Microhabitat Use by the Meadow Vole, *Microtus pennsylvanicus* (Ord), on a Reclaimed Grassland

by

Jason J. Anderson

Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

in the

Biological Sciences

Program

YOUNGSTOWN STATE UNIVERSITY
August, 1999

Microhabitat use by the meadow vole, *Microtus pennsylvanicus* (Ord), on a reclaimed grassland

by

Jason J. Anderson

I hereby release this thesis to the public. I understand this thesis will be housed at the Circulation Desk of the University Library and will be available for public access. I also authorize the University of other individuals to make copies of this thesis as needed for scholarly research.

Signature:

Jason J Anderson 8/13/99
Jason J. Anderson, Student Date

Approvals:

John D Usis 8/3/99
John D. Usis, Thesis Advisor Date

David B. MacLean 7/30/99
David B. Maclean, Committee Member Date

Courtenay N. Willis 8/4/99
Courtenay N. Willis, Committee Member Date

Paul C Peterson 8/4/99
Paul C. Peterson, Committee Member Date

8/16/99
Peter J. Kavinsky, Dean of Graduate Studies Date

ABSTRACT

I examined the effects of microhabitat quality on the population dynamics and the dispersal behavior of the meadow vole, *Microtus pennsylvanicus*, at the Browning Ferris Industries-Carbon Limestone Landfill/CLD, Mahoning County, Ohio, to identify meadow vole microhabitat selection. Voles were live trapped from May 19, 1998 to October 23, 1998 for a total of 80 traps nights using 72 Sherman traps (4 per 0.04ha) in 16 experimental grassland patches varying in density and quality of vegetative cover.

Plant species distributions were analyzed using Atlas GIS in order to determine relative coverage and dominance relationships. Dry weight biomass of standing crop and litter was used to distinguish patch quality. Grassland patches were categorized into four microhabitat types based on coverage values of the high quality forage species. Plant species present were ranked on a qualitative basis, according to diet preferences of meadow voles.

Microhabitat categories with the lowest nutritional quality and vegetative cover had the highest numbers of transient voles and highest mean distance traveled by resident voles. High mean distance traveled for resident voles suggests that quality resources are not located within the microhabitat category and traveling large distances to find quality resources is required. Therefore, it appears that microhabitat quality and nutritional quality, as well as vegetative cover, has significant effects on microhabitat selection by the meadow vole.

ACKNOWLEDGMENTS

I would like to extend my sincere gratitude to my advisor, Dr. John D. Usis for all of his patience and guidance throughout this study. I would also like to thank my committee members, Dr. David B. Maclean, Dr. Courtenay N. Willis and Dr. Paul Peterson for all of their time, energy and invaluable suggestions in beginning the study and analyzing the data.

I am greatly indebted to Dr. Thomas Maraffa and Dr. David T. Stephens for all of their invaluable instruction and assistance with Atlas GIS, they went above and beyond their duties. I would like to thank everyone at Browning Ferris Industries (BFI), especially Michael T. Heher, for their support and equipment. I am eternally grateful for all of the time, effort and resources BFI has devoted to all aspects of this research. I would like to extend my sincere gratitude to Youngstown State University's Department of Biological Sciences for its financial assistance and equipment support. I also would like to acknowledge the following individuals for their kindness and support during this period of research: Kimberly Ludt, Erica Richards, Ed "Julio" Budde, John Toy Jr., and Larry Tamasovich. Finally, I want to thank all my friends and family for their love and support during the past two years. To my family, without you I would not be were I am today, thanks Mom, Rob, Shannon, and to my Grandparents John and Marvel Houser. This work is dedicated to the memory of my father, Robert H. Anderson Sr. I wish you were here Dad.

TABLE OF CONTENTS

Page

ABSTRACT iii

ACKNOWLEDGMENTS iv

LIST OF TABLES vii

LIST OF FIGURES xi

INTRODUCTION 1

MATERIALS AND METHODS 7

  Site Description 7

  Plot arrangements 7

  Vegetation Sampling 10

  Plant Species Distribution 10

  Trapping Design and Population Dynamics 10

  Resident, Dispersers, and Transient Voles 12

  Statistical Analyses 12

RESULTS 14

  Assignment of Microhabitat Categories 21

  Plant Species Quality Values 24

  Plant Species Richness and Vegetative Coverage 29

  Resident and Transient Vole Travel Activity 31

  Food Quality 36

TABLE OF CONTENTS

Page

DISCUSSION 41

- Plant Species Richness and Vegetative Coverage 41
- Resident and Transient Vole Travel Activity 43
- Food Quality 46
- Conclusions 47

LITERATURE CITED 49

APPENDIX A 55

APPENDIX B 81

LIST OF TABLES

Table Page

1. Collection data summary for the meadow vole: number of males, number of females, number of captures, and number of recaptures at BFI from May 19, 1998 to October 23, 1998. Capture and recapture collections include the number of meadow voles found dead in each plot (n). 15

2. Collection data summary of the meadow vole for: mean weight and length of age structures (adults, subadults and juveniles). Numbers in parentheses are based on the voles collected at each age structure(n). 19

3. Summary of the coverage values of the abiotic and biotic structures in the 16 plots at BFI calculated by the Atlas GIS computer program. 20

4. Arrangements of the 16 plots into four microhabitat categories based on percent coverage of *Trifolium* species (clover), *Cirsium* species (thistle), bare ground, and plot plant species richness. 22

5. Comparison of coverage values of *Trifolium* species, *Cirsium* species and Bare Ground among the four microhabitat categories at BFI (* significant and ** highly significant). 26

6. Plant species quality ranking of the vegetation in the 16 plots at BFI. 4 = highly preferable by *M. pennsylvanicus*, 0 = least preferable by *M. pennsylvanicus*, (*A non-food source, but important in concealment from predation). 28

LIST OF TABLES CONTINUED

Table Page

7. The number of resident and transient meadow voles versus plant species richness of the 16 plots at BFI. 30

8. The number of resident and transient meadow voles versus plant species richness of the 16 plots at BFI arranged into the four microhabitat categories. 32

9. The mean distance traveled, in meters, of resident and transient meadow voles of the 16 plots at BFI. 33

10. The mean distance traveled, in meters, of resident and transient meadow voles of the 16 plots at BFI arranged into the four microhabitat categories. 35

10. Comparison of microhabitat quality among the four microhabitat categories at BFI (* significant and ** highly significant). 40

A1. – Plot 1 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 55

A2. – Plot 2 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 57

LIST OF TABLES CONTINUED

Table Page

A3. – Plot 3 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 59

A4. – Plot 4 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 61

A5. – Plot 5 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 62

A6. – Plot 6 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 64

A7. – Plot 7 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 66

A8. – Plot 8 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 67

A9. – Plot 9 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 68

LIST OF TABLES CONTINUED

Table Page

A10. – Plot 10 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 69

A11. – Plot 11 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 70

A12. – Plot 12 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 72

A13. – Plot 13 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 75

A14. – Plot 14 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 77

A15. – Plot 15 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 78

A16. – Plot 16 collection data for the meadow vole, *Microtus pennsylvanicus*, at the BFI/CLD Landfill, from May 19,1998 to October 23, 1998. 79

LIST OF FIGURES

Figure Page

1. Location of the Browning Ferris Industries (BFI) Carbon Limestone Landfill / CLD between the Northeastern Ohio's Mahoning and Western Pennsylvania's Lawrence Counties. 8

2. Diagram depicting a plot arrangement of 16 experimental 0.04-ha plots within a 150 x 150-m grassland interior, surrounding a 20-m wide mowed strip, and a 10-m mowed strip separating each plot located on BFI's Phase I reclaimed wasteland. 9

3. Biweekly estimated population size of the meadow vole from May 19, 1998 to October 23, 1998 at BFI, using the Schnabel Method of estimating populations.. 16

4. Biweekly estimated population size of the age structure (adults, subadults and juveniles) of the meadow vole from May 19, 1998 to October 23, 1998 at BFI, calculated using the Schnabel Method of estimating populations. 17

5. Percent coverage of *Trifolium* species, *Cirsium* species and Bare Ground of the 16 plots at BFI. 23

6. Percent coverage of *Trifolium* species, *Cirsium* species and Bare Ground, of the 16 plots at BFI arranged in the four microhabitat categories. 25

7. 'Quality' values of the vegetation, of the 16 plots, at BFI. 37

LIST OF FIGURES CONTINUED

Figure Page

B9. – Map of area covered by plant species on Plot 9 at the BFI/CLD Landfill, on July 25, 1998. 89

B10. – Map of area covered by plant species on Plot 10 at the BFI/CLD Landfill, on July 25, 1998. 90

B11. – Map of area covered by plant species on Plot 11 at the BFI/CLD Landfill, on July 25, 1998. 91

B12. – Map of area covered by plant species on Plot 12 at the BFI/CLD Landfill, on July 25, 1998. 92

B13. – Map of area covered by plant species on Plot 13 at the BFI/CLD Landfill, on July 25, 1998. 93

B14. – Map of area covered by plant species on Plot 14 at the BFI/CLD Landfill, on July 25, 1998. 94

B15. – Map of area covered by plant species on Plot 15 at the BFI/CLD Landfill, on July 25, 1998. 95

B16. – Map of area covered by plant species on Plot 16 at the BFI/CLD Landfill, on July 25, 1998. 96

INTRODUCTION

Microtus pennsylvanicus (Ord), the meadow vole, is the most widely distributed, abundant mammal, and the only species of *Microtus* inhabiting the open grassy fields in Ohio (Gottschang, 1981). Many studies have been done on the habitats of the meadow vole, but many questions are still left unanswered.

Microtus is Greek for "small ear" and *pennsylvanicus* refers to Pennsylvania, where it was first described. The meadow vole, or field mouse, are predominantly brown-colored animals with short fur. This small rodent has small beady black eyes and small round ears that are concealed by its fur. The tail is indistinctly bicolored, but it is dark above and lighter below, and always longer than the hind foot. Though similar in appearance to the southern bog lemming, the meadow vole is best described by its tail's length to its hind foot. This species of *Microtus* generally ranges from 129 to 174 mm in total length, possesses a tail that is 28 to 45 mm in length and a hind foot that is 16 to 22 mm in total length. In the wild, meadow voles can live between 12 and 18 months. The meadow vole is active during the day and night, year round. They are semifossorial and are capable of constructing elaborate tunnels and surface runways from the above ground vegetation. These tunnels and runways provide protection from predation, inclement weather and provide sights for the rearing of their young. A single burrow system that is built can contain several adults and young.

The meadow vole is rather antagonistic and commonly quarrels with other meadow voles, especially during the breeding season. During this time, breeding females strenuously defend their territories against other breeding females. Chewed ears and a chewed posterior are evidence of these encounters. Once the breeding season ceases, aggression ends and communal nesting commences (Merrit, 1987).

Female meadow voles become reproductively active at 25 days, whereas the males reach sexual maturity when they are 30 to 35 days old. Females are capable of producing six to eight litters a year. Litter sizes can range between one to 11 voles. The gestation period is approximately 21 days. The young are then weaned for up to two weeks, after which, they soon leave the nest permanently (Gottschang, 1981).

Hamilton (1940) described a typical habitat of *Microtus* as meadows with dense growths of vegetation, or with fields with a canopy of dead grasses. Areas consisting of grass comprising 50% or more of the vegetation are typical habitats of the meadow vole, *Microtus pennsylvanicus*. *M. pennsylvanicus* shows an association with grasses, especially bluegrass (*Poa compressa* L.,) and lovegrass (*Muhlenbergia sobolitera* Muhl.), (Zimmerman, 1965). The genus *Microtus* displays its role in the small mammal community as the principal herbivore in most plant communities it inhabits. In ecosystems with *Microtus* populations, it provides up to 90% of the biomass of small mammals (Getz, 1985). The meadow vole is a primary consumer of vegetation in old field communities (Golley, 1960). Anderson and Barrett (1982) suggest that consumer populations can directly influence the structure of the producer trophic level.

The meadow vole's population dynamics have been attributed to vegetative structure (e.g., coverage), predation and food quality (Hall et al., 1991). The presence or absence of *Microtus* contributes to various environmental factors, including habitat microclimate, vegetative structure, available food, competition and predation (Rose and Birney, 1985).

Elton (1939) discussed vegetative cover as the most essential component of patch quality to the population dynamics of small mammals. Getz (1960) stated that plant cover is one of the major factors in regulating population fluctuation of *M. pennsylvanicus*. Vegetative cover is defined as the sum total of above ground biomass (litter and standing crop), (Peles and Barrett, 1996). Vegetative cover provides attributes organized into abiotic and biotic components that affect population dynamics of the meadow vole (Birney et al., 1976). Biotic factors include: (1) concealment and protection from predators (Taitt et al., 1981; Taitt and Krebs, 1983; Rose and Birney, 1985; Getz, 1985), (2) food (Birney, et al., 1976) and (3) behavioral interactions among conspecifics (Taitt et al., 1981; Taitt and Krebs, 1983). The microhabitat abiotic conditions that are influenced by the biotic components of vegetative cover include humidity, light penetration, temperature, and soil moisture (Getz, 1971).

Several field experiments of the prairie vole, *M. ochrogaster*, displayed the effects of increased vegetative cover on this species. In a tall grass prairie in northeastern Oklahoma, a vole population increased tremendously during a single summer. Prairie vole numbers increased form zero to 24 individuals by late October on a 1-ha tall grass prairie removed of grazing cattle (Birney et al., 1976). A four-year study in eastern Colorado compared the communities of small mammals to those on control areas that were initially similar. *M. ochrogaster* became established on the experimental plots, displaying a pattern of increase numbers each spring to higher populations each summer or autumn (Grant et al., 1977). Direct correlation between vegetative cover and population density has also been shown for *M. pennsylvanicus* (Eadie, 1953; Birney et al., 1976).

Many *Microtus* populations have experienced multi-annual cycles in abundance. Data collected over the past two decades on *Microtus* communicates three demographic patterns: annual fluctuations, multi-annual, and both in a sequence. It appears that annual fluctuations in *Microtus* density are more common than multi-annual cycles (Taitt and Krebs, 1985). *Microtus* population cycling may be attributed to vegetative cover (Frank, 1957; Birney et al., 1976).

Predation has been shown to help regulate population dynamics of small mammals (Pearson, 1964; Taitt and Krebs, 1983; Desy and Batzli, 1989). *Microtus* is food for an enormous variety of vertebrate predators. There are three types of predators that have been identified and hypothesized to regulate microtine population dynamics: (1) specialist mammal predators that are instrumental in maintaining the fairly regular, multi-annual oscillations (Maclean et al., 1974; Fitzgerald, 1977; Hanski, 1987; Henttonen et al., 1978; Hanski, 1987; Korpimaki et al., 1991; Hanski and Korpimaki, 1995); (2) generalist predators have a stabilizing effect on rodent dynamics (Erlinge et al., 1983, 1984; Erlinge, 1987; Hanski et al., 1991) and; (3) nomadic predators similarly tend to stabilize avian prey dynamics (Korpimaki and Norrhahl, 1989, 1991). *Microtus* is mainly a grass eater, therefore, the more grass it needs to survive, the more it must venture out of its nest and become exposed to predators. Microtines do not hibernate or estivate to avoid the more dangerous and difficult seasons. They are active day and night, so they are exposed to risk from predators who are nocturnal and diurnal. A very small number of *Microtus* species create reserves of food, so most must leave the nest at frequent intervals to gather food (Pearson, 1985). The larger and more behaviorally dominant *Microtus*, can affect other small mammal species. In some instances it is the mere presence of *Microtus* that can attract predators to the area. This seems to be the case when microtine densities are extremely high (Rose and Birney, 1985).

Selection of habitats and vole distribution has been related to quantity and quality of vegetative cover (Wirtz and Pearson, 1960; Zimmerman, 1965; Miller, 1969; Getz, 1971; Hannsson, 1971; Klatt and Getz, 1987). The role of food quality in regulating population dynamics was originally described to interpret the population fluctuations of Arctic microtine rodents (Pitelka and Schultz, 1964). Quantity and quality of nutrient resources has been demonstrated in signaling the beginning of reproduction of *Microtus* (Berger et al., 1981; Cole and Batzli, 1979; Watts, 1970). When high quality food is available, microtine rodents reach the highest densities associated with cyclic peak populations (Batzli, 1985). Populations of voles are best understood when plant characteristics such as nutrient quality, secondary substances and herbivore acceptance are investigated (Batzli, 1983; Marquis and Batzli, 1989).

The goal of this study was to examine the effects of microhabitat quality on the population dynamics and dispersal behavior of the meadow vole at the Browning Ferris Industries-Carbon Limestone Landfill/CLD (BFI). The specific objectives of this study were:

(1) to correlate microhabitat selection of the meadow vole with plant species richness and vegetative coverage,

(2) use meadow vole behavior and travel activity in describing microhabitat selection, and

(3) to identify changes in meadow vole numbers arising from selection of microhabitats based on microhabitat nutritional quality.

Hypotheses to be tested were:

(1) Resident voles prefer more diverse microhabitats than transient voles.

(2) Resident voles mean distance traveled (activity) differ from transients.

(3) Meadow vole capture/recapture numbers are indicative of vole microhabitat selection.

(4) Resident voles prefer high quality microhabitats to low quality microhabitats.

MATERIALS AND METHODS

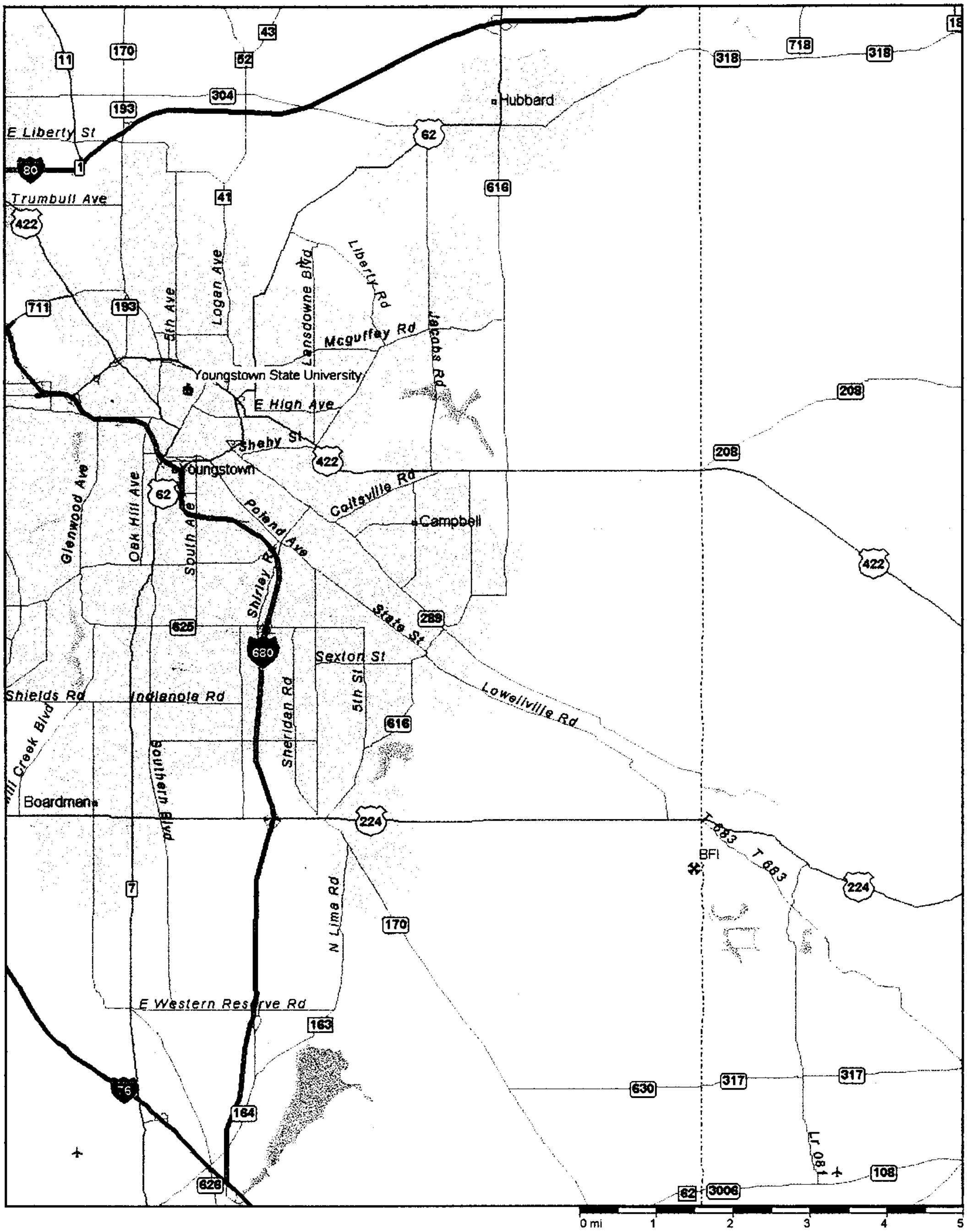
Site Description

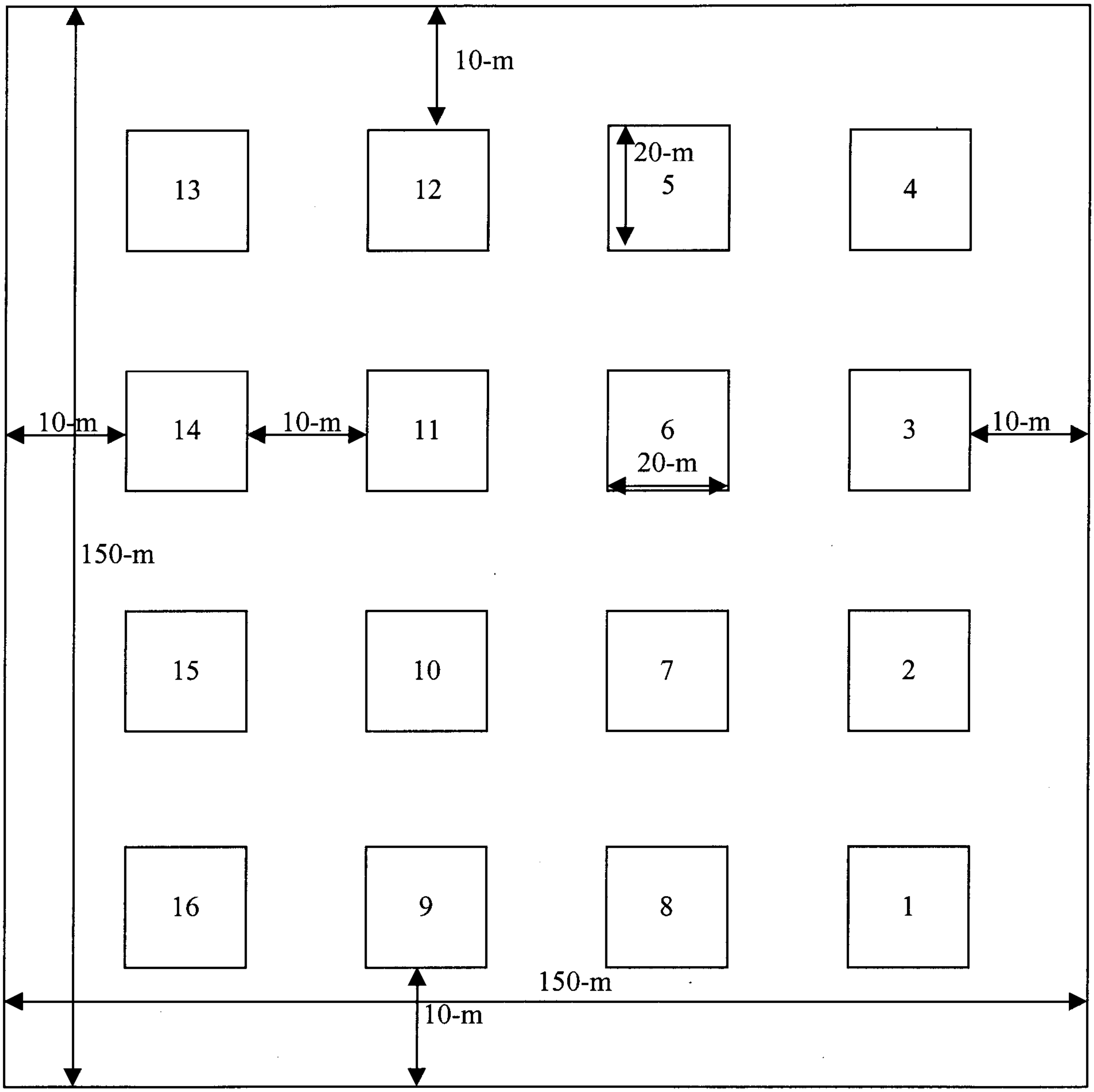
Browning-Ferris Industries (BFI) initiated a wildlife habitat improvement program at its Carbon Limestone Landfill site. In the spring of 1997, the Wildlife Habitat Council in conjunction with BFI, explored the possibility of incorporating wildlife habitat at its corporate site. Later that spring BFI contacted the Department of Biological Sciences at Youngstown State University, for its assistance in enhancing wildlife diversity as part of its improvement program at its landfill site. My thesis was conducted as a result of this initiative.

This study was conducted at the Browning Ferris Industries (BFI) – Carbon Limestone Landfill / CLD located in Lowellville, Lowellville Township, Mahoning County, Ohio and Lawrence County, Pennsylvania, (Fig. 1) (49° 35' 00" N, 25° 44' 50" E). The landfill comprises approximately 2500 acres of an old limestone strip mine. The landfill is approximately 13 miles from the campus of Youngstown State University and adjacent to the Ohio-Pennsylvania border in western Mahoning County. BFI's Phase I wasteland disposal served as the site of this field study. The reclaimed grassland is located approximately 800-m in a northeastern direction away from the main office within the Carbon Limestone Landfill. A reclaimed site of a landfill is described as being filled, capped and having no more waste being dumped and buried.

Plot Arrangements

The method used, by which the vole responses to microhabitat preference were investigated, is illustrated in Fig. 2. Sixteen 0.04-ha (20 x 20-m) experimental grassland


Hubbard
E Liberty St
80
Trumbull Ave
422
711
193
170
11
52
43
304
62
41
616
318
718
18
Logan Ave
5th Ave
Lansdowne Blvd
Liberty Rd
Mcguffey Rd
Jacobs Rd
Youngstown State University
E High Ave
Shehy St
Youngstown
208
Coitsville Rd
Campbell
Glenwood Ave
Oak Hill Ave
South Ave
Poland Ave
Shirley Rd
State St
289
625
680
Sexton St
Shields Rd
Indianola Rd
Sheridan Rd
5th St
Lowellville Rd
Mill Creek Blvd
Southern Blvd
Boardman
224
T 683
BFI
7
N Lima Rd
170
E Western Reserve Rd
163
76
164
626
630
317
Lr 081
108
3006
0 mi
1
2
3
4
5


10-m
13
12
20-m
5
4
10-m
14
10-m
11
6
20-m
3
10-m
150-m
15
10
7
2
16
9
8
1
150-m
10-m

plots were established. A 20-m wide mown path surrounded the entire 150 x 150-m plot to equalize edge effects and to segregate the plots from the surrounding environment. Ten-meter mowed strips further separated each individual plot.

Vegetation Sampling

Vegetation was sampled within each plot on July 25, 1998. Vegetation was gathered on three randomly selected 0.25-m^2 plots within each plot. The standing vegetation was clipped to ground level, sorted to species, oven-dried at 100 °C for 48 hr and then weighed to the nearest 0.5 g.

Plant Species Distribution

Plant species distributions were analyzed using Atlas GIS© in order to determine relative coverage and dominance relationships. The distribution of each plant species was drawn and digitized into the Atlas GIS computer program for all 16 plots. The mapping of each plot's vegetation was accomplished as follows, (1) a grid of 40 one-m^2 squares were established on each plot, and (2) each individual square's vegetation was then drawn and color coordinated. Atlas GIS then tabulated percent coverage and area coverage values of the various plant species to be tabulated.

Trapping Design and Population Dynamics

The study area was initially trapped from July 1997 to September 1997 to determine species composition and relative abundance of present rodent populations. Live-trapping procedures were conducted in the study area with Sherman traps, 3 x 3 ½ x

9", May 19, 1998 to October 23, 1998. Trapping was conducted on four consecutive days and nights each week. Traps were set in the evening and checked the following morning. On days when trapping did not occur, the traps were locked open to simulate a pre-baiting regime (Smith et al., 1975). Four Sherman traps were placed in each of the 16 plots. Trap location in each plot was arranged in a square pattern 7.6-m apart. Traps were baited with peanut butter, uncooked oats, and cotton was provided for nesting material.

When a vole was captured, its location was marked on a grid sheet and its sex, weight, and length were recorded. Weight was measured to the nearest 0.5-g and length was measured to the nearest 1.0-mm. The vole was then tagged on the left hind leg by a colored aluminum butt-end band purchased from the National Band and Tag Company® (red-female, blue-male). Each aluminum band possessed a number, which was recorded for each vole. Breeding condition of voles was also determined: testes scrotal or abdominal for males, and vaginal orifice perforate or nonperforate for females (Peles and Barrett, 1996).

The following information was collected upon capture of a rodent: plot number, trap number, species (*M. pennsylvanicus*), sex, band number, +/- (recapture), length, and weight and breeding condition. The age structure of *Microtus* was classified by weight: juveniles (<22-g), subadults (22-30-g), or adult (>30-g), respectively (Getz et al., 1978).

To estimate the meadow vole population, a repeated mark and recapture procedure was used. The Schnabel Method of Estimating Populations (Smith, 1996) was used to calculate the meadow vole population of the 150 x 150-m trapping area. Population estimations were calculated at biweekly intervals throughout the trapping period (Smith, 1996). Confidence limits cannot truly be determined and the calculation of standard errors becomes increasingly complex (Smith, 1996).

Residents, Dispersers, and Transients Voles

If a vole was found on the patch of their first capture for at least two consecutive trap weeks, it was considered a resident. Dispersers were defined as residents that remained on their original patch for three calendar weeks before moving; otherwise they were grouped with the transients (Peles and Barrett, 1996). Those individuals that moved between patches were considered dispersers from the plot in which they originated. Transient individuals were voles that were observed on a patch only during one trap week (Peles and Barrett, 1996).

Statistical Analyses

A simple linear correlation was used to test for significant differences ($P < 0.05$) of the relationship between transient and resident meadow voles versus the plant species richness of each plot. A one-way ANOVA was used to test for (1) significant differences ($P < 0.05$) in resident and transient vole numbers in the microhabitats, (2) significant differences ($P < 0.05$) in male and female meadow vole mean distance traveled, and (3) transient and resident vole mean distance traveled. A one-way ANOVA was used to compare differences between microhabitats of transient and resident vole mean distance traveled. A two-way ANOVA was also used to compare differences between sex and reproductive stage of the meadow voles. A one-way ANOVA was utilized to identify significant differences ($P < 0.05$) between captures and recaptures. A two-way ANOVA was also used to test for differences between captures/recaptures and microhabitats. Differences between coverage values of *Trifolium* species, *Cirsium* species, and bare ground were tested for significance ($P < 0.05$). A one-way ANOVA was used to test for significant differences between the quality of the 16 plots. One-way ANOVA was applied to the microhabitats and their overall quality to test for significant differences ($P < 0.05$). The overall nutritional quality of each plot was estimated by its percent coverage of the various plant species present multiplied by its corresponding quality ranking and then summed. One-way ANOVA's were used to compare for differences between (a) mean biweekly percent adult male and female meadow voles in breeding condition, (b) mean biweekly age structure (percent of adults, subadults, and juveniles), and (c) the mean monthly body mass of adult male and female voles. For all comparisons using ANOVA, separation of means was achieved using the Tukey's Honestly Significant Difference (HSD) Test where appropriate (Zar, 1996).

RESULTS

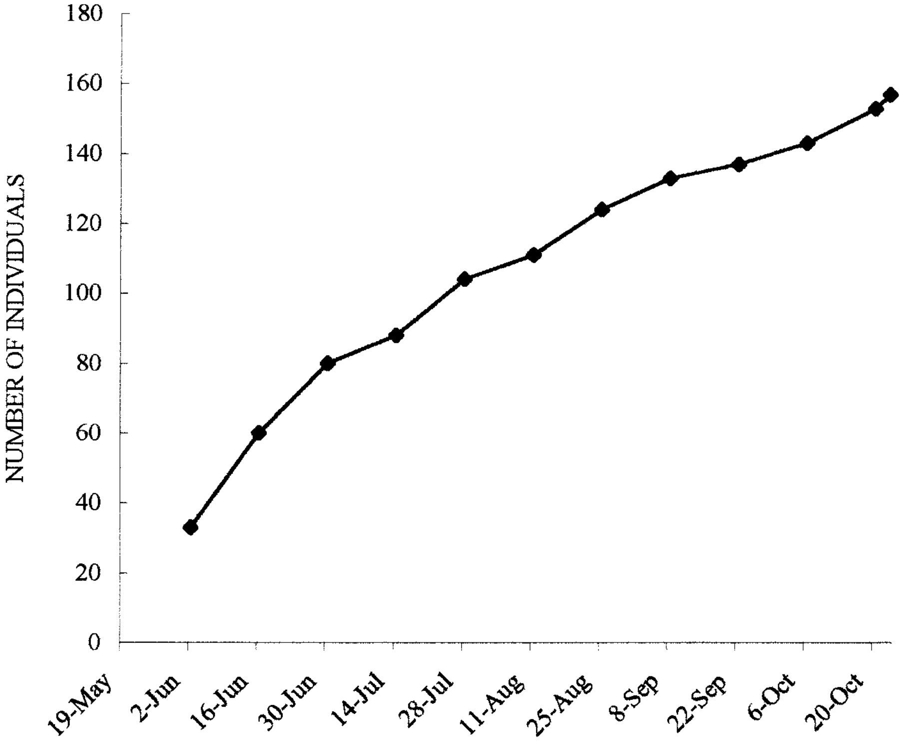
Trapping results are chronologically listed in Appendix A. A total number of 195 meadow voles were captured and 250 meadow voles were recaptured over a total of 72 collecting days (Table 1). Capture values ranged from a minimum of four voles (plot 9), to a maximum of 20 voles (plot 5). Recaptures displayed a range of two voles in plot 10 to 39 voles in plot 12. A total capture/recapture number of 445 meadow voles were trapped. There were a total of 41 voles found dead in traps, a total mortality of 9.2% during the trapping period. Of the 195 voles captured, 28 voles were found dead in the traps when checked the following morning. The mortality rate of meadow vole captures was 14.4%. The recaptures displayed only 13 dead meadow voles for a 5.2% mortality rate.

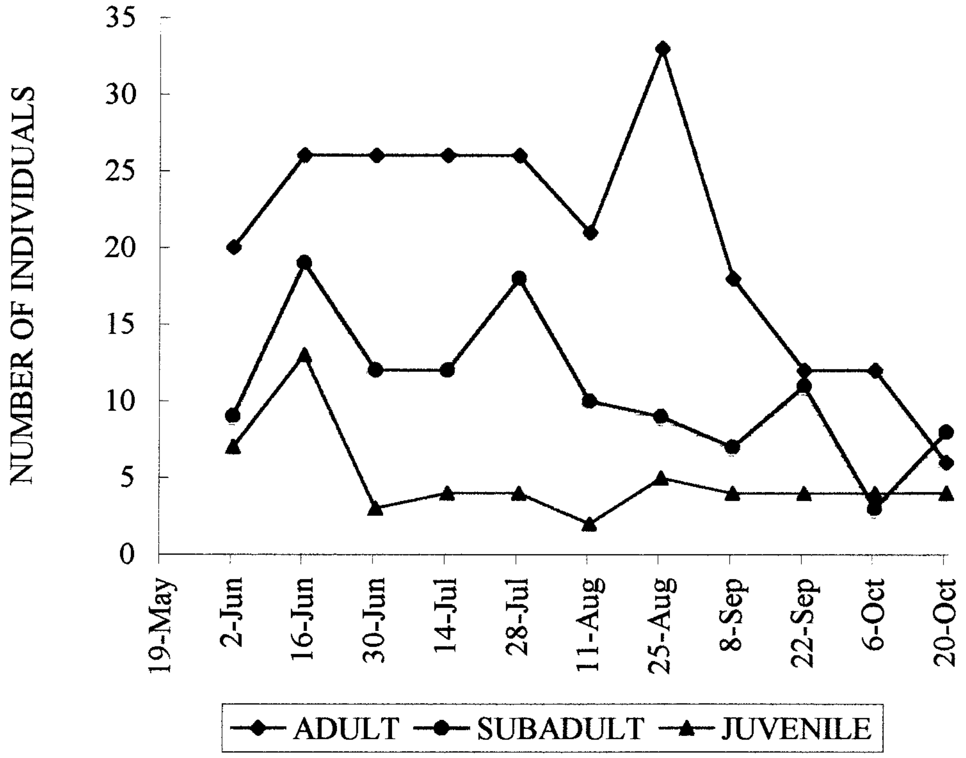
The Schnabel Method of estimating populations calculated the population of meadow voles for the 150 x 150-m area to be 152 individuals (Fig. 3). The biweekly age structure is displayed in Fig. 4. The highest number of adult meadow voles peaked in the fourteenth week (August 25). Adult voles reached their lowest total at the end of the trapping period in the twenty-second week (October 20). Subadults reached their highest total the fourth week (June 16). The subadult's lowest numbers were observed in the twentieth week (October 6). Juveniles tallied their greatest numbers in the fourth week as well. The juvenile's totals for the twelfth week (August 11) were the lowest.

The number of male/female meadow voles trapped was 157/261 (Table 1). Plot 15 recorded the fewest male meadow voles, possessing only one, while plot 2 contained 23 male voles. Five female meadow voles were trapped in plots 2, 9, and 10, the plots

TABLE 1 – Collection data summary for the meadow vole: number of males, number of females, number of captures, and number of recaptures at BFI from May 19, 1998 to October 23,1998. Capture and recapture collections include the number of meadow voles found dead in each plot (n).

Plot No.	Males	Females	Captures	Recaptures
1	19	18	15 (1)	23
2	23	5	16 (6)	17 (2)
3	19	10	17 (1)	14
4	7	12	9	10
5	11	23	20 (2)	16 (3)
6	6	25	12 (1)	20 (1)
7	3	10	6 (1)	8
8	4	13	9 (1)	9
9	3	5	4	4 (1)
10	7	5	10	2
11	15	30	10	35 (2)
12	16	37	18 (3)	39 (3)
13	10	20	10 (1)	22 (1)
14	6	9	15 (3)	4
15	1	19	7	13
16	7	20	17 (4)	14
TOTALS	157	261	195(28)	250(13)


NUMBER OF INDIVIDUALS
180
160
140
120
100
80
60
40
20
0
19-May
2-Jun
16-Jun
30-Jun
14-Jul
28-Jul
11-Aug
25-Aug
8-Sep
22-Sep
6-Oct
20-Oct


NUMBER OF INDIVIDUALS
35
30
25
20
15
10
5
0
19-May
2-Jun
16-Jun
30-Jun
14-Jul
28-Jul
11-Aug
25-Aug
8-Sep
22-Sep
6-Oct
20-Oct
ADULT
SUBADULT
JUVENILE

with the lowest female counts. The greatest numbers of female meadow voles were recorded for plot 12, with a count of 37.

Adult meadow vole mean weight ranged from 34.6-g in plot 3 to 42.4-g in plot 6 (Table 2). The longest mean adult vole length was recorded in plot 5 at 120.7-mm. The shortest adult meadow vole length recorded in plot 11 at 101.3-mm. Subadult meadow voles displayed a mean weight range of 24.8-g to 28.7-g. This can be seen in plots 2 and 12, respectively. Mean length of subadult meadow voles exhibited a high of 109.7-mm in plot 16 to a low of 89.5-mm in plot 4. Juvenile meadow vole mean weight ranged from 13.5-g in plot 7 to 20.9-g in plot 12. Juvenile meadow vole mean length ranged from a high in plot 5 of 101-mm (only based on one juvenile vole) to a low of 70.0-mm in plot 7. No juvenile meadow voles were collected in plots 8, 9, and 15.

The Atlas GIS generated maps of relative coverage are listed sequentially in Appendix B. A total number of 16 plant species and three other components (bare ground, rocks, and gas wells) were identified and mapped. The coverage values of the biotic and abiotic components in the 16 plots at BFI are summarized in Table 3. Meadow fescue, (*Festuca elatior* L ., dominated the study site at BFI. It accounted for as much as 98.23% of plot four. Plot 16 had the lowest percent coverage of *Festuca elatior*, but it still accounted for more that 50% of that plot's total vegetation. The *Trifolium* species (*pratense* and *repens*) represented the second most dominant species at BFI. Clover, Trifolium species, was present in all but one of the plots, plot 4. Thistle, *Cirsium* species, the next most common vegetation type, was absent in three plots, (4, 5, and 8). Conversely, several plant species foxtail grass (*Setaria glauca*) and yellow sweet clover (*Melilotus officinalis*) were only present in a single plot. *Setaria*

TABLE 2 – Collection data summary of the meadow vole for: mean weight and length of age structures (adults, subadults, and juveniles). Numbers in parentheses are based on the voles collected at each age structure (n).

	Age Structure								
	Adult			Subadult			Juvenile		
	$\bar{X}$ Weight(g)	(n)	$\bar{X}$ Length(mm)	$\bar{X}$ Weight(g)	(n)	$\bar{X}$ Length(mm)	$\bar{X}$ Weight(g)	(n)	$\bar{X}$ Length(mm)
Plot No.									
1	39.8	(17)	120.4	26.0	(8)	99.75	16.0	(12)	89.0
2	36.7	(11)	107.6	24.8	(13)	105.8	19.9	(9)	77.2
3	34.6	(16)	114.9	25.5	(13)	104.4	18.5	(2)	93.5
4	36.5	(13)	111.7	25.3	(4)	89.50	20.5	(2)	85.0
5	39.1	(25)	120.7	25.6	(10)	101.6	20.0	(1)	101
6	42.4	(26)	120.1	27.5	(3)	100.0	20.0	(3)	97.0
7	39.3	(11)	117.0	28.0	(1)	98.00	13.5	(2)	70.0
8	37.8	(6)	107.5	26.7	(12)	107.2	---	(0)	---
9	36.2	(5)	111.4	25.7	(3)	105.7	---	(0)	---
10	37.9	(7)	114.1	25.8	(2)	102.0	18.2	(3)	82.7
11	34.7	(24)	101.3	26.1	(20)	93.70	15.0	(1)	88.0
12	36.1	(32)	114.3	28.7	(14)	107.8	20.9	(9)	95.7
13	34.1	(19)	117.8	27.3	(7)	106.9	17.2	(6)	89.7
14	38.5	(10)	118.1	25.1	(4)	106.5	18.9	(5)	91.0
15	36.8	(14)	107.2	26.7	(6)	104.2	---	(0)	---
16	37.5	(14)	113.9	27.1	(13)	109.7	20.3	(3)	91.0

TABLE 3 - Summary of the coverage values of the plant species and objects in the 16 plots at BFI calculated by the AtlasGIS computer program.

	Percent Coverage															
	Plot No.															
Biotic/Abiotic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Biotic																
Ambrosia artemisiifolia	0	1.25	0	0	0	0	0.01	1.03	0.24	0	0	0	0	0	0	0.16
Aster pilosus	0.11	0.73	0.02	0.09	0	0.12	0.15	0.46	0.01	0	0	0	0.28	0	0	0.05
Cirsium spp.	1.52	3.95	0.96	0	0	0.02	0.03	0	0.91	0.01	0.06	0.02	12.31	1.24	6.98	10.52
Conyza canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0.36	0.14	0.14
Daucus carota	0	0.06	0.07	0	0	0	0	0.05	0	0	0	0	0	0	0	0
Erigeron annuus	0	1.73	3.94	0.02	0	0.07	0.02	0.16	1.00	0.03	0	0.01	0.45	0.04	0.62	2.02
Festuca elatior	83.73	85.12	88.29	98.23	95.35	90.32	87.30	72.74	77.57	75.16	90.58	85.34	69.32	95.38	85.10	56.35
Medicago sativa	0	0	0	0	0	0.01	0.05	1.80	0.18	18.70	0	0.06	0	0	0	0
Melilotus officinalis	0	0	0	0	0	0	0	0	0	0	0	0	1.90	0	0	0
Rumex crispus	0	0	0	0.02	0	0	0.03	0.04	0	0.04	0.11	0	0.07	0	0	0
Setaria glauca	0	0	0	0	0	0	0	0	0	0	4.64	0	0	0	0	0
Solidago altissima	0	0.05	0	0	0	0.07	0	0	1.94	0	0	0	2.46	0.16	0.16	1.50
Solidago graminifolia	0	0	0	0	0	0	0	0.02	0.82	0.02	0	0	2.41	0.13	0.31	0.22
Trifolium spp.	14.55	6.92	6.72	0	0.59	8.35	12.06	21.43	17.17	5.34	3.05	14.27	8.40	2.56	6.15	28.00
Verbascum blattaria	0	0.19	0	0.28	0	0.03	0.04	0.02	0	0	0	0.09	0	0	0.13	0
Vicia cracca	0	0	0	1.06	0	0	0	0	0	0	1.20	0.07	2.35	0.12	0	0
Abiotic																
Bare Ground	0.09	0	0	0.30	3.90	1.01	0.31	2.10	0.16	0.72	0	0.14	0.04	0.01	0	1.00
Gas Well	0	0	0	0	0.16	0	0	0.15	0	0	0	0	0	0	0	0
Rock(s)	0	0	0	0	0	0	0	0	0	0	0.36	0	0	0	0	0

glauca found only in plot 11 and *Melilotus officinalis* found in only plot 13. Plots 8, 13 and 16 had the highest number of plant species (10) and plot 5 had only *Trifolium* species and *Festuca elatior* present.

Three other components that were located in the study area other than vegetation were bare ground, rocks, and gas wells. Bare ground had its highest coverage value in plot 5 at 3.90% coverage. Rocks were found only in plot 11 with 0.11% coverage. Gas wells were numerous on the reclaimed grassland, two located within the study site with single wells found in plots 5 and 8.

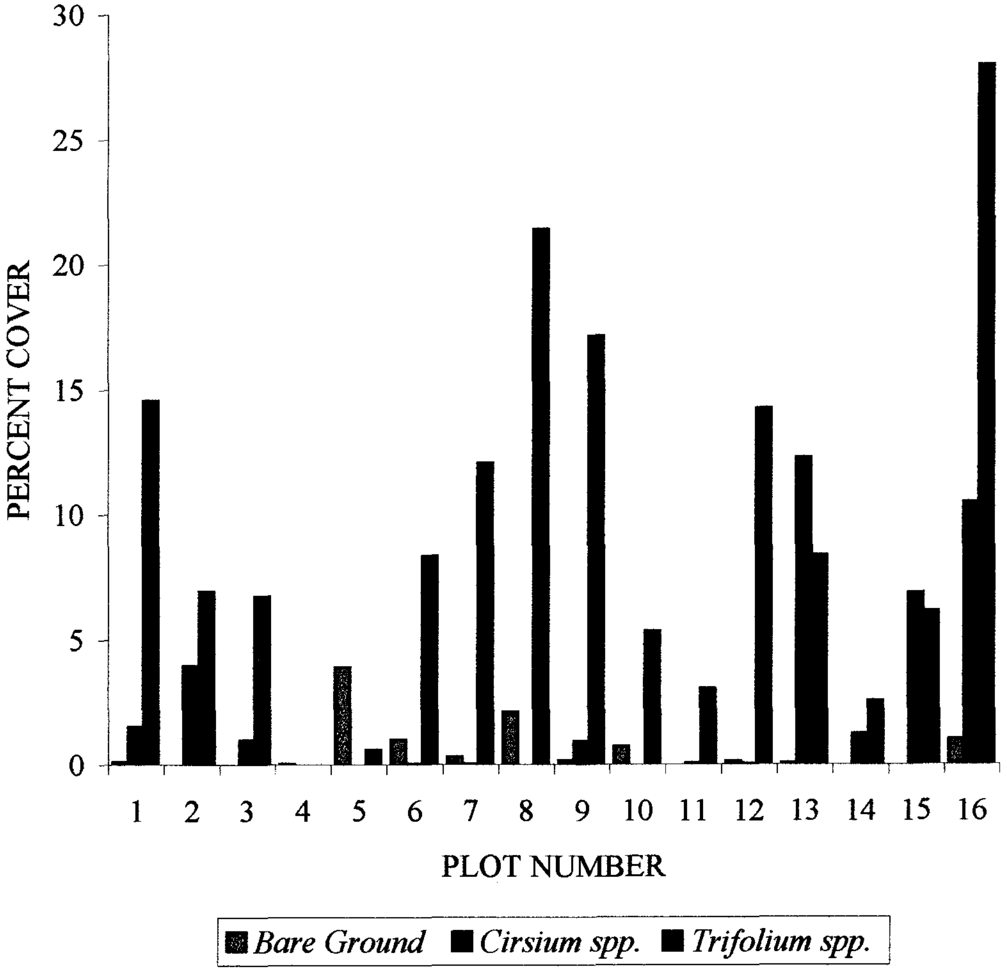
Assignment of Microhabitat Categories

Identification of microhabitat selection by the meadow vole was aided by arranging the 16 plots into four microhabitat categories based on the following criteria: coverage of *Trifolium* species, coverage of *Cirsium* species, bare ground and, plant species richness (Table 4). A two-way ANOVA was likewise used to compare differences between coverage values of all three factors and microhabitat category. The coverage values of *Trifolium* and *Cirsium* species were used because of their importance in the meadow vole's diet (*Trifolium* species especially, and *Cirsium* species to a minor extent) and concealment from predation (*Cirsium* species). The species richness of each plot describes the additional resources available to the vole.

The percent cover of *Trifolium* species (9.723 % ± 1.939 %), and *Cirsium* species (2.408 % ± 0.9986 %) and bare ground (0.5813 % ± 0.2526 %) was highly significant among plots throughout the trapping period ($F = 14.563$, $P < 0.000$ at $\alpha = 0.05$), (Fig. 5). A multiple comparison displayed a significant difference of *Trifolium* species for *Cirsium*

TABLE 4 – Arrangements of the 16 plots into four microhabitat categories based on percent coverage of *Trifolium* species (clover), *Cirsium* species (thistle), bare ground and plot species richness.

Microhabitat Category	Plot No.	Percent cover *Trifolium* spp.	Percent cover *Cirsium* spp.	Percent Cover Bare Ground	Number of Plant Species
A					
	4	0.0	0.00	0.03	6
	5	0.6	0.00	3.90	2
	6	8.4	0.02	1.01	8
	11	3.1	0.06	0	6
	14	2.6	1.24	0.01	8
B					
	1	14.6	1.52	0.09	4
	7	12.1	0.03	0.31	9
	12	14.3	0.02	0.14	7
C					
	2	6.9	3.95	0	8
	3	6.7	0.96	0	6
	10	5.3	0.01	0.72	7
	15	6.2	6.98	0	8
D					
	8	21.4	0.00	2.10	10
	9	17.2	0.91	0.16	9
	13	8.0	12.3	0.04	10
	16	28.0	10.5	1.00	10

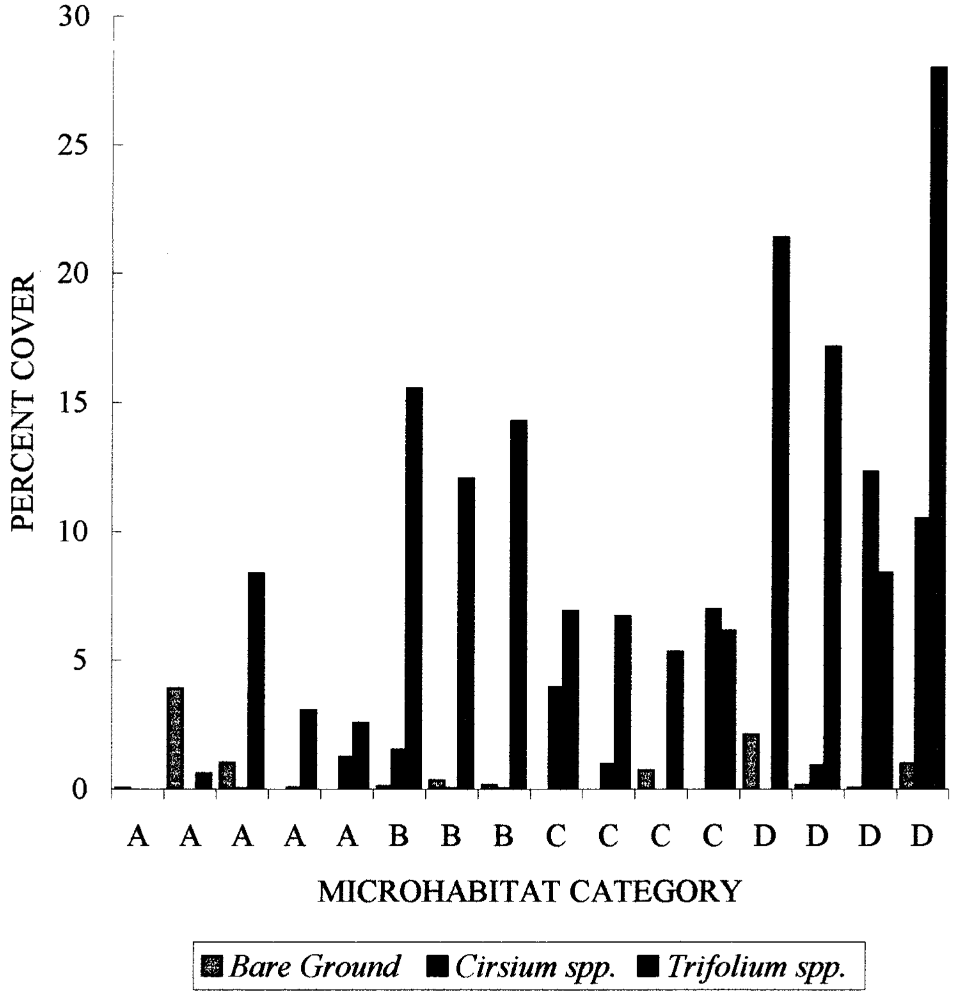

30
25
20
15
10
5
0
PERCENT COVER
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PLOT NUMBER
▨ Bare Ground
■ Cirsium spp.
■ Trifolium spp.

species and bare ground. However, *Cirsium* species was not significantly different from the percent cover of bare ground.

Trifolium species, *Cirsium* species and bare ground coverage values differed greatly between microhabitats ($F = 36.412$, $P < 0.001$ at $\alpha = 0.0001$), (Fig. 6). In addition, a highly significant interaction between microhabitat and the percent cover was observed ($F = 5.433$, $P < 0.000$ at $\alpha = 0.0001$). Tukey's HSD multiple comparison exhibited significant differences between microhabitat A versus D, and C versus D (Table 5). Microhabitat B did not differ from microhabitats A, C, and D.

Plant Species Quality Values

If an animal shows a consistent response to a particular food item, then diet composition will be related to availability of that item. Although there are several ways to make this comparison, Lechowicz (1983) a simple preference index (PI = proportion of diet divided by proportion of forage) allows one to assess a variety of patterns. If the herbivore responds to availability of the food item, there will be a positive correlation between percent of diet and percent of forage accounted for by that item; (Batzli, 1983) $PI > 1$ if consistently preferred, $PI < 1$ if consistently avoided, or $PI = 1$ if taken in the same amount as available (Batzli, 1983). Alternatively, an item may be taken irregularly or in relatively constant amounts no matter what its availability (no consistent preference or PI decreases with in creased availability, respectively), (Batzli, 1983). This method of analyses requires multiple samples from a variety of sites with different availability of food. Analyses that have been done on herbivorous microtines show three general



30
25
20
15
10
5
0
PERCENT COVER
A A A A A B B B C C C C D D D D
MICROHABITAT CATEGORY
Bare Ground
Cirsium spp.
Trifolium spp.

TABLE 5 – Comparison of coverage values of *Trifolium* species, *Cirsium* species, and Bare ground between the four microhabitat categories at BFI (* significant and ** highly significant).

Microhabitat Category	vs. Microhabitat Category	$\overline{X}$ diff. ± S.E.	Significance
A	B	-3.40 ± 1.44	0.102
	C	-1.77 ± 1.32	0.544
	D	-7.13 ± 1.32	0.000**
B	A	3.40 ± 1.44	0.102
	C	1.63 ± 1.51	0.701
	D	-3.73 ± 1.51	0.081
C	A	1.77 ± 1.32	0.544
	B	-1.63 ± 1.51	0.701
	D	-5.36 ± 1.39	0.003*
D	A	7.13 ± 1.32	0.000**
	B	3.73 ± 1.51	0.081
	C	5.36 ± 1.39	0.003*

responses to food items: consistent preference, consistent avoidance, or relatively constant intake (Batzli and Jung, 1980; Batzli and Pitelka, 1983).

The plant species that were present in the trapping area were assigned a quality value, ranging from 0 – 4: plant species receiving a four were most preferred by the meadow vole and those receiving a 1 were least preferred by the meadow vole (Table 6). Plant species that received a zero were not found in the literature and determined not to play a significant role in the resource utilization of the meadow vole, neither in diet nor concealment (Table 6).

Quality values of 1 were determined by a simple preference index (PI) of less than one, but not significant. Plant species with a PI <1 are considered less preferable by the organism. *Festuca elatior* L., also given a quality value of 1, is considered a non-food grass by the meadow vole, but is an important coverage factor to the meadow vole. A quality value of 2 was applied to those species that comprised 20 to 50% of the total fecal matter from the meadow vole's diet (Bucyanayandi and Bergeron, 1990; and Bergeron and Jodin, 1987). The species that were given a value of 3 contributed 50 to 65% of the overall vole diet, and received a PI value >1 but was not significant (Thompson, 1965; Bucyanayandi and Bergeron, 1990; and Bergeron and Jodin, 1987). The *Trifolium* species (*pratense* and *repens*) were the only plant species to receive a quality value of 4. The *Trifolium* species were given this value because of a PI > 1 (highly preferable) and contributed to greater than 70% of the vole's diet (Thompson, 1965; Bucyanayandi and Bergeron, 1990; and Bergeron and Jodin, 1987).

TABLE 6 – Plant species quality ranking of the vegetation in the 16 plots at BFI. 4 = highly preferable by *M. pennsylvanicus*, 0 = least preferable by *M. pennsylvanicus*. (* A non-food source, but important in concealment from predation)

Common Name	Scientific Name	Rank
Clover (red and white)	*Trifolium* spp (*pratense* and *repens*)	4
Thistle (bull and Canada)	*Cirsium* spp. (*arvense* and *vulgare*)	3
Alfalfa	*Medicago sativa*	3
Goldenrod	*Solidago graminifolia*	3
Aster	*Aster pilosus*	2
Canada Goldenrod	*Solidago altissima*	2
Vetch	*Vicia cracca*	2
Roman Ragweed	*Ambrosia artemisiifolia*	1
Queen Ann's Lace	*Daucus carota*	1
Meadow Fescue*	*Festuca elatior**	1*
Daisy Fleabane	*Erigeron annuus*	0
Horseweed	*Conyza canadensis*	0
Yellow Sweet Clover	*Melilotus officinalis*	0
Curled Dock	*Rumex crispus*	0
Foxtail Grass	*Setaria glauca*	0
Moth Mullein	*Verbascum blattaria*	0

Plant Species Richness and Vegetative Coverage

A simple linear correlation was performed to identify relationships of microhabitat selection of the meadow vole with plant species richness. Recall, if a vole was found on the plot of their first capture for at least two consecutive trap weeks, it was considered a resident. Dispersers were defined as residents that remained on their original plot for three calendar weeks before moving, otherwise they were grouped with the transients. Transient individuals were voles that were observed on a plot only during one trap week (Peles and Barrett, 1996).

Analyzing differences among plots

Plots 1, 3, 5, 12, and 14 exhibited the highest number of transient meadow voles (12, 14, and 10) respectively (Table 7). In contrast, plots 7, 9, and 15 had the lowest transient meadow vole count (3, 4, and 3), respectively. Plots with the highest resident meadow voles were 1, 2, and 11. However, plots 9 and 10 contained no voles labeled as residents.

Transient meadow voles displayed a negative correlation with respect to plant species richness, during the trapping season ($r = -0.578$, $P < 0.019$ at $\alpha = 0.05$). Resident voles, however, did not show a significant correlation with the number of plants species per plot ($r = -0.356$, $P < 0.176$ at $\alpha = 0.05$).

There was a significant effect of capture/recapture numbers of the meadow voles on the coverage of the *Trifolium* species, *Cirsium* species and bare ground among the 16 plots ($F = 15.779$, $P < 0.000$, at $\alpha = 0.0001$). Resident and transient vole numbers also displayed a significant effect when analyzed against the coverage values of the *Trifolium*

TABLE 7 – The number of resident and transient meadow voles versus plant species richness of the 16 plots at BFI.

Plot No.	Residents	Transients	No. of plant species
1	6	10	4
2	4	9	8
3	6	12	6
4	2	6	6
5	3	14	2
6	2	9	8
7	2	3	9
8	2	5	10
9	0	4	9
10	0	8	7
11	5	6	6
12	4	14	7
13	3	7	10
14	2	10	8
15	4	3	8
16	4	8	10
TOTALS	49	128	16

species, *Cirsium* species and bare ground among the 16 plots (F = 12.063, P < 0.000 at α = 0.0001).

Analyzing differences among microhabitats

There was no significant effect of microhabitat on the residents or transients meadow voles (F = 0.925, P < 0.444 at α = 0.05). However, there was a significant difference in the inhabitance between transient and resident meadow voles (F = 21.096, P < 0.0005 at α = 0.001). In addition, there was no significant interaction observed of activity and microhabitat (F = 0.287, P < 0.834 at α = 0.05). The number of transient and resident meadow voles in each of the four microhabitat categories can be seen in Table 8.

There was no significant effect of meadow vole capture and recapture numbers among the coverage values for the four microhabitat categories (F = 2.807, P < 0.058 at α = 0.05). There was no significant effect of resident or transient meadow voles among the coverage values of the four microhabitat categories (F = 1.060, P < 0.423 at α = 0.05).

Resident and Transient Vole Travel Activity

Analyzing differences among plots

Mean distances traveled by resident and transient meadow voles (Table 9) were used to identify microhabitat preference by voles. There was no significant difference in mean distance traveled by male and female meadow voles between plots traveled (F = 0.474, P < 0.496 at α = 0.05). Male voles displayed a (mean ± std. error) 26.61-m ± 11.36-m and the female meadow voles showed a 36.30-m ± 8.28-m. Both meadow vole

TABLE 8 – The number of resident and transient meadow voles versus plant species richness of the 16 plots at BFI arranged into the four microhabitat categories.

Microhabitat Category/Plot No.	Residents	Transients	No. of plant species
A			
4	2	6	6
5	3	14	2
6	2	9	8
11	5	6	6
14	2	10	8
$\bar{X}$	2.8	9.0	6.0
B			
1	6	10	4
7	2	3	9
12	4	14	7
$\bar{X}$	4.0	9.0	6.7
C			
2	4	9	8
3	6	12	6
10	0	8	7
15	4	3	8
$\bar{X}$	3.5	8.0	9.3
D			
8	2	5	10
9	0	4	9
13	3	7	10
16	4	8	10
$\bar{X}$	2.3	6.0	9.8

TABLE 9 – The mean distance traveled, in meters, of resident and transient meadow voles of the 16 plots at BFI.

Plot No.	Transients (m)	Residents (m)
1	8.38	38.59
2	13.63	23.92
3	4.53	20.04
4	1.79	55.94
5	0	10.13
6	10.89	30.20
7	0	77.11
8	0	3.80
9	0	0
10	0	0
11	11.34	39.07
12	25.26	17.89
13	0	58.69
14	0	12.97
15	41.99	37.09
16	15.05	2.80

sex ($F = 0.631$, $P < 0.430$ at $\alpha = 0.05$) and reproductive stage ($F = 0.281$, $P < 0.598$ at $\alpha = 0.05$) did not differ significantly between plots. However, a significant interaction between sex and reproductive condition was observed ($F = 5.719$, $P < 0.020$ at $\alpha = 0.05$). This implies there are significant differences in gender and reproductive age among the 16 plots.

Mean distance traveled by transient (8.31-m ± 2.92-m) and resident (26.77-m ± 5.75-m) voles were both significantly different ($F = 8.177$, $P < 0.008$ at $\alpha = 0.05$) among the plots. Transient meadow voles in plots 12 and 15 had the highest mean distance traveled at 25.26-m and 41.99-m respectively, (Table 9). In contrast, plots 5, 7, 8, 9, 10, 13 and 14 had a mean distance traveled of zero. Resident meadow voles of plots 4, 7 and 13 possessed the greatest mean distance traveled of 55.95-m, 77.11-m, and 58.69-m.

Analyzing differences among microhabitats

When the 16 plots were grouped into four microhabitat categories, based on the percent coverage of *Trifolium* species, *Cirsium* species, bare ground, and plot plant species richness, (Table 4), the microhabitat categories had no effect on the total distance traveled by resident and transient voles ($F = 1.090$, $P < 0.372$ at $\alpha = 0.05$), (Table 10). However, there was a significant difference in microhabitat categories when analyzed against the mean distance traveled by resident and transient voles ($F = 8.281$, $P < 0.008$ at $\alpha = 0.05$). In addition, there was no interaction of microhabitat category and mean distance traveled ($F = 0.841$, $P < 0.485$ at $\alpha = 0.05$) for transient and resident meadow voles. Microhabitat category B had the highest mean distance traveled by resident meadow voles (44.53-m). Microhabitat category D had the lowest mean distance

TABLE 10 – The mean distance traveled, in meters, of resident and transient meadow voles of the 16 plots at BFI arranged into the four microhabitat categories.

Microhabitat Category/Plot No.	Transients (m)	Residents (m)
A		
4	1.79	55.95
5	0	10.13
6	10.89	30.20
11	11.34	39.07
14	0	12.97
$\bar{X}$	4.80	29.66
B		
1	8.38	38.59
7	0	77.11
12	25.61	17.89
$\bar{X}$	11.33	44.53
C		
2	13.63	23.92
3	4.53	20.04
10	0	0
15	41.99	37.09
$\bar{X}$	15.04	20.26
D		
8	0	3.80
9	0	0
13	0	58.69
16	15.05	2.80
$\bar{X}$	3.76	16.32

traveled by resident voles (16.32-m). The highest mean distance traveled was by transient meadow voles utilizing microhabitat category C with a mean of 15.04-m. Microhabitat category D had the lowest transient meadow vole mean distance traveled (3.76-m). Both captured and recaptured meadow voles and microhabitat categories ($F = 1.102$, $P < 0.368$ at $\alpha = 0.05$) showed no statistical differences. In addition, there was no interaction observed among the number of captures and recaptures and microhabitat categories ($F = 0.593$, $P < 0.626$ at $\alpha = 0.05$).

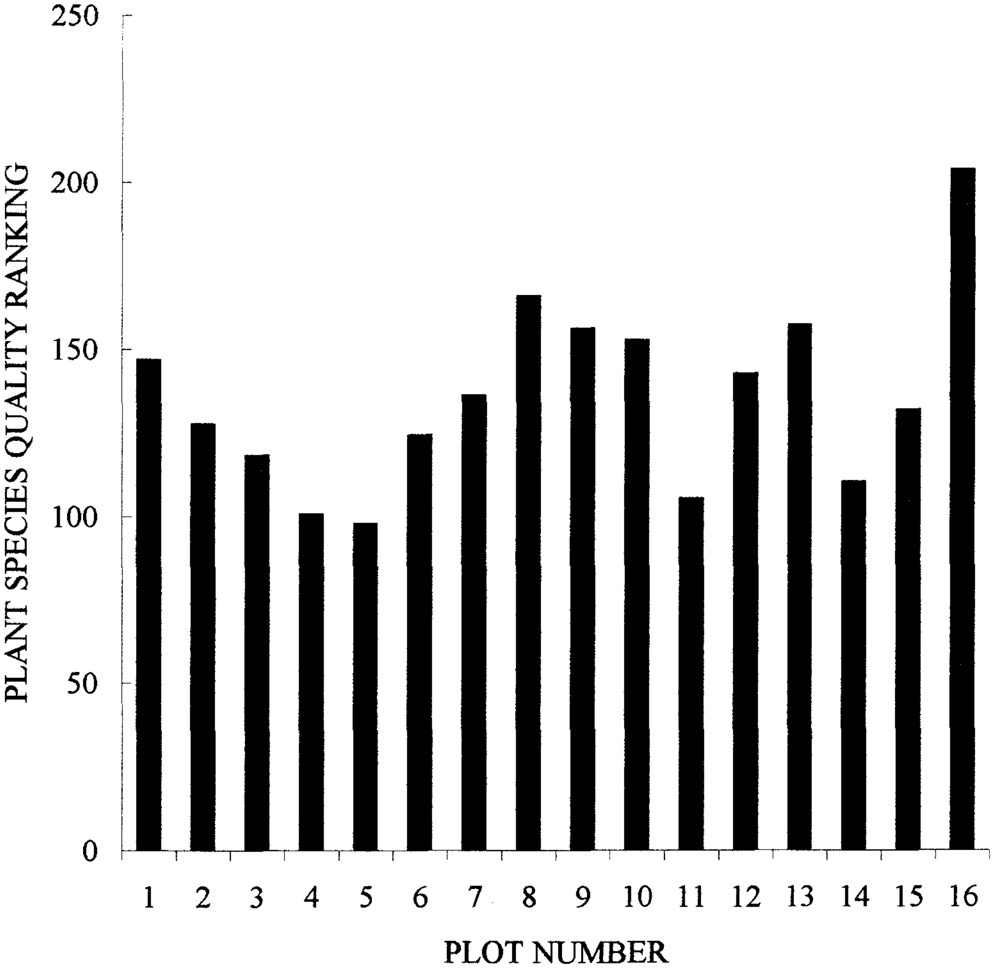
Food Quality

Analyzing differences among plots

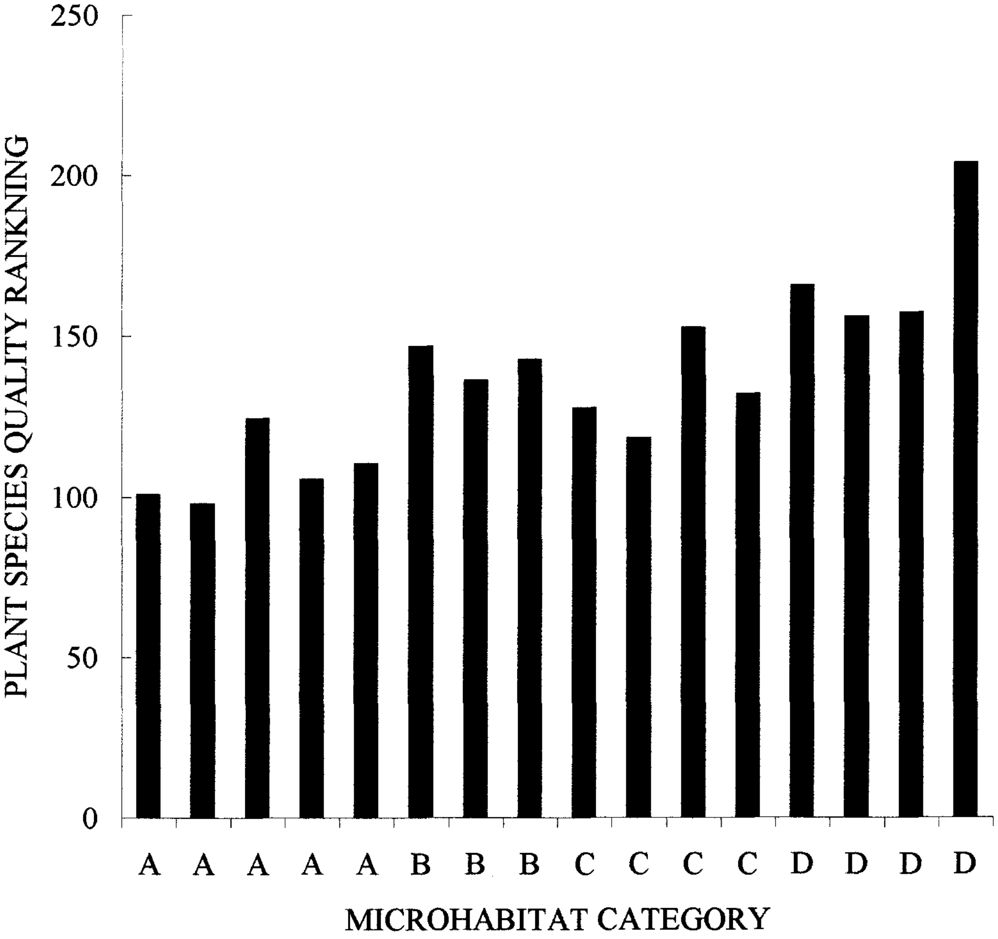
The changes in transient and resident vole numbers were compared with plant species quality. Recall the plant species present on each plot were assigned a 'quality' ranking based on their nutritional quality and/or percent of diet as stated in the literature. Plot 16 had the highest plant species 'quality' ranking at 203.83 (Fig.7). In contrast, plot 5 had the lowest plant species 'quality' ranking of 97.71. Capture and recapture vole numbers were highly significant among the 16 plots for nutritional quality ($F = 262.723$, $P < 0.000$ at $\alpha = 0.0001$). There was also a highly significant difference among the 16 plots for resident and transient meadow voles for nutritional quality ($F = 344.172$, $P < 0.000$ at $\alpha = 0.0001$).

Analyzing differences among microhabitats

The nutritional 'quality' in the four microhabitats differed significantly ($F = 13.630$, $P < 0.000$ at $\alpha = 0.0001$), (Fig. 8). Multiple comparisons revealed



PLANT SPECIES QUALITY RANKING
0
50
100
150
200
250
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PLOT NUMBER


250
200
150
100
50
0
PLANT SPECIES QUALITY RANKNING
A A A A A B B B C C C C D D D D
MICROHABITAT CATEGORY

significant differences between microhabitats A versus D, B versus A, and C versus D (Table 11). The nutritional quality in the four microhabitat categories ranged from a minimum of 108.62 (microhabitat A), to a maximum of 170.78 (microhabitat D). There was no statistical difference between the number of captures and recaptures and their microhabitat categories ($F = 0.593$, $P < 0.626$ at $\alpha = 0.05$). There was a highly significant effect of nutritional quality between the four microhabitats and transient and resident meadow vole numbers ($F = 5475.314$, $P < 0.000$, at $\alpha = 0.0001$).

TABLE 11 – Comparison of microhabitat quality between the four microhabitat categories at BFI (* significant and ** highly significant).

Microhabitat Category	vs. Microhabitat Category	$\bar{X}$ diff. ± S.E.	Significance
A	B	-34.25 ± 10.84	0.036*
	C	-24.95 ± 9.96	0.110
	D	-63.16 ± 9.96	0.000**
B	A	-34.25 ± 10.84	0.036*
	C	9.30 ± 11.34	0.844
	D	-28.91 ± 11.34	0.102
C	A	24.95 ± 9.96	0.110
	B	9.30 ± 11.34	0.844
	D	-38.21 ± 10.50	0.016*
D	A	63.16 ± 9.96	0.000**
	B	28.91 ± 11.34	0.102
	C	38.21 ± 10.50	0.016*

DISCUSSION

This study was designed to examine the effects of vegetative cover and food quality on the population dynamics and activity of the meadow vole, *Microtus pennsylvanicus* (Ord). Experimental plots were arranged into four microhabitat categories based on vegetation coverage, or lack thereof, and plant species richness and food quality. It was hypothesized that increased densities and activity patterns of the meadow vole would reflect increased microhabitat quality in highly preferable microhabitats, whereas vole densities and activity would be decreased in the less preferable microhabitats.

Plant Species Richness and Vegetative Coverage

Findings regarding vole traveling behavior with do not support the above hypothesis. For example, the number of transient meadow voles in each plot displayed a negative correlation with respect to plant species richness. This behavior indicates that microhabitat categories with a large number of transient voles possess a low number of plant species present. Transient meadow voles that are traveling will want to minimize their exposure. Microhabitats with numerous plant species will create patchiness and increase the risk of exposure of voles to predators and inclement weather. Microhabitats with fewer plant species can provide a more consistent coverage and reduce the exposure to predators and inclement weather. In addition, no correlation between the number of resident voles per microhabitat category and plant species richness was identified. The number of transient voles trapped in the microhabitat could mask the number of residents actually present. Meadow voles that were labeled, as transients voles could have been residents, but the infrequency of captures may have produced an underestimate of the number of residents present and not allow for correlation with microhabitat plant species richness. These findings regarding activity of meadow voles do not allow a clear identification of a microhabitat category preference.

It appears that resident meadow voles do not prefer a more diverse microhabitat. The number of resident voles decreases as the number of plant species increases (i.e., microhabitat category D, Table 7). Meadow voles residing in a microhabitat should attempt to reduce their exposure to predation and inclement weather and select habitats accordingly. These would be areas with continuous cover that result form fewer plant species. Other microhabitat category factors such as vegetation coverage, food quality and vole activity need to be included as well, to identify meadow vole microhabitat category preference.

Plots within microhabitat categories' possessing high quality plant species with high vegetative coverage values should have the highest capture/recapture numbers. The results of this study do not support this hypothesis. Microhabitat category D collectively had large coverage values for *Trifolium* species and *Cirsium* species, but the number of captures and recaptures were surprisingly low. The number of resident voles was also low. Microhabitat category A had the lowest coverage values for *Trifolium* species and *Cirsium* species, but had the highest number of transient voles. The high number of transient voles reflected the low coverage values of quality plant species in microhabitat category A, suggesting that the voles were unable to find quality resources and continued to move on to other habitats. Microhabitat category D accounted for the largest coverage values in clover and thistle and also has the lowest numbers of voles moving through it.

This may indicate that microhabitat category D provided quality plant species for the meadow vole. Positive relationships have been identified between meadow vole population density and vegetative cover (Eadie, 1953; Birney et al., 1976; Kotler et al., 1989). Protection from predation appears more likely to contribute to higher numbers of voles in dense vegetation (Getz, 1985). The more dense the vegetative cover, the greater the protection of voles form predators, especially from avian predators (Birney et al., 1976). *M. ochrogaster* commonly occurs in sparse habitats, even though it also occurs in dense vegetation (Getz, 1985). However, *M. pennsylvanicus* is seldom found in such short, sparse habitats (Getz, 1985).

Resident and Transient Vole Activity

There are numerous factors that can account for the population patterns of microtines. Spacing behavior, and food quality and quantity have been suggested by Taitt and Krebs (1985). The data of this study do not enable inferences about spacing behavior to be made. There are differences in the average density of *M. pennsylvanicus* in different habitats. Studies report that the meadow vole displays an annual maximum density of 172 voles/ha and a minimum average density of 23 voles/ha. Cyclic patterns reflect an average maximum density of 156 voles/ha and a minimum of 23 voles/ha (Taitt and Krebs, 1985). The average density in this study was152 voles/ha, which indicates a high meadow vole population. However, there was no significant difference between the capture and recapture numbers of the voles among the plots. Differences in vole capture and recapture numbers among the plots may indicate a habitat preference. If differences in capture and recapture numbers could be identified, reasons for these differences should be investigated. These differences may have allowed for identification or a plot and/or microhabitat preference. However, meadow vole capture and recapture numbers do not indicate a microhabitat category preference. It is not enough to know how many voles are being trapped, knowing which voles are staying and which voles are leaving is of greater importance in discovering a microhabitat selection. The use of resident and transient numbers suggested a better means for identifying vole microhabitat category selection.

Greenwood (1980) stated that there is a common feature among mammals: males tend to be the more dispersive sex. Adult *Microtus* males generally dominate the dispersing voles at the onset of a breeding season (Beacham, 1981; Lidicker, 1973; Pearson, 1960; Wolf and Lidicker, 1980). Although, if numbers from all of the seasons were summed, little sex or age bias occurs (Lidicker, 1985). The trapping results of this study do not reflect this trend. Many more female meadow voles were trapped than male voles. Females invest more into the rearing and raising of young than male do. The higher frequency of female captures may suggest that they are foraging for the necessary resource they need to ensure the survival of their young.

The mean distance traveled for female meadow was larger but not significantly greater than the male vole mean distance traveled. Researchers have shown that for *Microtus*, the longer traveling of male voles can be related to differences in reproductive activity (Madison, 1980; Webster and Brooks, 1981).

Transient individuals were voles that were observed on a patch only during one trap week. The transient vole distance traveled was expected to be higher and attributable to a continuous search for resources and breeding opportunities. The data of this study, however, do not support this. A short mean distance traveled can be attributed to the infrequency of captures and recaptures of transient meadow voles. Meadow voles that were trapped twice in the same plot and in the same trap would reflect a distance traveled of zero meters. For example, a transient adult male vole (b-122) was trapped twice in the same trap (#4) on plot (13), twice in one week (July 14 to July 21) for a distance traveled of zero meters. Recall, the estimated population of meadow voles at the study site was approximately 152 vole/ha indicating a high meadow vole population. Krebs (1970) has concluded that traveling distances in *M. ochrogaster* is smaller at higher population densities than at low populations. In contrast, Batzli (1968) reported travel distances of *M. californicus* was relatively constant and independent of population density. Thus, the literature contains debatable reports on the relation between distance traveled and population density (Abramsky and Tracy, 1980).

Madison (1984) described two types of microtine movements, local and distant reconnaissance. Local reconnaissance movements are zero to three meter movements around the nest. Distant reconnaissance are movements similar to local reconnaissance but of a greater distance (up to 50-m or more). The mean distance traveled by resident meadow voles was significantly different among the plots when compared to transient mean distance traveled. In addition, when the 16 plots were arranged into the four microhabitat categories, a significant difference between resident and transient voles was identified. Distant reconnaissance can be used to assess reproductive advantages for voles of either sex (Madison, 1984). However, distant reconnaissance might also be used to assess food quality and resources in adjacent areas.

Food Quality

While grass species *Festuca elatior* dominated all plots, there was a much greater variability in high quality vegetation types between plots (e.g., *Trifolium* species and *Medicago* species). Alfalfa (*Medicago* species) and clover (*Trifolium* species) are nutritious, high protein plant species and are highly preferred forage by the meadow vole (Batzli and Cole, 1979; Lindroth and Batzli, 1984; Marquis and Batzli, 1989). The overall quality of the microhabitat categories was established with a strong relationship with the percent coverage values of the vegetation. For example, microhabitat category D possessed not only the highest nutritional quality values, but also the highest percent coverage values of *Trifolium* and *Cirsium* species. Plots 4, 5, 6, 11, and 14 in microhabitat category A have the lowest quality and coverage values but, high capture/recapture and high transient and low resident numbers. These variables (overall quality and nutritional quality) are important for vole survivorship and growth, and high capture/recapture numbers reflected this for transients as a group. The findings of this study suggest that dispersal behavior (i.e., the number of residents or transients) of meadow voles be used as an indicator of vole microhabitat category selection. Meadow vole densities alone are not sufficient to show a microhabitat preference. Identifying the number of voles residing and traveling through the habitat may better illustrate microhabitat category preference.

Previous studies involving cover and food have recorded that food availability and predation influence meadow vole population dynamics (Taitt et al., 1981; Taitt and Krebs, 1983). It appears that once a threshold of cover is established, increasing the amount of cover does not increase plot quality, rather, vole densities respond to increasing quantity and quality of available food. Birney et. al., (1976) found that the quality of vegetation is more important than the quantity of the standing crop mass (coverage). This study does not support their findings, and suggests that quality and quantity of vegetation (coverage) are equally important in determining microhabitat preference for the meadow vole. For example, as coverage values of quality plant species (Fig. 7) and quality nutritional plant species increase (Fig. 8); the mean distance traveled by resident voles decreases (Table 10). This suggests that resident voles travel less distance by obtaining the necessary resources within a microhabitat category.

Conclusions

The following hypotheses were not accepted by the findings of this study: resident voles prefer diverse microhabitats than transients do, resident voles mean distance traveled (activity) differ from transients, and meadow vole capture/recapture numbers are indicative of vole microhabitat selection. However, one hypothesis was not rejected by the data: resident voles prefer high quality microhabitats to low quality microhabitats.

In summary, this study demonstrates that plot quality had significant effects on meadow vole microhabitat selection. The results document the role of vegetative cover and food quality as important factors in vole microhabitat category selection. From an applied ecological standpoint, the introduction of specific new cover types would result in an increase in meadow vole density by altering the patchiness of a microhabitat. However, *Microtus pennsylvanicus* responds not only to vegetative cover, but to the quality of the food resources, as well. This suggests that to enhance meadow vole densities, sufficient vegetative coverage and quality food resources need to be established. Future studies need to be designed to evaluate the effects of increased plot quality and meadow vole densities at higher levels of interaction (i.e., population, community, and ecosystem) and on food chain linkages among small mammal species and meadow vole predators.

LITERATURE CITED

Abramsky, Z. and C. R. Tracy. 1980. Relation between home range size and regulation of population size in *Microtus ochrogaster*. Oikos 34: 347-355. Copenhagen 1980.

Anderson, T. J. and G. W. Barrett. 1982. Effects of dried sewage sludge on meadow vole (*Microtus pennsylvanicus*) population in two grassland communities. J. Applied Ecology 19: 759-772.

Batzli, G. O. 1968. Dispersion patterns of mice in California annual grasslands. J. Mamm., 49: 239-250.

____ 1983. Responses of Arctic rodent populations to nutritional factors. Oikos 40: 369-406.

____ 1985. Nutrition. Pages 779-811, *in* R. H. Tamarin, editor. Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Batzli, G. O. and F. R. Cole. 1979. Nutritional ecology of microtine rodents: digestibility of forage. J. Mamm., 60: 740-750.

Batzli, G. O. and H. G. Jung. 1980. Nutritional ecology of microtine rodents: resource utilization near Atkasook, Alaska. Artic Alpine Res., 12: 483-499.

Batzli, G. O. and F. A. Pitelka. 1983. Nutritional ecology of microtine rodents: food habits of lemmings near Barrow, Alaska. J. Mamm., 64: 648-655.

Beacham, T. D. 1981. Some demographic aspects of dispersers in fluctuating populations of the vole, *Microtus townsendii*. Oikos 36: 273-280.

Berger, P. J., E. H. Sanders, and P. D. Gardner. 1981. Chemical triggering of reproduction in *Microtus montanus*. Science 214: 69-70.

Bergeron, J. M. and L. Jodin. 1987. Defining "high quality" food resources of herbivores: The case for meadow voles (*Microtus pennsylvanicus*). Oecologica 71: 510-517.

Birney, E. C., W. E. Grant, and D. D. Baird. 1976. Importance of vegetative cover to cycles of *Microtus* populations. Ecology 57: 1043-1051.

Bucyanayandi, J. D. and J. M. Bergeron. 1990. Effects of food quality on feeding patterns of meadow voles (*Microtus pennsylvanicus*) along a community gradient. J. Mamm., 71: 390-396.

Cole, F. R. and G. O. Batzli. 1979. Nutrition and population dynamics of the prairie vole, *Microtus ochrogaster*, in central Illinois. J. Anim. Ecol., 48: 455-470.

Desy, E. A. and G. O. Batzli. 1989. Effects of food availability and predation on prairie vole demography: A field experiment. Ecology 70: 411-421.

Eadie, W. R. 1953. Response of *Microtus* to vegetative cover. J. Mamm., 34: 263-264.

Elton, C. 1939. On the nature of cover. J. Wildl. Manag., 3: 332-335.

Erlinge, S., G. Goransson, G. Hogstedt, O. Liberg, J. Loman, I. Nilsson, T. von Schantz, and M. Sylven. 1983. Predation as a regulating factor in small rodent populations in southern Sweden. Oikos 40: 36-52.

Erlinge, S., G. Goransson, G. Hogstedt, G. Jansson, O. Liberg, J. Loman, I. N. Nilsson, T. von Schantz, and M. Sylven. 1984. Can vertebrate predators regulate their prey? Am. Nat., 123: 125-133.

Erlinge, S. 1987. Predation and non-cyclicity in a microtine population in southern Sweden. Oikos 50: 347-352.

Fitzgerald, B. M. 1977. Weasel predation on a cyclic population of the Montane vole (*Microtus montanus*) in California. J. Anim. Ecol., 46: 367-397.

Frank, F. 1957. The causality of Microtine cycles in Germany. J. Wildl. Manag., 21: 113-121.

Getz, L. L. 1960. A population study of the vole, *Microtus pennsylvanicus*. Am. Midl. Nat., 64: 392-405.

____ 1971. Microclimate, vegetative cover, and local distribution of the meadow vole. Transaction of the Illinois Academy of Science. 64: 9-21.

____ 1985. Habitats. Pages 286-309, *in* R. H. Tamarin, editor. Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Getz, L. L., F. R. Cole, and D. L. Gates. 1978. Use of interstate roadways as dispersal routes by *Microtus pennsylvanicus*. J. Mamm., 50: 208-212.

Golley, F. B. 1960. Energy dynamics of a food chain of an old field community. Ecol. Mono., 36: 186-205.

Gottschang, J. L. 1981. Meadow Vole or Field Mouse. Pages 95-97, *in* A guide to the Mammals of Ohio. The Ohio Sate University Press.

Grant, W. E., N. R. French, and D. M. Swift. 1977. Responses of a small mammal community to water and nitrogen treatments in a short grass prairie ecosystem. J. Mamm., 58: 637-652.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Anim. Behav., 28: 1140-1162.

Hall, A. T., P. E. Woods, and G. W. Barrett. 1991. Population dynamics of the meadow vole (*Microtus pennsylvanicus*) in nutrient-enriched old-field communities. J. Mamm., 72: 332-342.

Hamilton, W. J. 1940. Life and habits of field mice. Sci. Monthly, 50: 425-434.

Hansson, L. 1971. Habitat, food, and population dynamics of the field vole *Microtus agrestis* in south Sweden. Viltrevy 8: 268-378.

Hanski, I. L. 1987. Populations of small mammals cycle-unless they don't. Trends Ecol. and Evol., 2: 55-56.

Hanski, I. and E, Korpimaki. 1995. Microtine rodent dynamics in northern Europe: parameterized models for the predator-prey interaction. Ecology 76(3): 840-850.

Hanski, I., Hansson, L. and H. Henttonen. 1991. Specialist predators, generalist predators, and the microtine rodent cycle. J. Anim. Ecol., 60: 353-367.

Henttonen, H., T. Oksanen, A. Jortikka, and V. Haukisalmi. 1978. How much does weasels shape microtine cycles in the northern Fennoscandian taiga. Oikos 50: 353-365.

Klatt, B. J. and L. L. Getz. 1987. Vegetation characteristics of *Microtus ochrogaster* and *M. pennsylvanicus* habitats in east-central Illinois. J. Mamm., 68: 569-577.

Korpimaki, E. and K. Norrdahl. 1989. Predation on Tengmalm's owl: numerical responses, functional responses. Oikos 54: 154-164.

____ 1991. Numerical and functional responses of kestrels, short-eared owls, and long-eared owls to vole densities. Ecology 72: 814-826.

Korpimaki, E., K. Norrdahl, and T. Rinta-Jaskari. 1991. Responses of stoats and least weasels to fluctuating food abundances; is the low phase of the vole cycle due to mustelid predation? Oecologia (Berlin) 88: 552-561.

Kotler, B. P., M. S. Gaines, and B. J. Danielson. 1989. The effects of vegetative cover on the community structure of prairie rodents. Acta Therilogica 33: 379-391.

Krebs, C. J. 1970. *Microtus* population biology: Behavioral changes associated with the Population cycle in *M. ochrogaster* and *M. pennsylvanicus*. Ecology 51: 34-52.

Lechowicz, M. 1983. The sampling characteristics of electivity indices. Oecologia 52: 22-30.

Lidicker, W. Z. 1973. Regulation of numbers in an island population of the California vole, a problem in community dynamics. Ecol. Monogr., 43: 271-302.

Lidicker, W. Z. 1985. Dispersal. Pages 148-248, *in* R. H. Tamarin, editor. Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Lindroth, R. L. and G. O. Batzli. 1984. Food habits of the meadow vole (*Microtus pennsylvanicus*) in bluegrass and prairie habitats. J. Mamm., 65: 600-606.

Maclean, S. F., B. M. Fitzgerald, and F. A. Pitelka. 1974. Population cycles in arctic lemmings: winter reproduction and predation by weasels. Arctic and Alpine Research 6: 1-12.

Madison, D. M. 1980. Space use and social structure in meadow voles, *Microtus pennsylvanicus*. Behav. Ecol. and Sociobio., 7: 65-71.

Madison D. M. 1984. Group nesting and its ecological and evolutionary significance in overwintering microtine rodents. Pages 267-274, *in* J. F. Merritt, editor. Spec. Publ. Carnegie Mus. Nat. Hist., 10: 1-380.

Marquis, R. J. and G. O. Batzli. 1989. Influence of chemical factors on palatability of forage to voles. J. Mamm., 70: 503-511.

Merritt, J. F. Meadow Vole. Pages 195-198, 358, and 378 *in* Guide to the Mammals of Pennsylvania. The University of Pittsburgh Press. The Carnegie Museum of Natural History.

Miller, D. H. 1969. Northern records of the pine mouse in Vermont. J. Mamm., 45: 627-628.

Pearson, O. P. 1960. Habits of *Microtus californicus* revealed by automatic photographic recorders. Ecol. Monogr., 30: 231-249.

Pearson, O. P. 1964. Carnivore-mouse predation: an example of its intensity and bioengertics. J. Mamm., 45: 177-188.

____ 1985. Predation. Pages 535-566, *in* R. H. Tamarin, editor. Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Peles, J. D. and G. W. Barrett. 1996. Effects of vegetative cover on the population dynamics of meadow voles. J. Mamm., 77: 857-869.

Pitelka, F. A. and A. M. A. Schultz. 1964. The nutrient recovery hypothesis for Arctic microtine cycles. I. Introduction. Pages 55-68, *in* Grazing in terrestrial and marine environments, a symposium of the British Ecological Society (D. S. Crisp, ed.). Blackwell Scientific Publication, Oxford, United Kingdom, 322 pp.

Rose, R. K. and E. C. Birney. 1985. Community Ecology. Pages 310-339, *in* R. H. Tamarin, editor. Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Smith, M. H., R. H. Gardner, J. B. Gentry, D. W. Kaufman, and M. H. O'Farrell. 1975. Density estimation of small mammal populations. Pages 25-53, *in* Small Mammal: productivity and dynamics of populations (F. B. Golley, K. Petrusewicz, and L. Ryszkowski, eds.). Cambridge University Press, London, United Kingdom, 455 pp.

Smith, R. L. 1996. Ecology and Field Biology. Fifth Edition. Pages 189-193. HarperCollins College Publishers, New York, New York, 740 pp.

Strategic Mapping, Inc. 1996. Atlas GIS. Desktop Geographic Information System. Stategic Mapping, Inc., Santa Clara, CA.

Taitt, M. J., J. H. Gipps, C. J. Krebs, and Z. Dunderjerski. 1981. The effect of extra food and cover on declining populations of *Microtus townsendii*. Can. J. Zool., 59: 1593-1599.

Taitt, M. J. and C. J. Krebs. 1983. Predation, cover and food manipulations during a spring decline of *Microtus townsendii*. J. Anim. Ecol., 52: 837-848.

____ 1985. Population Dynamics and Cycles. Pages 567-620, *in* R. H. Tamarin, editor. Biology of New World *Microtus*. American Society of Mammalogists Special Publication Number 8.

Thompson, D. Q. 1965. Food preferences of the meadow vole (*Microtus pennsylvanicus*) in relation to habitat affinities. Amer. Midl. Nat., 74: 76-86.

Watts, C. H. S. 1970. Effects of supplemental food on breeding in woodland rodents. J. Mamm., 51: 169-171.

Webster, A.B. and R. J. Brooks. 1980. Effects of radio transmitters on the meadow vole, *Microtus pennsylvanicus*. Can. J. Zool., 58: 997-1001.

Wirtz, W. O. and P. G. Pearson. 1960. A preliminary analysis of habitat orientation in *Microtus* and *Peromyscus*. Am. Midl. Nat., 63: 131-142.

Wolf , J.O. and W. Z. Lidicker, Jr. 1980. Population ecology of the taiga vole (*Microtus xanthoganthu*) in interior Alaska. Can. J. Zool., 58: 1800-1812.

Zar, J. H. 1996. Biostatistical Analysis. Third Edition. Pages 371-375. Prentice-Hall, Inc., Simon & Schuster/A Viacom Co., Upper Saddle River, New Jersey.

Zimmerman, E. G. 1965. A comparison of habitat and food of two species of *Microtus*. J. Mamm., 46: 605-612.

TABLE A1. - Plot 1 collection data for the meadow vole, *Microtus pennsylvanicus* , at the BFI/CLD Landfil, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Colora/Band Number
21-May-98	1	capture	24.0	108	abdominal	b-57
26-May-98	3	capture	36.0	110	perforated	r-55
29-May-98	2	recapture	37.0	110	perforated	r-55
2-Jun-98	2	capture	10.0	70	abdominal	b-72
4-Jun-98	2	recapture	10.0	70	abdominal	b-72
4-Jun-98	3	capture	12.5	70	abdominal	b-73
5-Jun-98	3	capture	14.0	70	nonperforated	r-70
5-Jun-98	4	capture	42.5	121	perforated	r-69
11-Jun-98	2	recapture	43.0	122	perforated	r-69
16-Jun-98	1	recapture	27.0	108	scrotal	b-57
24-Jun-98	2	recapture	43.0	122	perforated	r-69
25-Jun-98	4	capture	38.5	121	scrotal	b-99
25-Jun-98	2	capture	19.5	78	nonperforated	r-86
30-Jun-98	2	recapture	44.0	122	perforated	r-69
30-Jun-98	3	recapture	21.0	79	nonperforated	r-86
1-Jul-98	2	capture[b]	8.00	60	n/a[c]	n/a
1-Jul-98	3	recapture	45.0	122	perforated	r-69
2-Jul-98	2	recapture	45.0	122	perforated	r-69
3-Jul-98	1	recapture	45.0	122	perforated	r-69
8-Jul-98	2	recapture	37.0	109	scrotal	b-57
16-Jul-98	2	capture	17.0	85	nonperforated	b-126
31-Jul-98	2	capture	18.0	95	abdominal	b-134
18-Aug-98	1	capture	34.0	96	perforated	r-134
18-Aug-98	2	recapture	20.0	96	abdominal	b-134

TABLE A1. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
18-Aug-98	4	capture	34.0	127	scrotal	b-148
19-Aug-98	1	recapture	33.0	128	nonperforated	r-133
19-Aug-98	3	recapture	22.0	79	perforated	r-86
3-Sep-98	1	recapture	21.0	96	abdominal	b-134
8-Sep-98	4	recapture	21.5	97	abdominal	b-134
9-Sep-98	2	capture	43.0	129	perforated	r-140
9-Sep-98	3	recapture	22.0	97	abdominal	b-134
10-Sep-98	2	capture	19.5	102	abdominal	b-163
15-Sep-98	4	recapture	28.0	101	abdominal	b-128
16-Sep-98	1	recapture	29.0	101	abdominal	b-128
17-Sep-98	3	recapture	28.0	102	abdominal	b-128
18-Sep-98	1	recapture	39.0	129	perforated	r-137
18-Sep-98	2	recapture	28.0	102	abdominal	b-128
1-Oct-98	4	recapture	37.0	134	perforated	r-134

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A2. - Plot 2 collection data for the meadow vole, *M. pennsylvanicus* , at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	2	capture	38.0	114	scrotal	b-53
21-May-98	2	capture	24.0	83	scrotal	b-56
22-May-98	2	capture	30.0	95	abdominal	b-58
22-May-98	3	capture[b]	38.0	89	n/a[c]	n/a[c]
27-May-98	4	capture[b]	18.5	76	n/a[c]	n/a[c]
28-May-98	4	recapture	24.0	83	scrotal	b-56
29-May-98	3	recapture	23.5	102	perforated	b-66
2-Jun-98	3	recapture	20.0	80	scrotal	b-62
4-Jun-98	1	recapture	25.0	83	scrotal	b-56
4-Jun-98	3	capture	31.0	105	scrotal	b-74
5-Jun-98	4	capture[b]	21.5	77	n/a[c]	n/a[c]
23-Jun-98	1	capture	47.5	119	perforated	r-80
23-Jun-98	4	capture	20.0	93	scrotal	b-96
30-Jun-98	4	recapture	21.0	93	scrotal	b-96
7-Jul-98	4	recapture	20.0	93	scrotal	b-96
10-Jul-98	1	capture	31.0	109	scrotal	b-120
10-Jul-98	3	capture	32.0	121	scrotal	b-119
21-Jul-98	4	recapture	23.0	93	scrotal	b-96
21-Jul-98	2	capture	19.0	98	abdominal	b-128
22-Jul-98	3	recapture	23.0	93	scrotal	b-96
23-Jul-98	3	recapture	21.0	102	abdominal	b-76
28-Jul-98	3	recapture	23.0	94	scrotal	b-96
29-Jul-98	2	recapture	23.0	94	scrotal	b-96
31-Jul-98	1	capture	27.0	121	abdominal	b-137
4-Aug-98	1	recapture	36.0	100	perforated	r-107
5-Aug-98	1	recapture	35.0	100	perforated	r-107

TABLE A2. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
7-Aug-98	1	capture	27.0	115	scrotal	b-131
12-Aug-98	3	recapture	28.0	115	scrotal	b-131
18-Aug-98	3	recapture[b]	28.0	115	n/a[c]	b-131
18-Aug-98	4	recapture	35.0	100	perforated	r-107
19-Aug-98	2	capture[b]	24.0	89	n/a[c]	n/a[c]
19-Aug-98	4	recapture[b]	36.0	100	n/a[c]	r-107
9-Sep-98	1	capture[b]	18.0	76	n/a[c]	n/a[c]
24-Sep-98	3	capture[b]	44.0	127	n/a[c]	n/a[c]

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A3. - Plot 3 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
26-May-98	3	recapture	30.0	95	scrotal	b-58
27-May-98	2	capture[b]	18.0	85	n/a[c]	n/a[c]
28-May-98	2	capture	23.5	100	perforated	b-66
4-Jun-98	1	recapture	24.0	100	perforated	b-66
4-Jun-98	2	capture	27.0	108	scrotal	b-75
5-Jun-98	3	recapture	27.0	108	scrotal	b-75
5-Jun-98	4	recapture	24.0	100	perforated	b-66
9-Jun-98	1	recapture	27.0	101	perforated	r-63
10-Jun-98	1	recapture	41.0	105	scrotal	b-74
10-Jun-98	2	capture	26.0	96	abdominal	b-83
10-Jun-98	3	recapture	31.0	101	perforated/gave birth (3)	r-63
11-Jun-98	4	recapture	27.0	108	scrotal	b-75
23-Jun-98	3	capture	25.0	109	scrotal	b-94
25-Jun-98	2	capture	31.0	100	scrotal	b-98
1-Jul-98	2	capture	28.5	113	scrotal	b-107
2-Jul-98	1	capture	31.0	112	abdominal	b-110
15-Jul-98	2	recapture	37.0	112	scrotal	b-110
21-Jul-98	2	capture	19.0	102	abdominal	b-128
22-Jul-98	1	capture	40.0	121	scrotal	b-129
31-Jul-98	2	recapture	31.0	100	scrotal	b-98
6-Aug-98	3	capture	23.0	101	abdominal	b-135
18-Aug-98	1	capture	46.0	132	perforated	r-132
18-Aug-98	3	recapture	28.0	110	scrotal	b-94
18-Aug-98	4	capture	31.5	128	perforated	r-133
19-Aug-98	1	recapture	32.5	101	scrotal	b-98
27-Aug-98	2	capture	35.0	119	scrotal	b-155

TABLE A3. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
8-Sep-98	1	recapture	36.5	119	scrotal	b-155
8-Oct-98	3	capture	34.0	103	abdominal	b-177
15-Oct-98	3	capture	22.0	103	nonperforated	r-159
21-Oct-98	1	capture	33.0	145	scrotal	b-184
22-Oct-98	1	recapture	33.0	145	scrotal	b-184

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A4. - Plot 4 collection data for the meadow vole, *M. Pennsylvanicus* , at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	2	capture	20.0	85	nonperforated	r-47
27-May-98	3	capture	22.0	77	abdominal	b-64
2-Jun-98	1	recapture	37.0	106	perforated	r-55
4-Jun-98	2	capture	27.0	102	perforated	r-63
4-Jun-98	3	capture	50.0	128	perforated	r-62
5-Jun-98	1	recapture	31.0	96	perforated	r-59
9-Jun-98	2	capture	23.0	77	abdominal	b-64
23-Jun-98	4	capture	38.5	127	scrotal	b-92
7-Jul-98	4	recapture	29.0	102	perforated	r-63
24-Jul-98	4	recapture	31.0	102	nonperforated	r-63
31-Jul-98	1	recapture	32.0	103	nonperforated	r-63
19-Aug-98	4	recapture	33.5	103	nonperforated	r-63
27-Aug-98	4	recapture	33.5	104	nonperforated	r-63
28-Aug-98	1	capture	48.0	133	scrotal	b-156
2-Sep-98	2	recapture	32.0	104	nonperforated	r-63
3-Sep-98	1	recapture	32.0	104	nonperforated	r-63
8-Sep-98	4	capture	38.0	121	scrotal	b-162
9-Sep-98	2	recapture	38.0	121	scrotal	b-162
29-Sep-98	4	capture	21.0	85	abdominal	b-173

[a] b = blue/male and r = red/ female

TABLE A5. - Plot 5 collection data for the meadow vole, M. pennsylvanicus, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	1	capture	42.0	121	nonperforated	r-46
28-May-98	4	capture	32.0	105	scrotal	b-65
2-Jun-98	4	capture	25.0	101	abdominal	b-70
4-Jun-98	3	capture	26.0	102	scrotal	b-76
4-Jun-98	4	capture	25.0	95	nonperforated	r-64
9-Jun-98	3	capture	26.5	108	scrotal	b-80
16-Jun-98	1	capture	32.0	121	scrotal	b-85
17-Jun-98	1	capture	37.0	112	perforated	r-77
17-Jun-98	2	capture	33.0	111	nonperforated	r-78
19-Jun-98	3	capture	24.5	102	scrotal	b-91
3-Jul-98	2	recapture	28.0	102	abdominal	b-90
8-Jul-98	1	capture	37.0	113	nonperforated	r-106
14-Jul-98	1	capture	34.0	120	perforated	r-110
14-Jul-98	2	recapture	27.0	108	scrotal	b-71
14-Jul-98	3	recapture	54.0	128	perforated	r-111
21-Jul-99	1	capture	44.5	127	scrotal	b-127
21-Jul-98	4	capture	49.0	129	perforated	r-116
28-Jul-98	1	recapture	34.5	120	perforated	r-110
31-Jul-98	4	capture[b]	22.0	84	n/a[c]	n/a[c]
6-Aug-98	1	recapture	36.0	120	perforated	r-110
7-Aug-98	1	recapture	36.0	120	perforated	r-110
19-Aug-98	1	recapture	36.0	120	perforated	r-110
19-Aug-98	3	recapture	49.0	129	perforated	r-116
20-Aug-98	4	capture[b]	24.0	104	n/a[c]	n/a[c]
20-Aug-98	1	recapture[b]	36.0	120	n/a[c]	r-110
20-Aug-98	2	recapture[b]	49.0	129	n/a[c]	r-116

TABLE A5. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
25-Aug-98	4	capture	20.0	101	abdominal	b-152
28-Aug-98	2	capture	36.0	120	nonperforated	r-138
1-Sep-98	2	recapture	36.0	120	nonperforated	r-138
3-Sep-98	2	recapture[b]	51.0	127	n/a[c]	r-98
4-Sep-98	2	recapture	36.5	120	perforated	r-138
1-Oct-98	1	capture	31.0	121	perforated	r-148
1-Oct-98	2	recapture	38.0	121	perforated	r-138
1-Oct-98	3	capture	27.0	110	abdominal	b-175
2-Oct-98	2	recapture	38.0	122	perforated	r-138
14-Oct-98	3	recapture	39.0	122	nonperforated	r-138

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A6. - Plot 6 collection data for the meadow vole, *M. pennsylvanicus* , at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
26-May-98	2	recapture	40.0	112	nonperforated	r-45
28-May-98	3	recapture	41.0	112	perforated	r-45
2-Jun-98	2	capture	27.0	106	scrotal	b-71
5-Jun-98	2	capture	25.5	89	scrotal	b-79
9-Jun-98	3	capture[b]	18.0	77	n/a[c]	n/a[c]
16-Jun-98	1	capture	30.0	105	abdominal	b-86
17-Jun-98	1	recapture	45.0	112	nonperforated	r-45
25-Jun-98	1	recapture	43.0	112	nonperforated	r-45
26-Jun-98	1	recapture	42.0	112	nonperforated	r-45
7-Jul-98	2	capture	36.0	113	nonperforated	b-113
7-Jul-98	3	capture	51.0	126	perforated	r-98
10-Jul-98	1	capture	36.0	113	nonperforated	b-113
14-Jul-98	2	capture	36.5	113	nonperforated	b-113
16-Jul-98	1	capture	37.0	113	perforated	b-113
21-Jul-98	2	capture	42.0	113	perforated	b-113
24-Jul-98	3	recapture	49.0	121	perforated	r-69
31-Jul-98	3	recapture	48.0	127	perforated	r-98
5-Aug-98	2	recapture	31.0	121	nonperforated	r-125
6-Aug-98	1	recapture[b]	31.0	121	n/a[c]	r-125
13-Aug-98	3	capture	21.0	107	abdominal	b-145
14-Aug-98	3	capture	21.0	107	perforated	r-131
14-Aug-98	2	recapture	50.0	127	perforated	r-98
18-Aug-98	3	capture	39.0	122	scrotal	b-146
19-Aug-98	3	capture	39.0	122	scrotal	b-146
21-Aug-98	3	recapture	48.0	127	perforated	r-98
25-Aug-98	3	recapture	48.0	127	perforated	r-98

TABLE A6. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
26-Aug-98	3	recapture	48.0	127	perforated	r-98
27-Aug-98	3	recapture	48.0	127	perforated	r-98
1-Sep-98	2	recapture	48.0	127	nonperforated	r-98
2-Sep-98	2	recapture	45.0	127	nonperforated	r-98
22-Sep-98	2	capture	32.0	122	perforated	r-145
1-Oct-98	3	recapture	45.5	126	perforated	r-136

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A7. - Plot 7 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	4	capture	40.0	115	nonperforated	r-45
21-May-98	4	capture	15.0	71	abdominal	b-55
4-Jun-98	2	recapture	40.0	115	perforated	r-45
9-Jun-98	2	recapture	38.0	115	perforated	r-45
9-Jun-98	3	capture	31.5	120	scrotal	b-82
18-Jun-98	3	recapture	43.0	115	perforated	r-45
19-Jun-98	3	recapture	44.0	116	perforated	r-45
24-Jun-98	3	recapture	43.0	115	perforated	r-45
1-Jul-98	3	capture	35.0	119	perforated	r-91
2-Jul-98	2	recapture	36.0	119	perforated	r-91
28-Jul-98	1	recapture	41.0	119	perforated	r-91
12-Aug-98	2	recapture	36.0	119	perforated	r-91
9-Sep-98	2	capture[b]	12.0	69	n/a[c]	n/a[c]
8-Oct-98	2	capture	28.0	98	abdominal	b-182

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A8. - Plot 8 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
29-May-98	4	recapture	35.0	101	scrotal	b-52
9-Jun-98	2	capture	25.0	85	nonperforated	r-74
9-Jun-98	3	capture	45.0	115	perforated	r-73
16-Jun-98	3	capture	39.0	115	scrotal	b-88
23-Jun-98	3	recapture	30.0	85	perforated	r-74
24-Jun-98	3	capture	36.0	128	perforated/gave birth (6)	r-82
30-Jun-98	3	recapture	37.0	101	perforated	r-71
7-Jul-98	3	recapture	35.0	85	perforated	r-74
9-Jul-98	3	capture	23.5	95	nonperforated	r-107
21-Jul-98	3	capture	29.0	101	nonperforated	r-117
22-Jul-98	3	capture	27.0	119	nonperforated	r-118
23-Jul-98	3	recapture	27.0	119	nonperforated	r-118
28-Jul-98	3	recapture	27.0	119	nonperforated	r-118
29-Jul-98	3	recapture	29.0	119	nonperforated	r-118
4-Aug-98	3	recapture	30.0	119	nonperforated	r-118
24-Sep-98	2	capture[b]	23.0	105	n/a[c]	n/a[c]
29-Sep-98	2	capture	25.0	110	abdominal	r-174
30-Sep-98	3	recapture	25.0	110	abdominal	r-174

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A9. - Plot 9 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	4	capture	39.0	106	nonperforated	r-44
26-May-98	2	recapture	35.0	101	scrotal	b-52
4-Jun-98	4	recapture	24.0	101	nonperforated	r-53
5-Jun-98	2	recapture[b]	25.0	101	n/a[c]	r-53
16-Jun-98	2	capture	28.0	115	scrotal	b-88
17-Jun-98	4	recapture	37.0	102	perforated	r-54
31-Jul-98	3	capture	35.0	128	perforated	r-123
21-Aug-98	4	capture	32.0	120	scrotal	b-150

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A10. - Plot 10 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill from, May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
27-May-98	3	recapture	35.0	101	scrotal	b-52
29-May-98	3	recapture	19.0	83	nonperforated	r-52
2-Jun-98	1	capture	22.0	100	abdominal	b-68
11-Jun-98	4	capture	14.5	70	nonperforated	r-76
16-Jun-98	1	capture	21.0	95	abdominal	b-87
23-Jun-98	3	capture	29.5	104	scrotal	b-95
6-Jul-98	1	capture	42.0	120	perforated	r-100
9-Jul-98	4	capture	42.0	127	abdominal	b-116
10-Jul-98	1	capture	35.0	108	scrotal	b-118
7-Aug-98	3	capture	33.0	120	abdominal	b-137
19-Aug-98	1	capture	34.0	114	nonperforated	r-135
22-Sep-98	1	capture	44.0	133	perforated	r-146

[a] b = blue/male and r = red/female

TABLE A11. - Plot 11 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color^a/Band Number
26-May-98	2	capture	37.0	100	perforated	r-54
28-May-98	2	recapture	35.0	100	scrotal	b-52
4-Jun-98	1	capture	23.5	96	scrotal	b-77
4-Jun-98	2	capture	31.5	96	perforated	r-65
5-Jun-98	3	recapture	31.0	96	perforated	r-65
11-Jun-98	2	recapture	32.0	105	nonperforated	r-75
19-Jun-98	1	recapture	33.0	96	nonperforated	r-65
23-Jun-98	2	recapture	33.5	96	perforated	r-65
24-Jun-98	2	capture	29.5	112	scrotal	b-97
24-Jun-98	1	recapture	33.5	105	perforated	r-75
25-Jun-98	3	capture	33.5	108	nonperforated	r-84
26-Jun-98	4	recapture	35.0	96	perforated	r-65
1-Jul-98	1	capture	15.0	88	nonperforated	r-90
2-Jul-98	3	capture	27.0	100	nonperforated	r-95
3-Jul-98	4	recapture	30.0	112	scrotal	b-97
7-Jul-98	1	recapture	22.0	88	nonperforated	r-90
7-Jul-98	3	capture	34.0	118	abdominal	b-114
7-Jul-98	4	recapture	31.0	112	scrotal	b-97
8-Jul-98	3	recapture	35.0	96	nonperforated	r-65
9-Jul-98	4	recapture	28.5	100	perforated	r-95
14-Jul-98	4	recapture	36.0	96	nonperforated	r-65
15-Jul-98	3	recapture	35.0	96	nonperforated	r-65
16-Jul-98	1	recapture	27.0	100	perforated	r-95
16-Jul-98	3	recapture	37.0	96	nonperforated	r-65
17-Jul-98	3	recapture	36.0	96	nonperforated	r-65
21-Jul-98	3	recapture	26.0	90	nonperforated	r-90

TABLE A11. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
22-Jul-98	3	recapture	26.0	90	nonperforated	r-90
23-Jul-98	4	recapture	30.0	100	perforated	r-95
24-Jul-98	4	recapture	30.0	100	perforated	r-95
28-Jul-98	2	recapture	36.0	96	nonperforated	r-65
28-Jul-98	4	recapture	31.0	100	perforated/gave birth (6)	r-90
4-Aug-98	3	recapture	38.0	96	perforated	r-65
6-Aug-98	3	recapture	38.0	96	perforated	r-65
6-Aug-98	4	recapture	28.0	90	nonperforated	r-90
7-Aug-98	3	recapture[b]	28.0	90	n/a[c]	r-90
7-Aug-98	3	recapture[b]	38.0	96	n/a[c]	r-65
19-Aug-98	3	recapture	33.5	112	scrotal	b-97
25-Aug-98	2	capture	23.0	101	abdominal	b-153
25-Aug-98	4	capture	38.5	126	scrotal	b-154
3-Sep-98	2	recapture	23.0	101	abdominal	b-153
4-Sep-98	1	recapture	23.0	101	abdominal	b-153
15-Sep-98	2	recapture	24.0	101	scrotal	b-153
16-Sep-98	2	recapture	23.5	101	scrotal	b-153
17-Sep-98	1	recapture	23.5	101	scrotal	b-153
18-Sep-98	2	recapture	23.5	101	scrotal	b-153

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A12. - Plot 12 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	4	capture	35.0	101	scrotal	b-52
21-May-98	1	capture[b]	21.0	83	n/a[c]	n/a[c]
22-May-98	2	recapture	35.0	101	scrotal	b-52
26-May-98	1	capture	24.0	102	nonperforated	r-53
2-Jun-98	2	recapture	35.0	101	perforated	b-52
4-Jun-98	4	recapture	20.0	89	scrotal	b-51
4-Jun-98	2	capture	26.5	113	scrotal	b-78
4-Jun-98	3	capture	21.0	104	nonperforated	r-68
5-Jun-98	4	recapture[b]	21.0	104	n/a[c]	r-68
5-Jun-98	3	recapture	38.0	101	perforated	b-52
9-Jun-98	2	recapture	26.5	113	scrotal	b-78
11-Jun-98	1	recapture	23.0	100	perforated	r-67
25-Jun-98	1	capture[b]	23.5	100	n/a[c]	n/a[c]
25-Jun-98	2	recapture	30.0	113	scrotal	b-78
7-Jul-98	2	capture	25.0	106	abdominal	b-111
7-Jul-98	3	capture	29.0	113	abdominal	b-112
8-Jul-98	2	recapture[b]	34.0	121	n/a[c]	b-114
10-Jul-98	2	recapture	34.0	113	scrotal	b-78
14-Jul-98	4	recapture	28.0	100	perforated	r-67
14-Jul-98	2	recapture	35.0	113	scrotal	b-78
15-Jul-98	4	recapture	28.0	100	perforated	r-67
15-Jul-98	3	recapture	30.0	104	abdominal	b-68
16-Jul-98	4	recapture	28.0	100	perforated	r-67

TABLE A12. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
21-Jul-98	4	capture	30.0	118	perforated	r-115
23-Jul-98	4	recapture	33.0	100	perforated	r-67
28-Jul-98	4	recapture	35.0	100	perforated	r-67
29-Jul-98	1	capture	42.5	126	perforated	r-120
29-Jul-98	2	capture	20.0	100	nonperforated	r-121
31-Jul-98	3	capture	23.0	94	abdominal	b-133
4-Aug-98	2	recapture	44.0	126	perforated	r-120
6-Aug-98	4	recapture	31.0	118	perforated	r-115
12-Aug-98	1	capture	28.0	125	nonperforated	r-129
12-Aug-98	4	recapture	39.0	126	perforated	r-120
13-Aug-98	1	recapture	37.0	100	perforated	r-67
14-Aug-98	1	recapture	38.0	100	perforated	r-67
18-Aug-98	1	recapture	38.0	100	perforated	r-67
19-Aug-98	1	recapture[b]	38.0	100	n/a[c]	r-67
20-Aug-98	2	recapture	39.0	126	perforated	r-120
25-Aug-98	2	capture	44.0	126	scrotal	b-151
26-Aug-98	4	capture	35.0	125	perforated	r-136
27-Aug-98	4	recapture	35.0	118	perforated	r-115
2-Sep-98	4	recapture	35.0	118	perforated	r-115
3-Sep-98	2	recapture	22.0	108	perforated	r-131
4-Sep-98	1	recapture	35.0	118	perforated	r-115
4-Sep-98	4	recapture	28.0	125	nonperforated	r-129
8-Sep-98	4	recapture	35.0	118	perforated	r-115
10-Sep-98	4	recapture	35.0	118	perforated	r-115
11-Sep-98	3	capture[b]	33.0	100	n/a[c]	n/a[c]
15-Sep-98	3	capture	20.0	103	abdominal	b-161

TABLE A12. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
16-Sep-98	1	recapture	33.0	125	perforated	r-129
17-Sep-98	4	recapture	35.0	118	perforated	r-115
17-Sep-98	2	recapture	34.0	125	perforated	r-129
22-Sep-98	2	recapture	34.0	125	perforated	r-129
22-Sep-98	3	capture	21.5	85	perforated	r-144
23-Sep-98	2	recapture	21.5	85	perforated	r-144
24-Sep-98	2	recapture	34.0	125	perforated	r-129
25-Sep-98	2	recapture	34.0	125	perforated	r-129

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A13. - Plot 13 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill. From May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
20-May-98	4	capture	16.0	76	nonperforated	r-49
4-Jun-98	3	capture	20.0	101	nonperforated	r-67
9-Jun-98	1	recapture	17.0	80	abdominal	b-61
16-Jun-98	2	recapture	20.0	101	nonperforated	r-67
19-Jun-98	2	recapture	25.0	105	perforated	r-67
25-Jun-98	1	recapture	25.0	105	perforated	r-67
2-Jul-98	2	recapture	30.0	105	perforated	r-67
2-Jul-98	3	capture	31.5	119	nonperforated	r-94
3-Jul-98	2	recapture	30.0	105	perforated	r-67
7-Jul-98	2	recapture	31.0	105	perforated	r-67
8-Jul-98	2	recapture	31.0	105	perforated	r-67
9-Jul-98	2	recapture	31.0	105	perforated	r-67
10-Jul-98	1	recapture	31.0	105	perforated	r-67
14-Jul-98	1	capture	28.0	108	perforated	r-109
14-Jul-98	4	capture	34.0	122	abdominal	b-122
14-Jul-98	3	recapture	34.0	119	nonperforated	r-94
17-Jul-98	2	recapture	31.0	105	perforated	r-67
17-Jul-98	3	recapture	34.0	113	perforated	r-97
21-Jul-98	4	recapture	33.0	122	scrotal	b-122
23-Jul-98	3	recapture	37.0	119	nonperforated	r-94
29-Jul-98	3	recapture	38.5	119	nonperforated	r-94
4-Aug-98	3	recapture[b]	40.0	119	n/a[c]	r-94
12-Aug-98	2	capture	38.0	121	scrotal	b-141
18-Aug-98	3	recapture	10.0	85	scrotal	b-143
19-Aug-98	2	capture	33.0	128	scrotal	b-149
20-Aug-98	3	capture[b]	30.0	110	n/a[c]	n/a[c]

TABLE A13. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
25-Aug-98	3	recapture	34.5	128	scrotal	b-149
26-Aug-98	3	recapture	35.0	128	scrotal	b-149
27-Aug-98	3	recapture	35.0	128	scrotal	b-149
28-Aug-98	3	recapture	35.0	128	scrotal	b-149
1-Sep-98	2	capture	20.0	95	perforated	r-139
13-Oct-98	1	capture	23.0	110	nonperforated	r-154

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A14. - Plot 14 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
21-May-98	4	capture	39.0	106	scrotal	b-54
2-Jun-98	4	capture	31.0	105	scrotal	b-67
4-Jun-98	4	capture	43.0	120	perforated	r-66
5-Jun-98	3	recapture	43.0	120	perforated	r-66
9-Jun-98	1	capture[b]	18.5	85	n/a[c]	n/a[c]
9-Jun-98	1	capture[b]	16.0	88	n/a[c]	n/a[c]
17-Jun-98	2	recapture	44.0	120	perforated	r-66
24-Jun-98	2	capture	37.5	119	perforated	r-81
22-Jul-98	2	recapture	29.5	115	scrotal	b-97
11-Aug-98	4	recapture	37.5	119	perforated	r-81
18-Aug-98	3	capture	31.0	126	scrotal	b-147
8-Sep-98	4	capture[b]	19.0	78	n/a[c]	n/a[c]
22-Sep-98	4	capture	21.0	89	scrotal	b-167
6-Oct-98	1	capture	23.0	113	nonperforated	r-149
6-Oct-98	3	capture	25.0	105	abdominal	b-178
6-Oct-98	4	capture	20.0	115	abdominal	b-179
7-Oct-98	1	capture	34.5	115	nonperforated	r-150
8-Oct-98	4	capture	23.0	93	nonperforated	r-152
13-Oct-98	1	capture	44.0	131	nonperforated	r-155

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A15. - Plot 5 collection data for the meadow vole, *M. pennsylvanicus* , at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
26-May-98	2	capture	43.0	107	scrotal	b-60
28-May-98	3	capture	28.0	105	nonperforated	r-58
2-Jun-98	3	capture	31.0	96	perforated	r-59
2-Jun-98	2	capture	39.0	107	perforated	r-60
5-Jun-98	3	recapture	36.0	107	perforated	r-60
9-Jun-98	2	recapture	33.0	105	nonperforated	r-58
10-Jun-98	1	recapture	35.0	105	perforated	r-58
11-Jun-98	2	recapture	36.5	107	perforated	r-60
19-Jun-98	1	recapture	37.0	105	perforated	r-58
23-Jun-98	4	recapture	38.0	105	perforated	r-58
25-Jun-98	2	capture	25.5	108	nonperforated	r-85
30-Jun-98	2	recapture	37.0	105	perforated	r-58
15-Jul-98	3	recapture	32.0	105	nonperforated	r-58
16-Jul-98	4	capture	25.5	103	nonperforated	r-113
24-Jul-98	1	recapture	25.5	103	nonperforated	r-113
28-Jul-98	1	recapture	25.5	103	nonperforated	r-113
18-Aug-98	2	recapture	36.0	108	perforated	r-85
19-Aug-98	3	recapture	38.0	108	perforated	r-85
9-Sep-98	1	recapture	30.0	103	perforated	r-113
22-Sep-98	2	capture	44.0	131	perforated	r-146

[a] b = blue/male and r = red/female

[b] dead

[c] not available

TABLE A16. - Plot 16 collection data for the meadow vole, *M. pennsylvanicus*, at the BFI/CLD Landfill, from May 19, 1998 to October 23, 1998.

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
29-May-98	2	recapture	28.0	103	nonperforated	r-58
9-Jun-98	1	capture	33.0	102	perforated	r-71
11-Jun-98	3	capture[b]	24.0	95	n/a[c]	n/a[c]
11-Jun-98	4	capture	42.5	113	scrotal	b-84
16-Jun-98	1	capture	27.0	100	abdominal	b-90
17-Jun-98	1	capture	37.0	113	nonperforated	r-79
18-Jun-98	1	recapture	28.0	100	abdominal	b-90
14-Jul-98	2	capture	42.0	119	perforated	r-112
28-Jul-98	1	recapture	42.0	119	perforated	r-112
29-Jul-98	4	capture	22.0	108	nonperforated	r-122
31-Jul-98	1	recapture	42.0	119	perforated	r-112
31-Jul-98	3	capture	29.0	113	nonperforated	r-124
5-Aug-98	3	capture[b]	19.0	78	n/a[c]	n/a[c]
5-Aug-98	1	recapture	42.0	119	perforated	r-112
6-Aug-98	1	recapture	42.0	119	perforated	r-112
11-Aug-98	1	capture	38.5	125	scrotal	b-140
13-Aug-98	1	capture	29.0	113	nonperforated	r-124
18-Aug-98	1	recapture	29.0	113	nonperforated	r-128
19-Aug-98	4	recapture	25.0	108	nonperforated	r-122
26-Aug-98	1	recapture	31.0	113	nonperforated	r-124
1-Sep-98	3	recapture	30.0	108	nonperforated	r-85
4-Sep-98	3	recapture	33.0	108	nonperforated	r-85
8-Sep-98	1	recapture	33.0	113	nonperforated	r-124
10-Sep-98	4	recapture	34.0	113	nonperforated	r-124
7-Oct-98	1	capture	22.0	108	nonperforated	r-151
7-Oct-98	2	capture	24.0	115	abdominal	b-180

TABLE A16. - continued

Date	Trap	Capture/Recapture	Weight (g)	Length (mm)	Breeding Condition	Color[a]/Band Number
13-Oct-98	4	capture	28.0	131	abdominal	b-183
15-Oct-98	1	capture	33.0	100	nonperforated	r-160
16-Oct-98	3	recapture	28.0	131	abdominal	b-183
23-Oct-98	1	capture[b]	23.0	96	n/a[c]	n/a[c]
23-Oct-98	2	capture[b]	20.0	87	n/a[c]	n/a[c]

[a] b = blue/male and r = red/female

[b] dead

[c] not available

Figure - B1

Map of area covered by plant species on Plot 1 at the BFI/CLD Landfill, on July 25, 1998.

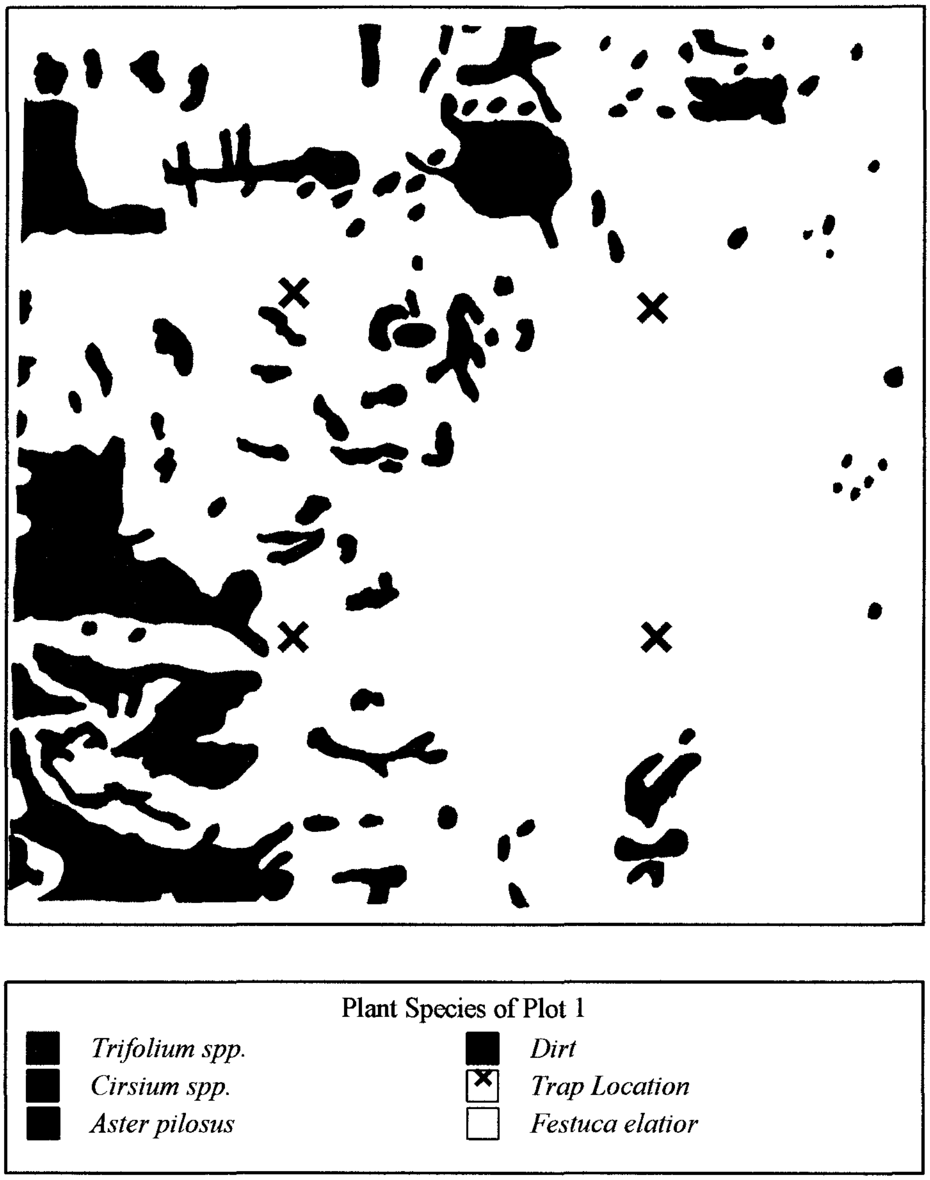
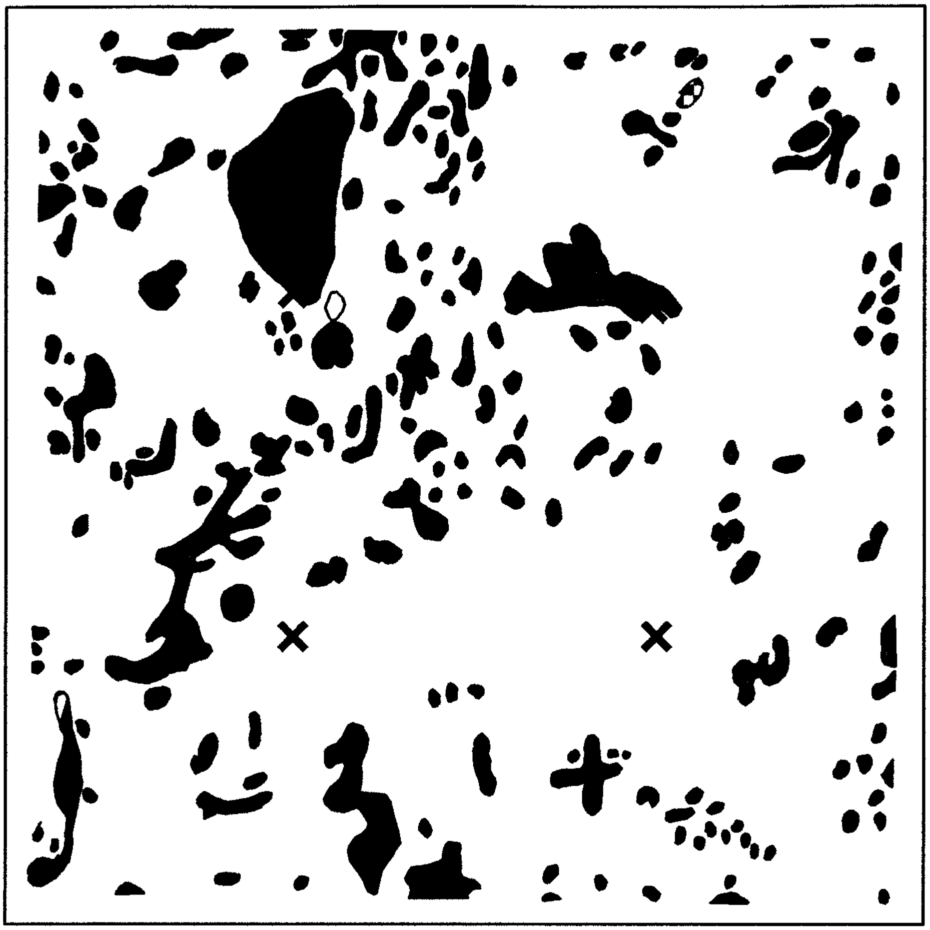


Figure - B2

Map of area covered by plant species on Plot 2 at the BFI/CLD Landfill, on July 25, 1998.



Plant Species of Plot 2

- ■ *Trifolium spp.*
- ■ *Cirsium spp.*
- ■ *Aster pilosus*
- ■ *Verbascum blattaria*
- ■ *Erigeron annuus*
- □ *Solidago altissima*
- □ *Festuca elatior*
- ▨ *Daucus carota*
- ■ *Ambrosia artemisiifolia*
- ☒ *Trap Location*

Figure - B3

Map of area covered by plant species on Plot 3 at the BFI/CLD Landfill, on July 25, 1998.

Figure - B4

Map of area covered by plant species on Plot 4 at the BFI/CLD Landfill, on July 25, 1998.

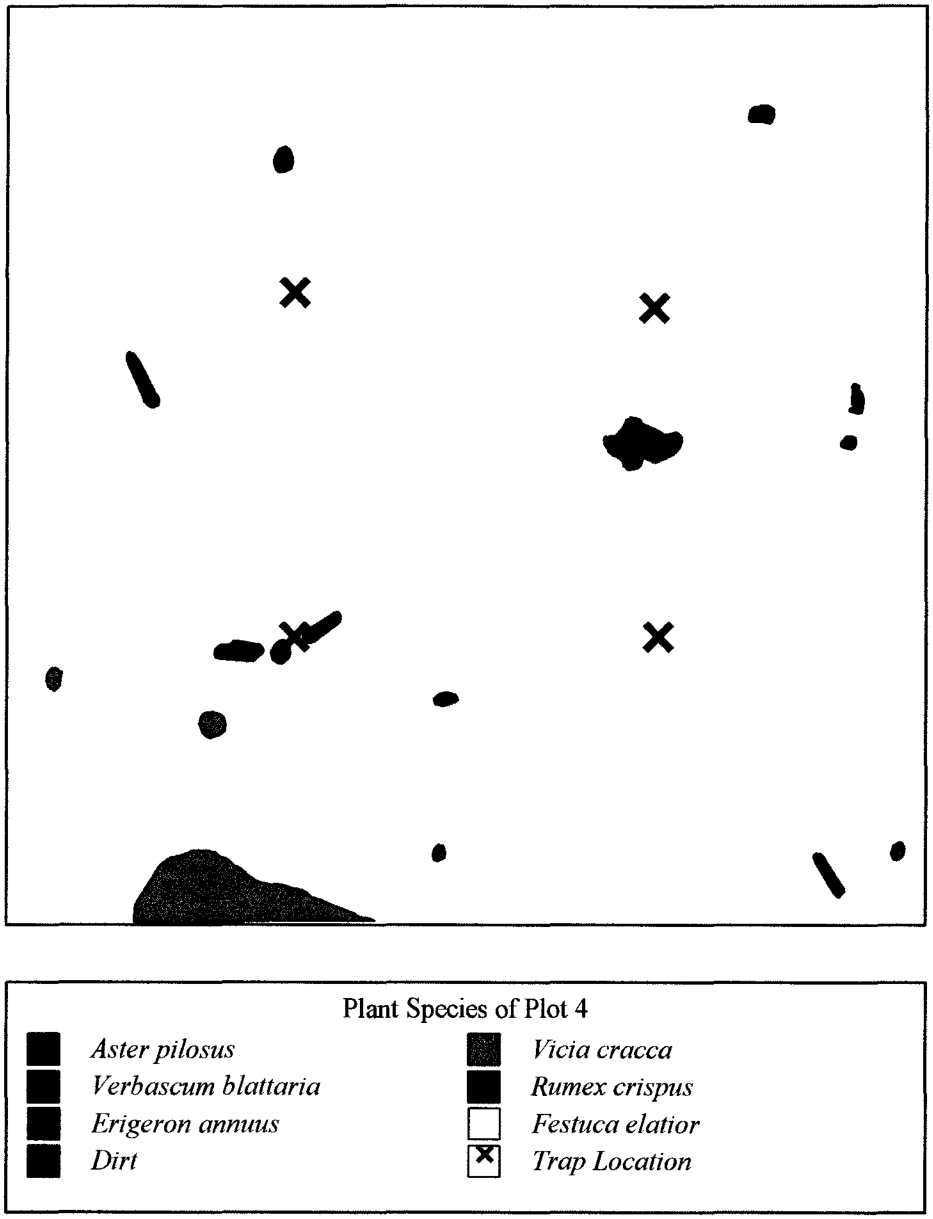


Figure - B5

Map of area covered by plant species on Plot 5 at the BFI/CLD Landfill, on July 25, 1998.

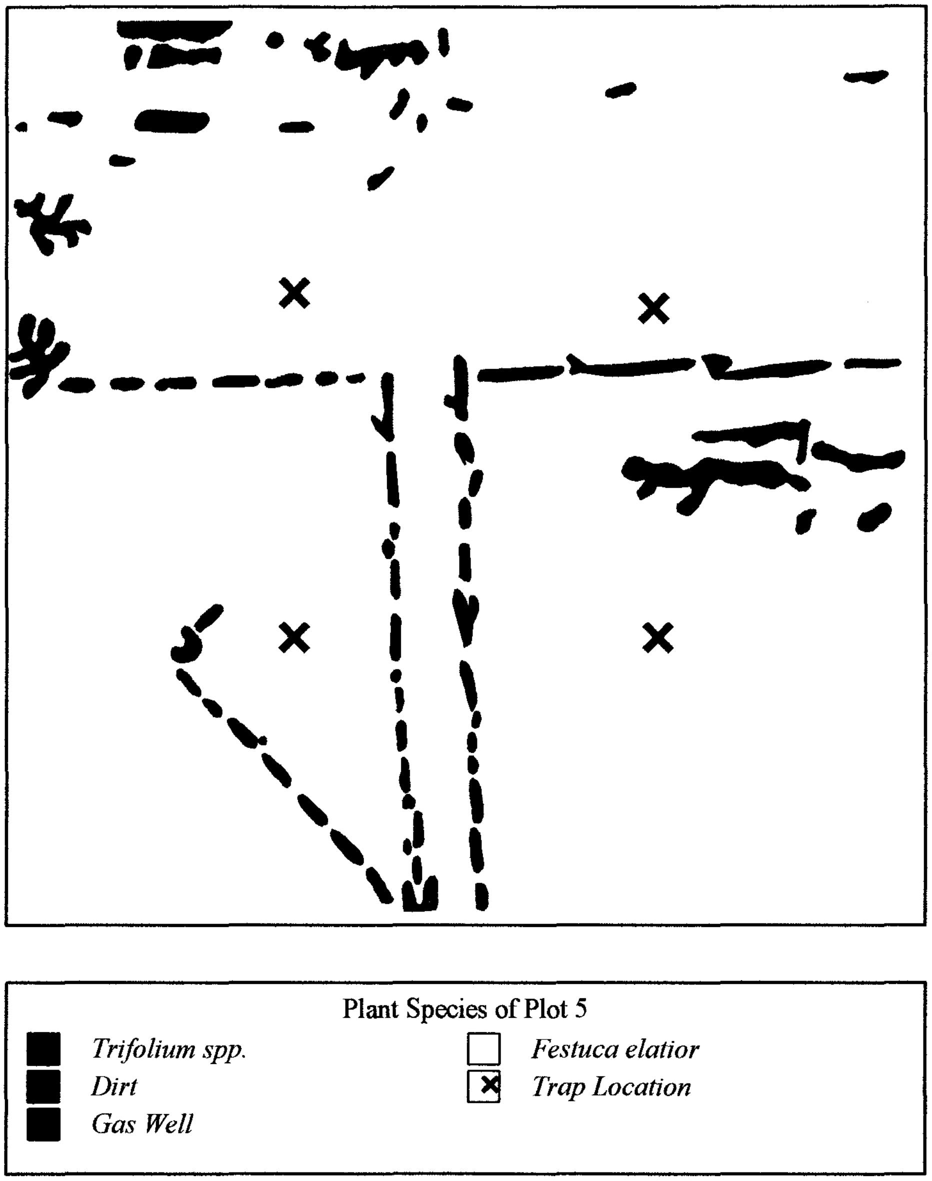


Figure - B6

Map of area covered by plant species on Plot 6 at the BFI/CLD Landfill, on July 25, 1998.

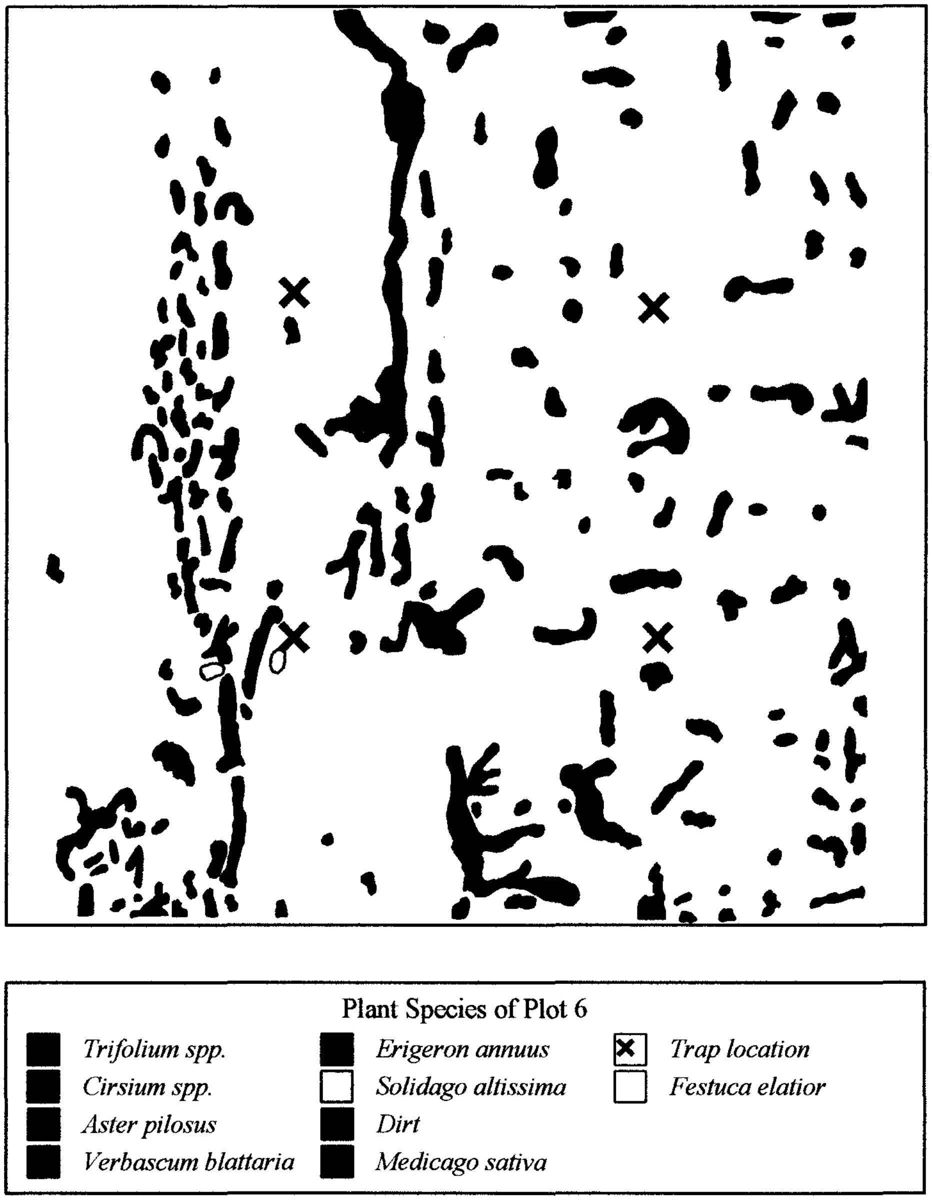


Figure - B7

Map of area covered by plant species on Plot 7 at the BFI/CLD Landfill, on July 25, 1998.

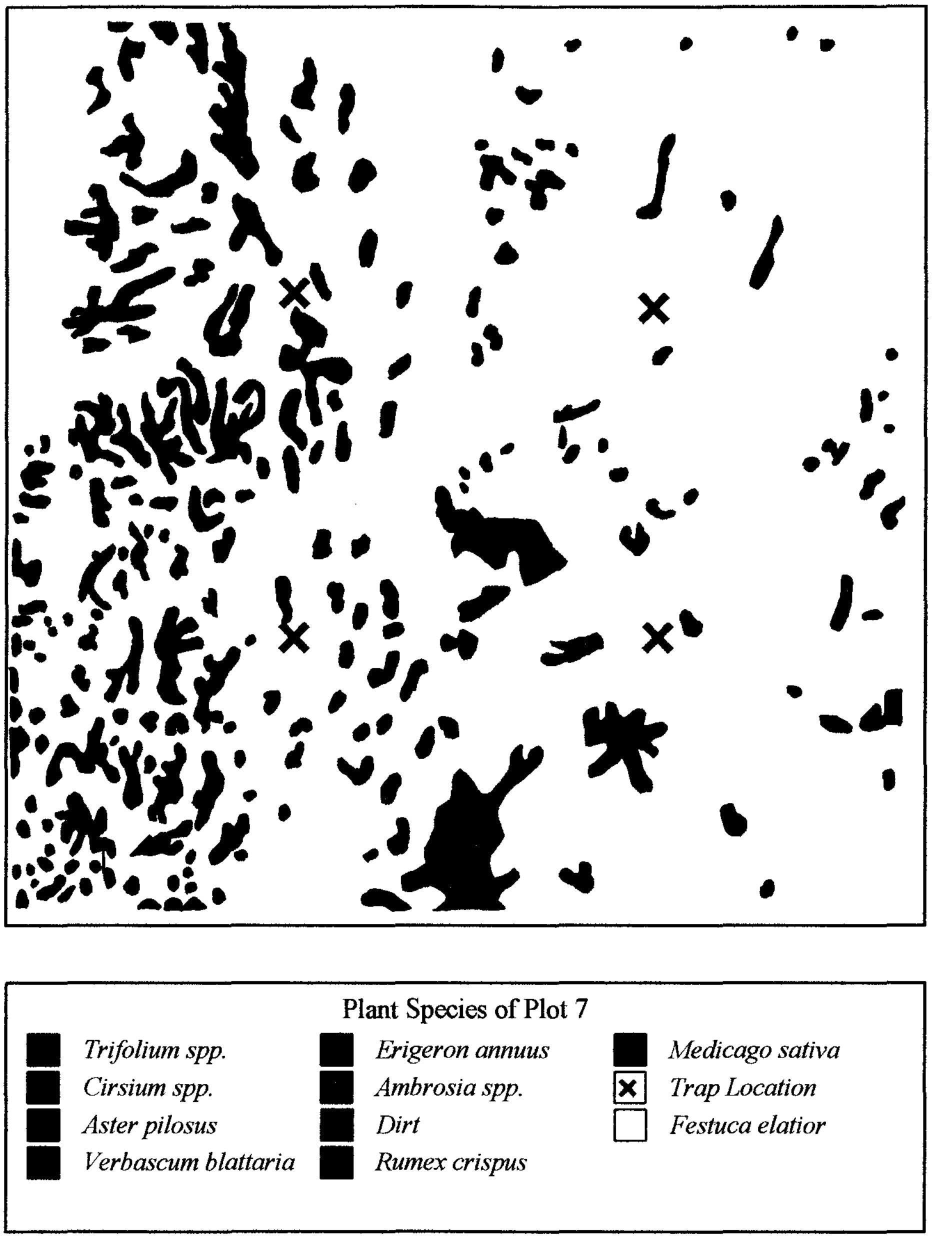


Figure - B8

Map of area covered by plant species on Plot 8 at the BFI/CLD Landfill, on July 25, 1998.

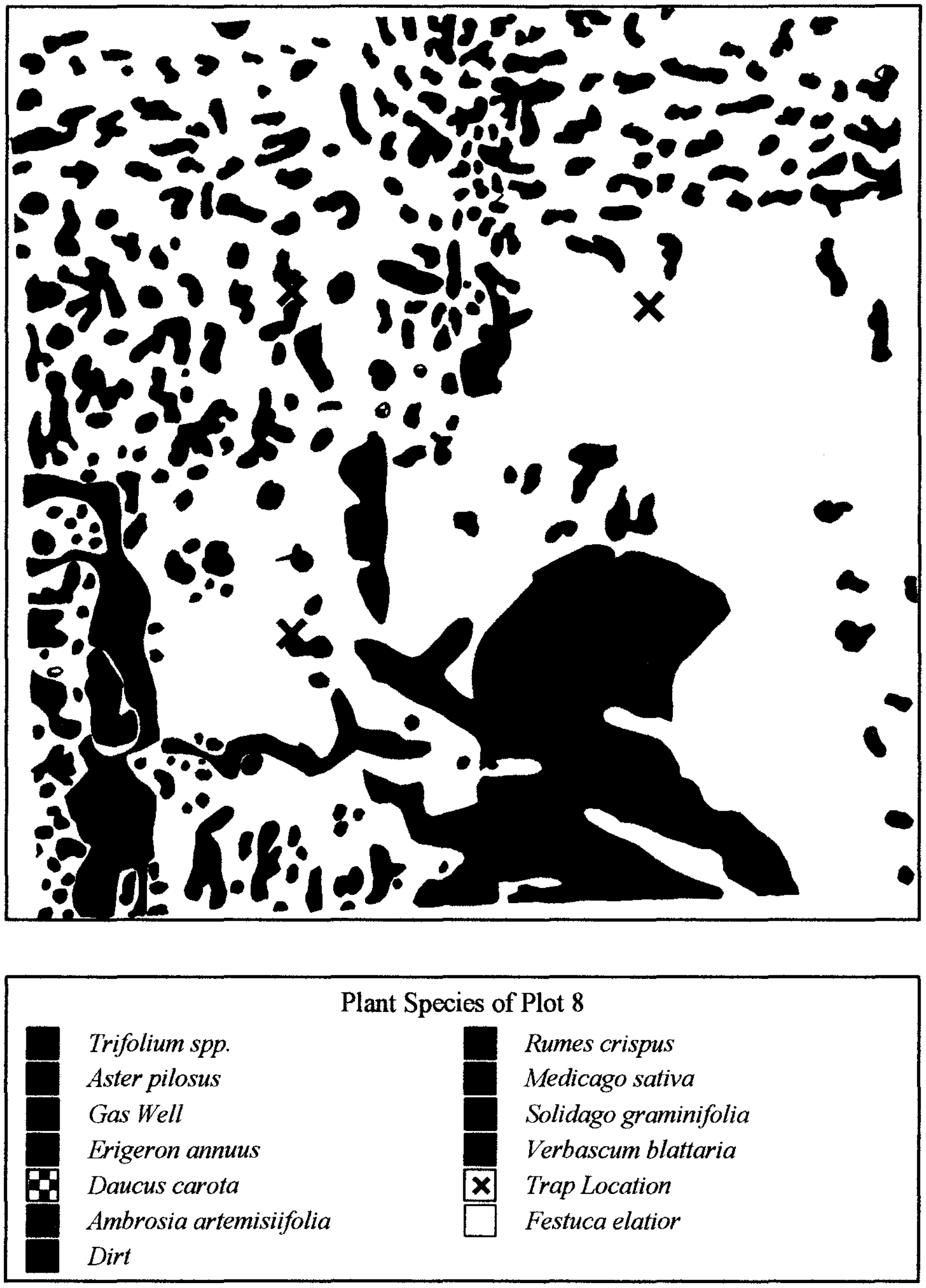
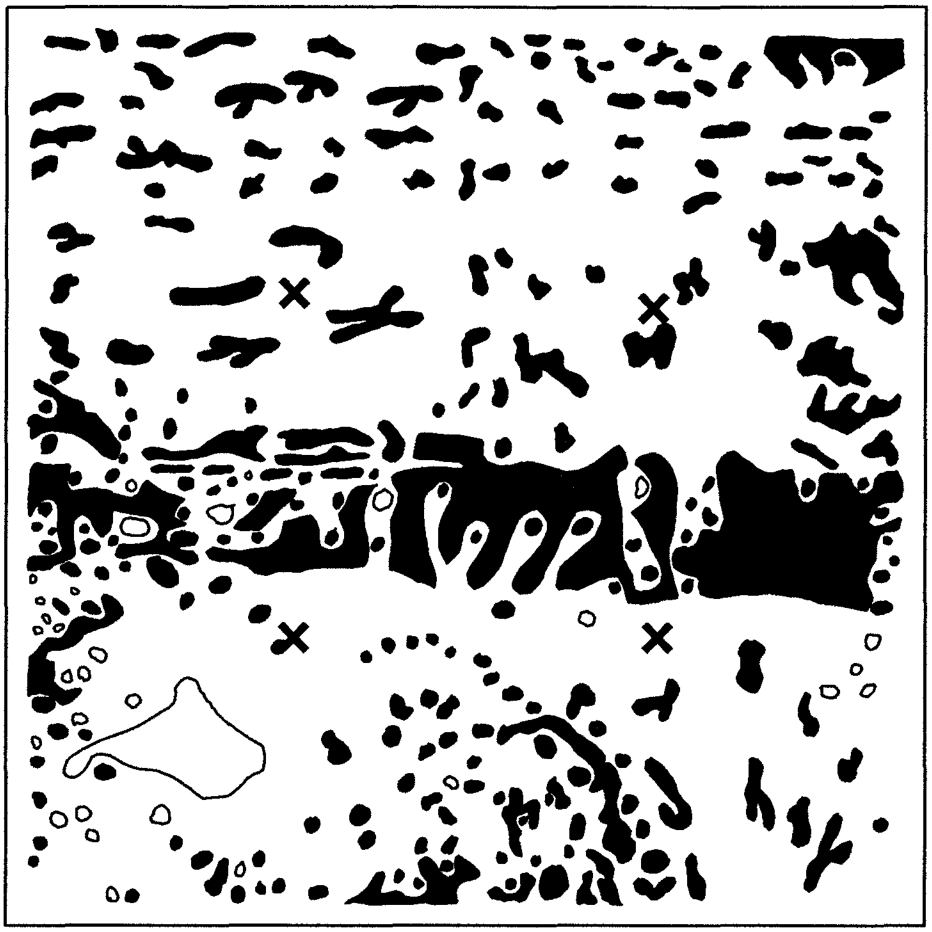


Figure - B9

Map of area covered by plant species on Plot 9 at the BFI/CLD Landfill, on July 25, 1998.



Plant Species of Plot 9

■ *Trifolium spp.*
■ *Cirsium spp.*
■ *Aster pilosus*
■ *Erigeron annuus*
■ *Dirt*
☐ *Solidago altissimsa*
■ *Ambrosia artemisiifolia*
■ *S. graminfolia*
■ *Medicago sativa*
☐ *Festuca elatior*
☒ *Trap Location*

Figure - B10

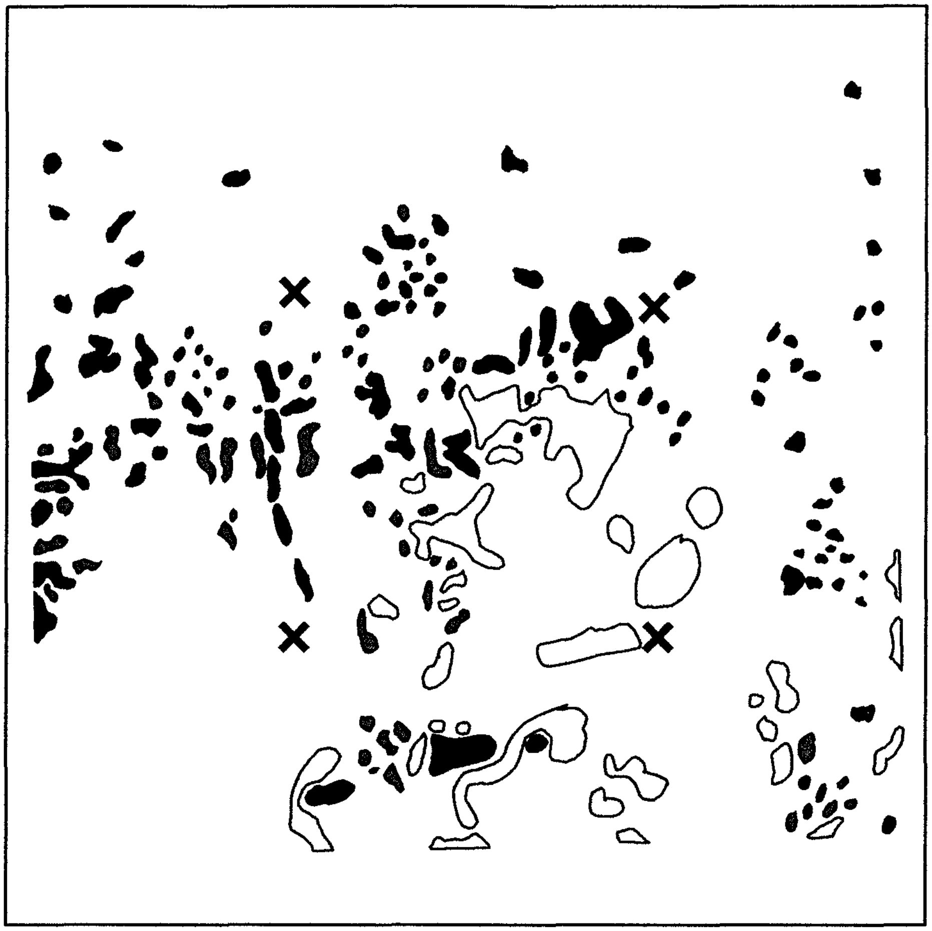
Map of area covered by plant species on Plot 10 at the BFI/CLD Landfill, on July 25, 1998.

Plant Species of Plot 10

■ *Trifolium spp.*
■ *Cirsium spp.*
■ *Erigeron annuus*
■ *Solidago graminifolia*
■ *Dirt*
■ *Rumex crispus*
■ *Medicago sativa*
☒ *Trap Location*
☐ *Festuca elatior*

Figure - B11

Map of area covered by plant species on Plot 11 at the BFI/CLD Landfill, on July 25, 1998.



Plant Species of Plot 11

■ *Trifolium spp.*
■ *Cirsium spp.*
▨ *Vicia cracca*
■ *Rumex crispus*
□ *Setaria glauca*
■ *Rock*
☒ *Trap Location*
□ *Festuca elatior*

Figure - B12

Map of area covered by plant species on Plot 12 at the BFI/CLD Landfill, on July 25, 1998.

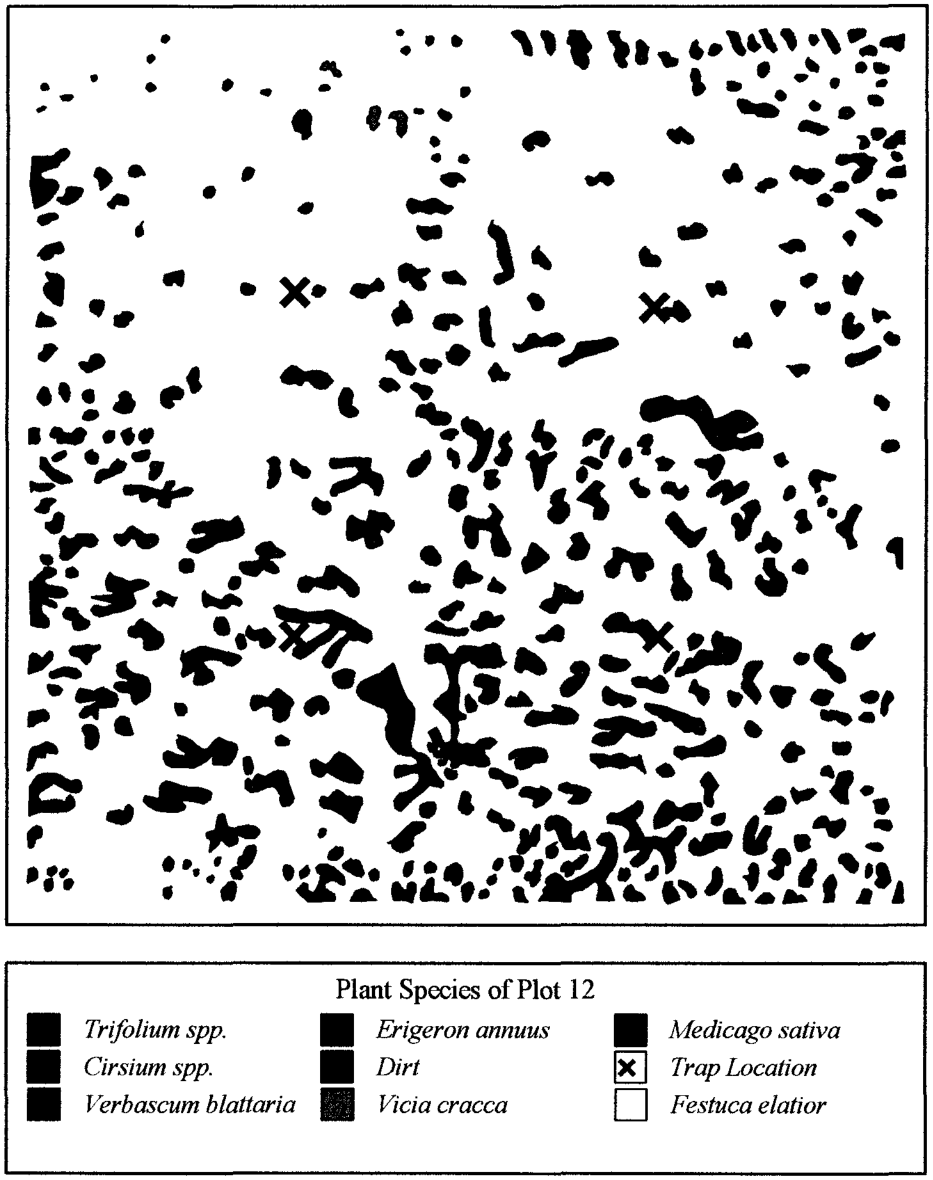


Figure - B13

Map of area covered by plant species on Plot 13 at the BFI/CLD Landfill, on July 25, 1998.

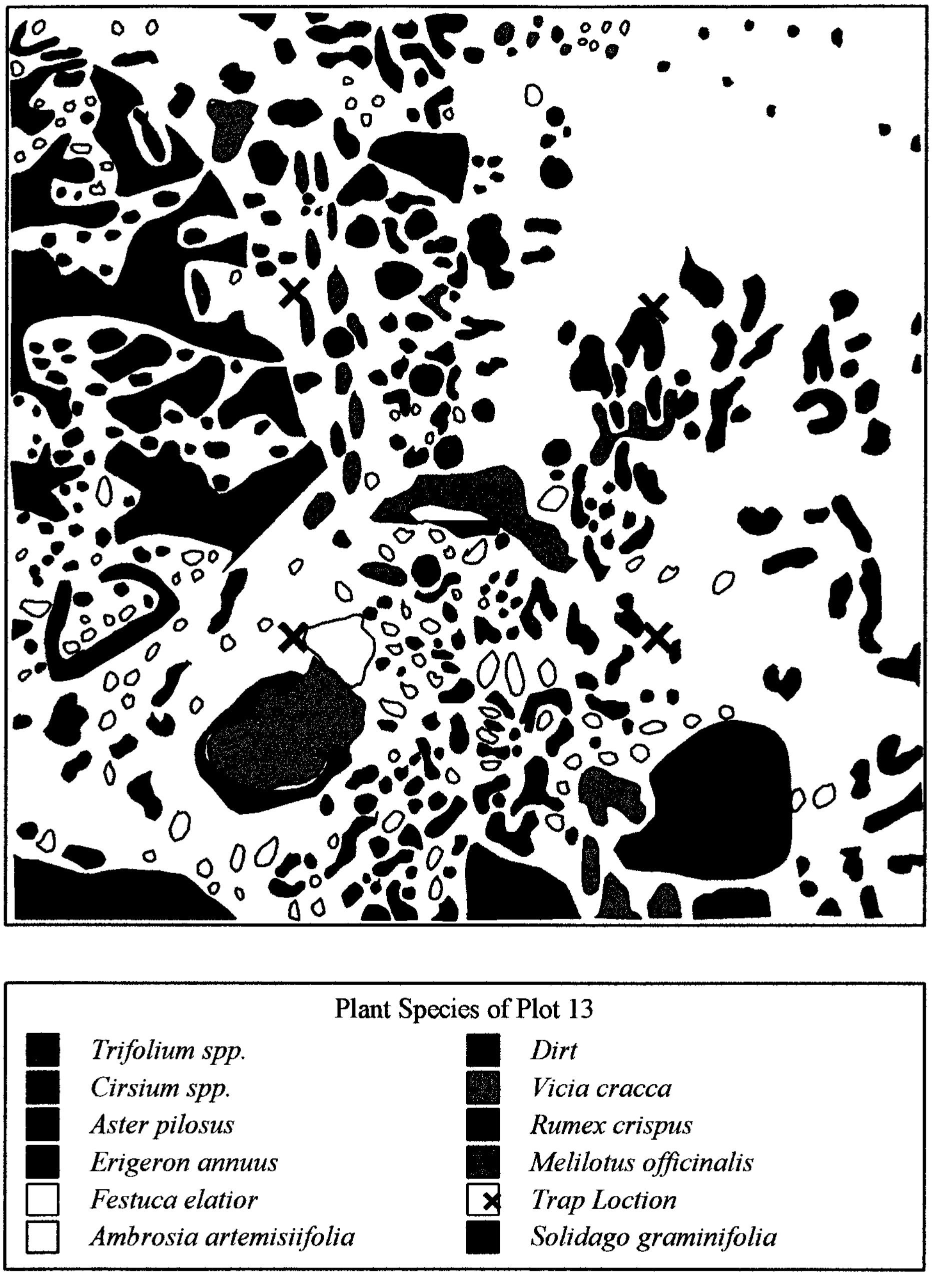
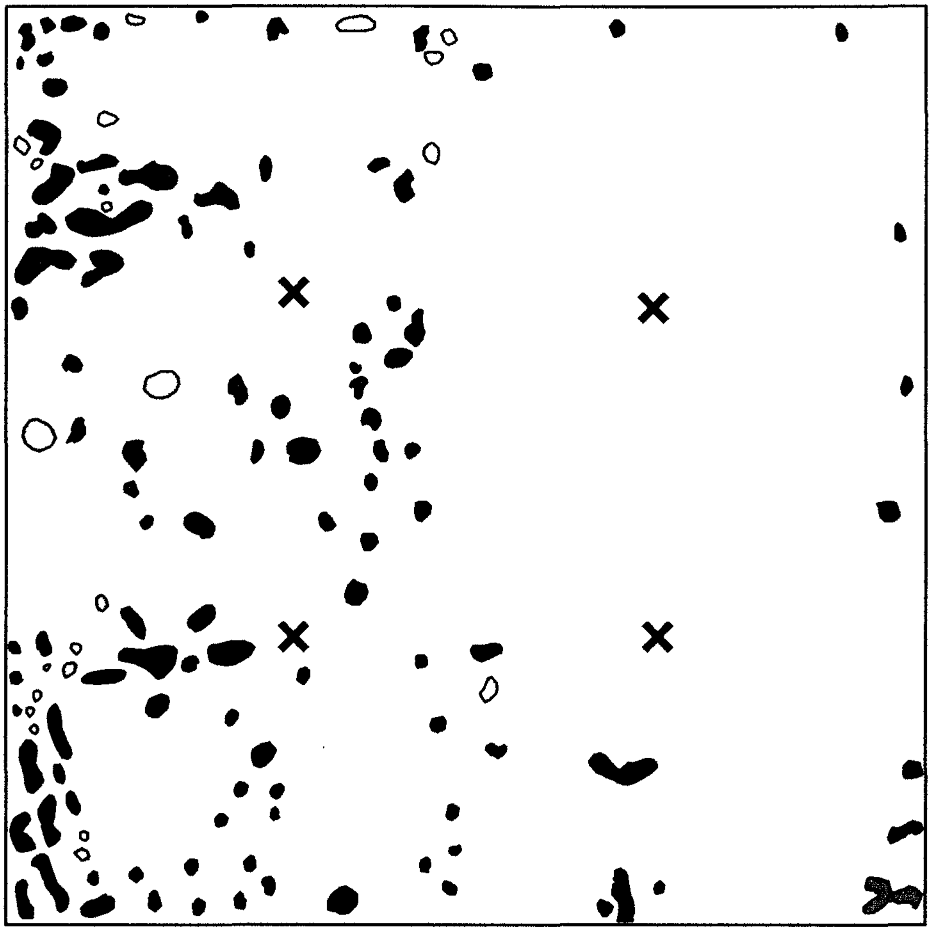


Figure - B14

Map of area covered by plant species on Plot 14 at the BFI/CLD Landfill, on July 25, 1998.



Plant Species of Plot 14

■ *Trifolium spp.*
■ *Cirsium spp.*
■ *Erigeron annuus*
□ *Conyza canadensis*
■ *Solidago graminifolia*
□ *S. altissima*
■ *Dirt*
▨ *Vicia cracca*
☒ *Trap Location*
□ *Festuca elatior*

Figure - B15

Map of area covered by plant species on Plot 15 at the BFI/CLD Landfill, on July 25, 1998.

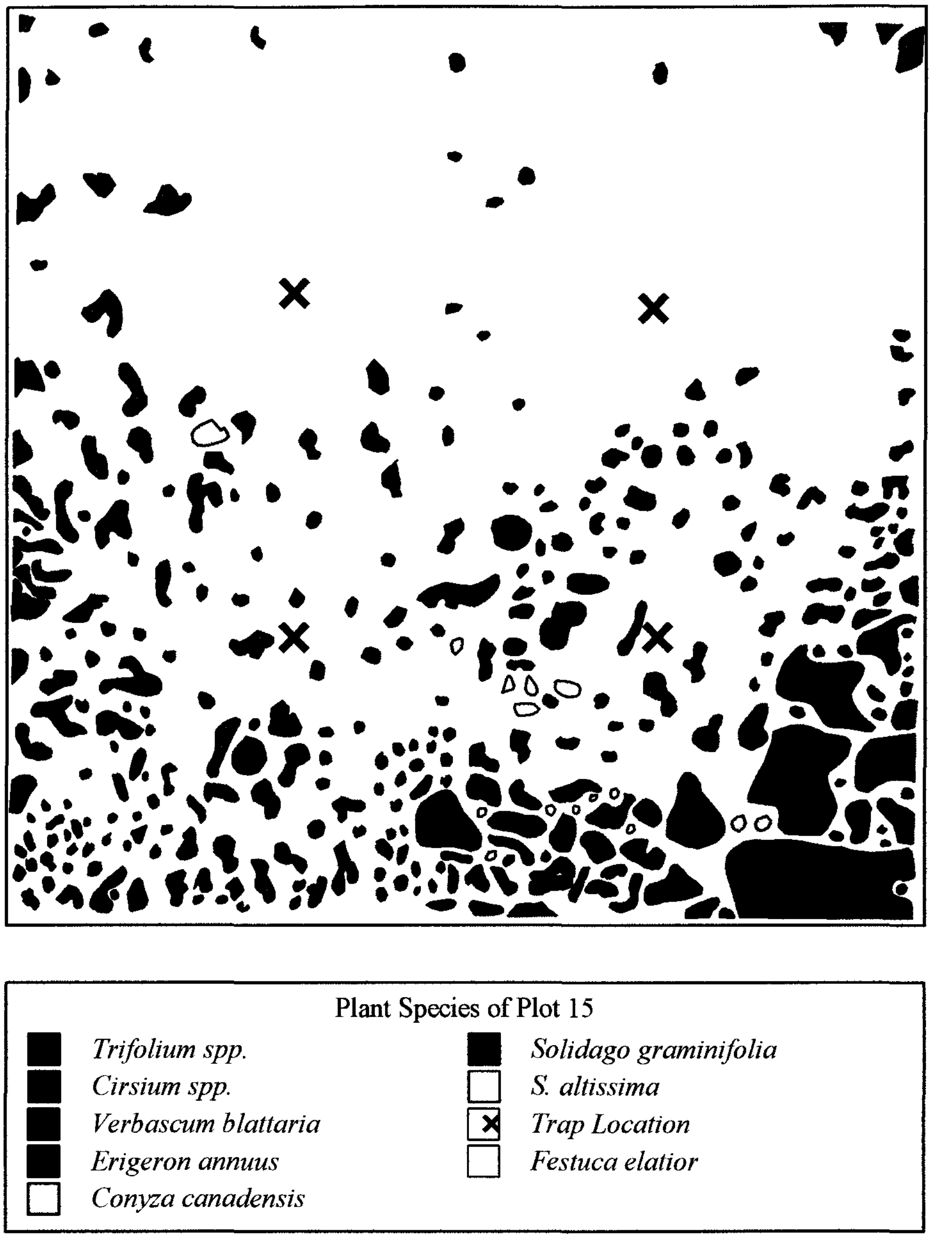
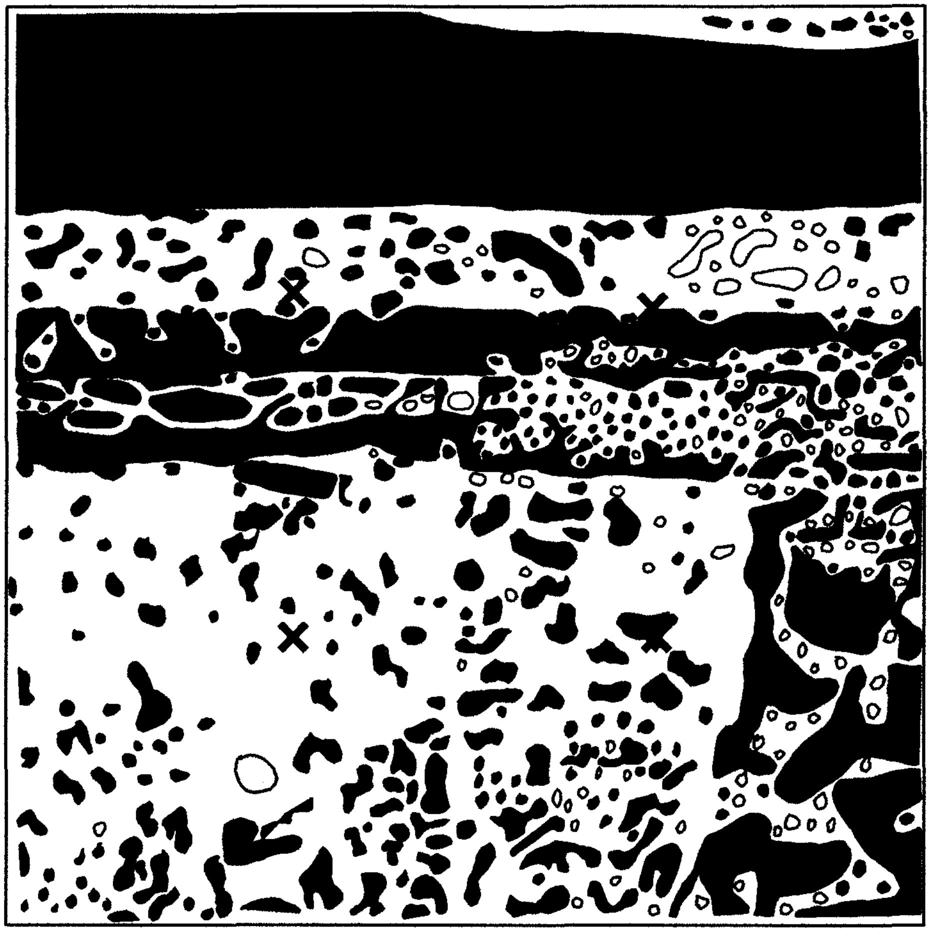


Figure - B16

Map of area covered by plant species on Plot 16 at the BFI/CLD Landfill, on July 25, 1998.



Plant Species of Plot 16

■ *Trifolium spp.*
■ *Cirsium spp.*
■ *Aster pilosus*
■ *Erigeron annuus*
☐ *Conyza canadensis*
■ *Solidago graminifolia*
☐ *S. altissima*
■ *Ambrosia artemisiifolia*
■ *Dirt*
☐ *Festuca elatior*
☒ *Trap Location*