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LICHENS AND AIR QUALITY IN BIG BEND NATIONAL PARK, TEXAS

Final Report

Contract PX 7029-0-0338

Pseudevernia intensa and *Usnea cirrosa*

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FINAL REPORT

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By

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INTRODUCTION

In 1966, 1969 and 1970 lichen collections were made at 38 localities in Big Bend National Park. At most of these localities all species of lichens found were collected and the vouchers are deposited in the University of Minnesota Herbarium. Label data for all collections are stored in a computer data base at the University of Minnesota and are retrievable by simple commands (Wetmore, 1979). A paper on the macrolichens (foliose and fruticose lichens) from these localities has been published (Wetmore, 1976) and most of the crustose lichens have been identified. Even though the general climate in the park is quite dry, several species of fruticose lichens were found at numerous localities in the mountains. At the time these collections were made color photographs were taken from various scenic vistas throughout the park.

Recently observations by various people have reported that visibility in the park has been degraded due to increased haze conditions. There has also been concern that the haze might be associated with air pollutants that might damage the vegetation of the park. Possible sources of the air pollution are Carlsbad, New Mexico and El Paso, Texas. These cities are about 250 miles northwest of the park and wind patterns are such that air masses from these cities could blow into the park.

Lichens are slow growing and remain alive for many years and therefore can be used as long term summarizers of air quality. They are also known to be very sensitive to many atmospheric pollutants. Some lichens are damaged or killed by low levels of sulfur dioxide (0.5 ppm, Nash, 1973), nitrogen oxides (2-4 ppm, Nash, 1976) and other strongly oxidizing compounds (Nash, 1972, 1975; Ferry et al., 1973). The algae of the thallus seem to be the first to show damage (Rao and Le Blanc, 1966; Pearson, 1973) and the first indication of damage is the discoloring and death of the algae which leads quickly to the death of the lichen thallus. In general, the fruticose lichens are most sensitive to air pollution, foliose lichens are intermediate in sensitivity and the crustose lichens least sensitive (De Slover and Le Blanc, 1968). There are exceptions and the nature of the substrate is also important since substrates with high pH seem to buffer the fallout and permit the persistence of more sensitive lichens.

Lichens can remain dormant for months and revive with the first moisture. Lichens are more sensitive to pollutants when they are wet and physiologically active (Rao and Le Blanc, 1966; Nash, 1973; Marsh and Nash, 1979; Richardson and Puckett, 1973) and are least sensitive when dry. Marsh and Nash (1979) reported that lichens of arid regions are relatively insensitive to air pollution because they are dry much of the time. However, their conclusions may not be justified since the sulfur dioxide levels where they studied were very low (.006 to .009 ppm) and they were observing foliose and crustose lichens which are more tolerant. Even in very arid areas, the lichen can take up enough water from an unsaturated atmosphere to begin growing so that the mere absence of rain is no indication of real continuous drought for the lichens and during the moist periods arid land species are just as sensitive as lichens in wetter climates.

Of the lichens known from Big Bend National Park those which probably would be most sensitive are the following:

Heterodermia applachensis (Kurok.) W. Culb.
Heterdermia diademata (Tayl.) Kurok.
Heterodermia rugulosa Kurok.
Parmelia crinita Ach.
Parmelia reticulata Tayl.
Parmelia subtinctoria Zahlbr.
Pseudevernia intensa (Nyl.) Hale & W. Culb.
Ramalina complanta (Se.) Ach.
Ramalina sinensis Jatta
Teloschistes chrysophthalmus (L.) Th. Fr.
Teloschistes flavicans (Sw.) Norm.
Usnea arizonica Mot.
Usnea cirrosa Mot.
Usnea hirta (L.) Wigg.
Usnea sublfloridana Stirt.

In studying air quality with lichens the best method is to compare the lichen flora of an area prior to the onset of the pollution and again afterward to detect the species which have been eliminated. This is seldom possible because of the lack of baseline information on lichens. The next best method is to compare the lichen flora within the polluted area with the lichen flora in a nearby area free from air pollution. In Big Bend it is possible to use the first method of study since complete collections were made at relocatable localities ten or more years ago.

METHODS

Prior to field work computer lists were prepared which listed the species previously collected at each locality. Localities from which fruticose lichens were known were specially noted for repeat visits in 1980.

Three weeks in April, 1980 were spent in Big Bend visiting as many of the old localities as possible. At each locality the lichen names were checked off on the computer lists as they were found. Species that required laboratory identification and species that appeared to be additions to theknown flora were collected. Most of the localities revisited in 1980 were in the mountain areas (Appendix A) because the macrolichens are more abundant there. Some new localities in the mountains were studied to add to the baseline for future studies and some new desert localities were studied.

Most of the scenic vista points were revisited and new black and white and color photographs were taken (Appendix B). The color photographs were taken with the same camera and lens as the originals in 1966, 1969 and 1970.

At five localities in the Chisos Mountains tree branches were photographed for long term monitoring. Branches were selected which had a good growth of fruticose lichens and a numbered aluminum tag was wired to the base of the branch. In most cases the branches were dead lower limbs, since these are the main ones on which the fruticose lichens were found. These photographs are meant to show the extent of coverage and species composition on the substrates rather than the size of individual thalli. The localities and directions to these tagged limbs are included in Appendix C.

All lichens collected in 1980 are deposited in the University of Minnesota herbarium and are being added to the computer data base which includes the records from the earlier collections. Nomenclature follows Wetmore (1976).

RESULTS

In general, at all of the localities revisited in 1980 all of the macrolichens were still present in good health and in similar abundance to those found in the earlier studies. The new collections were compared with the earlier collections from the herbarium and no difference was seen in apparent health of the thalli or frequency of thalli in fertile condition (with apothecia). Most of the crustose species were also found but some of the small, rare species were not found due to their scarcity. The most important localities are Casa Grande, with numerous *Ramalina sinensis*, and the pine forests around Emory Peak and on the East Rim most of the branches are covered with a luxurious growth of *Usnea* and *Pseudevernia*. Some of the rare foliose and fruticose lichens (*Sticta weigelli*, *Parmelia crinita*, *Teloschistes flavicans*) were also still growing in the park at other localities. In every locality visited there was no indication of widespread death of lichens (which would be indicated by discoloring of the lichens).

Photographs taken at the scenic vistas and general observations show similar visibilites when compared with those taken during the earlier visits. The average haze density seems to be about the same or only slightly worse in 1980 as in the earlier photos although there may be more frequent very hazy days now than then.

Most of the original localities studied were away from trails and roads and there has been no reduction of the lichen flora at these localities due to increased or continued human activity with the park. One exception is along the Lost Mine Trail where an original collection locality was on a small spur ridge running north from the trail near the first saddle and scenic vista. On this ridge some of the species found earlier are now absent from the ridgetop due to increased visitor traffic and trampling of the lichens. Teloschistes flavicans still occurs on the steep sides of the ridge but it has been eliminated from the top of the ridge. An area of future potential damage is on the saddle near the top of the unofficial trail to Casa Grande where increased use of this trail probably will result in damage to the vascular plants and to the lichens growing on them. The rare Ramalina sinensis occurs in the park only on the oaks at this locality and if visitor traffic leads to death of the oaks this lichen species will be eliminated from the park.

DISCUSSION

There seems to have been no decrease in the macrolichens in Big Bend over the past 10 years since all species recorded then were relocated at the same localities in 1980. The fruticose lichens (Usnea, Pseudevernia, Teloschistes) are especially sensitive to air pollution and most likely would have shown some effects from increased air pollution. The results obtained from this survey in 1980 could also be explained by some of the following hypothesis. 1. Any increase in air pollution is still too low in concentration to be detected by the lichens in the park; 2. the decreased visibility in the park is due to airborne materials (either gaseous or particulate) that are not damaging to lichens; 3. the pollution arrives in the park at times when the lichens are dormant and more tolerant of pollution; 4. there has been no increase in air pollution.

There are no local potential sources of air pollution and the most likely sources are 250 miles to the northwest at El Paso, Texas and Carlsbad, New Mexico. For these distant sources to have a significant direct effect (gaseous sulfur dioxide or nitrogen oxides) the levels of these gases near the sources would have to be at intolerably high levels, or there would have to be a direct "pipeline" flow of polluted air to Big Bend. The normal dispersion of air pollution over this distance would greatly reduce the concentration by the time the air mass reaches the park. If the supposed air quality degradation in the park is from these distant sources the levels may be too low to be toxic but still high enough to cause a decrease in visibility by some other indirect means. This may not be the case with acid rain which could easily travel this distance in air masses but there is no information available on the effects of acid rain on the survival of lichens. The effects of acid rain on lichens may be as damaging to lichens as gaseous pollutants and would probably also cause a loss of lichen species. These explanations, although possible, do not seem to be the most likely ones.

The second hypothesis is that materials in the air are not damaging to the lichens but can cause other forms of air quality loss. Many particulates in the air are not directly damaging to lichens but can cause death if they form a heavy coating over the thallus. Erbisch (personal communication) has shown lichen tolerance to iron dust from an iron mine operation in Michigan where his studies were carried out very near the mines. It is not likely that particulates from manufacturing at sources 250 miles away would arrive at Big Bend in very great quantities. However, dust blown from the dry lands surrounding Big Bend could be a source of airborne particulates and these could cause a decrease in visibility but little damage to the lichens. Significant amounts of dust in the air usually results in a dust layer over tree bark and lichens, as is obvious along gravel roads. Such dust covered lichens were not found in the forested areas of Big Bend where these studies were done. It does not appear that this is a likely explanation of the results.

Non particulate and non toxic air contaminants could cause a decrease in air quality. Some desert plants produce volatile terpenes and other compounds which cause desert haze (Went, 1960; Rasmussen and Went, 1965). These compounds have not been shown to be toxic to lichens and are a normal part of the desert environment. If these volatile compounds have greatly increased in recent years they could cause an increase in haze conditions without damaging the lichens.

The third possibility is that the suspected air pollutants arrive in the park when the lichens are dormant and therefore do not damage the lichens. Lichens are much more sensitive to air pollution when the thallus is wet and physiologically active (Rao and Le Blanc, 1966; Nash, 1973; Marsh and Nash, 1979). Most tables of lichen sensitivity are based on wet thalli being fumigated with experimental doses of gases (De Sloover and Le Blanc, 1968; Richardson and Puckett, 1973) but in the dry condition the pollutants do not react to damage the algae of the thallus. In desert areas this might reduce the utility of lichens as air quality monitors as proposed by Marsh and Nash (1979). In their study of the lichens of the Four Corners area (Marsh and Nash, 1979) they conclude that the lichen flora of arid regions are relatively insensitive to air pollution but this conclusion is not warranted. They have shown that the species growing there are just as sensitive to experimental sulfur dioxide fumigation as species of more moist regions when wet but the lichens are quite insensitive when dry. The mean annual level of sulfur dioxide in their area was very low (.006 to .009 ppm) which is below damaging levels for most lichens, however, there may be times when peak SO_2 levels are above damaging levels. Their conclusions are also based on observations of foliose and crustose species which are more tolerant.

In Big Bend there are numerous fruticose lichens to use as indicators. These fruticose species must have frequent moist conditions (from rain, fog or dew) to grow and during these moist times these lichens will be sensitive to pollution. The occurrence of these fruticose lichens in Big Bend indicates that there are frequent moist periods in the localities where they grow. With more frequent higher moisture conditions in the mountains of Big Bend this explanation (drought pollution tolerance) would not seem to be the best explanation for the persistence of the fruticose lichens in Big Bend.

The fourth hypothesis is that there has been no dramatic decrease in air quality in Big Bend. One of the main reasons for suspecting a decrease in air quality is the report of decreased visibility due to haze. In comparing color slides taken in 1966, 1969 and 1970 with those taken in 1980 and with general observations in 1980 there seems to be no great change in visibility (Appendix B). The old photos were taken on random days (whenever I happened to be on the ridges or peaks) and were not selected for clear days. The same randomness is true of the photos in 1980 since trips to collection localities were planned the evening before. This is not the case with the photos in the slide collection at the park, since probably only the best, most haze-free photos have been retained. General observations of hazy days in 1980 may indicate somewhat more frequent very hazy days but in general there seems to be no significant increase in haze. Given the great sensitivity of lichens to air pollution, it is not likely that much change in air quality could be tolerated by the lichens. This fourth explanation - that there has been no significant increase in air pollution and haze conditions are not much worse - seems to be the most likely explanation of conditions in Big Bend.

CONCLUSIONS

Fruticose lichens are good indicators of air quality, wherever they occur. Since these most sensitive fruticose lichens have shown no damage and are present at all localities where they were found 10 years ago, it seems safe to say that air quality has not decreased during the decade. Color photos taken then show similar or only slightly lighter haze conditions than in 1980. There is, however, the possibility that a slight increase in haze due to non toxic airborne volitiles from desert plants has occurred. Some of the reports of increased haze are probably due to faulty memories of the some of the observers.

This study has only been possible in this form because of prior baseline work done in the park. Few areas in the United States have such thorough data for the lichens. More of these baseline studies are necessary for as many areas as possible and the national parks are well suited to long term studies because of the isolation and size and lack of local disturbance of most of them. These projects should be encouraged whenever possible so that future changes can be documented.

RECOMMENDATIONS

In addition to the main purpose of this report which was to evaluate the lichen flora for any changes that might have occurred due to air pollution, the following recommendations are presented based on other observations during my visit to the park in 1980.

1. Development that would increase visitor activity in areas of especially rich lichens should be avoided. Some such areas are: the base of Emory peak on the north side at the base of the steep rock cliffs; in Boot Canyon below the patrol cabin; the saddle near the top of the southeast side of Casa Grande.
2. Limit the use or move the trail up the southeast side of Casa Grande to protect the vegetation on the saddle and to reduce the erosion below.
3. Periodically reevaluate the lichens of Big Bend using the established localities mentioned in this report and the photographic points of lichen branches and vistas.

SUMMARY

This study was undertaken because of reports of decreased visibility due to haze and increased air pollution in the park. Numerous localities where lichens had been collected 10 years ago were revisited in 1980 to look for any changes in the lichen flora. Photographs were taken from scenic vistas where photographs had been taken earlier. Permanent photographic points of lichens were established for long term monitoring. It is argued that fruticose lichens are just as useful for monitoring air quality in arid areas as in wetter areas. There has been no loss of lichen species at any locality over the past 10 years and haze conditions have not changed much. It is concluded that no significant increase in air pollution has occurred within the park over the past 10 years. Recommendations are presented for protection of critical lichen areas in the park and for the periodic restudy of the lichens for air quality monitoring.

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Appendix A

Collection localities visited in 1980 where collections were made in 1969 and 1970. The old locality numbers refer to localities listed in Wetmore (1976).

Lost Mine Trail at saddle (overlook), 10 April 1980. Old locality #2.

Boulder Meadow along trail to East Rim, 11 April 1980. Old locality #23.

Grapevine Hills, 13 April 1980. Near old locality #12 but higher in the hills.

Southwest slope of Emory Peak near stand of *Populus tremuloides*, 14 April 1980. Old locality #29.

Above Croton Spring, 15 April 1980. Old locality #30.

Burro Mesa Pouroff, 15 April 1980. Old locality #17.

Paint Gap Hills, 16 April 1980. Old locality #28.

Emory Peak at top, 18 April 1980. Old locality #11.

Below top of Casa Grande, at top of steep part of trail, 20 April 1980. Old locality #32.

East Rim, 23 April 1980. Old locality #19.

Boot Canyon near cabin, 23 April 1980. Near old locality #10 but east of cabin.

Hot Springs, 27 April 1980. Near old locality #6 but west of buildings.

Appendix B

Color photographs from scenic viewpoints taken over a ten year period.

1. Looking north at the junction of the main park road and the road to The Basin, May, 1969 and April, 1980. Fig. 1 & 2.
2. Looking north from the top of Emory Peak to The Basin and Casa Grande, May, 1969 and April, 1980. Fig. 3 & 4.
3. Looking toward The Basin and Pulliam Ridge from the top of Emory Peak, May, 1969 and April, 1980. Fig. 5 & 6.
4. Looking west over The Basin toward the Window from the top of Casa Grande, May, 1970 and April, 1980. Fig. 7 & 8.
5. Looking southeast from the East Rim to Chilicotal Mt., May, 1969 and April, 1980. Fig. 9 & 10.
6. Looking toward Casa Grande from the top of Emory Peak, May, 1969 and April, 1980.
7. Looking south from the saddle on the Lost Mine Trail, June, 1966 and April, 1980.
8. Looking out The Window from hill above the lodge near the east trail to Emory Peak, May, 1969 and April, 1980.

Fig. 1. May 1969

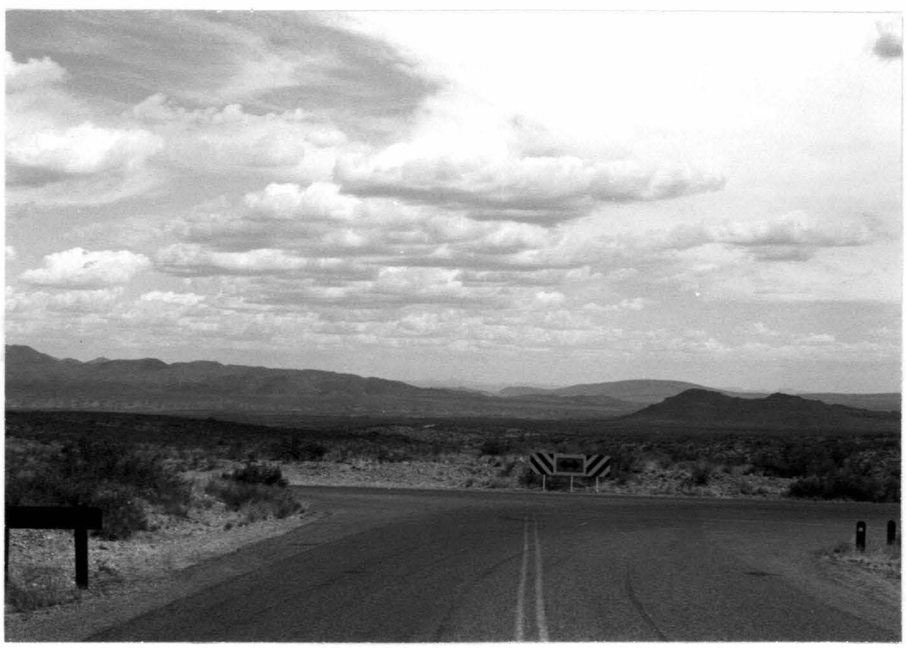

Fig. 2. April 1980

Fig. 3. May 1969

Fig. 4. April 1980

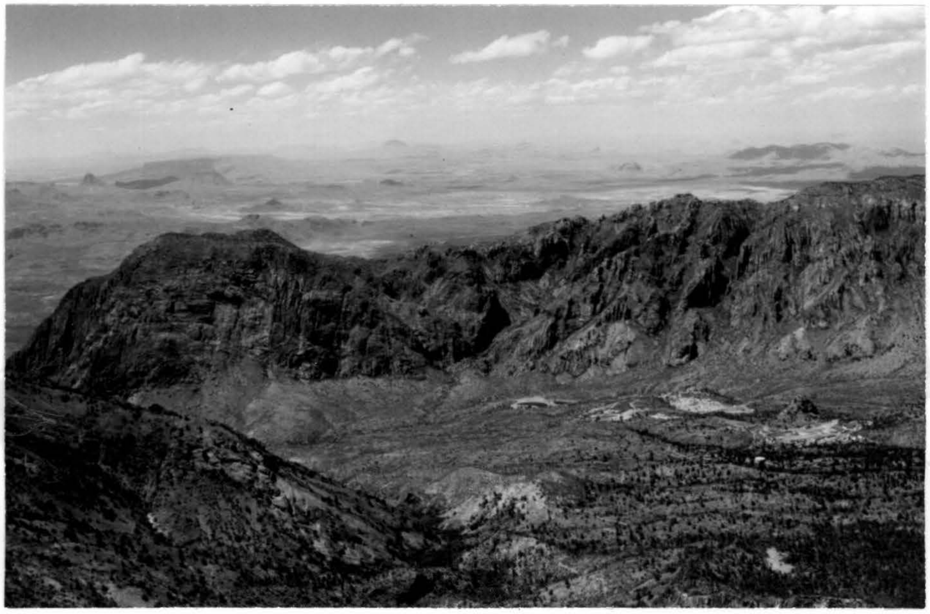

Fig. 5. May 1969

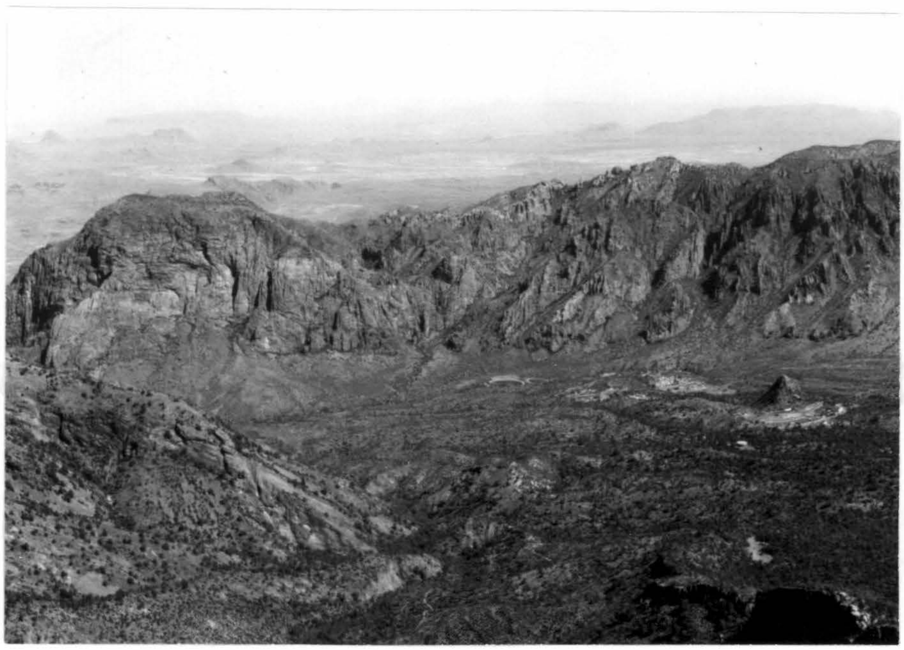

Fig. 6. April 1980

Fig. 7. May 1970

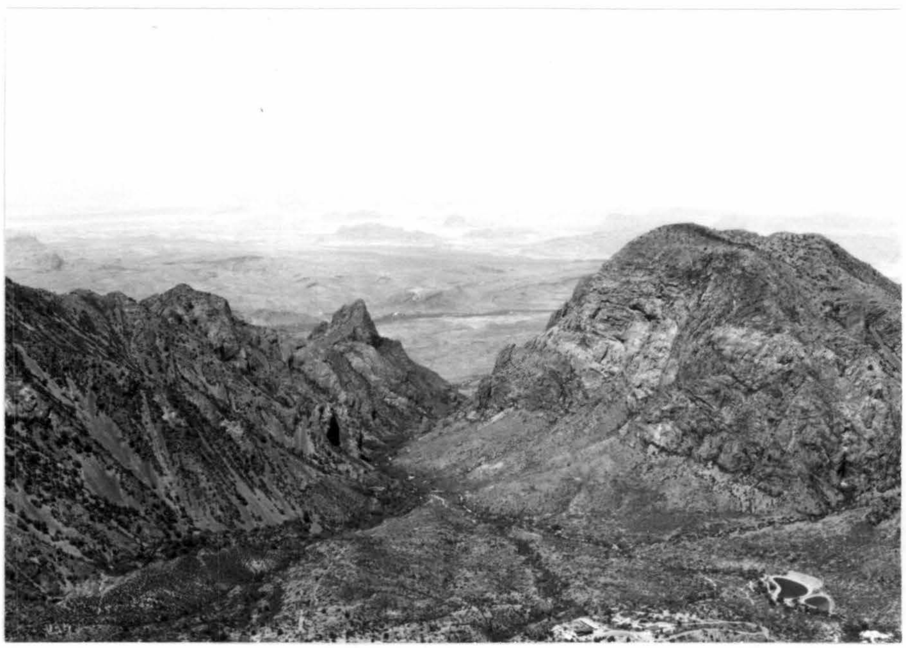

Fig. 8. April 1980

Fig. 9. May 1969

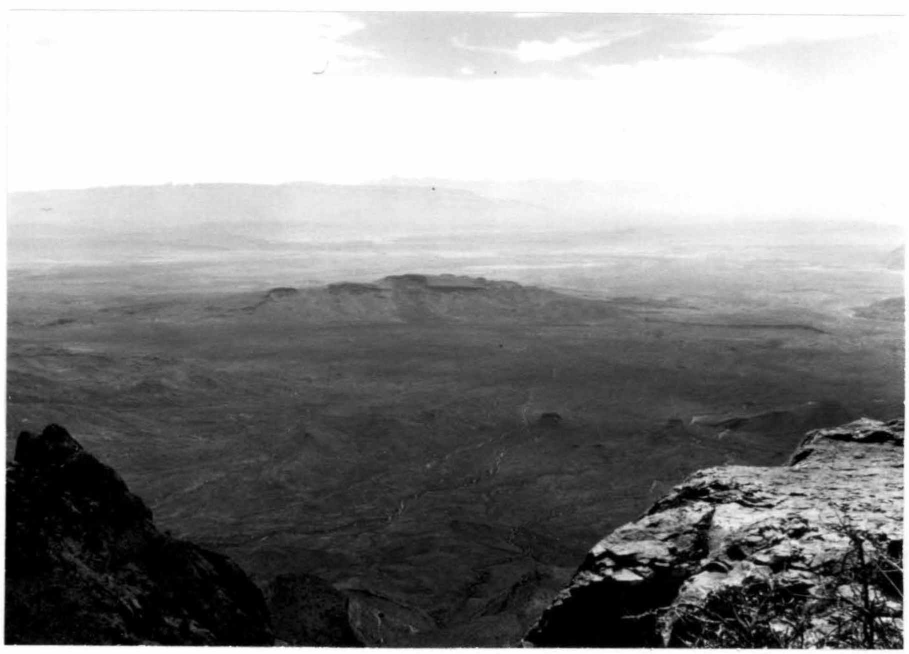

Fig. 10. April 1980

Appendix C

Tagged and Photographed Lichen Branches

Tag #1. Located along the Lost Mine Trail opposite a small spur ridge running north from the main trail, just north of the vista and saddle where an unofficial trail goes to the east side of Casa Grande. The tree is a large pinyon pine and the branch with the lichens is on the northeast side of the tree about 5 feet (1.5 m) above the ground. This branch has abundant *Pseudevernia intensa*. Fig. 11.

Tag #2. This is located on the southeast side of Casa Grande in the saddle where the unofficial trail emerges from between steep rock ledges onto the level area. This tag is on the first big pinyon pine on the west side of the saddle and the branch has abundant *Usnea cirrosa* and *Pseudevernia intensa*. Fig. 12.

Tag #3. Located near Tag #2 in a grove of oaks on the southeast side of Casa Grande on the saddle where the unofficial trail emerges from between steep rock ledges onto the level area. This tag is on the first oak clump to the left of and above a large boulder by the trail. The branch is on the northeast side and has abundant *Ramalina sinensis* and *Parmlia praesignis*. Fig. 13.

Tag #4. The locality is on the East Rim. This tag is on a pinyon pine located 280° and 166 ft. (50.6 m) from the sign marking the East Rim. The branch has abundant *Usnea cirrosa* and *Pseudevernia intensa*. Fig. 14.

Fig. 11. Photographic plot: Tag # 1

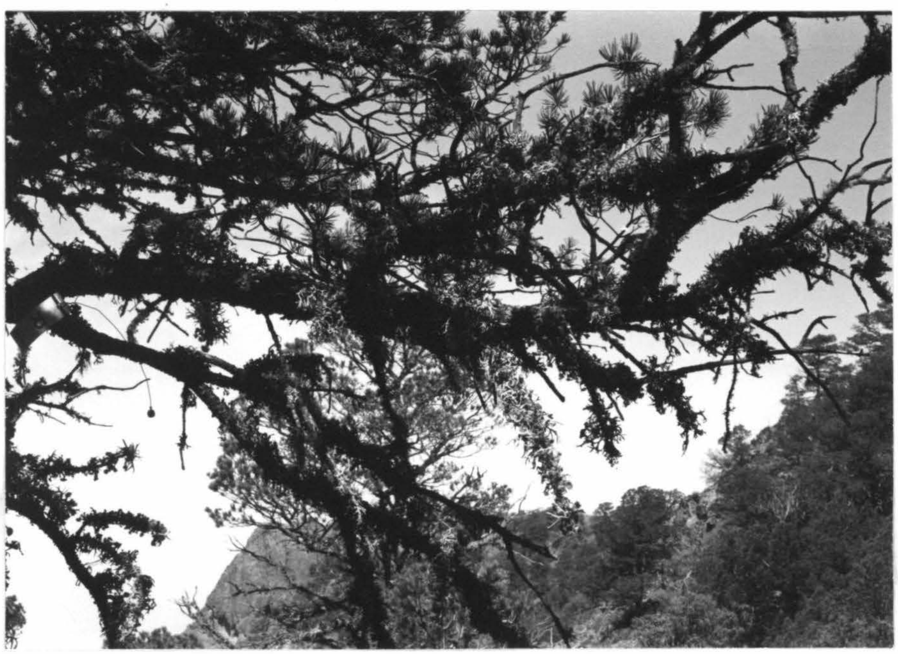

Fig. 12. Photographic plot: Tag # 2

Tag #5. Located on the East Rim near Tag #4 on a gray oak 45 ft. (13.7 m) north along the trail and on the right (east side) at the very edge of the cliff. This branch has abundant growth of Teloschistes chrysophthalmus and Usnea cirrosa. Fig. 15.

Tag #8. Located on the southwest slope of Emory Peak on the south side of the rock talus near the lower clump of Populus tremuloides. The tag is on the largest oak (emory oak) at the edge of the talus and this photograph is of the lower part of the main lower side branch. Species present are Parmelia crinita, Parmelia caperata and Parmelia flaventior. Fig. 16.

Tag #10. Located on the south side of Laguna Meadow near the deer exclosure. The tag is on a branch of a pinyon pine 185° and 26 ft. (7.9 m) from the southwest corner of the deer exclosure. Photographs are of the end of a branch 7 feet (2.1 m) up on the west side of the tree. The branch has abundant Usnea cirrosa and Pseudevernia intensa. Rocks are arranged around the base of the tree. Fig. 17.

Tag #11. Located near tag #10 at the south side of Laguna Meadow near the deer exclosure. The tag is on a pinyon pine 150° and 65 ft. (19.8 m) from the southwest corner of the deer exclosure. Photographs are of a branch 6½ ft. (1.9 m) up on the west side of the tree and have Usnea cirrosa and Pseudevernia intensa. Rocks are arranged around the base of the tree. Fig. 18.

Fig. 13. Photographic plot: Tag # 3

Fig. 14. Photographic plot: Tag # 4

Fig. 15. Photographic plot: Tag # 5

Fig. 16. Photographic plot: Tag # 8

Fig. 17. Photographic plot: Tag # 10

Fig. 18. Photographic plot: Tag # 11