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The Effect of Drought on Four Plant Communities in the Northern Mojave Desert.

Schultz, B. W. and W. K. Ostler. 1993.
Plant Ecologist, Desert Research Institute, Reno, NV
Department Manager, EG&G Energy Measurements, Las Vegas, NV.

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INTRODUCTION

Desert plant communities contain many perennial plant species that are well adapted to arid environments; therefore, one would intuitively believe that perennial desert species readily survive drought conditions. Abundant research on plant-soil-water relationships in North American deserts has shown that many species can maintain water uptake and growth when the soil-water potential is low. Little research, however, has focused on how prolonged drought conditions affect plant species in vegetation associations in desert ecosystems. A prolonged and widespread drought occurred in much of the western United States, including the Northern Mojave Desert, from 1987 through 1991. During this drought period vegetation characterization studies, initiated in 1990, by the U. S. Department of Energy (DOE) at Yucca Mountain, Nevada, allowed EG&G Energy Measurements to collect data that could be used to infer how both desert vegetation associations and desert plant species reacted to a prolonged drought. This paper presents the preliminary results.

OBJECTIVES

1. To determine how vegetation associations in the Yucca Mountain area respond to a prolonged drought.

2. To determine if plant species that occur in two or more vegetation associations respond similarly to drought.

STUDY SITE DESCRIPTION

Four primary vegetation associations occur in the Yucca Mountain Project area: Larrea tridentata-Ambrosia dumosa, Larrea tridentata-Lycium andersonii-Grayia spinosa, Coleogyne ramosissima, and Lycium andersonii-Grayia spinosa (Figures 1a-1e). The Coleogyne community consists of both low and high elevation (i.e., mountain summits versus valley bottoms) variations. Table 1 provides a relative description of each vegetation association, and the elevation and precipitation gradients that occur at Yucca Mountain.

METHODS

Twelve, 200 x 200-m ecological study plots (ESPs) were established in each vegetation association. The Coleogyne association had four ESPs in the upper

elevation association and eight ESPs in the lower elevation association.

Vegetation density measurements occurred in eight or ten, 2 x 50-m belt transects, located in each ESP. Each belt transect, in each ESP, was further divided into twenty-five, 2 x 2-m quadrats. Live and dead perennial plants, except seedlings from the current year, were identified by species in each 2 x 2-m quadrat. Data collection occurred in 1991 which was the first year that precipitation was sufficient to allow an accurate assess of living and dead plants.

The number of live and dead plants of each species in each ESP, in each vegetation association, was calculated. A ratio of live to dead plants (L:D) for each species in each vegetation association was determined.

The L:D ratio was used as a common index to assess how species responded to prolonged drought across vegetation associations. Species that have L:D ratios well below 1:1 are considered to have suffered substantial mortality from the drought. Species with L:D ratios well above 1:1 are considered to have endured the drought well. Species with L:D ratios near 1:1 are inconclusive.

An assumption was made that the L:D ratios prior to the drought were more or less equivalent among vegetation associations for individual species, and that changes in these ratios, between associations, were the result of drought conditions.

To test the hypothesis that the drought effected each of the vegetation associations similarly, we classified species that occurred in each vegetation association into two categories (L:D >1:1 and <1:1). A Chi-Square test was conducted to assess if differences existed among vegetation associations.

RESULTS

Vegetation Association Response

The number of live and dead plants in each vegetation association are reported in Table 2. The percent of all live plants after the drought was 64. The low elevation Coleogyne association had the lowest survival with 47.4%. The Larrea-Ambrosia and the Larrea-Lycium-Grayia association had roughly the same survival with 58.1% and 58.9% respectively. The high elevation Coleogyne and the Lycium-Grayia associations had much higher rates of survival at 79.2% and 82.0% respectively.

A Chi-square analysis performed on the live:dead ratios showed that the drought did not have a similar effect on the vegetation associations at Yucca Mountain, Nevada (Table 3). The Larrea-Ambrosia, high elevation Coleogyne, and Lycium-Grayia associations tended to have more species than expected in the >1:1 category, while the Larrea-Lycium-Grayia and low elevation Coleogyne had more species than expected in the <1:1 category. The X^2 of 28.0 ($p<.001$, df=4) suggests that this is not a random distribution.

Species Response

The response to drought of the 30 species analyzed is provided in Table 4. The percent of living plants for each species summed over all vegetation associations ranged from a low of 3% for Oryzopsis hymenoides to a high of 98% for Hilaria jamesii and Chrysothamnus nauseosus. Only three species O. hymenoides, Stipa speciosa and Atriplex confertifolia had overall rates under 50%. The median value for all species was 77%.

Twelve of the thirty species analyzed occurred in all vegetation associations. Seven species occurred in only Lycium-Grayia or the high elevation Coleogyne associations. Eight species occurred in all vegetation association except the high elevation Coleogyne. Two species occurred in all vegetation associations except the low elevation Coleogyne association and one species was absent from the high elevation Coleogyne and the Larrea-Ambrosia associations.

Species were present in most of the vegetation associations; however, they did not respond similarly across the vegetation associations. Species responses can be classified into three general categories: 1) species which had L:D ratios >1:1 in every vegetation association in which they occurred, 2) species which had L:D ratios ≤1:1 in the low elevation Coleogyne and/or Larrea-Lycium-Grayia vegetation associations and >1:1 in all others, and 3) species which had L:D ratios ≤1:1 in all but the Lycium-Grayia association (Table 5 and Figures 2-4).

Seventeen species (57 %) had L:D ratios ≥1:1 in every vegetation association in which they occurred. Figures 2a-2c show the specific level of response that three of these species had.

Ten species had L:D ratios >1:1 in both the lowest and highest elevation associations but had L:D ratios <1:1 in at least one of the two vegetation associations that occur at intermediate points on the elevation/precipitation gradient (Tables 1 and 5). Figures 3a and 3b show two of the species that had this response to the drought.

Three species (13 %) had L:D ratios >1:1 in only the Lycium-Grayia vegetation association and L:D ratio <1:1 in all other vegetation associations. The two most common bunch grasses in the project area, O. hymenoides and S. speciosa had this response to the drought (Figures 4a and 4b).

DISCUSSION AND CONCLUSIONS

1. Vegetation associations present in the northern Mojave Desert do not respond similarly to prolonged drought (Tables 2 and 3).

2. The effect that the prolonged drought had on the vegetation associations did not follow elevation and precipitation gradients (Tables 1, 2 and 3). The high elevation (Coleogyne and Lycium-Grayia) vegetation associations and to a lesser extent the lowest elevation association (Larrea-Ambrosia) were less affected by the drought. Vegetation associations at intermediate points on the elevation and precipitation gradient (i.e., Larrea-Lycium-Grayia and low elevation Coleogyne), had many species that appeared to suffer substantial severe mortality during the drought (Table 3).

3. Numerous soil factors probably determine how drought affects both a vegetation association and an individual species. Soil characteristics were highly variable between vegetation associations (Table 1 and personal observation), and this variation may help explain why individual species responded differently across vegetation associations. Additional research on plant-soil relationships, and how drought can affect species mortality, is necessary before definitive conclusions are possible.

4. Additional studies on how the L:D ratios present in the study plots sampled change as moisture conditions return towards the long-term average may help determine the dynamics of species populations in the northern Mojave Desert.

Table 1. General physiographic and abiotic characteristics of the five vegetation primary vegetation associations at Yucca Mountain.

Vegetation Association	Elevation Range (m)	Landform	Relative Precipitation (1992 ave.)	Average Soil Depth (cm)[†]
Larrea-Ambrosia	900-1050	Sandy alluvial plain	Lowest (166 mm)	80+
Larrea-Lycium-Grayia	1000-1200	Young gravelly alluvial outwash	Intermediate (219 mm)	60-100
Low elevation *Coleogyne*	1100-1300	Old alluvial fans	Intermediate (212 mm)	15-45
High Elevation *Coleogyne*	1400-1700	Flat mountain tops and mesas	Highest (260 mm)	30-45
Lycium-Grayia	1150-1500	Ridge tops and mountain sideslopes	Intermediate (220 mm)	30-45

[†] Personal observation of the authors.

Table 2. Total living and dead plants recorded in the vegetation associations at Yucca Mountain in 1991.

VEGETATION ASSOCIATIONS

	Larrea Ambrosia	*Larrea Lycium Grayia*	Low Elevation *Coleogyne*	High Elevation *Coleogyne*	*Lycium Grayia*	Total
Live plants	13,511	5,930	4,882	2,512	14,316	41,151
Dead plants	9,758	4,129	5,411	661	3,139	23,098
Percent Alive	58.1	58.9	47.4	79.2	82.0	64.0

Table 3. Chi-square analysis of live:dead ratios for 30 most common perennial species in the vegetation associations at Yucca Mountain in 1991.

VEGETATION ASSOCIATIONS

		Larrea Ambrosia	*Larrea Lycium Grayia*	Low Elevation *Coleogyne*	High Elevation *Coleogyne*	*Lycium Grayia*	Total
L:D >1:1	Obs.	17	11	11	18	30	87
	Exp.	15.9	17.4	15.9	15.1	22.8	
L:D <1:1	Obs.	4	12	10	2	0	28
	Exp.	5.1	5.6	5.1	4.9	7.2	
Total		21	23	21	20	30	115

Obs. = number of species observed.
Exp. = number of species expected.

$X^2 = 28.0$ $p<.001$, $df=4$

Table 4. The total number of plants (alive and dead) identified by species in the study locations at Yucca Mountain in 1991.

SPECIES	TOTAL LIVE	TOTAL DEAD	PERCENT ALIVE
*Acamptopappus shockleyi**	2,099	482	81
*Ambrosia dumosa**	10,447	4,803	69
Atriplex canescens	60	13	82
Atriplex confertifolia	851	777	52
Ceratoides lanata	1,023	337	75
Chrysothamnus nauseosus	39	1	98
Chrysothamnus teretifolius	434	63	87
Chrysothamnus viscidiflorus	183	42	81
Coleogyne ramosissima	2,164	979	69
Encelia virginensis	377	253	60
Ephedra nevadensis	3,677	726	84
Ephedra viridis	134	6	96
Eriogonum fasiculatum	1,304	848	61
Erioneuron pulchellum	1,338	399	77
Grayia spinosa	1,198	757	61
Gutierrezia sarothrae	401	143	74
Haplopappus cooperi	1,598	956	63
Haplopappus linearifolius	113	44	72
Hilaria jamesii	1,119	26	98
Hymenochlea salsola	981	504	66
Krameria parvifolia	2,627	253	91
Larrea tridentata	1,261	49	96
Lycium andersonii	1,538	388	80
Lycium pallidum	947	110	90
Menodora spinescens	2,104	1,162	64
Oryzopsis hymenoides	80	2,288	3
Salazaria mexicana	221	75	75
Sphaeralcea ambigua	1,359	76	95
Stephanomeria pauciflora	62	13	83
Stipa speciosa	1,439	1,921	43

* The actual percent alive values for these species should be slightly lower. Some dead specimens in the *Larrea-Ambrosia* association could not be separated between these two species. Only those that were positively identifiable were used in this analysis.

Table 5. Typical responses displayed by the 30 most common species analyzed for L:D ratios at Yucca Mountain, Nevada.

Response Type	Species
1. Species that had L:D ratios $\geq$ 1:1 in all of the vegetation associations in which they occurred.	*Chrysothamnus viscidiflorus*[1] *Chrysothamnus nauseosus*[1] *Chrysothamnus teretifolius*[1] *Coleogyne ramosissima* *Encelia virginensis* *Ephedra nevadensis* *Ephedra viridis*[1] *Gutierrezia sarothrae*[1] *Haplopappus linearifolius*[1] *Hilaria jamesii*[1] *Krameria parvifolia* *Lycium andersonii* *Lycium pallidum* *Larrea tridentata* *Salazaria mexicana* *Sphaeralcea ambigua* *Stephanomeria pauciflora*
2. Species that occurred across the entire elevation/precipitation gradient and had L:D ratios $\geq$ 1:1 in vegetation associations at the lowest and highest elevations, and L:D ratios < 1:1 in vegetation associations at intermediate points on elevation/precipitation gradient.	*Ambrosia dumosa* *Atriplex canescens* *Atriplex confertifolia* *Acamptopappus shockleyi* *Ceratoides lanata* *Erioneuron pulchellum* *Grayia spinosa* *Haplopappus cooperi* *Hymenoclea salsola* *Menodora spinescens*
3. Species that had L:D ratios <1:1 in all vegetation associations, except the Lycium-Grayia (i.e., highest elevation).	*Eriogonum fasiculatum* *Oryzopsis hymenoides* *Stipa speciosa*

[1] Species that were present only in the high elevation *Coleogyne* and *Lycium-Grayia* associations.

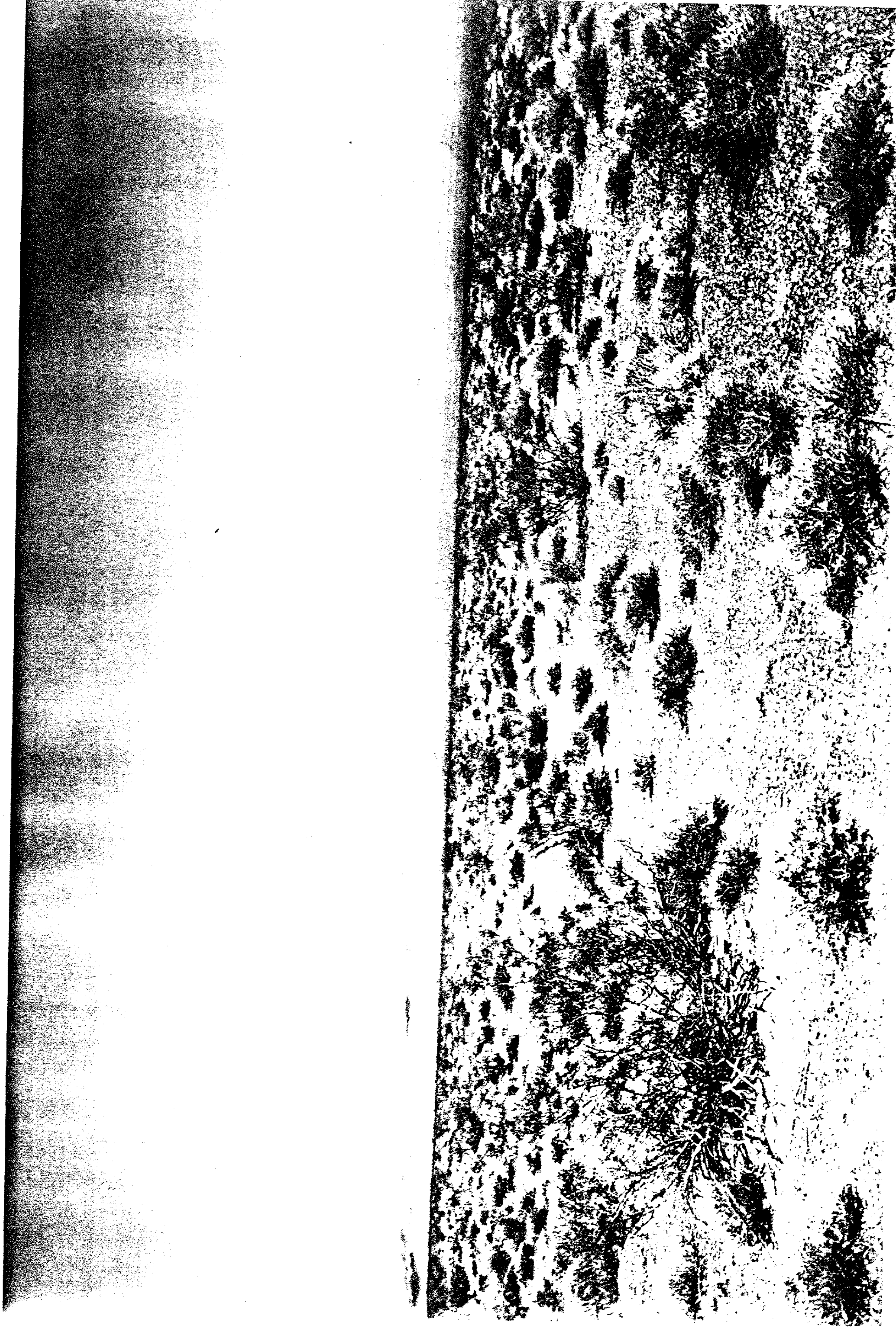
Figure Titles

Figure 1. a) Larrea-Ambrosia association, b) Larrea-Lycium-Grayia association, c) low elevation Coleogyne association, d) high elevation Coleogyne association, and e) the Lycium-Grayia association.

Figures 2a-2c. Three of the twelve species that had L:D rations $\geq$ 1:1 in each of the vegetation associations in which they occurred, and the variation in species response between vegetation associations. Values above each set of bars are the L:D ratio for the species.

Figures 3a and 3b. Two of the eight species that had L:D ratios $\geq$ 1:1 in the vegetation associations at the lowest and highest elevations, and L:D ratios $\leq$ 1:1 in one or both of the vegetation associations that occurred at intermediate points on the elevation/precipitation gradient. Values above each set of bars are the L:D ratio for the species.

Figures 4a and 4b. Two of the three species that had L:D ratios $\geq$ 1:1 in only the Lycium-Grayia vegetation association. Values above each set of bars are the L:D ratio for the species.



a.

LYCIUM ANDERSONII

b.

LYCIUM PALLIDUM

c.

LARREA TRIDENTATA

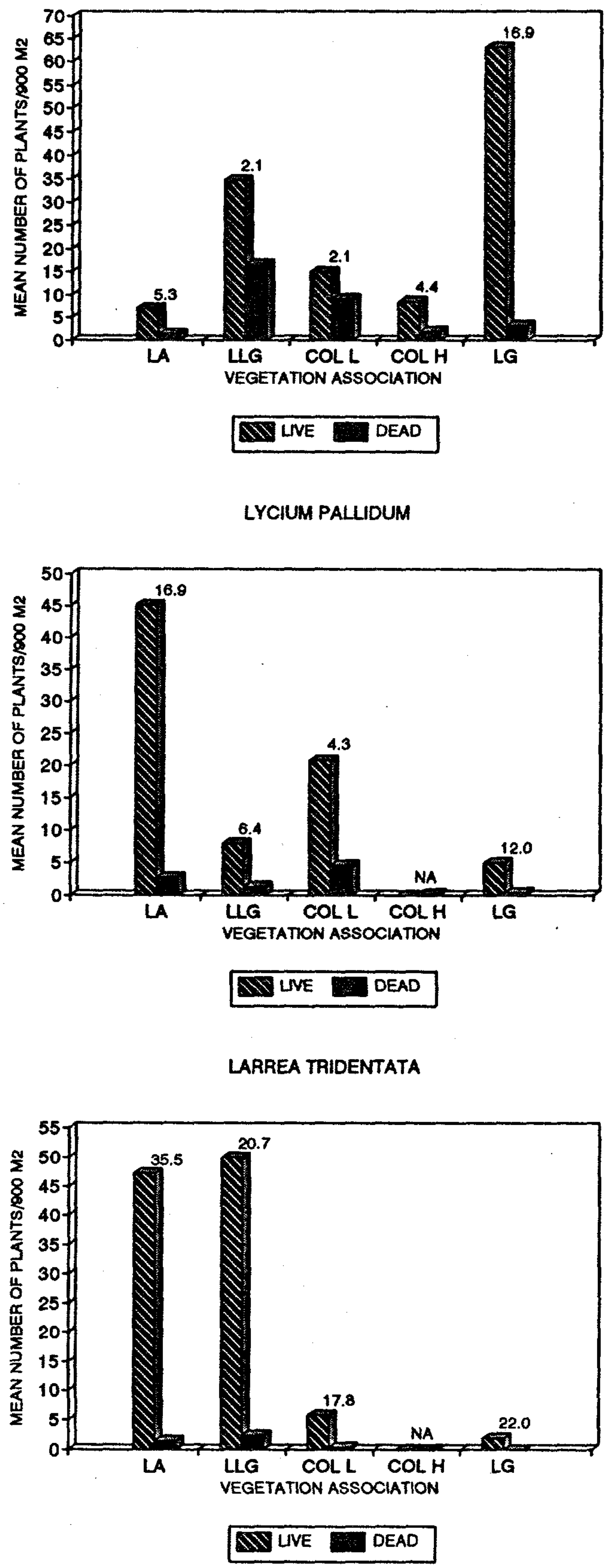
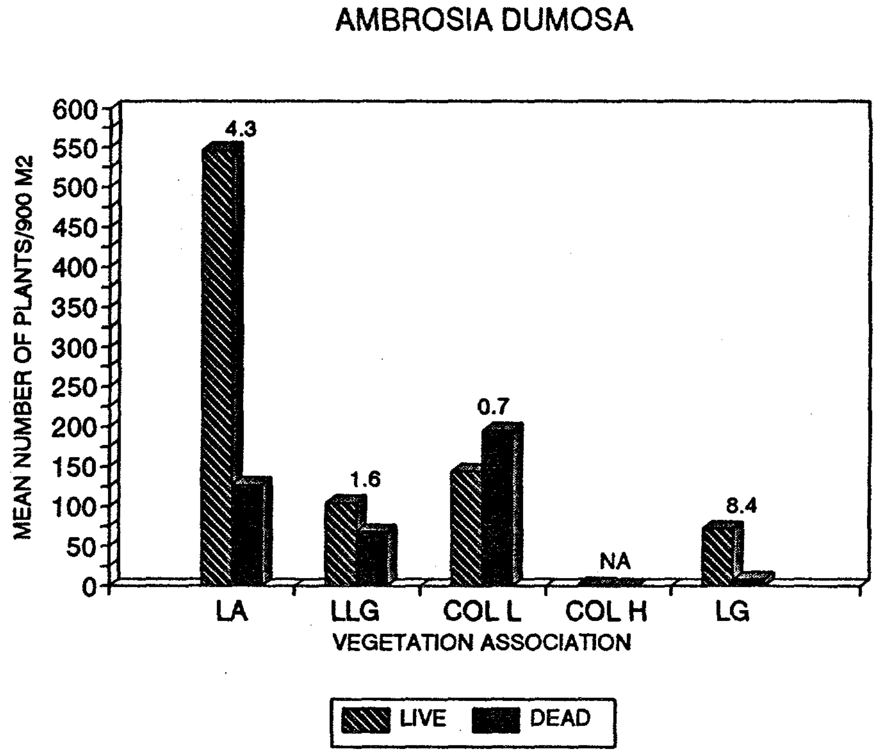


Figure 2.

a.


AMBROSIA DUMOSA
MEAN NUMBER OF PLANTS/900 M2
600
550
500
450
400
350
300
250
200
150
100
50
0
4.3
1.6
0.7
NA
8.4
LA
LLG
COL L
COL H
LG
VEGETATION ASSOCIATION
LIVE
DEAD

b.

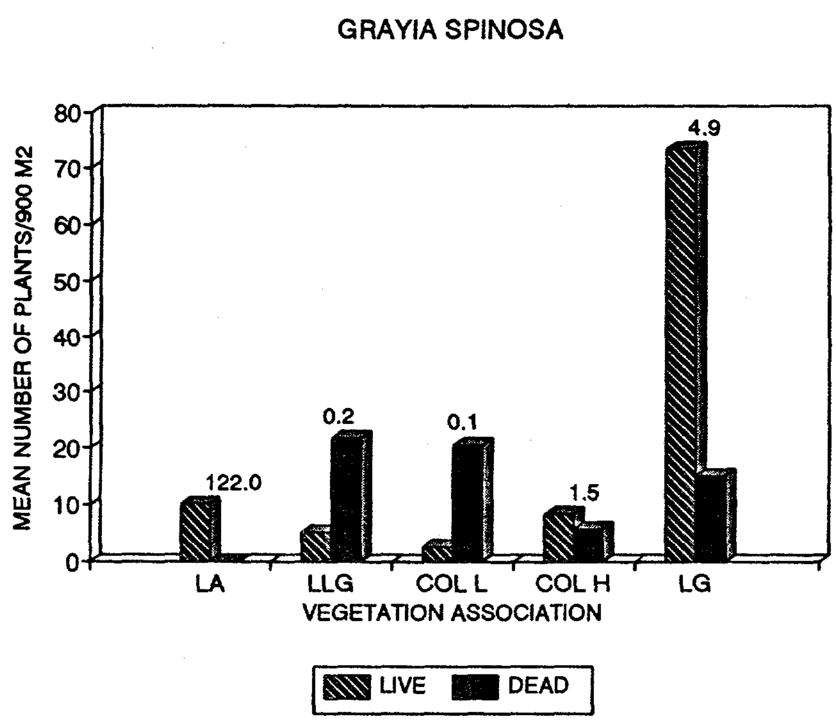
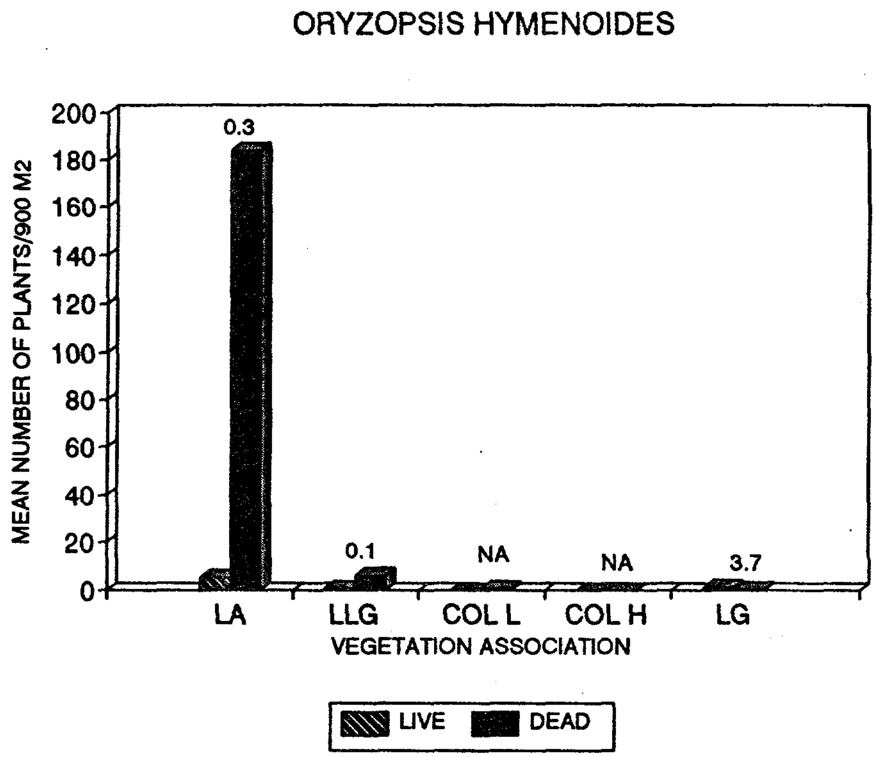

GRAYIA SPINOSA
MEAN NUMBER OF PLANTS/900 M2
80
70
60
50
40
30
20
10
0
122.0
0.2
0.1
1.5
4.9
LA
LLG
COL L
COL H
LG
VEGETATION ASSOCIATION
LIVE
DEAD

Figure 3.

a.


ORYZOPSIS HYMENOIDES
MEAN NUMBER OF PLANTS/900 M2
200
180
160
140
120
100
80
60
40
20
0
0.3
0.1
NA
NA
3.7
LA
LLG
COL L
COL H
LG
VEGETATION ASSOCIATION
LIVE
DEAD

b.

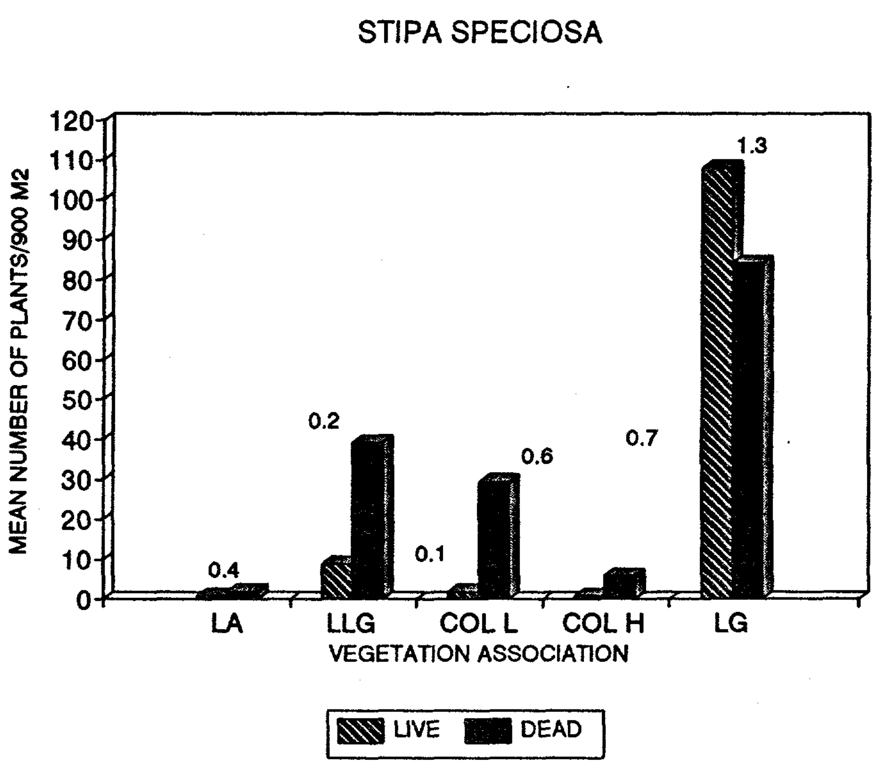

STIPA SPECIOSA
MEAN NUMBER OF PLANTS/900 M2
120
110
100
90
80
70
60
50
40
30
20
10
0
1.3
0.2
0.6
0.7
0.4
0.1
LA
LLG
COL L
COL H
LG
VEGETATION ASSOCIATION
LIVE
DEAD

Figure 4.