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In this paper we 1) review briefly the rodent damage problem in New York orchards, 2) discuss aspects of the basic biology of pine voles (Pitymys pinetorum) and meadow voles (Microtus pennsylvanicus) that might be used to advantage in designing new control techniques, and 3) describe field experiments now in progress.

From a field survey of damage that occurred to apple trees in the winter of 1977-78 we determined that 44 of 62 growers (71%) suffered damage caused by meadow voles. This may have been due in part to the concerted effort by growers to protect orchards from pine voles which had in previous years caused considerable loss of trees. The important point here is that growers are still faced with two pests that differ markedly in their behavior and habitat use but are nonetheless equals in their ability to inflict substantial damage to fruit trees. Because of this, growers must continue to guard against meadow vole damage while we seek a cost effective method to control the pine vole.

With regards to the meadow vole damage problem there are two important points to remember. The first is that populations of meadow voles can increase dramatically after an easy winter and a good production year. The resulting high fall population can lead to considerable damage especially when snow cover persists through most of the winter months. The 1977-78 winter provided exactly these conditions in New York and Pennsylvania. When meadow voles exhausted their usual grass and forb food supplies beneath the snow they turned to woody plants, including ornamentals, shade trees, fruit trees, aspen and even white pine. The end result of this situation is that most voles usually die over the winter but only after considerable damage has been done. The second point concerning meadow voles is that suitable options for control now exist. These include treatment of infested orchards and peripheral areas with zinc phosphide-treated corn or other suitable carrier baits and clean-mowing practices within and around the orchard. Hand-delivered or broadcast bait coupled with mowing for removal of overhead cover provide acceptable control that will last through the winter period.

The microtine rodents are in general an extremely successful group. They are nearly world-wide in distribution, are found at extremes of altitude, temperature and aridity, and occupy nearly every habitat type available (Richmond and Conaway 1969a). Although the pine and meadow vole differ markedly in certain respects, they are closely related forms (Richmond and Stehn 1976). Both are herbivores (Baily 1924, Benton 1955) and both have an extremely responsive and highly functional reproductive anatomy and physiology (Clulow and Langford 1971, Kirkpatrick and Valentine 1970, Richmond 1967). The obligate herbivory and sensitive reproductive apparatus of the pine and meadow vole are two characteristics that we hope to exploit in a management oriented research program.

The importance of food quantity and quality to the reproduction and mortality of voles is addressed in a classic paper by Hoffman (1958). Since that time research has identified more detailed relationships of voles to their herbaceous diet including increased ovulation rate (Negus and Pinter 1966), synchronized onset of breeding (Negus and Berger 1977) and increased frequency of littering (Richmond and Wade 1970); all due in part to the type and quality of forage in the diet. Negus and Berger (1977) suggest that M. montanus cues its reproductive effort from chemical signals in plant food resources. They suggest the presence of both inhibitory and stimulatory compounds that regulate both the onset and termination of reproduction.

Given the above facts it would seem obvious that manipulation of vole food resources in orchards may have potential for the control of these pests. Cengel et al. (1978) support this notion with their observations of enhanced reproductive rate and body condition of pine voles from managed versus unmanaged orchards. They postulate that these differences were due to the type and quality of forage available in the two orchards.

Based upon present knowledge of vole food habits, we are conducting preliminary experiments with 1) herbicides to manipulate forage quality and grassy cover, 2) alternate ground covers to identify toxic or inhibitory plants that will render the orchard undesirable for voles and finally 3) mowing to manipulate overhead cover thereby reducing its desirability to voles. Mowing is one aspect of this research that needs careful examination because confounding effects of such management are a real possibility. While mowing can reduce undesirable overhead cover that meadow voles need, it can also stimulate new plant growth which may be the key factor in triggering reproductive onset (Negus and Berger 1977 and Richmond, unpublished).

The prolific but delicately adjusted reproductive capacity of voles is another topic of interest because of its intrinsically interesting biology and its potential for manipulation. The general pattern of reproduction in microtine rodents is summarized by Richmond and Stehn (1976). The details and unique features of reproduction are not important to this paper except to lay background for their potential role in management. In brief, odors play an important role in vole behavior and reproduction. Voles are induced to estrus by male odors, their short gestation can be disrupted at virtually any time by the odor of a strange male, and sibling daughters fail to achieve reproductive status unless stimulated by a strange male (Richmond and Conaway 1969b, Hasler and Nalbandov 1974).

Based upon the above considerations it would seem fruitful to pursue management research that utilized certain knowledge gained from detailed laboratory studies. A role for attractants and repellants becomes a very real possibility due to the voles' high degree of reliance on olfactory signals for communication and reproduction. Olfactory cues might also be exploited to a much greater degree in the formulation of toxic baits. The possibility for pregnancy disruption (Stehn and Richmond 1975) using fabricated strange male odors should also be examined.

At present we are investigating the possibility that the more easily managed meadow vole can be used to control the more persistent pine vole. We know for example that the two species do not normally coexist (Gourley and Richmond 1972) and that in habitats outside the

intensively managed orchard system, meadow voles far outnumber pine voles (Bart and Richmond 1978). The additional facts that the meadow vole historically was more abundant, ranges farther, is much larger and more prolific all suggest that this species can replace the related pine vole in an unaided competitive struggle. Indeed we have observed many times that meadow voles do replace pine voles in abandoned orchards and other situations where the orchardist has ceased to control meadow voles with zinc phosphide-treated corn. Zinc phosphide treated-cracked corn is very effective against the surface dwelling meadow vole but has little effect on the subterranean pine vole. Further we have observed that intensively managed orchard habitats which inadvertently select against meadow voles are the only places where pine voles become extremely abundant. We are beginning our second year of research on this topic and at this time it is premature to report anything more than the experimental design of this work which is the topic of another paper in this symposium series.

Vegetation management with herbicides for the purpose of manipulating food quality and quantity as well as ground cover has considerable potential and we plan to expand our efforts in this area. We continue to examine efficacy of new baits and formulations as they become available. In 1978 we examined the effects of the rodenticide Volak (broadcast) and the herbicide Kerb (fall application) on vole populations. Again, it would be premature and perhaps to the sponsoring company's disadvantage to report preliminary results here except to say that we are encouraged by the results and plan additional testing of these and other materials.

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