February 1979

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Because of the lack of long-term studies on the population dynamics of pine voles in Pennsylvania orchards, a study intended to collect various population parameters was initiated in Adams County in November 1973 and continued until November 1977. Two orchards, 0.3 km apart, were chosen for study. Pine voles in Orchard A were live-trapped, and those in Orchard B were snap-trapped. Population density estimates were determined from capture-recapture data from Orchard A, and information on age structure, reproduction, and physical condition were recorded from necropsied voles from Orchard B. Both orchards were maintained and treated by orchard personnel with Endrin ground spray and/or zinc phosphide bait each year.

RESULTS: Population Density. Schnabel estimates of pine vole density were derived from 512 individuals captured 1007 times (Figure 1).

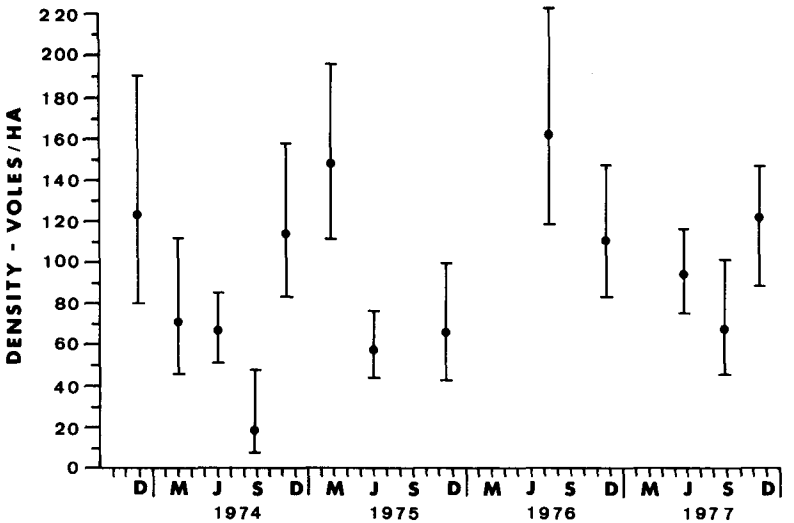

FIGURE 1. Schnabel density estimates of pine voles in Orchard A, November 1973-November 1977. (Dots indicate estimates and vertical lines are 95 percent confidence intervals.)

The lowest density was recorded in August 1974 (18 voles/ha) and the two highest densities occurred in March 1975 and July 1976 (147 and 162 voles/ha, respectively). Overall, 9 of the 12 density estimates were between 55 and 125 voles/ha.

Seasonally, spring densities were lower than fall densities of the same year. Variable summer and winter estimates, however, disrupt the seasonal trend. Although yearly lows occurred during the summers of 1974 and 1977, the highest density recorded during the study occurred in the summer of 1976. Likewise, a moderate density in winter 1974 is in

contrast to a very high density in winter 1975. These variations in density suggest that populations may reach high levels during any season of the year, and suggest the need for control throughout the year.

Applications of Endrin in November 1973, 1974, and 1975, and zinc phosphide in July 1975; June, July, and November 1976; and August and November 1977, were ineffective in maintaining densities at low (< 50 voles/ha) levels.

Reproduction. Table 1 shows the seasonal percentages of reproductively active adult females from Orchard B. Females were considered reproductively active if they were pregnant or showed evidence of having

TABLE 1. The percentages of reproductively active and pregnant adult females sampled from Orchard B, March 1974-November 1977.

Period	1974	1975	1976	1977	Years Combined
			PERCENTAGE REPRODUCTIVELY ACTIVE		
Feb-Mar	55.6 (27)[a]	63.6 (22)	--	--	59.2 (49)
May-Jun	97.1 (34)	84.2 (19)	--	64.0 (25)	83.3 (78)
Jul-Aug	100.0 (21)	--	93.1 (29)	88.9 (18)	94.1 (68)
Nov	88.9 (18)	86.4 (22)	81.6 (38)	77.8 (18)	83.3 (96)
			PERCENTAGE PREGNANT		
Feb-Mar	18.5 (27)	36.4 (22)	--	--	26.5 (49)
May-Jun	44.1 (34)	31.6 (19)	--	44.0 (25)	41.0 (78)
Jul-Aug	57.1 (21)	--	55.2 (29)	50.0 (18)	54.4 (68)
Nov	27.8 (18)	40.9 (22)	42.1 (38)	55.6 (18)	41.7 (96)

[a]Numbers in parentheses indicate sample size.

undergone a recent pregnancy. Summer was the peak breeding period and winter was a period of reduced breeding. Reproduction occurred during all seasons.

The mean number of embryos per pregnant female, based on 122 pregnancies, was 2.3. The most frequent number of embryos per female was 2 (59 pregnancies), followed by 3 (44 pregnancies), 1 (15 pregnancies), 4 (2 pregnancies), and 5 and 6 (1 pregnancy each). The mean number of corpora lutea of 158 females was 2.8. The most frequent number of corpora lutea per ovulating female was 3 (73 females), followed by 2 (59 females), 4 (16 females), 5 (5 females), 1 (4 females), and 6 (2 females). During all sampling periods, the mean number of corpora lutea was greater than the mean number of embryos. A pre-implantation loss of 15.9 percent was determined from 195 embryos and 232 corpora lutea, recorded from 83 pregnant females.

The average number of placental scars of 111 adult females was 2.5, and the average number of corpora albicantia of 139 females was 2.4. Both parameters had mode values of 2. Because of difficulties in detecting small corpora albicantia and the possibility of retention of placental scars for more than one generation, corpora albicantia and placental scar counts were used only for recognizing multiparous females.

Sexual Maturity. Table 2 shows the percentages of reproductively active females within the adult female population, grouped according to age and sampling period. The three youngest reproductively

TABLE 2. Percentages of reproductively active females grouped according to age and season, Orchard B.

Age (days)	1976	1977			Total
	Fall	Spring	Summer	Fall	
30-59	50.0 (6)[a]	0.0 (3)	0.0 (4)	0.0 (1)	18.7 (16)
60-89	66.7 (9)	0.0 (6)	100.0 (3)	75.0 (4)	54.5 (22)
90-119	25.0 (4)	50.0 (2)	80.0 (5)	0.0 (2)	46.2 (13)
120-149	87.7 (8)	66.7 (3)	100.0 (2)	100.0 (2)	86.7 (15)
150+	87.7 (16)	100.0 (12)	100.0 (7)	100.0 (9)	95.5 (44)

[a]Numbers in parentheses indicate sample size.

active females were caught during fall 1976 and were estimated to be 37, 41, and 59 days old. However, the two younger females were large for their estimated ages (total lengths of 113 and 112 mm, respectively), and their ages may have been underestimated. Over 50 percent of the females between the ages of 60 and 90 days were reproductively active, and all but 2 of 44 females were active after 150 days.

There appeared to be a delay in sexual maturity over the winter since no reproductively active females less than 90 days old were present in the spring 1977 sample. Delayed maturation in individuals born late in the breeding season appears to be an established pattern in other species and may be applicable to young over-wintering pine voles.

Age Structure. Juvenile percentages, as determined by pelage characteristics, ranged from 0.0 to 41.9 percent in Orchard A and from 2.4 to 21.4 percent in Orchard B (Table 3). The only significant

TABLE 3. The percentages of juveniles (as determined by pelage) in samples taken from Orchards A and B.

Season	1974	1975	1976	1977
		ORCHARD A		
Winter	21.9 (32)[a]	41.9 (62)	--	--
Spring	9.7 (31)	17.9 (28)	--	16.7 (48)
Summer	0.0 (7)	--	15.1 (53)	17.2 (29)
Fall	13.6 (44)	8.0 (25)	16.7 (48)	20.7 (58)
		ORCHARD B		
Winter	16.4 (55)	8.5 (47)	--	--
Spring	14.5 (69)	2.4 (42)	--	10.3 (68)
Summer	10.8 (37)	--	20.7 (87)	21.1 (38)
Fall	21.4 (42)	15.1 (53)	9.9 (71)	7.5 (40)

[a]Numbers in parentheses indicate sample size.

variation among sampling periods occurred in Orchard A where an unusually high proportion of juveniles was caught in winter 1975. There were also no significant seasonal differences, which appears contradictory to observed seasonal changes in reproduction. Mortality among juveniles prior to weaning may account for this discrepancy and should not be overlooked in modeling pine vole populations.

Additional information on age structure was obtained from age estimates, determined from eye lens weights, of 214 pine voles sampled in Orchard B between November 1976 and November 1977. Figure 2 shows the percentages of voles within 60-day age intervals during 4 sampling

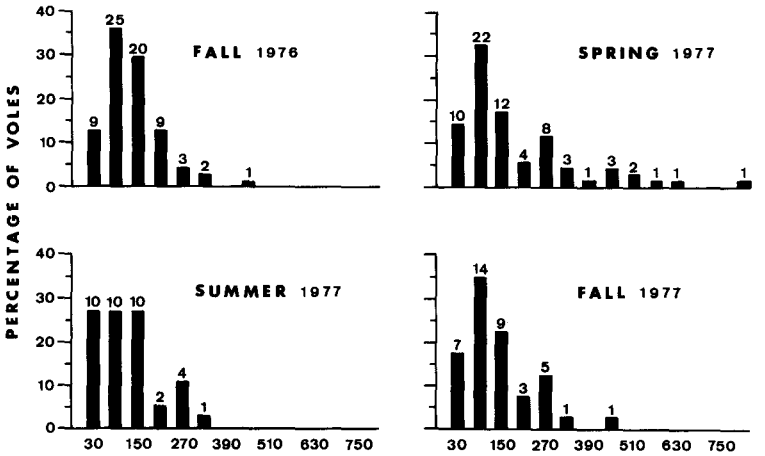

FIGURE 2. The percentage of voles within 60-day age intervals determined by eye lens weight aging criteria, November 1976-November 1977. (The numbers of voles per age interval are indicated above bars.)

periods. Most voles were less than 181 days old. Although voles frequently survived longer than 180 days, few lived longer than 1 year. The unusually high number of voles greater than 180 days of age caught during the spring of 1977 may be a result of an absence of control practices prior to sampling. However, further data are needed to confirm this possibility.

Physical Condition. Body weight/total length was used as an index to the physical condition of each individual. Figure 3 shows the average body weight/total length for adult males and adult non-pregnant females for each sampling period. For both sexes, physical condition declined from March 1974 through March 1975. By June 1975 an upward trend began and continued until November 1976. Thereafter, a second decline occurred which may have continued through August 1977. Overall, females were generally in better condition than males.

Comparisons between physical condition and reproductive activity revealed no apparent correlation. Similarly, no correlation could be detected between physical condition and the number of voles caught per 100 trap nights in Orchard B. Further investigation is needed to determine the relationship between physical condition and various population parameters.

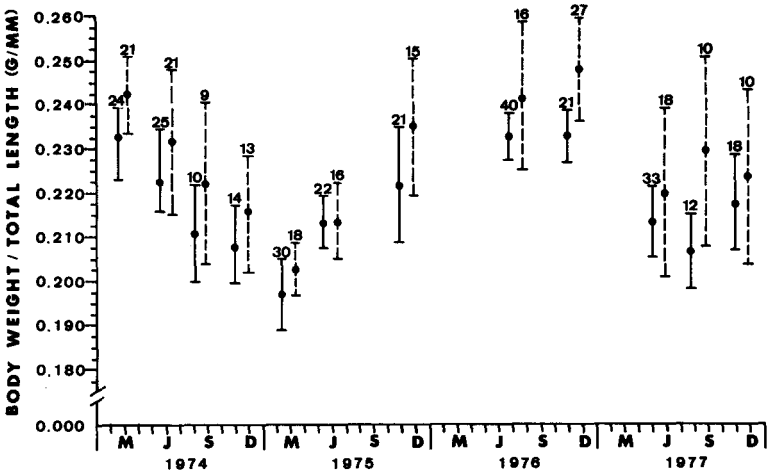

FIGURE 3. Body weight:total length ratios of 270 males (solid bars) and 194 females (broken bars) sampled from Orchard B, March 1974-November 1977. [Ninety-five percent confidence intervals and sample sizes (above bars) are indicated.]

CONCLUSIONS: The results of this study emphasize three important aspects of pine vole population dynamics that are often overlooked in control strategies: (1) populations may reach high densities during any season of the year; (2) a short life span and high reproductive rate results in a high population turnover; and (3) reproduction, though greatest in the summer, occurs during all seasons of the year. These conclusions stress the need for year-round management to maintain low (< 50 voles/ha) population levels, particularly before the breeding season when recruitment is greatest. Cultural practices in combination with toxicants may, therefore, be more effective in controlling pine voles than periodic treatments with toxicants alone.