LICHENS AND AIR QUALITY in SEQUOIA NATIONAL PARK

FINAL REPORT

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Letharia vulpina

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LICHENS OF SEQUOIA NATIONAL PARK

PREFACE

Under a grant from the National Park Service (USDI CX 0001-2-0034) a lichen study was to be performed in Sequoia National Park. This study was to survey the lichens of the park, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. This study is to establish baseline data for future restudy and determine the presence of any air quality problems as might be shown by the lichens at the time of the study. All work was done at the University of Minnesota with frequent consultation with Dr. James Bennett, NPS-AIR, Denver and with personnel in the park.

The park personnel have been very helpful during the field work which has contributed significantly to the success of the project. The study was made possible by funds from the National Park Service. Assistance in identification of some of the problem species was provided by Dr. Wm. Weber, Dr. Mason Hale and Dr. Theodore Esslinger. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

Lichens are composite plants composed of two different types of organisms. The lichen plant body (thallus) is made of fungi and algae living together in a symbiotic arrangement in which both partners are benefited and the composite plant body can grow in places where neither component could live alone. The thallus has no protective layer on the outside, such as the epidermis of a leaf, so the air in the thallus has free exchange with the atmosphere. Lichens are slow growing (a few millimeters per year) and remain alive for many years and so must have a habitat that is relatively undisturbed in order to survive. Lichens vary greatly in their ecological requirements but almost all of them can grow in places that only receive periodic moisture. When moisture is lacking they go dormant until the next rain or dew-fall. Some species can grow in habitats with very infrequent occurrences of moisture while others need high humidity and frequent wetting in order to survive. This difference in moisture requirements is very important in the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Some are damaged or killed by levels of sulfur dioxide as low as 13 ug/cubic meter (annual average) or by nitrogen oxides at 3834-7668 ug/cubic meter or by other strongly oxidizing compounds such as ozone. Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300 ug/cubic meter. The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae, which quickly leads to the death of the lichen. Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry. The nature of the substrate is also important in determining the sensitivity to sulfur dioxide since substrates with high pH seem to buffer the fallout and permit the persistence of more sensitive species than one would expect. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the levels in the substrate and the air and, since lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of the thallus of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of the sub-lethal but elevated levels in the air.

Sequoia National Park has over 403,000 acres and is located on the western edge of the Sierra Nevada Mts. with elevations from 2000 to over 14,000 ft. Most of the southwestern part of the park is in the Kaweah River drainage.

The lower elevations of the park have oak woodlands (*Quercus douglasii*, *Quercus wislizenii* and *Aesculus californica*) and chaparral (*Adenostoma fasciculatum*, *Ceanothus cuneatus* and *Arctostaphylos viscida*). At higher elevations this grades into ponderosa pine (*Pinus ponderosa* and *Pinus jeffreyi*) and white fir forest (*Abies concolor*) with areas of sequoia (*Sequoiadendron giganteum*) and red fir (*Abies magnifica*). The highest elevations have lodgepole pine (*Pinus contorta*), subalpine forest and finally alpine vegetation on some of the ridges and peaks (Vankat, 1982). Much of the park has been logged and burned at various times. The climate is generally dry on the west side of the mountains.

Few lichens have ever been collected in the park. Various monographers mention a few lichens but a recent study done for a masters thesis on the macrolichens of Sequoia and Kings Canyon provided the first list of lichens from Sequoia (Smith, 1980). Bonar (1971) described a fungus from the park ascribed to a lichen genus but it is a non-lichenized fungus.

METHODS

Field work was done during the summer of 1984. The month of May was spent collecting in the park and 1235 lichen collections were made at 35 localities. Field work this year was restricted to lower elevations up to about 7500 ft. in the Kaweah River drainage. Time and difficulty of access prevented collecting in the Kern River drainage and at elevations above 8000 ft. A complete list of collection localities is given in

Appendix I and are indicated on Fig. 1. Localities for collecting were selected first to give a general coverage of the park, within the limits mentioned above, second, to sample all vegetational types, third, to be in localities that should be rich in lichens. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens.

Identifications were carried out at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography for identification of the lichen substances where necessary. The original packet of each collection has been deposited in the University of Minnesota Herbarium and a representative set of duplicates will be sent to the park and to the Smithsonian Institution. All specimens deposited at the University of Minnesota are being entered into the computerized data base maintained there. Lists of species found at each locality are available from this data base at any time on request.

LICHEN FLORA

The following list of lichens is based on my collections, historical specimens in the University of Minnesota herbarium and those reported in the literature. This list includes 189 species collected for this study and 8 additional species not found in this study but previously reported. There are an additional 41 unidentified species. The species previously reported but not found in this study are not counted and are enclosed in brackets because some of them are probably based on misidentifications. In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983).: S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50ug per cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug per cubic meter.

Acarospora americana Magn.
Acarospora badiofusca (Nyl.) Th. Fr.
Acarospora chlorophana (Wahlenb. in Ach.) Mass.
Acarospora fuscata (Nyl.) Arn.
Acarospora radicata Magn.
3 additional unidentified species of Acarospora
Anisomeridium juistense (Erichs.) R. Harris
Arthonia intexta Almq.
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
Aspicilia cinerea (L.) Körb.
Aspicilia contorta (Hoffm.) Kremp.
Aspicilia laevata (Ach.) Arn.
3 additional unidentified species of Aspicilia
Bacidia beckhausii Körb.
1 additional unidentified species of Bacidia
Bryoria abbreviata (Müll. Arg.) Brodo & Hawksw. Also reported by Brodo & Hawksworth (1977), Smith (1980)
Bryoria fremontii (Tuck.) Brodo & Hawksw. Also reported by Smith (1980)
I [Bryoria fuscescens (Gyeln.) Brodo & Hawksw. Reported by Smith (1980) =misidentification?]
Buellia griseovirens (Turn. & Borr. ex Sm.) Almb.

Buellia penichra (Tuck.) Hasse
T Buellia punctata (Hoffm.) Mass.
Buellia turgescens Tuck.
2 additional unidentified species of Buellia
Calicium adaequatum Nyl.
Calicium corynellum (Ach.) Ach
Calicium glaucellum Ach.
I Calicium viride Pers.
Caloplaca bolacina (Tuck.) Herre
S-I Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr.
Caloplaca citrina (Hoffm.) Th. Fr.
Caloplaca decipiens (Arn.) Blomb. & Forss.
Caloplaca feracissima Magn.
Caloplaca laeta Magn.
Caloplaca squamosa (B. de Lesd.) Zahlbr.
4 additional unidentified species of Caloplaca
S-I Candelaria concolor (Dicks.) B. Stein.
Candelariella aurella (Hoffm.) Zahlbr.
Candelariella reflexa (Nyl.) Lett.
I Candelariella vitellina(Hoffm.) Müll. Arg.
1 additional unidentified species of Candelariella
S [Cetraria chlorophylla (Willd.) Vain. Reported by Smith (1980)]
Cetraria merrillii DuRietz
Chaenotheca brunneola (Ach.) Müll. Arg.
Chaenotheca carthusiae (Harm.) Lett.
Chaenotheca phaeocephala (Turn.) Th. Fr.
Chaenotheca trichialis (Ach.) Th. Fr.
Chaenotheca xyloxena Nadv.
Cladonia cariosa (Ach.) Spreng.
Cladonia chlorophaea (Flörke ex Somm.) Spreng.
I Cladonia coniocraea (Flörke) Spreng.
S-I Cladonia fimbriata (L.) Fr.
Collema conglomeratum Hoffm.
Collema furfuraceum (Arn.) DuRietz Reported by Smith (1980)
Collema nigrescens (Huds) DC. Also reported by Smith (1980)
Collema polycarpon Hoffm.
Collema undulatum Lauer. ex Flot.
Coniocybe sulphurea (Retz.) Nyl.
Cyphelium inquinans (Sm. in Sowerb. & Sm.) Trev.
Cyphelium pinicola Tibell
Dermatocarpon lachneum (Ach.) A. L. Sm.
Dermatocarpon miniatum (L.) Mann Also reported by Smith (1980)
Dermatocarpon reticulatum Magn.
Dimelaena oreina (Ach.) Norm.
Diploschistes scruposus (Schreb.) Norm.
I Evernia prunastri (L.) Ach.
[Heterodermia leucomelos (L.) Poelt Reported by Smith (1980) =misidentification?]
Huilia crustulata (Ach.) Hert.
Huilia macrocarpa (DC. in Lam. & DC.) Hert.
[Hypogymnia enteromorpha (Ach.) Nyl. Reported by Smith

(1980) =misidentification?]
Hypogymnia imshaugii Krog Also reported by Smith (1980)
Koerberia biformis Mass.
Koerberia sonomensis (Tuck.) Henss.
Lecania brunonis (Tuck.) Herre
I Lecanora carpinea (L.) Vain.
Lecanora cascadensis Magn.
Lecanora cenisia Ach.
I Lecanora chlarotera Nyl.
Lecanora mellea W. Web.
T Lecanora muralis (Schreb.) Rabenh.
Lecanora nigromarginata Magn.
Lecanora piniperda Körb.
Lecanora polytropa (Hoffm.) Rabenh.
I Lecanora saligna (Schrad.) Zahlbr.
6 additional unidentified species of Lecanora
Lecidea aeruginosa Borr. in Hook. & Sowerb.
Lecidea anthracophila Nyl.
Lecidea atrobrunnea (DC. in Lam. & DC.) Schaer.
Lecidea auriculata Th. Fr.
Lecidea berengeriana (Mass.) Th. Fr.
Lecidea fuscoatra Nyl.
Lecidea glaucopholis Nyl. ex Hasse
Lecidea globifera Ach.
Lecidea granulosa (Ehrh.) Ach.
Lecidea mannii Tuck.
Lecidea nipponica Zahlbr.
Lecidea plana (Lahm in Körb.) Nyl.
Lecidea saxosa R. Anders. ined.
I Lecidea scalaris (Ach.) Ach.
Lecidea tessellata Flörke
7 additional unidentified species of Lecidea
Lecidella carpathica Körb.
I Lecidella elaeochroma (Ach.) Choisy
Lecidella euphorea (Flörke) Hert.
Lecidella stigmatea (Ach.) Hert. & Leuck.
Lepidoma demissum (Rutstr.) Choisy
Lepraria finkii (B. de Lesd. in Hue) R. Harris ined.
3 additional unidentified species of Lepraria
Leptochidium albociliatum (Desm.) Choisy Also reported by Smith (1980)
[Leptogium burnetiae Dodge Reported by Smith (1980) =misidentification?]
Leptogium californicum Tuck. Also reported by Smith (1980)
Leptogium corniculatum (Hoffm.) Minks
Leptogium furfuraceum (Harm.) Sierk
Leptogium gelatinosum (With.) Laundon
Leptogium lichenoides (L.) Zahlbr. Also reported by Smith (1980)
[Leptogium saturninum (Dicks.) Nyl. Reported by Smith (1980)]
Leptogium tenuissimum (Dicks.) Körb.
2 additional unidentified species of Leptogium
Letharia columbiana (Nutt.) Thoms. Also reported by Smith

(1980)
Letharia vulpina (L.) Hue Also reported by Smith (1980)
Massalongia carnosa (Dicks.) Körb.
Micarea denigrata (Fr.) Hedl.
Micarea misella (Nyl.) Hedl.
Micarea prasina Fr.
1 additional unidentified species of _Micarea_
[_Mycocalicium sequoiae_ Bonar Not a lichen.
Mycocalicium subtile (Pers.) Szat.
S-I _Normandina pulchella_ (Borr.) Nyl. Also reported by Rundel (1968)
S _Ochrolechia androgyna_ (Hoffm.) Arn.
Pachyospora verrucosa (Ach.) Mass.
Pannaria praetermissa Nyl. in Chyd. & Furuhj.
1 additional unidentified species of _Pannaria_
[_Parmelia conspersa_ (Ehrh. ex Ach.) Ach. Reported by Smith (1980)]
Parmelia cumberlandia (Gyeln.) Hale Also reported by Smith (1980)
Parmelia disjuncta Erichs.
Parmelia elegantula (Zahlbr.) Szat. Also reported by Smith (1980)
I [_Parmelia exasperata_ DeNot. Reported by Smith (1980) =misidentification]
Parmelia glabra (Schaer.) Nyl.
Parmelia mexicana Gyeln.
Parmelia multispora Schneid.
Parmelia novomexicana Gyeln.
Parmelia quercina (Willd.) Vain. Hale Also reported by Smith (1980)
I _Parmelia saxatilis_ (L.) Ach.
Parmelia schmidtii (Hale) ined.
Parmelia sphaerosporella Müll. Arg. Also reported by Smith (1980)
I-T _Parmelia subargentifera_ Nyl.
S _Parmelia subaurifera_ Nyl.
Parmelia subdecipiens Vain.
Parmelia subolivacea Nyl. Also reported by Smith (1980)
Parmelia subramigera Gyeln.
Parmelia substygia Räs.
I-T _Parmelia sulcata_ Tayl. Also reported by Smith (1980)
Parmelia taractica Kremp.
Parmeliella cyanolepra (Tuck.) Herre
I _Parmeliopsis ambigua_ (Wulf.) Nyl.
Peltigera canina (L.) Willd. Also reported by Smith (1980)
Peltigera collina (Ach.) Schrad. Also reported by Smith (1980)
Peltigera membranacea (Ach.) Nyl. Also reported by Thomson (1950)
Peltigera rufescens (Weis) Humb.
Peltigera scabrosa Th. Fr.
Peltula bolanderi (Tuck.) Wetm.
Peltula euploca (Ach.) Ozenda & Clauz.
Phaeophyscia endococcina (Körb.) Moberg

Phaeophyscia nigricans (Flörke) Moberg
Phaeophyscia orbicularis (Neck.) Moberg
I *Physcia adscendens* (Fr.) Oliv. Also reported by Smith (1980)
I *Physcia aipolia* (Ehrh. ex Humb.) Furnrohr Also reported by Smith (1980)
Physcia biziana (Mass.) Zahlbr.
Physcia caesia (Hoffm.) Furnrohr
Physcia dimidiata (Arn.) Nyl.
T *Physcia dubia* (Hoffm.) Lett.
Physcia phaea (Tuck.) Thoms. Also reported by Smith (1980)
I *Physcia stellaris* (L.) Nyl. Also reported by Smith (1980)
I *Physcia tenella* (Scop.) DC. in Lam. & DC. Also reported by Smith (1980)
I *Physconia detersa* (Nyl.) Poelt Also reported by Smith (1980)
I *Physconia distorta* (With.) Laundon
Physconia enteroxantha (Nyl.) Poelt
Placynthiella icmalea (Ach.) Coppins & P. James
Placynthium nigrum (Huds.) S. Gray
I *Platismatia glauca* (L.) W. Culb. & C. Culb. Also reported by Smith (1980)
Pseudephebe pubescens (L.) Choisy
S *Ramalina farinacea* (L.) Ach. Also reported by Smith (1980)
1 additional unidentified species of *Ramalina*
Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr.
Rhizocarpon bolanderi (Tuck.) Herre
Rhizocarpon disporum (Naeg. ex Hepp) Müll. Arg.
Rhizocarpon geographicum (L.) DC
Rhizocarpon grande (Flörke ex Flot.) Arn.
Rhizocarpon macrosporum Räs.
2 additional unidentified species of *Rhizocarpon*
Rhizoplaca melanophthalma (DC. in Lam. & DC.) Leuck. & Poelt
Rinodina archaea (Ach.) Arn.
Rinodina confragosa (Ach.) Körb.
I *Rinodina exigua* (Ach.) S. Gray
Rinodina tephraspis (Tuck.) Herre
3 additional unidentified species of *Rinodina*
Sarcogyne clavus (DC. in Lam. & DC.) Kremp.
Sarcogyne simplex (Dav.) Nyl.
Staurothele fuscocuprea (Nyl.) Zsch.
Staurothele hazslinskyi (Körb.) Steiner in Penther & Zederb.
Toninia caeruleonigricans (Lightf.) Th. Fr.
Toninia squalida (Ach.) Mass.
Umbilicaria cinereorufescens (Schaer.) Frey
Umbilicaria phaea Tuck. Also reported by Smith (1980)
Umbilicaria polyphylla (L.) Baumg.
Umbilicaria torrefacta (Lightf.) Schrad.
Verrucaria stanfordii Herre
1 additional unidentified species of *Verrucaria*

I *Xanthoria candelaria* (L.) Th. Fr.
Xanthoria elegans (Link) Th. Fr.
S-I *Xanthoria fallax* (Hepp in Arn.) Arn. Also reported by Smith (1980)
I *Xanthoria polycarpa* (Hoffm.) Rieber Also reported by Smith (1980)
Xylographa abietina (Pers.) Zahlbr.
Xylographa opegraphella Will. in Rothr.
Xylographa vitiligo (Ach.) Laund.

DISCUSSION OF FLORA

Because of the dry climate in the park the lichen flora is not particularly rich but there are some rare localities with microhabitats suitable for the lichens requiring more moisture. The lichen flora is probably comparable with other areas with similar climate. Hebert & Meyer (1984) reported on the lichens of the San Joaquin valley in the foothills about 70 miles north of Sequoia and found 75 species. Forty eight of them are also found in Sequoia. Of the 27 species not found in Sequoia, some may be due to differing identifications but most are probably due to the more northern location of the San Juaquin area. During the 1985 field season one of my graduate students will study the lichens of the Kern Valley and when this study is completed another comparison will be made with the lichens of the Kaweah Valley in the present study.

This list of species includes many new records for the park and some rare species also. *Lecidea glaucopholis* has been found only a few times before and is one of the many California endemics along with *Buellia penichra*, *Caloplaca bolacina*, *Lecidea manii*, *Parmelia glabra*, *Parmelia schmidtii*, *Rhizocarpon bolanderi* and *Verrucaria stanfordii*. There are still quite a few unidentified species and some of these may be undescribed. There will be at least one new species of *Lecidea* that I will describe from the park. The most common species are *Letharia vulpina*, *Hypogymnia imshaugii* and *Parmelia glabra*.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the park. At some localities some species of *Parmelia* were in poor health and showed much insect damage but these localities were scattered and are not correlated with elevation or distance up the watershed so probably are due to other causes. These observations indicate that there is no air quality degradation in the park due to sulfur dioxide that causes observable damage to the lichen flora.

Since lichens are not known to be sensitive to acid precipitation, no conclusions can be drawn about this environmental contaminant. However, preliminary reports indicate that some species of *Umbilicaria* do show damage from acid precipitation by dying at the margins. No specimens of these lichens were seen in the park with dead margins that might be due to acid rain.

Sigal & Nash (1983) reported lichen damage in southern California near Los Angeles and attributed the damage to ozone and PAN based on laboratory experiments, field observations and field transplants. They showed distorted growth and stunted thalli in areas of high oxidant levels. Ross & Nash (1983) reported reduction of photosynthesis in *Parmelia* *caperata* when fumigated with 200 ug/cubic meter of ozone. Wallner & Fong (1982) reported widespread ozone damage to conifers in Sequoia National Park. When locating collection sites for this lichen study some localities were selected near the sites where Wallner & Fong found conifer damage due to ozone. I made note of the needle damage at many of the lichen collection sites and noticed similar damage. The lichens in the localities with severe conifer needle damage showed no consistent damage symptoms when compared with lichens at sites with little ozone damage. At some localities I found some distorted *Hypogymnia imshaugii* but there were healthy thalli of this species on the same branches. Unless there is genetic variability which produces some resistant thalli and some sensitive ones, it does not appear that the lichens in Sequoia show damage to ozone. Perhaps the effects described by Sigal and Nash were due more to PAN or a synergistic effect of PAN and ozone which is not present in Sequoia.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive species within the park to look for voids in the distributions that might be caused by air pollution. Showman (1975) has described and used this technique in assessing sulfur dioxide levels around a power plant in Ohio. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors.

There are only a few lichens in the park with known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983) and most of these are not very common. Species in the most sensitive category are usually absent when sulfur dioxide levels are above 50ug per cubic meter average annual concentrations. The species that occur in the park in this category are as follows. The S-I category is between Sensitive and Intermediate.

S-I *Caloplaca cerina* (Ehrh. ex Hedw.) Th. Fr.
S-I *Candelaria concolor* (Dicks.) B. Stein.
S-I *Cladonia fimbriata* (L.) Fr.
S-I *Normandina pulchella* (Borr.) Nyl.
S *Ochrolechia androgyna* (Hoffm.) Arn.
S *Parmelia subaurifera* Nyl.
S *Ramalina farinacea* (L.) Ach.
S-I *Xanthoria fallax* (Hepp) Arn.

The distributions of these species are mapped (Fig. 2-9). Although these species are not found at all localities and many are quite rare, there is no indication that the voids in the distributions are due to poor air quality. Some of the localities where collections were made do not have suitable habitats for some of these species.

CHEMICAL ANALYSIS

An important method of assessing the effects of air quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash & Sommerfeld, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

Two species of lichens were collected for elemental analysis at several localities in the park. In some cases both species were not present in quantities needed for the analysis.

METHODS

Lichen samples of two species were collected in plastic bags at various localities in different parts of the park for laboratory analysis. Species collected and the substrates were Hypogymnia imshaugii (trees) and Letharia vulpina (trees). These species were selected because they are the only ones present in abundance and relatively easy to clean.

Nine localities were selected to represent the geographical extremes of the park and are indicated on the map of collection localities. These localities are: Colony Mill, Halstead Meadow, Little Baldy Pass, Dorst Creek, Little Baldy ridge, Milk Ranch Peak, Oreole Lake, Atwell Mills and Eagle View, east of Giant Forest. Ten to 20 grams of each species were collected at each locality.

Lichens were air dried and cleaned of all bark under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for analysis. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and boron were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Centigrade for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. All reported values are above the lower detection limits of the instruments.

All of the levels found in the Sequoia lichens are within typical limits for similar lichens although there are no literature reports on analyses of either of these species. From these tables it can be seen that there is no consistent correlation between element levels and location in the park. Although one species may have somewhat higher levels of an element at one locality, the other species may have higher levels at another locality so there is no overall correlation between high element levels and any one locality. The sulfur levels in lichens tested range from 620 to 2030 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980). Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different

Table 1. Analysis of Sequoia lichens
Values in ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
L. vulpina	1166	3812	1510	669	490	379	59.1	53.3	11.5	2.5	4.8	4.7	1.3	0.9	0.2	650	Colony Mill
L. vulpina	1507	3910	1277	570	311	237	44.5	55.9	8.4	2.2	4.1	6.0	1.2	0.8	0.1	680	Colony Mill
L. vulpina	1419	4161	1511	624	474	359	45.1	59.8	9.1	2.3	5.5	5.8	1.4	0.9	0.3	700	Colony Mill
L. vulpina	1713	4076	1893	808	376	263	46.9	125.6	24.5	2.3	4.8	3.1	1.1	0.8	0.1	890	Halstead Mdw
L. vulpina	1764	3896	1842	775	308	211	40.6	125.5	22.2	2.1	4.1	3.1	0.6	0.7	0.2	790	Halstead Mdw
L. vulpina	1792	4060	1893	813	297	204	44.9	131.8	22.9	2.1	4.6	4.1	0.7	0.6	0.2	1690	Halstead Mdw
L. vulpina	590	2867	3138	689	464	344	56.7	78.1	26.0	3.0	5.5	24.1	1.3	0.8	0.3	930	L Baldy Pass
L. vulpina	554	2826	2289	640	531	408	60.4	65.1	24.0	3.2	5.9	19.8	1.5	0.9	0.2	1090	L Baldy Pass
L. vulpina	558	2851	2424	643	419	316	59.3	70.1	23.5	3.0	3.7	20.5	1.3	0.8	0.1	1070	L Baldy Pass
L. vulpina	343	2089	2943	517	282	187	40.6	43.7	25.3	2.1	3.8	11.1	0.9	0.6	0.2	700	Dorst Creek
L. vulpina	435	2469	2018	557	315	217	39.3	45.2	22.7	2.2	4.8	11.1	0.9	0.7	0.1	660	Dorst Creek
L. vulpina	470	2594	1926	586	261	178	31.7	48.4	21.9	2.0	3.0	10.2	0.8	0.5	0.2	740	Dorst Creek
L. vulpina	576	2589	1590	519	405	301	71.6	49.2	17.9	2.8	4.9	11.0	1.4	0.8	0.2	1005	L Baldy Rdg
L. vulpina	526	2462	1496	500	400	305	81.6	48.8	16.4	2.9	5.2	10.2	1.6	0.8	0.2	1000	L Baldy Rdg
L. vulpina	542	2270	1315	469	457	359	90.8	43.2	16.3	2.8	5.4	9.8	1.4	0.8	0.1	970	L Baldy Rdg
L. vulpina	813	3514	1291	469	309	237	51.6	26.8	16.0	2.7	4.8	9.1	1.1	0.6	0.3	900	Milk R Peak
L. vulpina	680	3225	1316	456	378	288	53.1	28.5	17.4	2.9	4.8	11.6	1.4	0.7	0.1	920	Milk R Peak
L. vulpina	715	3452	1333	454	403	307	58.1	27.8	16.5	2.9	6.1	11.4	1.2	0.7	0.3	880	Milk R Peak
L. vulpina	1160	3772	2555	907	197	142	41.9	231.4	22.3	2.0	4.9	4.7	0.8	0.6	0.1	760	Oreole Lake
L. vulpina	1095	3850	2554	947	265	187	46.6	253.5	19.8	1.8	5.4	5.0	0.8	0.5	0.2	620	Oreole Lake
L. vulpina	1204	3991	2557	1079	258	181	49.5	300.9	20.2	1.9	5.9	5.5	0.7	0.6	0.1	710	Oreole Lake
L. vulpina	659	3582	1904	595	333	232	45.0	53.7	15.8	2.5	5.3	6.7	1.1	0.5	0.2	990	Atwell Mill
L. vulpina	655	3441	1959	627	320	222	47.5	56.4	16.1	2.4	4.2	5.8	0.7	0.4	0.4	900	Atwell Mill
L. vulpina	660	3508	1908	592	371	248	47.9	52.0	17.6	2.3	6.2	6.9	1.2	0.4	0.2	940	Atwell Mill
L. vulpina	1320	3713	2225	635	371	279	52.7	139.4	18.5	2.1	4.5	11.0	1.1	0.6	0.2	960	Eagle View
L. vulpina	1538	3889	2500	682	386	290	58.1	150.1	16.9	2.1	5.2	10.7	1.0	0.5	0.2	905	Eagle View
L. vulpina	1261	3657	2466	670	386	289	49.1	159.6	17.2	2.0	4.8	13.1	1.3	0.6	0.1	840	Eagle View
H. imshaugii	2561	6931	6873	1643	1053	875	80.0	108.9	31.1	5.6	6.3	10.9	3.1	1.5	0.2	1760	Colony Mill
H. imshaugii	2523	6758	8042	1568	953	791	76.4	109.5	28.8	5.2	5.4	11.2	3.0	1.3	0.3	1780	Colony Mill
H. imshaugii	2725	6915	7384	1667	967	812	78.6	111.3	31.5	5.8	5.9	10.9	3.1	1.4	0.2	1770	Colony Mill
H. imshaugii	940	3866	6872	949	1412	1171	70.0	74.0	27.0	5.2	5.9	15.4	2.9	1.7	0.1	1400	L Baldy Pass
H. imshaugii	989	3915	6424	986	1553	1307	72.9	76.1	28.9	5.3	6.4	15.8	2.7	1.8	0.2	1300	L Baldy Pass
H. imshaugii	1031	3887	8099	1007	1604	1357	75.8	80.6	32.1	5.9	7.0	16.6	3.1	1.9	0.2	1470	L Baldy Pass
H. imshaugii	1008	4174	12128	1017	2297	1621	109.5	70.3	30.8	6.2	6.3	18.3	2.7	1.7	0.4	1910	Milk R Peak
H. imshaugii	979	4114	11469	871	1592	1144	101.1	58.7	28.2	5.8	5.9	13.8	2.3	1.4	0.2	2030	Milk R Peak
H. imshaugii	990	4232	9374	942	2013	1456	103.7	65.1	29.3	5.9	5.4	18.2	2.7	1.6	0.3	1860	Milk R Peak
H. imshaugii	2373	5714	14535	1028	1556	1279	84.2	227.0	32.9	5.1	7.4	16.0	2.9	1.9	0.5	1700	Eagle View
H. imshaugii	2426	5707	17051	1066	1595	1302	84.8	252.4	34.0	5.3	6.5	17.4	3.1	2.0	0.4	1730	Eagle View
H. imshaugii	2181	5471	16598	1018	1372	1095	81.9	261.8	31.9	4.9	6.9	17.1	2.7	1.7	0.4	1475	Eagle View

Table 2. Summary of analysis of Sequoia lichens
Values in ppm of thallus

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Letharia vulpina																	
Mean	1364	3961	1433	621	425	325	49.6	56.3	9.7	2.3	4.8	5.5	1.3	0.9	0.2	677	Colony Mill
Std. dev.	177	180	135	49	99	77	8.3	3.2	1.7	0.1	0.7	0.7	0.1	<.1	0.1	25	Colony Mill
Mean	1757	4011	1876	799	327	226	44.1	127.6	23.2	2.2	4.5	3.5	0.8	0.7	0.2	1123	Halstead Mdw
Std. dev.	40	100	29	21	43	32	3.2	3.6	1.2	0.1	0.4	0.6	0.3	0.1	0.1	493	Halstead Mdw
Mean	567	2848	2617	657	472	356	58.8	71.1	24.5	3.1	5.0	21.5	1.4	0.8	0.2	1030	L Baldy Pass
Std. dev.	20	21	456	27	57	47	1.9	6.6	1.3	0.1	1.2	2.3	0.1	0.1	0.1	87	L Baldy Pass
Mean	416	2384	2296	554	286	194	37.2	45.8	23.3	2.1	3.9	10.8	0.8	0.6	0.2	700	Dorst Creek
Std. dev.	66	263	563	35	27	21	4.8	2.4	1.8	0.1	0.9	0.5	<.1	0.1	0.1	40	Dorst Creek
Mean	548	2440	1467	496	421	322	81.3	47.1	16.9	2.8	5.2	10.3	1.5	0.8	0.2	992	L Baldy Rdg
Std. dev.	25	160	140	25	32	32	9.6	3.3	0.9	0.1	0.2	0.6	0.1	<.1	<.1	19	L Baldy Rdg
Mean	736	3397	1313	460	363	277	54.3	27.7	16.7	2.8	5.2	10.7	1.2	0.7	0.2	900	Milk R Peak
Std. dev.	69	152	21	8	48	37	3.4	0.8	0.7	0.1	0.7	1.4	0.2	0.1	0.1	20	Milk R Peak
Mean	1153	3871	2555	978	240	170	46.0	261.9	20.8	1.9	5.4	5.1	0.8	0.6	0.1	697	Oreole Lake
Std. dev.	55	111	1	90	37	24	3.8	35.5	1.4	0.1	0.5	0.4	<.1	0.1	<.1	71	Oreole Lake
Mean	658	3510	1924	605	341	234	46.8	54.0	16.5	2.4	5.2	6.4	1.0	0.4	0.2	943	Atwell Mill
Std. dev.	3	71	31	20	26	13	1.6	2.2	1.0	0.1	1.0	0.6	0.3	<.1	0.1	45	Atwell Mill
Mean	1373	3753	2397	662	381	286	53.3	149.7	17.5	2.1	4.8	11.6	1.1	0.5	0.2	902	Eagle View
Std. dev.	146	121	150	25	8	6	4.5	10.1	0.9	0.1	0.3	1.3	0.1	<.1	0.1	60	Eagle View
Hypogymnia imshaugii																	
Mean	2603	6868	7433	1626	991	826	78.4	109.9	30.4	5.5	5.9	11.0	3.1	1.4	0.2	1770	Colony Mill
Std. dev.	107	96	586	51	54	44	1.8	1.3	1.5	0.3	0.5	0.2	<.1	0.1	<.1	10	Colony Mill
Mean	987	3889	7131	981	1523	1278	72.9	76.9	29.3	5.5	6.4	15.9	2.9	1.8	0.2	1390	L Baldy Pass
Std. dev.	46	25	867	29	99	96	2.9	3.4	2.5	0.3	0.6	0.6	0.2	0.1	0.1	85	L Baldy Pass
Mean	992	4173	10990	943	1967	1407	104.7	64.7	29.4	5.9	5.9	16.7	2.5	1.6	0.3	1933	Milk R Peak
Std. dev.	14	59	1438	73	355	242	4.3	5.8	1.3	0.2	0.4	2.6	0.2	0.2	0.1	87	Milk R Peak
Mean	2327	5631	16061	1037	1508	1225	83.6	247.1	32.9	5.1	6.9	16.8	2.9	1.9	0.4	1635	Eagle View
Std. dev.	129	138	1341	25	119	114	1.5	18.0	1.0	0.2	0.5	0.7	0.2	0.2	<.1	139	Eagle View

species may accumulate different amounts of elements and this is evident when comparing sulfur levels of the two species. Letharia vulpina has lower levels than Hypogymnia imshaugii. Even when taking these differences into account there is no clear trend in accumulated levels of sulfur.

Of the other elements, only lead shows somewhat higher levels at Little Baldy Pass. Even though the lichens were collected a quarter of a mile from the road, there may have been some lead enhancement from automobile traffic.

CONCLUSIONS

There is no indication that the lichens of Sequoia National Park are being damaged by air quality. The lichen flora is reasonably diverse for such a dry area and there is no impoverishment of the lichen flora in any part of the Kaweah River drainage. There are only a few species with known sensitivies to sulfur dioxide in the park and those that are most sensitive are quite rare. This rarity seems to be due more to ecological and climatic conditions that pollution since these species are quite healthy when present. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at any locality. Although there is known to be ozone pollution in the park and the conifers show damage, the lichens do not show any abnormal growth or damage that could be attributed to ozone. In this case the conifers seem to be more sensitive than the lichens.

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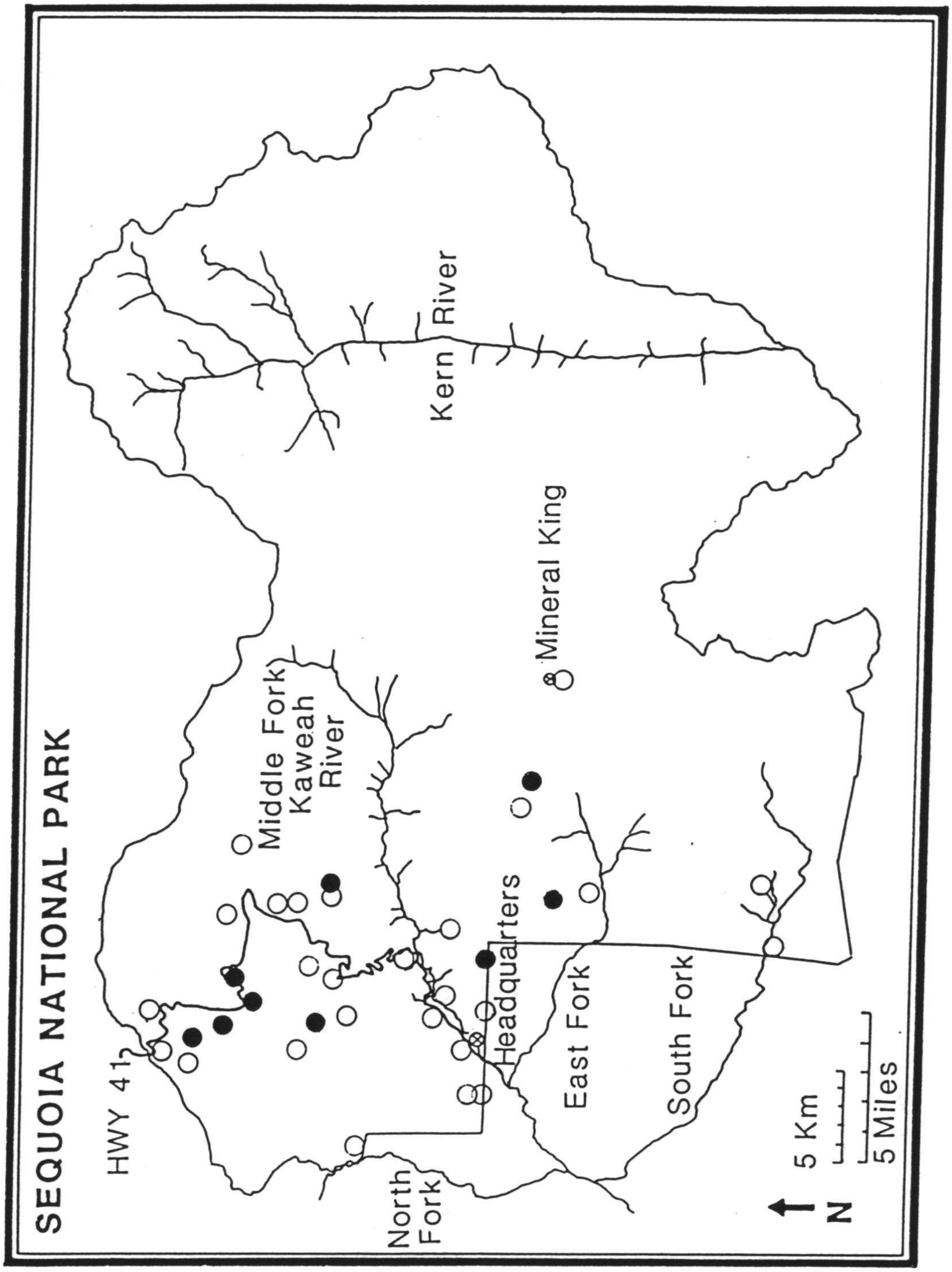

Fig. 1. Open circles are collection localities, closed circles are elemental analysis localities.

APPENDIX I

Collection Localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by collection number and date of collection.

Tulare County

50098- 50142 Just N of park headquarters at Ash Mountain. On S facing hill with oaks and some rocks, elev. 2000 ft. Sec. 34, T16S, R29E. 2 May 1984.

50143- 50187 Two miles E of Lookout Point Ranger Station on Mineral King Road. On S facing hillside near stream with evergreen oaks and brush and rocks, elev. 4600 ft. Sec. 20, T17S, R30E. 3 May 1984.

50188- 50230 0.5 miles W of Atwell Mill Ranger Station along Mineral King Road. In conifer woods with fir, pine and sequoia near stream, elev. 6500 ft. Sec. 11, T17S, R30E. 3 May 1984.

50231- 50266 Near Shepherd Peak W of Ash Mountain. On S facing slope in chamise brush, elev. 2200 ft. Sec. 32, T16S, R29E. 4 May 1984.

50267- 50300 Near Shepherd Peak W of Ash Mountain. On S facing slope in open oak woodland, elev. 2000 ft. Sec. 32, T16S, R29E. 4 May 1984.

50301- 50344 Near Buckeye Flat Campground along Paradise River. In valley along stream with buckeye, oaks and poison oak, elev. 3300 ft. Sec. 30, T16S, R30E. 4 May 1984.

50345- 50372 Crystal Cave. SE of parking lot on S facing slope with some rocks and oaks and few conifers, elev. 4500 ft. Sec. 33, T15S, R29E. 5 May 1984.

50373- 50414 Just N of Colony Mill S of wilderness road. On ridgetop with pines and firs and sequoia with few oaks, elev. 5800 ft. Corner of Sec. 2,3,10,11, T16S, R29E. 5 May 1984. chem

50415- 50448 North end of Log Meadow in Giant Forest. In old forest sequoia with firs and some pines, elev. 6800 ft. Sec. 5, T16S, R30E. 6 May 1984.

50449- 50477 One mile E of Lodgepole Campground along Middle Fork. In valley with firs and some lodgepole pine and rocks, elev. 7000 ft. Sec. 22, T15S, R30E. 6 May 1984.

50478-50521 Around CCC camp at Yucca Creek on North Fork of Kaweah River. On S facing slope above camp with oaks and some rocks near stream, elev. 1900 ft. Sec. 12, T16S, R28E. 7 May 1984.

50522-50563 Above Elk Creek W of Potwisha Campground. On east facing slope with chamise chaparral, elev. 2400 ft. Sec. 26, T16S, R29E. 8 May 1984.

50564-50596 One mile N of Hospital Rock. On steep S facing slope with oaks, elev. 3500 ft. Sec. 13, T16S, R29E. 9 May 1984.

50597-50626 Below Sunset Rock NW of Giant Forest. On hillside above stream with fir, pine and dogwood, elev. 5500 ft. Sec. 36, T15S, R29E. 9 May 1984.

50627-50667 Around Wolverton, N of Giant Forest. East of corrals on W and N facing slopes with pines and few fir, elev. 7500 ft. Sec. 29, T15S, R30E. 10 May 1984.

50668-50693 South of Halstead Meadow E of Little Baldy. In old fir stand near wet meadow and stream, elev. 7000 ft. Sec. 24, T15S, R29E. 10 May 1984. Chem

50694-50734 At junction of Crystal Cave road and Generals Highway. On steep S facing slope at bottom of valley with a stream in firs and sequoias, elev. 5500 ft. Sec. 1, T16S, R29E. 11 May 1984.

50735-50758 West side of Clover Creek 1 mile W of Lodgepole Visitor Center. On S facing hillside along stream in mature fir forest with some pines, elev. 7000 ft. Sec. 20, T15S, R30E. 11 May 1984.

50759-50815 Near Ladybug Campground 2 miles E of South Fork Ranger Station. In oaks along river and on rocks, elev. 4500 ft. Sec. 20, T18S, R30E. 12 May 1984.

50816-50835 South of South Fork Ranger Station. In N-S dry gulch with oaks and lots of poison oak, elev. 3800 ft. Sec. 19, T18S, R30E. 12 May 1984.

50836-50882 East of Ash Mountain park headquarters across Kaweah River. On north facing hillside along water flume with oaks and chamise, elev. 2200 ft. Sec. 34, T16S, R29E. 14 May 1984.

50883-50925 South of Potwisha Campground along water flume. On north facing hillside in oaks and brush, elev. 2100 ft. Sec. 26, T16S, R29E. 15 May 1984.

50926- West end of Little Baldy Saddle. On E facing slope of
50966 valley with fir and rock and some pine, elev. 7100 ft. Sec. 15, T15S, R29E. 16 May 1984. chem

50967- Muir Grove W of Dorst Campground. On W facing slope
50998 with fir and sequoia, elev. 6400 ft. T15S, R29E. 17 May 1984.

50999- Half mile W of Dorst Campground on N facing slope in
51030 fir forest with some pines and rock outcrops, elev. 6600 ft. Sec. 10, T15S, R29E. 17 May 1984.

51031- Lost Grove at NW corner of park. On S facing slope of
51055 valley with fir and sequoia, elev. 6400 ft. Sec. 4, T15S, R29E. 18 May 1984.

51056- Dorst Creek, NE of Campground. On S facing slope
51090 above road and along streams with fir and pines and rocks, elev. 6900 ft. Sec. 2, T15S, R29E. 18 May 1984.

51091- Ridge S of Little Baldy. On E facing slope of ridge
51116 in fir and pine forest with some incense cedar, elev. 6800 ft. 19 May 1984. chem

51117- East of General Sherman tree in Giant Forest. On W
51143 facing slopes with sequoia, fir and some pines, elev. 7100 ft. Sec. 32, T15S, R30E. 19 May 1984.

51144- Milk Ranch Peak at border of park E of headquarters.
51193 Around peak with white fir, incense cedar, pines and rocks, elev. 6100 ft. Sec. 1, T17S, R29E. 21 May 1984. chem

51194- Around Oreole Lake SW of Pine Top Mt. Around small
51229 lake with white fir, incense cedar and some pines, elev. 5700 ft. Sec. 8, T16S, R30E. 21 May 1984. chem

51230- Above Cool Spring Campground at Mineral King. In open
51251 fir forest on dry N facing slope with boulders, elev. 7700 ft. Sec. 16, T17S, R31E. 22 May 1984.

51252- Just E of Atwell Mill Campground. On S facing slope
51273 in pines with some incense cedar and fir, elev. 6400 ft. Sec. 12, T17S, R30E. 22 May 1984. chem

51274- Above High Sierra Trail 1 mile E of Log Meadow at
51302 edge of Giant Forest. On ridge and on W facing slope with red and white fir, some pines and sequoia, elev. 7500 ft. Sec. 4, T16S, R30E. 23 May 1984. chem

51303- One mile NE of Colony Peak. On E facing slope with
51335 white fir, incense cedar and some oak, elev. 5400 ft. Sec. 34, T15S, R29E. 24 May 1984.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in Sequoia National Park fall within the Sensitive and Sensitive/Intermediate categories as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50ug sulfur dioxide per cubic meter (average annual). The intermediate category includes species present between 50ug and 100ug. The S-I group falls between the Sensitive and Intermediate categories. Open circles are localities where the species was not found and solid circles are where it was found.

Note: Refer to text for interpretation of these maps and precautions concerning absence in parts of the park.

Fig. 2	S-I	Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr.
Fig. 3	S-I	Candelaria concolor (Dicks.) B. Stein.
Fig. 4	S-I	Cladonia fimbriata (L.) Fr.
Fig. 5	S-I	Normandina pulchella (Borr.) Nyl.
Fig. 6	S	Ochrolechia androgyna (Hoffm.) Arn.
Fig. 7	S	Parmelia subaurifera Nyl.
Fig. 8	S	Ramalina farinacea (L.) Ach.
Fig. 9	S-I	Xanthoria fallax (Hepp) Arn.

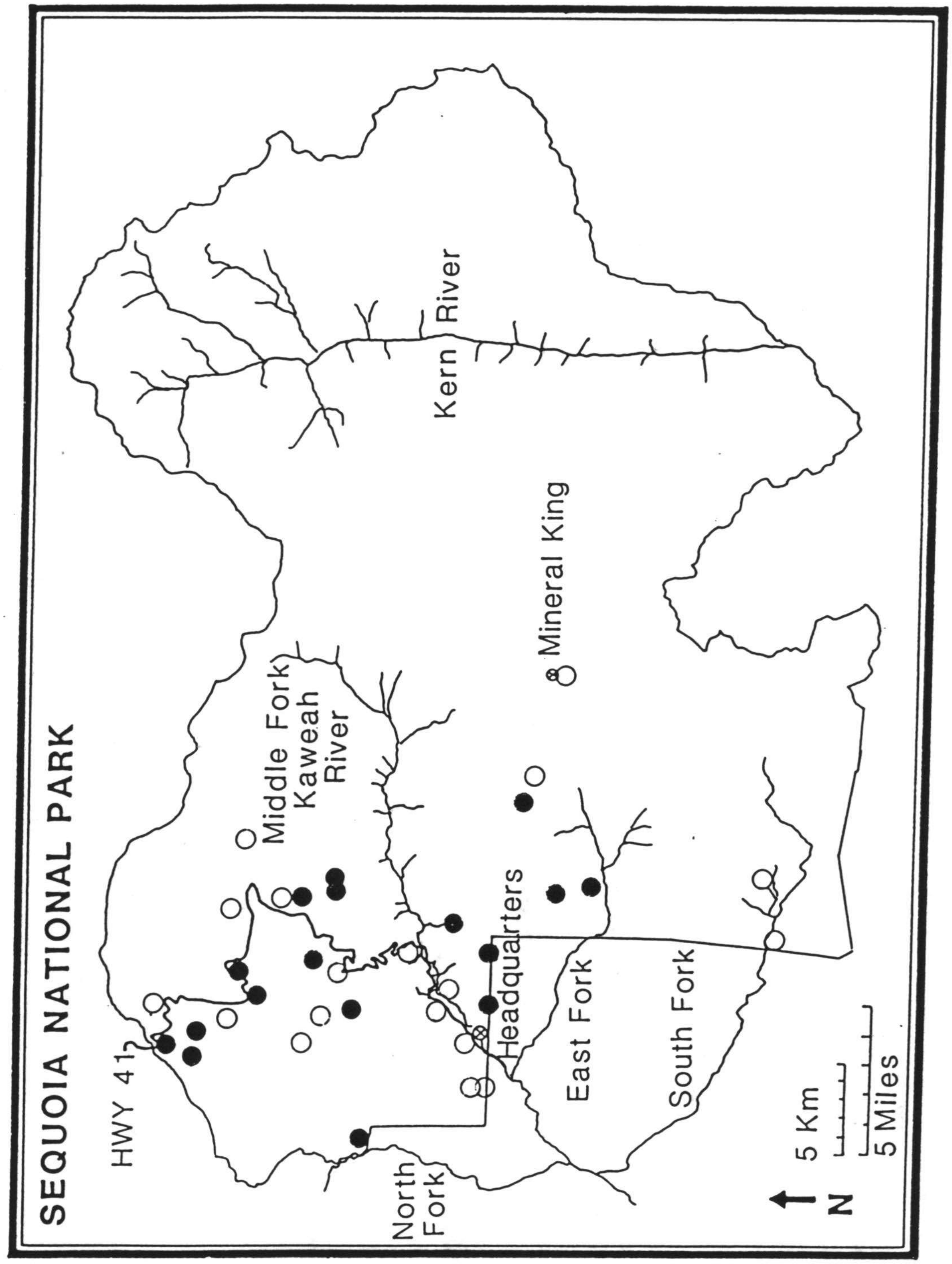

Fig. 2. <u>Caloplaca cerina</u>

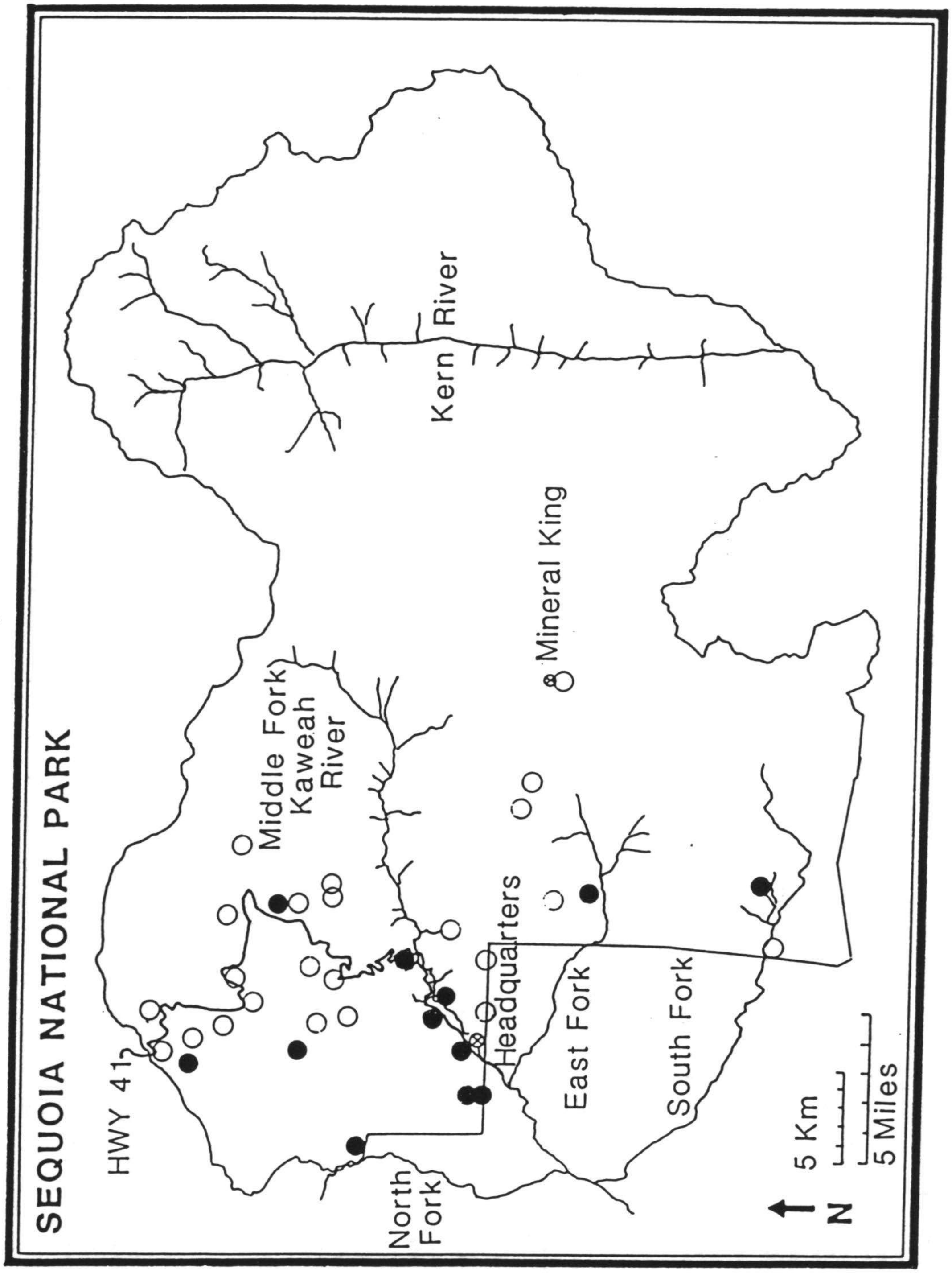

Fig. 3. <u>Candelaria concolor</u>

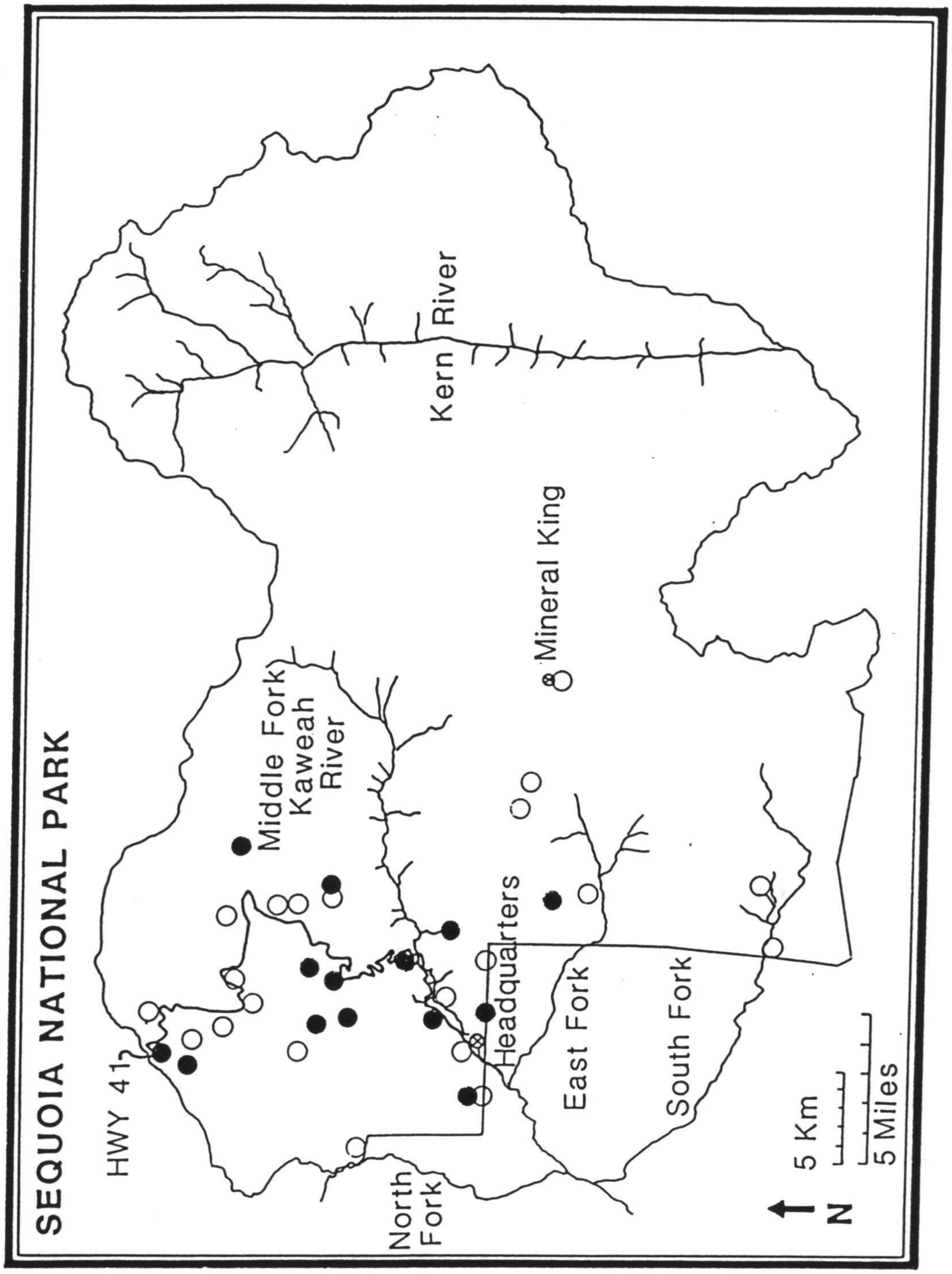

Fig. 4. Cladonia fimbriata

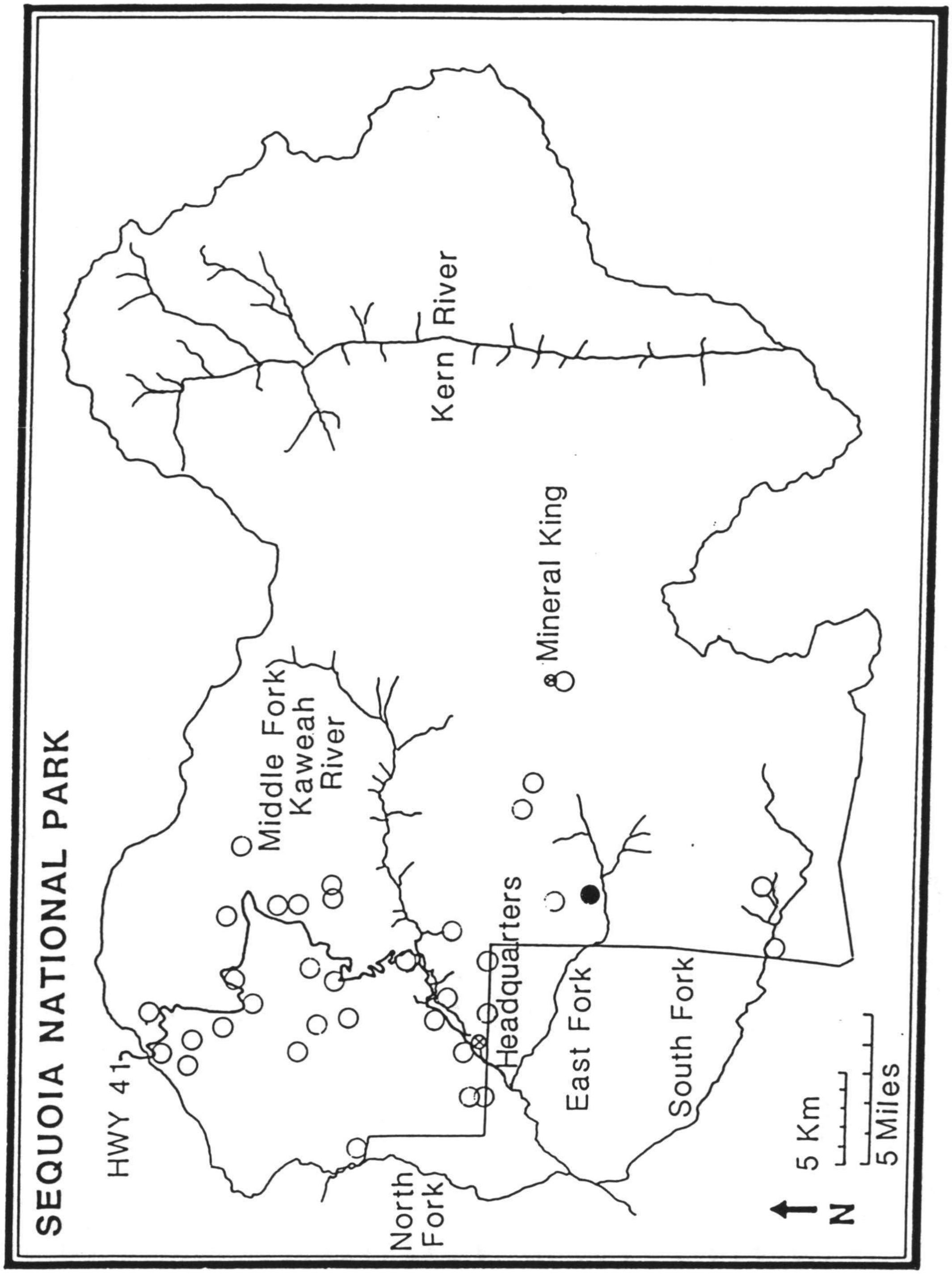

Fig. 5. <u>Normandina pulchella</u>

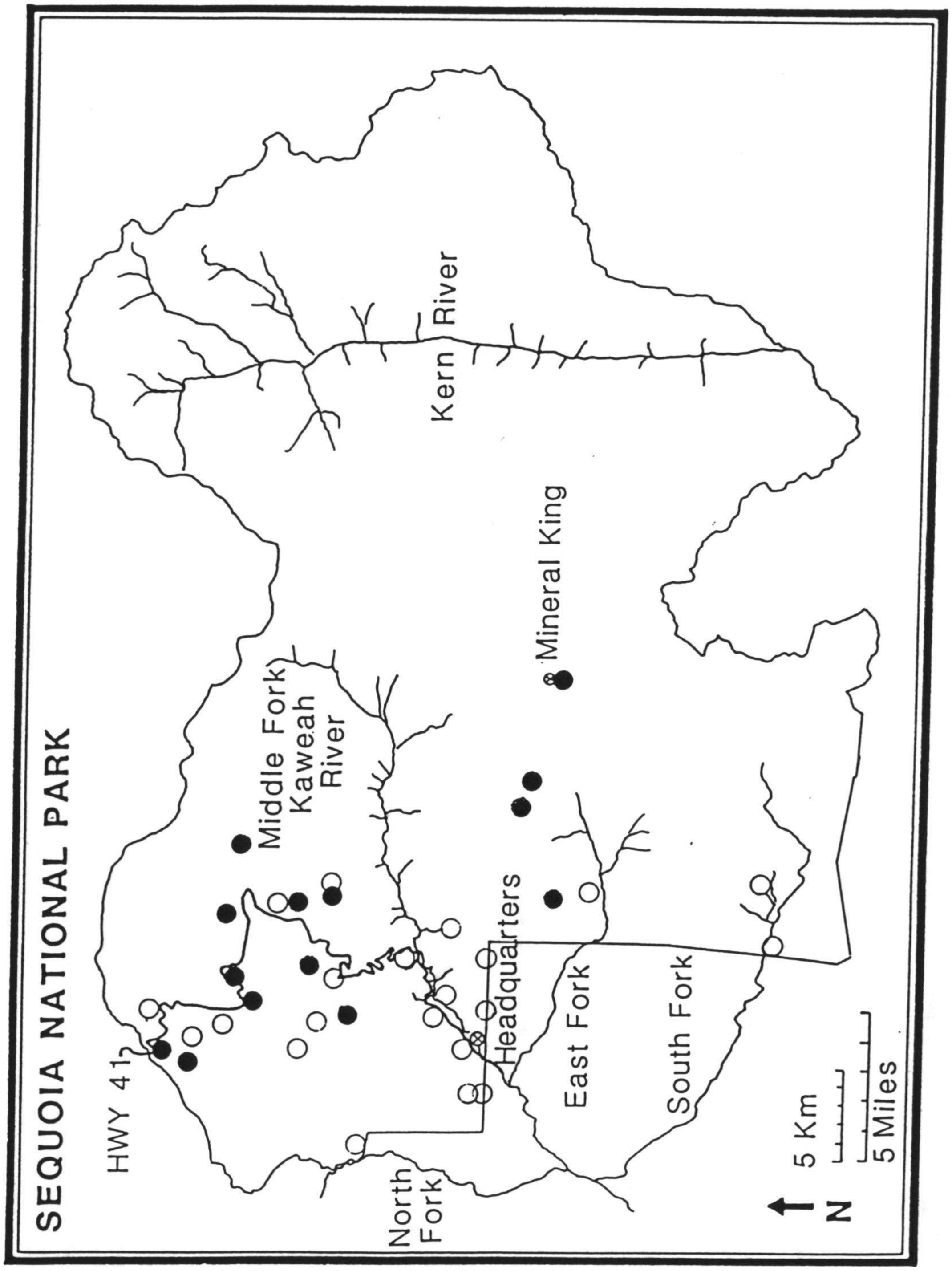

Fig. 6. Ochrolechia androgyna

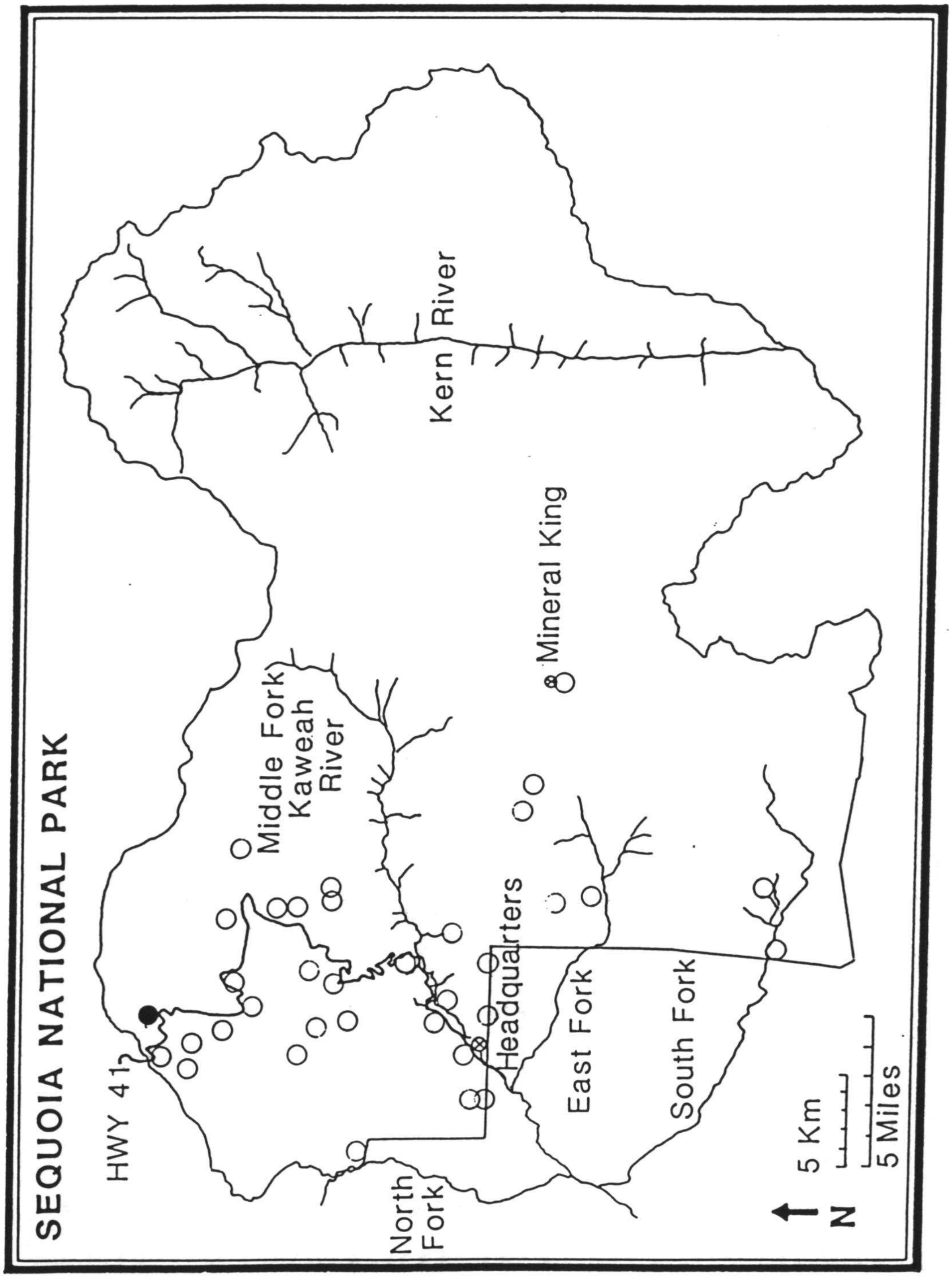

Fig. 7. Parmelia subaurifera

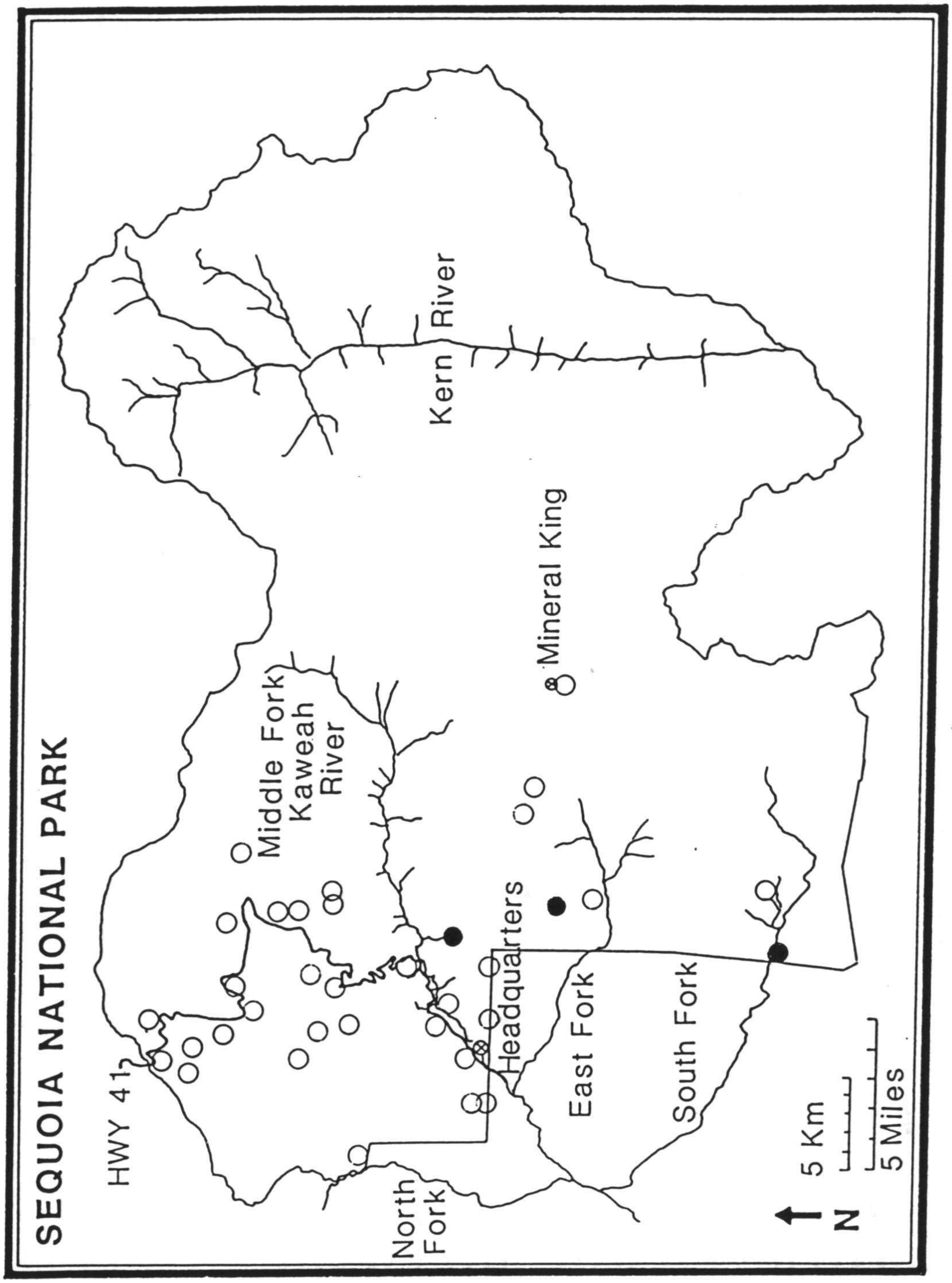

Fig. 8. Ramalina farinacea

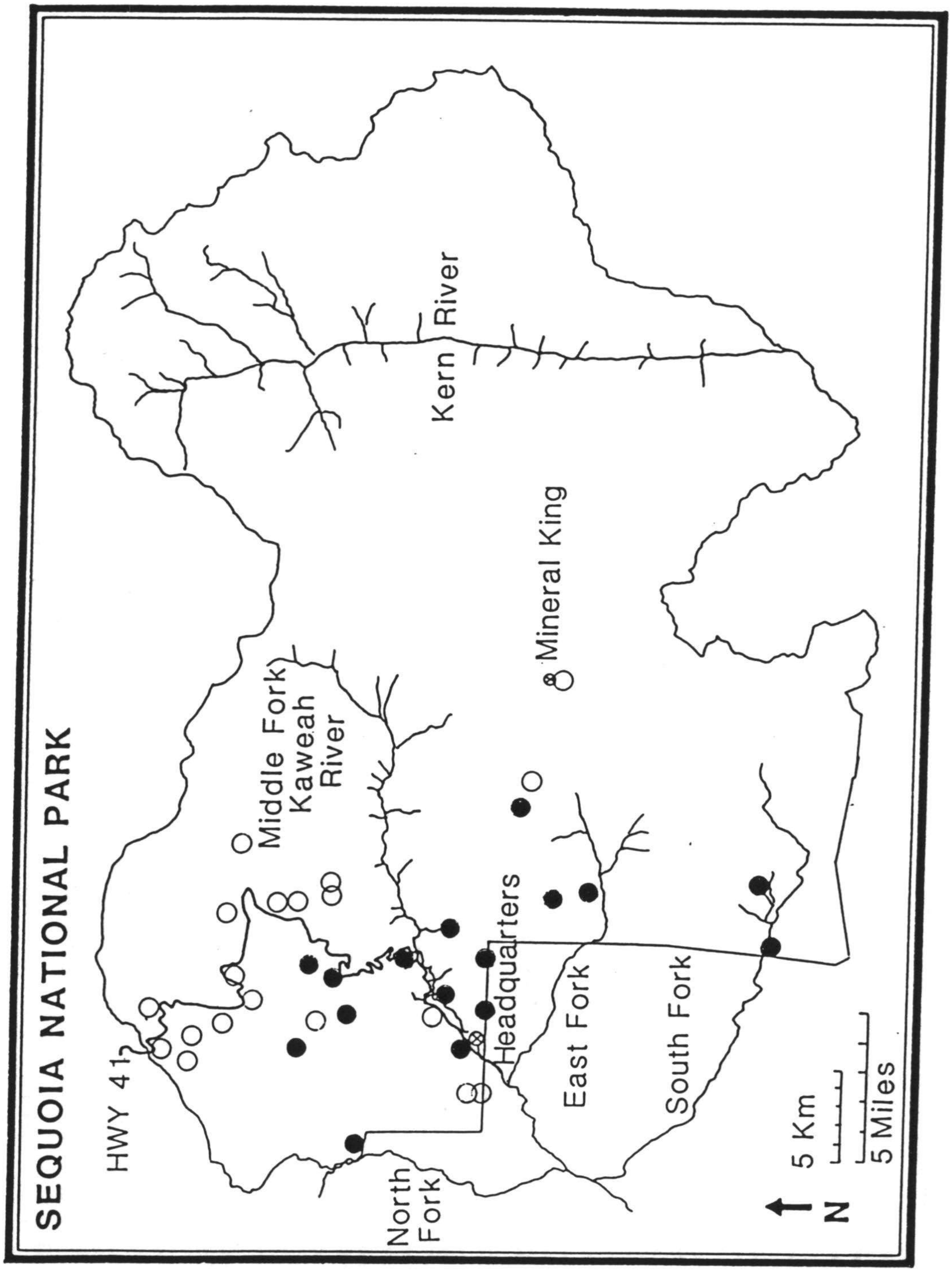

Fig. 9. <u>Xanthoria</u> <u>fallax</u>