Managing Human-Wildlife Interactions: Woodland (*Microtus pinetorum*) and Meadow (*Microtus pennsylvanicus*) Voles

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Introduction

Virginia is home to four species of voles, two of which are recognized for causing significant physical and economic damage within the agricultural, forestry, and green industries of the commonwealth. Estimates of the economic damage caused by meadow voles (*Microtus pennsylvanicus*) and woodland voles (*Microtus pinetorum*), formerly known as the pine vole, exceed $5 million annually to agricultural commodities, including vegetable and grain crops, fruit orchards, and flowering bulb production, as well as to nurseries, Christmas tree plantations, residential landscape plantings, and woodland parcels recently replanted with pine seedlings. The rock vole (*Microtus chrotorrhinus*) is a state-listed endangered species, restricted in distribution to a small number of remote mountain habitats in Highland and Bath Counties, and is not known to be problematic. The southern red-backed vole (*Myodes gapperi*) is abundant and widely distributed across the western two-thirds of the state; however, it stays mostly in moist forest habitats, and rarely interacts directly with humans, thus causing little damage. Rather than discussing the two species that rarely come into contact with humans, this publication focuses only on resolving problems associated with the injurious meadow and woodland voles.

Biology and Behavior

Both meadow and woodland voles have statewide distributions and can be found just about anywhere in Virginia where suitable habitat exists. They are small, mouse-like rodents (generally 3-7 inches in body length) that spend most of their lives in underground tunnels, a behavior referred to as a "fossorial" lifestyle. Voles are voracious herbivores, consuming nearly the equivalent of their body weight in plant material in the course of 24 hours. Their diet is wide and diverse, including any or all of the following: grasses and grains; tubers, rhizomes, or the fleshy roots of vegetable crops (e.g., potatoes, beets, carrots); the inner layer of bark (the cambium) on the stems and large roots of shrubs and trees; the network of fine roots of woody plants; dropped fruits from fruit trees and shrubs; and bulbs and corms of flowering ornamental plants (e.g., *Crocus* spp.). During the peak growing season, meadow voles consume mostly fresh green plant material, but will switch to seeds, grains, and woody material (i.e., fine roots, bark) during winter. Voles are extremely prolific animals, with a capacity to significantly increase population size in the span of a single year — a fact that explains why commercial agricultural operations and home landscapes can experience severe damage seemingly overnight.

Meadow Vole

The meadow vole has one of the most widespread distributions of any mammal in eastern North America. In fact, ecologists believe the meadow vole (considering all subspecies collectively) may be the most abundant mammal species in the eastern U.S. and one of the most prolific mammals in the world. Two subspecies of the meadow vole are recognized in Virginia: *Microtus pennsylvanicus pennsylvanicus*, which occurs almost statewide (including inland parts of the Eastern Shore), but not in counties along the coastal plain, and *Microtus pennsylvanicus nigrans*, which is restricted to only the coastal plain and Eastern Shore.

The meadow vole (sometimes incorrectly referred to as meadow mouse) is a stout, chunky rodent with a blunt, rounded snout (fig. 1). These physical characteristics help to quickly distinguish voles from true mice and shrews, many of which display longer, often pointy snouts. To the casual observer, it appears that meadow voles do not have ears, but small ears do exist under the coarse fur and are held close to the body. Having small ears is an advantage to fossorial animals as it helps them move quickly through narrow runways and underground passageways without much resistance, especially when escaping from predators. Meadow voles usually are a dull grayish-brown to dark brown color with faint yellow tinges on the upper body and a dull gray or dusky silver underside. The meadow vole is larger than most other voles, attaining an adult body length of 120-196 mm (4.7-7.7 inches), with an average length of 6.0 inches and a weight of 20-68 grams (0.7-2.4 ounces); males are slightly larger and heavier than females. The tail of a meadow vole averages about twice the length of the animal's hind foot, typically ranging from 32-68 mm (1.2-2.4 inches) long.

Figure 1. Image of meadow vole (*Microtus pennsylvanicus*). ("Meadow Vole" by Belen Bilgic Schneider, licensed under CC BY-NC-SA 2.0.) https://creativecommons.org/licenses/by-nc-sa/2.0/

The common name of "meadow vole" is appropriate for this species as it often is found in pastures, fallowed fields, wet meadows, and transitional edge habitats, such as where the forest grades into the field and where wetland meets upland. Preferred habitats include areas where thick grass and weed cover predominates, but they can be especially abundant in the moist weedy areas adjacent to streams, ponds, and wetlands. Meadow voles have become abundant in suburban landscapes, where they inhabit heavily mulched flower beds, ornamental landscape plantings, and even small vegetable garden plots common in residential neighborhoods. Given that many of today's residential communities occupy former agricultural cropland or abandoned orchards, vole populations that were present in those previous habitats will persist and survive in these newly landscaped residential areas.

The meadow vole is considered a semi-fossorial animal, as it spends much of its life underground but routinely emerges for short periods of activity at the surface. Interestingly, some individuals may live a significant portion of their life above ground, especially where a thick tangle of persistent vegetation covers the ground surface. Meadow voles characteristically create multi-branched trails or "runways" on the ground's surface beneath thick, matted vegetation, accumulated plant debris, or objects laid on the ground surface. Some of these trails terminate at small holes about 1 inch in diameter, often located along the edges of landscape beds (fig. 2). Where meadow voles are active, fresh grass clippings and small fecal droppings often will litter the floor of a runway. They also are notorious for girdling woody plants by gnawing away the protective bark at or just below the ground surface (fig. 3).

Figure 2. Example of the snake-like surface trails meadow voles create under vegetative cover. ("Vole lawn spring damage" by Christian Delbert, licensed under https://stock.adobe.com/.)

Figure 3. Characteristic example of girdling damage inflicted on a young sapling resulting from foraging activity of meadow voles. ("Rodent damage on planted tree seedlings near Stillwater, MN" by Eli Sagor, CC BY-NC 2.0.) https://creativecommons.org/licenses/by-nc/2.0/

Meadow voles typically are not social animals. During the birthing and brood-rearing period, females become territorial, especially near the nest chamber, and will vigorously fend off intruding voles. Globe-shaped grass nests, about 3-5 inches in diameter, are built in a chamber within the tunnel network or occasionally can be found tucked into thick ground cover along a surface runway. Males are more tolerant of each other and rarely engage in territorial competition. Males maintain a larger range than do females (males: approximately 2,100 square feet; females: 645-750 square feet), and the ranges of males often will overlap. Overlap among males and females occurs only temporarily when females are entering a new reproductive cycle.

Meadow vole populations in the mid-Atlantic region often display cyclic eruptions and die-offs, where populations peak every three to four years, followed by years with noticeably fewer individuals. These animals are extremely prolific, given that females breed at least four times each year, so population expansion can be rapid. Although litter size varies between two to 11 "pups," a typical litter averages three to six young. Females are capable of breeding again as soon as their current litter has weaned, which usually occurs about 14 days after birth. As an extreme example of the reproductive potential of meadow voles, a female raised in captivity for research purposes (and thus reared under especially favorable conditions) was reported to have produced 17 litters in one year. Females can mate for the first time as soon as one month after birth. The gestation period is about 20-21 days.

Population density of voles can be extremely variable, depending on time of year and habitat quality. Estimates of typical density range from 40-150 voles/acre, but can swell to more than 1,000/acre during a population eruption. During these periods of peak population status, the potential for conflicts with voles is greatest. Fortunately, for those affected by vole damage, the average life span of a meadow vole is about one year.

Predation plays a major role in vole populations. In fact, the extant literature suggests that meadow voles may be the most heavily preyed upon small mammal species in North America. A large, diverse group of small and mid-sized predators, including hawks and owls, foxes, coyotes, bobcats, weasels, raccoons, domestic and feral cats, and snakes, preys on voles whenever available (fig. 4). However, given the cyclic nature of meadow vole abundance, predators adaptively adjust their foraging to rely on other prey species during periods of lower vole numbers.

Figure 4. A coyote feeding on a captured vole. ("Coyote Eating a Vole Near Metzger Farm Open Space, Colorado" by Gary Bowen, licensed under CC BY-NC 2.0.) https://creativecommons.org/licenses/by-nc/2.0/

Woodland Vole

This rodent (fig. 5) is well-known to producers of tree fruits and nursery stock, as it has a long history for causing problems for these commodities. In Virginia, three subspecies of the woodland vole are recognized: *Microtus pinetorum carbonarius*, which occurs primarily in extreme southwestern Virginia; *Microtus pinetorum pinetorum*, which occupies habitats mostly in south-central Virginia; and *Microtus pinetorum scalopsoides*, the most wide-spread subspecies, which occurs throughout Virginia except in the extreme south-central Piedmont and the far southwestern counties.

Figure 5. A woodland vole concealed under thick cover. ("Pine Vole" by Brandon Keim, licensed under CC BY-NC-SA 2.0.) https://creativecommons.org/licenses/by-nc-sa/2.0/

Woodland voles are noticeably smaller than meadow voles (fig. 6), displaying an adult body length of 81-131 mm (3.3-5.1 inches) and a tail length equal to or just shorter than the length of its hind foot (12-30 mm, or 0.75-1.0 inch). Although fur color is highly variable among individuals, adult woodland voles commonly display two color patterns during the year: the summer coat typically is a shiny reddish or chestnut-brown color with black undertones on the upper body and a bland gray beneath, whereas the winter coat is noticeably less vibrant and darker overall. Some researchers describe the woodland vole's tail as being bi-colored, but this condition is not easily detected by most casual observers. The woodland vole has short, smooth, velvet-like fur, nondescript ears, a blunt snout, and readily evident digging claws on its front feet, all physical attributes that facilitate the animal's life and movements underground. The average weight for an adult woodland vole is 17-35 grams (0.6-1.2 ounces.).

Figure 6. Comparison of the physical appearance and size between meadow vole (bottom) vs. woodland vole (top). (Photo courtesy of Alan T. Eaton, University of New Hampshire Cooperative Extension.)

As its name implies, the woodland vole prefers forest interior and forest edge habitats that have a substantial accumulation of leaf litter rather than the grass-dominated fields or wet pastures favored by the meadow vole. However, woodland voles also will inhabit well-mulched landscaped beds and gardens in residential areas. In commercial orchards and nurseries, they occupy the vegetated areas beneath trees and the strips between rows of trees. Unlike the meadow vole, the woodland vole rarely comes above ground, but instead lives in an extensive network of subsurface tunnels and chambers. When a woodland vole does come out, it usually does so only at night and only for short forays where its exposure to predators is minimized. Although they are quite capable of digging their own tunnel systems, woodland voles readily occupy abandoned tunnel systems left behind by moles; they also are known to inhabit tunnels created by meadow voles, though usually not concurrently with meadow voles in the same parts of a shared tunnel network. They build nests (5-8 inches in diameter) lined with dry grasses and fine root hairs in side chambers of the tunnel system.

Female woodland voles reach sexual maturity about two months after birth and will mate at least twice, but sometimes up to four times, each year. Breeding activity extends from late winter (January or February) through mid-fall (October) for voles in western and northern Virginia; those in the southern Piedmont and Coastal Plain regions may breed year-round. Litter size is smaller than that of meadow voles; woodland voles produce litters of one to four young (an average of two) following a gestation period of 24 days. Young are weaned in about 17-21 days, substantially later than that observed in meadow voles (14 days). Woodland vole populations typically do not display the dramatic cyclic swings seen in meadow voles; population eruptions in woodland voles are uncommon due to their lower reproductive output, and their numbers remain relatively stable over time. The life span of a woodland vole often is less than a year, though some individuals survive 18-20 months in captivity.

Much of our understanding about space use and occupancy among woodland voles has come from research conducted in fruit orchards and landscape plant nurseries, facilities that maintain artificially uniform arrangements of the vegetation found on those properties (i.e., evenly spaced plants in rows). Thus, animal populations that live in these highly altered environments likely display different distributions than those living in more natural habitats. That said, it appears that woodland voles occupy ranges of about 450-500 square feet, many of which overlap with territories of adjoining individuals and are weakly defended. Population density among woodland voles is lower than that seen in meadow voles, averaging about six to 10 animals/acre, though local density may be noticeably higher in high-quality habitats.

Like meadow voles, woodland voles are preyed upon by a wide host of terrestrial and avian predators. However, because woodland voles rarely spend much time above ground, they are less vulnerable overall, so predation has less impact on the population than is true with meadow voles. Nevertheless, woodland voles appear frequently in the diet of snakes and especially among nocturnal predators such as owls, foxes, coyotes, and bobcats, indicating that vulnerability is highest at night when voles are most likely to venture above ground.

Economic Status and Importance

Given their abundance and prolific reproductive output, voles fill an extremely important ecological role — voles (especially meadow voles) represent a vital prey base that supports many other organisms higher in the food web. Therefore, their presence contributes significantly to maintaining high biodiversity.

However, in contrast to that ecological importance, voles unfortunately represent a serious economic threat to individuals and businesses involved in the production of agricultural commodities and producers of nursery and landscape plants. Similarly, residential property owners trying to maintain home landscapes and gardens, and foresters trying to re-establish the future forest after a timber harvest, also face substantial economic impacts where vole populations have erupted. Accurate estimates of the damage inflicted by voles are hard to obtain and often are not available for certain crops; our best data come from commercial fruit orchards, where estimates of annual damage and loss range from $100/acre to as much as $2,700/acre.

Strategies for Managing Vole Damage

Detecting and Recognizing Symptoms of Vole Damage

Dealing with voles is inherently difficult, but it must begin with determining if they are present and then assessing whether they are causing meaningful damage. Because these animals live primarily underground and seldom venture far from cover when at the surface, they rarely are observed directly. Instead, detection of their presence usually is made on the basis of physical evidence found in areas of suspected activity. Here is a short list of common symptoms and physical signs left by voles:

- A network of well-worn, 1-inch wide surface trails that randomly snake across the ground under vegetation that forms a thick ground cover (fig. 7), probably indicates the presence of meadow voles. This same type of trail network often will be found beneath synthetic weed barriers that have been laid down under mulch in landscaped beds or under other objects (e.g., boards or sheets of plywood) left on the ground surface for a period of time.

- Holes about 1 inch in diameter that appear to drop into the ground with little or no excavated materials deposited about the opening (fig. 8). Holes seem to appear at random within the animal's range, but they often will be found along a surface trail, especially where a trail seems to end.

- Partial or complete girdling of woody plants' upright stems at and just below the soil surface (fig. 9).

- Bulbs, corms, or tubers that display a concave wound where tissue has been scraped or chewed away. Narrow, parallel depressions or tracks may be evident in the wound where the animal's incisor teeth scraped out plant tissue.

- Plants that begin to show a decline in overall health or condition (fig. 10), as demonstrated by
  - Droopy branches and stems, or wilting foliage.
  - A progressive yellowing of the foliage and eventual leaf loss.
  - Fewer and/or small and poorly developed fruits.
  - Premature fruit drop.
  - Ability to physically lift a plant in apparent declining condition out of the soil with little effort (due to loss of root mass).

- The ability to jab an index finger or other rigid pointy object easily into the soil around the base of a plant suspected of being affected by voles. When pressed downward, the finger or object being used breaks through and falls into the void of an underground foraging tunnel created by voles.

Figure 7. Vole runways through a grass-covered field. ("Vole tracks and human feet, 2017 Dec 26" by "Dunnock_D," licensed under CC BY-NC 2.0.) https://creativecommons.org/licenses/by-nc/2.0/

Figure 8. Example from within blueberry plantings of the type of hole created by meadow voles, which provides access to their underground tunnel system. (Photo by author.)

Figure 9. Example of vole girdling damage to an apple sapling. (Photo by author.)

Figure 10. Commercial blueberry plants displaying stunted growth, chlorotic (yellowing) leaves, and visible dead stems due to voles feeding on the underground root systems. (Photo by author.)

Although the symptoms described above are useful to identify presence, they offer little in terms of defining population status or size. The physical evidence left behind from prior vole activity will persist for a period of time after a colony has collapsed or voles have moved to a different area. Therefore, before beginning to implement any management actions, it's important to establish if and where voles are active and whether the population is increasing or in decline. Failure to do so can lead to wasted time, effort, and money spent on materials trying to address a problem that either no longer exists or isn't bad enough to warrant the outlay.

Assessing Population Status and Potential Extent of Damage

Properly assessing and managing vole populations and the damage they cause takes effective monitoring strategies, diligently implemented and maintained. Several methods are available to perform such assessments, including conducting periodic trapping, implementing the apple activity index (AAI), or using the foraging activity index (FAI). Each of these approaches provides a different output, requires different interpretation, and has unique advantages and disadvantages. In many cases, producers likely will use a combination of assessment techniques.

Trapping as an Assessment Tool

Before implementing control methods, it's important to determine which species of vole is present. Of the three techniques identified above, only trapping provides a reliable way to identify the species involved. Although certain types of evidence may point to one species or another, relying on such evidence alone can be misleading. For example, meadow voles may have been present in the past, but have since been replaced by woodland vole recruits who have occupied the pre-existing tunnel network left behind by meadow voles. Periodic trapping also provides a way to properly assess vole status over time.

Given the fossorial habits of these target animals, the trapping strategy must be adapted to take into account where these animals live — underground. Trapping can be performed using baited wooden-based, spring-loaded mouse traps readily available at most hardware stores. Suitable baits include small, diced apple or pear chunks, a small gob of peanut butter, or a ball of peanut butter mixed with cut oatmeal. Given the strong aromatic characteristic of peanut butter, traps placed at the surface are susceptible to creating undesired nontarget captures (e.g., deer mice, shrews, chipmunks). For this reason, fruit baits sometimes are better than peanut butter to avoid the challenge of minimizing potential nontarget loss.

Once baited and "set," a snap trap never should be placed along a surface trail without some form of protection to limit nontarget access. Instead, traps set at the surface should be protected underneath an upturned and weighted 5-gallon bucket or placed under a cardboard shelter (fig. 11) or within a section of PVC pipe sufficiently large enough in diameter to allow the hammer of the trap to properly spring without obstruction. Alternatively, traps can be placed into a dug-out portion of the voles' underground trail system, the opening of which then is covered by a board. In commercial orchards, producers often place monitoring traps beneath a truck tire cut in half (i.e., cut around the middle of the tread to create two concave halves) that then is placed over one or more openings to a tunnel. Several nights of trapping should be enough to determine if voles are active in the area where damage was observed, and also to confirm what species of voles is present. If no voles are captured after several nights of trapping, that might indicate that voles have left the area, but first consider changing the type of bait used and try for a few more nights. When using the in-tunnel trap approach, finding the traps covered with soil usually indicates that voles have detected the traps and have attempted to bury them rather than fall prey to them. It's a signal to be more careful in setting the traps — try not to disturb the integrity of the tunnel system or leave loose soil within the tunnel at the trapping site, as these clues serve to alert these perceptive animals to the presence of potential danger.

Figure 11. Cardboard covering used to limit nontarget captures when trapping voles. (Photo courtesy of Stephen M. Vantassel, Montana Department of Agriculture.)

Apple Activity Index (AAI)

While trapping provides valuable information on the species of vole that is present, it represents only part of the knowledge needed to effectively address vole damage. It's also important to know something about the population trend in the affected area — is it increasing, is it decreasing, or is it stable? Although trapping sometimes can provide indications of numbers, other approaches usually are more effective. A commonly used technique to monitor vole numbers is the Apple Activity Index (AAI).

The AAI was developed by Dr. Ross Byers, former director of Virginia Tech's Alson H. Smith Jr. Agricultural Research and Extension Center, as a way to quickly assess the presence of voles and estimate the anticipated severity of their activity within orchards. In this technique, a population monitoring station was established at every third or fourth tree in a row within a block. Each station consisted of two sampling locations on opposite sides of the sample tree. At each of the two opposing sampling locations per sample tree, he placed a 1-inch slice of an apple in a runway or adjacent to a hole at that station, and then covered the apple and the adjoining section of the runway or hole with a protective cover (e.g., upturned and weighted 5-gallon bucket) to prevent other animals from reaching the bait. After 24 hours, he returned to each sample site to check each apple slice for signs of vole feeding (i.e., tooth marks).

At its most simple level, this technique confirms areas within a block where active vole populations exist. To gauge the presence and status of the vole population, he divided the number of stations where apple slices were consumed or fed upon by the total number of stations (i.e., calculate a proportion of sampling sites that support vole activity). Although this level of sampling likely is too intensive for forestry or home landscape applications, it can be replicated with fewer sampling stations randomly placed within an affected area to establish a population index.

Byers modified his original technique to provide a subjective index of estimated feeding severity. A close examination of the amount of each apple slice that had been consumed by voles during the 24-hour period theoretically gives clues to the status of the resident population. Assuming that only voles had access to the apple slice, if the entire apple slice is missing after 24 hours, the vole population would be classified as "highly active," whereas slices that show evidence of some lesser level of feeding constitute areas of "slight" activity. Because of the explosive breeding potential of voles, Byers believed that an index greater than 25% of all stations showing feeding activity indicated a potential for serious damage and a need to implement vole management.

Foraging Activity Index (FAI)

To obtain a more accurate assessment of vole abundance (and better predict the potential for damage), Dr. Leonard Askham at Washington State University refined the AAI to achieve a more objective estimate of feeding activity. This new method is called a Foraging Activity Index (FAI). This approach estimates the amount of feeding on each apple slice and assigns each estimate into one of five categories that serve to predict population abundance and the potential for damage. The categories of feeding activity are displayed in table 1.

Table 1. Parameters estimated from use of Foraging Activity Index (FAI) sampling to calculate a Foraging Index (FI) for voles, which then is used to establish a course of action on the need for vole damage management.

Category Value	% of Apple Consumed	Population Rank	Foraging Index (FI)
0	None	None	0
1	< 25%	Low	< 1.0
2	25 – 50%	Moderate	1.0 – 1.9
3	51 – 75%	High	2.0 – 2.9
4	> 75%	Severe	3.0 – 4.0

After inspecting all stations and examining all apple slices, the total number of apple slices that fall in each category is multiplied by their category value (e.g., 14 slices in Category 4 = 56). These values for each category level are added together and divided by the total number of stations to obtain the damage severity rating (Foraging Index, or FI) for the whole block. Table 2 provides a hypothetical example of what a typical assessment worksheet might look like.

Table 2. Hypothetical values derived from use of the Foraging Activity Index (FAI) to produce an overall block-wide Foraging Index (FI). In this example, sampling occurred beneath 50 trees in the block, each of which utilized two sampling locations on opposite sides of a tree. Thus, a total of 100 apple slices were placed in the field for this test.

Category Value		# Slices Observed/ Category		Total	Foraging Index (FI)
0	x	30	=	0	
1	x	23	=	23	
2	x	18	=	36	
3	x	15	=	45	
4	x	14	=	56	
		100 total slices		160	1.6*

* Estimated FI Rank (for entire block): 160/100 = 1.6 — this equates to a predicted "moderate" level of damage within this orchard, as determined from rankings provided in Table 1.

Several FAI assessments are made over a period of months (using the same monitoring stations in each trial) to provide an index to whether a population is increasing, decreasing, or staying about the same. The output from an FAI analysis is recommended to help determine when and what type of control may be needed to manage vole populations.

Dealing with Confirmed Vole Activity

Based on years of experience, field research, and well-intentioned attempts, growers have come to realize that it is nearly impossible to completely eradicate an established population of voles. Instead, a more appropriate goal would be to achieve an economically tolerable level of damage using integrated pest management techniques. Experienced growers have found that this is best accomplished through reliance primarily on the use of proper habitat management and nonlethal techniques, supplemented with periodic, tactical applications of chemical toxicants when warranted by results of FAI assessments.

Susceptibility of Plant Materials

Research conducted in commercial orchards suggests that voles, like other herbivores, often display preferences when choosing what to feed upon. Within orchards, voles clearly prefer apple over all other fruit trees. Among apple varieties, though, differences in susceptibility to vole damage appear more related to age of the plant than to cultivar. Comparable research on the susceptibility of forest tree species and horticultural or landscape plants is lacking. In fruit orchards, older and larger trees are less likely to succumb to vole damage because the bark is thicker and harder to penetrate than the bark on younger saplings; young saplings exhibit thin, succulent bark that voles easily gnaw through to access the inner cambium layer. Except in cases of a severe vole infestation, larger trees are unlikely to be girdled or root stripped sufficiently to induce tree mortality (but overall production and/or quality of fruit may suffer).

Regarding apple orchards, there also appears to be a relationship between the type of rootstock on which a cultivar is grafted and the amount of vole feeding damage observed. It is not yet clear whether the observed increase in damage is due to the palatability of roots in certain rootstocks or the pattern of rooting display by a rootstock. Plants having a taproot structure appear to be more susceptible to mortality from vole foraging damage than are plants that display a dense, spreading rooting pattern. However, additional research is needed to confirm nd elaborate on this observation.

Managing Vole Activity Using Husbandry Approaches

Vegetation Management

Areas characterized by continuous, unbroken swaths of dense, low-growing or mat-forming vegetation, pastures or fallowed fields that aren't mowed or burned regularly, and landscaped beds with a thick (i.e., greater than 2 inches) layer of an organic mulch are preferred habitats where vole activity should be anticipated, much more so than areas that lack these types of cover. Given this understanding, implementation of proper ground cover management is essential if meaningful management of vole populations is to be attained. Ideal habitat conditions that voles would seek include areas where actively growing ground cover vegetation is higher than several inches, or where dead or dormant vegetation remains erect around the base of trees and shrubs. The thick protective cover successfully hides voles from natural predators. The situation becomes most dire where the plants providing this cover also serve as potential food resources.

Another serious habitat-related reality is that landscaped beds that incorporate some form of physical barrier that then is covered with mulch, primarily to prevent weed growth, are notorious for harboring, and in fact enhancing, vole activity. It is difficult to detect vole presence beneath these barriers, and predators are blocked from gaining access to voles that remain very active under this protective layer. In many cases, gardeners are unaware of any problem until plants start dying or show signs of declining health as their root systems are being eaten away by voles. To reduce the likelihood of creating serious vole problems in home landscapes, refrain from using any form of physical weed barriers in landscaped beds and reduce the thickness of a mulch layer to no more than an inch.

Commercial fruit producers have learned that vegetation management within their blocks is critical to success in dealing with voles. In fact, many producers have converted to "clean cultivation," also known as "bare ground culture," beneath the trees in an effort to reduce the amount of cover and food afforded to voles. Under bare ground culture, all vegetation or ground cover beneath the tree, beginning at the trunk and extending out to the drip line, is removed by cultivation or careful use of appropriate herbicides. Additionally, dead plant material and dropped fruits routinely are removed from the area beneath the trees throughout the year. Finally, the grassed travel lanes between rows are mowed frequently to keep that cover less than 2 inches high. The reason for adopting these practices is to forcibly relegate voles to live within the managed vegetated strips, knowing that they will be wary to venture into exposed areas out of fear of predation. It is important to note that vole populations are unlikely to be eliminated using habitat management techniques alone, so producers should implement a comprehensive management scheme that includes vegetation management, frequent population monitoring, and options for reducing vole populations when conditions warrant.

The intensive and often stark "bare ground" management approach used in orchards probably would not be feasible for many property owners. Still, important lessons can be learned from orchard operations and applied to other locations, such as where landowners try to minimize the negative effects of voles on home landscapes and gardens. Where feasible, reducing the amount of protective cover and increasing the amount of unvegetated ground in landscaped beds obviously will increase voles' exposure and make them less comfortable spending time in such areas.

In forest management settings, site conditions are an important consideration. Vole activity typically becomes more pronounced following a timber harvest and during the regeneration or replanting stage. Residual slash and other woody debris left on-site following a harvest represent functional cover for voles and can increase the level of difficulty that predators encounter in finding or accessing voles. Where field conditions allow, using a prescribed burn as a site preparation tool can be a cost-efficient method to reduce cover and prepare the area for replanting. However, although such burns have definite advantages in eliminating debris, the effects on vole populations often can be short-lived. An infusion of released nutrients from the burning of the slash coupled with a flood of sunlight reaching the forest floor after the canopy has been opened will cause the dormant on-site seed bank to explode into a robust stand of new food-bearing annual plants, which creates an attractive food supply that will support a recovering vole population. In such cases, an approach to consider is to delay replanting of seedlings until this flush of growth has emerged and can be knocked back with an appropriate herbicide treatment. Doing so will exhaust part of that residual seed bank, remove vegetation that will compete for nutrients and water with the seedlings while also reducing potential food for voles, and reduce or eliminate the protective cover that voles desire. Seedling planting should occur soon after this herbicide treatment. Eventually, a new crop of pioneer herbaceous plants will emerge, but by then, the seedlings hopefully will be well on their way.

When reforesting old fields or abandoned pastures, the task is more difficult. The existing thick grass cover must be removed and then prevented from coming back in areas where seedlings are to be planted. If left in place, this herbaceous layer competes with seedlings for space and nutrients and provides beneficial protective cover within which voles will thrive. For this reason, bare ground culture in the replanting zone is encouraged until seedlings have become well-established. In the past, forest managers often created narrow (about 1-2 feet wide) herbicide-treated strips where seedlings were to be placed. Where soil and slope conditions allow, planting within these strips often was conducted using a tractor-towed mechanical planter. Although this approach may be a convenient and efficient method for replanting large acreages, mechanical replanting can create a unique problem. As the mechanical planter cuts a trench and loosens the soil into which the seedlings will be inserted, it essentially creates the equivalent of an artificial tunnel that leads directly from one seedling to the next. Voles quickly learn that they can use this network of freshly constructed trenches to access readily available food resources (i.e., the newly planted seedlings) in each row.

Today, a total site prep is preferred when attempting to reforest old fields, especially those where active vole populations are known to exist. If a prescribed burn can be conducted safely through the field, it will accomplish two tasks — it removes accumulated layers of organic matter that have built up over the years, and it also reduces protective cover and food resources available to voles. Where burning is not practical, safe, or allowable due to smoke management constraints, the entire site could be treated with an herbicide suitable for killing herbaceous weeds, grasses, and forbs, but especially mat-forming grasses like fescue. The intent is to create an inhospitable habitat for voles, one free of cover and without reliable food resources. Replanting also will be easier without that vegetative growth in the way. However, full-site herbicide treatments may not be suitable when attempting reforestation of hilly old field sites; once denuded, the potential for erosion within the now-barren area can increase. In hilly situations, herbicide treatments conducted in strips along the contours may be more practical, but the vegetated swaths left between the treated strips will need to be mowed or otherwise managed to help keep vole populations in check.

Alternatively, bush-hogging or flail-mowing may be used to knock down the existing herbaceous cover in the areas to be replanted. However, mowing's shortcoming is that it doesn't remove accumulated organic matter; it merely chops it up and knocks it closer to the ground. Relying entirely on repeatedly mowing actually can exacerbate vole problems because a layer of accumulated organic debris can build up at the ground surface, under which voles will become active. Where mowing is the only management option used, it may be necessary to periodically drag a rake through the field in an attempt to dislodge and reduce the accumulated organic layer.

Once seedlings have taken root and display good growth, rival vegetation needs to continue to be managed to prevent it from competing with and overtopping the seedlings. Potential methods include running a disc between the rows or making periodic passes with a tiller to lightly turn the soil. These techniques provide an added benefit in that they break up existing runways and tunnel systems that voles have created. Yet none of these options will prevent vegetation from resprouting immediately within the footprint of the seedlings, where feeding activity on the stem or root system of the seedlings can be most devastating. Other than the labor-intensive effort of periodically applying herbicide around each seedling, there are no other cost-effective ways to address herbaceous regrowth around each seedling.

Facilitate Natural Predation

In addition to reducing competition for space and nutrients between the desired crop and ground cover plants, proper vegetation management can also benefit producers by enhancing natural predation on voles. As noted earlier, thick growth of unmanaged ground cover vegetation within the production area presents a significant challenge for predators, primarily by reducing their ability to find and successfully hunt voles. Producers should acknowledge the contribution of predators in managing vole populations and make efforts to facilitate the success of predators who live near and within the production area. Adopting sound vegetation management practices (i.e., frequent mowing, implementation of herbicide strips) will improve detection of voles and help draw predators to areas of existing vole activity. To enhance the presence and effectiveness of avian predators such as hawks and owls, installing strategically distributed wooden hunting perches throughout the production block will provide these species platforms from which they can survey the site and launch an aerial attack. Something as simple as a 15-20 foot tall post with a 2 foot crossbar attached to the top, when installed at several locations where it will not interfere with routine operations, provides enhanced surveillance coverage of a block by avian predators. Finally, instead of trying to rid a site of snakes, these animals should be left alone as they are some of the most effective predators of voles.

Nonlethal Techniques

Physical Barriers

Orchardists historically installed wire mesh or plastic barriers around the base of every tree in a block. These tree guards, constructed of hardware cloth, wire mesh fencing, or heavy plastic, extend about 18 inches up the trunk (higher in areas of deep snow) and at least 1-2 inches below the soil line (fig. 12). Although these devices may provide some protection against meadow voles and perhaps rabbits or woodchucks, they do not prevent the damage caused by woodland voles that forage on the underground root system. Use of physical barriers to deter vole damage on a typical reforestation project quickly becomes expensive and rarely is practical.

Figure 12. A vole tree guard constructed of ½-inch mesh hardware cloth. (Photo courtesy of Alan T. Eaton, University of New Hampshire Cooperative Extension.)

A different form of physical barrier has emerged within the commercial marketplace, that being use of a coarse, granular aggregate material (e.g., poultry grit, crushed oyster shell, or Vole Bloc) to line the hole before the plants, bulbs, or tubers are placed into the hole during planting. The claim with such products is that voles prefer not to dig through this material to access the root system due to the sharp, angular texture of the aggregates. This is an intensive, plant-specific approach to vole deterrence and can become expensive if large numbers of items are to be planted.

Repellents

Most repellent products are designed for above-ground foliar applications, so their usefulness for managing vole populations is severely limited. Additionally, only a small number of active ingredients currently are registered as repellents for use on voles — capsaicin and putrescent egg solids are registered as foliar repellent treatments; however, little evidence exists of effective deterrence from their use.

Lethal Strategies

Chemical Treatment

Judicious and well-timed applications of rodenticides can be important tools for managing injurious vole populations. Yet the application of toxicants or poisons for the purpose of killing mammals or birds is strictly regulated (see [4VAC15-40-50 in Virginia's Administrative Code](https://law.lis.virginia.gov/admincode/title4/agency15/chapter40/section50/), https://law.lis.virginia.gov/admincode/title4/agency15/chapter40/section50/) and generally prohibited in Virginia, with exceptions when dealing with rodents on private property. Most rodenticides currently registered for use on voles are classified as "Restricted Use Products" by the Environmental Protection Agency; products listed under this classification can be obtained and applied only by individuals who possess a valid Pesticide Applicator Certification for Vertebrate Control (Section 7D). Forest managers or private landowners generally do not possess this certification, so their ability to acquire and use toxicants is restricted. However, they can hire a certified commercial applicator or service provider in the vicinity who can fill this need.

Several broad categories of rodenticides are marketed commercially today, each of which works by a different mode of action. A large number of products fall within what is known as anticoagulants, products that, as the name suggests, are designed to cause death by inducing internal bleeding in the target animal. Other rodenticides disrupt certain physiological processes (e.g., cause neurologic system failure or induce edema). Rodenticide product development has changed significantly in recent years, leading to the creation of more products and formulations, many of which have proven to be quite effective in accomplishing what they were designed to do. However, in the process, they also have become more lethal to anything that gains access to them. Within the anticoagulant group, two prominent categories now exist: first-generation anticoagulant rodenticides (FGARs) and second-generation anticoagulant rodenticides (SGARs). FGARs (e.g., warfarin, diphacinone, chlorophacinone) have been around for years and have formed the backbone of traditional treatment of vole damage problems. In recent years, FGARs have somewhat fallen out of favor and are being replaced by a number of SGARs, given claims of greater effectiveness. Unfortunately, as the use of SGARs has increased (formulated with ingredients such as brodifacoum, bromadiolone, difethialone, and difenacoum), so too have the negative environmental impacts associated with their use, especially the concurrent increase in lethal secondary exposures among nontarget species. An additional fear is that secondary exposure potentially can occur among domestic/companion animals or small children unless special precautions are taken to prevent access to these lethal materials.

In addition to a growing number of lethal nontarget deaths, there is mounting evidence that sub-lethal concentrations of some of these products linger within organisms that prey upon animals that have consumed SGARs, a process called "bioaccumulation." Predators that help manage vole populations (such as hawks, owls, foxes, weasels, and snakes) are dying from secondary pesticide exposure and the lethal effects of bioaccumulated toxins over time. Similar concerns also exist with benzenamines, another type of potent toxicant (i.e., bromethalin).

Another serious issue with rodenticide use relates to product registrations and compliance with labeling. Because vertebrate pesticide registrations are approved and labeled for specific species and site applications, those who consider using these products must recognize that not all rodenticide products are registered for use on all vole species equally. Growers are responsible for distinguishing and correctly identifying which species of voles are causing damage and then selecting the appropriate products that are registered for use on woodland voles vs. those approved for meadow voles — there are very distinct differences in what is allowed here in Virginia (table 3). Currently, no SGARs are registered for use on woodland voles, whereas several SGARs are registered for use on meadow voles. A grower who finds damage caused by both species in the same orchard must implement a treatment plan based on use of only FGARs, as dissemination of products available for meadow voles would be a violation of labeling restrictions for woodland voles.

Table 3. List of chemical active ingredients currently registered by the U.S. Environmental Protection Agency as legal for use to manage vole populations in Virginia, according to the species of vole and site restrictions on where a product can be used.

Chemical Active Ingredient	Meadow Vole	Woodland Vole
Brodifacoum	Indoor or Outdoor Use (label specific)	Not Registered
Bromadiolone	Indoor or Outdoor Use (label specific)	Not Registered
Bromethalin	Indoor or Outdoor Use (label specific)	Not Registered
Chlorophacinone	Indoor or Outdoor Use (label specific)	Indoor or Outdoor Use (label specific)
Cholecalciferol (vitamin D3)	Indoor or Outdoor Use (label specific)	Not Registered
Difenacoum	Indoor Use only	Not Registered
Difethiolone	Indoor or Outdoor Use (label specific)	Not Registered
Diphacinone	Indoor or Outdoor Use (label specific)	Indoor or Outdoor Use (label specific)
Imidacloprid	Indoor or Outdoor Use (label specific)	Indoor or Outdoor Use (label specific)
Warfarin	Indoor or Outdoor Use (label specific)	Indoor or Outdoor Use (label specific)
Zinc Phosphide (Zn3P2)	Indoor or Outdoor Use (label specific)	Indoor or Outdoor Use (label specific)

VoleX is a different type of toxicant strategy, available under a 25(B)-exempt registration in Virginia. It employs use of active ingredients that, by design, are intended to cause severe dehydration in the animal that consumes the product. The combination of sodium chloride and citric acid, applied to a corn gluten paraffin-coated bait, is intended to facilitate desiccation and makes the affected animal stop feeding. However, no objective research studies were found that assess the overall effectiveness of this approach.

Successful application of lethal chemical treatment occurs only by paying close attention to label instructions and following several important precautions. First, broadcast surface applications of rodenticides are not recommended and should be avoided, especially where ground cover vegetation has not been well-maintained. Toxicants dispensed using broadcast methods will become lodged in the thatch of such vegetation, well above the ground surface, and never reach the area where the target animals can access it. Instead, with the toxicant now spread over and lying on top of the vegetative mat, exposure to other passing organisms often results in undesired nontarget losses. Even where the ground cover vegetation has been well-maintained or eliminated through herbicide treatment, broadcasting toxicants onto bare soil should be avoided. The granulated or treated grain products are readily evident against the soil surface and frequently will be mistaken as grit or potential food by birds, which can ingest sufficient quantities to induce death. Finally, broadcasting toxicants on the ground will not be effective in controlling woodland voles — they rarely interact with the toxicant because they spend little, if any, time on the surface.

The appropriate method for applying toxicants is by hand baiting known "hot spots," as determined by your AAI, FAI, or trap monitoring programs. Once you have located sites of active vole presence, small quantities of rodenticide can be placed directly into burrow openings. Alternatively, subsurface PVC "t-tube" bait stations (fig. 13) can be installed where runways and holes are present. The potential for secondary exposure is nearly nonexistent using these methods and the likelihood of controlling localized vole problems will approach 90%.

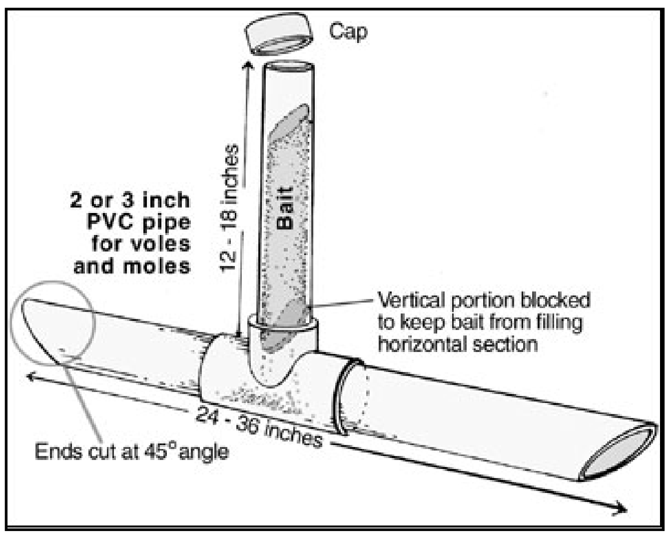

Figure 13. Schematic illustration of a PVC "t-tube" rodenticide delivery device that is inserted into the soil in known areas of vole activity. (Image courtesy of Missouri Cooperative Extension.)

An alternative to hand baiting that fruit producers and landscape nurseries have relied on is the use of mechanical baiters, known commonly as “mouse trail builders” or “burrow builders” (fig. 14). These tractor-mounted devices dispense a regulated amount of toxicant into an underground burrow created by the mechanism. In large-acreage production operations, burrow builders provide growers with an efficient and cost-effective means to treat a large area quickly and in a way that creates very low potential for secondary exposure. However, considerable time, effort, and money can be wasted and only marginal vole control will be achieved if this technique is applied in areas where vole activity has not been documented. Other typical operational problems can arise when mechanical trail baiters are improperly set for depth, used in unsuitable soil conditions, or applied at times of little or no vole presence. In orchards or nurseries, trails should be constructed on all sides of the tree (usually at about 2-4 inches in depth) and as close to the row as possible (without negatively cutting into the root system) so that the artificially created trails will intersect with burrows made by voles. Trails set too deep or too close to the surface will not make contact with existing tunnels, making the effort ineffective. Trail builders should be used only when soil moisture is sufficient to maintain the integrity of the newly created tunnel for several days. In dry or excessively sandy soils, tunnels created by the device will collapse, burying the toxicant and making it unavailable to the voles. In wet soils, excessive moisture rapidly degrades the toxicant and significantly shortens the period of its effectiveness. Finally, trail building should occur only after all other operational activities within the treatment area have finished, such as vehicle or pedestrian passage, to avoid collapsing any tunnel networks that have just been created.

Figure 14. A tractor-mounted mechanical burrow builder. (Photo courtesy of Eisler Machine and Welding, Lexington, Neb. Used by permission.)

When to Control

In addition to simply documenting vole presence, Dr. Askham’s FAI monitoring method also provides guidance on when to implement control and offers suggestions about what type of control treatment should be considered. Table 4 summarizes the suggested treatment protocol, based on output from the FAI assessment that is conducted within the production area. Although these prescriptions were developed specifically for fruit orchards, the protocol has been found to be relevant to other types of production, especially its reliance on appropriate and timely management of ground cover vegetation.

Table 4. Suggested treatment recommendations for managing vole populations based upon the output from performing a Feeding Index (FI) assessment.

Feeding Index (FI) Value	Recommended Treatment
0	None; continue population monitoring; mow between rows at least once every 2 weeks
< 1.0	Cultivate or treat rows with herbicide to reduce vegetative ground cover; mow between rows weekly; treat identified vole “hot spots” with hand-baited rodenticide
1.0 – 1.9	Same as above, but increase the frequency of mowing
2.0 – 2.9	Apply rodenticide to all sectors where vole activity has been detected; maintain strict control of ground cover vegetation
3.0 – 4.0	Emergency treatment is needed—remove all vegetative cover and forage from within the rows; multiple treatments of rodenticide likely will be required

Evaluating the Success of Treatment

A significant problem among producers is that many who apply some form of control treatment never conduct any follow-up to assess if the treatment impacted vole numbers. Without performing timely follow-up monitoring, there is no way to determine whether the treatment was effective and sufficient to properly manage an infestation of voles. Monitoring the effectiveness of rodenticide treatments actually is quite easy — a simplified version of the AAI, FAI, or trapping assessment techniques will accomplish this. To meaningfully gauge impact on vole activity, pretreatment and posttreatment assessments are needed.

Before treatment is implemented, place apple slices at 20 or more sampling stations in an area that contains active runs. Count the number of slices that were chewed overnight and calculate a percent visitation rate using the total number of sampling sites (e.g., slices at 13 of 20 sites chewed = 65% visitation). Apply the recommended treatment and wait one week, then repeat the sampling process using the same sample sites. Check the slices after 24 hours and recalculate the percent visitation (e.g., in round 2, slices at only 4 of 20 sites were chewed = 20% visitation). The relative reduction in the vole population, and hence the success of treatment, is reflected in the change between the two visitation percentages (i.e., 65% to 20% = 69% reduction).

Pre- and posttreatment trapping also can be used to monitor population reductions. Select 10-12 trees per row where vole activity has been detected and, for each selected tree, place four baited traps within the dripline (set and baited as outlined earlier). If voles are captured at more than two sample sites, reapplication or a change of treatment product may be warranted.

Voles remain active throughout the winter and will continue to breed, especially if the weather remains mild. Given this level of unrelenting activity, winter is a time when considerable damage can be inflicted on underground roots, tubers, and corms, primarily because other food resources (e.g., seeds, fresh grasses) typically are not available. Special attention is needed during winter in areas where accumulated snow covers the ground and persists for weeks at a time. Voles will tunnel within the layers of snow, which allows them to gain protected access to the parts of woody plants now shrouded by snow cover that normally would be out of reach. Despite applying a control treatment earlier in the year, vole problems can, and often do, become worse over the winter. Evidence of vole activity during the winter sometimes is easier to detect than at other times of year — simply look for tunnels in the snow. In severe cases, hand baiting these trails throughout the winter can help maintain some level of control until proper monitoring and treatment can be conducted after the snow has melted.

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Produced by Virginia Cooperative Extension, Virginia Tech, 2024

VT/0724/CNRE-181P