Vegetative habitat analysis of proposed mine sites in the Mojave Desert: The first step towards revegetation of disturbed desert communities

Jim Van Brunt

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VEGETATIVE HABITAT ANALYSIS OF PROPOSED MINE SITES IN THE MOJAVE DESERT: 
THE FIRST STEP TOWARDS REVEGETATION OF DISTURBED DESERT COMMUNITIES

A Thesis
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment 
of the Requirements for the Degree
Master of Science 
in
Biology

by
Jim Van Brunt
December 1993
VEGETATIVE HABITAT ANALYSIS OF PROPOSED MINE SITES IN THE MOJAVE DESERT: THE FIRST STEP TOWARDS REVEGETATION OF DISTURBED COMMUNITIES

A Thesis
Presented to the Faculty of California State University, San Bernardino

by
Jim Van Brunt
December 1993

Approved by:

Dr. David Polcyn, Chair, Biology

Dr. Jim Ferrari,

Dr. Richard Fehn,

11-30-93
Date
ABSTRACT

Due to changes in the laws that govern mining, mine companies are now required to revegetate any public land they disturb during the mining process. This project involved comparing three mine sites to determine if all three sites are similar enough in species composition to use a revegetation program currently being developed for one site on all three sites.

Data was collected using randomly placed line transects. The transects were walked and plants intersected by the line were used as sample species. The data between the sites was then analyzed using statistical and nonstatistical methods.

It was found that all three sites contained species that are typical of a Creosote Bush Scrub community found in the Mojave Desert. The species composition of the three sites was not identical. It was found that there was a significant difference between the sites statistically. It was determined that there was a significant difference in composition between the three sites. Even though statistically there was a difference between site the needs of the different species at each site are so similar that it was determined that one revegetation plan could be developed that could be used for all three sites.
ACKNOWLEDGMENTS

I would like to thank the Brubaker-Mann for the use of their mine sites and the support given to me during this project. I would also like to thank Dr. Polcyn for all the encouragement and extra time he has given me.

A special thanks to my wife Lise and my children Rory, Tyler, Katelyn, and Mark. Thanks for letting dad spend all that time in the field, in class, and on the computer. Without your support this would not have been possible. I love you very much!
TABLE OF CONTENTS

ABSTRACT ........................................ ii
ACKNOWLEDGEMENTS .............................. iii
LIST OF TABLES ................................ vi
LIST OF ILLUSTRATIONS ....................... vii
INTRODUCTION .................................. 1
METHODS AND MATERIALS ..................... 6
RESULTS ......................................... 15
DISCUSSION ..................................... 35
LITERATURE CITED .............................. 45
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Species names, identification numbers, and the sites in which the species are found</td>
<td>15</td>
</tr>
<tr>
<td>2.</td>
<td>Number of individuals of each species at each site and percent composition</td>
<td>18</td>
</tr>
<tr>
<td>3.</td>
<td>Summary of ANOVA. Coverage by site and species</td>
<td>25</td>
</tr>
<tr>
<td>4.</td>
<td>Summary of ANOVA. Density by site and species</td>
<td>27</td>
</tr>
<tr>
<td>5.</td>
<td>Summary of ANOVA. Frequency by site and species</td>
<td>29</td>
</tr>
<tr>
<td>6.</td>
<td>Species richness, diversity, and coefficient of community similarity</td>
<td>31</td>
</tr>
<tr>
<td>7.</td>
<td>Species richness, diversity, and coefficient of community similarity using the five dominant species found at each site</td>
<td>32</td>
</tr>
<tr>
<td>8.</td>
<td>Mean slope elevation and direction, maximum and minimum slope measurements</td>
<td>33</td>
</tr>
<tr>
<td>9.</td>
<td>Soil analysis summary</td>
<td>34</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1.</td>
<td>Map showing general location and relationship of the study sites</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Map showing in greater detail the location of sites 1 and 3</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td>Number of individuals of each species found at each site</td>
<td>17</td>
</tr>
<tr>
<td>4.</td>
<td>Relative density of all species found at each site</td>
<td>20</td>
</tr>
<tr>
<td>5.</td>
<td>Relative coverage for all species found at each site</td>
<td>21</td>
</tr>
<tr>
<td>6.</td>
<td>Relative frequency of all species found at each site</td>
<td>22</td>
</tr>
<tr>
<td>7.</td>
<td>Mean coverage of 18 plant species at 3 surveyed sites</td>
<td>26</td>
</tr>
<tr>
<td>8.</td>
<td>Mean density of 18 plant species at 3 surveyed sites</td>
<td>28</td>
</tr>
<tr>
<td>9.</td>
<td>Mean frequency of 18 plant species at 3 surveyed sites</td>
<td>30</td>
</tr>
</tbody>
</table>
Introduction

The rate of habitat destruction around the globe has increased in the past decades and this destruction has reached enormous proportions (Miller, 1992). Over the past decade the destruction and loss of public land has become a concern to the public and environmental/political groups. These groups have begun to put pressure on the government and other public agencies to take action. This pressure has caused a change in the attitude of many governmental agencies, and has resulted in amendments to the Surface Mining and Reclamation Act of 1975, mandating changes in how mine concerns operate.

In California, where mining in the desert is proceeding at an alarming rate, it is now required that each mine operation using public land have a reclamation plan on file with the county and state. In California reclamation is defined as:

"Reclamation" means the combined process of land treatment that minimizes water degradation, air pollution, damage to aquatic or wildlife habitat, flooding, erosion, and other adverse effects from surface mining operations, including adverse surface effects incidental to underground mines, so that mined lands are reclaimed to a usable condition which is readily adaptable for alternative land uses and create no danger to public health or safety. The process may extend to affected lands surrounding mined lands, and may require backfilling, grading, resoiling, revegetation, soil compaction, stabilization, or other measures." (SMARA, Art. 2, 2733, 1976).

As part of the reclamation plan a revegetation protocol must
be developed that returns the disturbed areas to a condition as close to the original habitat as possible.

Before a complete revegetation protocol can be developed as part of a reclamation plan, an analysis of the community that has been disturbed must be conducted. The current study was the first step in the process of developing a revegetation plan. This project involved analyzing and comparing three disturbed communities to see if the plant communities are similar enough to include all three under one revegetation plan.

This study was done for Brubaker-Mann, Inc. a small decorative rock company located in Barstow. The company has five operations that will require revegetation plans. Three of these operations will be covered by one revegetation plan as previously approved by San Bernardino County. Two of the operations are located just outside of Barstow near Interstate 15. The third site is located in Newberry Springs. The county has approved one of these 3 operations (Meridian Road) as the standard for all three, and this will be where the eventual test plots will be constructed and revegetation experiments conducted (SBC Staff Reports, 1990).

Brubaker-Mann would also like to include two additional mine sites as part of the Meridian Road revegetation plan, one located near Adelanto and another located near Afton Canyon.
The county will not allow Brubaker-Mann to use one plan for all their sites unless it can be shown that there is no significant difference between the standard site, Meridian, and the sites at Adelanto and Afton Canyon.

This study was conducted to compare the Adelanto, Afton Canyon, and Meridian communities in an effort to determine if the Adelanto and Afton Canyon communities were similar enough to the Meridian (control) community so that all three can be covered by one revegetation plan. The study will determine if the sites contain the same community type and if the vegetation found in each site is similar in species and distribution to the Meridian site. Comparing communities for similarity for a revegetation plan can be difficult. The problem arises in defining similarity. For the purpose of revegetation similarity must first be analyzed in terms of the community that the site is in. If the sites all exist in one type of community then the second consideration should be the species composition of the site. It is quite possible to have two areas being studied that are made of the same community but are very different in composition. This might be due to microhabitats created by precipitation, soils, or elevation (Randell, 1977). For the purpose of a revegetation plan the sites should have dominant species that are common between sites.
Figure 1. Map showing general location and relationship of the study sites.
Figure 2. Map showing in greater detail the location of sites 1 and 3.
Methods and Materials

The study areas are located within a 45 mile radius of Barstow in the heart of the Mojave Desert (Figure 1). The Meridian study area, Site 1, is located approximately 5 miles west of Barstow off Meridian Rd. near Interstate 15 (Figure 2). The Meridian site is characterized by a typical Mojave Creosotebush scrub community (Holland, 1986; Vasek and Barbour, 1977). The landscape is composed of rolling hills and small mountains with hardpan to fairly rocky soil. The hills are cut by washes and there is one area of desert pavement near the study area.

The Afton study area, Site 2, is located approximately 37 miles north-west of Barstow off Interstate 15 (Figure 3). The area is composed of flat hardpan expanses punctuated by small hills and mountains. The plant community is typical of a Mojave Creosotebush scrub community (Holland, 1986; BLM Report, 1989). There is a small dry lake next to the mining operation and the study area.

The Adelanto study area, Site 3, is located in Shadow Mountain, approximately 30 miles south-west of Barstow off Hwy 395 (Figure 2). The study area is slightly more mountainous than that found at Meridian or Adelanto sites. The plant community is characteristic of a Mojave Creosotebush scrub community as described by Turner (1982) and Holland (1986).

The general design of the study involved running line
transects and counting plants that are intersected by the line. The type of plant, its linear coverage and the number of each plant type was recorded. The data collected was used in the analysis of each site and in comparing sites.

Plant data was collected by using the line-intercept method as outlined by Brower and Zar (1977). The undisturbed study plots were randomly selected by using a spinning arrow attached to a square piece of cardboard. I held the spinner and stood in the center of the disturbed area, surrounded by the undisturbed community, and spun the arrow. When the arrow stopped spinning I walked along the direction indicated by the arrow until the edge of the disturbed area was reached. I then threw a small leather bean bag over my shoulder into the undisturbed area. Where the bag landed is where the first line transect was started.

The line direction for the first and all subsequent transects was determined by rolling a die. Each side of the die was assigned a direction of the compass. One on the die representing 0°, two representing 60°, three representing 120°, four representing 180°, five representing 240°, and six representing 300°. If 180° was rolled after 0° it was rejected, and another roll was made until some other direction was rolled. This ensured that no transect would go back over the same line as a previous transect.

Twenty-five line transects, each 25 meters in length, were randomly run at each site. A stake was driven into the
ground at the start and end of each transect. Each stake was spray painted orange and the transect number written on the stake in permanent black marker for future reference. A 50 meter tape was used to measure the distance between stakes, and a nail was driven into the top of each stake to use as an attachment site for the yellow contractors twine used to define the line between stakes for each transect. The string was stretched to keep it straight and, as much as possible, was kept the same height as the top of the stake the entire length of the transect.

The transect was walked from one end to the other. Each perennial species intercepted by the vertical plane defined by the line was identified, and the intercept length recorded. Intercept length was defined as the amount of the plant's foliage that actually intercepted the line. Measurements were made to the nearest millimeter. The species and intercept length were recorded on a data sheet and used to determine the number of individuals, linear density, relative density, frequency, relative frequency, intercept length, linear coverage index, relative coverage and importance value for each species present (described below; Brower and Zar 1977). For a given species, i, the linear density index (ID_i) is calculated as:

\[ ID_i = \frac{n_i}{L}, \]

where \( n_i \) is the total number of individuals of species \( i \) collected, and \( L \) is the total length of all transects.
The species' relative density (RD$_i$) is:

$$RD_i = \frac{n_i}{\sum n}.$$ where the $\sum n$ is the total number of individuals counted for all species. The linear coverage index (IC$_i$) for a species is:

$$IC_i = \frac{l_i}{L},$$ where $l_i$ is the sum of the intercept lengths for species $i$.

The relative coverage (RC$_i$) of species $i$ is:

$$RC_i = \frac{l_i}{\sum l},$$ where the $\sum l$ is the sum of the intercept lengths for all species.

The frequency of species $i$ ($f_i$) is defined as:

$$f_i = \frac{j_i}{k},$$ where $j_i$ is the number of transects containing species $i$, and $k$ is the total number of transects (25 in all cases in the current study).

The relative frequency of species $i$ (R$f_i$) is:

$$Rf_i = \frac{f_i}{\sum f},$$ where $\sum f$ is the sum of the frequencies of all species.

The importance value (IV$_i$) of species $i$ is:

$$IV_i = RD_i + RC_i + Rf_i.$$ The line transect intercept data was also used to calculate species richness, species diversity, and the coefficient of community similarity. Species richness is calculated as:
\[ D = \frac{s}{N}, \]

where \( s \) is the number of species and \( N \) is number of individuals of all species.

Species diversity is calculated as:

\[ H = \frac{(N \log N - \sum n_i \log n_i)}{N}, \]

where \( N \) is the number of individuals of all species and \( n_i \) is the number of individuals of each species. The coefficient of community similarity is calculated as:

\[ CC_s = \frac{c}{s_1 + s_2 - c}, \]

where \( c \) is the number of species in common between both sites, \( s_1 \) is the number of species in the first site being compared and \( s_2 \) is the number of species in the second site being compared.

After one transect was walked, and the data recorded, the string was rolled up to be used in the next transect. The next transect began exactly 10 m N of the end of the previous transect. The stakes were left in place for later reference if needed. All direction measurements were made using a hand compass, and all length measurements were made using a metric tape.

The slope of the ground at the mid-point of each transect was also recorded. The slope was measured in the direction that flowing water would take at the mid-point location. The slope was measured by using two meter sticks that were connected together, one on top of the other, by a small metal hinge at one end. A small level was hot glued
at the center of the top stick to indicate the level of the
top stick. A protractor was attached to the side of the
bottom stick at the hinged end. By laying the bottom stick
against the ground and reading the bottom side of the upper
stick against the protractor, the slope of the land could be
determined. Slope was measured by laying the slope device
on the ground pointing the unhinged end toward the direction
water would flow, and raising the end of the upper stick
until the bubble read level. The angle of slope was then
read off the protractor. The direction of the slope was
recorded in degrees from north, 0°.

An analysis of the soil from the sample plots was also
conducted. Soil was collected from the mid-point of a
randomly chosen transect (transect 5) at each site. The
sample was taken from the top 8 cm of the soil surface. The
soil was analyzed for pH, water holding potential, and soil
density.

The pH was determined using a pH meter. The procedure
followed was one suggested by Head (1980). To measure the
pH a 50 ml measure of soil was placed in a 200 ml beaker,
and 100 ml of purified water (pH 7) was added. The mixture
was shaken until the soil was suspended. The probe was
dipped into the water/soil mixture, and the pH value read
from the meter.

A second measure was made by allowing the soil
particles to settle and aspirating the excess water from the
beaker. The pH probe was then placed into the water and the reading made. There was no difference between the first and second readings for each sample.

Soil water holding capacity can be difficult to measure (Head, 1980) so a simple method was used which gave a reasonable measure of the water holding capacity of uniformly dried soil. Using a post hole digger, a 1000 ml core sample of soil from each site was placed in separate 9" X 13" (22.86 cm X 33.02 cm) Pyrex cooking pans. To remove all water and moisture from the soils the pans were placed in an oven set at 300° F (148.9° C) as suggested by Head (1980). The soil was stirred every four hours and the pans were removed after 24 hours. After removal from the oven 300 ml of soil was placed in a 500 ml Florence flask and immediately stoppered to prevent moisture from being absorbed from the atmosphere by the dry soil.

To analyze water holding capacity a piece of Ahlström, 613-20 grade medium speed, 15 cm filter paper was folded into a funnel shape and placed in the mouth of a 40 ml glass funnel. The paper was then saturated with distilled water while in the funnel. Any water in the funnel tube was expelled. The funnel with the paper in it was placed in the mouth of a 500 ml Erlenmeyer flask, which served as a collection flask for the filtrate. Twenty-five millimeters of the dried soil was measured in a graduated cylinder, massed, and poured into the filter paper inside the funnel.
One-hundred millimeters of water was measured in a graduated cylinder and slowly poured into the soil sample. Plastic wrap was placed over the top on the funnel to prevent evaporation and the sample was allowed to stand for one hour from the time the last water was added.

After one hour water was no longer dripping from the funnel. The drops left in the funnel due to adhesion were shaken into the collection flask which contained the filtrate. The water in the collection flask was then poured into the same graduated cylinder used to measure the initial volume of water. The filtrate volume was subtracted from the initial volume to give the volume of water held by the soil. The formula used to find water held by the soil \((W_s)\) is:

\[
W_i - W_f = W_i,
\]

where \(W_i\) is the initial volume of water and \(W_f\) is the volume of the filtrate. This procedure was performed once on a single sample from each site.

The soil density \((D_s)\) was determined as: \(D_s = M_s/V_s\), where \(M_s\) is the mass of the soil sample and \(V_s\) is the volume of the soil sample as determined by water displacement. After massing out 100 g of soil on a tared balance, the soil was poured from the cup into a 1 L graduated cylinder containing 200 ml of distilled water. The volume of the soil/water mixture was measured and recorded. The volume of the water that was displaced by the soil was assumed to be
the volume of the soil ($V_s$):

$$V_s = V_i - V_f,$$

where $V_i$ is the initial reading on the cylinder, and $V_f$ is the final volume of the soil and water mixture. The same procedure was used on one sample from each site.

Statistical analysis was carried out with the statistical programs SPSS/PC+ and KWIKSTAT. An analysis of variance, ANOVA, was used to determine if a significant difference existed between sites (Sokal and Rohlf, 1987). The ANOVA was run using SPSS. Both SPSS and KWIKSTAT were used to determine descriptive statistical data.
RESULTS

Plant Distribution

The total number of different species found in all three sites was 18 (Table 1).

Table 1. Species names, identification numbers, and the sites in which the species was found.

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Species Name</th>
<th>Site Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Larrea tridentata</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>2</td>
<td>Ambrosia dumosa</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>3</td>
<td>Atriplex confertifolia</td>
<td>1, 3</td>
</tr>
<tr>
<td>4</td>
<td>Atriplex hymenolytra</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Echinocactus polycephalus</td>
<td>1, 3</td>
</tr>
<tr>
<td>6</td>
<td>Ephedra nevadensis</td>
<td>1, 3</td>
</tr>
<tr>
<td>7</td>
<td>Lycium cooperi</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Lycium andersonii</td>
<td>1, 3</td>
</tr>
<tr>
<td>9</td>
<td>Echinocerus engelmanii</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Encelia virginensis</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Eriogonum fasciculatum</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Eurotia lanata</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Hymenolea salsola</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Lepidium fremontii</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Machaeranthera tortifolia</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Opuntia echinocarpa</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>Dalea fremontii</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>Yucca brevifolia</td>
<td>3</td>
</tr>
</tbody>
</table>

Two species, Larrea tridentata and Ambrosia dumosa, were common to all three sites. Six species were common to site one and to site three: Larrea tridentata, Ambrosia dumosa, Atriplex confertifolia, Echinocactus polycephalus, Ephedra nevadensis, and Lycium andersonii. Site 1 contained two species that were found in that site only, Atriplex hymenolytra and Lycium cooperi, while site three had nine
species peculiar to that site: *Encelia virginensis*,
*Eriogonum fasciculatum, Eurotia lanata, Hymenoclea salsola,*
*Lepidium fremontii, Yucca brevifolia, Dalea fremontii,*
*Opuntia echinocarpa,* and *Machaeranthera tortifolia.*

**Site 1:** Site one has a total of nine different species
present (Table 1, Figure 4). Three species made up 83.1% of
the total number of individuals: *Larrea tridentata, n=41;*
*Ambrosia dumosa, n=33;* and *Atriplex confertifolia, n=29*
(Figure 5). Six species made up the remaining 16.9% of the
total number of individuals: *Ephedra nevadensis, n=7; Lycium*
*andersonii, n=6;* and *Atriplex hymenolytra, n=5.* Three
species, *Echinocactus polycephalus, Lycium cooperi,* and
*Echinocerus engelmanii,* were represented by only a single
plant along the 625 m transect. The relative density in
site 1 follows a pattern similar to that of plant numbers
(Fig 6), with *Larrea* in the highest relative density (33.1%)
followed by *Ambrosia* (26.6%) *A. confertifolia* (23.4%) *Lycium*
*andersonii* (12.9%), *Ephedra* (5.6%), and *Atriplex hymenolytra*
(4.0%). *Echinocactus, Lycium cooperi* and *Echinocerus* had a
relative density of 0.8 percent.

Site 1 relative coverage is summarized in Figure 7.
*Larrea* had the highest coverage with 48.6%, followed by *A.*
*confertifolia* (21.0%) and *Ambrosia* (15.6%); these three
species made up 85.2% of the total measured coverage. The
remaining coverage was distributed among the remaining
species as follows: *Ephedra, 4.3%; A. hymenolytra, 3.4%; L.*
Figure 3. Number of individuals of each species found at each site. Species numbers are listed in Table 1.
<table>
<thead>
<tr>
<th>Species</th>
<th>Site 1</th>
<th></th>
<th>Site 2</th>
<th></th>
<th>Site 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Larrea tridentata</td>
<td>41</td>
<td>33.1</td>
<td>49</td>
<td>63.6</td>
<td>29</td>
<td>11.1</td>
</tr>
<tr>
<td>Ambrosia dumosa</td>
<td>33</td>
<td>26.6</td>
<td>28</td>
<td>36.4</td>
<td>45</td>
<td>17.2</td>
</tr>
<tr>
<td>Atriplex confertifolia</td>
<td>29</td>
<td>23.4</td>
<td>0</td>
<td>0.0</td>
<td>3</td>
<td>1.1</td>
</tr>
<tr>
<td>Atriplex hymenolytra</td>
<td>5</td>
<td>4.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Echinocactus polycephalus</td>
<td>1</td>
<td>0.8</td>
<td>0</td>
<td>0.0</td>
<td>5</td>
<td>1.9</td>
</tr>
<tr>
<td>Ephedra nevadensis</td>
<td>7</td>
<td>5.6</td>
<td>0</td>
<td>0.0</td>
<td>39</td>
<td>14.9</td>
</tr>
<tr>
<td>Lycium andersonii</td>
<td>1</td>
<td>0.8</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lycium cooperi</td>
<td>6</td>
<td>4.8</td>
<td>0</td>
<td>0.0</td>
<td>37</td>
<td>14.2</td>
</tr>
<tr>
<td>Echinocerus engelmannii</td>
<td>1</td>
<td>0.8</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Encelia virginsus</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>23</td>
<td>8.8</td>
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<tr>
<td>Eriogonum fasciculatum</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>10</td>
<td>3.8</td>
</tr>
<tr>
<td>Eurotia lanata</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>37</td>
<td>14.2</td>
</tr>
<tr>
<td>Hymenoclea salisola</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>9</td>
<td>3.4</td>
</tr>
<tr>
<td>Lepidium fremontii</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>8</td>
<td>3.1</td>
</tr>
<tr>
<td>Machaeranthera tortifolia</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>10</td>
<td>3.8</td>
</tr>
<tr>
<td>Opuntia echinocarpa</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>0.008</td>
</tr>
<tr>
<td>Dalea fremontii</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>3</td>
<td>0.012</td>
</tr>
<tr>
<td>Yucca brevifolia</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>0.004</td>
</tr>
</tbody>
</table>
andersonii, 3.2%, L. cooperi 0.6%, Echinocerus, 0.5%, and Echinocactus, 0.2%.

The relative frequency for Site 1 (Figure 8) once again shows Larrea, Ambrosia, and A. confertifolia as the dominant species with values of 29.2%, 18.5%, and 24.6% respectively. As would be expected due to their low occurrence Echinocactus, L. cooperi, and Echinocerus each had a low relative frequency of 1.5% each. A. hymenolytra, Ephedra and L. andersonii had values of 7.7%, 9.2%, and 6.2% respectively.

Site 2: Site 2 was represented by only two species, Larrea (n=49) and Ambrosia (n=28) (Table 1, Figure 4, Table 4). The relative density of each species at site 2 shows Larrea the most dense with 64% of the total density. Ambrosia had a relative density of 36%, Figure 6.

The same pattern was found for relative coverage (Figure 7); Larrea has the highest value with 76.2% of the total coverage followed by Ambrosia with 23.8%.

Although Larrea and Ambrosia showed large differences in relative density and coverage at Site 2 their relative frequencies are much more similar (Figure 8). Larrea had a relative frequency of 57% while Ambrosia had a relative frequency of 43%.

Site 3: Site 3 was represented by a total of 16 different species (Table 1, Table 2). Ambrosia was the most common occurring species (n=45) followed by Ephedra (n=39),
Figure 4. Relative density of all species found at each site. Species numbers are listed in Table 1.
Figure 5. Relative coverage for all species found at each site. Species numbers are listed in Table 1.
Figure 6. Relative frequency of all species found at each site. Species numbers are listed in Table 1.
L. andersonii, Erotia (n=37 each) and Larrea (n=29). The remaining species were present in lower abundance: Eriogonum and Machaeranthera (n=10 each), Hymenoclea (n=9), Lepidium (n=8), Echinocactus (n=5), Dalea (n=3), A. confertifolia (n=3), Opuntia (n=2), and Yucca (n=1).

Relative density values at site 3 show less dispersion than was found in the other two sites (Figure 6). The most abundant species were Ambrosia (RD=17.2%), Ephedra (RD=14.9%), L. andersonii (RD=14.2%), Erotia (RD=14.2%) and Larrea (RD=11.1%). Other species present were Encelia (RD=8.8%), Machaeranthera (RD=3.8%), Eriogonum (RD=3.8%), Hymenoclea (RD=3.4%), Lepidium (RD=3.1%), Echinocactus (RD=1.9%), A. confertifolia (RD=1.1%), Dalea (RD=1.1%), Opuntia (RD=0.6%) and Yucca (RD=0.2%).

Relative coverage data for site 3, (Figure 7), shows Larrea with the highest relative coverage even though it was fourth in both numbers of individuals and relative density (Figures 4 & 6). Larrea’s relative coverage was 18.2% followed by L. andersonii (17.2%), Ephedra (14.5%), Erotia (12.3%) and both Ambrosia and Encelia (10.7%), (Figure 7). Coverages of the remaining species are Hymenoclea (5.6%), Lepidium (2.4%), Echinocactus (1.1%), A. confertifolia (1.4%), Dalea (2.2%), Opuntia (0.3%) and Yucca (0.3%).

Data for relative frequency shows that L. andersonii had the highest value, 15.2% (Figure 8) followed by Ambrosia (13.0%), Larrea (12.3%), Ephedra (11.6%), Erotia (11.6%),
and Encelia (10.1%). The rarer species included Eriogonum (5.1%), Lepidium (4.3%), Machaeranthera (4.3%), Hymenoclea (4.3%), Echinocactus (2.9%), Dalea (1.4%), A. confertifolia (1.4%) Opuntia (1.4%) and Yucca (0.7%).

Statistical Analysis

An analysis of variance (ANOVA) was run to determine if there was a significant difference between the sites. The first ANOVA run analyzed coverage by site and species (Table 2). This showed a highly significant difference in plant coverage between sites (F=29.450, P<0.001). The F-ratio for species was 38.141 with a significance of R of 0.000, P<0.001. The comparison of F-ratios using 2 way interactions of site and species produced an F-ratio of 5.219 with a significance of F of 0.000. This indicates there is a significant interaction between the two variables. The interaction between site and species is represented graphically in Figure 11.

An ANOVA was run analyzing density by site and species which also indicates that there is a significant difference in density between the sites (Table 3). The analysis revealed a highly significant difference in plant density between sites (F= 42.247, P<0.001). Analysis of interaction between site and species shows there is interaction with an F-ratio of 8.118 and significance of F of 0.00. Plotting the mean density of species between site demonstrates the significant interaction, Figure 12.
Table 3. Summary of ANOVA. Coverage by site and species.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Signif of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITE</td>
<td>77.758</td>
<td>19</td>
<td>4.093</td>
<td>37.232</td>
<td>.000</td>
</tr>
<tr>
<td>SPECIES</td>
<td>6.474</td>
<td>2</td>
<td>3.237</td>
<td>29.450</td>
<td>.000</td>
</tr>
<tr>
<td>2-way Interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITE SPECIES</td>
<td>19.505</td>
<td>34</td>
<td>.574</td>
<td>5.219</td>
<td>.000</td>
</tr>
<tr>
<td>Explained</td>
<td>97.263</td>
<td>53</td>
<td>1.835</td>
<td>16.696</td>
<td>.000</td>
</tr>
<tr>
<td>Residual</td>
<td>142.345</td>
<td>1295</td>
<td>.110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>239.608</td>
<td>1348</td>
<td>.178</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 7. Mean coverage of 18 plant species at 3 surveyed sites. Species numbers correspond to list in Table 1.
Table 4. Summary of ANOVA. Density by site and species.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Signif of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITE</td>
<td>43.264</td>
<td>2</td>
<td>21.632</td>
<td>42.247</td>
<td>.000</td>
</tr>
<tr>
<td>SPECIES</td>
<td>282.552</td>
<td>17</td>
<td>16.621</td>
<td>32.460</td>
<td>.000</td>
</tr>
<tr>
<td>2-way Interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITE SPECIES</td>
<td>141.336</td>
<td>34</td>
<td>4.157</td>
<td>8.118</td>
<td>.000</td>
</tr>
<tr>
<td>Explained</td>
<td>467.310</td>
<td>53</td>
<td>8.817</td>
<td>17.220</td>
<td>.000</td>
</tr>
<tr>
<td>Residual</td>
<td>663.093</td>
<td>1295</td>
<td>.512</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1130.403</td>
<td>1348</td>
<td>.839</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 8. Mean density of 18 plant species at 3 surveyed sites. Species numbers correspond to list in Table 1.
Table 5. Summary of ANOVA. Frequency by site and species.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Signif of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td>73.073</td>
<td>19</td>
<td>3.846</td>
<td>52.828</td>
<td>.000</td>
</tr>
<tr>
<td>SITE</td>
<td>10.285</td>
<td>2</td>
<td>5.143</td>
<td>70.639</td>
<td>.000</td>
</tr>
<tr>
<td>SPECIES</td>
<td>62.755</td>
<td>17</td>
<td>3.691</td>
<td>50.706</td>
<td>.000</td>
</tr>
<tr>
<td>2-way Interactions</td>
<td>29.305</td>
<td>34</td>
<td>.862</td>
<td>11.839</td>
<td>.000</td>
</tr>
<tr>
<td>SITE SPECIES</td>
<td>29.305</td>
<td>34</td>
<td>.862</td>
<td>11.839</td>
<td>.000</td>
</tr>
<tr>
<td>Explained</td>
<td>102.378</td>
<td>53</td>
<td>1.932</td>
<td>26.533</td>
<td>.000</td>
</tr>
<tr>
<td>Residual</td>
<td>94.278</td>
<td>1295</td>
<td>.073</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>196.657</td>
<td>1348</td>
<td>.146</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 9. Mean frequency of 18 plant species at 3 surveyed sites. Species numbers correspond to list in Table 1.
The final ANOVA analyzed frequency by site and species, (Table 4). The results of this analysis mirror those of the first two analyses. There was a highly significant difference in plant frequency between sites ($F=70.639$, $P<0.001$). The F-ratio for species was 50.706 with a significance of 0.000 and $P<0.001$. The interaction between site and species has an F-ratio of 11.839 with a significance of 0.000. The interaction is shown graphically in Figure 13.

Species richness and species diversity was determined for each site. The coefficient of community similarity using all species was also determined comparing Site 1 to Site 2, Site 1 to Site 3, and Site 2 to Site 3. A second calculation was also done using only the five dominant species at each site. The results are recorded in Table 6 and Table 7.

Table 6. Species richness, diversity, and coefficient of community similarity.

<table>
<thead>
<tr>
<th>SITE</th>
<th>RICHNESS (D)</th>
<th>DIVERSITY (H)</th>
<th>SIMILARITY TO (CC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Site 1</td>
</tr>
<tr>
<td>1</td>
<td>0.81</td>
<td>0.7005</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0.23</td>
<td>0.2847</td>
<td>0.222</td>
</tr>
<tr>
<td>3</td>
<td>0.93</td>
<td>1.0005</td>
<td>0.333</td>
</tr>
</tbody>
</table>

The species richness and diversity data indicates that Site 3 has the greatest number of different species. The values for Site 1 also show that there is quite a bit of
diversity in that site. These figures are consistent with what one would expect since Site 1 and 3 have nine and fifteen species present, respectively, and six of the fifteen in Site 3 are found in Site 1.

Site 2 has very low richness and diversity values. This is no surprise when one considers that only two species were found in Site 2 and each is found in both Site 1 and Site 3.

The coefficient of community similarity indicates the greatest similarity between Site 1 and Site 3. Site 1 and Site 2 where next in similarity, with Site 2 and Site 3 the least similar.

Since revegetation is concerned with bringing back the dominant species in a community, an adjusted coefficient of similarity was done using the five dominant species in each site, (Table 7).

Table 7. Species richness, diversity, and coefficient of community similarity using the five dominant species found at each site.

<table>
<thead>
<tr>
<th>SITE</th>
<th>RICHNESS</th>
<th>DIVERSITY</th>
<th>SIMILARITY TO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.46</td>
<td>0.61</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0.23</td>
<td>0.28</td>
<td>0.40</td>
</tr>
<tr>
<td>3</td>
<td>0.34</td>
<td>0.69</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Using the five dominant species gives a different picture of similarity of the sites. In this comparison Site 1 and Site 3 have much closer similarity values. The
similarity coefficients of Site 1 to Site 2 and Site 2 to Site 3 are equal.

Slope

Analysis of slope data reveals quite a contrast between the three sites (Table 8). Site 1 had a mean slope of 8.92°, ranging from 4° to 13.5°. Site 2 had a minimum slope of 0° and a maximum slope of 2.5°, with a mean slope of 2.26°. Site 3 had a mean slope of 17.32°, ranging from a minimum slope of 10° and a maximum slope of 28°.

The mean direction of the slope was 140° for Site 1 (Table 8). Sites 2 and 3 had much more similar mean slope directions.

Table 8. Mean slope elevation and direction, maximum and minimum slope measurements.

<table>
<thead>
<tr>
<th>Site</th>
<th>Max Slope</th>
<th>Min Slope</th>
<th>Mean Slope</th>
<th>Mean Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.5</td>
<td>4.0</td>
<td>8.92</td>
<td>140.00</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>0.0</td>
<td>1.26</td>
<td>62.04</td>
</tr>
<tr>
<td>3</td>
<td>28.0</td>
<td>10.0</td>
<td>17.32</td>
<td>67.20</td>
</tr>
</tbody>
</table>

Soil Analysis

Soil analysis was performed to give a general indication of the soil characteristics from a random sample taken from each site. The difference in pH between the
three sites was slight; Site 1 had a pH value of 6.8, Site 2 pH 7.7 and Site 3 pH 7.3 (Table 9).

Soil density measurements also displayed very little difference between sites (Table 9). Site 3 had the highest density at 2.63 g/cc and Site 2 had the lowest at 2.38 g/cc. The Site 1 density value fell exactly between that of Sites 2 and 3 with a density of 2.5 g/cc.

The water holding capacity of the soil samples taken at each site were almost identical (Table 9). Site 2 and site 3 both had a water holding capacity of 0.27 ml of H₂O/ml of soil. Site 1 had a 0.1 ml difference with a holding capacity of 0.28 ml of H₂O/ml of soil.

Table 9. Soil analysis summary.

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>Density (g/cc)</th>
<th>Water Holding Capacity (ml H₂O / ml soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.8</td>
<td>2.50</td>
<td>0.28</td>
</tr>
<tr>
<td>2</td>
<td>7.7</td>
<td>2.38</td>
<td>0.27</td>
</tr>
<tr>
<td>3</td>
<td>7.3</td>
<td>2.63</td>
<td>0.27</td>
</tr>
</tbody>
</table>
DISCUSSION

The Creosote Bush Scrub community is well represented in the Mojave Desert, whose boundaries extend in the northwest to the southern extremity of the Sierra Nevada and the Tehachapi Mountains separating it from the San Joaquin Valley. In the south the San Gabriel and San Bernardino Mountains divide it from the San Bernardino Valley, and the Chuckwalla Range from the Colorado Desert. The Colorado River forms the eastern boundary (Parish, 1930). In the northeast and north there are no natural obstacles to cut off the Mojave from the deserts of southern Utah and Nevada. In these directions the western boundary of Nevada and Owens Lake region may be assumed as the northeastern and northern limits (Parish, 1930).

*Larrea* dominated communities are found mostly below 1,220 meters (approx. 4,000 ft.) but can be found more than 300 meters higher on south facing slopes along the northern edge of the species range (Brown, 1982). Creosote Brush Scrub distribution is extensive from the Death Valley region southwest across the Mojave desert to the little San Bernardino Mountains, eastward to northwestern Arizona and southern Nevada. It is the dominant plant community below 1210 meters in this region (Holland, 1986).

Soil characteristics that are found in association with *Larrea* dominated communities have been described. Soils are usually well drained with low water holding capacity on
slopes, fans, and valleys (Holland, 1986). Soils may also have a well developed surface pavement and a shallowly-placed caliche layer (Brown, 1982). Beatley (1976) also found soils without the pavement but with loam soil with large rock fragments scattered throughout. In general Larrea is excluded when high salt concentrations exist (Wallace and Romney, 1972, Holland, 1986). Larrea can be found where extreme temperatures exist, such as summer temperatures above 40°C and winter temperatures often below freezing (Brown, 1988). Severity of winter frost is usually cited as the primary limiting factor in the creosote bush communities range (Barbour, 1987), although Beatley (1974) has theorized that excessive rainfall during the winter period may be an important factor.

A primary indicator of the Creosote Bush Scrub community is the creosote bush, *Larrea tridentata*, (Vassek, 1977; Holland, 1986). Several other species are found associated with Larrea in a typical Creosote Bush Scrub community. Shreve (1942) described the association formed by Larrea and Bursage, *Ambrosia dumosa*, as a characteristic relationship found in a creosote community. Also listed as codominants besides *Ambrosia* are *Lycium andersoni*, *Grayea spinosa*, *Salazaria mexicana*, and *Atriplex confertifolia*.

In work done by Beatley, (1976), other species were listed as codominants in the creosote community. These include *Psorothamnus fremonti*, *Krameria parvifolia*, *Ephedra*
nevadensis, Acamptopappus schockley, Lycium pallidum, Yucca baccata, and Yucca brevifolia.

In 1966 Hunt studied vegetation in the northern Mojave Desert and described the creosote as the dominant unifying component of creosote communities, with other species joining Larrea with change in elevation or latitude. Hunt (1966) also adds Atriplex hymenolytra to the list of codominants with Larrea.

At first glance the Creosote Bush Scrub community seems to be quite uniform and monotonous throughout the Mojave Desert. However, the opposite is actually the case. There are significant local and regional differences found throughout the desert region. As the topographical diversity of an area increases so does the diversity of the community (Vassek, 1975). Community diversity is also influenced by relative community age (Barbour, 1982) and by the rockiness of the soil and precipitation (Woodell, 1969). Barbour (1988), comparing 17 different sites found tremendous diversity in Larrea cover, density, and biomass.

The plants found in all three sites included in the present study are typical of those expected in the Mojave Desert as described by Vasek and Barbour (1977), Turner (1982), and Holland (1986). Two species, Larrea tridentata and Ambrosia dumosa, were found in all three sites; both of these species are common to a Creosote-bush scrub community. No other species were common to all three sites.
While it does appear that all three sites are described best as Creosote bush scrub communities, there is a striking difference in the species composition of the three sites. Site 3 had the highest diversity with nine species present, Site 2 had the lowest diversity with only two species present, and Site 1 had 16. Besides *Larrea* and *Ambrosia* only four species were common to both Sites 1 and 3. Ten species found in Site 3 were not present in Site 1, and 14 species were found in Site 3 that were not present in Site 2. This indicates that even though all three sites were Creosote bush scrub, there is a difference between the species that coexist with *Larrea* and *Ambrosia* in each site.

The relative density data also displays a difference between the sites. Site 1 had relative densities that were closest between *Larrea*, *Ambrosia*, and *A. confertifolia*. In Site 3 the relative density is greatest and similar between *Ambrosia*, *Ephedra*, *L. andersonii*, and *Eurotia*. *Larrea* had the highest density of Site 2. The relative densities between sites presents an observable difference between sites.

*Larrea* has the greatest relative coverage in Sites 1 and 2, while no species dominated in Site 3. Four species *Larrea*, *Ephedra*, *L. andersonii*, and *Eurotia* all show relative coverages that are close with no species dominant.

The values for relative frequency of plants in the three sites shows a similar pattern as that for relative
coverage. Site 1 had three species (Larrea, Ambrosia, and A. confertifolia) that displayed similar frequencies. Site 3 had six species that had similar frequencies, all of which were considerably lower than those found in Sites 1 and 2. There is an apparent difference in relative frequency between sites.

The species richness data indicates a high richness in Sites 1 and 3 with values of 0.81 and 0.93 respectively. Site 2 had the lowest value, 0.23. Species richness is concerned with the number of species and the total number of individuals. The species richness data is consistent with what one would expect given that Site 3 had the greatest number of different species, 15, and individuals, 26. Site 1 had 9 species and 124 individuals while Site 2 had only 2 species and 77 individuals.

Species diversity data also follows the same pattern. Site 3 was found to have the highest diversity with a value of 1.0 while Site 1 was second at 0.7. Site 2 had the lowest value with 0.3. Once again this is consistent with species values as stated above.

The calculations indicate that there is certainly great diversity between Sites 2 and 3. There is also diversity between Sites 1 and 2 and 1 and 3. However, a great deal of the diversity in Sites 1 and 3 is created by a small number of members of several different species.

Since revegetation of a community is designed to bring
back the most dominant species of the community, a better comparison of sites would be to use the dominant species of each site (Table 4). When the five dominant species of Sites 1 and 3 are used, along with the two species found in Site 2, a different result emerges. In this case the richness values are much closer. Sites 1 and 3 are very close with values of 0.43 and 0.34, respectively. Site 2 still has a low richness value of 0.23, but all species found at this site are the two most dominant in Site 1.

The same relationship appears again when species diversity is recalculated. The values for Site 1 and 3 are almost identical, 0.61 and 0.69, respectively. Site 2 once again has the lowest value of 0.28. But once again this low diversity value is due to fewer number of species found at Site 2.

Coefficient of community similarity shows closer similarity when only the dominant species are considered (Table 4). When Site 2 is compared to Sites 1 and 3 a coefficient of 0.40 obtained. This is almost double and triple the values obtained using all species at each site. When Sites 1 and 3 are compared a value of 0.67 is obtained. This value is also doubled that of the value obtained using all species.

A statistical analysis revealed a significant difference between the three sites. An ANOVA run comparing the three sites revealed a low probability that the
difference between the three sites would be due to chance alone. Analysis of coverage by site and species, density by site and species, and frequency by site and species produced data that indicates a significant difference, P < 0.001. There was also a significant 2-way interaction between site and species, P < 0.001.

Slope also displayed a degree of difference between sites. The mean slope of each site was very different, with Site 2 having an almost level slope, Site 3 with a steep slope, and Site 1 a moderate slope. The mean slope direction was close between Sites 2 and 3, but Site 1 had no similarity in direction.

The soil analysis did show similarity between the three sites. The pH between sites was very close, as was the soil density. The water holding capacity was almost identical at all three sites.

This study indicates that the three sites are representative of a Mojave Desert Creosote bush community. While there is a difference between the sites in the plants present, all species are common to the Creosote bush scrub community. However, even though the species present in all three sites may be common to one community, there is a difference between coverage, density, and frequency of the species found at each site.

Revegetation is concerned with bringing back the dominant species in a disturbed community. While it would
be desirable to bring back all species originally present, the realities are that this may not be financially or ecologically possible.

In most cases a revegetation plan is designed to repopulate a few dominant species in numbers consistent with what existed before the disturbance or found in the community surrounding the disturbed site. Once these plant are established, nature is then allowed to take its course and repopulate other species indigenous to the community.

In comparing sites for similarity this idea must be kept in mind. The interest of the ecologist is not necessarily in the entire community but in those species that are dominant and primary indicators of the community type. The goal of any revegetation program is to bring a disturbed area to as close as reasonably possible to its original condition and then allow nature to continue the process. It is to this end that community similarity must be considered when comparing sites for revegetation. Site 1 had nine species present, all of which can be found in a typical Creosote bush scrub community.

Site 2 was also very typical of a Creosote bush community and in fact had only two species present. Both species present have been well documented as codominants in Creosote communities.

Site 3 had 15 different species present and was the least typical of a Creosote community. Some species found
at this site were not found in the other sites. However, the most common species were representative of a typical creosote community, and were common codominants with Larrea tridentata.

The ultimate question is do all three site show enough similarity when compared to the control site so all three can be encompassed under one revegetation plan. I believe the answer is yes.

Since a revegetation plan is not primarily concerned with initially revegetating the entire community but with establishing those species that are dominant a more focused view must be taken. One must look at the species present that will be replanted in each site.

Site 2 had two species present, Larrea tridentata and Ambrosia dumosa. The most dominant species was Larrea tridentata. Larrea was also the most dominant species in Site 1, followed by Ambrosia dumosa. While a revegetation plan for Site 1 would also include other species, it would include all species found in Site 2. It would seem that since the two dominant species in both sites, and the only species found in Site 2, are the same there would be no need for a separate plan for Site 2.

Site 1 and 3 were species rich with 9 and 15 species respectively. However, when one considers the five dominant species at each site, four of the five were found at both sites. The species Eurotia lanata was present in Site 3 and
not present in Site 1. This does not mean that Eurotia is not a Creosote community member. Randell (1977) found Eurotia lanata to be a codominant to Creosote bush communities at middle elevations in his analysis of desert scrub communities in Saline Valley, California. It is possible that since Site 3 is on a small mountain range the increase in elevation allows Eurotia lanata to grow when it might not at the elevation of Site 1. Any plan developed for Site 1 would include four of the five dominant species found in Site 3. In terms of a revegetation plan the two communities are similar enough to include all three sites under one revegetation plan.
LITERATURE CITED


