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Title: RELATION OF THE NORTHERN POCKET GOPHER TO FOREST HABITATS IN SOUTH-CENTRAL OREGON

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Reduction of pocket gopher damage to conifer seedlings is important to successful reforestation in many regions of the Pacific Northwest. The objective of this study was to determine the factors that influence the local distribution of the northern pocket gopher (*Thomomys talpoides* Richardson) in a forested region of south-central Oregon.

Pocket gopher habitat was represented by 19 variables measured on 157 sites located in Klamath and Lake Counties, Oregon. The seasonal peak of mound-building activity occurred at the same period throughout the study area. No significant correlation was found between gopher-activity level and the number of animals captured per acre.

A significant relationship was shown with the canonical correlation between the indexes to pocket gopher density (activity and catch) and the habitat. In general, an increase in activity and catch was

shown with increasing elevation and slope, and a tendency towards more mesic timber types.

The habitat preference of pocket gophers was associated significantly with more site disturbance and forb cover. This supports the assumption that site disturbances and increased forb cover caused by forest management activities improves pocket gopher habitat. A reduction in the amount of site disturbance, forb cover, or both, is suggested to decrease the probability of pocket gopher occurrence and associated tree damage.

Relation of the Northern Pocket Gopher to Forest Habitats in South-Central Oregon

by

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INTRODUCTION

Damage to conifer seedlings by pocket gophers has prevented successful reforestation in many regions of the Pacific Northwest (Dingle 1956, Hermann and Thomas 1963, Black et al. 1969, Barnes et al. 1970). Intensified forest-management increased the level of attention given gopher-caused damage and its relation to forest-land use (Kuck 1969, Crouch 1969, Barnes 1973). The ability of pocket gophers to respond successfully to disturbed conditions is well documented (Crouch 1933, Buechner 1942, Barnes 1974), but the factors that influence such a response are not entirely understood (Hooven 1971). Forest managers could anticipate areas becoming occupied by pocket gophers, i.e. gopher-caused tree damage, with knowledge of the factors that influence gopher distribution.

OBJECTIVES

The purpose of this study was to determine the factors that influence the local distribution of the northern pocket gopher (*Thomomys talpoides* Richardson) in a forested region of south-central Oregon. Specific objectives were to determine the factors important to pocket gopher occurrence and to determine the relationship of the indexes to gopher density to variations in the habitat.

REVIEW OF LITERATURE

Habitat Preference of Pocket Gophers

Pocket gophers (Thomomys) occur throughout western North America (Bailey 1915), and are believed to be the most morphologically variable of all mammals (Hall and Kelson 1959). This variability is reflected by their tolerance of a wide range of habitat types (Durrant 1946). Scheffer (1931) stated that pocket gophers may be found in ". . .almost any situation from sea level to the rugged mountain slopes above timberland."

Hooven (1971) reported the conditions that created a suitable habitat were unknown particularly in relation to forest sites, but suggested that pocket gophers were influenced by vegetation, elevation, and soil characteristics. The suitability of habitat may be influenced by the texture and depth of soil, drainage, climate, and the kind and amount of herbage yield (Turner et al. 1973). According to Barnes (1973), a single environmental component could have a dominant influence on gopher distribution.

Miller (1964) and Cunningham (1966) found that the northern pocket gopher had the greatest tolerance to soil type, and was found in all penetrable soils. Thaeler (1968) noted that the species occupied areas from deep valley soils to thin rocky soils on mountain slopes with textures ranging from sand to loam and clay. Kennerly (1964) regarded soil friability as a "high threshold" limiting factor to gopher distribution. Howard and Childs (1959) added soil fertility as an important factor, although Turner et al. (1973) stated that the chemical properties of the soil did not appear to limit the occurrence of gophers directly. Davis (1938) found that pocket gophers were as successful in acidic soils as they were in neutral or basic soils. Turner et al. (1973) stated that gophers lived successfully in soils where the mean soil moisture ranged from less than 10 percent to more than 50 percent. They found that pocket gophers preferred friable, light-textured soils with good drainage, poor water-holding capacity, and high porosity.

The northern pocket gopher was reported to prefer a vegetation type with a high composition of forbs (Phillips 1936, Moore and Reid 1951, Hermann and Thomas 1963, Myers and Vaughan 1964, Tryon and Cunningham 1968, Turner et al. 1973). Burton (1976) clarified this statement with his study of feeding habits; he determined that the gopher preferred succulent vegetation, whether it was forbs or fleshy-rooted grasses.

Pocket gophers were reported to prefer open areas free of even moderate tree or shrub coverage (Dalquest and Scheffer 1944). Moore and Reid (1951) found areas to be more favorable to gophers after the removal of the forest canopy. Turner et al. (1973) stated that in addition to a reduction in canopy coverage, soil disturbance improved the habitat; increased herbaceous vegetation usually follows soil disturbance and a reduction in forest canopy-coverage (Jameson 1967, McConnell and Smith 1970).

In addition to soil and vegetation, the climate and behavioral factors were thought to influence gopher distribution (Cunningham 1966). Hansen and Beck (1968) found that the presence or absence of pocket gophers could not be accounted for by vegetative differences alone. They stated that the behavior of the pocket gopher was such that relatively minor topographic or environmental barriers often effectively limited distribution. Dalquest and Scheffer (1944) observed that the northern pocket gopher generally occurred in small groups even on extensive, uniform terrain. They stated that, if not limited by barriers, the pocket gophers' success in geographic extension was related to their antisocial behavior and to their tolerance of habitat variation.

Effect of Habitat on Pocket Gopher Abundance

The factors that influenced pocket gopher habitat and distribution also affect gopher abundance. Interspecific competition, territorial requirements, texture and depth of soil, climate, and amount of herbaceous vegetation all influenced the size of pocket gopher populations (Turner *et al.* 1973).

Howard and Childs (1959) found pocket gophers to be most abundant in soils greater than 2 feet (0.61 m) in depth. Deep soils were required to insulate the animals from extreme surface temperatures. Miller (1964) also found pocket gophers abundant in deep soils, although they also occurred in hard clays and shallow gravels.

Vegetative composition and production were believed to be the most important factors determining pocket gopher abundance (Walker 1949, Barnes 1973). Tryon and Cunningham (1968) hypothesized that nutrition, associated with an abundance of forbs, accounted for higher pocket gopher densities. Keith et al. (1959) and Tietjen et al. (1967) showed a significant reduction in the number of pocket gophers by reducing the amount of vegetation with the application of 2,4-D herbicide.

The depth and water content of snow influenced population size by affecting gopher survival (Barnes 1973). Gentry et al. (1968) showed a trend of increasing numbers of small mammals with an increase in altitude in forested regions and a reverse trend in non-forested areas which supported higher populations at lower altitudes. Best (1973) though, found that elevation did not affect pocket gophers directly, and stated that the soil at different altitudes was the most important limiting factor.

Pocket gopher populations were lowest in the early spring and highest in the fall after the dispersion of juveniles (Turner et al.

1973). The rate of mound-building also was found to increase from spring to fall (Laycock 1957, Miller and Bond 1960). Reid et al. (1966) found a positive correlation between the number of fresh mounds and plugs made in a 48-hour period in the fall and the number of gophers removed from the same areas after the signs were counted. An estimate of population size, therefore, was obtained by counting pocket gopher surface sign.

STUDY AREA

This study was conducted in the Bly Unit of the East District of the Weyerhaeuser Company, Eastern Oregon Region, and included portions (about 20,000 acres; 8,100 hectares) of T36S R15E, Klamath County; T36S R16E, T37S R16E, T37S R17E, and T38S R17E, Lake County, Oregon. The climate is characterized by hot dry summers with rain and snow occurring mainly during the winter. The mean annual precipitation, based on adjusted climatological data for 27 years, is from 15 to 20 inches (38 to 51 cm) (U.S. Weather Bureau 1964).

Twenty-three soil series occur within the study area (Duncan and Steinbrenner 1975). These soils range in texture from coarse sandy loam to clay with friability from loose to firm. The soil depth ranges from shallow to deep, with from 10 to 80 percent rock content. These soils are poorly to excessively drained and very slow to moderately rapid in permeability.

The elevation of the area ranges from 4,600 feet (1,402 m) to 7,200 feet (2,194 m). Vegetation type varies in response to a climatic gradient from the xeric juniper (*Juniperus occidentalis* Hook.) and ponderosa pine (*Pinus ponderosa* Dougl.) to the more mesic white fir (Abies concolor (Gord. & Glend.) Lindl.) forest zones (Franklin and Dyrness 1973). Within these zones, rockflats, and riparian stands of aspen (Populus tremuloides Michx.) and mesic forbs occur. Other plant species identified within the study area are listed in Table A (Appendix).

Forest management activities have occurred within the area since 1938. Logging ranged from older salvage operations to more recent timber harvests where all merchantable volume was removed. Pre-commercial thinning occurred within some of the dense, non-merchantable stands. Site-preparation methods included slash-piling and deep-plowing, with seedlings planted in areas where forest fires and recent harvests occurred.

The area was selected for study primarily because of the habitat variability of the sites in which pocket gophers were known to occur.

MATERIALS AND METHODS

Sampling the Study Area

The habitat factors where pocket gophers occurred were sampled in June, 1975. A 100-foot (30.5-m) wide strip, on each side of all roads was inspected for the presence of old (1974) pocket gopher mounds, or casts formed during the winter of 1974-1975. I assumed that the sites where gophers occurred along the established road system represented the habitat conditions of the study area.

The road system was traveled by vehicle at a speed of less than 10 miles (16.1 km) per hour following the procedure described by Glass (1951). Ten percent of the road system sampled each day was randomly selected for inspection by foot travel. Eleven miles (17.7 km) of roads were resampled on foor to determine the accuracy of sampling by vehicle.

The sampling strip began at the edge of the road berm, where site disturbance from road construction was considered not to have influenced the sample. When mounds or winter casts were encountered, the location of each site was marked on aerial photographs (2 inches = 1 mile; 5.1 cm = 1.6 km). Notes on vegetation and physiognomy of each site were recorded.

Through July, August, and September 1975, each site was revisited to record the presence or absence of fresh (1975) pocket gopher sign, mounds or earth plugs. Fresh sign indicates burrow expansion or repair by older animals or establishment of new burrow systems by the young-of-the-year (Barnes 1973). I considered sites with fresh mounds or plugs to be areas where animals survived through the winter. If the animals could survive the winter, the most severe time of the year (Barnes 1973), the site was considered to be suitable pocket gopher habitat. Conversely, I assumed that the animals could not survive on sites where fresh mounds or plugs were not observed.

When fresh mounds or plugs were encountered within the area where sign formed during the previous year was found, a site number was assigned and plots were established for measurement of vegetative composition and animal abundance. Transects were installed by compass line 50 feet (15.2 m) from the berm of the road along the longest axis of each area occupied by gophers. Steel pins, as plot centers, were set in the ground at 25-foot (7.6-m) intervals along the transect lines.

A maximum of 10 plots, and a minimum of 3 plots, were established per site. When the areas occupied by gophers were larger, sites were established at 0.2-mile (0.3-km) intervals along the road in the direction of travel. If the area between sites exhibited obvious differences in slope, aspect, or kind or quantity of vegetation, another site was established at the point where differences were encountered.

During June 1976, similar sites were established in the areas that did not contain fresh mounds or plugs in the summer of 1975. Plots were established within each site in the same manner as those with fresh gopher sign. All sites then, with and without fresh pocket gopher sign located during the sampling of the study area in June 1975, were established.

Observations of the presence or absence of fresh pocket gopher mounds or plugs were made again, for each site, in June and July 1976. The areas where gophers could or could not survive then, were determined for two successive years.

Measurement of Habitat Variables

Pocket gopher habitat was represented by 19 variables obtained from each site as follows:

Elevation was recorded to the nearest 20 feet (6.1 m) as determined from topographic maps of the U.S. Geological Survey from the location of each site on aerial photographs.

Slope was measured with a Suunto clinometer and recorded to the nearest percent.

Aspect was determined with a Silva compass and recorded to the nearest degree.

<u>Tree canopy coverage</u> was recorded on each plot within each site facing the direction in which the transect was installed, using a 5 x 5 gridded spherical densiometer. No differentiation of tree species was made. Total coverage for each site was computed and a mean percentage recorded.

<u>Shrub, forb, and grass cover</u> was measured on mil-acre (4 m^2) plots about each plot center, following the procedure of Daubenmire (1959). The five most abundant species, by coverage, within each plot were recorded. Tree seedlings less than 4.5 feet (1.4 m) in height were recorded as shrubs. Grasses (Gramineae), sedges (Cyperaceae), and rushes (Juncaceae) were recorded as grass-like plants. All plant species measured were identified and classified according to the nomenclature of Hitchcock and Cronquist (1974). Plants were classified as shrubs, forbs, or grass-like plants, and a mean percentage cover for each group was calculated.

A sample of 10 sites was randomly selected, where all plant species occurring within each mil-acre (4 m^2) plot were measured. The relation of the five most abundant plants to all plants occurring within each plot was determined. Within the same sample of 10 sites, the difference between the years of vegetation measurement also was determined.

<u>Total ground cover</u>, the mean percentage cover of all vegetation measurements, except tree canopy coverage, was calculated for each site.

Timber and vegetative cover types were obtained from inventory files of the Weyerhaeuser Company. These types were verified with observations of the tree, shrub, and grass species that occurred within each site.

Estimates of timber volume were obtained from inventory files of the Weyerhaeuser Company. Total basal area was used as a measure of volume and recorded for all commercial species within the stand unit in which each site was located.

Treatment history was determined from historical records of past forest management activities of the Weyerhaeuser Company and classified by the extent of site disturbance.

Soil texture, friability, depth, percentage rock content, drainage, permeability, and productivity (site index) were obtained from the description of the soil series of each site (Duncan and Steinbrenner 1975).

Gradients of aspect, timber and cover type, treatment history, and all soil variables (except productivity) used in the analysis of these data are listed in Table B (Appendix).

Sampling Pocket Gopher Abundance

An estimation of the relative size of pocket gopher populations was determined by counting the quantity of active mounds formed within 48 hours (Reid *et al*. 1966). Before the activity measurements could be made, a determination of the seasonal peak in mound-building was necessary. To obtain a reliable index to population sizes, based on the amount of surface activity, the activity must peak at about the same time for the entire sampling area.

To determine the peak of mound-building, a stratified random sample of nine sites was selected from the areas located in the initial sampling of the study area. Each area was stratified by size, elevation, soil series, and timber and cover types. The sites were selected from three elevation zones and three combined timber and cover types. An effort was made to obtain a sample that was distributed geographically and representative of different soil series in each zone. All potential areas had to meet a minimum size requirement of 1 acre (0.4 ha).

Plot centers were located within each site in the same manner as described for all others. A second transect of plots, 50 feet (15.2 m) from and parallel to the first, was established, yielding 20 plots per site. Pocket gopher mounds and plugs, made within 48 hours, were noted on 1/100th acre (40.5 m^2) circular plots about each plot center. The percentage of plots with sign made within 48 hours was calculated after the observations for each site. These values were obtained on the same dates for all nine sampling sites during the latter part of July, August, and September 1975. A determination then,was made of the peak of mound-building activity for each sampling site.

Within 2 days of the activity measurements made during the latter part of September 1975, activity was measured by the same method on all sites with 10 plots each. Fifteen of these sites were randomly selected for removal trapping in addition to the nine sampling sites used for the determination of the peak of mound-building activity. Pocket gophers were trapped on all 24 sites for 3 consecutive days immediately after the activity was measured. Animals within an area 25 feet (7.6 m) wide on each side and parallel to the plot transect(s) were trapped. Macabee-kill traps were placed in all identified pocket gopher burrows located within these areas. The number of pocket gophers captured was adjusted to catch per acre for each trapping area.

All animals captured were labeled with the site number and date of capture, and frozen. In the laboratory, each adult male gopher was identified to species following the criterion of baculum length (Ingles 1965). Females and juvenile males were assumed to be of the same species.

Analysis of Data

All data were analyzed using the SIPS subsystem (Guthrie *et al.* 1973) of Oregon State University's CDC-3300 computer.

Student's t-test was used to determine if the means were significantly different between 1) the sites sampled by vehicle and foot travel; 2) the vegetation measurements made in 1975 and 1976; 3) the five most abundant plant species and all plant species per plot; and 4) the monthly activity levels.

Univariate regression was used to determine the relationship of the monthly animal activity levels to define the peak of seasonal mound-building. Stepwise regression was used to determine the relationship of the habitat variables to each of the indexes to density, activity level and catch per acre.

Pearson's correlation coefficient was calculated to determine the relationship of activity to catch. The canonical correlation (Harris 1975) was calculated to determine the relationship between the sets of variables, activity and catch, and the habitat.

Stepwise discriminant analysis of the Biomedical Computer Program series (Sampson 1974) was used to determine the separation of the two groups of sites, where gophers were found to survive and where they were not. Data from both 1975 and 1976 were analyzed with this method to determine the habitat variables important to pocket gopher distribution.

RESULTS AND DISCUSSION

One hundred and fifty-seven sites were located along the road system that contained evidence of pocket gopher activity formed during the previous year. The validity of sampling the study area by vehicle, recording only the five most abundant plant species on vegetation plots, and comparing the 1975 and 1976 vegetation measurements was confirmed by the t-test.

Effect of Habitat on Pocket Gopher Abundance

Of the nine sites selected to determine the peak of mound-building activity, one site did not exhibit fresh mounds or plugs during the summer 1975. Using the remaining eight sites, the levels of mound-building activity differed significantly ($P < 0.01$) between July, August, and September measurements.

Regression analysis indicated a significant ($P < 0.01$) relationship between the activity levels from July to August and from August to September ($R^2 = 0.81$ and 0.94, respectively). These data indicated that the peak of mound-building activity for the study area occurred during the same period (Fig. 1).

Sixty-nine animals were collected from the 24 sites. All adult male gophers captured were identified as the northern pocket gopher.

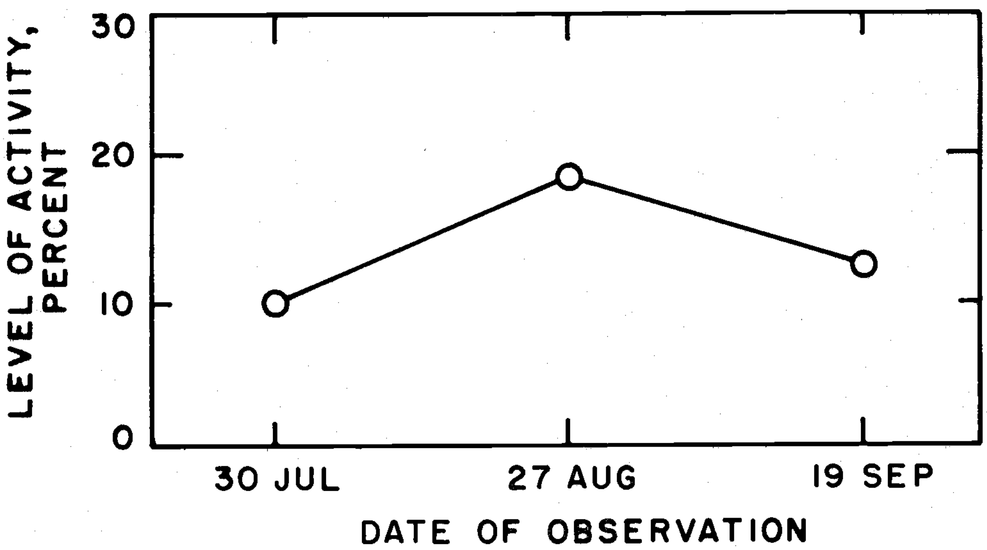

Fig. 1. The peak of mound-building activity as determined from eight sites sampled in Klamath and Lake Counties, Oregon, during summer 1975.

The number of animals captured ranged from 1.6 to 20.6 per acre (0.65 to 8.34 per ha).

No significant correlation was found between catch and activity level. This finding was contrary to the results of previous studies but might be accounted for by the variability of the sites observed. For example, the population density might have been lower within a site where little vegetation occurred. On a sparsely vegetated area, each animal would be expected to have a larger territory to meet its feeding requirements. With a larger territory, I would expect more pocket gopher activity to occur because of the need for a more extensive burrow system. Therefore, on such an area with a low density of gophers, the activity level might be greater than within an area in which the density was higher and which contained a greater amount of food.

When analyzed separately by regression, activity (from 53 sites) and catch (from 24 sites) showed no significant relationship to the habitat variables. Because of the poor correlation (0.4694) between activity level and catch, and no significant relationship to the habitat variables when analyzed separately, the use of activity and catch together, as an artificial index to density, was justified (W.S. Overton, Oregon State University, Corvallis, Personal communication).

The relationship of the habitat variables to activity and catch was determined by calculating their canonical correlation (Harris 1975). Because the sample size (24 sites) was small in relation to the large number of habitat variables (19), the correlation obtained could not be accepted with a high degree of reliability. A reduction of the number of habitat variables increased the reliability and made it possible to interpret the relationship of habitat to activity and catch more readily.

The number of habitat variables was reduced by selecting those that had the highest Pearson correlation coefficient for one habitat variable against another, as suggested by Harris (1975). Additional information for that selection was obtained by calculating and ranking the canonical correlation of activity and catch to each habitat variable (Table 1). From these calculations, the three and six variables with the highest relationship were selected. The correlation of activity and catch to these sets of habitat variables were significant ($P < 0.01$) (Table 2). More information was obtained by using activity and catch together than was obtained by either variable alone.

The artificial variables of the index to density and the habitat (the canonical variates) obtained using the three highest-ranked habitat variables were:

$$4.3904(\text{activity}) + 0.0680\ (\text{catch})\ :$$
$$0.0017(\text{elevation}) + 1.1056(\text{slope}) + 0.3963(\text{timber type})$$

Table 1. The ranking of the canonical correlations of activity and catch to each habitat variable from data collected from 24 sites in Klamath and Lake Counties, Oregon, in September 1975.

Variable	Canonical correlation	Rank
Elevation	0.5370	2
Slope	0.5125	3
Aspect	0.3114	10
Mean tree cover	0.3782	6
Mean shrub cover	0.3168	9
Mean forb cover	0.3579	7
Mean grass cover	0.0229	19
Total ground cover	0.3241	8
Timber type	0.5839	1
Cover type	0.2311	12
Timber volume	0.4499	4
Treatment history	0.4033	5
Soil texture	0.1146	18
Soil friability	0.1559	16
Soil depth	0.2457	11
Percentage rock content	0.1746	14
Soil drainage	0.1218	17
Soil permeability	0.1673	15
Productivity	0.1987	13

Table 2. The canonical correlations of activity and catch to the habitat variables from data collected from 24 sites in Klamath and Lake Counties, Oregon, in September 1975.

Habitat variables used	Canonical correlation	GCR (R^2)[1]	Level of significance
19 (all)	0.9895	0.9791	0.01[2]
6 (elevation, slope, mean tree cover, timber type, timber volume, and treatment history)	0.7944	0.6310	0.01
3 (elevation, slope, and timber type)	0.7471	0.5581	0.01

[1] GCR is an abbreviation of the greatest characteristic root, which is equivalent to the multiple correlation coefficient (R^2).

[2] This level of significance is not entirely reliable because of the small sample size and large number of habitat variables used.

The relationship of these sets of variables, in general, shows an increase in gopher activity level and catch per acre with an increase in elevation and slope, and a tendency towards the more mesic timber types (Fig. 2).

Although I would expect more mesic timber types to occur with increased elevation, no significant correlation between the two variables was found from data obtained in this study. The correlation coefficients between each of the habitat variables were less than 0.5. The combined effect of elevation, slope, and timber type was significant in describing activity and catch, together, but the low R^2 value (0.5581) indicated little predictive value.

The correlation between the three habitat variables and the artificial index to density (0.7471) was sufficient for describing their relationship. It is multivariate in that one variable could shadow the effect of the remaining variables. For instance, a lower elevation of the study area, with no slope and true fir timber type, could have a higher index to density than an area with the same elevation and slope but with a ponderosa pine type. Similarly, if an area indicated a high index to gopher density by the set of habitat variables, the area could have a higher activity level but a low catch per acre. The relationship then, of activity and catch to habitat, must be interpreted with regard to the combined effect of these variables.

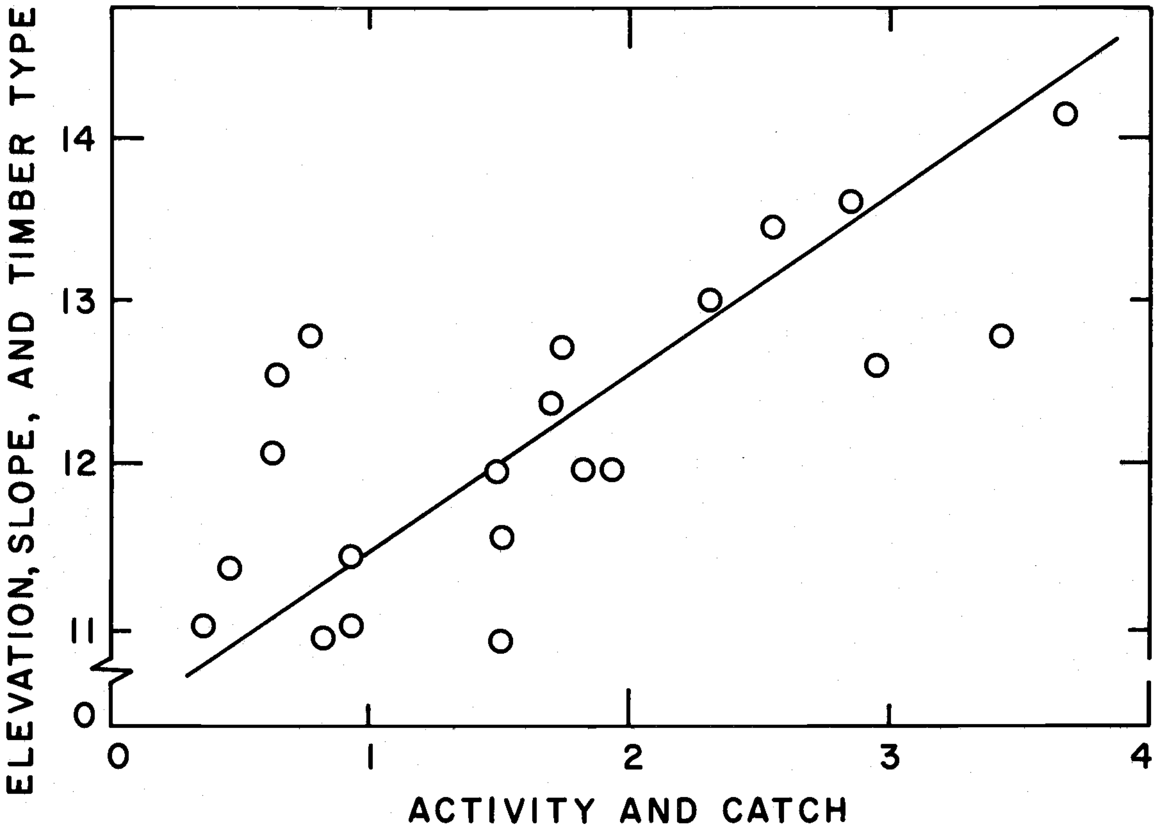

Fig. 2. Relationship of the canonical variates, activity and catch, to elevation, slope, and timber type from data collected from 24 sites in Klamath and Lake Counties, Oregon in September 1975.

From the analysis of these data, activity and catch were influenced by habitat conditions, but the low predictive value obtained did not allow extensive interpretation. It was suggested that the number of animals captured produced different amounts of surface sign per unit area because of habitat variability. Because activity and catch were not significantly related, it was useful to combine these data in order to obtain an indication of their relationship to the habitat.

Analyzing sets of variables, using canonical correlation, is useful as an aid in understanding complex relationships. In this study, however, results were limited by the habitat variability observed, the number of habitat variables measured, and the size of samples taken. Elevation, slope, and timber type are important to gopher abundance, but should be considered only as an indication of the habitat's influence on density. This relationship can be considered as a hypothesis, generated from this study, to be tested with additional research. With fewer variables, and a larger sample size, univariate methods of analysis would allow more definitive interpretation of results.

Within the study area, pocket gophers appeared to be more abundant (in terms of the amount of surface sign observed) within the set of habitat conditions indicated by this analysis. The more mesic timber types (mixed conifer, true fir, or meadows) generally occurred at higher elevations and supported more herbaceous vegetation than the pine or juniper types of lower elevations. When the water table is high, slope would create more favorable conditions for gophers because of soil drainage, than if no slope occurred and flooding limited population size.

The influence of habitat on pocket gopher abundance certainly is not limited to elevation, slope, and timber type. With the analytical methods followed and variables measured, some understanding of the influence of habitat on gopher abundance was provided, even though other variables, including some not measured in this study, influence density.

Habitat Preference of Pocket Gophers

Of the 157 sites with pocket gopher mounds of winter casts made in 1974, 87 had fresh mounds or plugs and 41 had no activity during the summer of 1975. The remainder of these sites were eliminated because of site disturbance resulting from forest management activities during 1975. Because only areas with evidence of past gopher activity were included in this study, the assumption that pocket gophers could get to unfavorable areas did not have to be made.

The results of the discriminant analysis, with 1975 data, showed a significant difference between the two groups, where gophers survived and where they did not (Table 3). All of the habitat variables contributed to the determination of the survival of pocket

Table 3. Comparison of the sites where pocket gophers survived (87 sites) to the sites where gophers did not survive (41 sites) from data collected during the summer 1975 in Klamath and Lake Counties, Oregon.

Habitat variables in order of importance	F[1]	df	Correctly classified Group 1[2]	Correctly classified Group 2[3]
			------ % ------	
Soil depth	6.71*	1/126	55.2	70.7
Aspect	6.13*	2/125	60.9	63.4
Mean forb cover	5.90*	3/124	64.4	68.3
Mean shrub cover	4.98*	4/123	65.5	70.7
Productivity	4.38*	5/122	63.2	75.6
Timber type	3.90*	6/121	64.4	63.4
Timber volume	3.93*	7/120	72.4	65.9
Percentage rock content	3.65*	8/119	71.3	63.4
Mean tree cover	3.36*	9/118	69.0	65.9
Soil friability	3.05*	10/117	70.1	68.3
Slope	2.79*	11/116	69.0	73.2
Treatment history	2.55*	12/115	67.8	73.2
Elevation	2.35*	13/114	66.7	73.2
Cover type	2.17	14/113	66.7	70.7
Mean grass cover	2.01	15/112	66.7	70.7
Total ground cover	1.88	16/111	67.8	70.7
Soil drainage	1.75	17/110	67.8	70.7
Soil permeability	1.64	18/109	67.8	73.2
Soil texture	1.54	19/108	70.1	70.7

[1]*F value significant at the 0.01 level.

[2]The group of sites where pocket gophers were found to survive.

[3]The group of sites where pocket gophers were not found to survive.

gophers on a specific area. The fewest number of variables with the highest probability of correct classification indicated the variables most important to the separation of the groups. The combined effect of soil depth, aspect, mean forb cover, and mean shrub cover was significantly more important in describing the possibility of an area where gophers could survive, than the remaining 15 variables.

The interpretation of habitat to gopher survival must include the combined effect of the habitat variables selected for any specific area. As with the relationship of habitat to activity and catch, any of these variables could shadow the effect of all other variables. If for example, an area had a high forb cover, shallow soil, moderate shrub cover and east aspect, the probability of having gophers might be as great as an area with low forb cover, deep soil, low shrub cover, and the same aspect. In general though, an area with a higher probability of having pocket gophers had deeper soils, more forb cover, less shrub cover, and aspect that ranged from south to northwest.

Data collected during the summer of 1976, from the 128 sites observed in 1975, were similarly analyzed. Seventy-three of the previous 87 sites had fresh mounds or plugs in 1976 and 29 of the 41 inactive sites exhibited no fresh gopher activity. Although all of the areas sampled in 1975 were revisited, several had been disturbed over winter. Other sites that were eliminated included those in which fresh sign occurred in 1976 where it did not in 1975, and conversely, where no fresh mounds or plugs were observed in 1976 where they were in 1975. The analysis of observations made in 1976, therefore, was based on sites where pocket gophers were present or absent for two successive years.

All habitat variables measured, except soil depth, significantly separated the two groups, where gophers survived for two years and where they did not (Table 4). The variables most important to that separation were treatment history and mean forb cover, the fewest number of variables with the highest correct classification of sites.

The classification of sites using treatment history and mean forb cover was based on the computation of the following linear discriminant functions:

Group 1 (where gophers survived) =

$$-3.482 + 12.766(\text{treatment}) + 2.634(\text{forb cover})$$

Group 2 (where gophers did not survive) =

$$-5.195 + 10.067(\text{treatment}) + 3.656(\text{forb cover})$$

In general, the probability of an area being classified as one where pocket gophers survived, had more site disturbance and a greater abundance of forb cover (Fig. 3). Again, this relationship must be interpreted with regard to the combination of variables. For example, gophers might have a higher probability of surviving on an area high in forb cover and with no previous forest management

Table 4. Comparison of the sites where pocket gophers survived (73 sites) to the sites where gophers did not survive (29 sites) for 2 successive years from data collected during the summer 1976 in Klamath and Lake Counties, Oregon.

Habitat variables in order of importance	F*[1]	df	Correctly classified	
			Group 1[2]	Group 2[3]
			%	
Treatment history	21.98	1/100	98.6	31.0
Mean forb cover	12.56	2/99	76.7	72.4
Aspect	9.28	3/98	72.6	65.5
Percentage rock content	7.58	4/97	79.5	58.6
Productivity	6.56	5/96	76.7	62.1
Mean tree cover	5.83	6/95	78.1	65.5
Timber type	5.33	7/94	78.1	65.5
Timber volume	4.95	8/93	83.6	65.5
Total ground cover	4.56	9/92	86.3	62.1
Slope	4.20	10/91	89.0	62.1
Cover type	3.85	11/90	90.4	65.5
Soil permeability	3.54	12/89	87.7	65.5
Soil texture	3.40	13/88	87.7	72.4
Soil drainage	3.52	14/87	87.7	72.4
Soil friability	3.41	15/86	91.8	72.4
Mean grass cover	3.24	16/85	91.8	72.4
Mean shrub cover	3.04	17/84	91.8	72.4
Elevation	2.84	18/83	91.8	72.4
Soil depth[4]				

[1] *F values significant at the 0.01 level.

[2] The group of sites where pocket gophers were found to survive.

[3] The group of sites where pocket gophers were not found to survive.

[4] Soil depth F value was not sufficient for further computation.

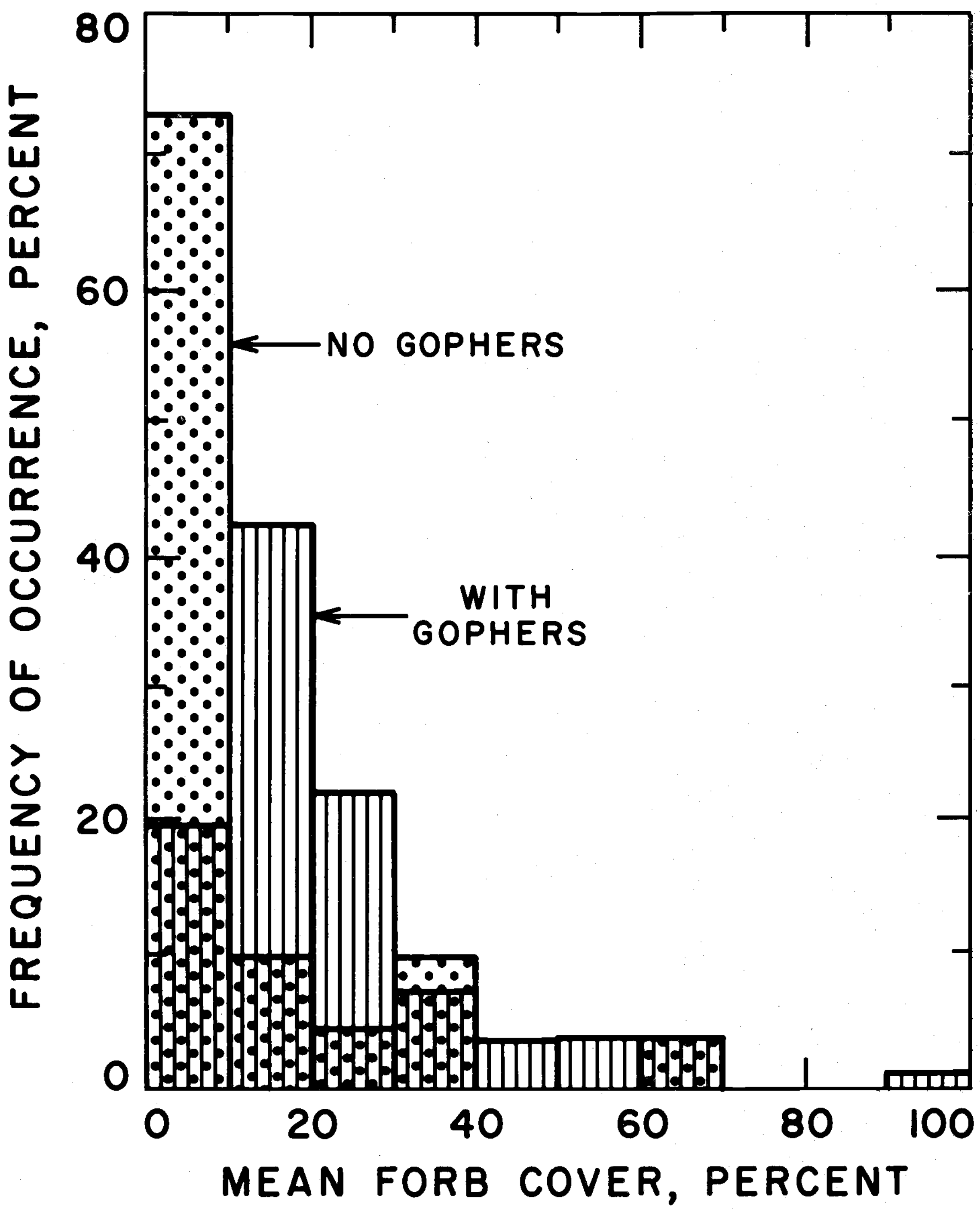

Fig. 3. The mean forb cover of the sites where pocket gophers did and did not occur during the summers of 1975 and 1976 in Klamath and Lake Counties, Oregon.

activities, than on an area that had been site prepared and planted, but low in forb cover.

Because herbaceous vegetation usually increases after site disturbances, I would expect that disturbances alone would be enough to determine the probability of areas being favorable to gophers. In the analysis, however, the probability was greater when the two variables, treatment history and forb cover, were combined.

Comparing these results to the results of the analysis of 1975 data, a greater probability of correct classification, with fewer variables was determined by the sites with two successive years of observations (Table 5).

The difference between these two sets of data probably was caused by the extent of error with only one year of observations. The possibility of error is less from sites where gophers were either present or absent for two successive years. Areas could be classified as favorable for gopher survival for one year by the extent of soil depth, forb and shrub cover, and aspect, but for gophers to survive for a longer period, treatment history and forb cover were more important.

The analysis followed in this study described the conditions important for gopher survival, and was not intended to predict pocket gopher occurrence. Although the distinction between description and prediction is subtle, an understanding of the habitat conditions

Table 5. Comparison of the sites where pocket gophers survived to the sites where gophers did not survive during 1975 and 1976 from data collected in Klamath and Lake Counties, Oregon.

Year	Habitat variables selected	F*[1]	df	Correctly classified	
				Group 1[2]	Group 2[3]
1975	Soil depth, aspect, mean forb cover, and mean shrub cover	4.98	4/123	65.5	70.7
1976	Treatment history and mean forb cover	12.56	2/99	76.7	72.4

[1] *F values significant at the 0.01 level.

[2] The group of sites where pocket gophers were found to survive.

[3] The group of sites where pocket gophers were not found to survive.

responsible for gopher occurrence was the objective of this study. The data indicate that increased site disturbance and forb cover will increase the probability of gopher survival. These data support the assumption that forest management activities improve pocket gopher habitat. To decrease the probability of gopher survival on a specific area, a reduction in the amount of site disturbance, forb cover, or both, is suggested. But whether harvest methods (shelterwood or partial cutting) or herbicide applications, alone, would significantly reduce pocket gopher potential is not entirely known. Additional studies are required to determine the response of gophers to such forestry practices.

CONCLUSIONS

Although no significant correlation was found between activity level and number of animals captured per acre, a significant relationship was shown between these indexes to animal density and the habitat variables. An increase in activity and catch was found in general with increasing elevation and slope, and a tendency towards the more mesic timber types.

The habitat preference of pocket gophers was shown by the separation of the two groups, where gophers survived and where they did not. The most significant findings were from data collected on the same sites for two successive years. These results showed a greater probability for an area to be favorable to pocket gophers when it had more site disturbance and greater forb cover.

The assumption that forest-management activities improve pocket gopher habitat is supported by the results of this study. A reduction in the amount of site disturbance, forb cover, or both, is suggested to decrease the probability of gopher occurrence and the associated gopher-caused tree damage.

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APPENDIX

Table A. Vascular plants identified on all sites within the study area in Klamath and Lake Counties, Oregon. Nomenclature follows Hitchcock and Cronquist (1974) systematic by the classification used in the analysis of this study.

Scientific name	Common name
TREES	
Calocedrus decurrens (Torr.) Florin.	Incense cedar
Juniperus occidentalis Hook.	Juniper
Abies concolor (Gord. & Glend.) Lindl.	White fir
Pinus contorta Dougl.	Lodgepole pine
Pinus ponderosa Dougl.	Ponderosa pine
Pinus lambertiana Dougl.	Sugar pine
Populus tremuloides Michx.	Aspen
SHRUBS	
Salix sp.	Willow
Berberis repens Lindl.	Creeping oregongrape
Ribes aureum Pursh	Golden currant
Ribes cereum Dougl.	Squaw currant
Amelanchier alnifolia Nutt.	Western serviceberry
Cercocarpus ledifolius Nutt.	Curl-leaf mountain-mahogany
Prunus subcordata Benth.	Kalmath plum
Purshia tridentata (Pursh) DC.	Bitter-brush
Rosa sp.	Wild rose
Ceanothus prostratus Benth.	Squaw carpet
Ceanothus velutinus Dougl.	Grease-wood
Arctostaphylos patula Greene	Green-leaf manzanita
Symphoricarpos albus (L.) Blake	Common snowberry
Symphoricarpos mollis Nutt.	Creeping snowberry
Artemisia tridentata Nutt.	Big sagebrush
Chrysothamnus nauseosus (Pall.) Britt.	Gray rabbit-brush
Chrysothamnus viscidiflorus (Hook.) Nutt.	Green rabbit-brush
Haplopappus bloomeri Gray	Rabbitbrush goldenweed
FORBS	
Equisetum sp.	Horsetail
Pteridium aquilinum (L.) Kuhn	Braken-fern
Urtica dioica L.	Nettle
Eriogonum sp.	Buckwheat

Table A. (Continued

Scientific name	Common name
Forbs (continued)	
Polygonum sp.	Knotweed
Silene sp.	Catchfly
Paeonia brownii Dougl.	Brown's peony
Descarainia sp.	Tansymustard
Phoenicaulis cheiranthoides Nutt.	Daggerpod
Fragaria vesca L.	Woods strawberry
Fragaria virginiana Duchsene	Broadpetal strawberry
Geum sp.	Avens
Potentilla sp.	Cinquefoil
Lathyrus sp.	Peavine
Lotus crassifolius (Benth.) Greene	Big deervetch
Lupinus sp.	Lupine
Trifolium sp.	Clover
Geranium sp.	Crane's-bill
Sidalcea oregana (Nutt.) Gray	Oregon checker-mallow
Clarkia sp.	Clarkia
Epilobium sp.	Willow weed
Gayophytum sp.	Ground smoke
Umbelliferae	Parsley
Osmorhiza occidentalis (Nutt.) Torr.	Western sweet-root
Perideridia sp.	Yampah
Collomia sp.	Collomia
Apocynum sibiricum Jacq.	Indian hemp
Gilia aggregata (Pursh) Spreng	Scarlet gilia
Navarretia sp.	Navarretia
Phlox sp.	Phlox
Phacelia sp.	Phacelia
Cryptantha sp.	White forget-me-not
Nicotiama attenuata Torr.	Coyote tobacco
Castilleja sp.	Indian paintbrush
Verbascum thapsus L.	Common mullein
Galium sp.	Bedstraw
Achillea millefolium L.	Yarrow
Agoseris sp.	False-dandelion
Antennaria sp.	Everlasting
Arnica cordifolia Hook.	Heart-leaf arnica
Aster sp.	Aster
Balsamorhiza sp.	Balsamroot
Cirsium sp.	Thistle

Table A. (Continued)

Scientific name	Common name
Erigeron sp.	Daisy
Eriophyllum lanatum (Pursh) Forbes.	Wooly sunflower
Hieracium sp.	Hawkweed
Madia sp.	Tarweed
Solidago sp.	Goldenrod
Taraxacum sp.	Dandelion
Tragopogon sp.	Goatsbeard
Wyethia sp.	Mule's-ears
Allium sp.	Wild onion
Brodiaea hyacinthina (Lindl.) Baker	Hyacinth brodiaea
Lilium washingtonianum Kell.	Shasta lily
Smilacina stellata (L.) Desf.	Starry false Solomon's seal
Veratrum californicum Durand	California false Hellebore
GRASS-LIKE	
Juncus sp.	Rush
Carex sp.	Sedge
Agropyron sp.	Wheatgrass
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Bromus tectorum L.	Cheatgrass
Bromus carinatus H. & A.	California brome
Dactylis glomerata L.	Orchard-grass
Elymus sp.	Wildrye
Festuca idahoensis Elmer	Idaho fescue
Hordeum brachyantherum Nevski	Meadow barley
Koeleria cristata Pers.	Prairie junegrass
Phleum pratense L.	Common timothy
Phleum alpinum L.	Mountain timothy
Poa sp.	Bluegrass
Sitanion hystrix (Nutt.) Smith	Bottlebrush squirreltail

Table B. Gradients used in the analysis of data collected from each site within Klamath and Lake Counties, Oregon.

Habitat variable	Gradient for analysis
Aspect	The aspect was coded as follows: 0 - None (no slope) 1 - N22W-N22E north 2 - N23E-N67E northeast 3 - N68E-S68E east 4 - S67E-S23E southeast 5 - S22E-S22W south 6 - S23W-S67W southwest 7 - S68W-N68W west 8 - N67W-N23W northwest
Timber type	The overstory component was recorded as: 1 - non-forest, dry 2 - juniper 3 - lodgepole pine 4 - ponderosa pine 5 - ponderosa pine-white fir 6 - mixed conifer 7 - white fir-ponderosa pine 8 - aspen-mixed conifer 9 - non-forest, wet
Cover type	The ground cover component was recorded as: 1 - xeric grasses, rockflats 2 - sagebrush-grass 3 - other dry shrubs-grass 4 - xeric shrubs-manzanita 5 - manzanita 6 - squaw carpet-manzanita 7 - snowbrush-manzanita 8 - snowbrush 9 - mesic forbs, meadows
Treatment history	Coded according to the extent of site disturbance as follows: 1 - no treatment 2 - partial cut, salvaged 3 - merchantable removal 4 - merchantable removal, precommercial thinned, site prepared, and planted

Table B. (Continued)

Habitat variable	Gradient for analysis
Treatment history (continued)	5 - site prepared and planted, no standing timber (old burn)
Soil texture	Recorded from the description of the soil series as follows: 1 - sandy loam } coarse 2 - stony sandy loam } coarse 3 - pumicy loam } medium 4 - stony loam } medium 5 - loam } medium 6 - stony clay loam } fine 7 - clay loam } fine 8 - clay } fine
Soil friability	Recorded from the description of the soil series as follows: 1 - loose 2 - loose-very friable 3 - very friable 4 - very friable-friable 5 - friable 6 - very friable-firm 7 - loose-very firm 8 - firm
Soil depth	Recorded from the description of the soil series as follows: 1 - shallow 2 - shallow-moderately deep 3 - moderately deep 4 - moderately deep-deep 5 - deep
Rock content	The percentage rock content by soil volume was recorded from the description of the soil series as follows: 1 - less than 10 2 - less than 20 3 - 25(10-40) 4 - 30(20-40; 10-50) 5 - 35(20-50) 6 - 40(30-50)

Table B. (Continued)

Habitat variable	Gradient for analysis
Rock content (continued)	7 - 50(20-80) 8 - more than 50 (The rock content of rock outcrops or the rock phase of soils is greater than 40 percent.)
Drainage	The soil drainage was recorded from the description of the soil series as follows: 1 - poorly 2 - imperfect-poorly 3 - imperfect 4 - moderate-imperfect 5 - well 6 - well-excessive
Permeability	The soil permeability was recorded from the description of the soil series as follows: 1 - very slowly 2 - slowly 3 - moderately slow 4 - moderate 5 - moderate-moderately rapid 6 - moderately rapid