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INTRODUCTION

Pine voles (*Microtus pinetorum*) and meadow voles (*M. pennsylvanicus*) co-occur in orchards but may exhibit mutual avoidance through temporal or spatial isolation. Though pine and meadow voles have exhibited overlapping home ranges, individuals of the two species seldom occupy the same $2m^2$ area at the same time (Pagano & Madison, 1981). Differences in habitat use by pine and meadow voles may contribute to their spatial separation in orchards. McAnich (1979) found a weak relationship between meadow vole numbers and soil compaction, soil moisture, thatch depth, and light intensity and no relationship between meadow vole occurrence and soil organic matter or cover density. However, Pagano and Madison (1981) report a strong correlation between meadow vole numbers and abundant cover during August. Pine voles exhibited a significant relationship with soil compaction, thatch depth, and light intensity.

Studies concerning pine and meadow vole movements and habitat use have monitored established vole populations usually in maintained orchards. This paper reports on the ecological parameters associated with pine vole colonization of an abandoned orchard. Thus, site selection by pine voles and the effect of pine vole movement and establishment on meadow voles could be determined.

MATERIALS AND METHODS

In an isolated abandoned orchard in Montgomery County Virginia, which contained an established meadow vole population, two trap grids (0.25 hectare each) were established in June, 1980. Each grid consisted of four tree rows (10 trees per row) and 5 aisle rows with 94 and 102 trapsites per grid. The grids were separated by 35 meters of continuous habitat and were trapped monthly. Aisle rows had large Sherman traps 6 meters apart and tree rows had 2 small Sherman traps at each active tree site. Traps were baited with oats and apples and were placed in vole runs. Tree traps were dug into runways and covered with tar paper. Meadow vole populations were monitored throughout the study while pine vole populations were monitored after their release in 1980 and 1981.

In September, 1980 94 pine voles (47♂♂, 47♀♀) were released on the control grid but subsequently colonized the experimental grid. Since few members of this population survived the winter, a second release of 100 pine voles (50 ♂♂, 50 ♀♀) was conducted on the experimental grid in July, 1981. Voles were released on the central portion of the grids, 2 pairs per tree.

All trapped animals were toe clipped and/or ear tagged, sexed, measured (total length and body length), and reproductive condition recorded (teats, vagina, and testes). All trap and recapture data was recorded on grid maps to note areas of overlap and movement patterns within the population. Population densities were calculated by minimum number known alive (MNKA) (Krebs, 1966) both before and after pine vole introduction.

Vegetation and soil characteristics for sites where either pine voles, meadow voles, or no voles were captured were quantified. Vegetative ground cover was determined for 0-25 cm in height, 25-50 cm and 50-100 cm using a 0.5 by 1 meter vegetation cover board. Tree cover was characterized for 0-1.5 m and 1.5-3 m using a 3 m high by 10 cm wide cover density board. At each site soil moisture and pH was recorded using a Takemura soil pH and humidity tester. Soil samples were obtained with a soil auger and litter, A horizon, and B horizon depths were measured with a ruler. The relative percentage of grasses and forbs were noted at each site.

In July, 1981 a random sample of 66 trap sites, at both trees and aisles, on each grid was chosen for habitat analysis. This sample served to characterize the habitat available in the orchard prior to the 1981 pine vole release. Experimental samples were obtained immediately after the July, September, October, and November trapping session at sites where either pine or meadow voles had been captured.

During September, 1981 a second random sample of 66 trap sites on each grid was conducted. This sample served as a control sample for the release of voles in 1980 since no habitat sampling had been done at that time. Experimental samples were then obtained for all trap sites at which two or more meadow or pine voles had been captured in July, 1980 through February, 1981.

Stepwise discriminant analyses were performed on habitat data from each grid to determine which habitat variables were most important in discriminating between sites where pine, meadow, or no voles occurred.

RESULTS

Meadow vole population densities followed the same pattern on both grids despite the presence or absence of pine voles. The initial density on the experimental grid in July, 1980 was 117/ha and was 55/ha on the control grid (Fig. 1). Meadow vole densities peaked in the fall of 1980 and then declined through 1981. However, the introduction of pine voles in September, 1980 and July, 1981 had no discernable effect on meadow voles densities.

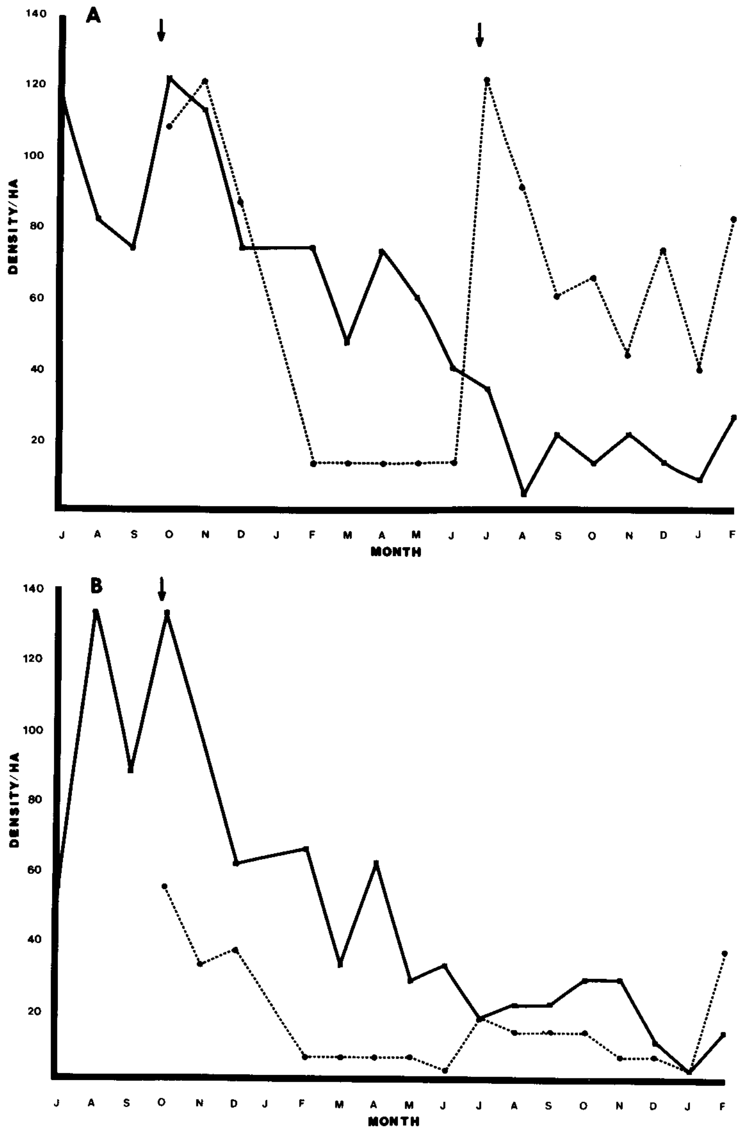

Figure 1. Population densities of M. pennsylvanicus (solid line) and M. pinetorum (dashed lines) from July 1979 - February 1982 on the experimental grid (A) and control grid (B). Downward arrow marks the points of introduction of M. pinetorum on the grids.

Throughout the study, meadow and pine voles were rarely captured at the same trap sites either within or between trapping periods. After the colonization of the experimental grid by pine voles in 1980, 36% of the trap sites captured only meadow voles, 22% captured only pine voles, while less than 16% of the trap sites captured both species. A similar distribution pattern occurred on the control grid with 49% of the trap sites capturing meadow voles, 7% pine voles, and less than 10% captured both species. After the second pine vole release, meadow and pine voles again exhibited spatial separation with 38% of the trap sites on the experimental grid capturing only meadow voles, 29% pine voles, and at 4% of the trap sites both species were captured. Pine voles were captured at five sites (4%) at which meadow voles had been caught during previous trapping sessions. Similar distribution patterns occurred on the control grid. During trapping sessions when pine voles were present, 23% of the meadow voles captured on each grid occurred at aisle trapsites adjacent to tree sites concurrently used by pine voles.

Pine vole densities were always greatest on the experimental grid, even though the 1980 release was on the control grid. This may have been due to the significantly lower amount of grass, greater depth of litter, and greater depth of the A horizon on the experimental grid when compared to the control grid. Pine vole occurrence was positively correlated with litter depth and negatively correlated with the occurrence of grasses, while the opposite correlations occurred with meadow voles (Table 1). Pine vole habitat was also characterized by high amounts of tree cover. Meadow voles were found in areas with a high percentage of low vegetative cover.

Both before and after the pine vole release, meadow voles were primarily captured at aisle sites. Prior to the pine vole introduction, 96% of the meadow voles captured on both grids were at aisle sites. After the release, 83% of the meadow vole captures on the experimental grid, and 89% on the control grid, were at aisle sites. Seventy seven percent of the pine voles captured on the experimental grid and 49% on the control grid were under trees.

Stepwise discriminant function analyses showed which habitat variables accounted for most of the variation in trap sites utilized by pine and meadow voles or no voles. Results from the experimental grid during the first year (i.e., July, 1980 - February, 1981) showed soil moisture and depth of the A soil horizon to be the most discriminating variables. Using these 2 habitat variables the analysis correctly classified 93% of the meadow vole sites, 37% of the pine voles sites, and 70% of the no vole sites. The depth of the A horizon was greatest at pine vole trapsites ($\overline{X}$ = 2.1 cm) least at meadow vole sites ($\overline{X}$ = 0.2 cm), and moderate at no-vole sites ($\overline{X}$ = 0.5 cm). Soil moisture was lower at no vole sites ($\overline{X}$ = 34.3%) than either pine ($\overline{X}$ = 46.1%) or meadow vole ($\overline{X}$ = 52.9%) trap sites. Similar results occurred on the control grid where soil moisture alone was the principal ıactor discriminating between trapsites, with lower soil moisture at no vole sites ($\overline{X}$ = 32.7%) than at either pine ($\overline{X}$ = 36.5%) or meadow vole sites ($\overline{X}$ = 47.3%).

During the second year (March, 1981 - November, 1981) low vegetative cover (0-25 cm), low tree cover (0-1.5), and depth of the A soil horizon were the most discriminating variables on the experimental grid. Using these habitat characteristics the analysis correctly classified 79% of the meadow vole trapsites, 64% of the pine vole sites, and 67% of the no vole sites. Mean low tree cover at no vole sites was 40.3% which did not differ from pine vole sites (37.9%), but both differed from meadow vole sites (3.6%). Mean low vegetative cover was 39.2% for pine vole sites while both no vole and meadow vole sites exceeded 69 percent. Depth for the A horizon was greatest for no vole sites ($\overline{X}$ = 4.2 cm) and lower for pine ($\overline{X}$ = 1.4 cm) and meadow vole sites ($\overline{X}$ = < 0.2 cm).

On the control grid the relative percentage of grasses and percent soil moisture were the discriminating variables for the second year. Using these variables 79% of the meadow vole sites, 64% of the pine vole sites, and 67% of the no vole sites were correctly classified. The percent grass cover was lowest at pine vole ($\overline{X}$ = 18.0%) and no vole sites ($\overline{X}$ = 25.3%) and greatest at meadow vole sites ($\overline{X}$ = 78.3%). As on the experimental grid, soil moisture was greatest at meadow vole sites, ($\overline{X}$ = 48.3%) and lower at pine vole($\overline{X}$ = 31.8%) and no vole sites ($\overline{X}$ = 31.6%).

A second set of discriminant analyses was conducted to discriminate between meadow and pine vole sites in the experimental samples. Each analysis used only two habitat variables to correctly classify at least 75% of the trap sites as either pine or meadow vole sites. For the first year low vegetative cover and low tree cover discriminated between the habitats of the two species on the experimental grid. Pine voles associated with reduced low vegetative cover ($\overline{X}$ = 42.2%) and more tree cover ($\overline{X}$ = 33.4%) than meadow voles ($\overline{X}$ = 75.1% and 3.3%, respectively). On the control grid meadow voles occurred in areas with thin A horizon's ($\overline{X}$ = 1.8 cm) as compared to pine voles ($\overline{X}$ = 19.5 cm).

During the second year meadow voles on the experimental grid associated with less litter ($\overline{X}$ = 0.37 cm) and thicker low vegetative cover ($\overline{X}$ = 72.9%) than did pine voles ($\overline{X}$ = 2.0 cm and 8.5% respectively). On the control grid meadow voles occurred in moist areas ($\overline{X}$ = 48.3% moisture) with a high occurrence of grasses ($\overline{X}$ = 78.3%) while pine voles were found in drier areas ($\overline{X}$ = 31.8% moisture) with a high occurrence of forbs ($\overline{X}$ = 82.0%).

DISCUSSION

The introduction of pine voles into an orchard containing only meadow voles had little effect on meadow vole density or spatial distribution. Similar density patterns for meadow voles occurred on both the control and experimental grids whether pine voles were present or not. However, because meadow vole densities declined from November, 1980 through January, 1982 it is difficult to ascertain what impact pine voles would have had on a more substantial meadow vole population. Pine voles exhibited spatial isolation from meadow voles which occupied grassy aisle areas while pine voles primarily occupied areas under trees. Meadow voles selected moist areas with abundant low vegetative cover such as grasses, while pine voles selected areas beneath trees where there was a substantial A soil horizon and litter layer, moderate soil moisture, and good low tree cover. Fisher and Anthony (1980) determined that litter layers and A horizon soil characteristics were important to pine vole establishment. Additionally Benton (1955) and Paul (1970) working in wooded habitats correlated cover conditions with pine vole occurence. These variables and others were significant in pine vole establishment when sypatric potential competitors were present. On occassion, meadow voles used burrows under trees which were previously utilized by pine voles, but in only one instance was a meadow vole found under a tree concurrently used by pine voles. More frequently, pine voles occurred in habitats typical for meadow voles but never for extended periods of time. These pine voles may have been exploring for more suitable habitat or dispersing to new areas.

The lack of a significant effect of an introduced pine vole population on an established meadow vole population suggests that these two species may exhibit little competitive interaction in the field. Due to extensive differences in their habitat preferences and mode of life (i.e. forsorial vs. terrestrial) one might expect little competition except perhaps for food resources. Since forage quality is relatively high in orchards competition for food would be minimal. Thus, pine and meadow voles co-exist in limited areas such as orchards with minimal interaction and pine voles exhibited no measurable effect on meadow vole spatial patterns. However, further research is needed to determine whether pine vole habitat use is limited by the presence of meadow voles.

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