1974

# Composition and Biomass Contribution of Lichen and Moss Communities in the Hot Desert Ecosystems

Thomas H. Nash III

Sally White

Janet M. Nash



Recommended Citation

Nash, Thomas H., III, White, Sally, Nash, Janet M. 1974. Composition and Biomass Contribution of Lichen and Moss Communities in the Hot Desert Ecosystems. U.S. International Biological Program, Desert Biome, Utah State University, Logan, Utah, Reports of 1973 Progress, Volume 3: Process Studies, RM 74-19.

**1973 PROGRESS REPORT**
**[FINAL]**

# COMPOSITION AND BIOMASS CONTRIBUTION OF LICHEN AND MOSS COMMUNITIES IN THE HOT DESERT ECOSYSTEMS

Thomas H. Nash III, Project Leader
Sally White and Janet M. Nash
Arizona State University

**US/IBP DESERT BIOME**
**RESEARCH MEMORANDUM 74-19**

Reprint from Reports of 1973 Progress, Volume 3: Process Studies
Plant Section, pp. 159-165

1973 Proposal No. 2.3.1.11

**MAY, 1974**



Citation format: Author(s). 1974. Title
US/IBP Desert Biome Res. Memo. 74-19. 7 pp.

Ecology Center, Utah State University, Logan, Utah 84322

## ABSTRACT

The general objective of this study was to determine the relative abundance of lichens and mosses at each of the southern desert validation sites. At each site, sampling was conducted over bajada, north slope and south slope locations. Altogether, 61 lichen species and 18 moss species were found. The largest number of lichens was 47 at Jornada's north slope; the largest number of mosses, 14 at Silverbell's bajada location. Lichen species numbers and abundance, as determined by cover or biomass, always exceeded moss species numbers and abundance. On the bajada portion of the validation sites, lichen cover was quite low: 0.012% at Rock valley, 0.041% at Silverbell and 0.0031% at Jornada. On the bajada sites moss cover was zero at Rock Valley and Jornada and was 0.020% at Silverbell. Species numbers and abundance for both lichens and mosses were greater on north slopes than south slopes. Lichen cover ranged up to 8.1% on the north slope at Jornada; moss cover, up to 0.27% on the north slope at Silverbell. Lichen biomass ranged from 0.088 g/$m^2$ on the Rock Valley bajada location to 38.281 g/$m^2$ on the Jornada north slope. Moss biomass ranged from zero at several locations to 0.534 g/$m^2$ on the Silverbell bajada. Lichens containing blue-green algae covered from 0.1 to 6.0 $m^2$/ha. Lichens, especially those containing blue-green algae, might have greater abundance on less disturbed bajada locations. The greater abundance of lichens on the north slopes is consistent with data from the literature, which demonstrates that desert lichens are photosynthetically adapted to cool temperatures.

## INTRODUCTION

Lichens are prominent components of southern desert ecosystems. Orange, yellow, green and black patterns on desert cliffs and rocks illustrate their abundance. From a functional point of view, lichens are important in nitrogen fixation, as initiators of xeric succession and as nutrient sinks. Both lichens and mosses are used by ecologists as environmental indicators. Many species are substrate specific; others respond to slight changes in environmental parameters, such as water availability. In addition, both lichens and mosses are sensitive indicators of air pollution.

The following quantitative study was justified in that practically no information is available concerning the relative abundance of lichens in hot desert ecosystems. An initial study by Pearson (1972) at the Curlew Valley Validation Site indicated that lichens and mosses are important members of cold desert communities. At the sagebrush site at Curlew Valley over 50% of the ground is covered with lichens and over 25% is covered by mosses. The fact that over 32% of the ground is covered with *Collema tenax*, a lichen containing *Nostoc*, implies that lichens may be important in nitrogen fixation in this community.

## OBJECTIVES

The general objective was to determine the relative abundance of lichens at the three hot desert validation sites; Jornada, Silverbell and Rock Valley. The specific objectives were:

1. to identify typical lichen and moss species found on each of the hot desert validation sites,
2. to determine the relative importance of each species by measuring its respective cover at each site,
3. to estimate the biomass of each species,
4. to evaluate the relative importance of lichens containing blue-green algae.

## METHODS

Because desert lichens and mosses are extremely slow-growing perennials, it was assumed that sampling at one point in time would provide representative data on the importance of lichens and mosses in each validation area. The Silverbell site was sampled in April, Jornada in May, and Rock Valley in June. To estimate lichen and moss cover, two 1 m by 1000 m belt transects (Oosting, 1956) were sampled across each of the validation sites, which are located on gentle bajadas. The bajada transects were parallel and were separated by 300 m with the first quadrat of transect two being in the equivalent position of quadrat 501 of transect one. The sampling design was initially chosen to provide a representative sample of the Silverbell site. Because marked differences in lichen and moss communities were observed on different aspects, additional belt transects (1 m by 120 m) were constructed on north and south slopes at each site. The lengths of these transects were determined by the physical constraints imposed by the size of the hills existing at the Silverbell site. Along each transect, cover data estimated to the nearest $cm^2$ were recorded for each species for each $m^2$. A 10 x 10 cm frame, which was subdivided into 1 $cm^2$ divisions, was employed to increase the precision of the estimates. Specimens which could not be reliably identified in the field were collected for later identification in the laboratory.Voucher specimens for all the species are deposited in the cryptogamic herbarium at Arizona State University.

Biomass values of lichens and mosses that could be readily separated from their substrate were obtained by the gravimetric technique (Jackson, 1958) after the samples were dried in a forced convection oven at 60 C for 24 hours. Crustose lichens, which are actually imbedded in the rock substratum, presented a special problem. Separate estimates for biomass of crustose species were obtained by employing (1) the muffle furnace technique (Jackson, 1958); (2) titration technique (Jackson, 1958) to determine total organic carbon; and (3) gravimetric techniques on scraped samples. To check the assumption that different sized specimens of the same species had the same biomass per unit area, regressions of biomass as a function of cover were run. Average biomass per $cm^2$ for a species or a group of morphologically similar species were then used to extrapolate to the lichen and moss community biomass.

## RESULTS

More lichen species were present at all sites than moss species (Tables 1-4). On the bajada locations the largest number of moss (14) and lichen (19) species were both found at the Silverbell site. At each of the sites the north slope consistently had more species of both lichens and mosses. The greatest lichen diversity was found on the north slope at the Jornada site (47 species); the greatest moss diversity, on the north slope at the Silverbell site (10 species). The actual number of lichen species at each site is probably slightly higher because the category "unknown black crust" may include several species which are currently poorly defined taxonomically.

In terms of morphological form, all the mosses were acrocarps and most of the lichens were crustose species. On the bajada transects all the lichen species were crustose except for three foliose *Parmelia* species on the Silverbell site, two foliose *Collema* species, and *Thyrea pulvinata* which is subfruticose. On the north and south slope transects, *Dermatocarpon miniatum* and *Xanthoria fallax* and species of *Collema*, *Heterodermia*, *Parmelia* and *Physcia* are foliose, *Thyrea pulvinata* is subfruticose, and all the rest are crustose. Foliose species were much more abundant on north-facing slopes.

Cover data (Tables 1-4) generally parallel the data on species numbers. Lichen cover consistently exceeded moss cover, varying from a factor of 2 at the Silverbell bajada area to a factor of 400 on the Jornada north slope. On the bajada locations the greatest lichen and moss cover was found at Silverbell. North slopes consistently had higher lichen and moss cover than south slopes. The highest lichen cover of more than 8% was found on the north slope of Jornada; the lowest lichen cover of 0.003% at the Jornada bajada area. The highest moss cover of 0.27% was found on the north slope at Silverbell; the lowest of 0% on the bajadas at Rock Valley and Jornada and the south slopes at Rock Valley and Silverbell.

Data for crustose lichen biomass, as determined by the muffle furnace and titration techniques, are rather variable. In some cases the standard deviation exceeds the mean. Because the gravimetric procedure yielded less variable data, its results have been used for the calculation of biomass data (Table 5). In general, the biomass estimates are of the same order of magnitude from all three procedures. In several instances the estimated values are within 10% of each other. Consequently, it is felt that the data are reasonably accurate. Different-sized lichens or mosses within a particular morphological group were found to have equivalent biomasses per unit area. Regressions of lichen biomass as a function of size yielded a significant relationship ($\alpha = 0.01$) with 75 to 90% of the variability explained by the line.

At all sites. lichen biomass exceeded moss biomass. At sites where mosses occur, lichen biomass is 2 to 152 times greater. On the bajadas, Silverbell had the greatest biomass for both lichens and mosses. On north slopes, Silverbell had the greatest biomass of mosses; Jornada had the greatest biomass of lichens. On south slopes Jornada had the highest biomass of both lichens and mosses.

Cover data for lichens containing blue-green algae (Table 6) are relatively constant compared to the cover data for all lichens (Tables 1 & 2). Numerically the numbers are rather small, varying from 0.1 to 6.0 $m^2/ha$. Examination of the relative importance of blue-green-containing lichens to the lichen community as a whole reveals data which vary from 0.3% on the Jornada north-facing slope to 97.5% on the Jornada bajada. Thus variations among lichen communities are primarily due to variation among green alga-containing lichens.

Table 1. Lichen cover data ($m^2/ha$) from bajada belt transects from the three validation sites

| Species | Rock Valley | Silverbell | Jornada |
|---|---|---|---|
| *Acarospora fuscata* | 0.1080 | 0.0308 | 0.0045 |
| *Acarospora schleicheri* | -- | 0.0120 | -- |
| *Acarospora smaragdula* | -- | -- | 0.0025 |
| *Acarospora strigata* | 0.9645 | 0.0048 | -- |
| *Caloplaca squamosa* | -- | 0.0524 | -- |
| *Candelariella aurella* | 0.0005 | -- | -- |
| *Collema coccophorum* | 0.0150 | 0.1984 | -- |
| *Collema polycarpon* | 0.0010 | 0.0170 | -- |
| *Dermatocarpon lachneum* | -- | 1.8441 | -- |
| *Dermatocarpon plumbeum* | -- | -- | 0.0010 |
| *Heppia lutosa* | -- | 0.1149 | 0.0100 |
| *Lecanora calcarea* | 0.0135 | 0.0309 | -- |
| *Lecanora cinerea* | 0.0130 | -- | -- |
| *Lecanora muralis* | -- | 0.0117 | -- |
| *Lecidea decipiens* | -- | 0.0043 | -- |
| *Parmelia kurokawae* | -- | 0.0835 | -- |
| *Parmelia lineola* | -- | 0.0032 | -- |
| *Parmelia weberi* | -- | 0.0298 | -- |
| *Peltula euploca* | -- | 0.0160 | -- |
| *Peltula obscurans* var. *deserticola* | 0.0010 | -- | 0.0115 |
| *Peltula obscurans* var. *hassei* | 0.0125 | 0.2723 | 0.1505 |
| *Peltula polyspora* | -- | 0.0074 | -- |
| *Thyrea pulvinata* | -- | 0.0021 | -- |
| Unknown black crust | 0.1040 | 1.3830 | 0.1385 |
| Totals | 1.2330 | 4.1186 | 0.3185 |
| No. of species | 10 | 19 | 7 |

## DISCUSSION

Lichens are more abundant at the Curlew Valley sites than in the southern desert validation sites. At one Curlew Valley location, Pearson (1972) found a lichen cover of 60.2% and an estimated lichen biomass of 219 kg/ha. In contrast, for hot desert validation sites the highest lichen cover value on a bajada was 0.04% with 3.8 kg/ha biomass at Silverbell. Higher values of 8.1% cover and 382.8 kg/ha biomass were found on a north slope at Jornada. However, there are no north slope data available at Curlew Valley for comparison.

The results of the bajada sampling at the hot desert sites are not necessarily indicative of potential lichen development in these deserts. In relatively undisturbed areas with stable soils, soil lichen cover may vary from approximately 10 to 100%. Species of *Collema* and *Heppiaceae*, both of which contain blue-green algae, are usually the

Table 2. Cover data ($m^2/ha$) from belt transects placed on north and south slopes at the three validation sites

| Species | Rock Valley North | Rock Valley South | Silverbell North | Silverbell South | Jornada North | Jornada South |
|---|---|---|---|---|---|---|
| *Acarospora chlorophana* (Wahlenb. *ex* Ach.) Mass. | -- | -- | -- | -- | 6.392 | -- |
| *Acarospora fuscata* (Schrad.) Arn. | 0.450 | -- | 5.083 | 0.075 | -- | -- |
| *Acarospora schleicheri* (Ach.) Mass. | -- | -- | 6.850 | 0.008 | 39.217 | 17.992 |
| *Acarospora smaragdula* (Wahlenb. *ex* Ach.) Mass. | -- | -- | -- | -- | 9.567 | 13.825 |
| *Acarospora strigata* (Nyl.) Jatta | 4.900 | 0.058 | 2.400 | 0.042 | 5.500 | 8.542 |
| *Buellia novomexicana* B. de Lesd. | -- | -- | -- | -- | 7.183 | -- |
| *Buellia retrovertans* Tuck. | -- | -- | 0.483 | -- | 6.525 | 0.050 |
| *Caloplaca amabilis* Zahlbr. | 0.025 | -- | 5.558 | -- | -- | -- |
| *Caloplaca saxicola* Nordin | -- | -- | 0.092 | -- | -- | -- |
| *Caloplaca squamosa* B. de Lesd. | -- | -- | 12.667 | 0.400 | 119.492 | 14.458 |
| *Candelariella aurella* (Hoffm.) Zahlbr. | 0.050 | -- | -- | -- | -- | -- |
| *Candelariella rosulans* (Müll. Arg.) Zahlbr. | -- | -- | -- | -- | 4.767 | 1.533 |
| *Candelariella submexicana* B. de Lesd. | -- | -- | 0.317 | -- | 1.017 | 0.367 |
| *Collema coccophorum* Tuck. | -- | -- | 0.217 | -- | -- | -- |
| *Collema polycarpon* Hoffm. | -- | -- | -- | -- | 0.433 | -- |
| *Dermatocarpon lachneum* (Ach.) A. L. Sm. | 6.117 | 2.475 | 1.217 | -- | 0.033 | 0.250 |
| *Dermatocarpon miniatum* (L.) Mann | 0.025 | -- | 1.042 | -- | 2.500 | -- |
| *Dermatocarpon plumbeum* (B. de Lesd.) Zahlbr. | 0.033 | -- | -- | -- | -- | -- |
| *Dimelaena oreina* (Ach.) Norm. | -- | -- | -- | -- | 0.250 | -- |
| *Diploschistes actinostomus* (Pers.) Zahlbr. | -- | -- | -- | -- | 0.067 | -- |
| *Endocarpon pusillum* Hedw. | -- | -- | -- | -- | 0.067 | -- |
| *Fulgensia bracteata* (Hoffm.) Räs. | 0.025 | -- | -- | -- | -- | -- |
| *Heppia lutosa* (Ach.) Nyl. | 0.092 | 0.658 | 0.008 | -- | -- | -- |
| *Heterodermia* Trev. | -- | -- | -- | -- | 1.142 | -- |
| *Lecanora alphoplaca* (Wahlenb. *ex* Ach.) Ach. | -- | -- | 0.317 | -- | 0.333 | 0.083 |
| *Lecanora calcarea* (L.) Somm. | 0.067 | -- | 18.217 | -- | 20.733 | -- |
| *Lecanora cenisia* Ach. | -- | -- | -- | -- | 0.400 | -- |
| *Lecanora cinerea* (L.) Somm. | 0.083 | -- | 49.150 | -- | 16.567 | 0.917 |
| *Lecanora dispersa* (Pers.) Somm. | -- | -- | -- | -- | 0.208 | -- |
| *Lecanora frustulosa* (Dicks.) Ach. | -- | -- | -- | -- | 26.542 | -- |
| *Lecanora garovaglii* (Körb.) Zahlbr. | -- | -- | -- | -- | 1.075 | -- |
| *Lecanora muralis* (Schreb.) Rabenh. | -- | -- | 5.958 | -- | 3.458 | 0.017 |
| *Lecidea decipiens* (Hedw.) Ach. | 0.392 | -- | -- | -- | -- | -- |
| *Lecidella stigmatea* (Ach.) Hert. & Leuck. | -- | -- | -- | -- | 0.133 | -- |
| *Lepraria* sp. Ach. | -- | -- | -- | -- | 1.508 | 0.042 |
| *Parmelia arseneana* Gyeln. | -- | -- | -- | -- | 0.333 | -- |
| *Parmelia bolliana* Müll. Arg. | -- | -- | -- | -- | 41.700 | -- |
| *Parmelia conspersa* (Ach.) Ach. | -- | -- | -- | -- | 4.592 | -- |
| *Parmelia dissensa* Nash | -- | -- | -- | -- | 3.958 | -- |
| *Parmelia flaventior* Nash | -- | -- | -- | -- | 6.408 | -- |
| *Parmelia kurokawae* Hale | -- | -- | 50.742 | -- | -- | -- |
| *Parmelia lineola* Berry | -- | -- | -- | -- | 93.742 | -- |
| *Parmelia mexicana* Gyel | -- | -- | -- | -- | 257.217 | 10.725 |
| *Parmelia psoromifera* Kurok. | -- | -- | -- | -- | 60.442 | -- |
| *Parmelia reticulata* | -- | -- | -- | -- | 1.600 | -- |
| *Parmelia tinctina* Mah. & Gill | -- | -- | -- | -- | 2.708 | -- |
| *Parmelia weberi* Hale | -- | -- | 93.825 | -- | -- | -- |
| *Peltula euploca* (Ach.) Wetm. | -- | -- | 0.092 | 0.033 | 1.058 | -- |
| *Peltula obscurans* var. *hassei* (Zahldr.) Wetm. | 0.100 | -- | 5.642 | 2.125 | 0.567 | 0.933 |
| *Peltula polyspora* (Tuck.) Wetm. | 0.108 | -- | -- | -- | -- | 0.083 |
| *Physcia caesia* (Hoffm.) Hampe | -- | -- | -- | -- | 31.208 | 0.850 |
| *Physcia callosa* Nyl. | -- | -- | -- | -- | 3.000 | -- |
| *Physcia halei* Thoms. | -- | -- | -- | -- | 6.767 | 0.083 |
| *Physcia muscigena* | -- | -- | -- | -- | 0.333 | -- |
| *Physcia orbicularis* (Neck.) Poetsch | 0.008 | -- | -- | -- | 1.358 | -- |
| *Physcia stellaris* (L) Nyl. | -- | -- | -- | -- | 12.192 | -- |
| *Rhizocarpon disporum* (Naeg. *ex* Hepp) Müll. Arg. | -- | -- | -- | -- | 8.608 | -- |
| *Thyrea pulvinata* (Schaer.) Mass. | 0.342 | -- | -- | -- | 0.025 | -- |
| *Toninia caeruleonigricans* (Lightf.) Th. Fr. | 0.158 | -- | -- | -- | -- | -- |
| *Verrucaria fuscella* (Turn.) Ach. | -- | -- | 0.033 | -- | -- | -- |
| *Xanthoria fallax* (Hepp) Arn. | -- | -- | -- | -- | 0.200 | -- |
| Total | 12.975 | 3.191 | 259.910 | 2.683 | 813.125 | 70.750 |
| # species | 17 | 3 | 21 | 6 | 47 | 17 |

dominant organisms. Because lichens containing blue-green algae are estimated to fix up to 50% of the total nitrogen fixed in coastal coniferous forest ecosystems (Denison, 1973) and tropical rain forests (Forman, personal communication), the relative importance of nitrogen-fixing by desert lichens should be examined. One potentially important factor, which may result in decreased community productivity on disturbed sites, is the reduction of nitrogen fixation resulting from lichen destruction. The potential importance of blue-green-containing lichens on hot desert sites is illustrated by the fact that their frequency in contiguous $m^2$ quadrats along the bajada transects ranged from 4 to 17% whereas their cover only ranged from 0.003 to 0.04%.

Each of the hot desert validation sites has a distinctive lichen community. This is supported by the fact that of the 61 species found by combining all the sites, 42 species were found at only one site; 13, at two sites; and only 6 at all three sites (Table 2). The differences should not necessarily be interpreted as implying vast differences among the lichen floras of the Mohave, Sonoran and Chihuahuan deserts. A few of the species do have restricted ranges which are found within one of the three deserts. However, the primary factors which account for differences among the three validation sites are most likely substrate, elevation and possibly precipitation. The Rock Valley (Mohave), Silverbell

Table 3. Moss cover data ($m^2/ha$) from bajada transects from the three validation sites

| Species | Rock Valley | Silverbell | Jornada |
|---|---|---|---|
| *Bryum argenteum* Hedw. | -- | 0.1207 | -- |
| *Bryum caespiticium* Hedw. | -- | 0.1153 | -- |
| *Bryum* sp. | -- | 0.0135 | -- |
| *Crossidium aberrans* Holz. & Bartr. | -- | 0.1217 | -- |
| *Crossidium erosum* Holz. & Bartr. | -- | 0.0165 | -- |
| *Desmatodon plinthobius* Sull. et Lesq. *ex* Sull. | -- | 0.0010 | -- |
| *Funaria muehlenbergii* Hedw. f. *ex* Turn. | -- | 0.2215 | -- |
| *Grimmia* sp. | -- | 0.5600 | -- |
| *Husnotiella Torquescens* (Card.) Bartr. | -- | 0.1257 | -- |
| *Pottia arizonica* Wareh. | -- | 0.0405 | -- |
| *Pterigoneurum ovatum* (Hedw.) Dix | -- | 0.2480 | -- |
| *Tortula aurea* Bartr. | -- | 0.0005 | -- |
| *Tortula intermedia* (Brid.) Berk | -- | 0.3935 | -- |
| *Weissia controversa* Hedw. | -- | 0.0010 | -- |
| Totals | 0.0000 | 1.9794 | 0.0000 |
| # species | 0 | 14 | 0 |

Table 4. Moss cover data ($m^2/ha$) from belt transects placed on north and south slopes at the three validation sites

| Species | Rock Valley | | Silverbell | | Jornada | |
|---|---|---|---|---|---|---|
| | North | South | North | South | North | South |
| *Bryum argenteum* Hedw. | -- | -- | 0.908 | -- | -- | -- |
| *Bryum caespiticium* Hedw. | -- | -- | 1.712 | -- | -- | -- |
| *Bryum* sp. | -- | -- | 0.187 | -- | -- | -- |
| *Coscinodon wrightii* Sull. | -- | -- | 0.100 | -- | -- | -- |
| *Crossidium aberrans* Holz. & Bartr. | 0.050 | -- | 1.283 | -- | -- | -- |
| *Desmatodon plinthobius* Sull. et Lesq. *ex* Sull. | -- | -- | 0.008 | -- | -- | -- |
| *Funaria muehlenbergii* Hedw. f. *ex* Turn. | -- | -- | 0.279 | -- | -- | -- |
| *Grimmia laevigata* (Brid.) Brid. | -- | -- | -- | -- | 2.508 | 0.383 |
| *Grimmia* sp. | 0.067 | -- | -- | -- | -- | -- |
| *Husnotiella torquescens* (Card.) Bartr. | -- | -- | 1.679 | -- | -- | -- |
| *Tortula aurea* Bartr. | -- | -- | 1.079 | -- | -- | -- |
| *Tortula bistratosa* Flow. | 5.483 | -- | -- | -- | -- | -- |
| *Tortula intermedia* (Brid.) Berk. | -- | -- | 19.767 | -- | -- | -- |
| *Trichostomum* sp. | -- | -- | -- | -- | 0.350 | -- |
| Totals | 5.600 | 0.000 | 27.002 | 0.000 | 2.858 | 0.383 |
| # species | 3 | 0 | 10 | 0 | 2 | 1 |

(Sonoran) and Jornada (Chihuahuan) sites have respectively limestone, igneous and granitic substrates. They are respectively at 1000 m, 600 m and 1500 m elevation. Rock Valley has 100 mm mean precipitation which usually occurs during winter months; Silverbell, about 200 mm precipitation, during summer and winter; and Jornada, 210 mm precipitation, usually during the summer. The primary difference between Rock Valley and the other validation sites is, in terms of lichen development, the limestone substrate. Arid limestone is a particularly poor lichen substrate. For example, although Dr. Nash has collected extensively in the Southwest, he has never collected any *Parmelia* species on limestone in deserts. Although the lower rainfall at Rock Valley may also be important, the fact that most of the rain occurs during the winter implies that this rain is more effective (per unit rainfall) than summer rain in enhancing lichen growth because lower winter temperatures will lead to a lower evaporation rate. The primary difference between Silverbell and Jornada is probably the cooler temperatures which occur at the higher elevation at Jornada. Many of the lichens collected only at Jornada have also been collected at equivalent elevations (and exposure) in the Sonoran Desert on igneous rocks.

Because there are no data on the importance of mosses at the Curlew Valley site, comparisons between cold and warm desert moss communities are impossible. Among the three hot desert validation sites there are certainly conspicuous differences. Of the 18 species listed in Tables 3 and 4, 17 were found at only one site and one at two sites. The distribution patterns of the species are so poorly understood that we cannot effectively evaluate the validity

Table 5. Estimation of lichen and moss biomass ($g/m^2$) from cover data for the Jornada, Rock Valley and Silverbell sites. Weights are based on gravimetric determinations

| Morphological group | Weight (g)/ $cm^2$ | Standard Deviation of weight | Bajada sites | | | Slopes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Rock Valley | | Silverbell | | Jornada | |
| | | | Rock Valley | Silverbell | Jornada | North | South | North | South | North | South |
| Lichens: | | | | | | | | | | | |
| *Parmelias* (*D. miniatum*, *Collemas*, *Thyrea*) | 0.040 | ± .005 | 0.0006 | 0.0126 | -- | 0.0144 | -- | 5.804 | -- | 23.2733 | 0.4290 |
| *Physcias* (*Heterodermia*, *Xanthoria*) | 0.025 | ± .004 | -- | -- | -- | 0.0002 | -- | -- | -- | 1.4427 | 0.0021 |
| Crustose-placodiform (some *Lecanoras*, *Caloplacas*, *C. submexicana*) | 0.084 | ± .006 | -- | 0.0035 | -- | -- | -- | 1.6255 | 0.0336 | 4.1769 | 1.2467 |
| Crustose-squamulose (*D. lachneum*, *L. decipiens*) | 0.118 | ± .008 | -- | 0.2317 | -- | 0.7789 | 0.3697 | 0.0876 | -- | 0.1180 | 0.0295 |
| Other crustose | 0.072 | ± .010 | 0.0876 | 0.1279 | 0.0229 | 0.4325 | 0.0042 | 6.7854 | 0.1644 | 9.2706 | 3.2292 |
| Total lichen | -- | -- | 0.0882 | 0.3757 | 0.0229 | 1.2260 | 0.3739 | 14.3025 | 0.1980 | 38.2815 | 4.9365 |
| Mosses: | | | | | | | | | | | |
| *B. argenteum* + *C. wrightii* | 0.046 | ± .007 | -- | 0.056 | -- | -- | -- | 0.064 | -- | -- | -- |
| *Tortulas* + *Grimmias* | 0.096 | ± .011 | -- | 0.0378 | -- | 0.5328 | -- | 2.0012 | -- | 0.2408 | 0.0368 |
| Other mosses | 0.031 | ± .005 | -- | 0.0454 | -- | 0.0015 | -- | 0.1977 | -- | 0.0108 | -- |
| Total moss | -- | -- | -- | 0.0888 | -- | 0.5343 | -- | 2.2353 | -- | 0.2516 | 0.0368 |

Table 6. Cover ($m^2/ha$) of lichens containing blue-green algae and the percentage of the lichens which contain blue-green algae

| Location | Bajada | | North slope | | South slope | |
|---|---|---|---|---|---|---|
| | Cover | Percentage | Cover | Percentage | Cover | Percentage |
| Rock Valley | 0.1335 | 10.8% | 0.642 | 4.9% | 0.658 | 20.6% |
| Silverbell | 2.011 | 48.8% | 5.959 | 2.3% | 2.158 | 80.4% |
| Jornada | 0.3105 | 97.5% | 2.083 | 0.3% | 1.016 | 1.4% |

of the implied differences. However, *Pottia arizonica* and *Tortula bistratosa* are species which have restricted distributions in the Sonoran and Mohave areas respectively.

Although different species of lichens and mosses are found at each of the hot desert validation sites, there are consistent patterns between north and south slopes. Without exception there are more species and greater cover and biomass on north slopes than on south slopes. The species probably grow best on the north slope because of the more favorable moisture regime and lower temperatures, both of which occur predominantly in the winter. Lange and his associates in an excellent series of papers (1970a; 1970b; 1971) have demonstrated that desert lichens from Israel are physiologically adapted to cool temperatures when the thallus is moist. On a clear day photosynthesis occurs only in the early morning hours immediately after sunrise. As temperatures increase and thallus water content decreases, photosynthesis and respiration become essentially zero. During the night, lichen thalli can extract moisture from the air even when the atmosphere is not saturated and when no dew has occurred. These observations are consistent with the observed lichen distribution patterns in North America. The north slope is a more favorable habitat because of the cooler surface temperatures during winter. The reduced rates of evaporation on north slopes imply that the length of time during which net photosynthesis can occur is longer on the north slopes. Thus, the probability of cryptogamic survival is probably greater on north slopes.


## ACKNOWLEDGEMENTS

We are deeply indebted to Dr. William A. Weber of the University of Colorado Museum for his invaluable assistance in the moss identifications. In addition, we would like to thank the Rock Valley, Silverbell and Jornada site coordinators and Dr. John Ludwig for assistance in the field.


## LITERATURE CITED


DENISON, W. C. 1973. Life in tall trees. Sci. Amer. 228(6): 74-80.

JACKSON, M. L. 1958. Soil chemical analysis. Prentice Hall, Inc., Englewood cliffs, N. J. 453 pp.

LANGE, O. L., and M. EVANARI. 1971. Experimentell-ökologische Untersuchungen an Flechten der Negev-Wüste IV. Wachstumsmessungen an *Caloplaca aurantia* (Pers.) Hellb. Flora 160:100-104.

LANGE, O. L., E.-D. SCHULTZE, and W. KOCH. 1970a. Experimentell-ökologische Untersuchungen an Flechten der Negev-Wüste. II. $CO_2$-Gaswechsel und Wasserhaushalt von *Ramalina macriformis* (Del) Bory am natürlichen Standort Während der sommerlichen Trockenperiode. Flora 159: 38-62.

LANGE, O. L., E.-D. SCHULTZE, and W. KOCH. 1970b. Experimentell-ökologische Untersuchungen an Flechten der Negev-Wüste. III. $CO_2$-Gaswechsel und Wasserhaushalt von Krusten - und Blattflechten am natürlichen Standort während der sommer lichen Trockenperiode. Flora 159: 525-538.

OOSTING, H. J. 1956. The study of plant communities. W. H. Freeman and Co., San Francisco. 440 pp.

PEARSON, L. 1972. Survey of lichens and contribution of lichens to total productivity at the Curlew Valley Validation Sites, IBP, *in* Balph, D. F. (Coordinator). Curlew Valley Validation Site report. US/IBP Desert Biome Research Memo., RM 72-1. 188 pp.