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CONTROL OF VEGETATION DAMAGE BY SMALL RODENTS ON RECLAIMED LAND

Paper Presented
by

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INTRODUCTION

Land disturbed during the mining of the oil sands of northeastern Alberta will require extensive programs of reclamation and revegetation. The long term reclamation objective is to establish a self-sustaining plant community of similar productivity to that of the predisturbed state (Fedkenheuer 1979). Typically a dense ground cover of agronomic grasses and legumes has first been established to stabilize the sand dykes. Tree and shrub planting programs have then been implemented on some reclamation sites once a dense ground cover has been established. The tree and shrub planting program is considered one means of accelerating the establishment of an early serai forest community.

The afforestation programs have been only moderately successful, however, because of the high mortality of some species of young trees (Seiner and Thompson 1977; Fedkenheuer 1979; Shopik 1980). Sapling death has been attributed to insect defoliation, to damage during planting, to disease, to nutrient and moisture deficiencies, to competition with ground cover (e.g., grasses and legumes), and to small rodent damage (Radvanyi 1978; Sherstabetoff et al. 1978; Fedkenheuer 1979; Shopik 1980). Damage by small rodents, particularly *Microtus pennsylvanicus* (the meadow vole) is believed to be one of the major causes of sapling death.

A study of the small rodent problem in afforestation sites was begun by LGL Limited in 1977. First, an extensive review of the literature on small mammal damage to plants and methods of control was completed (Green 1978). Field studies of small rodents, small rodent damage, vegetation cover, and tree and shrub performance in reclamation areas on the Suncor lease were begun in 1978 (Green 1980b, 1980c). Similar field studies of small rodent populations and small rodent damage in natural forest and shrub communities in the Athabasca Basin were conducted during 1978 and 1979 (Green 1980c).

METHODS

STUDY PLOTS

Six reclamation study areas were established on the Suncor Inc. lease during 1978 (Figure 1). All six areas were on Slope 6 (305 m to 320 m level) of the Suncor Inc. Tar Island dyke. Construction of Slope 6 was completed in the fall of 1977 and preparation for seeding was begun in the spring of 1978. Details of preparation and seeding are summarized by Green (1980a). All study plots were of similar design. Each consisted of a 1.13 ha (250 m x 45 m) vegetation treatment area within which was located a 0.76 ha small rodent live-trapping grid (Figure 2).

Three methods of controlling small mammal damage that were recommended by Green (1978) were initially evaluated in this study—the application of an animal repellent to seedlings, the provision of supplementary food supplies/ and a reduction of ground cover. The experimental plots included a control plot, four single treatment plots, and one plot that combined three of the treatments. However, beginning in 1980, emphasis was placed on an evaluation of ground cover manipulation as a method of control. The repellent and supplementary food treatments subsequently were discontinued; a discussion of these latter treatments is included in Green (1980a).

Two basic types of ground covers were assessed in this study. The first treatment involved the hydroseeded application of agronomic grasses such as creeping red fescue, brome grass, crested wheatgrass, and pubescent wheatgrass and of legumes such as alfalfa, common clover, alsike clover, and sanfoin. This seed mix was applied to the entire treatment area of the Supplementary Food, Repellent, and Control study areas. On the Stripping Trial study area, however, only a horizontal 15 m wide strip along the top and bottom of each study area was hydroseeded, such that a central 15 m wide strip was left unvegetated. The second treatment initially involved only revegetation by natural means; following preparation of the soil in 1978, no amendments or seed were applied to either the Reduced Cover or Combined Treatment study areas. In summer 1980, however, a seed mix of *Agropyron violacium, Festuca saximontana,* and *Poa palustris* was sparsely hydroseeded on these two sites.

During May and early June of 1979, Suncor Inc. planted approximately 1,200 tree and shrub seedlings on each experimental plot. Twelve

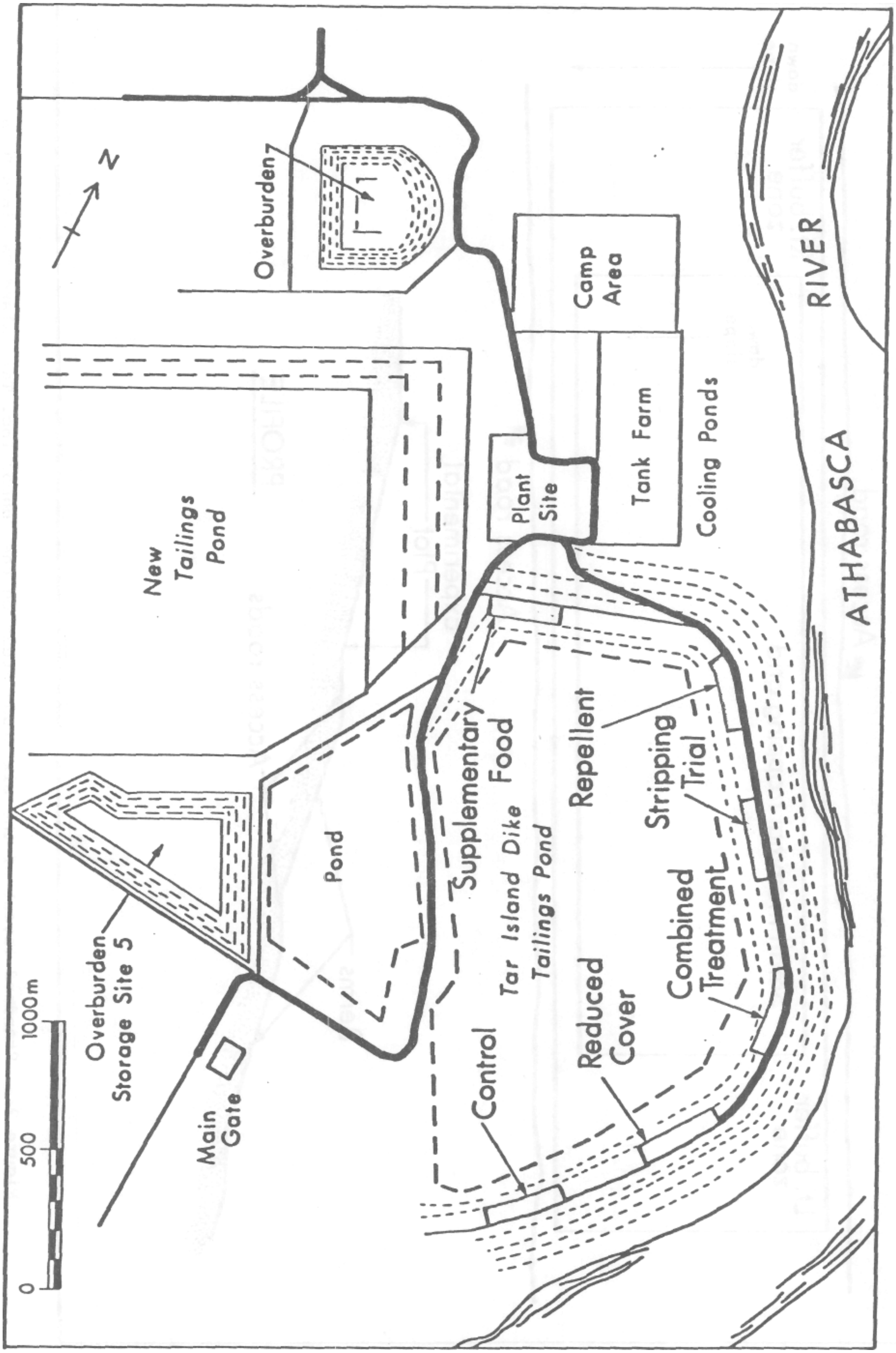

Figure 1. Location of the six study areas on the Suncor Inc. reclamation sites

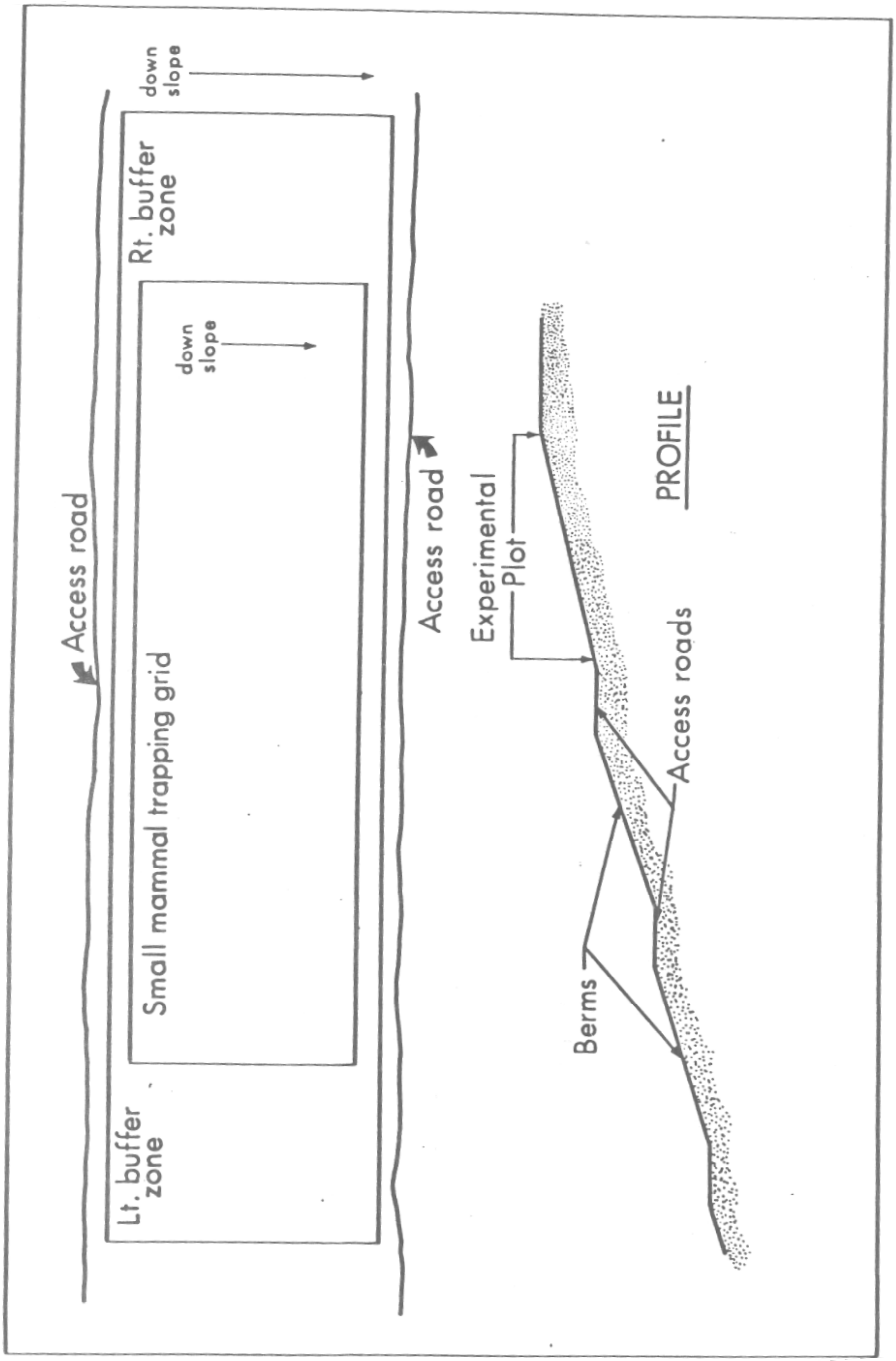

Figure 2. Standard layout of the six study areas on the Suncor Inc. Tar Island Tailings Dike

species of trees and shrubs were planted at 2.1 m spacings in blocks consisting of double rows of each species that varied from 14 to 20 seedlings long. Species planted were dogwood. Laurel willow, Siberian larch, Basford willow, caragana, Northwest poplar, acute willow, white spruce, Scots pine, chokecherry, Walker poplar, and Russian olive. Three blocks of seedlings were established on each study plot. The tree and shrub planting blocks on the Stripping Trial differed from the remaining five study areas in that planting blocks of paper birch, trembling aspen, alder, and Siberian larch at 1 m spacings also were established within the central unvegetated *area.*

VEGETATION ANALYSES

Vegetation analyses were conducted by LGL Limited on the six study plots during late June of 1979, 1980 and 1981. Estimates were made of the density, species composition, and vertical distribution of vegetation cover. Within each study area, information was obtained from 30 random sampling locations during 1979 and 50 random sampling locations during 1980 and 1981. The percent ground cover of each plant species present within a 1 m^2 quadrat was estimated using a Braun-Blanquet cover scale (Kershaw 1966) (Figure 3). Vertical composition of vegetation was estimated following Nudds (1977). Tree and shrub densities and amounts of small rodent damage within a 16 m^2 quadrat were estimated.

Enumeration and evaluation of all seedlings were conducted by Suncor Inc. during June and August of 1980 and 1981. Tree and shrub assessments included a measure of plant height, condition, and rodent damage. Survival rates also were determined for each species.

SMALL MAMMAL TRAPPING TECHNIQUES

Small mammal live-trapping techniques were similar to those described by Krebs et al. (1969). The trapping grid on each study area consisted of a 5 x 20 grid of trapping stations at 10 m intervals. One live trap was placed within a 1.5 m radius of each trap station. Each study area was live-trapped for three days, once every three weeks from late April/ early May to late November during 1979 to 1981. During 1978, all study areas were live-trapped only during September and October.

All new animals were ear-tagged with a numbered fingerling fish tag when first captured. After tagging or when tagged animals were captured

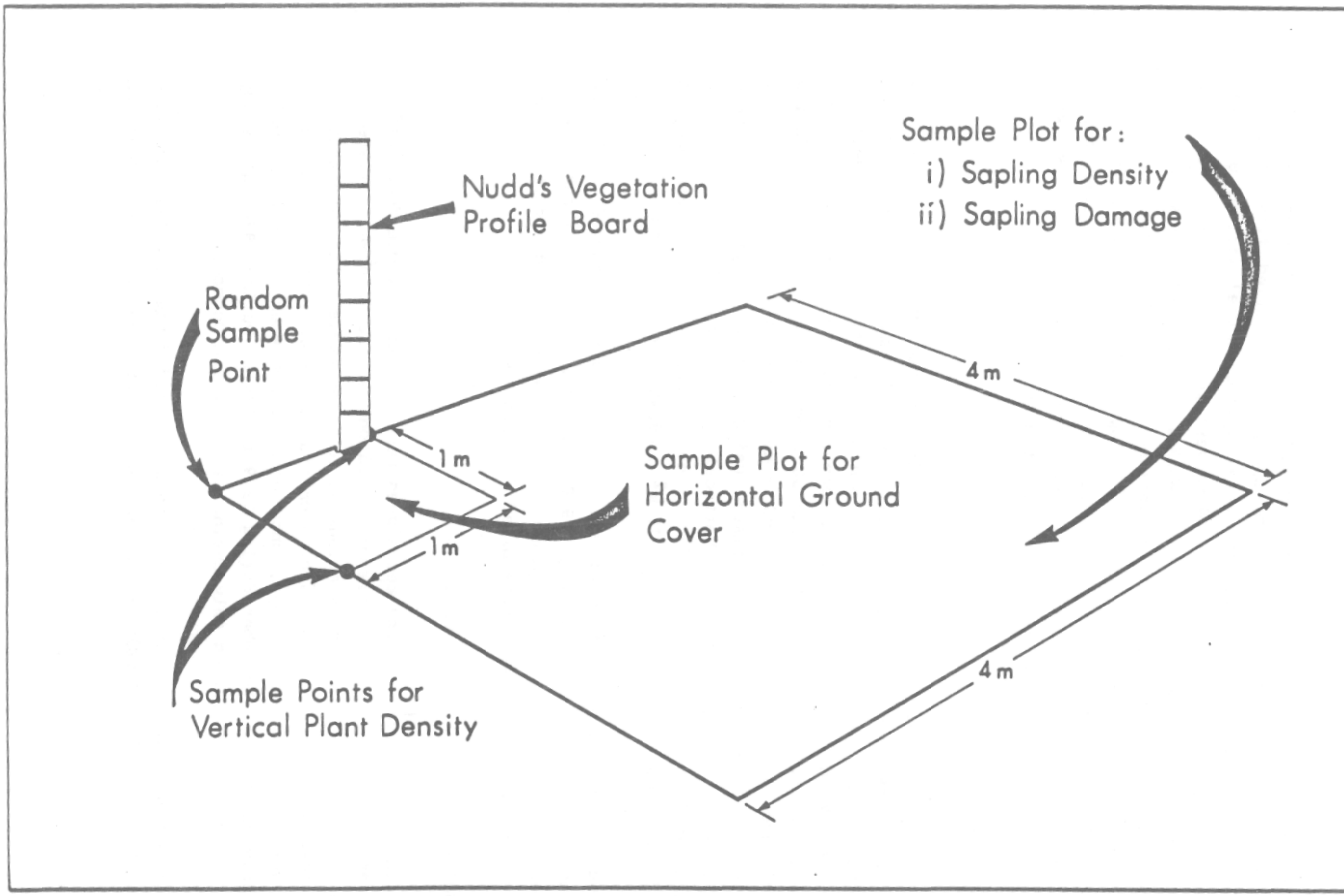

Figure 3. The configuration of the vegetation sampling quadrats. (The 16 m^2 quadrat for sapling densities and damage, the 1 m^2 quadrat for ground cover densities, and the vertical cover sample points are shown.)

during subsequent trapping periods, the tag number, species, trap location, sex, breeding condition, weight, body length, an estimate of age, number of wounds on the posterior portion of the body, and number of sub-dermal parasites *(Cuterebra* spp.) were recorded.

RESULTS

SMALL RODENT POPULATIONS

During this study, four species of small rodent, *Clethrionomys gapperi, Microtus pennsylvanicus, Peromyscus maniculatus,* and Zapus *hudsonicus,* were captured on the six study areas. In addition, two species of shrews, *Sorex cinereus* and *Sorex obscurus,* and two species of mustelid, *Mustela erminea* and *Mustela nival is,* were captured. Woodchucks *(Marmota monax),* snowshoe hares: *(Lepus atnericanus),* and red fox *(Vulpes vulpes)* were observed but not captured on the reclamation sites. Because only *C. gapperi, M. pennsylvanicus,* and P. *maniculatus* were captured regularly and in moderate to high numbers, demographic analyses were restricted to these three species.

Population changes of small rodents were assessed using the minimum number known to be alive (MNA) (Chitty and Phipps 1966) as a biased estimate of population size. Comparisons of MNA estimates of C. *gapperi, M. pennsylvanicus,* and P. maniculatus on each of the six study areas (Figures 4 to 6) indicate that habitat use and seasonal population trends differed among study areas and among species.

Microtus pennsylvanicus was the most abundant species of small rodent on most study areas. Numbers were consistently highest on the Supplementary Food study area, followed by the Repellent and Control study areas (all areas with agronomic grass and legume cover). Numbers of *M. pennsylvanicus* increased appreciably between 1979 and 1980 on almost all study areas except the Reduced Cover study area. Peak numbers of *M. pennsylvanicus* were attained on most study areas by mid- to late September 1980 and remained high on some areas until spring 1981. Numbers declined rapidly on all areas during early summer 1981.

Based on this study and on information obtained by Radvanyi (1978) and Michielson and Radvanyi (1979) during a four-year study of small rodent populations on established reclamation sites within the Suncor Inc. lease, it appears that *M. pennsylvanicus* populations in reclamation

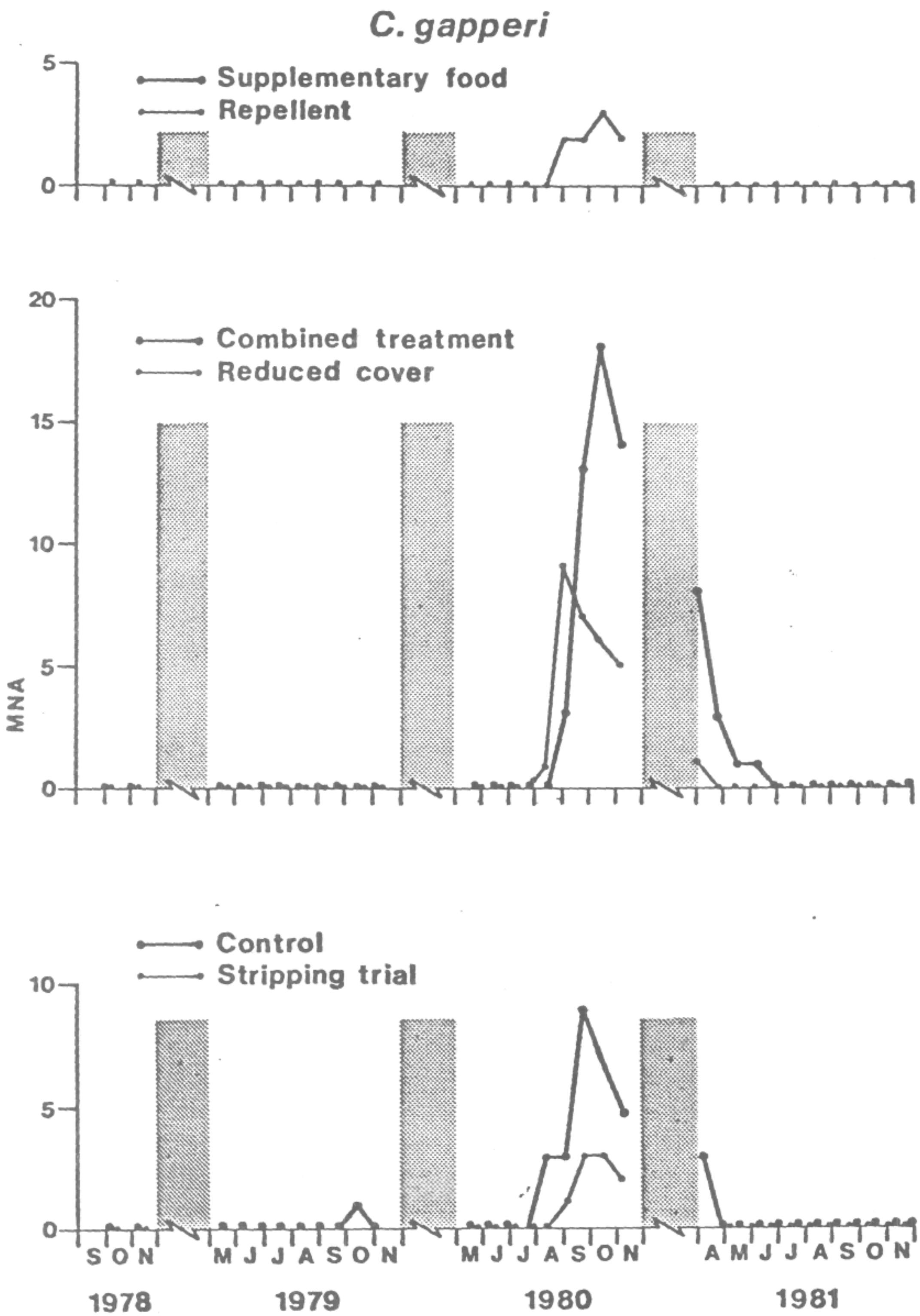

Figure 4. Population estimates of *C. gapperi*. (The MNA during each trapping period is indicated. No *C. gapperi* were captured on the Supplementary Food study area. The shaded areas indicate periods when no trapping was conducted.)

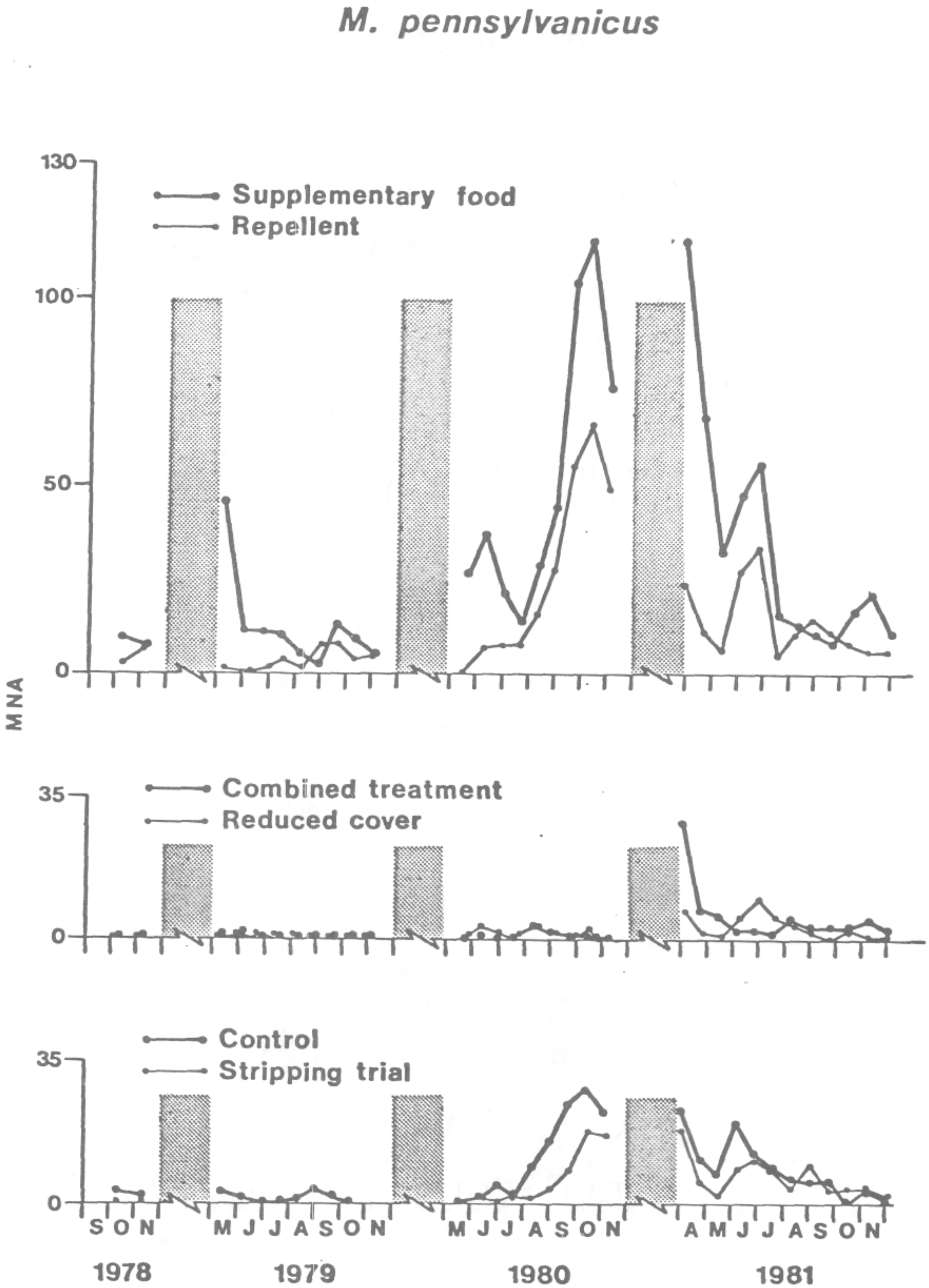

Figure 5. Population estimates of M. *pennsylvanicus*. (The MNA during each trapping period is indicated. The shaded areas indicate periods when no trapping was conducted.)

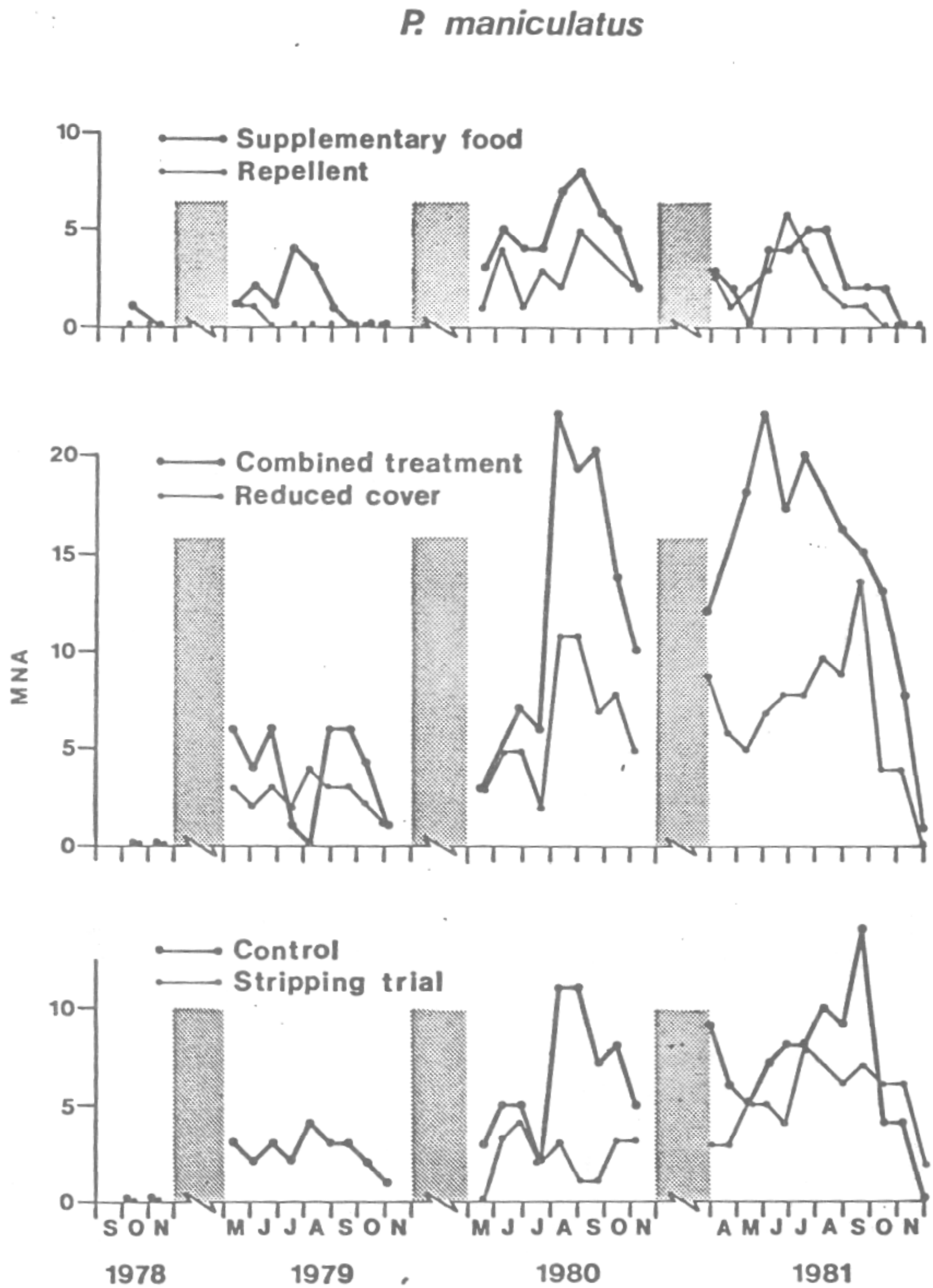

Figure 6. Population estimates of *P. maniculatus*. (The MNA during each trapping period is indicated. The shaded areas indicate periods when no trapping was conducted.)

sites undergo cyclic fluctuations in population size every three to four years. Michielson and Radvanyi (1979) indicated that their study populations increased from low numbers in 1975 to peak numbers during spring 1978, and then declined to low numbers in fall 1978. In this study, most study populations increased from low numbers in fall 1978 to peak numbers during May and June 1981 and then declined sharply. These cyclic changes in number are similar to the 3 to 4 year cycles observed in a number of microtine populations in natural areas (Krebs and Myers 1974).

Peromyscus maniculatus was present in low numbers on all study areas but was most abundant on the Reduced Cover, Combined Treatment, and Control study areas. Population trends on these three study areas and the Stripping Trial study area indicate that numbers of *P. maniculatus* have increased gradually over the 1979/81 period. Numbers on the Supplementary Food and Repellent study areas, however, have changed little during the same period (0 to 9 animals).

Prior to 1980, only one C. *gapperi* had been captured on any of the reclamation study areas. However, during late summer 1980, numbers of *C. gapperi* increased on all areas with the exception of the Supplementary Food study area, where no *C. gapperi* were captured. Numbers of *C. gapperi* were highest on the Combined Treatment, Reduced Cover, and Control study areas. During 1981, C. *gapperi* were absent from all study areas with the exception of the Reduced Cover, Combined Treatment and Control study areas during the early spring.

These population trends plus reproductive information (i.e., proportions of mature animals in breeding condition, pregnancy rates) showed that *M. pennsylvanicus* and *P. maniculatus* rapidly established resident, breeding populations in reclamation areas. In contrast, C. *gapperi* were only sporadically abundant and appeared to be transient, non-breeding animals.

VEGETATION COVER

Assessments of vegetation cover on the six study areas during 1979/81 show that the vertical and horizontal structure and species composition of plant cover differed greatly among grids hydroseeded in 1978 (Supplementary Food, Repellent, Stripping Trial, and Control study areas) and those allowed to revegetate by natural means until hydroseeding in 1980

(Reduced Cover and Combined Treatment study areas). As of 1981, ground cover on the former group of study areas was dense and consisted primarily of a few agronomic grasses and legumes (Table 1). Tree and shrub cover generally was minimal (Table 2). In contrast, ground cover on the latter two study areas (the Reduced Cover and Combined Treatment study areas) was sparse and consisted of a wide variety of native herbaceous plants, a number of "weeds," agronomic grasses, and some legumes. Tree and shrub cover on these two areas was well developed and included natural introductions of several native species as well as the species planted in 1979. Vertical distribution of plant cover was minimal on the four study areas hydroseeded in 1978; most plant cover was <25 cm tall (Table 3). In contrast, vertical cover on the two naturally-revegetating areas was well developed; a variety of ground cover species were present 0 cm to 50 cm above ground level and good development of tree and shrub growth accounted for much of the plant cover 50 cm to 150 cm above ground.

TREE AND SHRUB PERFORMANCE

Based on the tree and shrub assessments during 1980 and 1981, striking differences existed between the growth, condition, and survival of trees and shrubs on the areas with reduced cover and trees and shrubs on areas with dense grass/legume cover (Table 4). Trees and shrubs on the areas with reduced cover were characterized by good growth, good condition and high survival. In contrast, trees and shrubs on the areas hydroseeded in 1978 were characterized by poor to moderate growth, poor to fair condition and moderate survival.

DAMAGE

Before 1981, there was little damage to trees and shrubs on most study areas. Damage during 1979/80, however, tended to be greatest on the Supplementary Food study area. Damage to seedlings increased sharply during winter 1980/81.

At the time of the 1981 assessments, amounts of damage were high on the Supplementary Food study area and moderate on the Repellent, Stripping Trial and Control study areas (Tables 2 and 4). All of these areas had dense ground covers predominated by agronomic grasses and legumes. In contrast, very little damage to trees and shrubs was recorded on either of the two study areas with reduced ground cover.

Table 1. Density and species composition of ground cover on the study areas during 1981. (Mean percent cover for the 50 sample quadrats on each study area is indicated.)

Species	Supplementary Food	Repellent	Combined Treatment	Reduced Cover	Stripping Trial	Control
Agropyron albicans	-	0.10	0.50	0.05	0.10	0.40
Agropyron cristatum	0.90	1.40	-	0.15	1.55	2.95
Agropyron violacium	-	-	-	2.16	-	-
Alnus spp.	-	-	0.30	-	0.05	-
Aster spp.	-	-	0.05	-	-	-
Avena sativa	-	-	0.10	-	-	-
Betula papyrifera	-	-	-	-	0.30	-
Bromus spp.	14.20	10.70	0.90	0.90	6.30	5.80
Calamagrostis spp.	-	-	0.40	2.80	-	-
Caragana aborescens	-	0.60	0.30	-	-	-
Carex spp.	-	-	0.35	-	-	-
Chenopodium album	0.35	0.05	1.25	1.25	-	0.05
Cornus stolonifera	-	-	-	0.30	-	-
Convolvulus sepium	-	-	0.20	-	-	-
Deschampsia spp.	-	-	1.55	0.60	-	-
Elaeagnus angustifolia	-	-	-	-	-	0.30
Epilobium angustifolium	0.15	-	3.15	1.75	-	-
Equisetum sylvaticum	-	0.05	0.20	0.05	-	-
Festuca spp.	42.10	22.10	3.30	1.55	13.00	18.30
Fragaria virginiana	-	-	0.30	-	-	-
Galium trifolium	-	-	-	0.30	-	-
Hieracium canadense	0.05	-	0.55	0.20	-	-
Hieracium umbellatum	0.10	-	0.60	3.45	-	-
Larix siberica	-	-	-	0.10	0.05	-
Medicago sativa	13.65	4.95	0.55	0.15	1.30	2.45
Petasites sagittatus	-	-	-	0.30	-	-
Phleum spp.	-	-	-	0.05	-	-
Populus deltoides	0.30	0.35	0.30	1.90	-	1.95
Populus tremuloides	-	0.05	-	0.30	-	-
Prunus pensylvanica	-	-	0.30	0.05	-	0.10
Salix spp.	0.35	0.05	2.55	1.80	-	0.30
Sanfoin	0.20	-	-	-	0.05	0.05
Trifolium hybridum	0.05	0.05	0.15	0.05	0.15	-
Trifolium pratense	0.40	-	-	-	0.05	-
Litter	84.00	58.10	1.75	1.55	29.05	29.65
Deadfall	-	-	-	-	-	0.15
TOTAL GROUND COVER (± 1 S.E.)	156.8 (150.6)	98.5 (96.4)	19.6 (17.9)	21.8 (19.0)	51.9 (49.2)	62.4 (59.1)

Table 2. Estimates of tree and shrub stem densities and small rodent damage on the six study areas during 1981. (Densities of live trees and shrubs [stems/ha] and the proportion of all trees sampled that were damaged by rodents are indicated for each species on each study area.)

Species	Supplementary Food		Repellent		Combined Treatment		Reduced Cover		Stripping Trial		Control	
	Stem Density	Damage	Stem Density	Damage	Stem Density	Damage	Stem Density	Damage	Stem Density	Damage	Stem Density	Damage
Acute willow	75	0.0	13	0.0	3063	0.0	1088	0.0	-	-	75	0.0
Alder	-	-	-	-	163	0.0	25	0.0	75	0.0	-	-
Aspen	38	0.34	75	0.51	213	0.0	113	0.0	-	-	-	-
Basford willow	75	0.0	213	0.36	588	0.0	863	0.04	88	0.0	213	0.12
Caragana	25	0.0	425	0.0	188	0.0	113	0.0	-	-	50	0.0
Chokecherry	63	0.79	63	0.60	200	0.0	38	0.0	-	-	313	0.0
Dogwood	188	0.40	25	0.0	125	0.0	913	0.03	400	0.0	75	0.0
Gooseberry	-	-	-	-	75	0.0	-	-	-	-	-	-
Laurel willow	113	0.66	275	0.0	1125	0.12	625	0.0	-	-	113	0.44
Northwest poplar	125	0.90	238	0.10	63	0.21	538	0.0	63	0.0	88	0.15
Paper birch	-	-	-	-	-	-	-	-	175	0.0	-	-
Raspberry	-	-	-	-	638	0.0	-	-	-	-	-	-
Russian olive	88	0.57	-	-	-	-	213	0.0	-	-	250	0.0
Salix spp.	-	-	-	-	38	0.0	575	0.0	100	0.0	-	-
Saskatoon	-	-	-	-	-	-	-	-	88	0.0	-	-
Siberian larch	75	0.51	-	-	38	0.0	113	0.0	25	0.0	100	0.0
Walker poplar	125	0.60	-	-	238	0.0	375	0.0	113	0.34	563	0.04
White spruce	50	0.0	13	0.0	38	0.0	38	0.0	50	0.0	-	-
Wood rose	-	-	-	-	138	0.0	-	-	-	-	-	-

Table 3. Vertical distribution of vegetation cover on the six study areas during 1981. (The mean cumulative percent cover ± 1 S.E. in each 25 cm vertical segment is indicated. Means are based on cumulative estimates of percent cover for all species present in the 1 m^2 quadrat for the 50 samples on each study area.)

	Mean Percent Vertical Cover					
Study Area	0-25 cm	25-50 cm	50-75 cm	75-100 cm	100-125 cm	125-150 cm
Supplementary Food	84.7 ± 18.9	17.8 ± 18.5	1.8 ± 2.6	0.1 ± 0.3	0.0 -	0.0 -
Repellent	65.8 ± 33.3	10.0 ± 10.6	2.3 ± 3.0	0.8 ± 3.0	0.0 ± 0.2	0.0 ± 0.2
Combined Treatment	31.8 ± 31.3	18.2 ± 26.0	10.0 ± 19.9	6.5 ± 13.5	4.0 ± 13.1	1.6 ± 6.4
Reduced Cover	34.1 ± 31.2	16.7 ± 22.1	10.8 ± 19.6	6.0 ± 14.8	4.8 ± 14.0	2.4 ± 9.5
Control	48.1 ± 36.7	8.5 ± 14.5	2.3 ± 5.9	0.7 ± 2.5	0.2 ± 1.2	0.0 ± 0.2
Stripping Trial	52.2 ± 34.9	8.7 ± 14.3	2.5 ± 5.8	0.3 ± 0.6	0.0 ± 0.2	0.0 -

Table 4. Summary of the Suncor tree and shrub assessments during 1981. (Mean values ± 1 S.E. for rodent damage, plant height, plant conditions, and percent survival of seedlings are indicated for all species on each study area.)

Study Areas	Total Number	Rodent Damage[a]	Total Height (cm)	Plant Condition[b]	Percent Survival
Agronomic Grass/Legume Cover					
Supplementary Food	1148	3.1 ± 0.7	26.7 ± 11.0	1.5 ± 0.5	50.2 ± 19.8
Repellent	1047	1.1 ± 0.1	51.8 ± 22.8	2.8 ± 0.3	41.5 ± 27.9
Stripping Trial	1113	1.1 ± 0.1	42.4 ± 17.5	2.7 ± 0.3	68.3 ± 25.4
Control	1314	1.1 ± 0.1	61.7 ± 31.1	2.5 ± 0.4	47.9 ± 20.2
Naturally-Revegetating Areas					
Combined Treatment	1382	1.0 ± 0.1	97.4 ± 54.0	3.0 ± 0.6	75.7 ± 23.8
Reduced Cover	770	1.0 ± 0.0	108.6 ± 64.4	3.1 ± 0.7	78.5 ± 20.2

[a] A value of 1.0 indicates no damage; 4.0 indicates complete girdling of the stem.
[b] A value of 1.0 indicates poor condition; 4.0 indicates excellent condition.

Comparisons of the amount of damage to different tree species during 1981 suggested that willows and poplars were most susceptible to damage, whereas white spruce and caragana were almost resistant (Green 1982). Other species such as chokecherry, dogwood, Siberian larch, Scots pine, and Russian olive suffered intermediate amounts of damage.

MULTIVARIATE ANALYSES

Several multivariate statistical techniques were used to assess relationships between habitat structure, amounts of damage, small rodent abundance, and tree/shrub performance. Initially a factor analysis was used to reduce a large number of habitat variables to a smaller number of independent factors that characterized vegetation cover. Factor analyses were performed on the combined vegetation data for 1980 and 1981 using the BMDP4M program (Dixon and Brown 1979). The factor analysis was performed by a standard method—a principal component analysis followed by Varimax (orthogonal) rotation of those principal components with eigenvalues exceeding 1.0. Biological interpretations of the eight habitat factors are summarized in Table 5. Values of each factor were calculated for each habitat sampling point. These values provide indices of the eight habitat characteristics measured by these factors and used in several multivariate analyses described below.

Small Rodent Damage and Habitat Structure

Previous studies of small mammal damage to saplings and shrubs have suggested that amounts of damage are related to habitat structure (e.g., density of ground cover, abundance, and diversity of food types, density of trees and shrubs) (e.g., Eadie 1953; Howard 1967; Buckner 1970). In this study, a stepwise multiple discriminant analysis (BMDP7M; Dixon and Brown 1979) was performed to determine which indices of habitat structure and small rodent abundance best distinguished those tree planting blocks with no damage from tree planting blocks with damage.

Based on damage estimates obtained during 1980, none of the eight habitat factors or small rodent numbers were significant predictors of damage. In 1981, however, the presence or absence *of* damage was significantly related to the local abundance of *M. pennsylvanicus* and to the value of the *Agropyron* / hawkweed factor. The local abundance of *M. pennsylvanicus* was the predictor variable that best separated the two categories of damage; tree planting blocks with damage tended to occur

Table 5. Factor analysis of vegetation cover. (Habitat variables that characterize the eight habitat factors are described. Only variables whose factor loadings were greater than ± 0.250 are included in the descriptions below. Names assigned to each factor are used in all further discussions of the analysis.)

Factor	Name	Description
1	Grass/legume	- positive values represent a high percent ground cover and vertical cover of fescues, brome grass, alfalfa and litter, a dense accumulation of plant litter, a dense vertical cover (by all plant species) up to a height of 25 cm, and a moderate percent ground cover of common clover and crested wheatgrass.
2	Vertical cover	- positive values represent the presence of vertical cover in 25 cm increments from a height of 25 to 150 cm above ground.
3	*Agropyron*/hawkweed	- positive values represent a dense vertical cover and ground cover of *Agropyron violacium* and hawkweed (common ground cover components of the two study areas with reduced plant cover).
4	Fescue/*P. maniculatus*	- positive values represent the presence of dense vertical and ground cover of *Festuca saximontana*, a dense ground cover of hawkweed, and moderate numbers of *P. maniculatus*.
5	Common clover	- positive values represent the presence of dense vertical and ground cover of common clover.
6	Lamb's quarters	- positive values represent a dense vertical and ground cover of Lamb's quarters.
7	Crested wheatgrass	- positive values represent a high percent ground cover and vertical cover of crested wheatgrass.
8	Sanfoin	- positive values represent a dense vertical and horizontal growth of sanfoin.

where *M. pennsylvanicus* was abundant, whereas tree planting blocks with no damage tended to occur where *M. pennsylvanicus* was not abundant. Planting blocks with no damage also tended to be located in areas with dense ground covers of *A. violacium* and hawkweed, whereas planting blocks with damage tended to occur where such ground cover was sparse. High values of the *A. violacium* / hawkweed factor were recorded on the two study areas with reduced plant cover, so the results show that damage tended to be least on those study areas. The discriminant model accurately predicted the damage category in 65.8% of the 120 tree planting blocks.

Small Rodent Abundance and Habitat Structure

Relationships between small rodent abundance and habitat structure also indicated that ground cover communities strongly influenced the local abundance of *M. pennsylvanicus.* Stepwise multiple regression (SMR) analyses of the relationship between habitat structure and small rodent abundance were performed using the BMDP2R program (Dixon and Brown 1979). Four separate SMR analyses were performed; two for *M. pennsylvanicus* in 1980 and 1981, and two for P. *maniculatus* in 1980 and 1981. Only habitat factors with P-ratios larger than 4.0 were allowed to enter the SMR model.

During 1980, three habitat factors explained 42.5% of the spatial variation in the abundance of *M. pennsylvanicus* on the six study areas (Table 6). The grass/legume factor was the most important predictor variable and was positively associated with numbers of *M, pennsylvanicus.* The sanfoin factor and the common clover factor were both positively associated with the abundance of *M. pennsylvanicus* and accounted for an additional 2.8% and 2.6% of the variance in captures, respectively.

The relationship between spatial variation in the abundance of *M. pennsylvanicus* and vegetation structure in 1981 was similar to that in 1980. Three habitat factors, the grass/legume, the crested wheatgrass, and the common clover factors, accounted for 38.8% of the spatial variation in *M. pennsylvanicus* (Table 6). The grass/legume factor and the common clover factor were positively associated with abundance whereas the crested wheatgrass was negatively associated with numbers of *M. pennsylvanicus.*

Table 6. SMR analysis of the relationship between *M. pennsylvanicus* abundance and habitat factors during 1980 and 1981. (See Table 5 for explanation of variable names. Small rodent abundance is expressed as the number of captures per trap-night and was transformed using a log [x+1] transformation for use in the MRA.)

Factor Name	Step at which Factor Entered Equation	Regression Coefficient at Last Step	S.E. of Regression Coefficient at Last Step	R^2 at Each Step	Increase in R^2 Attributable to Factor	P[b]
1980 Analysis[a]						
Constant		0.019				
Grass/legume	1	0.020	0.002	0.360	0.360	***
Sanfoin	2	0.004	0.001	0.388	0.028	***
Common Clover	3	0.006	0.001	0.415	0.027	***
1981 Analysis[c]						
Constant		0.013				
Grass/legume	1	0.020	0.002	0.316	0.316	***
Crested Wheatgrass	2	-0.008	0.002	0.367	0.051	***
Common Clover	3	0.012	0.004	0.388	0.021	***

[a] Multiple R-square=0.415, standard error of estimates=0.0255, df=2,297, F-ratio=94.19, $P < 0.001$.

[b] Two-sided significance levels: *** means $0.001 \geq P$.

[c] Multiple R-square=0.3883, standard error of estimates=0.0268, df=2,296, F-ratio=62.63, $P < 0.001$.

Multiple regression analyses for *P. maniculatus* indicated that local variation in the abundance of this species during both years was poorly associated with all of the habitat variables measured.

Tree and Shrub Performance and Habitat Structure

Total height, survival, and condition for each of 12 tree and shrub species were evaluated by Suncor on each study area. We wanted to reduce these 36 values (3 variables x 12 species) to just a few indices of height, survival, and condition. To do this, three separate principal component analyses (BMDP4M; Dixon and Brown 1979) were performed on the Suncor estimates of growth, survival, and condition, respectively. The first two principal components of growth, the first principal component of condition, and the first principal component of survival were used in all further analyses as indices of the respective parameters. Seven habitat factors, similar to those described in Table 5, were used to describe plant cover on the five study areas (the Stripping Trial was excluded from the analyses because the tree planting blocks on this area were not identical to the other five areas). Three separate stepwise multiple regression analyses (BMDP2R; Dixon and Brown 1979) then were used to assess relationships between growth, condition, and survival, respectively, and the factors describing vegetation cover and small rodent abundance. Results of the analyses are summarized in Table 7; further details are provided by Green (1982).

During 1980, when amounts of damage to trees and shrubs were small, tree and shrub performance was related to the density and composition of ground cover. Trees and shrubs in better condition tended to be taller than plants in poor condition. Trees and shrubs that were located in areas with ground covers dominated by *F. saximontana* and Lamb's quarters (i.e., the Reduced Cover and Combined Treatment study areas) or with high local abundances of *P. maniculatus* (again the two reduced cover study areas) also tended to be taller. This suggests that during 1980, sparse ground covers such as those present in the Reduced Cover and Combined Treatment study areas were most suitable for tree and shrub growth. In contrast, tree and shrub growth in areas dominated by a dense cover of agronomic grasses and legumes tended to be poor.

Tree and shrub condition during 1980 was negatively associated with the local abundance of *M. pennsylvanicus* and the density of grass/legume cover. Because damage was included in the analysis but was not a

Table 7. Stepwise multiple regression analyses of tree/shrub performance variables in relation to habitat factors and rodent abundance during 1980 and 1981.

Variable Name	Step at which Factor Entered Equation	Regression Coefficient at Last Step	S.E. of Regression Coefficient at Last Step	R^2 at Each Step	Increase in R^2 Attributable to Factor	p[a]
1980 PC1 Plant Height						
Constant		0.026				
Condition	1	0.212	0.061	0.094	0.094	***
1981 PC1 Plant Height						
Constant		0.029				
Condition	1	0.247	0.067	0.103	0.103	***
1980 PC2 Plant Height						
Constant						
P. maniculatus (captures/TN)	1	-6.043	1.781	0.105	0.105	***
Condition	2	-0.220	0.059	0.178	0.073	***
F. saximontana	3	-0.566	0.206	0.224	0.045	***
Lamb's quarters	4	-0.176	0.046	0.268	0.045	***
Damage	5	-2.169	1.056	0.294	0.026	***
1981 PC2 Plant Height						
Constant		0.369				
Damage	1	-0.233	0.035	0.269	0.269	***
1980 Condition[f]						
Constant		0.289				
M. pennsylvanicus (captures/TN)	1	-13.787	1.777	0.372	0.372	***
Grass/legume cover	2	-0.476	0.055	0.592	0.229	***
Vertical cover	3	0.709	0.270	0.609	0.017	***
1981 Condition[g]						
Constant		0.599				
Damage	1	-0.595	0.051	0.703	0.703	***
Grass/legume cover	2	-0.198	0.049	0.755	0.052	***
P. maniculatus (captures/TN)	3	3.485	1.489	0.769	0.014	***
F. saximontana cover	4	0.112	0.029	0.782	0.013	***
A. violacium/hawkweed cover	5	0.096	0.027	0.797	0.015	***
Vertical cover	6	0.081	0.028	0.805	0.008	***
Common clover/sanfoin cover	7	-0.274	0.115	0.815	0.010	***
1980 Survival[h]						
Constant		0.236				
Condition	1	0.626	0.050	0.655	0.655	***
Crested wheatgrass cover	2	-0.124	0.032	0.704	0.049	***
F. saximontana cover	3	-0.317	0.115	0.722	0.018	***

...continued

Table 7. Continued

Variable Name	Step at which Factor Entered Equation	Regression Coefficient at Last Step	S.E. of Regression Coefficient at Last Step	R^2 at Each Step	Increase in R^2 Attributable to Factor	P[a]
1981 Survival[i]						
Constant		-0.470				
Grass/legume cover	1	-0.325	0.037	0.378	0.378	***
Lamb's quarters cover	2	0.300	0.056	0.558	0.180	***
F. saximontana cover	3	0.179	0.032	0.601	0.043	***
Vertical cover	4	0.109	0.028	0.648	0.047	***
A. violacium/hawkweed cover	5	0.100	0.028	0.683	0.035	***
P. maniculatus (captures/TN)	6	5.059	1.494	0.712	0.024	***

[a] Two-sided significance levels *** $P < 0.001$.

[b] R^2=0.094; S.E. of estimate=0.447; df=1,118; F-ratio=12.30; $P < 0.001$.

[c] R^2=0.103; S.E. of estimate=0.630; df=1,118; F-ratio=13.59; $P < 0.001$.

[d] R^2=0.294; S.E. of estimate=0.370; df=5,114; F-ratio=9.51; $P < 0.001$.

[e] R^2=0.275; S.E. of estimate=0.356; df=1,118; F-ratio=44.76; $P < 0.001$.

[f] R^2=0.609; S.E. of estimate=0.429; df=3,116; F-ratio=60.09; $P < 0.001$.

[g] R^2=0.815; S.E. of estimate=0.382; df=7,112, F-ratio=70.40; $P < 0.001$.

[h] R^2=0.722; S.E. of estimate=0.326; df=3,116; F-ratio=100.58; $P < 0.001$.

[i] R^2=0.712; S.E. of estimate=0.397; df=6,113; F-ratio=46.64; $P < 0.001$.

significant predictor variable of condition, the negative association between condition and *M. pennsylvanicus* numbers probably reflects habitat conditions that supported high numbers of these species (dense horizontal and vertical ground cover dominated by agronomic grasses and alfalfa, common clover, and sanfoin).

During 1981, tree and shrub height again appeared to be negatively related to ground cover. Height of coniferous trees and most shrubs was positively associated with tree/shrub condition. In turn, tree/shrub condition was negatively influenced by increasing densities of ground cover dominated by agronomic grasses and legumes. Height of willows and poplars was negatively associated with damage or, in other words, height was negatively affected by damage. Because damage tended to be highest in areas preferred by *M. pennsylvanicus,* growth of poplars and willows, by inference, was poorer in areas with a dense ground cover of agronomic grasses and legumes. The close association between low tree/shrub survival and a dense ground cover of agronomic grasses and legumes and between good tree and shrub survival and habitat parameters typical of the sparse ground covers on the two reduced cover study areas (i.e., a ground cover predominated by Lamb's quarters, *F. saximontana, A. violacium,* and hawkweed, a high local abundance of *P. maniculatus,* and good vertical development of vegetation cover 25 cm to 150 cm above ground level) are in direct agreement with this conclusion.

In summary, the results of the three multivariate analyses during 1980 and 1981 generally are in agreement and suggest:

1. Dense ground covers predominated by agronomic grasses (creeping red fescue, brome grass, and crested wheatgrass) and legumes (alfalfa and common clover) seriously hinder tree and shrub performance (e.g., poor growth, condition, and survival) ; and

2. Sparse herbaceous ground covers, such as that present on the Reduced Cover and Combined Treatment study areas, appear to be the most suitable vegetation cover for good tree and shrub performance (good growth, condition, and survival).

SYNTHESIS AND CONCLUSIONS

Based on this study and previous research by Radvanyi (1978), Michielsen and Radvanyi (1979), and Green (198Oa, 198Oc), a number of conclusions concerning small rodent damage to trees and shrubs on reclamation areas and the performance of tree and shrub species on reclamation areas can be stated (characteristics of small rodent populations, vegetation, tree performance, and small rodent damage on each study area are summarized in Table 8).

1. The grass/legume ground cover used to stabilize tailing sand berms creates a vegetation community highly suitable to *M. pennsylvanicus*.

2. Once established in new reclamation sites, *M. pennsylvanicus* populations can increase rapidly and undergo cyclic fluctuations in abundance on the order of once every three to four years.

3. New reclamation sites are only moderately suitable for *P. maniculatus* and are poorly suited to C. *gapperi* (these two species of small rodent are the most abundant species in adjacent natural forested communities).

4. High local abundances of *M. pennsylvanicus* are closely associated with development of dense grass and legume ground cover.

5. Damage to trees and shrubs tends to be most severe in areas with a high local abundance of *M. pennsylvanicus,* strongly suggesting that this species is largely responsible for the girdling damage on reclamation areas.

6. Assuming this relationship is correct, local abundances of *M. pennsylvanicus* appear to be the proximate cause of damage, whereas the development of dense vegetation cover dominated by agronomic grasses and legumes is the ultimate cause of damage.

7. Development of dense ground covers of grass and legumes can result in reduced tree and shrub performance (poor growth, condition and survival), possibly as a result of competition for nutrients and water.

In addition to providing information on these aspects of small rodent demography, small rodent damage, vegetation cover, and tree/shrub performance, this study has provided an opportunity to observe the

Table 8. Characteristics of small rodent populations, vegetation, and small rodent damage on the six study areas of 1981.

	Supplementary Food	Repellent	Combined Treatment	Reduced Cover	Stripping Trial	Control
C. gapperi						
Numbers[a]	0	3	18	9	3	9
Breeding activity	-	low	high	low	none	low
Pregnancies	-	none	none	none	none	none
M. pennsylvanicus						
Numbers[a]	116	67	32	11	19	31
Breeding activity	high	high	moderate	moderate	high	high
Pregnancies	moderate	moderate	low	low	moderate	moderate
P. maniculatus						
Numbers[a]	8	6	22	14	6	8
Breeding activity	low	moderate	moderate	high	high	moderate
Pregnancies	low	none	moderate	low	none	none
Ground Cover						
Total percent cover	156.8	98.5	19.6	21.8	62.4	51.9
Dominant species[b]	Red fescue Brome grass Alfalfa	Red fescue Brome grass Alfalfa	*Festuca saximontana* Fireweed Willows	Hawkweed Reed grass *Agropyron violacium*	Red fescue Brome grass Crested wheatgrass	Red fescue Brome grass Crested wheatgrass
Litter (percent cover)	84.0	58.1	1.8	1.6	29.7	29.1
Trees and Shrubs						
Growth	poor	moderate	high	high	moderate	moderate
Condition	poor	fair	good	good	fair	fair
Survival	moderate	moderate	high	high	moderate	moderate
Small Rodent Damage						
Suncor assessments	high	moderate	low	negligible	moderate	moderate
LGL assessments	high	moderate	low	low	low	moderate

[a]Peak MNA during 1979-1981.

[b]The three most dominant ground cover species, based on estimates of mean percent ground cover during 1981, are shown.

establishment of two types of ground cover communities in reclamation areas—agronomic grass and legume ground cover and a natural successional ground cover—and the subsequent use of these areas by small rodents.

At the start of this study (summer 1978), no plant cover was present on any of the six study areas and it is likely that all areas were uninhabited by small rodents. Following hydroseeding of four of the six study areas and the subsequent establishment of sparse grass and legume cover, small rodents had begun to utilize the hydroseeded areas by the early fall 1978.

In adjacent natural forest communities *C. gapperi* is the most abundant species of small rodent, *P. maniculatus* is moderately abundant, and *M. pennsylvanicus* is only common within pockets of suitable vegetation (Green 1980c). However, the creation of reclamation areas with good development of grass and legume cover has provided a large area of habitat, highly suitable for habitation by *M. pennsylvanicus* and, to a lesser extent, *P. maniculatus.* It appears, then, that the creation of grass and legume-dominated reclamation areas has allowed *M. pennsylvanicus* to establish large resident, breeding populations in an area that formerly was not well suited for this species. These populations increased rapidly and now appear to undergo cyclic fluctuations in number (as described by Krebs and Myers [1974]) on the order of once every three to four years.

In contrast, C. *gapperi* has not become well established in reclamation sites even though it is abundant in adjacent forested sites. Because *C. gapperi* prefers mature forested communities, failure of this species to establish on the existing reclamation sites is not unexpected. However, as tree and shrub cover increases on the reclamation sites, increased use of these areas by *C. gapperi* can be expected.

The reclamation study areas appear to provide an adequate habitat for *P. maniculatus;* breeding populations have become established and numbers are similar to those in some adjacent forested areas. *Peromyscus maniculatus* prefers natural areas with well-developed tree and shrub cover and will likely increase in number as trees and shrubs become better established on the reclamation sites.

Reclamation practices, currently in use in the Fort McMurray area generally involve hydroseeding with *a* mix of a soil stabilizer, agronomic grasses and legumes. This results in the rapid establishment of a vegetation mat that reduces soil erosion. Tree and shrub planting programs have been undertaken in order to accelerate the establishment of a self-sustaining vegetation community and to aid in soil stabilization.

Results of this study indicate, however, that the dense ground covers and tree planting programs are not compatible for two major reasons. First, the dense grass and legume ground covers probably compete with the young trees and shrubs for water and nutrients. The poor growth, condition, and survival of trees and shrubs in areas of dense ground cover suggests that the grass and legume species used are capable of reducing tree and shrub performance. Trees and shrubs stressed by competition would be less able to withstand the additional stress of small rodent damage and consequently would be more susceptible to damage. And second, the development of dense grass and legume cover creates a vegetation community highly suitable for *M. pennsylvanicus.* Girdling damage by *M. pennsylvanicus* can reach high levels during the peak phase of this small rodent's population cycle. Because trees and shrubs in areas of dense grass and legume cover may already be stressed by competition and because the same ground cover ultimately results in increased amounts of damage (as a result of high *M. pennsylvanicus* numbers), poor tree and shrub performance can be anticipated.

Because stabilization of the tailings sand berms is necessary to reduce erosion by wind and water, the use of ground covers cannot be totally eliminated. Some form of ground cover and/or soil stabilizer is necessary. Widespread use of an artificial soil stabilizer, such as hydromulch, is not feasible because of the large size of the reclamation areas. The solution appears to be the development of a seed mix which will result in a ground cover community with several characteristics:

1. a well-developed root system to help stabilize the tailings sand;

2. a poor capability to compete with trees and shrubs for water and nutrients;

3. a minimal development of above-ground plant cover to reduce the attractiveness to *M. pennsylvanicus;* and

4. a reproductive capability sufficient to maintain a self-sustaining vegetation community.

Several species of grasses, which may meet these criteria, are currently being tested on the Reduced Cover and Combined Treatment study areas.

Tree and shrub survival might also be enhanced through timing of the reclamation program. For example, trees and shrubs might first be planted on reclamation sites and allowed to establish prior to the application of a sparse ground cover mix. In addition, because *M. pennsylvanicus* populations appear to reach high numbers only once every three to four years and because damage can be expected to increase to critical levels during these peak, years, trees and shrubs should be planted immediately following the population decline. The trees and shrubs consequently would have two to three complete growing seasons before the next population peak of *M. pennsylvanicus* and likely would be better able to withstand the stress of girdling damage.

REFERENCES CITED

Buckner, C.H. 1970. *The* strategy for controlling rodent damage to pines in the Canadian mid-west. Proc. Vert. Pest. Conf. 4:43-48.

Chitty, D. and E. Phipps. 1966. Seasonal changes in survival in mixed populations of two species of vole. J. Anim. Ecol. 35:313-331.

Dixon, W.J. and M.B. Brown, eds. 1979. BMDP-79. Biomedical computer programs P-series. Univ. of Calif. Press, Berkeley. 880 pp.

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

Fedkenheuer, A.W. 1979. Native shrub research for oil sands reclamation. Professional paper 1979-4, Syncrude Canada Ltd. 14 pp.

Green, J.E. 1978. Techniques for the control of small mammal damage to plants: a review. Prep, for the Alberta Oil Sands Environmental Research Program by LGL Ltd., environmental research associates. AOSERP Report 38. 111 pp.

Green, J.E. 1980a. Small mammal populations of northeastern Alberta. II. Populations in reclamation areas. Prep, for the Alberta Oil Sands Environmental Research Program by LGL Ltd., environmental research associates. AOSERP Report 108. 136 pp.

Green, J.E. 1980b. Small rodent populations and related damage to trees and shrubs on reclamation areas. 1980 Field Studies Interim Report. Prep, for Suncor Inc. and Alsands Energy Ltd. by LGL Ltd., environmental research associates. 56 pp.

Green, J.E. 1980c. Small mammal populations of northeastern Alberta. I. Populations in natural habitats. Prep, for the Alberta Oil Sands Environmental Research Program by LGL Ltd., environmental research associates. AOSERP Report 107. 301 pp.

Green, J.E. 1982. Small rodent populations and related damage to trees and shrubs on reclamation areas. Prep, for Alsands Energy Ltd. and Suncor Inc. by LGL Ltd., environmental research associates. 121 pp.

Howard, W.E. 1967. Biocontrol and chemosterHants. Pages 343-386 in W.W. Kilgore and R.L. Doutt, eds. Pest control: biological, physical and selected chemical methods. Academic Press, New York.

Kershaw, K.A. 1966. Quantitative and dynamic ecology. Edward Arnold Publ. Limited, London. 183 pp.

Krebs, C.J., B.L. Keller, and R.H. Tamarin. 1969. *Microtus* population biology: demographic changes in fluctuating populations of *M. ochrogaster* and *M. pennsylvanicus* in southern Indiana. Ecology 50:587-607.

Krebs, C.J. and J.H. Myers. 1974. Population cycles in small mammals. Adv. in Ecol. Res. 8:267-399.

Michielsen, J. and A. Radvanyi. 1979. Great Canadian Oil Sands small mammal study. Final report. Prep, for Great Canadian Oil Sands Limited. 65 pp.

Nudds, T.D. 1977. Quantifying the vegetative structure of wildlife cover. Wildl. Soc. Bull. 5:113-117.

Radvanyi, A. 1978. The return of the rodents—year three in the assessment of harmful small mammals in the Alberta oil sands reclamation and afforestation program. Final report. Fisheries and Environment Canada, Can. Wildl. Serv. 82 pp.

Seiner, J. and R. Thompson. 1977. Reclamation for afforestation by suitable native and introduced tree and shrub species. Prep, for the Alberta Oil Sands Environmental Research Program by the Alberta Forest Service, Lands Use Branch, Sub-project VE 7.1. 93 pp.

Sherstabetoff, J., G.B. Dunsworth, and S.K. Takyi. 1978. An interim report on reclamation afforestation by suitable native and introduced tree species. Prep, for the Alberta Oil Sands nvironmental Research Program by the Alberta Forest Service. AOSERP Report 41. 115 pp.

Shopik, T.D. 1980. 1979 Afforestation Report. Suncor Inc. Oil Sands Division. Environmental Affairs. 1980-02-05. 17 pp. + appendices.

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DISCUSSION RELATING TO JEFF GREEN'S PAPER

Frank Pells, Brenda Mines: Is the cycle of mice independent of your planting cycle?

Answer: It could be coincidental and I really can't answer your question. We started our study in 1978 and unfortunately that was the year that the microtene populations declined very rapidly on the older reclamation sites that had already been established. It's interesting that Al Kennedy, when speaking about the Esso Project at Judy Creek yesterday said that they also had high population numbers for 1981 and high amounts of damage. One of the things that has been suggested, for natural populations anyways, is that these populations cycle circuitously across very wide geographical regions so perhaps it doesn't really matter when you start your areas - you still may have cycling populations which could be influenced by immigration of animals from older reclamation sites. When the numbers go up there, you're probably going to get very high influx into your reclamation sites.

Phil Burton, Monenco Consultants: Jeff, would you say that rodent damaged is associated more with high shoot cover of the ground (grasses and legumes) or with litter accumulation?

Answer: Our analysis couldn't distinguish that - I think both are important. Basically they both add to the ground cover which protects the small rodents from predation and climatic extremes. Rodents definitely go for areas of very high ground cover accumulation. They need to have some green shoot material for food, but they also like to have a lot of plant accumulation for nesting, and building runways.

Jack Thirgood, U.B.C.: How do you apply the grass turf in strips?

Answer: One of the treatments which I didn't go into very much is called the stripping trial. What we did was to seed a ten metre wide horizontal band at the top of the berm and another ten metre band across the bottom, leaving a band which varied between 20 m and 25 m wide in the middle which was unseeded. Then trees were planted into that. The trees have done somewhat better, but one of the problems we face with working on a slope is water washing grass seed down into the area so that it begins to seed over like the other areas.

Jack Thirgood, U.B.C.: I hope not (interval of unclear recording). Have you tried removing the turf?

Answer: We haven't tried that. Prior to our study Suncor did try a manipulation in which they would clear off one and a half metre radius and plant the trees into that. The area wasn't big enough and the grass came back very quickly. An alternative reclamation strategy might be to do something like we've done on our two reduced-cover plots in which you plant your trees first and use physical means of controlling erosion be it through soil stabilizers or sand-bagging or whatever. It's fairly labour intensive. But get the trees well established, let the roots get going, then plant your sparse shrubbery.

Jack Thirgood, U.B.C.: Could you plant the trees and then use *a* herbicide?

Answer: That would probably be a very acceptable technique.

Dave Fraser, University of Victoria: Did anybody try habitat manipulation to increase prédation pressure?

Answer: One of the problems with that technique is that predators only remove excess of microtene populations. Predators can keep that peak population down, but in natural situations they can't stop the cycling. I suspect that prédation might reduce the population but it isn't going to be as effective as habitat manipulation which can result in very large changes in population numbers.

Dave Fraser, University of Victoria: How about leaving islands of natural vegetation to relieve pressure on reclaimed areas?

Answer: Yes, and that would also be one route of investigation into making these reclamation sites more suitable for other types of wildlife species as well.

C.J. Lloyd, U.B.C.: (Distorted recording. The question related to selecting damage resistant species for planting.)

Answer: Among the tree species we planted there is a definite preference for white spruce and caragana. There are clearly certain species which they leave strictly alone.