Succession of Pinyon-Juniper Communities after Mechanical Disturbance in Southcentral New Mexico

M.R. SCHOTT AND R.D. PIEPER

Abstract

Principal component analysis (PCA) was used to interpret secondary succession of pinyon-juniper stands after cabling or bulldozing. Soil types were used to separate 93 sample units into 3 groupings. A PCA was run on 2 of the groupings. Groups of sample units were defined as community types for each ordination. Stepwise discriminant analysis using environmental variables was used to assist in delineation of community types. Species that contributed the most to the first 3 principal components were compared among community types for each ordination using an analysis of variance and a comparison of the least squares means. Grasses on the deeper soils usually increased after cabling, but after 25 years they had declined to near pretreatment levels. Wavyleaf oak (*Quercus undulata* Torr.) increased after cabling, and on the older cablings it had reached higher cover values than on the other community types. Pinyon and juniper response appeared to be dependent on density and size of trees before cabling. If the stand was near climax before cabling, pinyons rapidly became dominant on the site. If it was seral, there would be more junipers, but their slow growth and the time they require for maturation required more time before they dominated the site. The successional pattern following cabling on relatively deep soils is similar to what was found after fire, but it occurs faster. Cover of grasses and shrubs increased more on rock-free soils compared to sites treated similarly but with rock. The ordinations indicated that succession in pinyon-juniper communities is directional and leads towards climax with a decrease in variability among sites.

Key Words: vegetation changes, Ordination, principal component analysis, botanical composition

Distribution of the pinyon-juniper complex in the Southwest is extensive, covering about 77 million hectares (Pieper 1977). This vegetation type constitutes a valuable resource supplying food and cover for many wildlife species, food and fuel for man, forage for livestock, and watershed, water storage, etc. Since settlement of the American West, distribution and density of trees in the pinyon-juniper complex has increased (West et al. 1975). A decline in forb and grass production has accompanied these increases (Arnold and Schroeder 1955; Johnsen 1962). Livetock grazing, a lower incidence of wildfire, and climatic change are often suggested as reasons for this expansion (Springfield 1976).

Authors are research associate, Oregon State University, 97331 and professor, Dept. of Animal and range Sciences, New Mexico State University, Las Cruces 88003.
Journal Article 1110, Agr. Exp. Sta., New Mexico State University, Las Cruces, NM 88003.
Manuscript accepted 24 July 1986.

Several studies have dealt with community response following disturbance. Dwyer and Pieper (1967) studied the effects of a wildlife on a juniper stand in south central New Mexico. They found the fire mortality of junipers varied according to size, with the smaller trees more susceptible. The forb component was not affected by the fire, and grasses recovered within 2 years. Clary and Jameson (1981) examined understory response after girdling pinyons and junipers and treatment of live oak (*Quercus turbinella* Greene) with herbicide on several soil types in Arizona. They reported increased production for all grasses, most forbs, and about half the shrub species. However, there were measurable differences in vegetation response on different soils.

Hessing et al. (1982) investigated early succession of a pinyon-juniper woodland in a northern Arizona powerline corridor. The study area had been bulldozed, used as an access road and reseeded. The seeding was considered a failure and seedbed preparation added significantly to site disturbance. They reported that only 1 woody species, wolfberry (*Lycium pallidum* Miers) had become established on the site after 5 years. This species is often associated with disturbed areas. Forbs were more abundant of the cleared sites than under the adjacent tree canopy; however, most of these forbs were invaders or annuals. Grasses were significantly less abundant on the cleared site than on neighboring undisturbed site. The authors suggested recolonization of disturbed sites would be a slow process requiring many years. Another powerline study in northern New Mexico by Ludwig et al. (1977) showed similar results in areas which had been bulldozed. Annual forbs dominated these bladed sites for about 4 years, after which these authors propose that grasses would supplant the forbs. They found no difference in density of the trees between the treated site and the control because of reproduction. However, the treated site had significantly less tree cover than the control. Grass cover was significantly greater on the treated site than on the control. Tree

Table 1. Multiple comparisons of the species percent cover for the groups from the rocky soil. Least squares means were used for the comparison.

	*Lycurus phleoides**	*Muhlenbergia dubia**	*Gutierrezia sarothrae**	*Juniperus deppeana***	*Pinus edulis**
Group	Mean	Mean	Mean	Mean	Mean
uncabled	0.13 B[1]	2.00 AB	0.20 B	4.63 A	11.91 A
1954 cable	0.36 AB	1.05 B	0.57 B	1.87 B	7.21 B
1975 cable	0.60 A	1.07 B	1.40 A	0.25 B	3.10 BC
1975 cable	0.13 B	3.48 A	0.41 B	1.76 B	2.48 C

[1]Means followed by different letters are significantly different (*$P<.05$, **$P<.15$).

establishment occurred within 5 years following treatment, but recovery of the tree canopy to pretreatment values was estimated to require at least 100 years.

A few studies have examined more than the first few years following disturbance. Burkhardt and Tisdale (1969, 1976) investigated secondary succession following fire in western juniper (*Juniperus occidentalis* Hook.) communities in southwestern Idaho. Barney and Frischknecht (1974) did a similar study for stands of Utah juniper-single leaf pinyon (*J. osteosperma* (Torr.) Little -*Pinus monophylla* Torr. & Frem.) in Utah. Arnold et al. (1964) examined succession in Utah pinyon-juniper (*P. edulis* Engelm.) communities in Arizona following fire, grazing, and tree control treatments. Finally, Tausch and Tueller (1977) evaluated succession following chaining of Utah juniper-single leaf pinyon communities in eastern Nevada.

Successional patterns common to both fire and chaining may be summarized from these studies and 3 examples are shown in Figure 1. Generally, following catastrophic disturbance an annual community forms. It is replaced by a perennial grass community, which is replaced by perennial grasses, forbs and half shrubs. This mixed community gradually becomes dominated by shrubs and junipers, and succeeds to climax. The pattern is similar for fire and cabling disturbance. However, rate of change is much faster after cabling than after fire because more plants survive cabling.

These generalized models may not apply to every area and pinyon-juniper community. Clary and Jameson (1981) reported that vegetation on limestone-derived soils responds differently to tree removal than vegetation on basalt-derived soils.

There are many studies of secondary succession in pinyon-juniper communities. Most reported changes the first few years following disturbance. Several have dealt with more than the first few years after disturbance; most of these long-term studies were concerned with succession following fire. Succession studies beyond the first few years after cabling are rare, and none have dealt with succession following cabling in pinyon-one-seed juniper communities. The objective of this study was to determine secondary successional patterns following disturbance by cabling and bulldozing.

Methods

Field Methods

The study area was restricted to the Sacramento Mountains of south central New Mexico. Study sites were selected through interviews with Forest Service personnel and by ground reconnaissance. Cabling and bulldozing were the major treatments sampled. All the known pinyon-juniper treatments were examined before site selection. Selection criteria were soil uniformity, aspect, slope, and elevation to assure environmental similarity among sites.

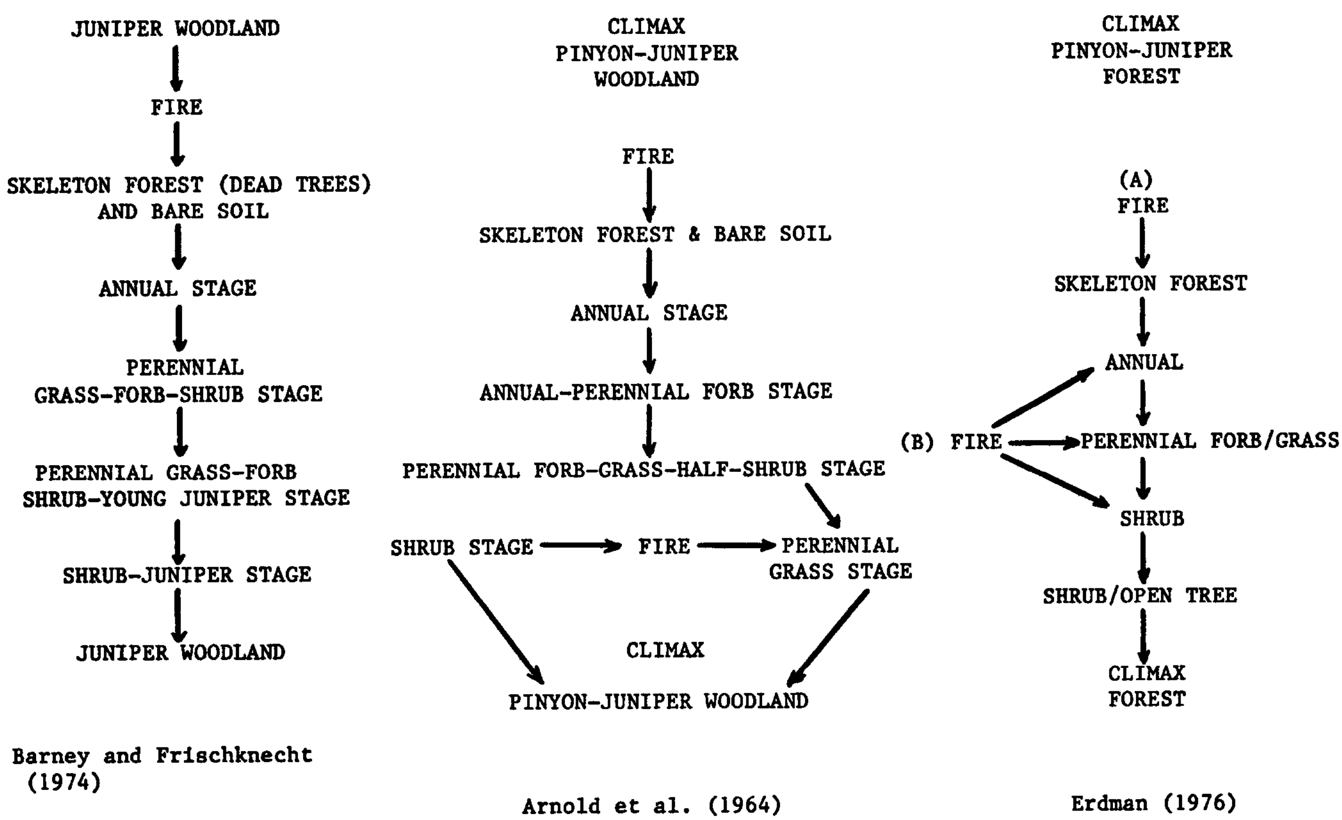

Fig. 1. *General successional models of pinyon-juniper communities.*

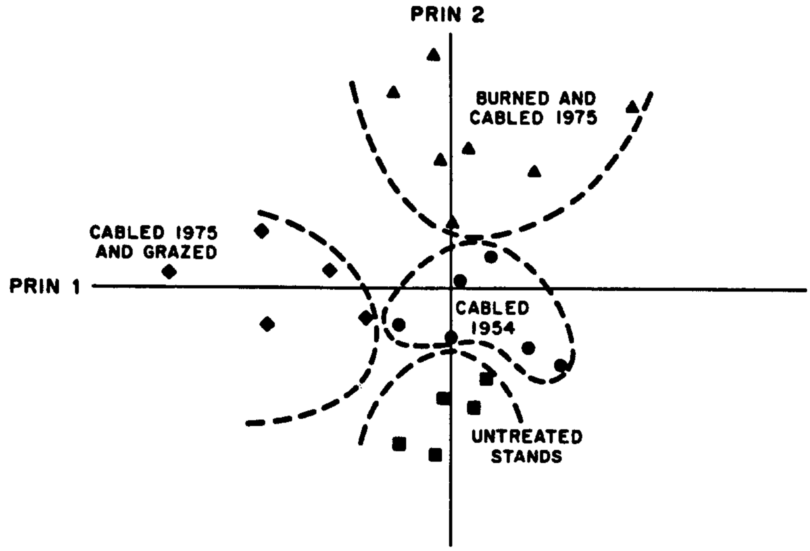

Fig. 2. *Ordination based on the first 2 principal components of the sample units from the* Pinus edulis - Juniperus deppeana / Muhlenbergia dubia *habitat type. Sample units of the uncabled community type are represented by ■, sample units which represent the community type which had been cabled in 1954 are represented by ●, stands from the two community types which had been cabled in 1975 are represented by ▲ for the one with evidence of fire, and by ◆ for the one with the greater grazing. Axis 1 represents successional direction and axis 2, the variation due to different histories of disturbance.*

Sample sites were sampled during the summer of 1982 and 1983. A 15×25 m macroplot was located subjectively on each area, with the long axis parallel to the slope to minimize slope-related variations between sample units. Within the macroplot, two 25 m transects were established randomly using a 25 m tape with the restriction that they were at least 2 m apart. Twenty 2×5 dm microplots were placed at 1 m intervals along each transect, and canopy cover was estimated for each herbaceous species found rooted within the microplot. Forty microplots were sampled per macroplot. Systematic placement of the microplots helped eliminate subjective bias during sampling. Cover classes were used because of the difficulty in precise estimation of percent cover. Cover classes of Daubenmire (1959) were modified to estimate percent cover: Class 1 (0–5%); Class 2 (>5–25%); Class 3 (>25–50%); Class 4 (>50–75%); Class 5 (>75–95%), Class 6 (>95–100%). Cover values for the microplots were summarized for each species. Points located at the 4 corners of the 2×5 dm frame were used to estimate percent bare ground, litter, cryptogam, rock and vegetation. There were 80 points per transect, or 160 points per macroplot. Canopy cover of woody species was estimated using line intercept along the tape which defined each belt transect. Measurements were made to the nearest centimeter.

Analytical Methods

Ordination has been defined a the arrangement of stands in a multi-dimensional space such that similar stands are close and dissimilar stands far apart (Bray and Curtis 1957; Gauch 1982). One object of ordination is to aid in the interpretation of community relationships to environment. Studies of secondary succession reflect the type, degree and time since disturbance as axes of the ordination. The use of time since disturbance has been used as an axis by several authors (Huschle and Hironaka 1980; Peet and Christiansen 1980).

Principal component analysis (PCA) was conducted on cover estimates of the species to ordinate sampled sites (Legendre and Legendre 1983). PCA fits a line through the swarm of sample units, which accounts for most of the variation among sample units. Sample units were separated into 3 groups on the basis of soils. A PCA was run on 2 of the soil-derived groups; the third grouping consisted of 8 sample units and was not ordinated. Clusters of sample units were defined as community types, which were evaluated within each of the 2 ordinations, using a stepwise discriminant analysis procedure based on soil depth to a restrictive layer, aspect, elevation, slope, percent rockiness, bare ground, litter cover, type of disturbance, and severity of disturbance (Pielou 1977; Neff and Marcus.1980). Species which added most to the first 3 principal components were examined for differences among community types for each PCA using an Analysis of Variance (Ott 1977). Least square means were used to compare groups if there were significant differences.

Table 2. Mulitple comparisons of the species percent cover for the groups from the third ordination, the *Pinus edulis-Juniperus monosperma/Muhlenbergia pauciflora* habitat type. Least square means were used for the comparisons.

Group	*Bouteloua curtipendula** Mean	*Bouteloua gracilis** Mean	*Muhlenbergia repens**** Mean	*Eriogonum hierac-ifolium**** Mean	*Gutierrezia sarothrae**** Mean	*Quercus undulata*** Mean	*Juniperus mono-sperma**** Mean	*Pinus edulis** Mean
1975 cable on deep soil	0.378 B[1]	26.188 A	1.408 AB	0.046 C	0.856 AB	2.060 C	2.711 B	0.640 C
1975 cable on normal soil	2.98 A	19.956 B	2.417 A	0.314 AB	1.078 A	2.020 C	2.640 B	4.296 B
1950 cablings with low amounts of pinyon	2.686 A	10.206 C	0.028 B	0.418 A	0.528 B	11.135 B	7.253 A	7.853 B
1950 cabling with high amounts of pinyon	2.194 A	5.238 D	0.889 B	0.290 AB	0.456 BC	16.944 A	1.922 B	24.036A
Uncabled	1.060 B	9.309 CD	0.071 B	0.131 BC	0.211 C	8.400 B	10.058 A	19.371 A

[1]Means followed by different letters are significantly different (*$P<.001$, **$P<.005$, ***$P<.05$).

Results and Discussion

Vegetational Analyses

Sample units were separated initially on the basis of soil and PCA was run on 2 of the groupings. The group with the fewest sample units occurred in the *Pinus edulis-Juniperus monosperma/-Bouteloua gracilis* habitat type (Kennedy 1983), which was found on a clayey, mixed, mesic Haplustalf soil (U.S. Forest Service ND). Because there were only 8 sample units in this habitat type, they were not ordinated. Four sample units were old growth stands near climax. The other sample units were from stands where the trees had been removed by bulldozing (push) in 1965.

Species were analyzed to determine if their cover values differed between 2 treatments. Six species were significantly different ($P < .01$). Blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) in the old growth stands had an average cover estimate of 1.9%, while blue grama in the push stands had an average cover value of 32.9%. Removal of the trees resulted in a significant increase in blue grama. Denttooth (*Chenopodium incisum* Poir) had an average cover estimate value of 1.0% in the old growth stands, but was rarely sampled in the pushed sample units. Pinyon ricegrass (*Piptochaetium fimbriatum* (H.B.K.) Hitch.), like denttooth, was found only under tree canopies; thus, it did not occur on the pushed sites. Snakeweed (*Gutierrezia sarothrae* (Pursh) Britt & Rusby) did not occur in the old growth stands, but had an average cover estimate of 1.6% on the pushed sites. As expected, pinyon had greater canopy cover values in old growth stands than in the pushed stands, 28.3% and 0.01%, respectively. Few juvenile pinyons had become established since bulldozing. One-seed juniper (*Juniperus monosperma* (Engelm.) Sarg.) response was similar to that of pinyon, in that old growth sites had greater canopy cover than the pushed stands, 28.3 and 0.7%, respectively.

Blue grama was negatively correlated with denttooth (r = −.6042), one-seed juniper (r = −.7396), pinyon (r = −.7421) and pinyon ricegrass (r = −.8318). Both pinyon and juniper have a negative effect on blue grama by shading, litter accumulation, and interception of rain by their canopies (Johnsen 1962, Jameson 1967). One-seed juniper also appears to have an allelopathic effect on blue grama, and it competes for soil water (Jameson 1965, 1966). Both denttooth and pinyon ricegrass were positively correlated with both pinyon and juniper, r = −.49 and r = −.77, respectively for pinyon, and r = −.58 and r = −.74, respectively for juniper. Denttooth and pinyon ricegrass are positively correlated (r = −.68). These species appear to do well under the canopies of pinyon and one-seed junipers, while blue grama does not. This explains the negative correlation between these species and blue grama. Pinyon and one-seed junipers are strongly correlated in these stands (r = −.91).

A PCA was run on sample units from the dry phase of the *Pinus edulis-Juniperus deppeana/Muhlenbergia dubia* habitat type (Kennedy 1983) (Fig. 2). This habitat type occurs on a Tortugas, gravelly loam, rock outcrop complex, which was a loamy-skeletal, carbonatic, mesic, Lithic Haplustoll (Bailey et al. 1982). Four point clusters were produced by the ordination.

Sample units comprising 2 clusters are from areas which were two-way cabled in 1975. Each cabling forms its own cluster. Community structure before the cabling was probably different for the 2 areas, resulting in different community-types after cabling. Both

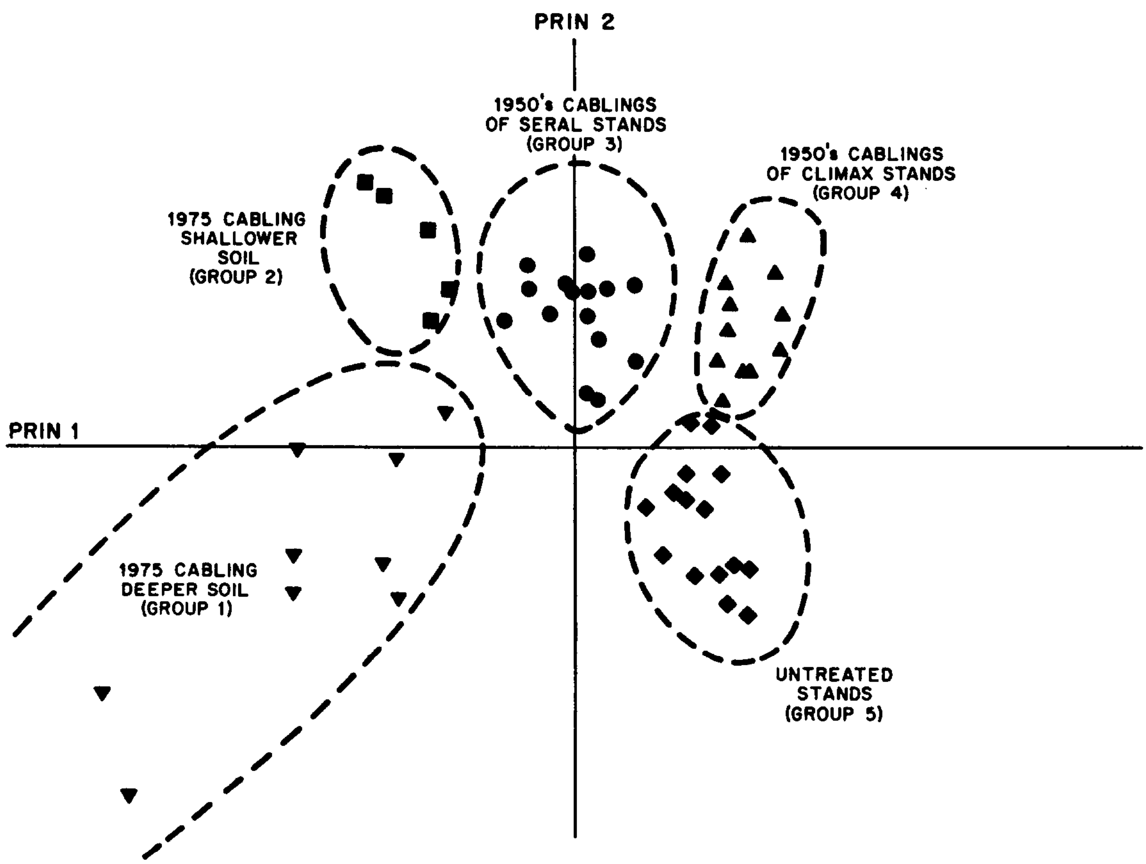

Fig. 3. *Ordination based on the first 2 principal componens of the sample units from the* Pinus edulis - Juniperus monosperma / Muhlenbergia pauciflora *habitat type. Sample units on deeper soils which were cabled in 1975 (group 1) are represented by ▼. The other-sample units cabled in 1975 (group 2) are represented by ■. Sample units which were not near climax prior to cabling in the 1950's (group 3) are represented by ●. sample units which were near climax prior to cabling in the 1950's (group 4) are represented by ▲. Untreated sample units (group 5) are repesented by ◆. The ordination displays the similarity between groups 4 and 5. Also, it shows the direction of succession, from the upper left of the figure to the lower right. Successional direction is from left to right on principal component 1 and from high to low on principal component 2 with the expection of group 1 which is separated because of its deeper soil.*

areas showed evidence of firewood cutting around the turn of the century, but one area also had evidence of fire before the woodcutting. The other received more grazing pressure than the former. Another cluster was comprised from sample units which had been two-way cabled in 1954. The final cluster was largely comprised from sample units which had received minimal disturbance from firewood cutting or historic fire.

SDA selected only the degree of disturbance the sample unit received to discriminate between clusters, and its classification had a 42.3% agreement with the PCA clusters. One cluster had minimal disturbance, and the other 3 clusters had been severely disturbed. Thus, the SDA placed the 3 clusters which had received severe disturbance into 1 cluster. Sample units were selected to minimize differences attributable to environmental variables such as elevation, aspect, and slope, which is why the SDA was only able to select 1 variable.

Species which contributed the most to the first 3 principal components were analyzed for differences among clusters (Table 1). There were no differences in the cover estimates among clusters for blue grama, which is in contrast to the data from the sample units of the first PCA. The difference in response may be the result of differences in soils. On rocky soils, blue grama is prevented from spreading because it spreads by tillering, and rock interferes with formation of adventitious roots (Hyder et al. 1971).

Pine muhly (*Muhlenbergia dubia* Fourn.) has significantly greater coverage estimates on the burned 1975 cabling than most of the other clusters. The burn may have stimulated the pine muhly.

Wolftail (*Lycurus phleoides* H.B.K.) has the opposite response to grazing pressure; it appears to increase with disturbance. Its greatest coverage occurs on the other 1975 cabling. This cabling receives more grazing pressure than the first which, combined with the actual cabling, probably acted to release the wolftail.

Snakeweed, also a disturbance species, had greater coverage on the burned 1975 cabling than in the other clusters. Differences in these 3 species probably account for separation of the 2 clusters comprising the 1975 cablings. However, none of these species show strong correlation with each other.

There is little response by grass species following cabling on these rocky soils. Pine muhly and wolftail show slight increases on the 1975 cablings. They probably increased because of tree removal, but differences between the 2 groups appear to be caused by events before cabling.

Both one-seed juniper and alligator-juniper (*Juniperus deppeana* Steud.) had significantly greater cover estimates on uncabled sample units. There was no difference in canopy cover among the treated stands. Cover values of both juniper species on the cablings were contributed by plants which either survived the cabling or became established from seeds which were on the areas before cabling, or were brought in by animals from adjacent stands. One-seed juniper seeds are known to remain viable for 20 years (Johnsen 1959). With removal of the mature junipers, the only seed sources are those that were present under tree canopies before cabling and those brought in by animals (Salomonson 1978). Junipers seldom become established in the first few years following cabling. After establishment they grow slowly and can reach seed bearing age at 10 years, but the optimum is between 50–200 years (Tueller and Clark 1975). The combination of slow growth in junipers and limited seedling establishment helps explain why there is little difference in juniper cover between the 1954 cabling and the 1975 cabling.

Pinyon also has the greatest canopy coverage for the cluster of uncabled sample units, but the cluster of sample units cabled in 1954 exhibited greater canopy coverage than clusters comprised of sample units cabled in 1975. Compared to juniper, pinyon is faster growing and produces seed at an early age. Also, pinyon readily replaces itself in old growth stands more readily than junipers do. Thus, at the time of the cablings, there were probably a large number of young pinyons and only a few junipers. Cabling is not effective in removing young trees (Aro 1971; Springfield 1976). The faster growing rate, combined with greater densities of reproductive trees surviving cabling accounts for the greater canopy cover on the cluster comprised of sample units from 1954 cablings.

There were no difference in the coverage of either wavyleaf oak (*Quercus undulata* (Torr.)) or skunkbush (*Rhus trilobata* Nutt.) among any of the clusters. Canopy cover of wavyleaf oak averaged about 9.5% for the clusters. Firewood cutting before cabling may have released the oak, which would account for the amount of oak found in the uncabled sample units. Another possible explanation for the amount of oak on uncabled sites is that junipers in rocky broken soils do not compete as much with oak as on less broken soils. Juniper lateral root systems may be restricted by rocky soil, reducing the competition between oaks and junipers. Wavyleaf oak spreads by adventitious roots, and shallow soil and rock outcroppings may control the amount of oak as it does for blue grama (Tucker 1961). Skunkbush does not spread vegetatively, but it may have been released by firewood cutting, and was showing maximum expression before cabling.

The PCA (Fig. 2) illustrates the successional direction. The uncabled group is low on principal component 2, and near the center of the other principal component. The group cabled in 1975, and which received the grazing pressure, is found on the left side of principal component 1. The other group which was cabled in 1975, but had been burned, is placed high on principal component 2. As succession occurs, variation among sample units decreases and there is movement towards the untreated stands. The initial process is fairly rapid; the 1954 grouping is about half way between the uncabled group and the 1975 cabling groups, although there is only 21 years between the 1954 cabling group and the 1975 cabling groups.

Sample units of the second PCA were in the *PCA edulis-Juniperus monosperma/Muhlenbergia pauciflora* habitat type described by Kennedy (1983). This habitat type was found on the Tortugas soil series, where it was cobbly rather than gravelly and there were fewer rock outcroppings. Five clusters were delineated from the PCA (Fig. 3). Two clusters were comprised of sample units cabled in 1975, 2 were comprised of stands cabled in 1954 through 1959, and the last cluster was made up from uncabled stands.

New Mexican muhly (*Muhlenbergia pauciflora* Buckl.) is present on all the sample units, but often to a lesser degree than that reported by Kennedy. Grazing pressure may have caused a decrease in its cover, because an ungrazed plant was rarely observed during sampling.

SDA selected aspect, soil depth and percent bare ground as the basis for classification. Its classification had an 81% agreement with the clusters delineated from the PCA. One of the clusters comprised of sample units from a 1975 cabling is delineated by deeper soils and the SDA has a 100% agreement with the grouping. The other 1975 cluster is separated mainly on the basis of aspect. Stands in ths cluster faced east, while most of the other sample units faced N to NE. The SDA has a 100% agreement with this grouping (group 2). The 3 remaining groups appear to be separated on the basis of percent bare ground. As expected, the group comprised of uncabled stands has the least amount of bare ground, averaging 13.9%. The other group, comprised of stands cabled in 1954 through 1959, had about the same amount of bare ground as the groups comprised of stands cabled in 1975 averaging 33.8% bare ground. Those sample units of the 1951 and 59 cablings with high pinyon densities had an average of 18.0% bare ground, approaching that found of the uncabled group. SDA classification has a 58.8% agreement with this group. The SDA places 2 sample units of this group in the groups with low pinyon densities and 3 with the uncabled groups. Group 4 appears to grade into group 5, and is less clearly defined as would be expected since the main difference is related to pinyon density.

There were significant differences among the groups for 8 species: blue grama, sideoats grama (*Bouteloua curtipendula* Michx Torr.) creeping muhly (*Muhlenbergia repens* (Presl. Hitch.), wild buckwheat (*Eriogonum hieracifolium* Benth.), snakeweed, one-seed juniper, wavyleaf oak and pinyon (Table 2). Sample units on the 1975 cabled area with deep soil had the highest cover estimates for blue grama. Deeper soils and tree removal appear to account for the high cover values. Sample units with "normal" soils cabled in 1975 have less blue grama than the first, but more than those on sites cabled in the 1950's or the control. Soil depth accounts for the differences between the first 2 groups, and the more recent removal of the pinyon and one-seed junipers is the reason for the differences between the remaining groups. There is no difference in the amount of blue grama found on uncabled sample units and those cabled in the 1950's. However, those with low densities of pinyon had significantly more blue grama than those with high densities of pinyon. The relatively large cover of both pinyon and oak in this group may have caused a reduction in blue grama cover.

Sideoats grama cover on sample units with deep soil cabled in 1975 showed an opposite response to that of blue grama. This group and the uncabled sample units had the least amount of sideoats grama. The other groups had the most. Sideoats grama appears to increase with tree removal. Creeping muhly exhibited its highest coverage on those sample units cabled in 1975, reflecting the more recent disturbance of these groups; there was no difference in its coverage among the remaining groups. Wild buckwheat has the least coverage on the deeper soils of those sample groups with little difference in its coverage among the other groups. Snakeweed has the highest coverage on the 1975 cablings and the least on uncabled stands, which may reflect the response to the more recent cabling disturbance. Wavyleaf oak is the only shrub species which reflected differences among the groups. Wavyleaf oak had the greatest cover on sites cabled in the 1950's with high pinyon densities. Sample units cabled in 1975 had the least amount of oak. Most of the sample units in the uncabled areas have had some firewood cutting on them, which may account for relatively high cover of wavyleaf oak. Firewood cutting opened up the stand, which may have released the oak. Sample units on the older cablings have large values for wavyleaf oak cover. This oak species is known to increase after fire, and cabling has an effect similar to that of fire in removal of overstory. Low coverages of oak on those sample units cabled in 1975 were unexpected. There are 2 possible explanations for the low coverages. The areas might have had small amounts of oak present before cabling due to competition from the trees; or cabling directly or indirectly destroyed some of the oak.

One-seed juniper had the greatest canopy coverage in the uncabled sample units and those cabled in the 1950's with the low pinyon cover. There were no differences in pinyon cover among the other groups. The difference in the amount of juniper and pinyon between groups cabled in the 1950's with low and high amounts of pinyon may be a reflection of the age of the stand before cabling. Pinyon typically has the greater cover in old undisturbed stands and there are many small pinyons under the canopy. In contrast, young one-seed junipers are not common under the canopy of near climax stands (Salomonson 1978). Those sample units cabled in the 1950's with high cover of pinyon were probably near climax at the time of cabling, while the groups with low pinyon cover were probably from much younger stands at the time of cabling.

Successional Patterns

A general scenario of secondary succession following cabling on this soil is similar to what was reported by Tausch and Tueller (1977). The cabling removes most of the trees and some of the wavyleaf oak. Initially, grasses respond to the overstory removal, but somewhere between 8 and 28 years, grass cover declines. Snakeweed has a response similar to that of grasses, an initial increase following cabling followed by a deceases to the same level as the uncabled site after 28 years. Wavyleaf oak is at its lowest levels soon after cabling. It slowly increases for the first few years. Somewhere between 8 and 28 years, oak canopy coverages exceed or equal those of uncabled areas. Sometime, around 28 years, pinyons and junipers start suppressing the oak and become dominant. If the stand was near climax at the time of cabling, pinyon rapidly becomes dominant on the stand. However, if the stand was not nearly climax, there will be less pinyon and more junipers on the stand. This depends entirely on the number of young trees of each species found in the stand at the time of cabling.

Examining the second ordination (Fig. 3) groups 1 and 2 are placed to the left on Figure 3. The deeper soil of group 1 causes this group to be placed lower on the second axis than group 2. Both these groups display a large amount of variability among the sample units which comprise them. Group 3 is located in the upper center of the figure. Group 4 is to the upper right, and group 5 is in the right center of the figure. Distance between cabled and uncabled stands decreases as succession moves forward to the climax. Group 5, the uncabled sample units, still exhibits a large amount of distance among stands, but this is due to firewood cutting and fire disturbances these stands have received. This decrease in distance satisfies the cone model of Huschle and Hironaka (1981) where succession is directional, and there is less distance among sample units nearing climax than among early successional units. Group 4 is more similar to the uncabled groups. This is probably due to the character of the community before cabling. These sample units probably had many young pinyons under the canopy and cabling released these trees through the rapid succession towards climax.

Succession in this habitat type also appears to fit the general successional models of Arnold et al. (1964), Barney and Frischknecht (1974) and Erdman (1970) (Fig. 1). The rate of succession is faster than these authors found after fire, and these results are more similar to those Clary and Jameson (1981) found for succession following chaining in Arizona. Succession in the *Pinus edulis-Juniperus deppeana/Muhlenbergia dubia* h.t. does not appear to follow the model of Arnold et al. (1964) or that of Barney and Frischknecht (1974). The rocky soil limits the increase in grass cover following cabling and the shrub stage does not occur. The shrubs do not appear to spread beyond what is found in the uncabled stands. This may be due to the way wavyleaf oak spreads. This species does not appear to reproduce often from seed and, if it did, it is a poor disperser. Rather, this species spreads by adventitious suckers on its roots, and rocky soil may restrict the spread.

Conclusions

Succession after cabling pinyon-one-seed juniper communities may or may not follow the general successional models of Arnold et al. (1964), Barney and Frischknecht (1974) and Erdman (1970), depending on the soil they are found on. Rocky, shallow soils do not exhibit the grass or grass shrub stages after cabling. There is a small response by a few grass species after cabling, but if all the grasses are included, response is minimal. There proved to be no difference in shrub cover on 1975 cabling, 1954 cablings, and uncabled stands, which indicates shrubs failed to respond to the tree removal. Wavyleaf oak is the dominant shrub on these sites, and it spreads primarily by adventitious shoots from its roots. Rocky, broken soil may restrict the spread of the oak, which could account for the lack of response after cabling. Both alligator and one-seed juniper have the same coverage on both the 1954 and 1975 cablings. These species are slow growing and need time for maturation. Slow growth and low establishment of the junipers accounts for the lack of differences among the cablings. Young pinyons are common under the canopies of old growth stands, and their small size allows many of them to survive cabling. Pinyons have fast growth rates when compared to junipers, and also mature faster. Because of their faster growth rates and availability of a seed source, the 1954 cabling had a greater coverage of pinyon than the 1975 cablings.

Cablings on less rocky soils follow the generalized successional models of Arnold et al. (1964) and Barney and Frischknecht (1974). Coverages of the grass species and snakeweed increase after cabling. However, the increases have disappeared after 25 to 2 years. Wavyleaf oak appears to decline initially after cabling, but it gradually increases until it reaches maximum coverages 25 to 28 years after cabling. Pinyons and one-seed junipers start to become dominant 28 years after cabling. Which species becomes dominant depends on the structure of the stand before cabling. If the stand was near climax, pinyons became dominant after cabling. If the stand was at a lower seral stage, one-seed juniper became dominant.

Succession on both of these soils support the cone model of Huschle and Hironaka (1980) for secondary succession. Succession on both areas appears to directional, and variability within community types appears to decrease with succession. Community types represented by stands which had been cabled in 1975 had the greatest variability, while community types which were represented by uncabled stands had the least variability. Firewood cutting probably caused most of the variability found within these community types.

Literature Cited

Arnold, J.F., D.A. Jameson, and E.H. Reid. 1964. The pinyon-juniper type of Arizona: Effects of grazing, fire, and tree control. USDA Prod. Res. Rep. 84.

Arnold, J.F., and W.L. Schroeder. 1955. Juniper control increases forage production on the Fort Apache Indian Reservation. USDA, For. Serv., Rocky Mt. For. and Range Exp. Sta. Pap. No. 18.

Aro, R.S. 1971. Evaluation of pinyon-juniper conversion to grassland. J. Range Manage. 24:188-197.

Bailey, O.F., L.A. Daughtery, and G.B. Donart. 1982. Soil survey of the Fort Stanton Experimental Ranch Phase 1. New Mexico State Univ.. Las Cruces. Agr. Exp. Sta., Spec. Rep. 43.

Barney, M.A., and N.C. Frischknecht. 1974. Vegetation change following fire in the pinyon-juniper type of west-central Utah. J. Range Manage. 27:91-96.

Bray, R.A., and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

Burkhardt, J.W., and E.W. Tisdale. 1969. Nature and successional status of western juniper vegetation in Idaho. J. Range Manage. 22:264-270.

Burkhardt, J.W., and E.W. Tisdale. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 15:472-484.

Clary, W.P., and D.A. Jameson. 1981. Herbage production following tree and shrub removal in the pinyon-juniper type of Arizona. J. Range Manage. 34:109-113.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-64.

Dwyer, D.D., and R.D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. J. Range Manage. 20:359-362.

Gauch, H.G. 1982. Mulivariate analysis in community Ecology. Cambridge University Press, New York.

Hessing, M.B., C.D. Johnson, and R.P. Balda. 1982. Early succession of a pinyon-juniper woodland in a northern Arizona powerline corridor. The S.W. Nat. 27:1-9.

Huschle, G., and M. Hironaka. 1980. Classification and ordination of seral plant communities. J. Range Manage. 33:179-182.

Hyder, D.N., A.C. Everson, and R.E. Bement. 1971. Seedling morphology and seedling failures with blue grama. J. Range Manage. 24:287-292.

Jameson, D.A. 1965. Reduction of understory grass growth by chemicals in litter of *Juniperus*. Proc. 16th Annu. Meeting. AIBS. (Abstr.)

Jameson, D.A. 1966. Pinyon-juniper litter reduces growth of blue grama. J. Range Manage. 19:214-217.

Jameson, D.A. 1967. The relationship of tree overstory and herbaceous understory vegetation. J. Range Manage. 23:217-218.

Johnsen, T.N. 1959. Longevity of stored juniper seeds. Ecology. 40:487-488.

Johnsen, T.N. 1962. One-seed juniper invasion of northern Arizona grasslands. Ecol. Monog. 32:187-207.

Kennedy, K.L. 1983. A habitat type classification of the pinyon-juniper woodlands of the Lincolns National Forest, New Mexico. p. 54-61. *In:* Moir, W.H. and L.Hendzel (Tech. Coords.) Proceedings of the workshop on southwestern habitat types. Albuquerque, New Mexico. USDA, For. Serv.

Legendre, L., and P. Legendre. 1983. Numerical ecology: Developments in environmental modelling 3. Elsevier Scientific Publishing Co., New York.

Ludwig, J.L., W.G. Whitford, A.B. Rodney, and R.E. Grieve. 1977. An evaluation of transmission line construction on pinyon-juniper woodland and grassland communities in New Mexico. J. Environmental Manage. 5:127-137.

Neff, N.A., and L.F. Marcus. 1980. A survey of multivariate methods for systematics. American Museum of Natural History, New York.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxbury Press, North Sciuate, Mass.

Peet, R.K., and N.L. Christiansen. 1980. Succession: A population process. Vegetatio. 43:131-140.

Pielou, E.C. 1977. Mathematical ecology. John Wiley & Sons. New York.

Pieper, R.D. 1977. The southwestern pinyon-juniper ecosystem. Proceedings of the workshop. Ecology, use, and management of pinyon-juniper woodlands. USDA, For. Serv., Rocky Mt. For. and Range Exp. Sta., Gen. Tech. Rep. RM-39.

Salomonson, M.G. 1978. Adaptations for animal dispersal of one-seed juniper. Oecologia. 32:333-339.

Springfield, H.W. 1976. Characteristics and management of southwestern pinyon-juniper ranges: The status of our knowledge. USDA, For. Serv., Rocky Mtn For. and Range Exp. Sta., Res. Pap. RM-160.

Tausch, R.J., and P.T. Tueller. 1977. Plant succession following chaining of pinyon-juniper woodlands in eastern Nevada. J. Range Manage. 30:44-49.

Tucker, J.M. 1961. Studies in the *Quercus undulata* complex I. A preliminary statement. Amer. J. Bot. 48:202-208.

Tueller, P.T., and J.E. Clark. 1975. Autecology of pinyon-juniper species of the Great Basin and Colorado Plateau. p. 27-39. *In:* Gifford, G.F. and F.E. Busby (Eds.). The pinyon-juniper ecosystem. Utah State Univ., Loga, Utah.

USDA Forest Service. ND. Soils of the Lincoln National Forest. Smokey Bear District, Lincoln National Forest, New Mexico.

West, N.E., K.H. Rea, and R.J. Tausch. 1975. Basic synecological relationships in pinyon-juniper woodlands. p. 41-53. *In:* Gifford, G.E., and F.E. Busby (Eds.). The pinyon-juniper ecosystem. Utah State Univ., Logan, Utah.