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INTRODUCTION

With increased concern over the effects of pesticides on ecosystems and non-target species, the use of many toxic materials has either been banned or severly restricted. Consequently, a more ecological approach to vole damage is necessary to develop sounder methods of control. Distribution of pine voles (Microtus pinetorum), both seasonally and geographically, indicates that this species is not readily adaptable to a wide range of habitat types or conditions. If there are certain factors limiting the occurrence and abundance of pine voles, and they can be detected, we may be able to exploit this knowledge to adversely affect vole populations by manipulating their habitat.

The objectives of this study were to: (1) quantitatively measure both environmental parameters and control methods influencing the distribution and amount of damage done by pine and meadow voles (Microtus pennsylvanicus) in southern New England apple orchards, and (2) measure parameters which may determine intra-orchard distribution of the 2 species.

METHODS

Environmental parameters that could have an influence on damage caused by distribution and site selection of pine and meadow voles were measured at 2 habitat levels. The first level, interorchard, is the general habitat of the orchard and its surrounding landscape. The second level, intra-orchard, is the specific microhabitat used by individual animals.

Inter-orchard

At the general habitat level, 65 orchards in the southern New England area were visited to assess vole damage and habitat conditions. These orchards were selected to include areas of frequent, occasional, and rare (or none) vole damage throughout the study area (Fig. 1).

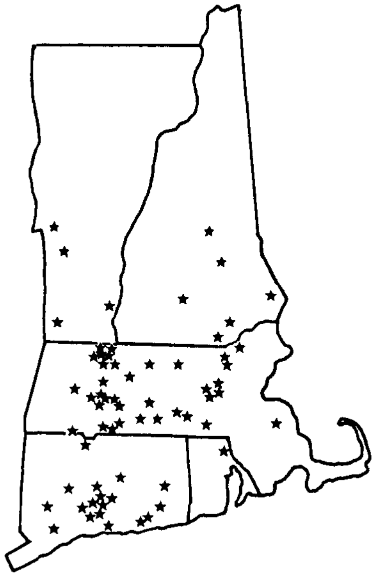

Figure 1. Distribution of orchards assessed for damage.

Damage at each orchard was determined through an interview with the owner/manager about conditions for the past 5-10 years and by random transects through the orchard to locate burrows, runways, and damaged trees. A Damage Index (DI) value was then calculated for each species at the orchard. DI values were:

0 - species not found
1 - species found, no damage recorded
2 - some damage occasional years
3 - some damage every year
4 - intensive damage occasional years
5 - intensive damage every year

Interviews with the owner/manager were done to find the control methods used for the past several years; type of poison, type of bait, application method and frequency of application, and whether herbicides were used around the trees; age of the orchard blocks; and tree types and rootstock in the blocks. Random transects through the orchards were done to measure tree densities, topography, and ground cover. Random soil samples (1 sample/2-4 ha) were taken of the top 25 cm of the orchard. Soil samples were analyzed for the amounts of gravel, sand, silt, clay, and organic matter present, pH, bulk density, and water moisture.

Intra-orchard

At each of the orchards used in the general habitat analysis, site specific soil and vegetation samples were taken from trees which were known to have been damaged by either pine or meadow voles. In addition, samples were taken from trees which showed no signs of damage and which had no burrows or runways under them.

The distribution of voles at 7 western Massachusetts orchards were determined by trapping. Each trapping area consisted of 10-12 randomly located grops of 3 trees in a row. Two Sherman live traps were placed under the dripline of each tree following the procedure of Gettle (1975). Each trapping area was trapped for 3 3-day periods in a consecuetive fall and spring. Parameters measured at each trap site were: tree type, dripline radius, distance to neighboring trees, soil type, vegetation, slope, and number of burrows and runways.

Analysis

Data for both habitat levels were tested using discriminant function analysis, a procedure for detecting and quantifying differences between sample groups from multivariate data. Discriminant analysis has 3 major purposes. The first purpose, discrimination, is to answer the question, "can we distinguish between groups?" The second and third purposes, are classification and prediction, i.e., "how can we distinguish between groups so that future subjects may be correcty grouped?" Assumptions, data compilation, and calculations for the discriminant procedure are discussed by Lindeman et al. (1980). Groupings on the vole data were determined by the type of species present and/or the amount of damage occuring. At present, only soil data from the inter-orchard and infested trees has been analyzed.

RESULTS

Inter-orchard

Discriminant function analyses of the random soil samples taken from each orchard and their corresponding DI values showed a 44.3% correct classification for pine voles

Table 1. Discriminant function classification results for random soil samples and pine vole DI values.

Actual DI Value	Predicted DI Values					
	0	1	2	3	4	5
0	67.9%	14.9	0.0	7.9	4.6	4.7
1	31.6	37.3	0.0	12.3	7.1	11.7
2	28.0	10.1	28.9	14.0	4.8	14.2
3	14.7	23.6	2.6	39.0	5.6	14.4
4	0.0	0.0	0.0	31.6	36.8	31.6
5	0.0	0.0	1.4	1.4	0.0	97.1

Table 2. Discriminant function classification results for random soil samples and meadow vole DI values.

Actual DI Value	Predicted DI Values				
	0	1	2	3	4
0	39.8%	28.0	2.8	21.0	8.4
1	26.1	49.7	10.9	10.2	3.0
2	30.4	13.8	30.7	16.6	8.5
3	10.7	28.0	14.9	28.2	18.2
4	10.1	7.5	0.0	20.9	61.6

Table 3. Standardized discriminant function coefficients for pine vole DI values and random soil samples.

	Separate DI Values			Pooled DI	
Variable	Func. 1	Func. 2	Func. 3	Func. 1	Func. 2
Organic Matter	-.90	-.14	-.55	-.30	-.58
Gravel	-.34	-.49	.19	-.58	-.07
Sand	-.69	.13	-.15	.53	-.16
Clay	-.81	-.14	.79	-.01	-.15
pH	-.20	-.09	-.48	-.10	.20
Litter Depth	.16	-.93	-.08	-.27	.19
Bulk Density	-.11	.16	.01	.19	-.82
Moisture Content	.26	.26	.02	.40	-.19
DI Means					
0	.21	.80	-.11	.53	.25
1	.44	.10	-.02		
2	-1.01	.05	.26	-.21	.37
3	.33	-.39	.09		
4	-.72	-.71	-1.04	-1.64	.69
5	-.66	-.12	-1.06		

Table 4. Standardized discriminant function coefficients for meadow vole DI values and random soil samples.

	Separate DI Values			Pooled DI	
Variable	Func. 1	Func. 2	Func. 3	Func. 1	Func. 2
Organic Matter	-.11	-.77	.04	-.68	.66
Gravel	-.49	-.38	-.19	-.81	-.38
Sand	.72	-.44	-.69	-.53	-.09
Clay	.31	-.87	-.72	-.63	-.76
pH	-.13	.17	-.20	.15	.52
Litter Depth	-.35	.26	.05	-.72	-.11
Bulk Density	.25	-.41	1.01	.05	.01
Moisture Content	.30	.10	.80	.33	-.04
DI Means					
0	.20	.35	.18	.62	.12
1	.55	.37	-.13		
2	.21	-.89	-.09	-.25	-.17
3	-.38	-.01	.27		
4	-1.78	.25	-.33	-.86	1.05

Table 5. Discriminant function classification results for random soil samples and combined pine vole DI values.

Actual DI Value	Predicted DI Values 0-1	2-3	4-5
0-1	76.4%	17.4	6.2
2-3	40.7	45.3	14.0
4-5	17.5	13.4	69.1

Table 6. Discriminant function classification results for random soil samples and combined meadow vole DI values.

Actual DI Value	Predicted DI Values 0-1	2-3	4-5
0-1	74.8%	14.8	10.4
2-3	33.3	43.0	23.7
4-5	0.0	22.6	77.4

Table 7. Discriminant function classification for soil samples taken from pine vole, meadow vole, and uninfested trees.

		Predicted Group Membership		
Actual Group	Samples	Pine	Meadow	Neither
Pine Vole Damaged	30	46.7%	20.0	33.3
Meadow Vole Damaged	18	50.0	33.3	16.7
Undamaged Trees	35	28.6	22.9	48.6

(Table 1) and a 40.1% correct classification for meadow voles (Table 2). About 70% of the samples, however, were classified into either the correct DI value or the value just above or below it on the scale. There was little overlap between orchards with no damage and those exhibiting intensive damage. Percent organic matter and litter depth were the variables most correlated with high DI values for pine voles while soil moisture was correlated with low DI values (Table 3). Percent sand was correlated with low meadow vole levels (Table 4).

When these tests were repeated using combined DI values (0-1, 2-3, 4-5) the number of samples correctly classified was 61.3% for pine voles (Table 5) and 55.5% for meadow voles (Table 6). For both species most of the incorrectly classified samples were from the occasional damage DI values (2-3). There was little overlap between the samples for orchards with no damage and those with heavy damage. High percentages of organic matter, gravel, and moisture were related to high DI values for pine voles (Table 3). High DI values for meadow voles were related to the amount of organic matter in the soil.

Intre-orchard

Analysis of the soil data taken from damaged and undamaged trees showed no correlation between predicted and observed groups (Table 7). The samples correctly classified was only 44.6% which is only slightly better than random chance. When only the pine and meadow vole trees were tested, the number of samples correctly classified was 70.8% (Table 8). This analysis would seem to indicate that uninfested trees do not represent vole resistant trees but are instead unoccupied habitat.

The most important variables in this discrimination were sand, silt, organic matter, and bulk density. High percentages of organic matter and bulk density were favorable to pine voles while high quantitities of sand and silt were favorable to meadow voles.

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Table 8. Discriminant function classification for soil samples taken from pine vole and meadow vole infested trees.

		Predicted Group	
Actual Group	Samples	Pine	Meadow
Pine Vole Damaged	30	73.3%	26.7
Meadow Vole Damaged	18	33.3	66.7

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