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Abstract: Efficacy trials using zinc phosphide (ZP) steam-rolled oats (2% a.i., EPA Reg. No. 56228-5), and cholecalciferol mixed (CHOL) grain bait (.075% a.i., EPA Reg. No. 12455-57), were conducted during summer 1990 to compare their effectiveness in controlling rodent damage to plastic tubing systems used to collect sap from sugar maples *(Acer saccharum)* in Vermont. A 24(c) Special Local Needs registration for ZP to control rodent damage has existed in Vermont since the 1960s. However, no formal efficacy trials have been conducted for this specific use of ZP, and the previous supplemental label did not include instructions for prebaiting or bait reapplication. Cumulative catch estimates of squirrels (Sciuridae) before and after rodenticide applications indicated that both ZP- and CHOL- treated baits may be effective in reducing tubing damage in areas where damage is particularly severe. In an effort to gain more insight into red squirrel *(Tamiasciurus hudsonicus)* movements in and around sugar bushes (woodlots managed for maple syrup production), 10 red squirrels were fitted with radio collars and monitored twice daily from August through October 1990. Red squirrel movements were often centered around small stands of conifers (29%), isolated apple *(Malus* spp.) trees (5%), and scattered blackberry *(Rubus* spp.) and raspberry thickets (12%), even though these areas comprised only a small portion of the sugar bush studied. In addition, habitat evaluation suggests that sugar bushes where tubing damage is most severe often have higher total basal areas. Management of sugar bushes to reduce these habitat types may decrease tubing damage.

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Damage to plastic tubing systems used in the maple industry may exceed $300,000 annually in Vermont (Howard and Pelsue 1987). May and Slate (1989) indicated damage was caused primarily by gnawing activity of the red squirrel, gray squirrel *(Sciurus carolinensis),* and eastern chipmunk *(Tamias striates).* Several cultural and chemical methods of control, including exclusion, repellents, habitat modification, shooting, trapping, and rodenticides, have been tried with limited success. Although there has been a 24(c) registration for zinc phosphide (ZP) bait to control squirrels and chipmunks in Vermont sugar bushes since the 1960s, few producers currently use it because of poor success in controlling damage.

Most rodents use olfactory cues in locating food (Marsh et a1.1970). ZP has a characteristic phosphorus odor described by most as garlic-like. This odor may result, in part, from phosphine gas liberated by the rodenticide (Howard and Cole 1967, Howard et al. 1968). Howard et al. (1968) found that as the amount of bait at feeding stations was increased, phosphine gas odorwas sufficiently strong to reducetheresponsesof California ground squirrels *(Spermophilus beecheyi douglasii)* to the stations. The poor success in controlling rodent damage in Vermont sugar bushes may be due to a similar bait acceptance problem.

Cholecalciterol (CHOL), which has no odor, and ZP were field tested for efficacy in Vermont sugar bushes. Tests were conducted under the authority of a State Experimental Use Permit, as part of an ongoing project involving: (1) field trials of repellents; (2) removable drop lines; (3) electrified polywire to exclude rodents from plastic tubing systems; (4) use of radio telemetry to examine red squirrel behavior within sugar bushes; and (5) monitoring mast production in order to attempt to predict years when rodent populations may increase, and damage may be high.

We would like to thank the following landowners participating in this study: H. Morse, Jr., E. H. Long, J. N. Laggis, J. Cota, and D. R. Marvin. We also appreciate cooperation and guidance from the Vermont Department of Agriculture and Markets, and the Vermont Fish and Wildlife Department. V. J. Kriesel, from Bell Laboratories, provided CHOL used in the field trials. Dr. Kilpatrick, from the University of Vermont, provided the receiver and antenna used in telemetry studies.

STUDY AREAS

ZP was applied in 0.81-ha plots in 2 sugar bushes between 1 August 1990 and 9 October 1990. CHOL was applied in 0.81ha plots in each of 3 sugar bushes between 21 August 1990 and 9 October 1990. Elevations of application sites ranged from 341-472 m. All sites were managed at least partially for maple syrup production, and most had been selectively thinned to promote the release of sugar maples. All sites were dominated by sugar maple. However, 9 other tree species including American beech (Fagus grandifolia), yellow birch *(Betula alleghaniensis), eastern* hemlock *(Tsuga canadensis),* red spruce *(Picea rubens), striped* maple (Acer pensylvanicum), black cherry (Prunusserotina),bittemut hickory (Caryacordcformis),

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eastern hophornbeam *(Ostrya virginiana)*, and American basswood *(Tilia arnericana)* were present at varying densities. Total stem density and basal area averaged 68.4 trees/ha and 24.5 m2/ha respectively on the 5 application sites. Most sites had sizable areas covered by blackberry and raspberry canes.

METHODS

Cumulative catch estimates of squirrel populations before and after rodenticide applications were made using 48 x 15 x 15-cm single-door live traps. Traps were covered with white, plastic-mesh sandbags to provide a dry area for trapped animals and to help reduce trap stress. Each 0.81-ha plot was divided into quadrants. Three live traps were placed randomly at the bases of trees in each quadrant. Traps were opened and baited with peanutbutter shortly after dawn each morning and checked just before dusk each evening. At the Morse South (MS) site, live trapping was also conducted on 2 additional 0.81-ha plots immediately adjacent to the treatment plot. At the Morse North (NN site, live trapping was conducted on 1 additional 0.81-ha plot adjacent to the treatment plot. During the preapplication period, red and gray squirrels were tagged with National Band and Tag Co. size 1005-1 self-piercing ear tags, and released. Mark and recapture efforts continued at each site for approximately 3-4 weeks until no new squirrels were captured. Population estimates were based on cumulative catch. Squirrels captured during postapplication censuses were humanely euthanized to reduce tubing damage at these sites.

Victor' rat and mouse snap traps baited with peanut butter were used to capture and estimate the populations of small rodents in areas adjacent to treatment plots prior to rodenticide applications. After applications were completed, snap traps were used again within treatment plots to assess rodenticide efficacy.

ZP plots were prebaited with untreated oats to increase bait acceptance. CHOL plots were not prebaited. Applications of both rodenticides were administered simultaneously. Large, aluminum rat-bait boxes, wired to trees approximately 1.2-1.5 m above ground, were used to bait squirrels. Bait stations constructed of 3.8-cm PVC pipe in the shape of an inverted `17were wired to the base of trees (Tobin and Richmond 1987) to bait chipmunks, mice, and microtine mammals. Four boxes (1 per quadrant), and 8 Ts (2 per quadrant), were placed in each plot. Each box and T-tube received 142 g of bait. Bait was replaced as necessary. Upon completion of the trials, unconsumed bait from both types of bait stations was collected and disposed of according to label directions.

Nine red squirrels were fitted with AVM Instrument brass, tuned-loop radio collars, and monitored with a Wildlife Materials TRX-1000S receiver and a 4-element, hand-held Yagi antenna, between 27 July and 20 November 1990. All 9 collared squirrels were within a 2.8-ha stand dominated by oldage sugar maples at 341 m elevation.

RESULTS

Zinc Phosphide

A total of 5.67 kg of ZP-treated grain was applied in 2 test sites between 1 August 1990 and 9 October 1990 after a 3-4 week prebaiting period (Table 1). Acceptance of treated bait in boxes was poor despite good acceptance of the prebait. This was likely a result of bait shyness associated with the odor of ZP. Most rodenticide added to bait stations was replacement of bait that had become damp and was not consumed.

Table 1. Amount of zinc phosphide applied at 2 Vermont test sites between August and September 1990.

MS SITE'		CA SITE	
Date	Amount (g)	Date	Amount (g)
9/10	1,701	8/1	1,701
9/21	567	8/14	1 1
Total	2,268		3,402

' Bait stations were removed from MS and CA sites on 9 October and 4 September, respectively.

Cholecalciferol

A total of 12.5 kg of CHOL was applied in three 0.8- ha test sites between 21 August 1990 and 9 October 1990 (Table 2). CHOL appeared to be readily accepted by rodents feeding in bait boxes as well as in T-tube bait stations. Postapplication surveys indicated fewer squirrels present at each site (Fig. 1). There were no known nontarget deaths as a result of CHOL or ZP grain applications.

Table 2. Amounts of cholecalciferol applied at 3 Vermont sugar bushes between August and October 1990.

MN SITE'		L SITE		H SITE	
Date	Amount (g)	Date	Amount (g)	Date	Amount (g)
9/10	1,701.0	8/21	1,701.0	8/21	1,701.0
9/21	850.5	8/29	1,559.2	8/28	1,701.0
10/1	779.6	9/4	1.134.0	9/5	567.0
		9/11	779.6		
Total	3,331.1		4,394.2		3,969.0

' Bait stations removed from MN, L, and H sites on 9 October, 17 September, and 17 September 1990, respectively.

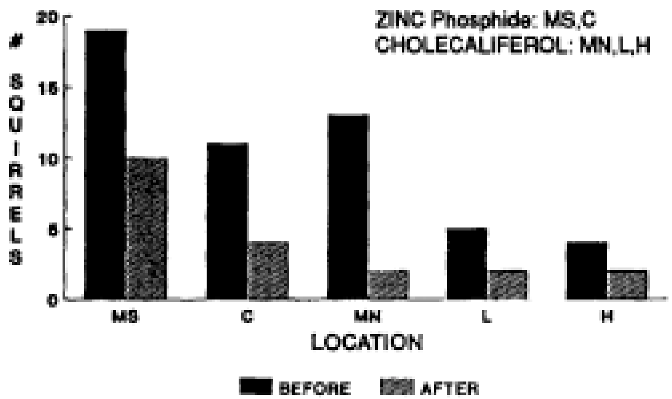

Fig. 1. Numbers of squirrels caught at rodenticide trial plots in Vermont sugar bushes before and after applications, AugustOctober 1990.

Largernumbers of small rodents, primarily shrews (Blarina spp.), were caught after the application in 3 of the 5 study sites. Although numbers of deer mice (Peromyscus spp.) were 360 lower immediately after application (Fig. 2), controlling tubing damage caused by small rodents with CHOL may be impractical due to their fecundity.

Sugar bushes where tubing damage was most severe had higher total basal area and higher squirrel populations than those with minimal damage (Table 3). There was no apparent relationship between the extent of tubing damage and stem density.

Table 3. Habitat characteristics and pretreatment squirrel populations at rodenticide application sites in Vermont sugar bushes, August through October 1990.

Sugar Bush	Total BA (mz/ha)	Total Stem Density (trees/ha)	Tree Species Diversity	No. of Squirrels Prior to Application
CA'	29.8	53.9	4	11
MN'	27.5	126.2	4	13
MS'	25.2	24.9	2	19
LiJs	23.9	66.4	7	1
UP	23.4	66.8	6	1
HK	22.5	80.7	3	4
BUb	20.2	101.1	4	2
LL	17.9	35.0	8	5

' Tubing damage was most severe in these locations. b Applications were not made on the LU, BL, or BU sites because of low initial squirrel estimates.

Red squirrel movements in sugar bushes were often centered around small stands of conifers and blackberry thickets (Fig. 3), even though these species comprised only a small portion of the total habitat. Peak occurrence of squirrels in blackberry thickets, apple trees, and cornfields appeared to correspond with fruit maturation (Table 4). In addition, these thickets provided very effective escape cover.

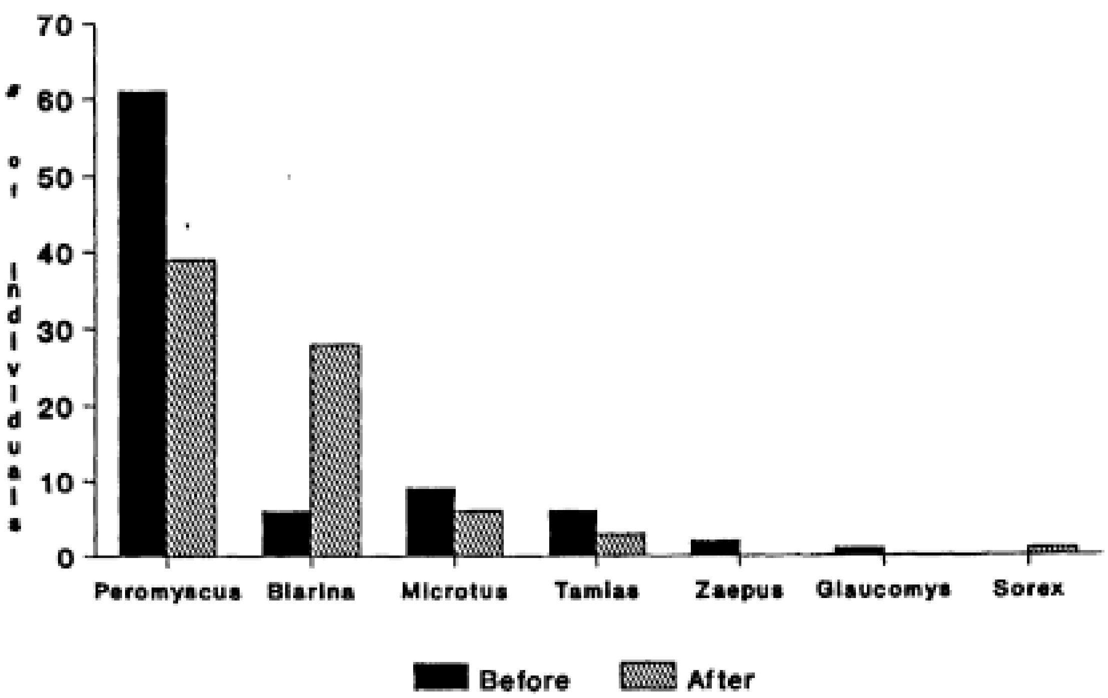

Fig. 2. Numbers of small mammal species trapped before and after rodenticide applications at all Vermont sugar bush plots, August-October 1990.

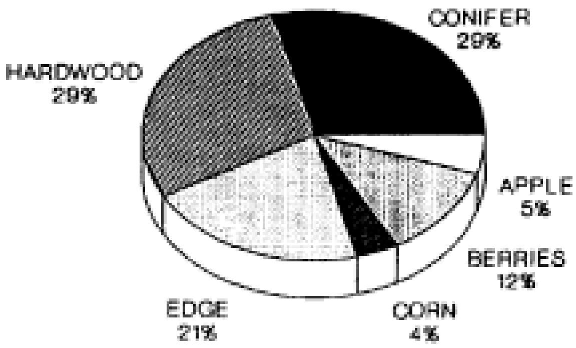

Fig. 3. Percent occurrence of (n = 360 observations) 7 radiocollared squirrels in 6 Vermont sugar bush habitat types during 27 July-20 November 1990.

Table 4. Number of telemetry observations (n = 295) of red squirrels in selected Vermont sugar bush habitats between 27 July and 20 November 1990.

	Hard-woods	Berries	Apple	Corn	Coni-fers	Edge
July'	3	1	2	0	0	0
August	50	32	39	27	0	0
September	19	46	26	5	9	3
October	9	7	3	0	5	5
November	0	0	3	0	1	0
Total	81	86	73	32	15	8

' Data for July includes 1 week of observation.

DISCUSSION

Rodenticide Efficacy

Although bait acceptance appeared to be good in T-tube stations using both CHOL and ZP, snap-trapping results did not indicate short-term impacts on local population of small rodents. Deish (1986) found that poisoning of prairie dogs in western South Dakota did not cause statistically significant losses of deer mice, and doncluded that use of ZP appears to impose minimum impacts to nontarget small mammals.

ZP and CHOL appear to be equally successful in reducing red squirrel populations in Vermont sugar bushes. One distinct advantage in using CHOL is that a 2-3 week prebaiting period is not necessary. Although ZP has a tendency to be ineffective if the grain becomes damp, this problem may be avoided by regularly checking bait boxes and replacing bait during wet weather. Because only small amounts of bait (< 142 g) should be used at any one time, wastage is minimal.

Habitat Evaluation

Small, irregularly-shaped sugar bushes with extensive edge had more severe rodent damage to tubing systems. Trees located on the edge of a stand have higher seed supplies and tend to attract more squirrels (Larson and Schubert 1970). These edge trees also tend to have higher nutrient content (Gurnell 1982). This may explain why squirrels were attracted to trees along the edges of sugar bushes. Quality as well as quantity of f sap may also be important to squirrels. Sullivan and Sullivan (1982) noted tree-barking damage was more severe on lodgepole pines (Pines contorta) that had been fertilized than on trees that were not fertilized. Sugar makers planning to fertilize stands to offset the effects of acid deposition and general decline in sugar maple growth and production should consider the potential impact of fertilization on increasing squirrel damage.

Field trials

Radio telemetry studies and earlier observations suggest that dmingofrodenticideapplications tocontrol squirrel damage to maple tubing systems may be very important. The time of year when most tubing damage occurs appears to be highly variable. However, in one closely monitored sugar bush, damage in 1989 and 1990 occurred between May and August. These months coincide with breeding and dispersal of young squirrels born in the spring, resulting in more opportunities for agonistic behavior. Gurnell (1987) observed that this is when most tree debarking by red squirrels occurs, and suggests that aggressive agonistic behavior is channeled into debarking behavior. Attraction to salt deposits left on and in tubing after washing with chlorine solutions, attraction to sap in the tubing during the spring, and the general tendency of rodents to gnaw, are other reasons squirrels may be attracted to plastic tubing systems (May and Slate 1989).

Tubing damage also varies annually. Field trials using electric polywire and repellents (May and Slate 1989), as well as a test using connectors that allow vulnerable droplines to be removed, sustained substantially less damage in 1990 than in the previous year (Fig. 4). This may be the result of decreased squirrel activity within the sugar bush due to a decrease in maple mast production in 1990 (Fig. 5).

0'

Fig. 4. Tubing damage control trials in Vermont sugar bushes during 1989 and 1990. Quick-lock test was initiated during February 1990.

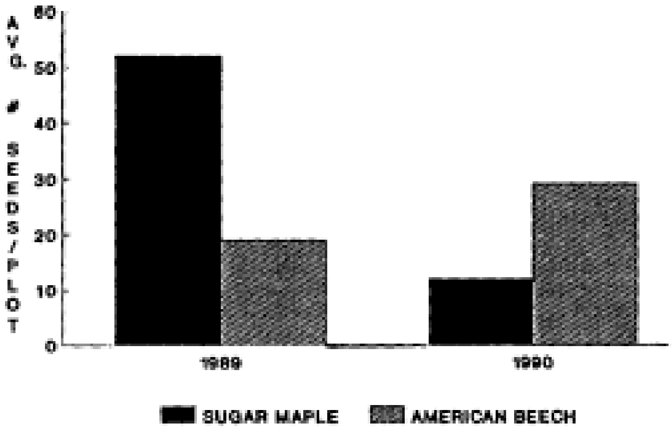

Fig. 5. Sugar maple and American beech seedling counts in a Vermont sugarbush during 1989 and 1990.

MANAGEMENT IMPLICATIONS

Several factors should be considered when planning measures to control squirrel damage to maple tubing systems. These include severity of the damage, cost of control, dispersal of young squirrels in late summer, and seasonal use of adjacent habitat types by squirrels throughout the year. An integrated approach using several methods (i.e., habitat modification, quick-lock connectors, reduction in the use of chlorine solutions to wash tubing, snap trapping, and rodenticides) will likely achieve the best results (May and Slate 1989). Lethal controls provide only a temporary reduction in tubing damage because of recruitment, immigration, and fecundity of squirrels and chipmunks. Therefore, removals need to be repeated periodically. Wood (1965) stated that management of wildlife populations provides the most desirable densities compatible with land-use practices and productivity of the habitat. Decisions to use lethal methods to control rodent damage to tubing systems must consider current land-use practices and management objectives.

Current recommendations to reduce rodent damage to plastic tubing systems used to collect maple sap include: (1) Reduce or discontinue use of chlorine solutions to wash tubing. If chlorine solutions are used, tubing should be rinsed thor oughly. (2) Use quick-lock connectors that allow vulnerable drop lines to be easily removed after the sugaring season. (3) Selectively thin conifers, apple trees, and berry vines from sugar bushes where damage is severe. (4) Use snap-traps wired to trees in small sugar bushes, or localized areas of heavy damage in large bushes. (5) In large sugar bushes where damage is severe, ZP may be used if it is registered for this use. Proper prebaiting is very important when using this method. Although CHOL appears to be equally successful in controlling squirrel damage in sugar bushes, it is not currently registered for this purpose.

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