1975. The maintained orchard has had no form of vole control beyond mowing for five years. The other orchard has been completely abandoned for six years. Both orchards are the same age and have similar topography and soil types.

Trapping was initiated in September 1977 and will continue until July 1978 at seven week intervals. Three trapping sessions have been completed: one in late summer (September), one in mid-autumn (October), and one in early winter (December). An area of approximately 0.3 hectares is being trapped in each orchard, comprising six tree rows with nine to ten trees per row. In both orchards, trees are spaced on the average 8.5 m apart within and between rows. The trapping grid consists of 164 stations and 221 traps. Two traps are placed at every tree, and one midway between each tree in the row. Ten traps are also placed in each aisle at 8.5 m distances. Traps are prebaited, then set and checked morning and evening for five days. All captured voles are sexed, aged by pelage, weighed, and assessed for reproductive condition. New individuals are toe-clipped with a unique identification number.

Vegetation data were collected in the fall after the leaves had dropped. A 1 X 1 m quadrat frame was placed on the ground under every tree and midway between all trees within rows in the study grid. Plots were also taken in the aisles at randomly selected locations along a metric tape. Within the frame, percent cover to a height of one meter was estimated by species. Percent uncovered ground, including bare ground and litter, was also estimated. Overlap of cover by different species was not subtracted. Values presented in Table 1 are mean total percent cover of major vegetation types for the entire study grid. Woody cover includes cover by stems and by Japanese honeysuckle (_Lonicera japonica_)which has persistent leaves.

Table 1. Mean total percent cover by vegetation type in the maintained and abandoned orchards.

Vegetation type	Maintained orchard	Abandoned orchard
Grass	52	9
Forb	20	3
Woody	5	25
Uncovered ground	38	63

Because this study is still in progress, the data has not been completely analyzed. Some preliminary results from the trapping follow. Most captures have occurred at trees. Very few (0-4) voles have been captured in the aisles during each trapping session in both orchards. Captures in traps located midway between trees and at trees noticeably increased in December in both orchards indicating greater activity at this time. Total number of captures and recaptures steadily increased from September to December and were greater in the abandoned orchard in September and October, and greater in the maintained orchard in December (Table 2).

Table 2. Total captures, recaptures, trap mortality, and number of different individuals during each trapping session in the maintained (M.O.) and abandoned (A.O.) orchards.

	Total Captures		Total Recaptures		Number Individuals		Trap Mortality	
Month	M.O.	A.O.	M.O.	A.O.	M.O.	A.O.	M.O.	A.O.
Sept.	39	44	8	15	31	29	1	6
Oct.	64	113	14	45	50	68	26	8
Dec	191	131	98	55	93	76	18	18

In both orchards, most recaptures generally occurred at the same trees. Movement was restricted to two to three adjacent trees within a row, or less often, across to an adjacent tree row. Voles captured in December that had been previously marked in September and October were usually taken at the same tree, or in the same area of two to four adjacent trees in a row. This was true for both orchards and for adults and immatures alike. These results point to a similarity in general behavior between pine voles in the two orchards.

The number of different individuals captured during each trapping session is also presented in Table 2. These values may be used as relative indices of population size for comparing the two orchards. Doubts about the randomness of our samples prevents us from presenting any specific density estimates until the study is completed and the data further analyzed. A live trapping session followed by a total trap-out is planned for this fall. This should provide a general insight into the amount of bias present in estimating population size using models which assume equal probability of capture.

For all three trapping periods combined, a total of 158 and 131 different individuals were handled in the maintained orchard and the abandoned orchard, respectively.

Comparison of these values and the values for each period does not suggest significant differences in population sizes between the two orchards. However, Noffsinger's (1976) data revealed the existence of a similar pregnancy rate in both orchards in July and September. Thus, it is not unexpected to find a similar number of voles in both orchards at the time of our samples. Noffsinger (1976) also found that the number of pregnant females in the abandoned orchard sharply declined in November. Our data tend to confirm this since in December, 28 percent of the captured voles in the maintained orchard were immatures (juveniles and subadults) as opposed to only 16 percent in the abandoned orchard.

The lack of apparent differences in population sizes may also be attributed to differences in trappability. Some evidence to support this may be found in the recapture rates of previously marked individuals. Of 67 adults in the December sample of the maintained orchard, only 21 percent had been captured during previous trapping sessions. In the abandoned orchard in December, however, 55 percent of 64 adults had been previously marked. Many of the new adults in the maintained orchard in December were probably present on the grid and of trappable age in October, and some even in September. However, the abundant food supply in the maintained orchard in September and October may have reduced their susceptibility to trapping. This speculation will be examined later this fall during the proposed trap-out.

Despite the existence of possible biases in the data, these results indicate that there is large population of pine voles in the abandoned orchard. Clearly, this species can persist in orchards which have lost their dense herbaceous ground cover. However, the pine vole is essentially a woodland species adapted to a deciduous forest habitat. In the abandoned orchard, increased canopy closure and the invasion of the understory by several woody species presents a basic vegetation structure similar to that of deciduous woods. Thus, it may not be unusual to find relatively high numbers of voles in abandoned orchards which have reverted to a dominant understory cover type of woody species. We feel that it is very important to continue studies on the pine vole in orchards with different understory vegetation types. This may reveal a certain cover type which is nonconducive to pine voles invasion or population maintenance.

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STATUS OF PP581 (VOLAK) RODENTICIDE DEVELOPMENT

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INTRODUCTION: In the Proceedings of the first Eastern Pine and Meadow Vole Symposium (March 1977, Winchester VA), ICI was introduced and basic technical information on PP581 presented. PP581 is a second-generation anticoagulant rodenticide, with the approved common chemical name of brodifacoum. The compound is also known as TALON™ in the form of 50 ppm (0.005%) grain-base pelletized bait as developed for control of commensal rodents. The proposed trade name for the orchard formulation of PP581 is VOLAK™. Brodifacoum has been seen to possess several novel characteristics in work with commensal and other rodent species, suggesting a considerable general potential for control of many pest species of rodents and in various use situations. These characteristics are:

1. Single-feeding action for most species. (Defined as giving over 90% control in 1 day no-choice or 3 day choice tests with 50 ppm bait)
2. Effective on anticoagulant resistant rodents. (As based on US and UK lab studies with warfarin-and cross-resistant rats and mice which were successfully killed by PP581)
3. No bait avoidance. (Beyond that avoidance shown by rodents to any new object or foodstuff, bait avoidance is not a factor and bait is well accepted by most rodents. The lapse of several days till death reduces the chance of rodents associating bait ingestion with poisoning symptoms.
4. Antidotable. (Vitamin K_1 injections are antidotal, as is the case for existing anticoagulant products)
5. Low hazard. (PP581 baits at 50 ppm should be as safe to most non-target animals and the environment as other anticoagulants in current use)

Against commensal rodents, namely the Norway rat, roof rat, and house mouse, the 50 ppm TALON formulation has shown between 40-6o% acceptance in the lab and generally over 80% control in field trials, giving near 100% control in several cases. Data to support a national TALON registration for commensal rodents has been submitted to EPA and it is expected that sales of TALON will commence in 1979.

EFFICACY TO ORCHARD VOLES: The efficacy characteristics as listed above would suggest advantages in the control of *Microtus* in orchards. Notably, the single-feeding action and good bait acceptance, if demonstrated for voles, should allow for an application rate lower than for existing anti-coagulants with less potency. Byers has also reported suspected diphacinone resistance in pine mice (J. Amer. Hort. Soc. 103:65, 1978), hence efficacy to resistant rodents would be an additional advantage. In an effort to verify these and other potential advantages, studies of PP581 against *Microtus* have been conducted in the lab and field over the previous two years by Dr. Ross Byers and by ICI personnel. Based on data to date, which is summarized in the following sections, PP581 (VOLAK) has considerable promise as a single-feeding vole rodenticide of excellent efficacy.

ACUTE ORAL TOXICITY: Determinations of LD_{50} values for PP581 and other anticoagulants have been made (Byers, op cit) and are summarized below with equivalent amounts of 50 ppm bait to give an LD_{50} for a 25 g vole:

	Brodifacoum (PP581)		Chlorophacinone		Diphacinone	
SPECIES	LD_{50} (mg/kg)	Bait (g)	LD_{50} (mg/kg)	Bait (g)	LD_{50} (mg/kg)	Bait (g)
Pine	0.36	0.18	14.2	7.1	57.0	28.5
Meadow	0.72	0.36	-Not Determined-		14.0	7.0

Based on the LD_{50} determinations, it can be seen that the high oral toxicity of brodifacoum to *Microtus* should offer the potential of a single-feeding action, given suitable bait acceptance.

VOLAK BAIT EFFICACY STUDIES (LAB): Results (from Byers, op cit) from one and two day choice feeding tests with 50 ppm anticoagulant baits utilizing pine mice are summarized below:

Test Regime	Brodifacoum (PP581)	Chlorophacinone	Diphacinone
1 day choice test	9/10 killed	4/10 killed	0/10 killed
2 day choice test	10/10 killed	6/10 killed	0/10 killed

It can be seen from the above that PP581 appeared to act as an "acute" or single-feeding toxicant, namely giving good control after short periods of exposure to voles. Refinements in the testing procedure led to the establishment of a new protocol involving a 3 day choice test to assess efficacy of single-feeding baits with *Microtus*. This protocol, developed jointly by Ross Byers and Steve Palmateer (EPA) was presented at the ASTM Conference in Sacramento, Ca. in March 1977, and will be published in 1979 in a special publication of ASTM. Utilizing a draft of this protocol, with slight modifications, a 3 day choice test was conducted at ICI to provide more detailed information and verify single-feeding efficacy. Pine mice trapped from Winchester, Va. orchards were used. The results are summarized below:

Pine Mice	Av. Body Weight(g)	Av. Daily Pre-Test Consumpt.[1]	Av. Daily Test Consumpt.[2] PP581	Av. Daily Test Consumpt.[2] EPA	Av. Days to Death[3]	Av. Total Dose(mg/kg)	Av. Percent Accept.[4]
10 male	25.4±1.7	2.7±1.0	5.3±2.4	1.6±0.8	6.0±1.4	31.0±12.4	75.9±10.1
10 female	25.0±3.5	2.0±0.6	4.7±1.7	1.5±0.7	6.7±2.1	29.1±12.2	75.8±9.9
Total Avs.	25.2±2.7	2.4±0.9	5.0±2.1	1.6±0.8	6.4±1.8	30.1±12.3	75.8±10.0

(Above values all ± one Standard Deviation)

1 - voles held for 6 days, given apples and ground chow ad lib; chow weighed
2 - voles had choice of 2 bowls during test, one with PP581 and other EPA diet
3 - days to death counted with beginning of test period as day 1
4 - % accept. expresses what % of total test intake was PP581

Three day choice tests with PP581 by Byers and Palmateer according to the same protocol also resulted in good acceptance and complete or near complete kills. Based on the LD_{50} studies, only 1 to 2 pellets (0.2-0.4 g) contain an average LD_{50} dose for pine and meadow voles. Therefore, good bait acceptance helps ensure kills for more animals after limited feeding.

HAND BAIT FIELD TRIALS: Trials in Virginia[1] and Indiana[2] orchards were conducted during the dormant season with various anticoagulants. Results (Byers, op cit and unpublished) are summarized below:

Species	Brodifacoum (PP581) rate	Brodifacoum (PP581) kill*	Chlorophacinone rate	Chlorophacinone kill*	Diphacinone rate	Diphacinone kill*
Pine[1]	10 lb/A	94%	10 lb/A	96%	10 lb/A	69%
Pine[1]	5 lb/A	99%	10 lb/A	93%	10 lb/A	93%
Pine[1]	5 lb/A	95%	-Not Applied-		10 lb/A	91%
Meadow[2]	12 lb/A	100%	12 lb/A	87%	12 lb/A	87%

* - % kill inferred from reduction in voles trapped after treatment in comparison with trapping in control plots

Similar field trials have been conducted in Romney WV by Mr Dick Whiteman of ICI and preliminary reports indicate effective control was achieved at rates comparable to the above. Based on these trials, it appears that PP581 was as efficacious, if not more so, than existing anticoagulant vole rodenticides; even when used at half the rate of existing products. The results also suggested that PP581 might be especially efficacious as a broadcast bait.

FIELD EVALUATIONS OF BROADCAST APPLICATIONS: Dormant broadcast applications were conducted in Virginia[1] and Indiana[2] orchards for various anticoagulants. Results (from Byers, op cit and unpublished) are summarized below:

	Brodifacoum (PP581)		Chlorophacinone		Diphacinone	
Species	rate	kill	rate	kill	rate	kill
Pine[1]	25 lb/A	100%	22 lb/A	96%	-Not	Applied-
Pine[1]	15 lb/A	93%	15 lb/A	66%	-Not	Applied-
Meadow[2]	24 lb/A	93%	24 lb/A	86%	24 lb/A	74%

While it is not suprising that meadow mice can be effectively controlled with PP581, the possibility of effectively controlling pine voles by broadcast applications of 15 lb/A or less offers a promising approach to practical, cost-effective control of this troublesome species. However, hand baiting, although more laborious, will probably continue to be demonstrated as more effective at lower rates for both species with PP581 than broadcast applications.

As a further refinement, it might be suggested that PP581 as a liquid formulation, sprayed on vegetation, would be efficacious. Initial ranging studies indicate brodifacoum is not cost competitive by this application method. Such a spray, of course could also present a greater potential hazard to non-target organisms and the environment than use of broadcast baits where discrete particles are thinly distributed beneath vegetative cover. A spray is also potentially more hazardous than hand baiting where such baits are covered by a shingle or other object.

VOLAK REGISTRATION: ICI is firmly committed to achieving a national registration for broadcast and hand applications of VOLAK for control of Microtus pests in dormant orchards. In-house supportive environmental and toxicological studies have already been scheduled or initiated in the US and at ICI headquarters in the UK. Residue determinations for this compound are also being developed. Although modified VOLAK formulations and additional application techniques will be evaluated in the lab and in preliminary field trials in the months ahead, the current VOLAK formulation (50 ppm pellet) as tested in the studies reported herein, appears suitably efficacious for advanced field testing. It has therefore been decided to pursue field evaluations of VOLAK in additional regions of the country and against other species. ICI has submitted a request to EPA for an Experimental Use Permit for VOLAK to allow larger-scale field evaluations in several states during 1978 and 1979. Based on the available data, several researchers (notably many of those represented in this Proceedings) have expressed their willingness to evaluate VOLAK in the field. Orchards in Northeastern, Southeastern, Midwestern and Western states will be involved in these evaluations.

ICI is interested in having additional qualified researchers involved in the VOLAK field program and would welcome a response or inquiry from any interested party. Field protocols for different species have been developed which should help allow for comparison of results from trials in different parts of the country. Full national registration of VOLAK will take some time, especially due to the effort required to generate the detailed toxicological and environmental data as required by EPA. In the interum, selected researchers and growers will have access to VOLAK as an experimental compound. Once registration of the similar commensal product (TALON) is achieved, it is possible that VOLAK could be made more quickly available to growers on a regional basis under the provisions of section 24C of FIFRA, if a special need for the compound could be adequately documented and presented.

FIVE YEARS OF CONTROLLING MEADOW AND PINE VOLE WITH RAMIK BROWN

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Testing of Ramik for control of orchard mice was begun in 1972 in New York. By 1974 there were many test locations all over the Northeast, and by 1975 tests were conducted all over the country. Analyzing the results of some of the early testing suggested some refinements of application technique and formulation. These changes were made to better adapt Ramik to the conditions found in the orchard, and to make it more attractive to the voles. Some of the parameters examined are outlined below:

1. Bait flavor
2. Weather effects on the bait
3. Pellet size
4. Toxicant concentration
5. Method of placement
   a. Bait stations
   b. Hand placement vs. machine application
   c. Trail builder application
   d. Band vs. broadcast treatments
   e. Aerial vs. ground application
6. Timing of application

By 1975, the refining of Ramik Brown was complete with 0.005% diphacinone in an apple flavored, weather resistant, 3/16 X 3/16 inch, extruded pellet. Optimum placement varies with the vole species and is still not completely agreed upon. For pine vole, placement in the active vole tunnels is generally most satisfactory but some researchers have shown good results with broadcast, band, or trail builder applications. Meadow vole control has generally been with the broadcast or band applications.

Several of the above parameters, plus the effect of different rates of product per acre, were compiled from the many locations where they were tested and are presented below. All rates were converted to a broadcast per acre basis for uniformity. Control is expressed as a mean percent control based on the change in vole captures or activity from pre-treatment to post-treatment monitoring for individual treatments, and are adjusted for changes in the untreated control plot.

Pine vole control with Ramik Brown has been tested at 20 locations in the Northeast at four rates of product per acre. These locations were in Virginia, West Virginia, Pennsylvania, New York, Connecticut and Massachusetts. The mean per cent control obtained with three rates of Ramik Brown (Table 1), indicates only fair control obtained with single applications, while the two applications of 10 pounds of Ramik Brown per acre gave good control.

Table 1: Control of pine vole with Ramik Brown hand placed into active vole tunnels.

Pounds of product per acre	Mean % Control	Number of Test Locations
10 + 10	85	9
10	68	18
20	72	7

Control of meadow vole with Ramik Brown appears to be approximately 10% better than the control of pine vole at comparable rates (Table 2). Again, only three rates are compared out of five tested in over 25 locations in the states of Connecticut, Massachusetts, New York, Pennsylvania, Virginia, West Virginia, Ohio, Michigan, Oregon and Washington. As in the pine vole test, the single applications were less efficacious than two applications spaced approximately three weeks apart. For control of either species of voles, the 20 pound per acre rate appeared to have no advantage over the 10 pound per acre rate when applied only once in a season.

Table 2: Control of meadow vole with Ramik Brown applied to orchards.

Pounds of product per acre	Mean % Control	Number of Test Locations
10 + 10	93	13
10	75	21
20	78	6

The standard treatment for meadow vole control in many states is zinc phosphide-treated, cracked corn. Comparison of the efficacy of that treatment to Ramik Brown (Table 3) indicates that, in six locations in the Northeast, where direct comparisons were made, Ramik Brown provided control while zinc phosphide-treated cracked corn did not.

Table 3: Comparison of Ramik Brown with zinc phosphide (2%) on cracked corn for meadow vole control in orchards.

Pounds of product per acre	Mean % Control with Ramik Brown	Mean % Control with zinc phosphide
10 + 10 (1)*	82	1
6.7 to 10 (6)	72	17

* Number in ( ) is the number of test locations.

To illustrate flexibility in methods of application of Ramik Brown for control of meadow vole; three rates of Ramik Brown are compared with three applications methods in Table 4. There was no apparent difference between either ground or aerial broadcast applications of the bait. There also was no apparent difference between broadcast treatments and the same amount of Ramik Brown applied in a band under the dripline of tree rows. The band treatments concentrate the bait into the area of greatest vole activity.

Table 4: Comparison of application methods for meadow vole control with Ramik Brown applied to orchards.

Pounds product per acre	Band	Broadcast Ground	Broadcast Aerial
10 + 10	96 (2)*	93 (7)	82 (1)
10	77 (8)	68 (8)	81 (4)

* Number in ( ) represents the number of locations that rate and

application method were used.

Ramik Brown has been found to be an effective rodenticide for control of orchard voles, in extensive testing, under many conditions. Two applications, at approximately three week intervals, have provided the best control of both meadow and pine vole, but single applications have also been effective. Increased rates of Ramik Brown at a single application have not normally increased control. Ramik Brown has provided better control of meadow vole than did zinc phosphide, in all locations where direct comparisons were made. Aerial and ground applications of Ramik Brown for meadow vole control have resulted in no apparent difference.

AN UPDATE ON ROZOL FOR ORCHARD MOUSE CONTROL

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ROZOL continues its advance in establishing itself as a reliable product for controlling orchard mice.

ROZOL GROUND SPRAY CONCENTRATE is still the only alternative to Endrin, not only from the persistence point of view, but for its effectiveness. Environmentally, ROZOL GROUND SPRAY CONCENTRATE is proving to be a desirable product because shortly after it controls the mice, it degrades into non-toxic metabolites, thus lacking the residue problems that exist with Endrin.

Furthermore, mouse resistance to Endrin has developed after many years of orchard use. Clear field data has established that ROZOL GROUND SPRAY CONCENTRATE is more effective than Endrin in these area. Besides - higher Endrin dosages, in spite of their increased environmental hazard, have not resulted in higher control.

Endrin also poses other problems, such as toxicity to non-target species, particularly fish. No such accidents have been known to be caused by ROZOL.

Whenever a certain amount of adequate vegetation exists, and when properly applied according to label directions, ROZOL should prove effective after a single application with the corresponding savings in time and labor.

Various agencies of the Federal government have encouraged us to complete the research necessary to secure EPA registration. Unfortunately, radioactive tests with C14 required by EPA to prove the fate of ROZOL after it has been sprayed have taken a long time, but hopefully, they will be concluded in the early part of this year. I am sure that EPA will be pleased to learn that ROZOL GROUND SPRAY CONCENTRATE is biodegradable and that it constitutes a valuable alternative to Endrin.

Meanwhile, ROZOL GROUND SPRAY CONCENTRATE is still available under most State labels.

ROZOL is also available in the form of a PARAFFINIZED PELLET which I am sure most of the growers have used by now. It has been giving excellent results both against pine voles and meadow voles, and is available also in most states for the control of both rodents.

EPA registration for these pellets is also being pursued and hopefully should be granted during the course of the year.

We feel gratified by the excellent reception that ROZOL has been granted by industry, and we are encouraged to continue adapting the product to give utmost performance in controlling orchard mice.

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