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Introduction

In the summer of 1980 we initiated a large-scale vole population study in the lower Hudson Valley of New York and had questions regarding trapping designs and sampling procedures. Would samples reflect populations as they occurred in the orchard or would results merely be artifacts of the trapping design?

Renzulli et al. (1980) examined how time interval between trapping periods, trap spacing, and grid size affected demographic estimates in meadow voles, Microtus pennsylvanicus, in non-orchard habitats. In other small mammal studies conducted in non-orchard habitats, 2 traps per station are often utilized to avoid the exclusion of animals or compare different types of traps (Krebs 1966, Beacham and Krebs 1980, Glass and Slade 1980, Rose and Gaines 1978, Stickel 1954, Rose et al. 1977). Few, however, actually evaluate the relative efficiency of 1 versus 2 traps per station. Stickel (1954) found a slight increase in number of captures per individual when 2 traps were used instead of 1, but no conclusions were reached.

The relative efficiency of different trapping designs in sampling vole populations in orchards has received little attention. McAninch (1979) found that Sherman live traps were more efficient than snap traps when one of each was placed under the dripline, but other information is limited. Likewise, questions concerning effects of trap movement, day versus night trapping, and trappability need to be addressed in the orchard where densities are often higher than in other habitats and where vole movements are highly influenced by tree and row spacing (Gettle 1975). Thus, a pilot study with the following objectives was initiated:

1) To study the effects of 1 and 2 traps per tree (trap station) and movement of traps during a trapping session on the size and composition of vole sample obtained.
2) To determine the minimum number of trapping sessions needed to mark at least 80% of the trappable population under the different trapping

designs.
3) To determine if any segments of the population are being excluded from capture by trapping only during daylight hours.
4) To determine if trappability of sex and age groups differs within each trapping design or between designs.

Methods

The study area, located in the Minard apple orchard near New Paltz, New York, was a 0.4 ha orchard block bordered on 1 side by a paved road, another by a gravel road and hedgerow, and on the other 2 sides by orchard driveways. Apple trees were spaced at 9 m intervals in rows which were likewise 9 m apart. The block was 6 rows wide and 10 trees long. Each trap station consisted of a circle defined by the dripline of the tree and was divided into 4 equal quadrants.

The experiment was divided into 3 phases:
Phase 1: From June 28 to July 2, 1980, 2 Sherman live traps (5x5x18cm) were randomly placed in 2 of the 4 quadrants under the dripline of each tree within the vole runway system. Traps were checked every 3-4 hours during the day hours and closed at night. Two trapping sessions, i.e., a 3-4 hr interval culminating with a trap check, were conducted each day. After 6 trapping sessions, when few new voles were being captured, traps were moved to the 2 remaining quadrants around the same tree, so that eventually all 4 quadrants under the tree had been trapped. Three more trapping sessions were conducted, after which traps were set overnight for a final session. Voles were sexed and classified as adults or immatures (juveniles and subadults) based on body weight and the condition of mammae and genitalia.
Phase 2: This phase of the experiment, conducted July 3 to 5, began the day after Phase 1 ended in order to minimize the impact of vole movements into and out of the study area. Two traps were placed in the runways of each of 2 randomly chosen quadrants under the dripline. Two trapping sessions were conducted per day for a total of 6 sessions; traps were not moved.
Phase 3: This phase was conducted on July 6-7 and immediately followed Phase 2. One trap was placed in a randomly chosen quadrant at each tree. Five trapping sessions were conducted, 2 on the first day and 3 on the second. Traps were not moved.
Statistical tests were from Sokal and Rohlf (1969).

Results and Discussion

The number of new voles captured after the first 3 trapping sessions was low under all 3 trapping designs for all sex and age groups (Figs. 1,2,3). The trappable population under each phase of the experiment was defined as the total number of individual voles captured, i.e., 64, 49, and 33 for Phases 1,2, and 3, respectively.

Eighty to 90% of the trappable population were captured by the third trapping session in all phases of the experiment (Table 1). The number of new voles captured declined linearly with successive trap sessions for the first 2 phases (Fig. 1,2,3, Table 2). These regressions were significant ($P<0.05$) for most sex and age groups in Phase 1 and 2 but not Phase 3. By comparing the slopes of the regression lines

Table 1. Cumulative percent and number of original pine vole captures for the first 3 trapping sessions for the comparison of the 3 phases of an experiment conducted June 28 to July 7, 1980 near New Paltz, New York.

Trapping Session	Phase I (N=64) percent	Phase I (N=64) number	Phase 2 (N=49) percent	Phase 2 (N=49) number	Phase 3 (N=33) percent	Phase 3 (N=33) number
1	50.0[a]	32	55.1	27	60.6	20
2	76.6	49	83.7	41	75.8	25
3	79.7	51	89.8	44	78.8	26

a Chi-square test revealed no significant differences (P<0.05) between the 3 phases during trapping session 1, 2, or 3.

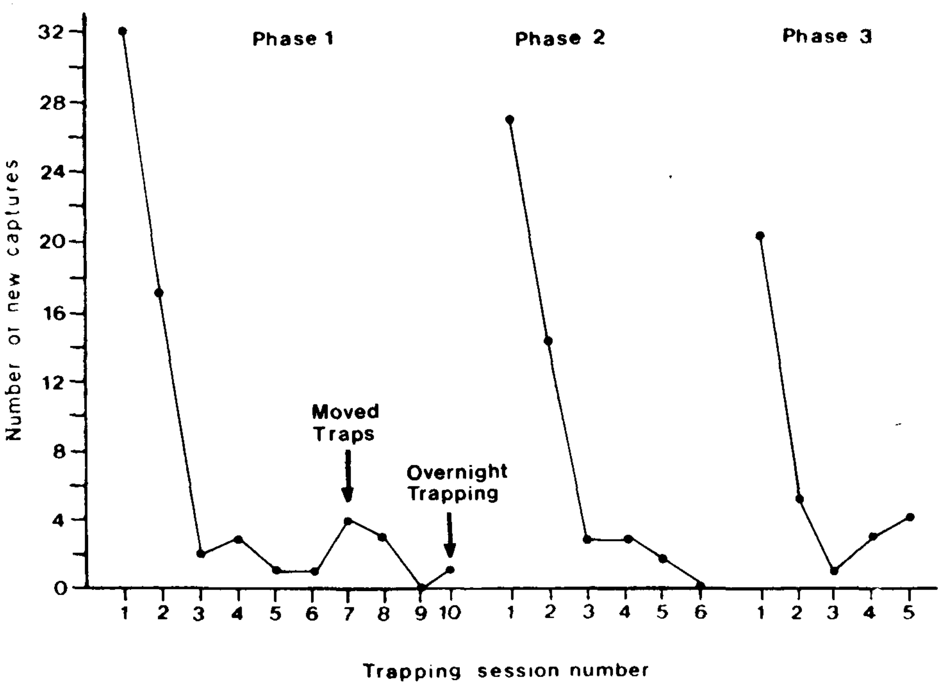

Fig. 1. Number of pine voles captured in each trapping session during the comparison of 3 phases of an experiment conducted June 28 to July 7, 1980 near New Paltz, New York.

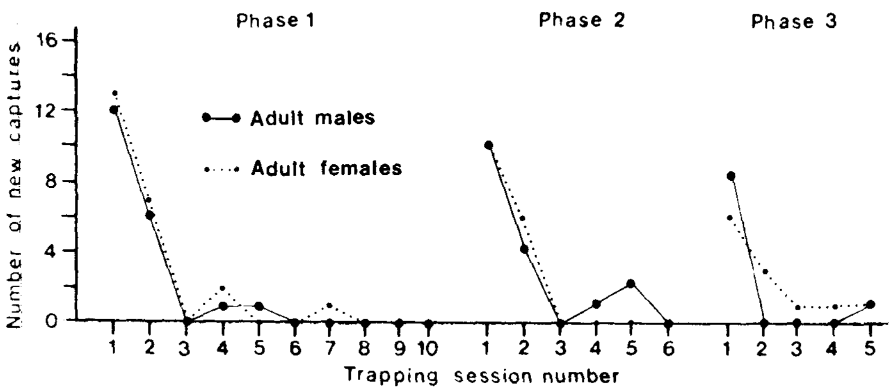

Fig. 2. Number of adult male and female pine voles captured in each trapping session during a comparison of 3 phases of an experiment conducted June 28 to July 7, 1980 near New Paltz, New York.

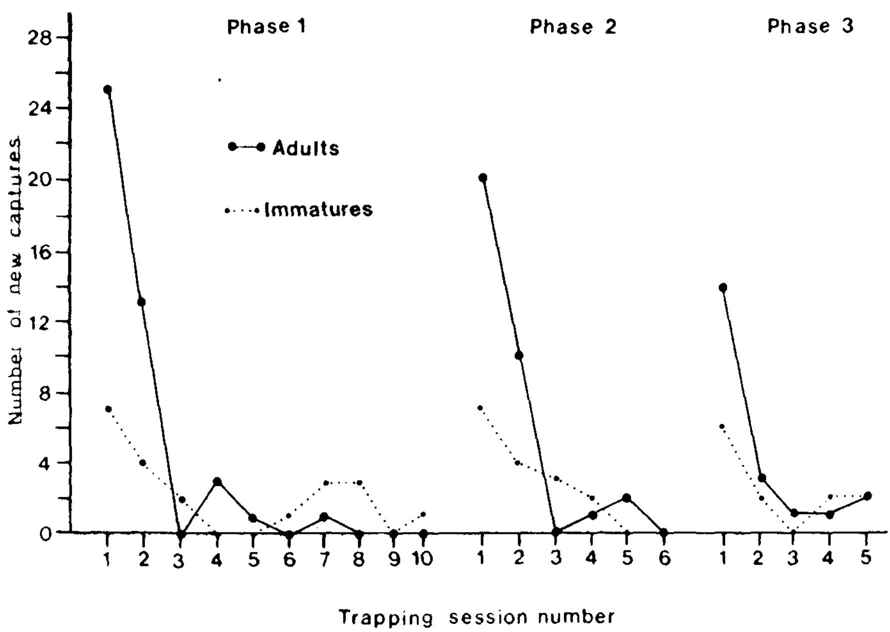

Fig. 3. Number of adults and immatures captured in each trapping session during the comparison of 3 phases of an experiment conducted June 28 to July 7, 1980 near New Paltz, New York.

Table 2. Regression statistics of original vole captures on trap session number for the comparison of 3 phases of an experiment conducted June 28 to July 7, 1980 near New Paltz, New York.

		Phase 1	Phase 2	Phase 3
Total Voles				
Slope	=	-2.3636	-4.8857	-3.4000
Intercept	=	19.4000	25.2667	16.8000
R^2	=	0.4880	0.7639	0.4957
P	=	0.0246	0.0228	0.1844
Adult Males				
Slope	=	-0.9333	-1.5714	-1.4000
Intercept	=	7.1333	8.3333	6.0000
R^2	=	0.5061	0.5933	0.4016
P	=	0.0210	0.0731	0.2509
Adult Females				
Slope	=	-1.0242	-1.9429	-1.2000
Intercept	=	7.9333	9.4667	6.000
R^2	=	0.5088	0.7078	0.7500
P	=	0.0206	0.0358	0.0577
Immature Voles				
Slope	=	-0.4061	-1.3714	-0.8000
Intercept	=	4.3333	7.4667	4.8000
R^2	=	0.3029	0.9315	0.3333
P	=	0.0992	0.0018	0.3081

of any one sex or age group between Phases 1, 2, and 3, we could determine if the rate of capturing the trappable population varied with the trapping design. Likewise, by comparing the slopes of lines within any one phase, differences in rates of capture for the different sex and age groups for any one trapping design could be determined. Because most of the trappable population had been captured by the third trapping session and the number of new captures after this point were negligible and appeared to fluctuate randomly (Figs. 1, 2, 3), regressions of new vole captures on trap session number were also calculated for the first 3 sessions.

Comparison of the slopes of these regression lines indicated no significant differences existed within the total vole group, adult male group, or immature group.in Phases 1, 2, or 3. However, slopes of lines for adult females were significantly different (P=0.0103) between Phases 1 and 3, a result that might have been due to the small sample size of Phase 3. A comparison of slopes within any one phase of the experiment indicated no significant difference in rates of capture between adult females and adult males for any given phase. However, rates of capture of adults versus immatures differed significantly within Phase 1 (P=0.0017) and within Phase 2 (P=0.0052). Adult sex ratios did not differ significantly between Phases 1, 2, or 3, nor did adult to immature ratios, further evidence that the 3 different trapping designs sampled the same population (Table 3).

Table 3. Comparison of sex and age ratios of pine voles for the three phases of an experiment conducted June 28 to July 7, 1980, near New Paltz, New York.

	Phase 1	Phase 2	Phase 3
Adult males[a] / Adult females	0.87:1 (n=43)	1.06:1 (n=33)	0.75:1 (n=21)
Adults[b] / Immatures	2.05:1 (n=64)	2.06:1 (n=49)	1.75:1 (n=33)

[a] χ^2 test revealed no significant difference (P<0.05) from a 1:1 ratio in any phase of the experiment

[b] χ^2 test revealed no significant difference (P<0.05) from a 2:1 ratio in any phase of the experiment

Estimates of relative abundance or population density from Phases 1, 2, and 3 provided an additional basis for comparing the 3 trapping designs. Mean catch per unit effort did not differ significantly between the 3 phases (P<0.05)(Table 4). A Lincoln Index (Lincoln 1930)

Table 4. Comparison of number of captures of pine voles per 100 trap sessions for the 3 phases of an experiment conducted June 28 to July 2, 1980, near New Paltz, New York.

Trapping Session	Pine Voles Captured/100 Trap Sessions[a]		
Number	Phase 1	Phase 2	Phase 3
1	30.33	23.18	34.19
2	20.56	19.57	23.93
3	9.30	17.72	13.33
4	17.06	24.03	16.81
5	16.81	20.51	25.64
6	14.72	13.56	-
7	10.05	-	-
8	22.22	-	-
9	9.28	-	-
10	13.56	-	-
MEAN±S.D.	16.39±6.65	19.76±3.82	22.78±8.13

[a] Captures per 100 trap sessions were corrected for sprung traps (Nelson and Clark 1973).

was used to compute population estimates. Confidence limits (P=0.95) were calculated according to Bailey (1951). An estimate of 75.7±8.7 was computed for Phase 2 and 71.4±9.0 for Phase 3 using the 64 voles trapped in Phase 1 as the number marked and released. A second estimate of 78.1±8.6 was calculated for Phase 3 utilizing the 64 originally marked voles plus 7 new voles marked in Phase 2 for a total of 71 marked and released voles. Differences in the population estimates were not significant (P<0.05).

Moving traps to different quadrants around a tree did not markedly change the sex or age composition of the catch. A total of 7 new voles, 1 adult female and 6 immatures, was captured in Phase 1 subsequent to moving traps (Fig. 3). Four of these 6 immatures were recaptured in subsequent trapping sessions indicating that they were not being excluded from capture by other, possibly more dominant, voles. Although 7 new voles were captured upon moving traps, the age ratios indicate that the same population was sampled with trap movement (Phase 1) and without trap movement (Phases 2 and 3)(Table 3). One possible explanation for the capture of 6 new immature voles upon trap movement is that these voles might have just entered the trappable population about the time that traps were moved. In any event, it seems probable that these immatures would have been captured without trap movement in Phase 1 because a substantial proportion of immatures were captured after the first 3 trapping sessions in Phases 2 and 3 (Fig. 3).

The 1 overnight trapping session produced only 1 new immature vole captured on the periphery of the study area. Thus, it appears that no segment of the population was excluded from capture by trapping only during the daytime.

Phases 2 and 3 involved less effort than Phase 1. Traps were not moved, and fewer trapping sessions were involved. As expected, fewer voles were captured in Phases 2 and 3. However, trapping success did not change markedly (Table 4), and new segments of the population were not encountered. Only 14.3% of the voles captured in Phase 2 and 9.1% of those captured in Phase 3 were captures of new, unmarked individuals.

Often, more than 1 trap per station is recommended to reduce the probability that the capture of an individual will prevent the capture of another at the same location. A trap station is said to be saturated with traps if at least 1 of 2 or more traps at a station remains unoccupied. Trap station saturation is particularly important to mark-recapture estimators that assume equal trap exposure or probability of capture for all individuals in a population.

In spite of high trapping success for each trapping session (9% to 30%) and vole densities of approximately 175/ha, trap station saturation was achieved with 2 traps per station. During any given trapping session, 2 occupied traps were found at only 3% of the stations in Phase 1 and at 5.8% of the stations in Phase 2. These percentages increased to 3.5 and 6.5, respectively, when the data were adjusted for sprung traps (Nelson and Clark 1973).

Trappability, calculated according to a modification of Beacham (1979), was highest for adult females and lowest for immatures in all 3 phases, but the difference was significant only in Phase 1 (P=≤0.05)

(Table 5). Immatures differed significantly between Phases 1 and 2

Table 5. Trappability indices of sex and age groups of pine voles trapped during 3 phases of an experiment conducted June 20 to July 7, 1980 near New Paltz, New York.[a]

	Phase 1	Phase 2	Phase 3
Adult Males	.321 (n = 19)	.456 (n = 15)	.420 (n = 7)
Adult Females	.357 (n = 23)	.531 (n = 16)	.446 (n = 13)
Immatures	.188 (n = 24)	.398 (n = 18)	.320 (n = 15)

[a] Trappability = $\dfrac{\sum^{N} \dfrac{\text{No. of captures for an animal}}{\text{No. of possible captures for that animal}}}{N}$

where N is the number of animals captured at least once

(P<0.05). Trappability decreased slightly for all groups in Phase 3, possibly because fewer traps were set. The lower trappability indices of immatures for all phases agree with the lower rates of capture revealed in the regression analysis. These combined data suggest that perhaps immatures are subject to underestimation in any trapping design.

Summary and Conclusions

Different sex and age groups of a pine vole population were sampled in equal proportions in Phases 1, 2, and 3. We conclude that one trap per tree will adequately sample a pine vole population in most orchard studies unless a very high number of captures is required as with Jolly-Seber survival estimates (Arnason and Baniuk 1980). In our study, voles were captured in both traps only 3 to 6% of the time when 2 traps were placed at each station. Thus the use of 1 trap per tree is justified to reduce effort and increase replication.

Approximately 80 to 90% of the trappable population under each trapping design were captured by the third of 6,3-4 hr trapping sessions. Regardless of trapping design, the first 3 trapping sessions were the most important for the capture of new voles. For most studies we feel it is not necessary to move traps or extend trapping far beyond 3 trapping sessions unless it is necessary to capture nearly all voles present or a large number of recaptures.

In studies involving pine voles, traps are often checked only once or twice daily (McAninch 1979, Hayne 1977, Paul 1970). However, by using a 3-4 hr trapping interval, up to 3 trapping sessions can be completed per day. This interval seemed to allow voles adequate time to encounter traps, and trap mortality was practically eliminated. Likewise, trapping only during the day reduced the possibility of trap mortality on cold nights and did not appear to exclude any segment of the population from capture.

Trappability was somewhat lower for immatures than for adults regardless of trapping design. Adult females appeared to be slightly more trappable than either adult males or immatures. Hayne (1978), however, reported no difference in trappability of these groups when he trapped for 2 trapping sessions, each 24 hr long. Possibly relative trappability differs with length of trapping session, season, or reproductive condition. This study supports Hayne's (1977) conclusion that some voles are trapped more often than others, an important bias if trapping is continued over a long period of time.

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