

Plant Succession on Disturbed Sites in Four Plant Associations in the Northern Mojave Desert

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Abstract—The U. S. Department of Energy (DOE) is studying Yucca Mountain, Nevada, to determine the mountain's suitability for the long-term storage of high-level nuclear waste. DOE has made a commitment to reclaim all lands disturbed by the project, and to return disturbed sites to a stable ecological state, with a vegetation composition and productivity similar to predisturbance conditions. During 1991 and 1992 EG&G Energy Measurements implemented a study to determine which plant species naturally invade disturbed sites in the Yucca Mountain Project area. Fifty-seven study plots were established on disturbances in four primary vegetation associations. Measurements of absolute perennial plant density occurred in three to six belt transects in each study plot. Mean density was calculated and density values from the disturbed sites were compared with those of undisturbed sites. Across all four vegetation associations, needle-leaf rabbitbrush (*Chrysothamnus teretifolius*) had the highest relative density in disturbed sites, but was not a major component in undisturbed sites. Bursage (*Ambrosia dumosa*) had the highest density in undisturbed sites, but also had high densities in disturbed areas. Total species density was higher in undisturbed sites, compared to disturbed sites. The results of this study will aid in the development of reclamation plans for site-specific disturbances at Yucca Mountain.

In 1979, the Department of Energy identified Yucca Mountain in Nye County, Nevada as a potential site for the long-term storage of high-level nuclear waste. Initial geologic exploration to determine the suitability of Yucca Mountain for waste storage commenced shortly thereafter. Road construction, drill pad construction, trenching activities, drilling geologic exploration wells, and other construction activities created disturbances at many locations. Site characterization activities will ultimately disturb approximately 180 ha (445 ac), which the DOE, Yucca Mountain Project, has made a commitment to reclaim. The ability to conduct successful reclamation

in the Mojave Desert may require an understanding of which plant species are best adapted to environmentally harsh sites. In order to aid in the development of a program for reclaiming areas disturbed by site characterization activities, a study was initiated to determine characteristics of natural plant succession that has occurred on various disturbances since the commencement of activities in 1979.

Natural succession in the Mojave Desert appears to be a slow process. Carpenter and others (1986) reported that disturbed areas in the eastern Mojave Desert require approximately 65 to 100 years for plant cover to be comparable to that of undisturbed areas. Vasek and others (1975) stated that natural revegetation of disturbed areas in the Mojave Desert is a process that may require centuries.

Secondary succession studies conducted in the Mojave Desert have indicated that in the early seral stages, disturbed sites are dominated by short-lived and intermediate-lived plant species. Vasek (1980) reported that a severely disturbed borrow pit was dominated by short-lived shrubs such as brittlebush (*Encelia frutescens*), wire-lettuce (*Stephanomeria pauciflora*), and bursage, whereas undisturbed areas surrounding the borrow pit were dominated by long-lived perennials such as creosote bush (*Larrea tridentata*) and prickly-pear cactus (*Opuntia bigelovii*). The author concluded that the long-lived perennials were removed during disturbance and approximately 9 years was required for long-lived perennial seedlings to appear in the disturbed area. Succession studies conducted at the Wahmonie ghost town (located on the Nevada Test Site and is within 20 kilometers of Yucca Mountain) have shown similar results. Wells (1961) reported that after 31 years since disturbance at the Wahmonie site that the disturbed areas had greater numbers of desert needlegrass (*Stipa speciosa*), burrobrush (*Hymenoclea salsola*), and Nevada Mormon tea (*Ephedra nevadensis*). Creosote bush and hopsage (*Grayia spinosa*) were absent in the disturbance, but were dominants in the undisturbed areas adjacent to the site. Webb and Wilshire (1979) visited the Wahmonie sites 24 years after the study conducted by Wells 1961. These researchers noted that after 55 years, the disturbed areas were lacking in density of long-lived perennials such as creosote bush, hopsage, box thorn (*Lycium andersonii*), and Nevada Mormon tea found in the adjacent undisturbed areas. They suggested that the rate of revegetation at the disturbance was related to the soil compaction levels.

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Objectives

This study was designed to inventory past disturbances and describe the plant succession that has occurred since the initial disturbance. Specific objectives were to: 1) identify the species present in disturbed sites, and categorize these by the four vegetation associations present at Yucca Mountain; 2) determine the differences in species density and composition in disturbed and undisturbed sites; 3) determine if species occurred in the same proportion in both disturbed and undisturbed sites.

Study Area and Methods

Yucca Mountain occurs in the Northern Mojave Desert (Figure 1). Four primary vegetation associations, Creosotebush-Bursage (CB), Creosotebush-Boxthorn-Hopsage (CBH), Blackbrush (B), and Boxthorn-Hopsage (BH), characterize the area (Beatley 1976). Elevation in the study area ranges from 994 to 1,789 m above sea level, and the average annual precipitation varies from about 115 to 170 mm (4.5 to 7.0 in), depending upon elevation. Most precipitation occurs between November

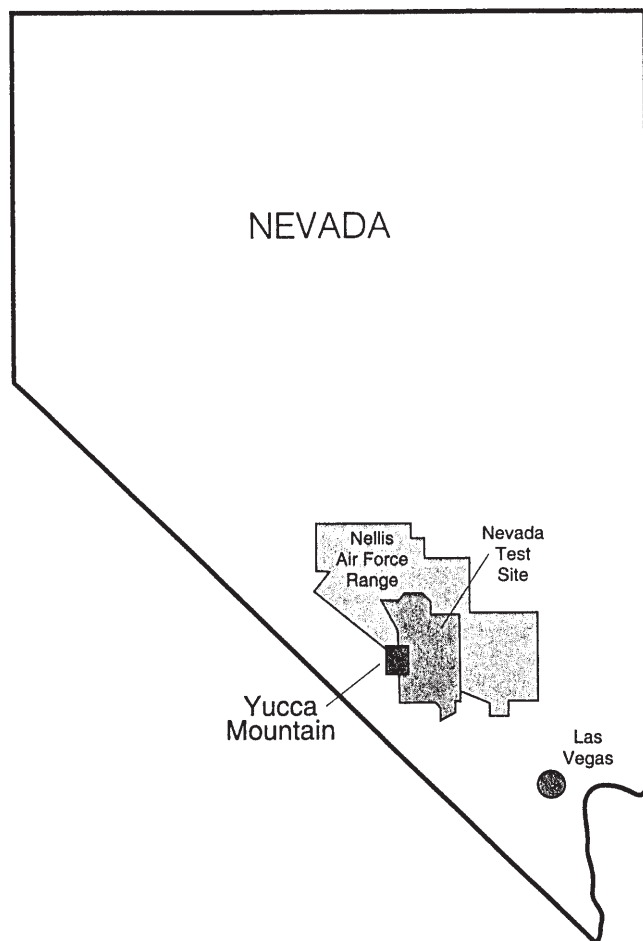


Figure 1—General location of Yucca Mountain, Nevada (not to scale).

and March; however, intense localized thunderstorms may occur during the summer months.

During 1991 and 1992, 57 disturbed sites were identified which were large enough to establish belt transects for vegetation studies. Disturbance ages range from six to twelve years since heavy equipment operations ceased; however, some of the disturbance sites have had light vehicle disturbance after the initial activities. The disturbance type (e.g., cut slope, drill pad, etc.) and the initial vegetation association present at each site was recorded. Three to six, 2 x 20-m belt transects were randomly located and established on each disturbed site. Absolute density was measured for each perennial species present in each belt transect. Mean density (plants/100m²) of each species was calculated.

Twelve study plots were established in undisturbed areas in each of the four vegetation associations (48 total study plots). Absolute density measurements occurred in 1992, in eight to ten randomly located 2 x 50-m belt transects in each study plot. Species absolute density was converted to mean density values for each vegetation association. Mean density values between disturbed and undisturbed areas within vegetation associations were compared.

Results

Disturbed vs. Undisturbed

Average density on disturbed sites across all vegetation associations was 72.3 plants/100 m² which was over 70% that in undisturbed areas (101.7 plants/100 m²) (Table 1). Within the disturbed areas, needle-leaf rabbitbrush had the highest density, followed by matchweed (*Gutierrezia sarothrae*), bursage, wire-lettuce, desert trumpet (*Eriogonum inflatum*), shadscale (*Atriplex confertifolia*) and rubber rabbitbrush (*Chrysothamnus nauseosus*) (Figure 2). With the exception of bursage, these species were minor components in the undisturbed areas as indicated by their low densities (<3 plants/100 m²). Within the undisturbed areas, bursage had the highest plant densities (26.9 plants/100 m²), followed by Nevada Mormon tea, ratany (*Krameria parvifolia*), blackbrush (*Coleogyne ramosissima*), menodora (*Menodora spinescens*), and goldenhead (*Acamptopappus shockleyi*) (Figure 2; Table 1). Nevada Mormon tea, ratany, blackbrush, menodora and goldenhead were minor components in the disturbed areas, with each species comprising less than 1% of the total density.

Vegetation Association Characteristics

Differences in densities of species were apparent within vegetation associations. Generally, many of the species that were dominant in the disturbed areas, were minor components in the undisturbed areas and vice-versa.

Creosotebush-Bursage Association—Density in the undisturbed Creosotebush-Bursage vegetation association was four times greater than that in the disturbed areas. Bursage had the highest density in both disturbed and undisturbed sites (Figures 3); however, density of bursage was over three times as high in the undisturbed as that in

Table 1—Mean density (plants/100 m²) of perennial plant species present in disturbed (DIS) and undisturbed (UND) communities in Creosotebush-Bursage (CB), Blackbrush (B), Boxthorn-Hopsage (BH), and Creosotebush-Boxthorn-Hopsage (CBH) vegetation associations at Yucca Mountain, Nevada. Nomenclature follows Munz, 1974.

Species	Common Name	Code	B		CB		BH		CBH	
			DIS (n=37)	UND (n=108)	DIS (n=34)	UND (n=108)	DIS (n=116)	UND (n=108)	DIS (n=88)	UND (n=108)
<i>Acamptopappus shockleyi</i>	Goldenhead	ACSH	0.0	0.0	0.2	18.3	0.0	0.2	0.0	0.3
<i>Ambrosia dumosa</i>	Bursage	AMDU	0.5	17.9	20.3	70.0	1.8	7.8	6.4	11.7
<i>Aristida longiseta</i>	Sandwort	ARFE	0.1	0.0	0.0	0.0	0.4	0.5	0.0	0.0
<i>Aristida purpurea</i>	Purple threeawn	ARPU	0.0	0.0	0.0	0.0	1.7	0.0	0.3	0.0
<i>Artemisia spinescens</i>	Budsage	ARSP	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
<i>Artemisia tridentata</i>	Big sagebrush	ARTR	0.3	0.0	0.0	0.0	0.0	0.2	0.0	0.0
<i>Atriplex canescens</i>	Fourwing saltbush	ATCA	3.7	0.2	0.0	0.0	2.1	0.4	0.1	0.1
<i>Atriplex confertifolia</i>	Shadscale	ATCO	0.5	5.8	0.0	1.7	8.2	5.0	0.0	0.2
<i>Brickellia watsonii</i>	Brickellbush	BRWA	0.0	0.0	0.0	0.0	3.3	0.3	0.9	0.0
<i>Ceratoides lanata</i>	Winterfat	CELA	0.0	0.1	0.0	3.4	0.1	4.9	0.0	1.0
<i>Chrysothamnus nauseosus</i>	Rubber rabbitbrush	CHNA	5.1	0.0	0.0	0.0	6.0	0.3	0.9	0.0
<i>Chrysothamnus paniculatus</i>	Black-stem rabbitbrush	CHPA	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0
<i>Chrysothamnus teretifolia</i>	Needle leaf rabbitbrush	CHTE	19.3	1.4	0.1	0.0	33.5	3.4	15.4	0.0
<i>Chrysothamnus viscidiflorus</i>	Yellow rabbitbrush	CHVI	0.5	0.2	0.0	0.0	3.7	1.6	0.0	0.0
<i>Coleogyne ramosissima</i>	Blackbrush	CORA	3.2	17.9	0.0	1.4	0.1	0.0	0.0	0.5
<i>Descurainia sophia</i>	Tansy-mustard	DESO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
<i>Echinocereus engelmannii</i>	Hedgehog cactus	ECEN	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
<i>Echinocactus polycephalus</i>	Cottontop barrelcactus	ECPO	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
<i>Encelia virginensis</i>	Brittlebush	ENVI	1.6	1.8	0.0	0.1	3.1	0.8	0.3	0.9
<i>Ephedra nevadensis</i>	Nevada Mormon tea	EPNE	0.1	7.1	0.4	5.6	0.6	14.5	1.0	8.3
<i>Ephedra viridis</i>	Green Ephedra	EPVI	0.0	0.2	0.0	0.0	0.0	1.0	0.0	0.0
<i>Eriogonum fasciculatum</i>	California buckwheat	ERFA	0.1	0.6	0.4	0.0	1.0	10.8	1.1	0.7
<i>Eriogonum inflatum</i>	Desert trumpet	ERIN	0.0	0.0	1.2	0.0	3.2	0.3	12.0	0.0
<i>Eriogonum microthecum</i>	Buckwheat	ERMI	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0
<i>Erioneuron pulchellum</i>	Fluff grass	ERPU	0.0	0.4	0.1	0.3	2.7	10.7	5.8	0.8
<i>Euphorbia albomarginata</i>	Rattlesnake weed	EUAL	0.0	0.1	1.5	0.0	0.0	0.0	0.4	0.1
<i>Grayia spinosa</i>	Spiny hopsage	GRSP	0.0	1.2	0.0	1.6	0.0	8.1	0.1	0.6
<i>Gutierrezia sarothrae</i>	Matchweed	GUSA	0.3	0.0	0.0	0.0	12.4	4.1	0.0	0.0
<i>Haplopappus cooperi</i>	Goldenbush	HACO	0.3	0.8	0.0	1.2	0.6	10.7	1.0	2.1
<i>Haplopappus linearifolius</i>	Interior goldenbush	HALI	1.1	0.0	0.1	0.0	0.8	1.1	0.0	0.0
<i>Hilaria jamesii</i>	Galleta	HIJA	2.4	2.3	0.0	0.0	0.3	8.1	0.0	0.0
<i>Hymenoclea salsola</i>	Burrobrush	HYSA	1.6	0.9	0.1	0.0	1.3	5.5	2.4	2.8
<i>Krameria parvifolia</i>	Ratany	KRPA	0.0	9.0	0.2	5.6	0.0	0.0	0.0	10.1
<i>Larrea tridentata</i>	Creosote bush	LATR	0.0	0.7	1.3	6.0	0.1	0.2	1.1	5.5
<i>Lepidium fremontii</i>	Desert pepperweed	LEFR	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0
<i>Leptodactylon pungens</i>	Prickly gilia	LEPU	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
<i>Lycium andersonii</i>	Box thorn	LYAN	1.3	2.5	0.3	0.8	0.5	7.0	0.3	3.8
<i>Lycium pallidum</i>	Wolfberry	LYPA	0.1	2.3	1.0	5.3	0.0	0.6	0.2	0.9
<i>Machaeranthera tortifolia</i>	Desert-aster	MATO	0.0	0.5	0.0	0.6	0.4	0.1	0.0	0.0
<i>Menodora spinescens</i>	Menodora	MESP	0.3	1.3	0.0	14.6	0.3	1.3	0.2	2.4
<i>Mirabilis bigelovii</i>	Desert wishbone bush	MIBI	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1
<i>Muhlenbergia porteri</i>	Bush muhly	MUPO	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
<i>Opuntia basilaris</i>	Beavertail pricklypear	OPBA	0.0	0.1	0.0	0.0	0.0	0.4	0.0	0.1
<i>Opuntia echinocarpa</i>	Strawtop pricklypear	OPEC	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
<i>Oryzopsis hymenoides</i>	Indian ricegrass	ORHY	1.0	0.0	0.0	1.3	0.3	0.1	0.1	0.1
<i>Psoralea argophylla</i>	Indigo bush	PSFR	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0
<i>Salazaria mexicana</i>	Bladdersage	SAME	0.0	0.4	0.0	0.1	0.0	0.7	0.0	1.1
<i>Sitanion hystrix</i>	Squirreltail	SIHY	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
<i>Sitanion jubatum</i>	Foxtail barley	SIJU	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Sphaeralcea ambigua</i>	Globemallow	SPAM	6.2	0.0	0.0	0.1	2.3	12.2	1.0	0.1
<i>Sporobolus cryptandrus</i>	Sand dropseed	SPCR	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0
<i>Stephanomeria pauciflora</i>	Wire-lettuce	STPA	1.5	0.1	3.5	0.0	5.3	0.3	8.2	0.2
<i>Stipa speciosa</i>	Desert needlegrass	STSP	0.6	0.4	0.0	0.1	2.5	12.1	0.6	1.0
<i>Tetradymia axillaris</i>	Longspine horsebush	TEAX	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
<i>Tetradymia glabrata</i>	Littleleaf horsebush	TEGL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Yucca brevifolia</i>	Joshua tree	YUBR	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Forbs			8.0	0.2	6.3	0.1	10.9	12.9	21.7	0.5
Total Grasses			5.7	3.0	0.1	1.6	8.2	31.7	6.7	1.9
Total Shrubs			40.1	73.3	24.9	136.5	80.4	92.9	31.7	53.2
Total Mean Density			53.7	76.4	31.3	138.3	99.6	137.4	60.1	55.6

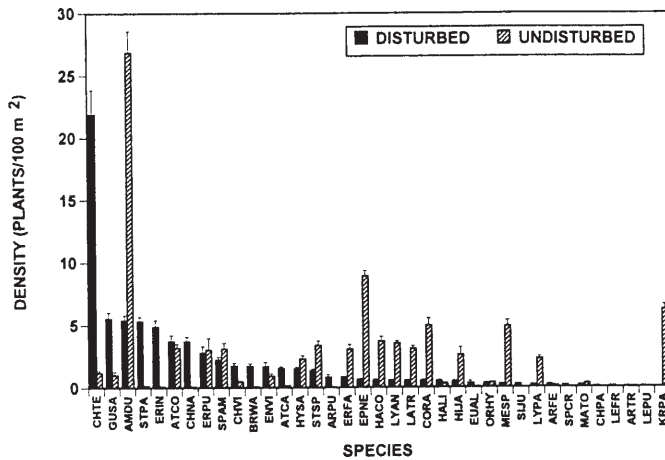


Figure 2—Average density ($\pm$ SE) of perennial plants found in 57 disturbed sites and 48 undisturbed sites at Yucca Mountain, Nevada. Minor species, found in both disturbed and undisturbed areas, are not shown. See Table 1 for species codes.

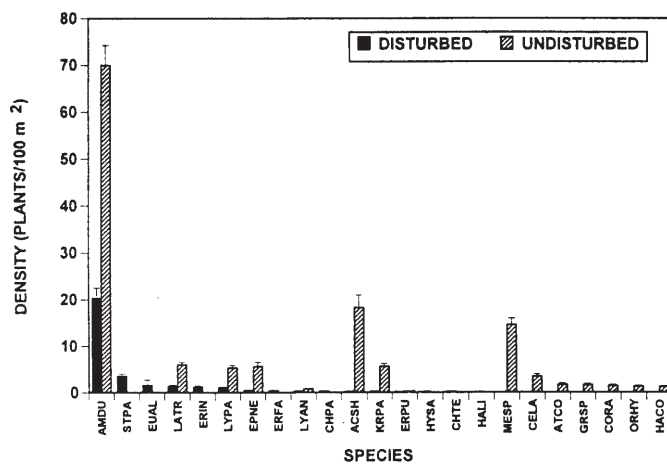


Figure 3—Average density ($\pm$ SE) of perennial plants found on disturbed and undisturbed sites in the Creosotebush-Bursage vegetation association at Yucca Mountain, Nevada. Minor species are not shown. See Table 1 for species codes.

the disturbed sites (70.0 and 20.3 plants/100 m respectively; Table 1). Wire-lettuce and desert trumpet had substantially greater densities (95 and 64 times greater) within disturbed sites when compared to undisturbed sites (Table 1). Creosotebush densities in disturbed and undisturbed areas were substantially different (Table 1). *Menodora*, wolfberry (*Lycium pallidum*), and winterfat (*Ceratoides lanata*), subdominants in the undisturbed sites were not encountered in the disturbed sites.

Creosotebush-Boxthorn-Hopsage Association—

Density in the disturbed areas was similar to that of the undisturbed areas (Table 1). Generally species occurring

in this association that had high densities in disturbed sites had low densities in undisturbed sites (Figure 4; Table 1). The converse was apparent for the undisturbed sites (Figure 4; Table 1). Needle-leaf rabbitbrush, desert trumpet, and wire-lettuce had the highest density of all species occurring in the disturbed sites. These same species were either absent or virtually absent from undisturbed sites. Disturbances in Creosotebush-Boxthorn-Hopsage sites apparently has altered the environmental conditions so that these three species, which do not normally occur in this vegetation association, not only became established, but dominated the new plant assemblage. Disturbance virtually eliminated ratany, the second most abundant species in undisturbed sites.

Blackbrush Association—Species density in undisturbed area in this association was 22.9 plants/100 m² greater than that in the disturbed sites (Table 1). Again many of the species that were the most common in disturbed sites were not among the common species in undisturbed sites (Figure 5; Table 1). Needle-leaf rabbitbrush was the dominant species in the disturbances and its density was nearly 14 times greater than in the undisturbed (Table 1). Nine additional species, Globemallow (*Sphaeralcea ambigua*), rubber rabbitbrush, fourwing saltbush (*Atriplex canescens*), Squirreltail (*Sitanion jubatum*), wire-lettuce, interior goldenbush, and Indian ricegrass (*Oryzopsis hymenoides*) occurred in disturbed sites, but were essentially absent in the undisturbed sites (Figure 5; Table 1). Five species, blackbrush, bursage, shadscale, ratany, and Nevada Mormon tea had substantially greater densities in undisturbed sites. The latter four species were almost absent in the disturbed sites.

Boxthorn-Hopsage Association—Density in the disturbed areas was less than that of the undisturbed sites within this vegetation association. As seen in the Blackbrush and the Creosotebush-Boxthorn-Hopsage

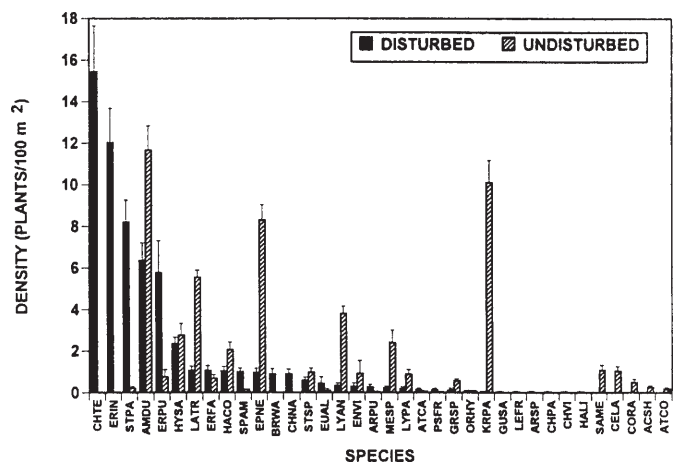


Figure 4—Average density ($\pm$ SE) of perennial plants found on disturbed and undisturbed sites in the Creosotebush-Boxthorn-Hopsage vegetation association at Yucca Mountain, Nevada. Minor species are not shown. See Table 1 for species codes.

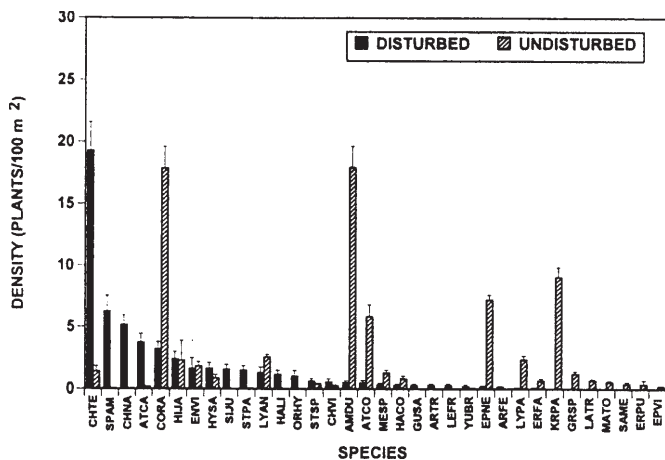


Figure 5—Average density ($\pm$ SE) of perennial plants found on disturbed and undisturbed sites in the Blackbrush vegetation association at Yucca Mountain, Nevada. Minor species not shown. See Table 1 for species codes.

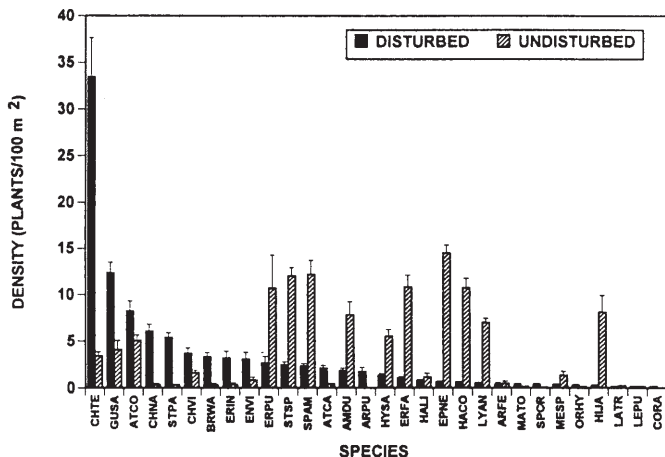


Figure 6—Average density ($\pm$ SE) of perennial plants found on disturbed and undisturbed site in the Boxthorn-Hopsage vegetation association at Yucca Mountain, Nevada. Minor species not shown. See Table 1 for species codes.

associations, species that had high relative densities in disturbed sites generally did not have high relative densities in undisturbed sites (Table 1). Three species, needle-leaf rabbitbrush, matchweed, and shadscale had the highest densities in disturbed sites. These same species accounted for less than 10% of the plants present in undisturbed sites (Figure 6). Eight additional species had densities that were higher in disturbed sites, compared to undisturbed sites. Ten species had substantially higher densities in undisturbed sites when compared to disturbed sites. Mormon tea, the most abundant species in undisturbed sites, was among the least abundant species in disturbed sites (Table 1).

Discussion and Conclusions

Generally species that had high densities in disturbed vegetation associations in the Northern Mojave Desert did not have similar density values in undisturbed vegetation associations. Bursage in the Creosotebush-Bursage vegetation association was the lone exception. Although the absolute density between disturbed and undisturbed sites for bursage was markedly different (Table 1), this species was the dominant in both disturbed and undisturbed as indicated by the proportions of the total density (Figure 3). Bursage germinates and grows well in slightly disturbed soils and lightly shifting sands (Vasek, 1979). These conditions probably prevail in both the undisturbed and disturbed sites of the Creosote-Bursage vegetation association at Yucca Mountain which have soils that generally have >90% sand content.

Needle-leaf rabbitbrush dominates secondary succession in the Blackbrush, Boxthorn-Hopsage, and Creosotebush-Boxthorn-Hopsage vegetation associations. The high abundance of needle-leaf rabbitbrush on disturbed sites in three different vegetation associations suggests that this species may be a good choice for use in reclaiming disturbed sites. Even though this species is lacking in the undisturbed areas it may be important in ameliorating the disturbance, thus enhancing the germination and establishment of the more desirable species in the adjacent undisturbed areas. Other species having high densities in disturbed sites may also be good candidates for use during site-specific reclamation for this same reason.

Densities of species in this study when compared to that of the studies conducted at the Wahmonie ghost town (located approximately 20 km east of Yucca Mountain) (Wells, 1961; Webb and Wilshire, 1980) are somewhat different. Vegetation at the Wahmonie site is a Boxthorn-Hopsage/Blackbrush transition similar to those described in this study. Wells (1961) reported that desert needlegrass, boxthorn and Nevada Mormon tea were the most abundant species in the disturbed areas after 33 years since disturbance. Webb and Wilshire (1980) revisited the site and reported that desert needlegrass, Nevada Mormon tea and burrobrush were the most abundant species 51 years after disturbance. In this study, these species were found in the disturbance areas, but they were generally minor components of the total density. The differences in the species composition between the Wahmonie studies and this study may be age related; all disturbances in this study were less than 15 years old. Carpenter and others (1986) noted that disturbed sites in early successional stages in the eastern portion of the Mojave Desert are dominated by short-lived species that include globe-mallow, rayless goldenhead (*Acamptopappus spaecephalus*), burrobrush, and matchweed. The disturbed sites in this study appear to be dominated by short-lived species, some of which are similar in growth form and reproductive strategy to those described above. The dominance of needle-leaf rabbitbrush in most of the disturbed areas in this study and the lack of it in the undisturbed areas may be indicative that this species is short-lived.

Disturbances at Yucca Mountain appear to have altered the micro-environment to such an extent that plant species which do not normally occur, or rarely occur in a

plant community now dominate the new plant assemblage. After six to twelve years of succession, vegetation density in disturbed sites is still substantially less than in undisturbed sites (except in the Creosote-Boxthorn-Hopsage association). The dominant species of undisturbed areas are in low proportion or are generally lacking in the disturbed sites indicating that after 15 years that the disturbed sites are in early successional stages. Secondary succession appears to be a very slow process on these disturbed sites.

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