AN ABSTRACT OF THE THESIS OF

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Title: THE RESPONSE OF ANIMALS TO HERBICIDE-INDUCED HABITAT CHANGES

Abstract approved: Hugh C. Black

The objectives of this investigation were to examine the changes in vegetation resulting from application of herbicides, and to study the effects of these vegetative changes on the abundance and composition of small-mammal populations, and on deer usage of treated and untreated plots.

Three areas in western Oregon were selected for study and half of each was treated with a combination of herbicides designed to control grasses and forbs without injuring Douglas-fir (*Pseudotsuga menziesii* (Mirb.) franco).

The effects of herbicide treatment were to eliminate or suppress grasses, control forbs, and to promote growth of shrubs and trees.

Small mammals primarily associated with grass or meadow habitats decreased in abundance. The Oregon vole (*Microtus oregoni*) was the species most affected by the reduction in grassy

vegetation. Species that find optimum habitat in brushy areas increased in abundance on treated plots. The deer mouse (Peromyscus maniculatus) was the most common species to demonstrate a positive response on treated plots. The community response depended on the relative species composition.

Deer activity, as measured by pellet-group counts, was greater on treated plots during the growing seasons. No significant differences were found in the occurrence of browsing as a result of herbicide-induced habitat changes. Browsing was influenced by season. Herbicide treatments improved deer habitat during the growing season without significantly increasing the browsing of Douglas-fir seedlings.

The Response of Animals to Herbicide-induced Habitat Changes

by

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INTRODUCTION

Problem

Expanding human populations accompanied by increased desires for a higher standard of living create greater demands on the various natural resources. Nowhere is this more evident than in the pressures exerted on renewable products of forest lands. Not only are more timber, wildlife, water, and recreation required, but conflicts between the various resource users are increasing. This means that more efficient utilization and intensive management of forest environments will be required in the future.

Vegetation is at the base of any management plan. This component of the forest system is easiest to manipulate and often can be used to control or regulate other elements. Man has favored those species that have been most useful. Problems often arise, however, when trying to favor certain species in preference to less useful ones. Many of these problems can be handled most conveniently, efficiently, and economically with chemicals. As Freed (1967, page 12) stated, "These tools permit destruction or selective suppression of undesirable species in order that desirable ones may be encouraged."

Use of herbicides to control vegetation is a well documented tool of forest managers. Their primary use in forestry involves control of weed species (plants growing where they are not desired) which compete with desirable forest crop trees. Weeds normally include brush and grasses which compete with seedlings for water, nutrients, light, and space. Selective herbicides are used to kill or suppress these unwanted species and thereby improve conditions for survival and growth of tree seedlings.

Although herbicides are useful tools of forest management, many controversies over their use are encountered. One area of greatest concern involves the effects of herbicides on wildlife. George (1961) has classified the effects of herbicides on wildlife as primary and secondary. Primary effects include direct toxicological and physiological results. Secondary influences encompass indirect toxicological and ecological effects.

The primary effects of herbicides have been studied extensively. Most results indicate that there is little direct danger to wildlife when the chemicals are applied properly and at recommended rates (Brown, 1967; George, 1961).

Few data are available on the secondary effects of herbicides. However, these chemical compounds can create significant changes in habitat utilized by animals. It is important, therefore, for resource managers to know and understand the nature of a given herbicide's influence on the habitat and of wildlife responses to that influence. The relationship of big game and small mammals with the various stages of forest succession also suggests possible use of herbicides to regulate the distribution and abundance of animal populations. The possibility of controlling animal damage through habitat manipulation is of particular interest to foresters.

The problem is that little is known concerning the secondary or ecological effects of this management practice on wildlife populations.

Objectives

The purpose of this study, which was conducted in cooperation with the Bureau of Land Management, was to determine the impact of herbicide-induced vegetational changes on usage of forest lands by wildlife.

The specific objectives included the following: (1) to study the effects of herbicide application on the vegetation; (2) to study the effects of herbicide-induced vegetational changes on the composition and abundance of small mammals; and (3) to study the effects of habitat changes on activity of black-tailed deer (Odocoileus hemionus columbianus (Richardson)) and on the occurrence of browsing damage to Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings.

METHODS

Study Areas

I selected three ecologically similar areas for study. Two units were located in the Eugene District and one in the Salem District of the Bureau of Land Management (Figure 1). Use of herbicides was planned on these areas to facilitate forest regeneration. Repeated attempts to reforest these areas had failed because of vegetative competition and animal damage. Browsing of surviving coniferous seedlings by deer was common on all three areas.

The areas were large (30 to 70 acres) clear-cuttings ranging in age from 8 to 12 years since logging. After timber removal, the slash was burned and several unsuccessful attempts at reforestation were made. The areas were further characterized by uniform cover, gentle topography, slightly southern exposures, and heavy deer usage. Detailed descriptions of each area are included in the Appendix.

The "*Tsuga heterophylla* Zone" described by Franklin and Dyrness (1969) encompasses all three areas. Following their classification of secondary succession, the three sites were in the latter part of the weed stage. The presence of a significant number of shrubs indicated that succession was approaching the shrub-dominated period.

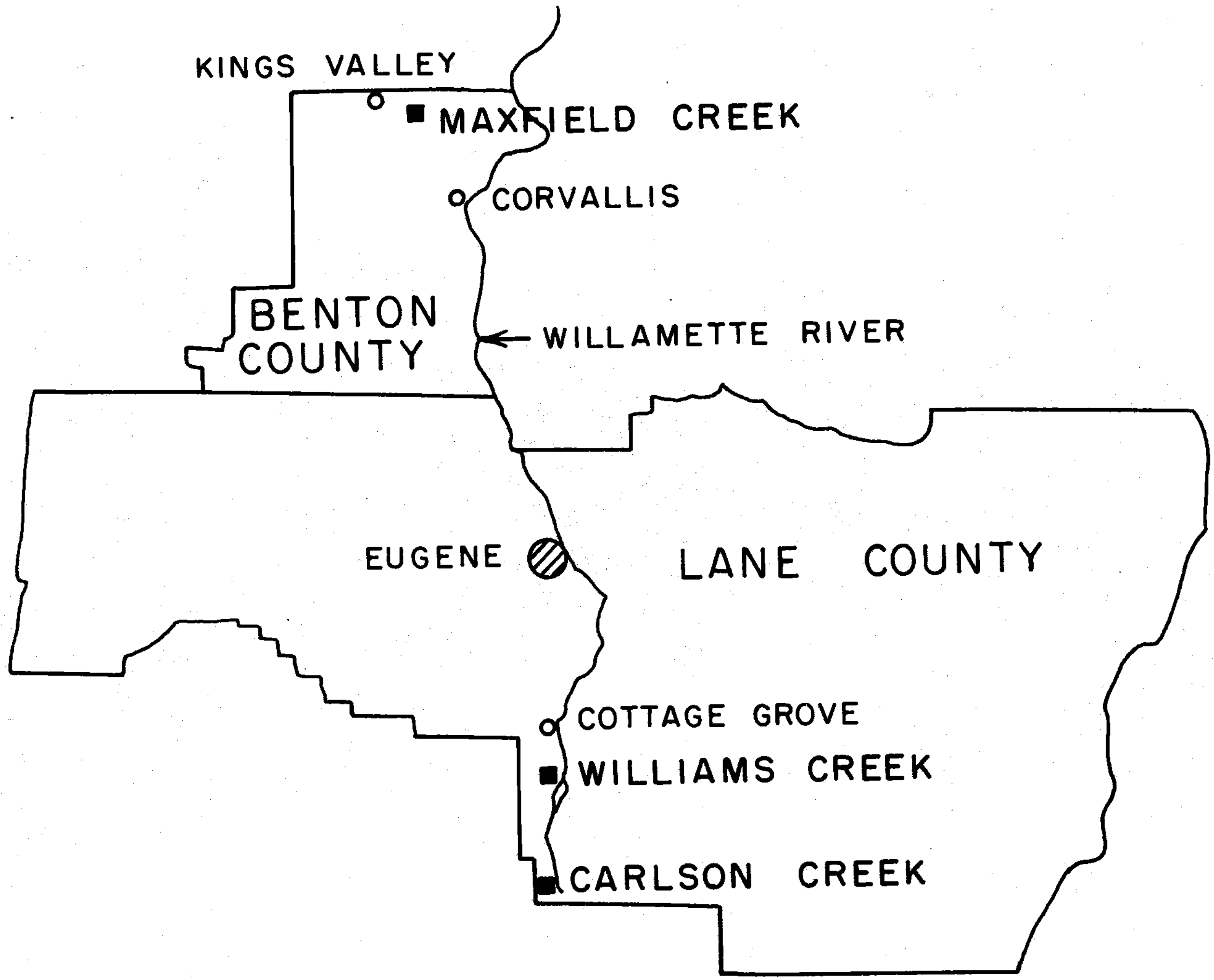

Figure 1. Map showing the location of the three study areas in Benton and Lane Counties, Oregon.

All three areas are in a similar climatic zone, although the units at Carlson Creek and Williams Creek lie in the Western Cascade province and the Maxfield Creek unit is located in the eastern part of the Coast Range. The climate is characterized by mild, wet winters and dry summers. Most of the precipitation falls between October and March in the form of rain (Franklin and Dyrness, 1969). Small diurnal variations in temperature and prolonged cloudy periods also characterize the region.

I set up a thermograph and rain gauge near the center of each area. My purpose was to obtain a local description of temperature and precipitation. These data are presented in Table 1. Observations were begun in April, 1970 and cover a period of 18 months. This period represents three seasons of variable environmental conditions.

Treatment

I divided each of the three study areas in half and arbitrarily selected one side for treatment with herbicides. The procedure followed a factorial design with three similar areas and two treatments, that is, treated and untreated. All observations were duplicated on each side or plot.

The Bureau of Land Management applied herbicides in the spring, prior to bud burst, of 1970 and 1971. All chemicals were

Table 1. Mean maximum and minimum temperatures and precipitation recorded on the three study areas from May 1970 to October 1971.

	Carlson Creek			Williams Creek			Maxfield Creek		
	Mean Maximum Temp	Mean Minimum Temp	Precipitation	Mean Maximum Temp	Mean Minimum Temp	Precipitation	Mean Maximum Temp	Mean Minimum Temp	Precipitation
	°F	°F	inches	°F	°F	inches	°F	°F	inches
May, 1970	51	40	1.36	62	38	1.29	60	40	1.69[1]
June	69	47	0.54	70	47	0.58	68	48	1.00
July	76	49	0	77	48	0	74	50	0.03
Aug.	75	47	0	77	46	0	72	49	0.58
Sept.	64	44	2.81	66	40	1.33	63	47	1.82
Oct.	57	40	6.34	65[2]	38[2]	5.45	55	41	2.12
Nov.	48	36	10.35	49	36	9.29	46	36	1.91[3]
Dec.	39	29	11.25	42	31	9.70	38	32	--
Jan., 1971	39	30	0.35[4]	43	31	8.35	40	32	10.47
Feb.	43	31	5.14	46	31	4.45	42	33	6.51
March	44	30	9.21	47	31	8.55	43	32	3.72[5]
April	50	33	3.17	54	34	4.28	51	35	2.42
May	57	38	4.30	61	41	4.30	58	41	2.85
June	62	42	2.34	65	44	2.05	60	44	1.92
July	73	49	0.49	76	50	0.36	72	51	0.36
Aug.	75	50	2.28	78	51	1.67	74	53	1.61
Sept.	65	44	3.30	68	44	3.07	63	47	2.09
Oct.	53	38	3.78	56	37	3.44	54	41	3.77

[1] Based on 28 days of observation.

[2] Based on 9 days of observation.

[3] Based on incomplete data. A leak was discovered in the rain gauge.

[4] Based on 2 days of observation.

[5] Based on 16 days of observation.

applied by helicopter. Treatment consisted of a combination of herbicides designed to give maximum control of grasses and forbs without injuring the Douglas-fir. The combinations and amounts of herbicides used in this study were based on results of recent field tests (Newton, 1970) and on operational tests to control herbaceous vegetation.

Grasses and forbs predominated the first year. Therefore, a combination of 4 pounds each of atrazine and dalapon and 1 pound each of 2, 4-D and silvex[1] carried in 20 gallons of water was applied to each acre on one half of each area. The herbicide mixture was modified in the second year to 4 pounds each of atrazine and 2, 4-D carried in 18 gallons of water and 2 gallons of diesel oil per acre.

Shrubs and forbs made up a greater proportion of the vegetation in the second year. An increased amount of 2, 4-D and the addition of oil to the carrier were used to give greater control of shrubby vegetation. Dalapon was eliminated because perennial grasses were less abundant in the second year.

Both herbicide mixtures were designed to give similar results in vegetative control and I have treated them as one treatment.

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[1]Common names for the chemicals 2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine; 2, 2-dichloropropionic acid; (2, 4-dichlorophenoxy) acetic acid; and 2-(2, 4, 5-trichlorophenoxy) propionic acid, respectively. Nomenclature follows that of the Weed Science Society of America.

Control of vegetation is the variable of interest rather than the chemical treatments used.

Vegetative Sampling

In order to examine the vegetational responses to herbicide treatment, I systematically located sampling grids of 40 stations each on both plots of each study area (Figure 2). Stations were arranged in five lines of eight each[2] with centers spaced at intervals of 100 feet. A circular sub-plot of 1 mil-acre, centered at each station, was the sampling unit.

De Vos and Mosby (1969) defined seven units of measure commonly utilized in vegetative analysis. I included three, frequency, cover, and presence-absence.

Frequency is a measure of abundance. Although certain inherent disadvantages or limitations exist in using this measure (Kershaw, 1964), I judged them as minor and the method adequate. On each sub-plot I recorded the presence of one or more plants of each species as an occurrence. The frequency with which a species occurred was estimated by calculating the percentage of sub-plots on which it was

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[2] An exception to this arrangement was necessary on the study area at Maxfield Creek in order to maintain all of the sampling stations on a comparable aspect. For this reason stations were arranged in seven lines of six each (two stations were omitted on one line) on one side.

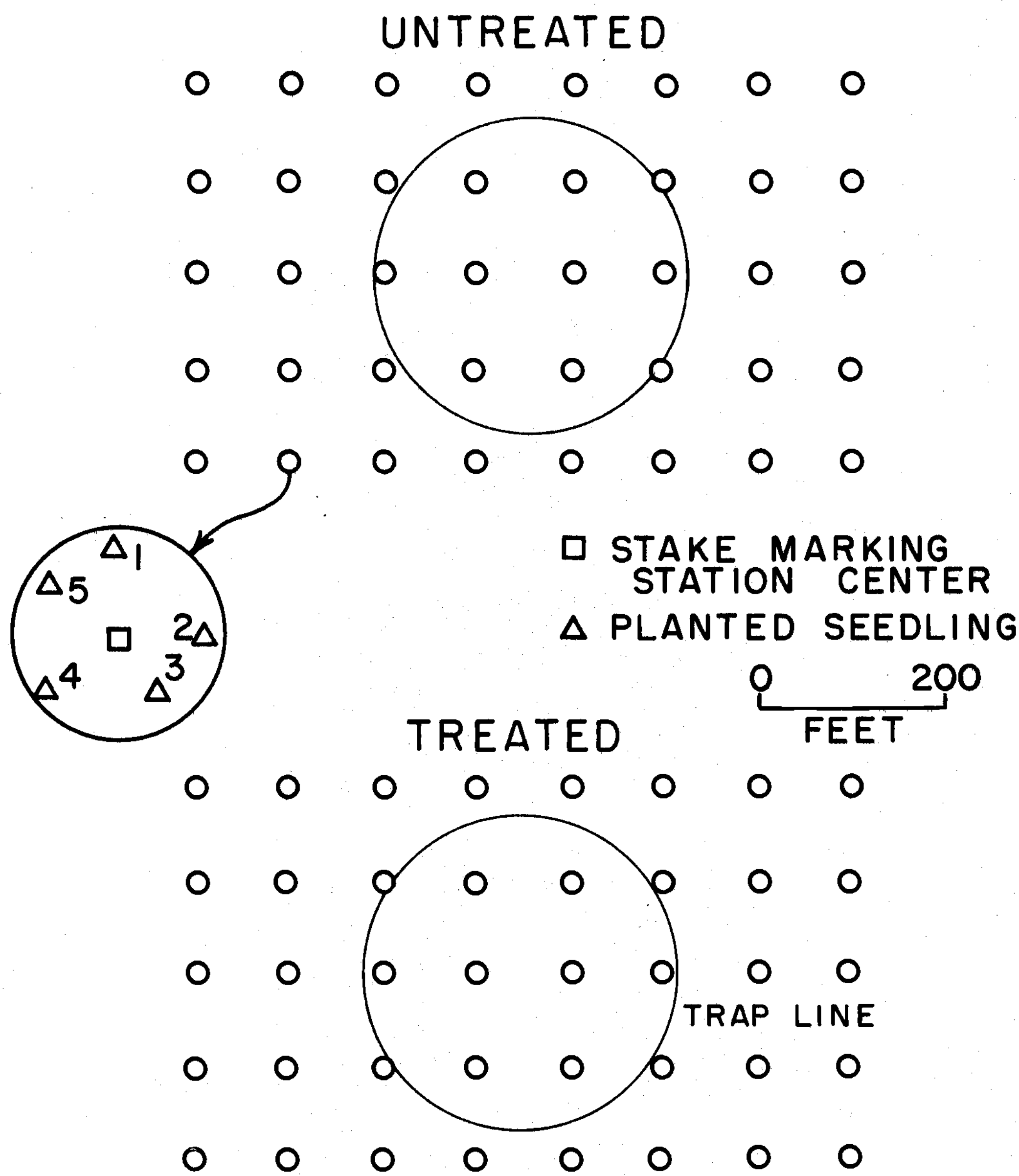

Figure 2. Diagram of the distribution of field sampling stations.

found. Initially, I attempted to examine all 40 stations on each side, but this proved too time consuming. Examination of data from two areas indicated that 10 samples per plot would give similar results to those obtained by sampling 40 stations. Therefore, the frequency of occurrence was based on 10, 1 mil-acre samples selected at random from a possible 40. Only species rooted within the 1 mil-acre sub-plots were recorded.

Realizing the value of having some measure of cover class, I grouped species into grasses, forbs, or shrubs. Cover classes were based on the percentage of a sampling sub-plot occupied by one of these groups of vegetation. I visually estimated the cover of each plant group and placed it in one of the following cover classes:

Cover class	Plant cover, percent
1	0- 5
2	5-25
3	25-50
4	50-75
5	75-100

Species found on the study areas, but not encountered on vegetation-sampling sub-plots also were recorded as present and are included in the plant list found in the Appendix.

Small Mammal Sampling

Following Calhoun's (1959) scheme, I located a circular trap-line of 40 stations near the center of each plot (Figure 2). Trapping stations were spaced at 25-foot intervals (Figure 3). Two Sherman-type small-mammal traps were placed at or near each station (Figure 4). A large welded-wire rabbit trap was placed at every other station. I sampled populations of small mammals with both mark-recapture and removal-trapping procedures.

Mark-recapture Trapping

The apparent uniformity in composition, distribution, and abundance of vegetation on each study area prior to treatment with herbicides suggested uniform habitat conditions for wildlife. Therefore, similar numbers and species of small mammals were expected. Based on the reported low toxicity of the herbicides used (George, 1961), I expected that any differences in animal abundance or relative species composition after treatment would be greatest when habitat differences became most pronounced. I also anticipated that changes in abundance of small mammals as influenced by herbicides would be gradual, increasing with time as vegetative changes became most pronounced. Any acute differences or responses after treatment would suggest that some factor other than habitat change was

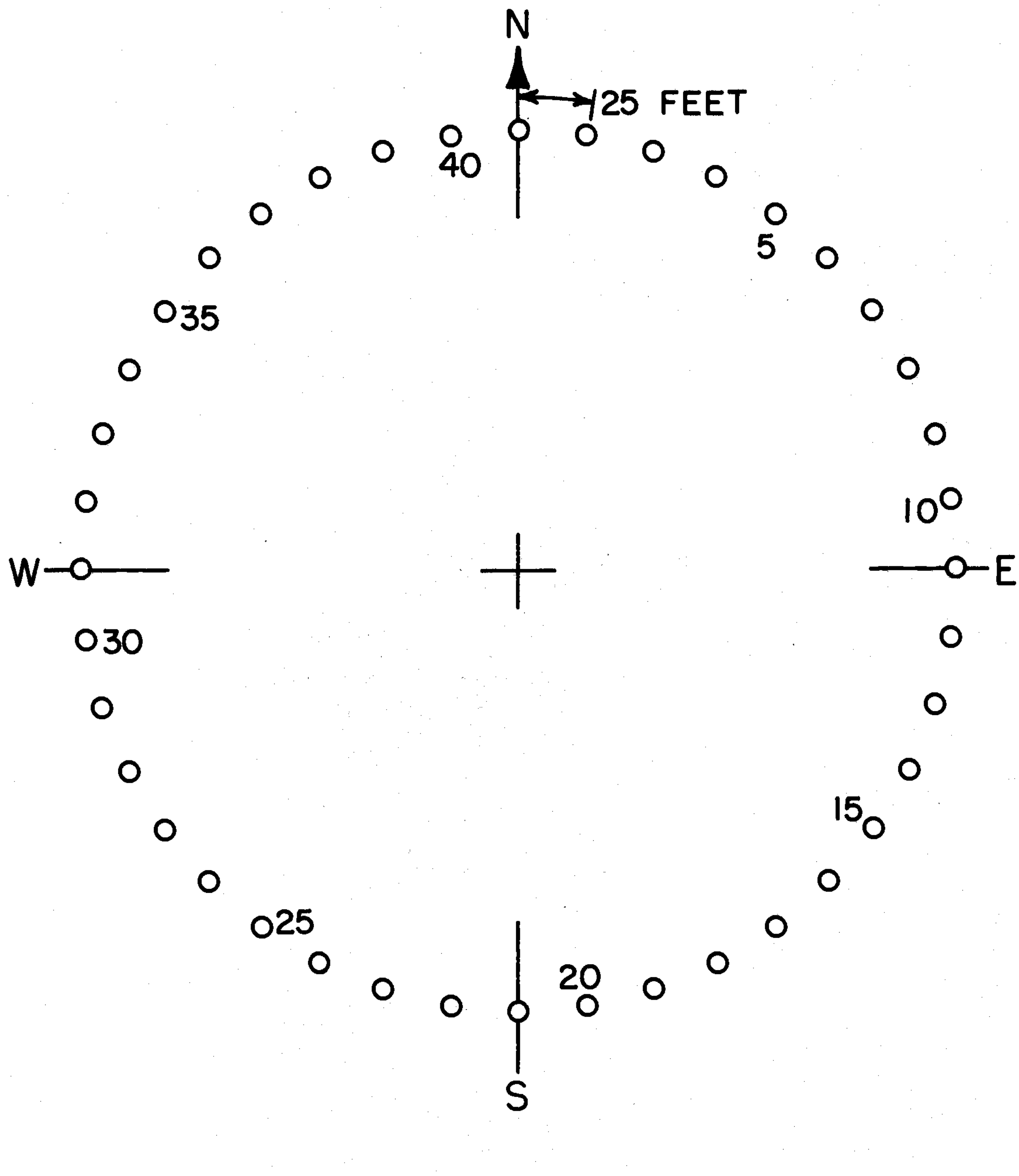

Figure 3. Diagram of the arrangement and spacing of trapping stations on the circular traplines.

Figure 4. Typical arrangement of small-mammal traps at a trapping station.

operating.

In view of these assumptions, I conducted mark-recapture trapping for two purposes: (1) to evaluate the hypothesis of similarity in small mammal abundance and composition between sides of each area prior to herbicide application, and (2) this procedure was designed to investigate whether or not acute responses to treatment occurred.

Mark-recapture trapping was conducted prior to herbicide treatments. This consisted of trapping for three nights and identifying, sexing, aging, ear-tagging, and releasing animals caught. This procedure was repeated at the time of herbicide application and at monthly intervals thereafter until removal trapping began in June of both years. Four periods of mark-recapture trapping were conducted each year.

Data from this sequence of trapping were analyzed by pairing numbers of small mammals of each species caught on treated and untreated plots from each study area and period of trapping. Student's t-distribution was used to test the hypothesis that the mean of the differences between pairs equals zero (Snedecor and Cochran, 1967).

Removal Trapping

Calhoun (1964) proposed that small mammal communities have a well organized social structure with dominant and subordinate species. He suggested that dominant species have a higher probability of capture because of some behavioral characteristic such as a large home range. Gentry _et al_. (1968) and Schamberger (1965) have obtained results supporting Calhoun's theory of dominance. Although abundance affects the expression of dominance and probability of capture, some subordinate species commonly are more numerous than dominant ones. This suggests that with mark-recapture data we will be limited in making estimates of abundance and relative species composition to the dominant species and individuals, or at least to those with the highest probability of capture.

Because of the suspected differences in probability of capture within and among species, removal trapping was utilized in censusing the small-mammal populations and in estimating the relative species composition of the communities. Removal trapping commonly results in an increased exposure to traps for subordinate species following removal of dominant animals. Calhoun (1959) and Gentry _et al_. (1968) suggested that a 30-day period of removal trapping is preferred if accurate estimates of populations and elimination of immigration effects are desired.

I conducted continuous-removal trapping for 30 days following the final period of mark-recapture trapping each year. This procedure consists of removing all mammals captured during a period of 30 days. Because catches usually decline after a week of removal trapping, traps were checked every other day after 7 days of trapping.

Several exceptions to these procedures were made. Because California ground squirrels (*Spermophilus beecheyi* (Richardson)) often disturb small mammal traps, they were captured in the large welded-wire traps and removed from the areas regardless of the trapping procedure followed. Other species of mammals were released in all instances after capture. These species were as follows: black-tailed jackrabbit (*Lepus californicus* Gray), brush rabbit (*Sylvilagus bachmani* (Waterhouse)), porcupine (*Erethizon dorsatum* (Linnaeus)), spotted skunk (*Spilogale gracilis* Merriam), and striped skunk (*Mephitis mephitis* (Schreber)).

Several graphical and mathematical methods are available for estimating population levels from removal-trapping data (Overton and Davis, 1969). All of these methods are limited to situations where all or nearly all catchable animals are removed, or where trapping success declines with increasing effort. If the accumulative number of animals removed continues to increase with trapping effort, the estimate of the population level is indeterminate. Graphical methods were advantageous, as applied to my study, because differences in rates of capture and number of animals removed can be examined visually. I followed a graphical approach described as a "Davis graph" by Overton and Davis (1969).

The small-mammal communities can respond to modifications of habitat by changes in abundance or diversity. Diversity has two main components, richness and equitability. Kricher (1972) defined richness as the number of species in a sample, and equitability as the distribution of individuals among species. Abundance also affects diversity, but this attribute is an inherent factor of both richness and equitability. Diversity is greatest when richness is high and the total number of individuals is evenly distributed among the species.

Abundance, richness, and equitability can remain constant and a community still may respond to treatment by changes in kinds of species or by shifts in the relative species composition. Overton (1971) developed an analysis program (AIDN) that allows an examination of these community responses. I followed this program to evaluate responses of the small mammal communities to herbicide induced habitat changes.

Deer Activity Sampling

My objectives in this part of the study concerned the influence of habitat manipulation on deer activity and browsing damage. To answer the questions posed by these objectives, five 2-0 Douglas-fir seedlings (mid-elevation, Willamette Valley seed source) were planted around each sampling station (i.e., 200 seedlings per plot).

Seedlings in each cluster of five were numbered in a clock-wise direction starting with the tree north of the station center. In addition to the 200 trees planted on each plot, I identified a sample of 50 established seedlings on each plot. All trees were marked with a numbered stake located 3 feet north of the seedling.

These marked seedlings were examined monthly for browsing damage. Other forms of injury such as rabbit clipping, frost damage, snow breakage, etc. also were recorded.

Deer activity was determined by systematic pellet-group counts. The stakes marking the first planted tree in each cluster were used as centers for 2 mil-acre, circular sampling sub-plots. All 40 sub-plots on each side were examined monthly and pellet-groups were counted and removed. Only groups containing more than 30 pellets were recorded. Groups falling on the boundary of the sample sub-plot were counted if the mid-point of the group fell within the circle.

Neff (1968) and VanEtten and Bennett (1965) review the major sources of error and disadvantages associated with use of this indirect method of population analysis. Because my interests involved the distribution and trend of usage by deer, an index value is adequate for evaluating differences as influenced by habitat manipulation with herbicides. Such an approach removes most of the sources of error associated with this technique.

Because of expected variation in browsing activity and pellet-group counts caused by seasonal differences in food, monthly data were combined into periods corresponding to the growing and dormant seasons for Douglas-fir. Data for 18 months, or 3 periods of 6 months each, were used in the analysis of deer activity. Analysis of variance procedures were followed to evaluate browsing damage and pellet-group data. A 3x3x2 factorial design was followed with 3 areas, 3 seasons, and 2 treatments. The three seasons correspond with two periods in the growing season and one in the dormant season. The two treatments are untreated and treated with herbicides.

RESULTS AND DISCUSSION

Vegetation

I made a reconnaissance of vegetative composition and distribution in the spring of the first year. The procedures were similar to those followed in subsequent vegetational sampling. The purpose of this reconnaissance was to examine systematically the vegetative uniformity of each area prior to herbicide application.

Results showed a uniform species composition, abundance, and distribution throughout each study site for grasses and forbs. Shrub species tended to have a more contiguous distribution and larger differences in frequency of occurrence between plots. The survey also demonstrated that vegetative conditions were similar among the three areas. However, many of the grass and forb species had not emerged by the time of this early spring examination. Given the species present at this season and the minor exceptions noted, these examinations confirmed my preliminary observations that the areas were uniform in vegetative cover and composition.

Grass was the predominant vegetation on all three study areas, with perennial grasses and forbs being most abundant. The most prevalent grasses were Elymus glaucus Buckl. (western rye-grass) and Holcus lanatus L. (velvet grass), while Hypochaeris radicata L.

(false dandelion), Senecio jacobaea L. (tansy ragwort), Chrysanthemum leucanthemum L. (ox-eyed daisy), and Iris tenax Dougl. (Oregon iris) dominated the forb component. Berberis aquifolium Pursh. (Oregon grape) and Rubus vitifolius C. & S. (trailing blackberry) were the most common shrub species.

Observations during and after application of herbicides confirmed that coverage was complete in the first year. Coverage in the second year also was excellent, although some minor skips in application occurred.

Herbicides affect the vegetative component of an ecosystem by altering one or more of the following parameters: abundance, species diversity, or spatial distribution. The homogeneity of vegetation and the uniformity of herbicide coverage suggested that changes in distribution would be of minor significance. Therefore, I was primarily interested in vegetative changes in abundance and species diversity as a result of herbicide application.

I measured plant abundance by the frequency of species occurrence. Of the 137 species identified, less than 40 occurred often enough to warrant making comparisons in this response. Tables 2, 3, and 4 contain the frequency values for these common species on the Carlson, Williams, and Maxfield units, respectively. Results indicate that grasses were affected most and shrubs least by herbicide treatment.

Table 2. Response of vegetation to treatment with herbicides as measured by the frequency of occurrence on the Carlson Creek area.

Plants	1970		1971	
	Untreated	Treated	Untreated	Treated
	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)
Grasses				
Aira caryophyllea	82.5	0	80	80
Elymus glaucus	100	50	100	80
Festuca sp.	75	0	90	70
Holcus lanatus	97.5	20	100	80
Forbs				
Campanula scouleri	55	20	60	0
Cerastium holesteoides	55	0	70	20
Crepis capillaris	75	10	70	10
Epilobium minutum	27.5	0	80	0
Galium triflorum	32.5	10	60	60
Hypochaeris radicata	97.5	80	100	100
Lotus micranthus	55	20	60	60
Luzula multiflora	72.5	0	80	0
Senecio jacobaea	95	50	100	30
Stachys rigida	55	20	60	0
Vicia americana	67.5	0	60	30
Polystichum munitum	35	40	50	20
Shrubs				
Berberis aquifolium	42.5	30	50	20
Rubus leucodermis	12.5	50	20	30
Rubus vitifolius	52.5	40	50	20

Table 3. Response of vegetation to treatment with herbicides as measured by the frequency of occurrence on the Williams Creek area.

Plants	1970		1971	
	Untreated	Treated	Untreated	Treated
	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)
Grasses				
Aira caryophyllea	62.5	0	90	20
Elymus glaucus	67.5	0	70	10
Holcus lanatus	97.5	10	100	60
Forbs				
Chrysanthemum leucanthemum	82.5	0	90	30
Crepis capillaris	50	0	20	0
Fragaria bracteata	92.5	100	100	80
Hypochaeris radicata	57.5	90	70	70
Iris tenax	32.5	30	50	30
Lotus micranthus	30	10	100	40
Luzula multiflora	25	0	80	0
Madia gracillis	32.5	0	60	0
Senecio jacobeae	77.5	20	90	0
Thermopsis gracilis	25	50	30	40
Vicia sp.	70	0	60	0
Shrubs				
Berberis aquifolium	22.5	50	40	20
Ceanothus velutinus	37.5	20	50	10
Gaultheria shallon	27.5	80	20	90
Holodiscus discolor	42.5	40	40	60
Rosa gymnocarpa	32.5	60	0	60
Rubus vitifolius	80	50	80	70
Symphorocarpos sp.	52.5	90	40	80
Whipplea modesta	90	60	100	40

Table 4. Response of vegetation to treatment with herbicides as measured by the frequency of occurrence on the Maxfield Creek area.

Plants	1970		1971	
	Untreated	Treated	Untreated	Treated
	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)
Grasses				
Aira caryophyllea	70	0	20	0
Cynosurus echinatus	50	0	80	0
Elymus glaucus	100	60	100	100
Holcus lanatus	90	10	60	10
Forbs				
Arenaria macrophylla	20	0	60	0
Chrysanthemum leucanthemum	40	0	100	40
Cirsium arvense	30	70	20	70
Fragaria bracteata	80	20	90	10
Iris tenax	80	10	90	60
Lathyrus sp.	20	40	30	60
Plantago lanceolata	40	0	70	0
Rumex acetosella	20	0	70	30
Senecio jacobeae	100	40	80	10
Vicia sp.	20	0	60	0
Shrubs				
Berberis aquifolium	0	50	10	70
Holodiscus discolor	30	80	50	40
Prunus emarginata	50	60	30	30
Rosa gymnocarpa	30	30	60	50
Rubus parviflorus	40	90	40	70
Rubus vitifolius	90	100	80	100
Symphoricarpos albus	40	20	50	20

All grasses showed a marked reduction in abundance after treatment, especially in the first year. This response was less dramatic in the second year, with two species, Aira caryophyllea L. (silvery hair-grass) at the Carlson Creek unit and Elymus glaucus Buckl. at the Maxfield Creek site, appearing unaffected.

These data show one of the disadvantages often encountered in using frequency of occurrence as a measure of plant abundance, especially when large sampling plots are used. The disadvantage is that the procedure is an insensitive indicator of small shifts in relative species abundance. For example, grasses were abundant and uniformly distributed before application of herbicides. Abundance was reduced, but these plants remained widely distributed and continued to occur in a high percentage of the samples. For the two grasses mentioned above, the sampling procedure shows that distribution was unaffected, but it fails to show the observed reduction in abundance.

It was for this reason that I made observations of cover class. Cover class values for the three major groups of plants are presented in Table 5. These data demonstrate the wide difference in abundance of grasses on untreated and treated plots.

Table 5. Estimates of abundance by cover classes for each of the major plant groups.

Areas	Year	Treatment	Plant Groups Grass	Forb	Shrub
Carlson Creek	1970	Untreated	5	2	1
		Treated	1	2	1
	1971	Untreated	5	4	2
		Treated	1	1	1
Williams Creek	1970	Untreated	3	3	2
		Treated	1	2	3
	1971	Untreated	3	5	2
		Treated	1	2	3
Maxfield Creek	1970	Untreated	5	1	3
		Treated	1	2	4
	1971	Untreated	5	1	3
		Treated	1	2	4

Forbs varied widely in their response to the herbicide treatments. Most species were reduced in frequency and cover class. Other species such as Fragaria bracteata Hel. (western wood strawberry), Galium triflorum Michx. (fragrant bedstraw), Hypochaeris radicata L., Iris tenax Dougl., and Polystichum munitum (Kaulf.) (western sword fern) were unaffected. Cirsium arvense (L.) Scop. (Canada thistle), Thermopsis gracilis How. (slender thermopsis), Lathyrus sp., and Pteridium aquilinum (L.) Kuhn. (bracken fern) increased on treated areas.

The response of shrubs to herbicide treatment is not readily apparent from examination of the data alone. Initial differences in frequency and distribution between sides of each area must be considered. Generally, shrubs were not greatly affected by treatment. Although several species exhibited extensive damage and were suppressed initially, the reduction of competition for moisture through control of grasses promoted their recovery and their vigor. The net result was a small increase in cover class values of shrub species on treated plots. Species that showed damage initially were as follows: Acer circinatum Pursh. (vine maple), Ribes sanguineum Pursh. (red-flowering currant), and Vaccinium parvifolium J. E. Sm. (red huckleberry).

Species diversity was affected on all three areas. I found a greater variety of species on untreated plots. This does not mean that herbicides eliminated any species, but rather that the abundance was so reduced that the probability of sampling was low. Differences in diversity were primarily in the forb component of the vegetation with similar species of grasses and shrubs occurring on both sides of an area.

I observed no indication of invasion by new species, although a few resistant species such as Canada thistle, trailing blackberry, and bracken fern did increase in abundance on treated plots. Although more species were identified the second year, this was probably a result of my experience and because of seasonal variation in vegetation rather than invasion of new plants. Not only was I more familiar with the plants, but a late spring in the second year resulted in both spring and summer vegetation being present during the sampling period. The majority of plant species, including all of the important species, were identified in both years.

In addition to the direct effects of the herbicide treatment, other factors influenced the vegetative response. One such factor is the shading or protection of smaller plants by logging debris and overlying vegetation. The absorption of atrazine and dalapon through the roots makes this of little importance in the case of grass control. However, the chemicals 2, 4-D and silvex which were applied to control forbs and shrubs, primarily are foliar sprays. Any sheltering that restricts the herbicides from reaching the leaves reduces the effectiveness of these chemicals. Fragrant bedstraw is an example of a plant found in micro-environments shaded by other vegetation and slash. This sheltering effect may have accounted for bedstraw having been unaffected by the herbicides.

Another complicating factor is the ability of species that produce small, abundant, wind-dispersed seeds to invade or re-establish themselves in a habitat rapidly after disturbance. This phenomenon was observed in the rapid increase of Canada thistle on the Maxfield Creek unit. This also may explain the response of false dandelion and silvery hair-grass.

Many of the forb and shrub species were dormant or had not emerged at the time of herbicide application. Oregon iris, slender thermopsis, and bracken fern along with the deciduous shrubs are examples of species that were limited in their exposure to herbicides at the time of treatment. These plants, therefore, were relatively unaffected.

Forest managers apply herbicide treatments, like the one used in this study, to reduce competing vegetation and provide environmental conditions favorable for the survival and growth of tree seedlings. The only tree species extensively examined in this study was Douglas-fir. I used the planted seedlings to evaluate survival and to assess the success of herbicide applications from the aspect of forest management.

Herbicide treatment greatly favored survival of planted Douglas-fir seedlings (Table 6).

Table 6. Percentage of recently planted Douglas-fir seedlings surviving after two growing seasons in the field.[1]

Treatment	Area		
	Carlson Creek	Williams Creek	Maxfield Creek
	Percent	Percent	Percent
Untreated	14.0	12.0	24.5
Treated	61.5	64.5	62.5

[1]Calculated from the number of live seedlings remaining from a sample of 200 seedlings on each plot.

Height measurements were taken on the sample of established seedlings. Measurements were made before application of herbicides in 1970 and at yearly intervals thereafter. The mean heights in centimeters and their 95 percent confidence limits are displayed in Figure 5.

Trees on treated plots grew more than those on untreated sides. This is evident from the spacing between consecutive means on a given plot. The results also show that seedlings responded more in the second year after release from competition.

As a forest management tool, the herbicide treatments were successful in reducing competition from other vegetation and in providing a more favorable environment for survival and growth of Douglas-fir seedlings.

Herbicides altered the habitat by changing the abundance and species diversity of the vegetation. The result was to change the habitat from one dominated by perennial grasses and forbs to one

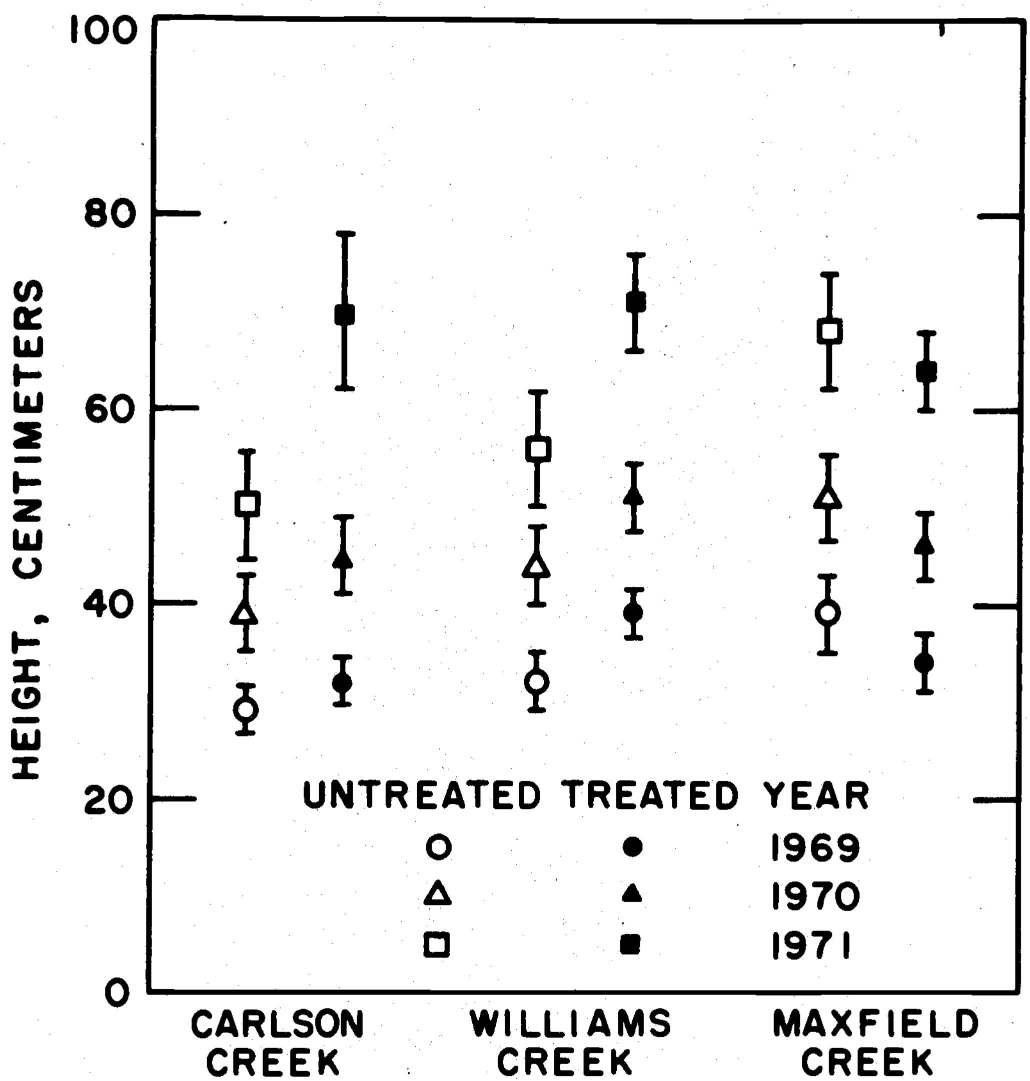

Figure 5. The initial and subsequent yearly observations of mean heights, with 95 percent confidence limits, of established Douglas-fir seedlings.

characterized by shrubs, forbs, and Douglas-fir.

Small Mammals

Mark-recapture Trapping

My mark-recapture data reflected the phenomenon of social dominance postulated by Calhoun (1964). In addition, many of the species found failed to be recaptured or occurred at such low densities that standard analysis methods (Overton and Davis, 1969) are not justified. Another problem was the high trap mortality that was associated with trapped short-tailed weasels (Mustela erminea Linnaeus) and the two species of shrews, the vagrant shrew (Sorex vagrans Baird) and the trowbridge shrew (S. trowbridgii Baird). Only two species of small mammals occurred often enough to warrant making population estimates. These were the deer mouse (Peromyscus maniculatus (Wagner)) and the creeping or Oregon vole (Microtus oregoni (Bachman)).

Since my major concern was a relative estimate of abundance and species composition, index values of these parameters are sufficient and perhaps under the above circumstances were best. I felt the best index or indicator of abundance and species composition was the number of individuals of each species caught during each of the mark-recapture periods (Table 7). Only three species occurred

Table 7. Small mammals caught during each 3-day period of mark-recapture trapping.

Species	1970								1971							
	Untreated Period				Treated Period				Untreated Period				Treated Period			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Carlson Creek																
Sorex sp.	4	4	13	4	2	3	12	5	1	8	7	2	3	6	2	2
Eutamias townsendii	-	-	-	2	-	-	-	-	-	-	1	2	-	-	-	-
Spermophilus beecheyi	-	-	2	7	-	-	1	1	-	-	-	-	-	-	1	-
Peromyscus maniculatus	16	10	15	4	14	11	15	19	4	11	10	12	3	10	9	14
Phenacomys longicadus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Microtus oregoni	1	1	6	3	-	-	2	-	1	4	2	3	-	2	-	-
Zapus trinotatus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Mustela erminea	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Williams Creek																
Sorex sp.	12	14	9	8	7	12	17	4	6	5	5	3	1	3	1	5
Neurotrichus gibbsii	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-
Eutamias townsendii	-	-	1	3	-	-	1	3	-	1	1	-	-	-	-	3
Spermophilus beecheyi	-	3	-	1	-	2	-	1	-	2	1	-	-	-	-	-
Peromyscus maniculatus	8	7	12	9	8	6	12	13	7	12	13	8	5	6	9	15
Microtus oregoni	3	10	8	27	3	16	13	10	3	6	1	1	-	2	-	-
Zapus trinotatus	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-
Mustela erminea	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Maxfield Creek																
Sorex sp.	14	4	9	6	13	8	12	5	4	9	3	14	11	2	2	1
Neurotrichus gibbsii	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Eutamias townsendii	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	1
Spermophilus beecheyi	-	-	-	1	-	-	1	1	-	-	-	-	-	-	1	-
Peromyscus maniculatus	6	13	10	9	5	10	9	17	4	3	2	2	5	4	8	7
Microtus oregoni	9	15	13	16	-	6	18	7	4	20	5	16	3	12	5	7
Zapus trinotatus	-	-	-	4	-	-	-	2	-	-	2	12	-	-	-	5
Mustela erminea	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-

with sufficient numbers to justify further evaluation and one of these actually represents two species. I encountered difficulty in identifying shrews in the first year of sampling. Therefore, data for vagrant shrews and trowbridge shrews were combined for analysis.

If the assumption of similarity in the kinds and numbers of small mammals is correct, the mean of the differences between pairs in the first period should not vary significantly from zero. No evidence was found to reject this hypothesis. This indicated that the numbers and kinds of animals were similar between sides of each area prior to herbicide application.

The paired numbers of individuals (on untreated and treated plots) of each species for all periods of mark-recapture trapping at all three areas, were examined for the influence of treatment.

For the deer mouse and shrews, the tests provided no evidence on which to reject the hypothesis that the mean of the differences equals zero. This indicated that the herbicide treatment had little effect on numbers of deer mice and shrews. The greatest differences in numbers of deer mice occurred during the fourth periods, suggesting that treated sides were more favorable for them. If, in fact, paired data from the fourth periods had been analyzed separately, significant differences between untreated and treated plots would have been suggested.

A significant difference was demonstrated between paired numbers of Oregon voles on untreated and treated plots. Indications are that the habitat was made less favorable through alteration of the vegetation with herbicides. Again, differences between pairs were greatest during the last two periods of trapping each year.

Although not numerous, the following species of small mammals were captured during mark-recapture trapping: shrew-mole (Neurotrichus gibbsii (Baird)), short-tailed weasel, striped skunk, California ground squirrel, Townsend's chipmunk (Eutamias townsendii (Bachman)), mazama pocket gopher (Thomomys monticola mazama Merriam), tree phenacomys or red tree mouse (Phenacomys longicaudus True), California vole (Microtus californicus (Peale)), Pacific jumping mouse (Zapus trinotatus Rhoads), porcupine, and the black-tailed jackrabbit.

A few Pacific jumping mice occurred on the Maxfield Creek unit during the fourth period of 1971. These meager observations do not justify conclusions, but they do suggest a response similar to that of the Oregon vole.

In summary, mark-recapture data from the first trapping periods in each year support the assumption of uniform numbers and species composition of small mammals. Data for the remaining three periods in each year do not indicate any acute responses after treatment and, in fact, show little response to herbicide application. The greatest differences were observed during the last periods of trapping when the vegetative conditions were most altered.

Removal Trapping

I censused small mammal populations with removal trapping. These data are summarized in Table 8 according to animals caught by species and by their relative proportions in the small mammal communities.

Analysis of variance shows habitat manipulation with herbicides had a significant effect on the overall response of the small mammal communities. As expected, significant differences also were observed as related to area and year of sampling. Degree and direction of community response depended on species composition. An examination of the various species populations showed that five species accounted for more than 95 percent of the animals removed during trapping. These were: *Microtus oregoni*, *Peromyscus maniculatus*, *Sorex vagrans*, *S. trowbridgii*, and *Zapus trinotatus*.

The Oregon or creeping vole represented 38.3 percent of the 1,170 animals removed. The response of this species to herbicide-induced changes in habitat was characterized by lower abundance and decreased relative position in the communities. Seventy-nine percent of the Oregon voles were captured on the three untreated plots. The response of *Microtus oregoni* on the three areas is

Table 8. Small mammals removed from the three study areas in both years and percentage composition in the small-mammal communities.

Area Species	1970				1971			
	Untreated		Treated		Untreated		Treated	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Carlson Creek								
Sorex vagrans	30	39.5	11	17.5	5	11.1	1	2.2
Sorex trowbridgii	4	5.3	15	23.8	3	6.7	7	15.2
Neurotrichus gibbsii	-	--	1	1.6	-	--	-	--
Eutamias townsendii	3	3.9	3	4.8	4	8.9	1	2.2
Peromyscus maniculatus	18	23.7	33	52.4	20	44.4	35	76.1
Microtus oregoni	19	25.0	-	--	9	20.0	1	2.2
Zapus trinotatus	2	2.6	-	--	4	8.9	1	2.2
Total	76	100.0	63	100.0	45	100.0	46	100.0
Williams Creek								
Sorex vagrans	39	21.1	38	33.0	5	16.1	3	8.1
Sorex trowbridgii	7	3.8	11	9.6	3	9.7	2	5.4
Neurotrichus gibbsii	-	--	1	0.9	-	--	-	--
Eutamias townsendii	6	3.2	4	3.5	4	12.9	4	10.8
Spermophilus beecheyi	1	0.5	-	--	-	--	-	--
Peromyscus maniculatus	30	16.2	26	22.6	12	38.7	27	73.0
Microtus californicus	1	0.5	-	--	-	--	1	2.7
Microtus oregoni	94	50.8	35	30.4	5	16.1	--	--
Zapus trinotatus	4	2.2	-	--	2	6.5	-	--
Mustela erminea	3	1.6	-	--	-	--	-	--
Total	185	100.0	115	100.0	31	100.0	37	100.0

Table 8. Continued

Area Species	1970 Untreated Number	1970 Untreated Percent	1970 Treated Number	1970 Treated Percent	1971 Untreated Number	1971 Untreated Percent	1971 Treated Number	1971 Treated Percent
Maxfield Creek								
Sorex vagrans	40	14.3	14	12.4	28	23.7	7	11.5
Sorex bendirii	-	--	-	--	-	--	1	1.6
Sorex trowbridgii	2	0.7	18	15.9	-	--	2	3.3
Neurotrichus gibbsii	-	--	1	0.9	-	--	-	--
Eutamias townsendii	-	--	4	3.5	-	--	2	3.3
Spermophilus beecheyi	1	0.4	3	2.7	-	--	-	--
Peromyscus maniculatus	25	8.9	33	29.2	2	1.7	13	21.3
Microtus oregoni	174	62.1	37	32.7	52	44.1	22	36.1
Zapus trinotatus	34	12.1	3	2.7	34	28.8	14	23.0
Mustela erminea	4	1.4	-	--	2	1.7	-	--
Total	280	100.0	113	100.0	118	100.0	61	100.0

similar to the response for one area shown in Figure 6.

About 80 percent of the 448 voles were removed in the first year of trapping. The genus Microtus is known for extreme fluctuations in population levels from year to year. Differences in numbers of M. oregoni between untreated and treated plots were not as apparent in the second year. The trend or direction of the response was similar, however, to that observed in the first year.

The Oregon vole occurs in a wide range of habitats, although it is found principally in the moist coniferous forests of British Columbia, California, Oregon, and Washington (Maser and Storm, 1970). Goertz (1964) listed this species' habitat preferences as grassy cutover areas, woodland, glade, forest, south slope, and riparian. He further found that heavy ground cover of mixed grasses and forbs produced the best trapping results. Maser and Storm (1970, p. 137) reported this species as ". . . most abundant in association with seral vegetation of recently logged or burned areas." Others report that it finds optimum conditions of habitat in the perennial grass and forb stage of forest succession.

Food requirements of the Oregon vole are not well documented, but indications are that grass, leaves, and bark constitute the bulk of the diet. This species, and most of the species in the genus, prefer dense cover, utilizing the duff of the forest floor or dense grass for their burrows and runways (Burt and Grossenheider, 1964).

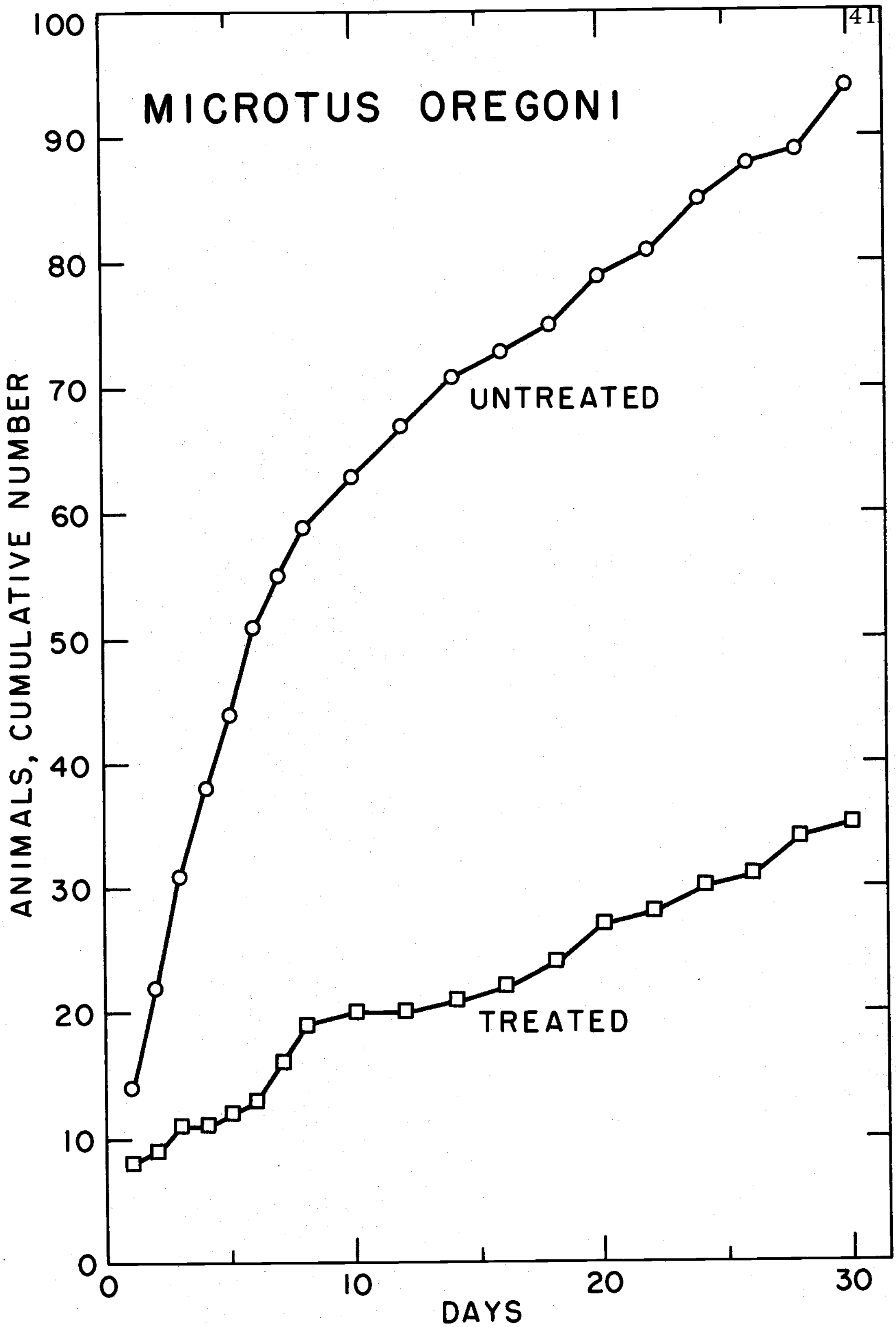

Figure 6. The cumulative number of Microtus oregoni removed from untreated and treated plots on the Williams Creek area in 1970.

Deer mice were the next most abundant species accounting for 23.4 percent of the captures. Of these 274 animals, 61 percent were taken on treated plots and 60 percent were removed in the first year. *Peromyscus maniculatus* demonstrated a response opposite to that of the Oregon vole (Figure 7). This species responded to habitat changes with increased numbers and large increases in its relative proportion of the communities.

The genus *Peromyscus*, in particular the species *P. maniculatus*, is ubiquitous in North America, occurring in a wide variety of habitats (Baker, 1968; Hooper, 1968; and Ingles, 1965). This species chiefly inhabits brushy and forested sites.

Deer mice occur abundantly in early and late stages of succession, but generally are secondary to other genera in the perennial grass stages. Baker (1968, page 109) wrote, "The paucity of *Peromyscus* in the intermediate perennial grass stage points to the fact that mice of this genus do not effectively utilize this situation, in which the dominant small rodents include such genera as grass eating *Microtus* and *Sigmodon*."

Food and cover preferences of *P. maniculatus* help explain their use of various habitats. Grains, seeds, fruits, and insects have been reported as preferred foods (Jameson, 1952), but grasses, leaves, and bark are seldom consumed (Ingles, 1965). Even large populations rarely alter plant cover, although alterations in food

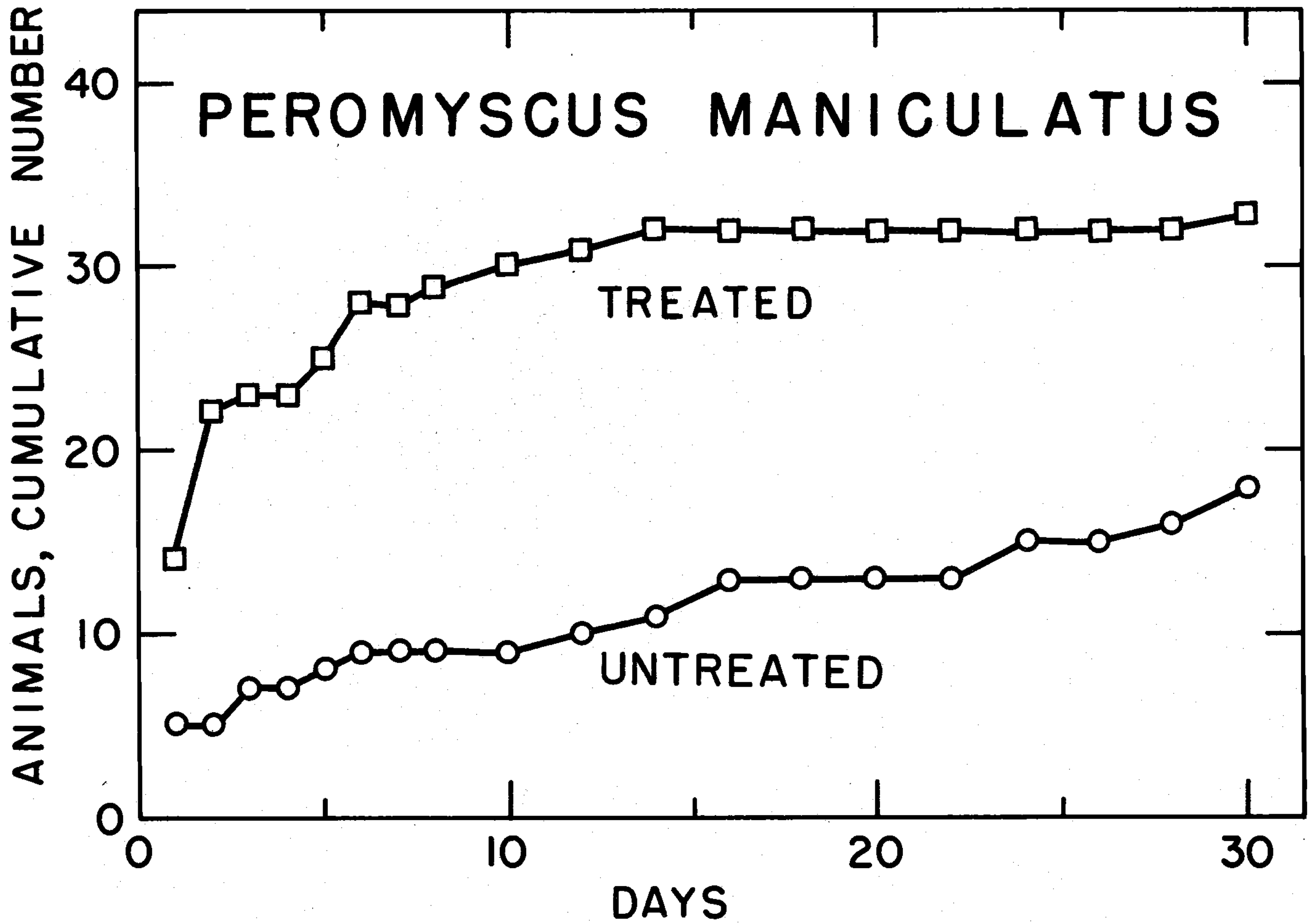

Figure 7. The cumulative number of Peromyscus maniculatus removed from untreated and treated plots on the Carlson Creek area in 1970.

resources may influence mouse density (Jameson, 1953). Gashwiler (1965, 1967) also suggested a relation between abundance of Douglas-fir seed and populations of deer mice. In regard to cover requirements, deer mice do not confine themselves to dense vegetation or runways, often moving in open situations (Baker, 1968). These preferences of food and cover are best provided in brushy and forested areas.

The two species of shrews demonstrated opposite responses to herbicide-induced habitat changes (Figure 8). Populations of Sorex vagrans and M. oregoni correlated with each other and both responded in much the same way to habitat changes. Populations of Sorex trowbridgii, however, correlated with and responded similar to the populations of deer mice.

The trowbridge shrew was the least abundant of the two shrews, accounting for only 6.3 percent of the small mammals trapped. Seventy-four percent of these 74 animals were taken on the three treated plots and 77 percent were removed in 1970.

Few studies have been made of the biology and ecology of this species. Ingles (1965) and Burt and Grossenheider (1964) described the habitat as in the litter on the floor of coniferous forests and wooded areas. Jameson (1955) reported that the trowbridge shrew is a common forest-dweller occurring sparingly in brushlands and cutovers. The diet probably consists mostly of arthropods, although

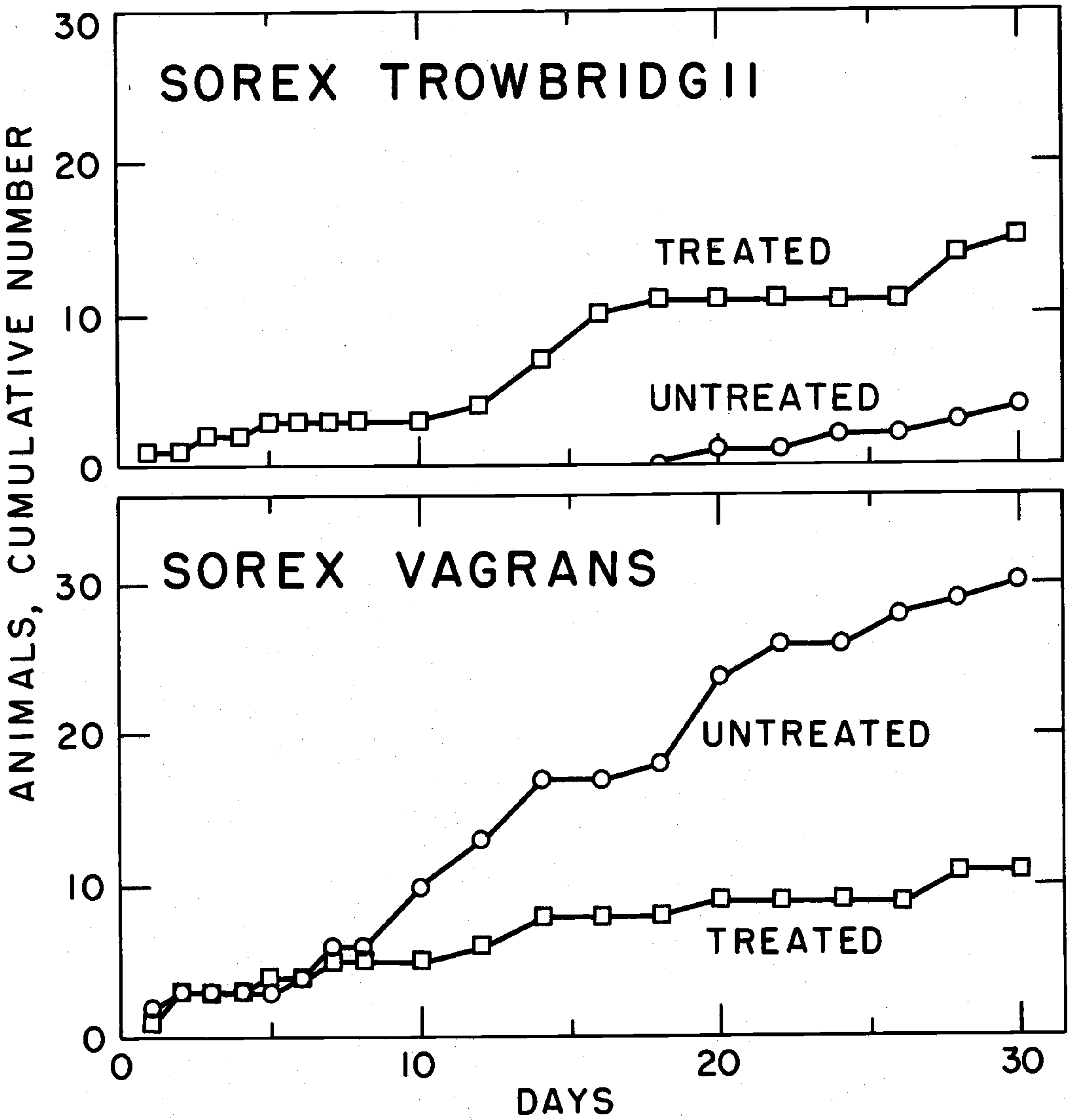

Figure 8. The cumulative number of Sorex trowbridgii and S. vagrans removed from untreated and treated plots on the Carlson Creek area in 1970.

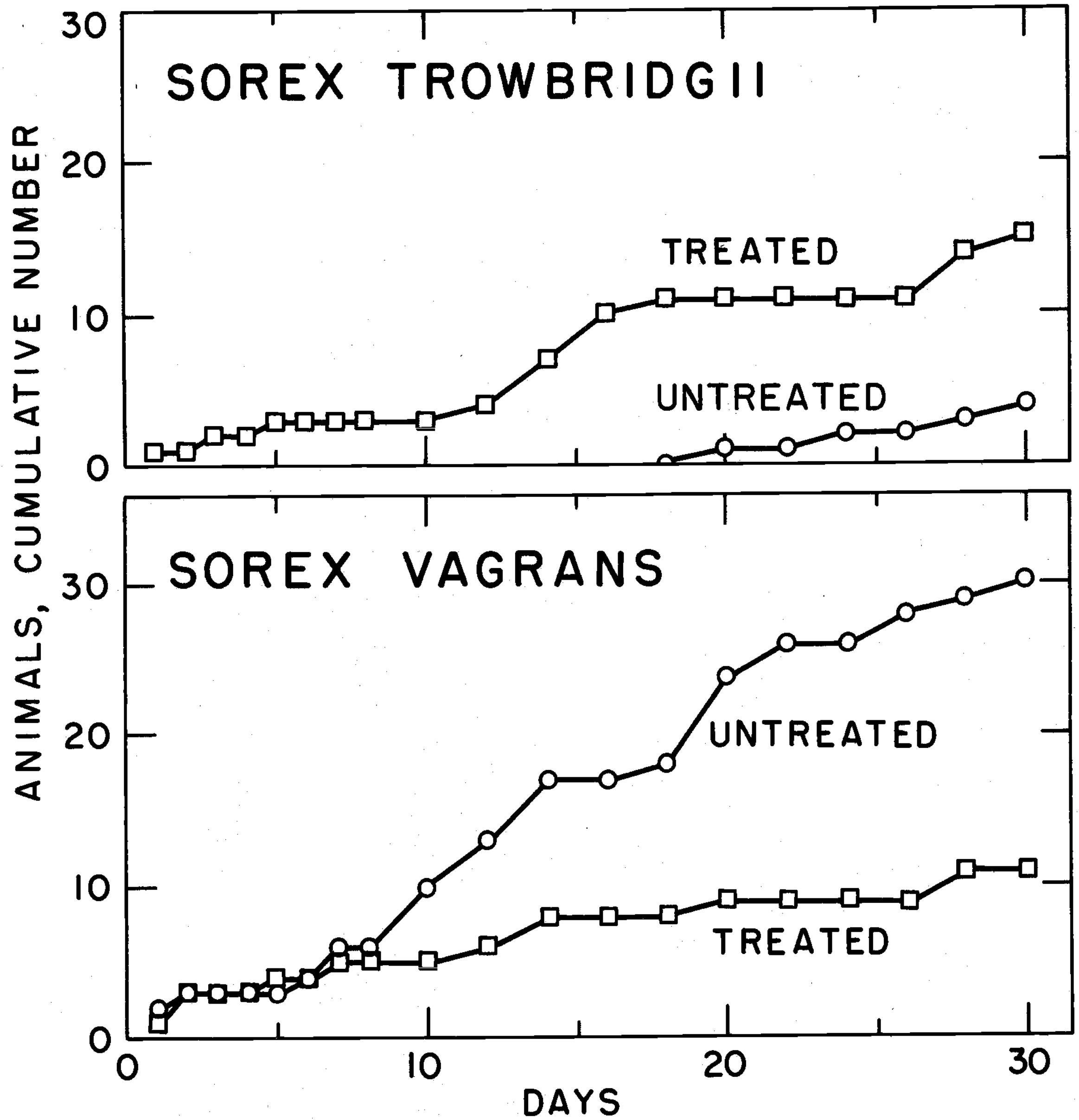

Figure 8. The cumulative number of Sorex trowbridgii and S. vagrans removed from untreated and treated plots on the Carlson Creek area in 1970.

Ingles (1965) suggested considerable plant material may be eaten, including Douglas-fir seed.

The more abundant vagrant shrew accounted for 18.9 percent of the animals removed. Sixty-seven percent of these 221 vagrant shrews were removed from untreated plots of the three study areas. Like the trowbridge shrew, 78 percent were removed the first year.

The vagrant shrew is represented by a large number of subspecies (Findley, 1955), which occur in nearly all conceivable types of habitats in western North America. The subspecies involved in this study was predominately *S. v. vagrans*. One *S. v. pacificus* also was captured. Preferred habitat for *S. v. vagrans* appears to be wet meadows. Findley (1955, page 24) stated that, "The ecological requirements of jumping mice, genus *Zapus*, and the subspecies of *Sorex vagrans* that dwell in hydroseres are essentially similar."

Zapus trinotatus accounted for 8.4 per cent of the animals removed. However, this species comprised a significant proportion of the community only at the Maxfield Creek area. Of the 98 jumping mice trapped, 87 percent were captured at Maxfield Creek, 82 percent were taken on untreated plots of all three areas, and 54 percent were removed in the second year. This was the only species to have more individuals removed in 1971 than in 1970. The Pacific jumping mouse responded to treatment with reduced abundance in much the same pattern as that of *M. oregoni* and S. *vagrans*

(Figure 9).

Pacific jumping mice occur primarily in wet meadow situations, especially near a forest edge. Burt and Grossenheider (1964) described the habitat of the Pacific jumping mouse as including wet marshy areas, open meadows, and woods. Food consists almost entirely of seeds of wild grasses (Ingles, 1965).

Eutamias townsendii represented 3 percent of the catch. Chipmunks showed no consistent response and they were not abundant on any of the areas studied. This species appears to prefer forested and brush-dominated sites. Seeds and fruits constitute the bulk of its diet.

Certain species occurred together with greater frequency or higher correlation. This suggests similar habitat preferences for these groupings, but a lack of direct competition or overlapping niches. Two groups were evident, one composed of *M. oregoni*, *S. vagrans*, and *Z. trinotatus* and a second group that contained *P. maniculatus*, *S. trowbridgii*, and *E. townsendii*. All of these species frequently occur together, however, certain ones correlate higher with each other than with other species.

The alteration of vegetation on these sites from perennial grasses to shrubs and forbs would improve the carrying capacity of the habitat for deer mice, trowbridge shrews, and possibly chipmunks. This change in vegetation would have an adverse effect on

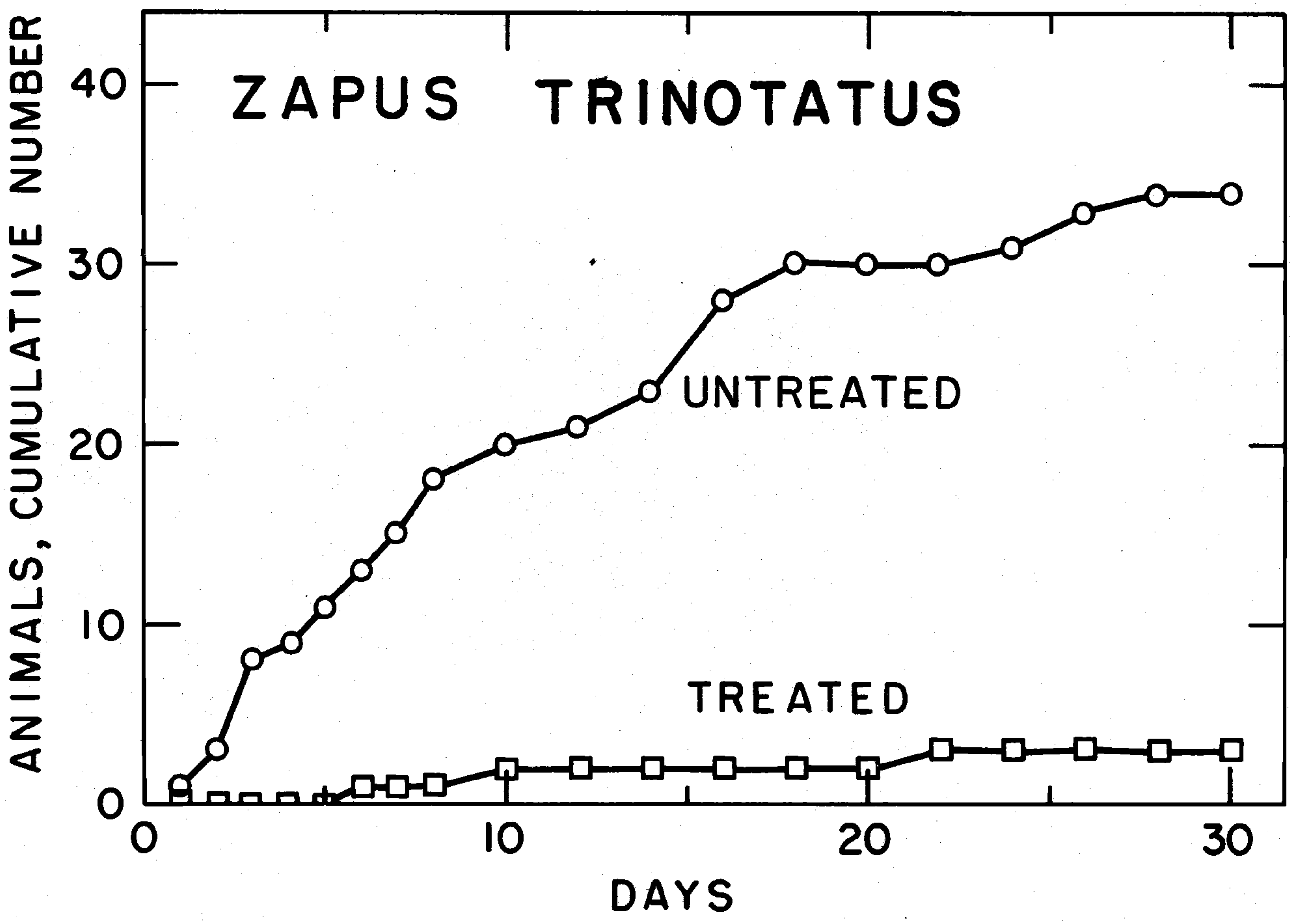

Figure 9. The cumulative number of Zapus trinotatus removed from untreated and treated plots on the Maxfield Creek area in 1970.

the carrying capacity for the Oregon vole, vagrant shrew, and jumping mouse.

Where M. oregoni was the most abundant species, the community response in numbers paralleled that of the vole. Where the Oregon vole was not abundant, the response was small. The responses of the small-mammal communities depended on the relative composition of each species.

I found differences in diversity, as measured with Simpson's D-Square, to be associated with equitability rather than richness. Of the 11 species sampled during removal trapping, 6 species accounted for more than 98 percent of the animals captured. The remaining 5 species contributed little to the estimates of diversity. Differences in richness were generally attributable to infrequent captures of these 5 uncommon species. The 6 species that were abundant enough to influence diversity were present on all areas. Eight species were found on both treated and untreated plots. Only one species, Mustela erminea, was found on untreated plots only; and two species were caught only on treated sides, Sorex bendirii and Neurotrichus gibbsii. Species richness was, for practical purposes, quite uniform among areas and between years and treatments.

These conclusions are based on removal trapping data only. When mark-recapture and removal data are combined, differences in species richness and representation are indicated. Presence or absence of species is presented in Table 9.

The small mammal community at the Williams Creek area demonstrated the greatest variety of species, 15. Twelve species were found at the Carlson Creek unit, and 11 species at the Maxfield Creek site. Communities on treated plots exhibited slightly more variety, as did communities sampled in the second year. Ten of the 18 species were found on all three study areas, 11 occurred on both treated and untreated plots, and 13 were captured in both years.

These differences, however, are not very important in that most resulted from single captures. A good example is that of the pocket gopher, which is a species unlikely to be captured with the trapping techniques I followed. Another example is that of the black-tailed jackrabbit, which was observed on both sides of the Williams Creek area, but was seldom captured and then only on the treated plot. Another species, Phenacomys longicaudus True, is primarily arboreal (Maser and Storm, 1970) and its capture probably represented an unusual visitor to the area. If these and other species represented by single or infrequent captures are disregarded as inconclusive of real differences in richness, then apparent differences disappear. Even including these differences, the influence of richness on community diversity is negligible.

The relative distribution of individuals within a community,

Table 9. Occurrence of small-mammals by area, year, and treatment.

Species	Areas			Years		Treatments	
	Carlson Creek	Williams Creek	Maxfield Creek	1970	1971	Untreated	Treated
Sorex vagrans	X	X	X	X	X	X	X
Sorex bendiri	-	-	X	-	X	-	X
Sorex trowbridgii	X	X	X	X	X	X	X
Neurotrichus gibbsii	X	X	X	X	X	-	X
Sylvilagus bachmani	-	X	-	-	X	X	X
Lepus californicus	-	X	-	X	X	-	X
Eutamias townsendii	X	X	X	X	X	X	X
Spermophilus beecheyi	X	X	X	X	X	X	X
Thomomys monticola mazama	X	-	-	X	-	-	X
Peromyscus maniculatus	X	X	X	X	X	X	X
Phenacomys longicaudus	X	-	-	-	X	X	-
Microtus californicus	-	X	-	X	X	X	X
Microtus oregoni	X	X	X	X	X	X	X
Zapus trinotatus	X	X	X	X	X	X	X
Erethizon dorsatum	-	X	-	X	X	-	X
Mustela erminea	X	X	X	X	X	X	X
Spilogale gracilis	-	X	-	-	X	X	X
Mephitis mephitis	X	X	X	X	X	X	X
Total	12	15	11	14	17	13	16

X Present

\- Absent

that is, the equitability among the six abundant species described previously affects diversity estimates. "Simpson's Diversity Index" values (Table 10) were used to evaluate the community response.

Table 10. Simpson's diversity index values for the small-mammal communities.[1]

Year	Area					
	Carlson Creek		Williams Creek		Maxfield Creek	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
1970	.7206	.6359	.6678	.7366	.5704	.7640
1971	.7299	.3960	.7680	.4456	.6659	.7562

[1]Index values of diversity range from a theoretical maximum diversity of 1.0 to a minimum of 0.

The small-mammal communities at Williams Creek appeared most diverse and those at the Maxfield Creek area least so. Communities on untreated plots generally were more diverse, and those in 1970 were only slightly more equitable than communities in 1971.

These measures of diversity indicated that herbicide-induced vegetative changes decreased community diversity at the Carlson Creek area, but increased it at the Maxfield Creek site. The community of small mammals on the Williams Creek unit responded much like those on Maxfield Creek in 1970 and similar to those on Carlson Creek in 1971. Not only was this pattern of response indicated, but similar values of diversity suggested similarity between small-mammal communities on the Williams Creek and Maxfield Creek units in 1970, and on the Carlson Creek and Williams Creek areas in 1971.

Realizing that two communities can be quite different but possess the same estimate of diversity, a similarity index (Overton, 1971) was used to evaluate the community structure and this pattern of diversity. The data (Table 11) show that, in fact, the small-mammal community at the Williams Creek area was most similar to that on the Maxfield Creek area in 1970, and correlated with the small-mammal community on the Carlson Creek area in the second year. Results indicate that small-mammal communities on the Carlson Creek and Maxfield Creek sites were least alike with regard to community structure and response to changes in habitat.

Microtus oregoni was the most abundant member of the small-mammal communities on the Maxfield Creek area in both 1970 and 1971. The community at the Williams Creek area in 1970 also possessed a similar community structure. Because of the large percentage this species represented of these communities, diversity was low. The effect of habitat manipulation with herbicides was to reduce the numbers and relative abundance of Oregon voles. A more equitable distribution of individuals among the species resulted, and diversity of these communities was increased.

Communites at the Carlson Creek area, however, were

Table 11. Similarity index (Overton, 1971) of the small-mammal communities.[1]

Locations of communities		Communities (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Carlson Creek, Untreated, 1970	(1)	1.00											
Carlson Creek, Treated, 1970	(2)	.65	1.00										
Carlson Creek, Untreated, 1971	(3)	.76	.87	1.00									
Carlson Creek, Treated, 1971	(4)	.50	.94	.89	1.00								
Williams Creek, Untreated, 1970	(5)	.83	.38	.68	.33	1.00							
Williams Creek, Treated, 1970	(6)	.98	.65	.78	.50	.90	1.00						
Williams Creek, Untreated, 1971	(7)	.81	.89	.98	.86	.68	.82	1.00					
Williams Creek, Treated, 1971	(8)	.54	.92	.90	.98	.33	.53	.88	1.00				
Maxfield Creek, Untreated, 1970	(9)	.68	.19	.56	.17	.96	.76	.53	.16	1.00			
Maxfield Creek, Treated, 1970	(10)	.82	.73	.89	.68	.88	.90	.89	.65	.79	1.00		
Maxfield Creek, Untreated, 1971	(11)	.70	.14	.49	.08	.85	.73	.48	.07	.91	.66	1.00	
Maxfield Creek, Treated, 1971	(12)	.75	.47	.80	.48	.88	.79	.76	.46	.89	.86	.90	1.00

[1] Similarity index is analogous to correlation. Perfect similarity equals 1.00 and no similarity equals 0.0, based on the relative proportion each species comprises of each community.

characterized by equitable distributions of individuals within the species populations. Habitat changes affected populations of _M. oregoni_ and _S. vagrans_ adversely and _P. maniculatus_ favorably, resulting in communities composed largely of deer mice. The small mammal community at the Williams Creek area in 1971 had a community structure similar to those on the Carlson Creek area. These communities were not very equitable in that deer mice comprised the major proportion of the communities. This explains the observed reduction in community diversity after herbicide treatment at Carlson Creek in both years and at Williams Creek in the second year.

In summary, the relative species composition determined the degree and direction of community response to habitat changes induced with herbicides. Those species of small mammals commonly associated with grass or meadow situations responded with reduced numbers and relative position in the communities. Species of mammals that do not find optimum habitat conditions in grass or meadow situations responded to treatment with increased abundance.

Deer Activity

Pellet-group Counts

Counts of deer pellet groups are summarized in Table 12 and graphically presented in Figure 10. An analysis of variance,

Table 12. Monthly counts of deer-pellet groups on untreated and treated plots of the three study areas.

Season	Month	Carlson Creek		Williams Creek		Maxfield Creek	
		Untreated	Treated	Untreated	Treated	Untreated	Treated
Growing Season							
	May, 1970	6	2	7	0	6	7
	June	13	29	7	17	2	11
	July	4	9	2	16	5	23
	August	1	2	3	19	1	9
	September	0	5	4	12	0	10
	October	0	10	3	27	2	15
Dormant Season							
	November	10	6	16	20	7	16
	December	-(11)[1]	-(7)[1]	30	18	2	5
	January, 1971	33(22)[1]	35(28)[1]	49	49	5	33
	February	25	19	34	17	4	11
	March	28	11	11	25	7	28
	April						
Growing Season							
	May	15	11	9	17	6	4
	June	17	7	24	4	12	16
	July	37	13	25	26	1	6
	August	4	18	7	15	7	19
	September	10	25	9	24	0	12
	October	4	7	5	23	4	17

[1]During December, snow conditions prevented counting and removing pellet groups. January counts, therefore, represent the pooled pellet groups for December and January. Missed values were calculated as follows:

$$\frac{30}{79} + \frac{2}{7} \; / \; 2 = .33, \quad (33)(.33) = 22, \quad 33 - 22 = 11.$$

The calculated values are in parentheses.

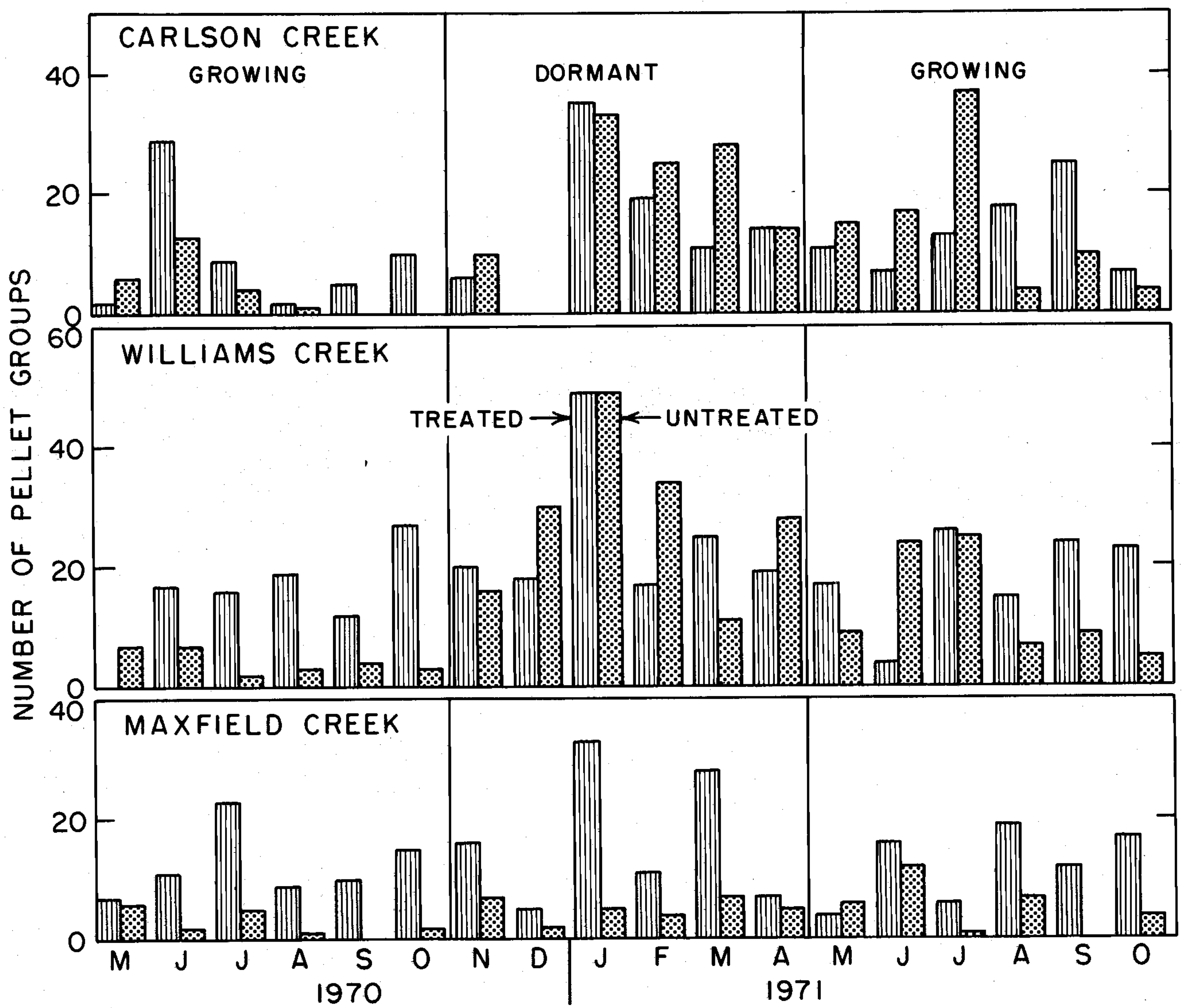

Figure 10. Monthly counts of deer-pellet groups on untreated and treated plots of the three areas.

performed on the logarithms of these observations, showed significant differences in pellet-group counts among areas and seasons as expected. However, no significant difference was indicated for the effect of treatment alone. Significant interactions were suggested, indicating that area and season must be considered when evaluating the effect of herbicide-induced changes in habitat on the activity of deer (Tables 13 and 14; Figure 11).

Patterns of seasonal use in relation to changes in habitat were evident. During the growing seasons, significantly more pellet-groups were counted on treated plots than on untreated plots, which suggests greater use of these altered habitats by black-tailed deer. Pellet-group counts taken during the dormant period were higher on all plots, but differences between treated and untreated plots were neither significant nor readily apparent.

During the second year of observations, 1971, the uniform distribution of activity, as measured by pellet-group counts, carried over into the spring and early summer. This variation in the seasonal pattern of use corresponded with the late spring and bud burst experienced in 1971.

The effect of changes in vegetation on deer usage also depended on area. Generally, the pattern described previously was exhibited on the Carlson Creek and Williams Creek areas. The main difference was the greater abundance of pellets on the Williams Creek area.

Table 13. Two-way table of the mean number of deer-pellet groups for factors of season and treatment.

Seasons	Untreated		Treated		Row	
	Total	Mean	Total	Mean	Total	Means
Growing	66	3.7	223	12.4	289	8.0
Dormant	308	17.1	333	18.5	641	17.8
Growing	196	10.9	264	14.7	460	12.8
Column Total	570		820		1390	
Interaction Means	10.5		15.2			12.9

Table 14. Two-way table of the mean number of deer-pellet groups for factors of area and treatment.

Area	Untreated		Treated		Row	
	Total	Mean	Total	Mean	Total	Means
Carlson Creek	221	12.3	223	12.4	444	12.3
Williams Creek	273	15.2	348	19.3	621	17.2
Maxfield Creek	76	4.2	249	13.8	325	9.0
Column Total	570		820		1390	
Interaction Means	10.5		15.2			12.9

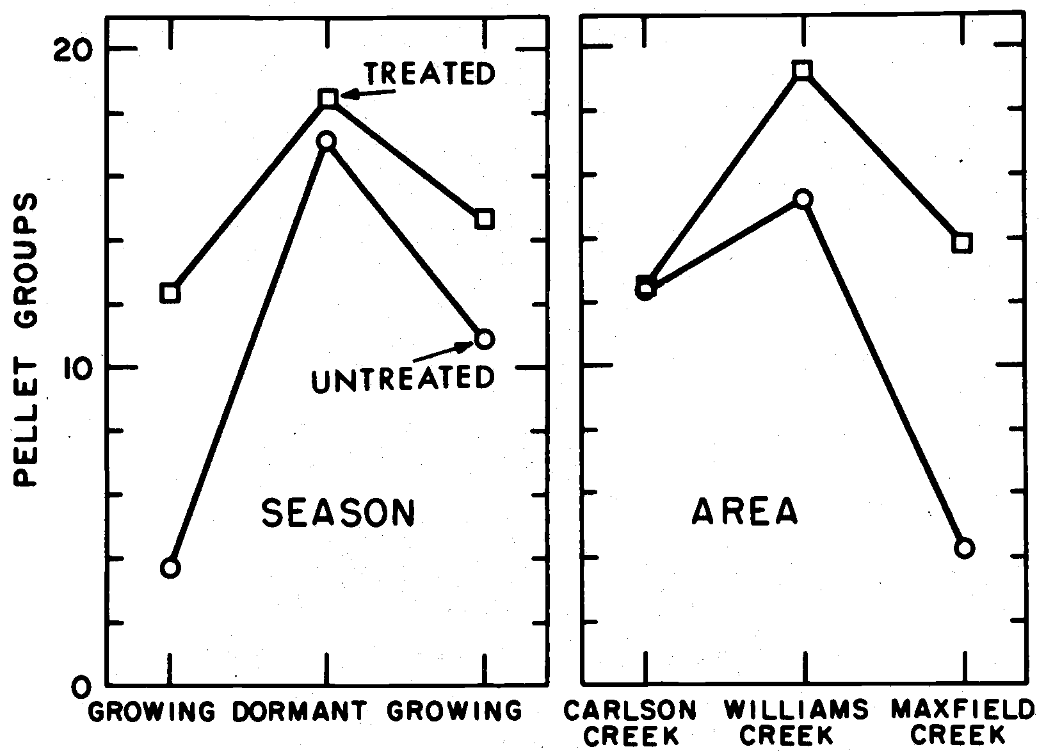

Figure 11. The mean number of deer-pellet groups for factors of season and treatment and area and treatment without the influence of area or season, respectively.

The seasonal pattern of pellet-group counts at the Maxfield Creek area was similar, but more activity occurred on the treated plot throughout the study.

Shrubs, especially trailing blackberry, were abundant and a more important component of the vegetation at Maxfield Creek than at the other two areas. After treatment, trailing blackberry responded with increased vigor and abundance. This species is a preferred food of black-tailed deer (Crouch, 1964).

The greatest differences in vegetation between treated and untreated plots might be expected to occur soon after treatments, that is, during the growing seasons. The increased vigor of shrubs observed on treated plots would tend to increase the favorableness or carrying capacity of these areas for deer.

The greater number of pellet-groups counted during the dormant season suggests that these areas were primarily wintering grounds. Although activity was greater during this season, it was also more evenly distributed. Minimal differences in vegetation might be expected during the dormant season. If this were so, the differences in favorableness of plots also would be minimal and differences in pellet-group counts would not be significant.

In summary, pellet-group counts indicate that changes in habitat affected the seasonal use by deer more than the overall use. The net result of herbicide application was to improve the habitat for black-tailed deer.

Occurrence of Browsing

Analysis of the browsing data revealed similar results for samples of both recently-planted and established seedlings. No significant difference in the percentage of seedlings injured by deer browsing was indicated due to the effects of changes in habitat. The only factor appearing to influence significantly the occurrence of browsing was season.

Browsing of established seedlings revealed two principal periods of deer feeding activity (Figure 12). The first period of intensive browsing began with bud burst and lasted about one month. A second period of frequent browsing occurred during the winter months of the dormant season. The greatest amount of seasonal activity, as measured by the mean percentage of trees browsed one or more times each month, occurred during the growing seasons.

Recently-planted seedlings, however, sustained the heaviest injury during the dormant season, especially in the late fall (Figure 13). A period of increased spring activity also was indicated, but browsing was not as extensive as that observed on established seedlings.

Recently-planted seedlings of Douglas-fir were partially protected by other vegetation from browsing during the growing seasons.

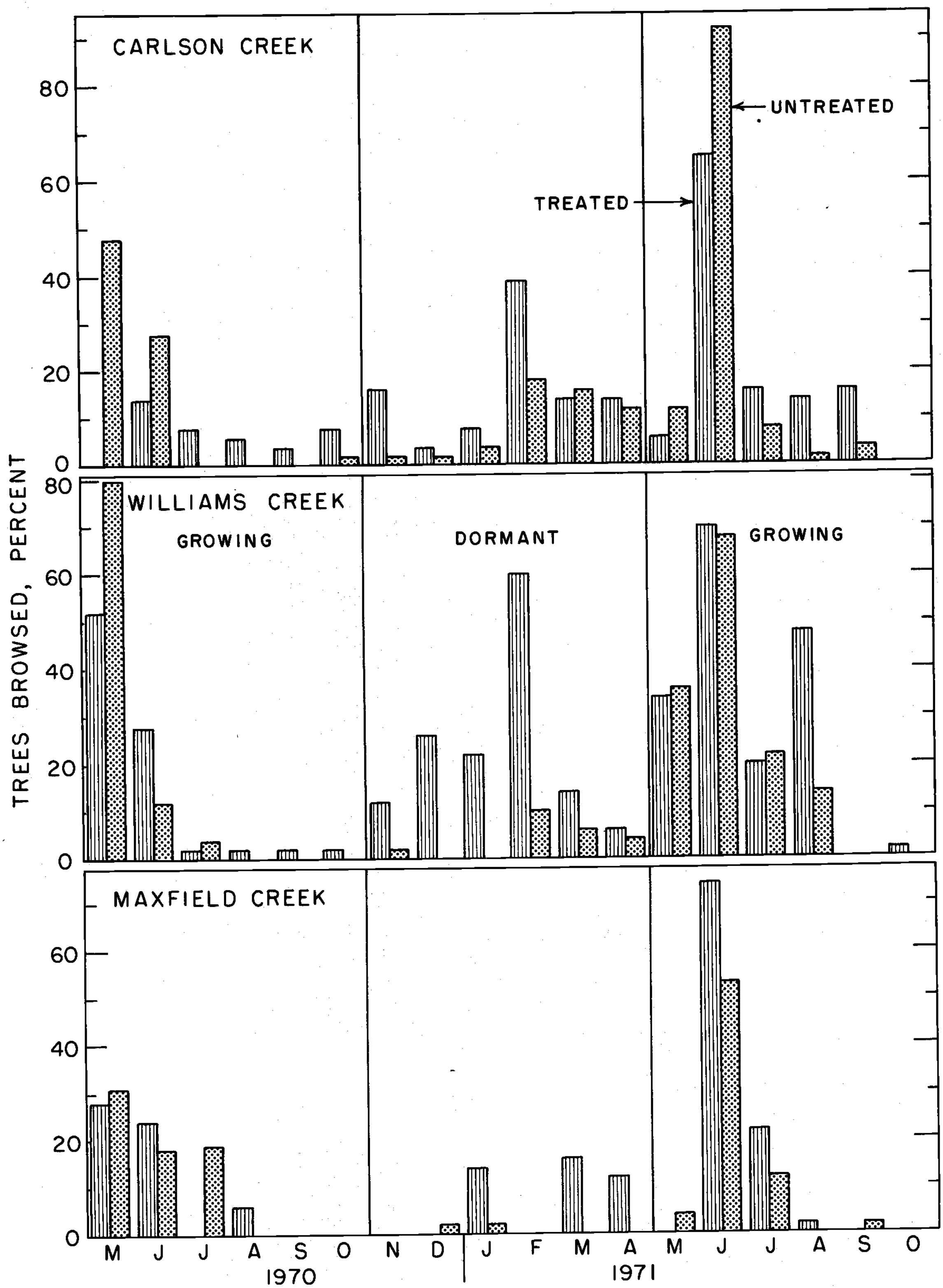

Figure 12. Percentage of established Douglas-fir seedlings browsed by black-tailed deer one or more times each month.

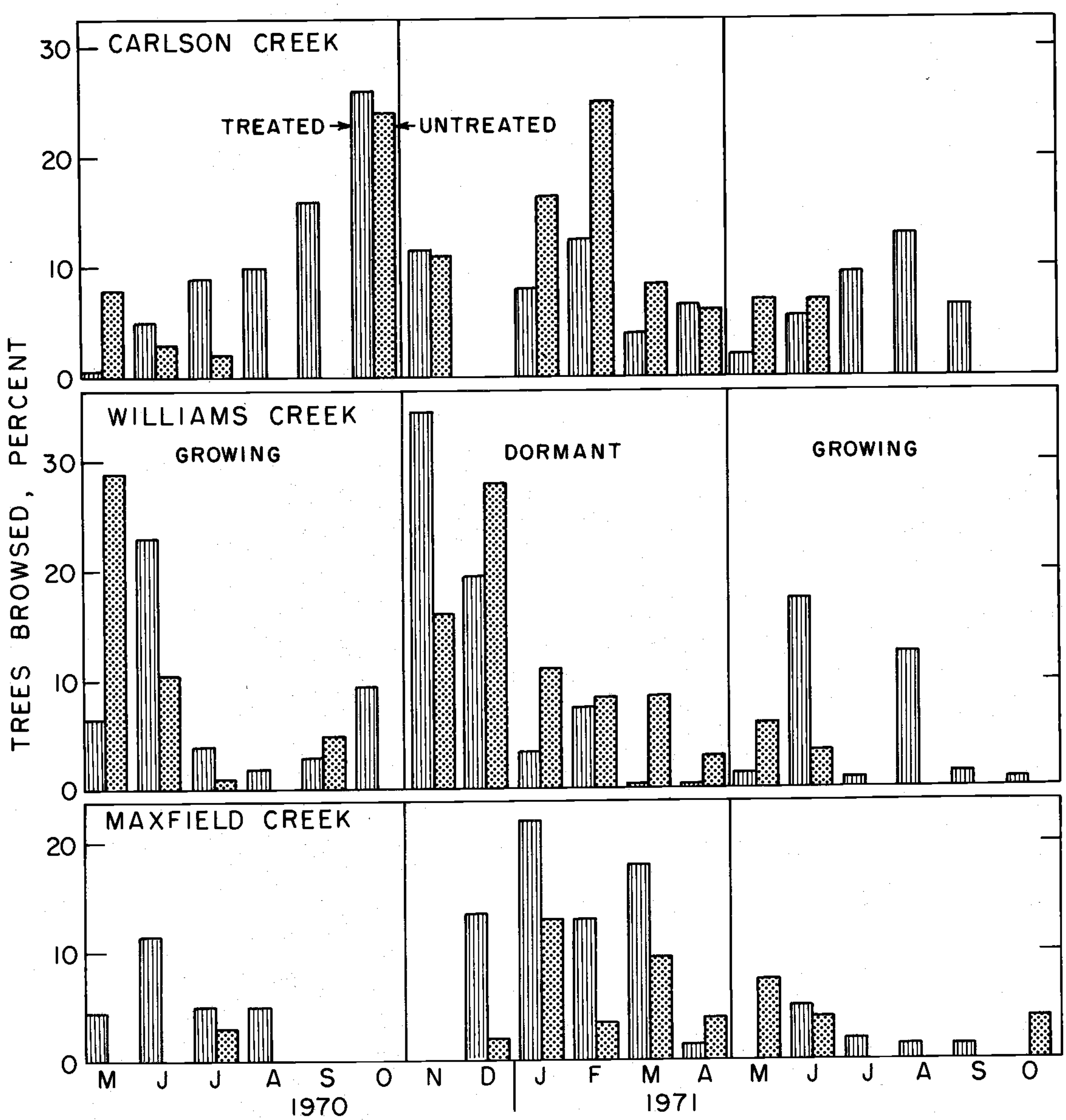

Figure 13. Percentage of recently-planted Douglas-fir seedlings browsed by black-tailed deer one or more times each month.

Even on treated plots, substantial protection was afforded by shrubs and ferns. Allen (1969) and Dimock (1970), on sites supporting dense cover of salmonberry and bracken fern, respectively, found that Douglas-fir was not readily browsed until seedlings reached a height of 30 to 36 inches. At this height, terminal shoots were beginning to occur in and above the upper layer of vegetation. Crouch (1964) also found a negative relationship between mean height of understory vegetation and browsing incidence. The established seedlings, which were larger, did not have this kind of protection and were, therefore, available at all seasons.

This protective cover was lost during the dormant season with the die-back and loss of foliage experienced by other vegetation. As expected, the mean percentages of trees browsed were similar for both samples of seedlings during the dormant season.

This pattern of browsing observed on established seedlings is not uncommon. In western Washington, Crouch (1968) found intensive browsing commenced with bud burst and lasted only a short time. Others (Browning and Lauppe, 1964) have observed similar patterns of spring browsing. It is interesting to note that this spring browsing appears unrelated to the availability of other preferred plant species.

Winter browsing, however, does appear affected by the availability of other preferred vegetation (Crouch, 1964). Herbaceous forage is highly preferred by deer, but when not available, Douglas-fir is preferred to most other woody browse. Although browsing normally increases in winter, it is usually not as intensive as in the spring. Extensive winter injury would be more likely during hard winters when other forage is scarce.

Although more browsing may occur during the spring, the severity of damage to height growth is another question. My study was not designed to examine quantitatively this aspect of deer browsing, but I judged that suppression of height growth was most severe as a result of browsing during the dormant season. Swanson (1970) studied elk and deer browsing combined and found browsing of terminals during the dormant season had a greater effect on retarding height growth Loss of the terminal shoot by browsing during the spring is often compensated for by a lateral assuming dominance and thereby minimizing the suppression of growth.

Trends, although not statistically different, in browsing among areas and between treated and untreated plots occurred. The highest mean percentage of trees browsed occurred at the Williams Creek area. The least injury was sustained by seedlings at Maxfield Creek.

Seedlings on treated plots received more browsing than those on untreated plots. These trends in deer activity suggested by the distribution of browsing agree with the trends in deer activity suggested by pellet-group counts.

The major influence in browsing by deer is their numbers. Although I found no marked correlation between pellet-group counts and occurrence of browsing, my observations support the importance of numbers. Many other environmental factors, as reviewed by Crouch (1969), modify the importance of deer numbers and the amount of browsing.

One of the most intriguing aspects of the interaction between wildlife and herbicides is the possibility of alleviating or controlling animal damage through habitat modification. Perhaps the outstanding example of control of animal numbers by environmental manipulation is a study of the effects of 2, 4-D on the food supply and abundance of pocket gophers on rangelands in Colorado (Keith et al., 1959; Tiejen et al , 1967). These investigators showed that a reduction in density of pocket gophers, after herbicide treatment of weedy rangeland, was caused by a reduction of perennial forbs (an abundant food source of gophers). Lawrence (1967, page 91) stated,

> To utilize an ecological approach to wildlife damage control requires basic information concerning food preference, habitat requirement, seasonal activity patterns for the animal as well as detailed information on the ecology of the vegetative type in which control would be attempted.

Ecological control of deer browsing in western Oregon through habitat manipulation may be possible, but more information on deer and their habitat requirements is needed.

SUMMARY AND CONCLUSIONS

Use of herbicides to control vegetation that competes with forest regeneration for water, light, nutrients, and space is a common tool of forest managers. This practice has profound effects on habitats occupied by wildlife, and in turn this practice may affect the impact of animal damage to forest regeneration.

The purpose of this study was to examine the impact of herbicide-induced vegetational changes on usage of forest lands by wildlife. Specific objectives included the following: (1) to study the effects of herbicide application on the vegetation, (2) to study the effects of herbicide-induced vegetational changes on the composition and abundance of small mammals, and (3) to study the effects of habitat changes on the activity of black-tailed deer and on the occurrence of browsing damage to Douglas-fir seedlings.

Three areas in western Oregon were selected for study. All were large clear-cuttings with a dense cover of herbaceous vegetation and were poorly stocked with Douglas-fir.

Half of each area was treated with a combination of herbicides. Atrazine and dalapon were used to control grasses, and 2, 4-D and silvex were applied for control of broad-leaved vegetation. Chemicals were applied in the spring prior to bud burst.

Extensive surveys were made to evaluate the responses of the vegetation to treatment. Mark-recapture and removal trapping were used to sample populations of small mammals for evaluation of their responses to herbicide-induced vegetative changes. Usage of areas by black-tailed deer was examined by monthly counts of pellet groups. The occurrence of browsing damage to Douglas-fir seedlings also was recorded monthly. Recently-planted and established seedlings were examined to evaluate the effects of habitat manipulation on browsing incidence.

Grass was the major component of the vegetation on all three study areas. Vegetative changes as a result of treatment were pronounced. The most important results were a reduction in number of species, chiefly of grasses and forbs, and in ground cover on treated plots. Survival and growth of Douglas-fir, and growth of most shrubs also were greater on treated areas.

Five species of small mammals occurred with sufficient abundance to justify evaluating their responses to these changes in vegetation. The five species were: the Oregon vole, deer mouse, vagrant shrew, trowbridge shrew, and Pacific jumping mouse.

Mark-recapture data demonstrated that the kinds and numbers of small mammals were similar between plots on each area prior to application of herbicides. Data also indicated that no acute responses, suggesting toxic effects of the herbicides, occurred.

Censuses of small mammals based on removal trapping showed that the effects of habitat changes on populations of small mammals depend on the species. Those species that prefer grassy habitats or meadow situations, such as the Oregon vole, were less abundant on treated plots. Other species that prefer brushy habitats, such as the deer mouse, were more abundant on treated plots. Small-mammal populations were useful "biological indicators" of habitat alteration. The abundance and relative species composition of small-mammal populations were affected by effective control of herbaceous vegetation.

Changes in vegetation affected the seasonal pattern of deer usage as measured by pellet-group counts. More activity was indicated on treated plots during the growing seasons.

No significant differences in the amount of browsing was found as a result of habitat changes. Seasonal differences in activity were indicated. Two periods of intensive activity occurred, one during the spring and the other during the winter. Spring browsing was most intensive soon after bud burst.

The herbicide-induced vegetative changes appeared to improve habitat for black-tailed deer during the growing season without significantly increasing the browsing of Douglas-fir seedlings.

In conclusion, the use of herbicides as a forest-management practice had a significant effect on vegetation. Survival and growth of Douglas-fir was increased on treated plots. The changes in vegetation affected wildlife populations. The degree and direction of animal responses depended on the species' environmental requirements, food and cover preferences, and seasonal patterns of activity.

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APPENDIX

Site Descriptions

Carlson Creek

This area is a 47 acre clear-cutting located approximately 16 miles south of Cottage Grove, Oregon in the E 1/2, E 1/2, Sec. 13, T 23 S, R 4 W, Willamette Meridian. Timber harvest was completed in March 1959, slash burned, and plantings of Douglas-fir were made in the winters of 1960, 1964, and 1970.

This site has a slightly southern aspect, gentle slopes, and is about 2,000 feet in elevation. Thomas *et al.* (1969) described the soil as being in the Honeygrove series, which is characterized by deep, well drained soils formed in colluvium from basic igneous and sedimentary rock.

Williams Creek

This area is situated 5 miles south of Cottage Grove, Oregon on the west side of the Cottage Grove Reservoir. This 74 acre clear-cutting is located principally in the E 1/2, NW 1/4, Sec. 29, T 29 S, R 3 W, Willamette Meridian. Timber harvest was completed in December 1963, slash burned, and Douglas-fir seedlings were planted in 1964, 1967, and 1970.

The Williams Creek unit is characterized by a southerly aspect, moderate slopes, and an elevation of about 1,100 feet. The soil associations fall in the Jory series, which is similar in character to the Honeygrove series but is found in foothills of the Coast Range and Cascade Mountains (Thomas et al., 1969).

Maxfield Creek

The Maxfield Creek area is a clear-cutting of 34 acres located about 5 miles southeast of Kings Valley, Oregon in the NE 1/4, NE 1/4, Sec. 19, T 10 S, R 5 W, Willamette Meridian. Logging was finished, slash burned, and Douglas-fir seed were distributed in 1962. Plantings of Douglas-fir seedlings followed in 1967 and 1970.

This unit has a southeast aspect, gentle to moderate slopes, and lies at an elevation of about 1700 feet. Soil falls in the Ritner series, which occur as secondary soils in mapping units of Jory and Nekia series (Thomas et al., 1969). This series consists of deep soils derived from colluvium.

LIST OF PLANTS[1]

Scientific Name	Common Name	Area[2]
Polypodiaceae		
Polystichum munitum (Kaulf.) Presl.	western sword fern	1, 2, 3
Pteridium aquilinum (L.) Kuhn.	western brake-fern (bracken fern)	1, 2, 3
Taxaceae		
Taxus brevifolia Nutt.	western yew	1
Pinaceae		
Abies grandis (Dougl.) Lindl.	grand fir	3
Pinus ponderosa Dougl.	western yellow pine (ponderosa pine)	3
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir	1, 2, 3
Tsuga heterophylla (Raf.) Sarg.	western hemlock	1
Graminae		
Aira caryophyllea L.	silvery hair-grass	1, 2, 3
Bromus commutatus Schrad.	downy-sheathed cheat	1, 2
Bromus sitchensis Trin.	Alaska brome-grass	2, 3
Bromus vulgaris (Hook.) Shear.	narrow-flowered brome-grass	1, 2, 3
Cynosurus echinatus L.	bristly dog's-tail grass	1, 2, 3
Elymus glaucus Buckl.	western rye-grass	1, 2, 3
Festuca myuros L.	rat-tail fescue	1, 2
Festuca pacifica Piper	Pacific fescue	1, 2
Festuca rubra L.	red fescue	3
Holcus lanatus L.	velvet grass	1, 2, 3
Poa compressa L.	Canada bluegrass	3

[1] Scientific and common names after Peck (1961). Local common names are in parentheses.

[2] Units 1, 2 and 3 represent the Carlson Creek, Williams Creek and Maxfield Creek units, respectively.

Cyperaceae		
Carex sp. (Rupp.) L.	sedge	1, 2, 3
Juncaceae		
Juncus effusus L.	common rush	2
Luzula multiflora (Retz.)Lej.	common wood-rush	1, 2, 3
Liliaceae		
Calochortus tolmiei H. & A.	Oregon mariposa lily	3
Disporum sp. Salisb.	fairy bells	2, 3
Smilacina sp. Desf.	false solomon's seal	1, 2
Trillium ovatum Prush.	western trillium, wake robin	1, 3
Iridaceae		
Iris tenax Dougl.	Oregon iris	1, 2, 3
Salicaceae		
Alnus sp. Hill	alder	3
Corylus cornuta Marsh.	western hazel	1, 2, 3
Salix sp. (Tourn.) L.	willow	1, 2, 3
Fagaceae		
Castanopsis chrysophylla (Dougl.) A. DC.	chinquapin	1, 2
Quercus garryana Dougl.	Oregon oak	3
Polygonaceae		
Rumex acetosella L.	red sorrel	1, 2, 3
Portulacaceae		
Montia sibirica (L.) How.	western spring beauty (candy flower)	1, 3
Carophyllaceae		
Arenaria macrophylla Hook.	large-leaved sandwort	1, 2, 3
Cerastium holosteoides Fries		
Cerastium semidecandrum	little mouse-ear	3

Cerastium glomeratum Thuill.	sticky mouse-ear	1, 3
Silene hookeri Nutt.	Hooker's pink	3
Stellaria media (L.) Cyr.	common chickweed	1, 2, 3
Ranunculaceae		
Anemone oregana Gray	Oregon anemone	2
Aquilegia formosa Fisch.	western columbine	3
Delphinium sp. (Tourn.) L.	larkspur	3
Myosurus sp. (Dill.) L.)	mouse-tail	1
Ranunculus occidentalis Nutt.	western buttercup	3
Ranunculus uncinatus D. Don.	little buttercup	1
Berberidaceae		
Berberis aquifolium Pursh.	Oregon grape	1, 2, 3
Vancouveria hexandra	inside-out flower	1, 2, 3
Fumariaceae		
Dicentra formosa (Andr.) Walp.	western bleeding-heart	2, 3
Cruciferae		
Cardamine oligosperma Nutt.	little western bitter cress	1, 3
Dentaria tenella Pursh.	slender dentaria (spring beauty)	1, 2, 3
Hydrangeaceae		
Whipplea modesta Torr.	whipple-vine	1, 2, 3
Ribesaceae		
Ribes lobbii Gray.	pioneer gooseberry	1
Ribes sanguineum Pursh.	red-flowering or Oregon currant	3

Rosaceae

Crataegus douglasii Lindl.	Douglas' hawthorn	2
Fragaria bracteata Hel.	western wood strawberry	2, 3
Holodiscus discolor (Pursh) Maxim.	ocean-spray	1, 2, 3
Potentilla gracilis Dougl.	slender cinquefoil	3
Prunus emarginata (Dougl.) Walp.	bitter cherry	1, 2, 3
Rosa eglanteria L.	sweetbriar rose, eglantine	3
Rosa gymnocarpa Nutt.	little wild rose	1, 2, 3
Rubus laciniatus Willd.	evergreen blackberry	2
Rubus leucodermis Dougl.	western blackcap	1, 2, 3
Rubus nivalis Dougl.	snow bramble	1, 2
Rubus parviflorus Nutt.	thimble berry	1, 2, 3
Rubus procerus Muell.	Himalaya berry	2
Rubus vitifolius C. & S.	western dewberry (trailing blackberry)	1, 2, 3

Leguminosae

Lathyrus holochlorus (Piper) C. L. Hitchc.	thin-leaved pea	2, 3
Lotus micranthus Benth.	small-flowered lotus	1, 2, 3
Lupinus polyphyllus Lindl.	large-leaved lupine	1, 2
Psoralea physodes Dougl.	California tea	2
Thermopsis gracilis How.	slender thermopsis (yellow pea)	2
Trifolium repens L.	white clover (common clover)	1, 2
Vicia americana Muhl.	american vetch	1, 2, 3
Vicia angustifolia (L.) Reich.	smaller common vetch	2
Vicia tetrasperma (L.) Moench.	slender vetch	2

Oxalidaceae		
Oxalis suksdorfii Trel.	western yellow oxalis	1, 2
Geraniaceae		
Geranium dissectum L.	cut-leaved geranium	1, 2, 3
Geranium molle L.	dove's-foot geranium	1
Anacardiaceae		
Rhus diversiloba T. & G.	poison oak	2
Aceraceae		
Acer circinatum Pursh.	vine maple	3
Rhamnaceae		
Ceanothus velutinus Dougl.	sticky laurel, mountain balm (snow brush)	
Hypericaceae		
Hypericum formosum H. B. K.	western St. John's-wort	3
Hypericum perforatum L.	common St. John's-wort	1, 2, 3
Violaceae		
Viola glabella Nutt.	smooth woodland violet	1, 3
Viola sempervirens Greene	evergreen violet	1, 3
Onagraceae		
Epilobium angustifolium L.	fire-weed	1, 2
Epilobium franciscanum Barb.	Pacific willow-herb	1, 2
Epilobium minutum Lindl.	small-flowered willow-herb	1, 3
Epilobium paniculatum Nutt.	tall annual willow-herb	2
Umbelliferae		
Daucus carota L.	wild carrot	3
Ligusticum apiifolium (Nutt.) Gray	parsely-leaved lovage	3

Osmorhiza chilensis (Hook.) Arn.	western sweet cicely	3
Torilis arvensis (Huds.) Link.	field hedge-parsley	3
Cornaceae		
Cornus nuttallii Aud.	western flowering dogwood	2
Ericaceae		
Arbutus menziesii Pursh.	madrono (madrone)	2
Arctostaphylos columbiana Piper	bristly manzanita	1, 2
Gaultheria shallon Pursh.	salal	1, 2
Vaccinium parvifolium J. E. Sm.	red huckleberry	1, 2
Primulaceae		
Dodecatheon hendersonii Gray	broad-leaved shooting star	1
Trientalis latifolia Hook.	broad-leaved star-flower	1, 2, 3
Gentianaceae		
Centaurium umbellatum Gilib.	centaury	1, 2
Apocynaceae		
Apocynum sp. (Tourn.) L.	dog bane	2
Convolvulaceae		
Convolvulus nyctagineus Greene	night-blooming morning-glory	3
Polemoniaceae		
Collomia heterophylla Hook.	varied-leaved collomia	1, 2
Hydrophyllaceae		
Nemophila parviflora Dougl.	small-flowered nemophila	1, 3
Boraginaceae		
Cynoglossum grande Dougl.	great hound's tongue	2

Labiatae		
Prunella vulgaris L.	heal-all	1, 2, 3
Stachys rigida Nutt.	rigid hedge nettle	1, 2
Scrophulariaceae		
Parentucellia viscosa (L.) Car.	yellow weed	1, 2
Synthyris reniformis (Dougl.) Benth.	round-leaved synthyris, snow queen	1, 2, 3
Veronica sp. (Tourn.) L.	speedwell	1, 2
Plantaginaceae		
Plantago lanceolata L.	English plantain	1, 2, 3
Rubiaceae		
Galium aparine L.	cleavers	3
Galium triflorum Michx.	fragrant bedstraw	1, 2
Caprifoliaceae		
Linnaea borealis L.	American twin-flower	2
Lonicera ciliosa (Pursh.) Poir.	orange honeysuckle	2
Lonicera hispidula Dougl.	hairy honeysuckle	2
Symphoricarpos albus (L.) Blake	snowberry	1, 2, 3
Symphoricarpos mollis Nutt.	creeping snowberry	2
Campanulaceae		
Campanula scouleri Hook.	Scouler's campanula	1, 2, 3
Campanula prenanthoides Dur.	California harebell	1

Compositae

Achillea millefolium L.	yarrow	3
Agoseris grandiflora (Nutt.) Green	large-flowered agoseris	1
Anaphalis margaritacea (L.) B. & H.	pearly everlasting	1, 2, 3
Arctium minus (Hill) Bernh.	common burdock	3
Bellis perennis L.	daisy	3
Chrysanthemum leucanthemum L.	ox-eyed daisy	1, 2, 3
Cirsium arvense (L.) Scop.	Canada thistle (Canadian thistle)	1, 2, 3
Cirsium vulgare (Savi) Airy-Shaw	common thistle	1, 2
Crepis capillaris (L.) Wallr.	smooth hawksbeard	1, 2
Erechtites prenanthoides DC.	Australian fireweed	2
Eriophyllum lanatum (Pursh.) Forbes	common woolly sunflower	3
Gnaphalium purpureum L.	purplish cudweed	1, 2
Hypochaeris radicata L.	hairy cat's-ears; gosmore (false dandelion)	1, 2, 3
Madia gracilis (J. E. Sm.) Keck	common tarweed	1, 2, 3
Senecio jacobaea L.	tansy ragwort	1, 2, 3
Solidago sp. L.	goldenrod	2
Taraxacum officinale Weber	dandelion	3

List of Small Mammals[1]

Scientific Name	Common Name
Sorex vagrans vagrans Baird	vagrant shrew
Sorex vagrans pacificus Coues	(Pacific shrew)
Sorex bendiri (Merriam)	Pacific water shrew
Sorex trowbridgii (Baird)	Trowbridge's shrew
Neurotrichus gibbsii (Baird)	shrew-mole
Sylvilagus bachmani (Waterhouse)	brush rabbit
Lepus californicus Gray	black-tailed jackrabbit
Eutamias townsendii (Bachman)	Townsend's chipmunk
Spermophilus beecheyi (Richardson)	California ground squirrel (graydigger)
Thomomys monticola mazama Merriam	Mazama pocket gopher
Peromyscus maniculatus (Wagner)	deer mouse
Phenacomys longicaudus True	red tree mouse
Microtus californicus (Peale)	California vole
Microtus oregoni (Bachman)	Creeping vole (Oregon vole)
Zapus trinotatus Rhoads	Pacific jumping mouse
Erethizon dorsatum (Linnaeus)	porcupine
Mustela erminea Linnaeus	ermine (short-tailed weasel)
Spilogale gracilis Merriam	western spotted skunk
Mephitis mephitis (Schreber)	striped skunk

[1] Scientific and common names after Hall and Kelson (1959). Local common names are in parentheses

Appendix Table A. Analysis of variance table for removal trapping data.

Source	Degrees of Freedom df	Sum of Squares SS	Mean Squares MS	F Ratio
Area (A)	2	0.520	0.260	15.797**(2/2)
Year (Y)	1	0.206	0.206	12.525**(1/2)
Treatment (T)	1	0.321	0.321	19.525**(1/2)
Interaction				
A X Y	2	0.215	0.108	6.545**(2/2)
A X T	2	0.034	0.017	1.038 (2/2)
Y X T	1	0.029	0.029	1.753 (1/2)
A X Y X T	2	0.033	0.016	
Total	11	1.358		

**Significant at the 0.01 level. The degrees of freedom are multiplied by five (the number of important species) to test the F ratios.

Appendix Table B. Analysis of variance table for pellet-group count data.

Source	Degrees of Freedom df	Sum of Squares SS	Mean Squares MS	F Ratio
Area (A)	2	1.354	0.677	7.336**(2/88)
Season (S)	2	2.926	1.463	9.543* (2/4)
Treatment (T)	1	1.637	1.637	4.114 (1/2)
Interaction				
A X T	2	0.796	0.398	4.310* (2/88)
A X S	4	0.613	0.153	1.661 (4/88)
S X T	2	0.647	0.324	3.506* (2/88)
A X S X T	4	0.071	0.018	0.193 (4/88)
Error	90-2 = 88	8.122	0.092	
Total	105	16.166		

*Significant at the 0.05 level

**Significant at the 0.01 level

Appendix Table C. Analysis of variance table for the percentage of established seedlings browsed.

Source	Degrees of Freedom df	Sum of Squares SS	Mean Squares MS	F Ratio
Area (A)	2	1413.389	706.694	1.719 (2/90)
Season (S)	2	2032.056	1016.028	11.468*(2/4)
Treatment (T)	1	374.083	374.083	2.615 (1/2)
Interaction				
A X T	2	286.056	143.038	0.348 (2/90)
A X S	4	354.389	88.597	0.216 (4/90)
S X T	2	891.056	445.528	1.084 (2/90)
A X S X T	4	160.722	40.181	0.098 (4/90)
Error	90	37000.500	411.117	
Total	107	42512.251		

*Significant at the 0.05 level.

Appendix Table D. Analysis of variance table for the percentage of recently-planted seedlings browsed.

Source	Degrees of Freedom df	Sum of Squares SS	Mean Squares MS	F Ratio
Area (A)	2	250.257	125.128	2.386 (2/90)
Season (S)	2	743.781	371.890	11.693*(2/4)
Treatment (T)	1	92.722	92.722	9.907 (1/2)
A X T	2	18.718	9.359	0.178 (2/90)
A X S	4	127.182	31.795	0.606 (4/90)
S X T	2	43.006	21.503	0.410 (2/90)
A X S X T	4	222.279	55.570	1.059 (4/90)
Error	90	4720.576	52.451	
Total	107	6218.521		

*Significant at the 0.05 level.