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LICHENS AND AIR QUALITY
in
SEQUOIA NATIONAL PARK
and
KINGS CANYON NATIONAL PARK

SUPPLEMENTARY REPORT

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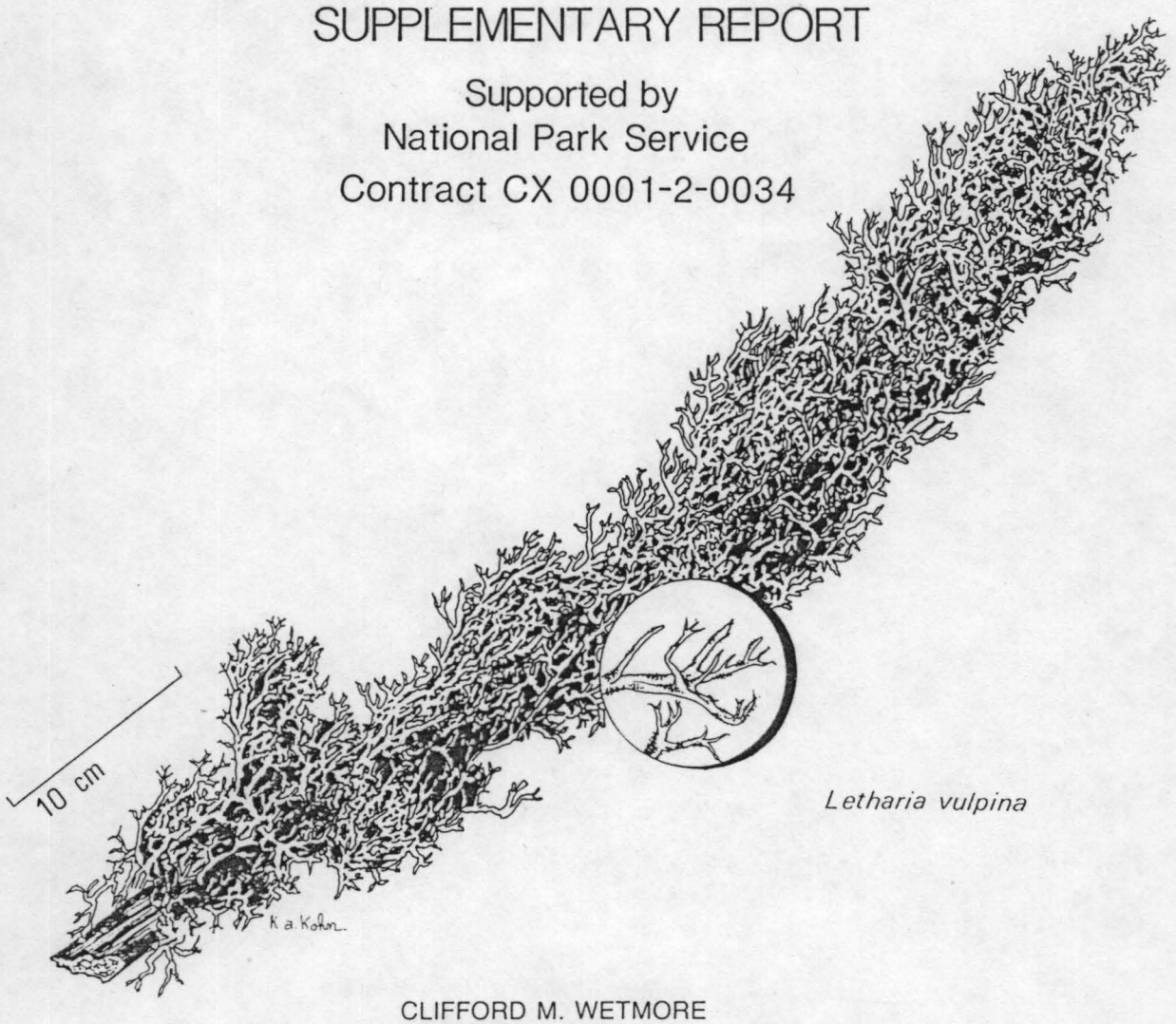

Letharia vulpina

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IN
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Supplementary Report

National Park Service
Contract CX 0001-2-0034

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LICHENS OF SEQUOIA AND KINGS CANYON NATIONAL PARKS

PREFACE

Under a grant from the National Park Service (USDI CX 0001-2-0034) a lichen study was to be performed in Kern Canyon of Sequoia National Park and in the Grant Grove Section of Kings Canyon National Park. This part of the study continues the study done on the Kaweah Drainage in Sequoia NP in 1984. 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. All field work for this part of the study was done by Judy Blakeman. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

Sequoia and Kings Canyon National Parks are 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 which was covered in the 1985 report (Wetmore, 1985). At that time no work was done in Kings Canyon NP or in Kern Canyon. With the availability of a graduate student to continue the study, the Grant Grove and Redwood Canyon areas of Kings Canyon and also Kern Canyon were studied in 1985. There are two quite different types of areas to be covered in one report and so the different areas are kept separate or noted wherever possible.

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 pine (Pinus ponderosa and Pinus jeffreyi) and white fir forest (Abies concolor) with areas of sequoia (Sequoiadendron giganteum) and red fir (Abies magnifica) (Vankat, 1982). The climate is generally dry but the higher elevations present in the Grant Grove area provide a more moist climate. The Kern Canyon area is in the rain shadow and is even drier although some localities in Kern Canyon are in the pine-fir zone.

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 and Kings Canyon (Smith, 1980) prior to the 1984 study (Wetmore, 1985).

METHODS

Field work was done during the summer of 1985 by Judy Blakeman. About 470 lichen collections were made at 17 localities in the Grant Grove Section of Kings Canyon NP and in Kern Canyon of Sequoia NP. 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 these two areas of the park, 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 by Clifford Wetmore 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 included in Appendix III.

LICHEN FLORA

The following list of lichens is based on the collections of Judy Blakeman and a few of my collections from 1984 that were previously unidentified. There are no literature reports from these areas of these parks. This list includes 116 species collected in 1985 for this study. There are an additional 23 unidentified species from the 1985 collections. The list also includes 3 species collected in 1984 but not on the 1984 list and one species included in 1984 list based on a literature report but only found in 1985. One species listed in 1984 (Lepidoma demissum) should be deleted because is based on a misidentification. In the first columns the letters indicate whether the species is being reported from Kings Canyon or Kern Canyon followed by 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.

SPECIES LIST FOR 1985 COLLECTIONS

207 species found (1984 & 1985)
116 species collected in 1985
100 also found in 1984 (including 3 not on first list)
61 species on 1984 list & Kern Canyon
77 species on 1984 list and Grant Grove
*=15 new records for park in 1985 (not counting 3 from 1984)
6 new records from Grant
9 new records from Kern
(#)=1 species reported in literature, only found in 1985
(*)=3 species found in 1984 but not on 1984 list
1 species on 1984 list not correct (Lepidoma demissum)
K=Kern
G=Grant

K Acarospora americana Magn.
KG Acarospora badiofusca (Nyl.) Th. Fr.
G Acarospora chlorophana (Wahlenb. in Ach.) Mass.
G Acarospora fuscata (Nyl.) Arn.
K Acarospora radicata Magn.
3 additional unidentified species of Acarospora
G *Arthonia dispersa (Schrad.) Nyl.
G *Aspicilia alphoplaca (Wahlenb. in Ach.) Poelt & Leuck.
KG Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
KG (*)Aspicilia cinereorufescens (Ach.) Mass.
K *Bacidia hegetschweileri (Hepp) Vain.
K *Biatorella microhaema Norm. in Th. Fr.
1 additional unidentified species of Biatorella
G Bryoria abbreviata (Müll. Arg.) Brodo & Hawksw.
G Buellia penichra (Tuck.) Hasse
G T Buellia punctata (Hoffm.) Mass.
K Buellia turgescens Tuck.
1 additional unidentified species of Buellia
G Calicium adaequatum Nyl.
G I Calicium viride Pers.
G S-ICaloplaca cerina (Ehrh. ex Hedw.) Th. Fr.
K *Caloplaca epithallina Lynge
K *Caloplaca stilliciorum (Vahl) Lynge
G *Caloplaca vitellinula (Nyl.) Oliv.
1 additional unidentified species of Caloplaca
KG S-ICandelaria concolor (Dicks.) B. Stein.
KG Candelariella aurella (Hoffm.) Zahlbr.
KG Candelariella reflexa (Nyl.) Lett.
KG (*)Candelariella rosulans (Müll. Arg.) Zahlbr.
KG I Candelariella vitellina(Hoffm.) Müll. Arg.
1 additional unidentified species of Candelariella
G Cladonia chlorophaea (Flörke ex Somm.) Spreng.

G S-I*Cladonia fimbriata* (L.) Fr.
1 unidentified species of *Collema*
K *Dermatocarpon miniatum* (L.) Mann
KG *Dermatocarpon reticulatum* Magn.
K (*)*Dimelaena thysanota* (Tuck.) Hale & W. Culb.
G *Diploschistes scruposus* (Schreb.) Norm.
G I *Evernia prunastri* (L.) Ach.
G *Hypogymnia imshaugii* Krog
G *Koerberia sonomensis* (Tuck.) Henss.
G I *Lecanora carpinea* (L.) Vain.
K *Lecanora cascadensis* Magn.
G *Lecanora cenisia* Ach.
G I *Lecanora chlarotera* Nyl.
G *Lecanora hagenii* (Ach.) Ach.
G T *Lecanora muralis* (Schreb.) Rabenh.
KG *Lecanora piniperda* Körb.
G *Lecanora polytropa* (Hoffm.) Rabenh.
K *Lecanora rupicola* (L.) Zahlbr.
K I *Lecanora saligna* (Schrad.) Zahlbr.
4 additional unidentified species of *Lecanora*
G *Lecidea aeruginosa* Borr. in Hook. & Sowerb.
G *Lecidea anthracophila* Nyl.
KG *Lecidea atrobrunnea* (DC. in Lam. & DC.) Schaer.
KG *Lecidea auriculata* Th. Fr.
G *Lecidea glaucopholis* Nyl. ex Hasse
G *Lecidea globifera* Ach.
KG *Lecidea granulosa* (Ehrh.) Ach.
G I *Lecidea scalaris* (Ach.) Ach.
2 additional unidentified species of *Lecidea*
G *Lecidella euphorea* (Flörke) Hert.
K *Lecidella stigmatea* (Ach.) Hert. & Leuck.
K *Lepraria finkii* (B. de Lesd. in Hue) R. Harris
2 additional unidentified species of *Lepraria*
KG *Leptochidium albociliatum* (Desm.) Choisy
KG *Leptogium californicum* Tuck.
G *Letharia columbiana* (Nutt.) Thoms.
KG *Letharia vulpina* (L.) Hue
G *Massalongia carnosa* (Dicks.) Körb.
G *Micarea denigrata* (Fr.) Hedl.
1 additional unidentified species of *Micarea*
G (#)*Mycocalicium sequoiae* Bonar
KG S-I*Normandina pulchella* (Borr.) Nyl.
G S *Ochrolechia androgyna* (Hoffm.) Arn.
KG *Parmelia cumberlandia* (Gyeln.) Hale
K *Parmelia disjuncta* Erichs.
KG *Parmelia elegantula* (Zahlbr.) Szat.
G *Parmelia glabra* (Schaer.) Nyl.
KG *Parmelia mexicana* Gyeln.
K *Parmelia plittii* Gyeln.
K *Parmelia sorediosa* Almb.
K I-T*Parmelia subargentifera* Nyl.
G *Parmelia subelegantula* Essl.
G *Parmelia subolivacea* Nyl.

KG Parmelia substygia Räs.
KG I-T Parmelia sulcata Tayl.
G Peltigera canina (L.) Willd.
K Peltigera scabrosa Th. Fr.
K Peltula bolanderi (Tuck.) Wetm.
KG Phaeophyscia endococcina (Körb.) Moberg
K Phaeophyscia orbicularis (Neck.) Moberg
K I Physcia adscendens (Fr.) Oliv.
G I Physcia aipolia (Ehrh. ex Humb.) Furnrohr
KG Physcia biziana (Mass.) Zahlbr.
KG Physcia caesia (Hoffm.) Furnrohr
KG Physcia dimidiata (Arn.) Nyl.
KG T Physcia dubia (Hoffm.) Lett.
K I Physcia stellaris (L.) Nyl.
KG I Physcia tenella (Scop.) DC. in Lam. & DC.
KG I Physconia detersa (Nyl.) Poelt
G I Physconia distorta (With.) Laundon
KG Physconia enteroxantha (Nyl.) Poelt
KG Placynthiella icmalea (Ach.) Coppins & P. James
G I Platismatia glauca (L.) W. Culb. & C. Culb.
G *Polychidium muscicola (Sw.) S. Gray
K Pseudephebe pubescens (L.) Choisy
G S Ramalina farinacea (L.) Ach.
1 additional unidentified species of Ramalina
G Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr.
KG Rhizocarpon bolanderi (Tuck.) Herre
K Rhizocarpon disporum (Naeg. ex Hepp) Müll. Arg.
KG Rhizocarpon geographicum (L.) DC
K Rhizocarpon grande (Flörke ex Flot.) Arn.
KG Rhizocarpon macrosporum Räs.
1 additional unidentified species of Rhizocarpon
K Rhizoplaca melanophthalma (DC. in Lam. & DC.) Leuck. & Poelt
G Rinodina archaea (Ach.) Arn.
G I Rinodina exigua (Ach.) S. Gray
1 additional unidentified species of Rinodina
K Staurothele fuscocuprea (Nyl.) Zsch.
K Umbilicaria cinereorufescens (Schaer.) Frey
KG Umbilicaria phaea Tuck.
K Umbilicaria torrefacta (Lightf.) Schrad.
K *Umbilicaria vellea (L.) Ach.
KG I Xanthoria candelaria (L.) Th. Fr.
KG Xanthoria elegans (Link) Th. Fr.
KG I Xanthoria polycarpa (Hoffm.) Rieber
K *Xanthoria sorediata (Vain.) Poelt
1 additional unidentified species of Xanthoria

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 of Grant Grove is comparable to that found at the higher elevations of Sequoia with 77 species found in both areas and 6 new records from Grant Grove. Comparing Kern Canyon with the 1984 report, 61 species were found in both areas with 9 new records from Kern Canyon. In total 116 species were found in 1985, 100 of these were also found in 1984. The 1985 study produced 15 new records for the parks. 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 they reported but not found in Sequoia, some may be due to differing identifications but most are probably due to the more northern location of the San Joaquin area. No additional species reported by Hebert & Meyer were found in 1985.

The lichen flora of Grant Grove seems to be similar to that of the Giant Forest area of Sequoia. Parmelia subelegantula was described from Canada and is present in the more northern Kings Canyon but not in Sequoia. The other new 1985 records may also show these northern affinities. Many of the new records from Kern Canyon show affinities with the Rocky Mountain lichen flora. Caloplaca epithallina, Caloplaca stillicidiorum, Lecanora rupicola, Parmelia plittii, Parmelia sorediosa and Umbilicaria vellea are all common in the Rocky Mountains. None of the California endemics were found in the

Kern but Dimelaena thysanota is only found west of the Rockies. This lack of California endemic lichens in Kern should be compared with the vascular plant flora for similarities. Additional differences between the floras may also be due to thoroughness of collecting and experience in collecting but there seem to be real floristic differences between these areas too.

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. The scarcity of lichens in the Kern area are mainly due to the drier climate there. 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 damage to specimens of these lichens were seen in the park 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. Wallner & Fong (1982) reported moderate to slight ozone damage to conifers in

Grant Grove and slight damage in Kern Canyon. No evidence was found in the 1985 localities of damage that could be attributed to ozone damage to the lichens.

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 S-I category is between Sensitive and Intermediate. The species that occur in these categories in the 1985 study areas in the park park are as follows.

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 Ramalina farinacea (L.) Ach.

The distributions of these species are mapped (Fig. 2-7). These distribution maps also include the 1984 localities for these species. Most of these species are too rare to have meaning with this technique but there is no indication that

the voids in the distributions are due to poor air quality.

ELEMENTAL 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.

METHODS

Hypogymnia imshaugii and Letharia vulpina were collected from tree branches in spunbound olefin bags at four localities in the park for laboratory analysis. These species were selected because they are the only ones present in abundance and relatively easy to clean.

Four localities were selected in the Grant Grove and Redwood Canyon areas for elemental analysis and are indicated on the map of collection localities with a "+" (Fig. 1). In the Kern Canyon and these two species were too rare to provide the amounts needed for analysis although both species are present in Kern. The localities used are: Grant West (near Swale Campground south of Sequoia Lake Road), Grant North (near northern boundary east of highway), Kings Overlook (south of main highway near Kings Canyon Overlook) and Redwood

Canyon (1.5 miles from trailhead on trail to Hart Meadow). 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 B 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 Celsius 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 except Cr are above the lower detection limits of the instruments. Table 3 gives the grand means of the 1984 and

Table 1. Analysis of Kings Canyon lichens
Values in ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
H. imshaugii	1360	4467	10931	908	984	691	93.0	116.0	23.9	4.4	5.0	10.5	2.0	1.2	<.1	1320	Grant North
H. imshaugii	1190	4093	10820	815	913	644	84.2	107.4	21.7	4.1	4.5	9.7	1.9	1.1	<.1	1310	Grant North
H. imshaugii	1352	4366	12666	876	881	624	94.6	123.8	23.1	4.5	5.1	9.5	1.6	1.2	<.1	1280	Grant North
H. imshaugii	1238	4085	13694	1024	790	533	72.8	255.1	25.1	4.2	4.1	13.5	2.1	1.1	<.1	1300	Grant West
H. imshaugii	1371	4233	15753	1047	709	482	71.9	268.9	26.1	4.2	4.0	12.0	1.9	1.1	<.1	1140	Grant West
H. imshaugii	1258	4011	15007	1065	774	526	70.8	279.8	24.5	4.0	3.7	13.0	1.4	1.1	<.1	1220	Grant West
H. imshaugii	1288	4328	7644	831	953	682	103.4	137.9	22.7	4.4	5.7	11.2	2.2	1.2	<.1	1320	Kings Overl.
H. imshaugii	1182	4274	7202	833	1009	733	102.4	137.3	22.8	4.4	6.1	11.0	2.3	1.3	<.1	1150	Kings Overl.
H. imshaugii	1115	4091	8492	777	968	695	99.6	120.1	21.9	4.2	5.9	12.8	2.1	1.1	<.1	1300	Kings Overl.
H. imshaugii	1268	3837	14155	1079	1017	776	81.1	202.4	24.8	5.3	5.0	13.7	2.0	1.3	<.1	1460	Redw. Canyon
H. imshaugii	1235	3835	14175	1159	1105	852	85.1	211.6	26.5	5.5	5.9	15.2	2.4	1.6	<.1	1720	Redw. Canyon
H. imshaugii	1266	3909	16760	1074	1035	780	84.2	214.9	25.4	5.3	5.0	15.9	2.0	1.4	<.1	1620	Redw. Canyon
L. vulpina	1758	4348	3234	743	339	222	69.1	141.8	15.0	2.3	4.0	6.0	0.8	0.5	<.1	860	Grant North
L. vulpina	1679	4038	3329	731	294	197	64.4	136.9	15.9	2.3	3.9	7.8	0.7	0.6	<.1	750	Grant North
L. vulpina	1644	3912	3454	715	236	158	64.2	135.0	17.1	2.2	3.8	7.4	0.6	1.0	<.1	860	Grant North
L. vulpina	839	3534	3469	683	238	161	55.5	135.7	21.3	2.2	2.9	10.7	0.5	0.4	<.1	1110	Grant West
L. vulpina	889	3524	3293	760	274	187	59.1	147.0	21.5	2.1	3.0	8.6	0.8	0.5	<.1	1030	Grant West
L. vulpina	1188	3864	3470	886	333	227	60.9	174.0	22.0	2.2	3.0	9.1	0.7	0.5	<.1	1020	Grant West
L. vulpina	1119	3726	2131	697	382	274	92.8	77.4	17.5	2.4	4.9	6.6	0.8	0.6	<.1	880	Kings Overl.
L. vulpina	1274	4008	2322	715	360	253	88.2	79.7	19.5	2.3	4.7	6.5	0.8	0.6	<.1	820	Kings Overl.
L. vulpina	1261	3853	2405	686	321	227	82.6	76.9	18.5	2.3	4.5	7.6	0.6	0.5	<.1	850	Kings Overl.
L. vulpina	542	2418	2496	545	346	254	104.8	54.5	24.9	2.8	4.2	10.5	0.9	0.6	<.1	920	Redw. Canyon
L. vulpina	552	2500	2329	558	395	292	105.1	56.3	27.8	3.0	4.5	9.3	1.3	0.7	<.1	920	Redw. Canyon
L. vulpina	574	2540	2241	511	341	251	85.3	49.1	25.8	2.8	3.8	9.7	0.9	0.5	<.1	900	Redw. Canyon

Table 2. Summary of analysis of Kings Canyon lichens
Values in ppm of thallus

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Hypogymnia imshaugii																	
Mean	1301	4308	11472	866	926	653	90.6	115.7	22.9	4.3	4.9	9.9	1.8	1.1	#	1303	Grant North
Std. dev.	96	194	1035	47	53	34	5.6	8.2	1.1	0.2	0.3	0.5	0.2	<.1		21	Grant North
Mean	1289	4109	14818	1046	758	514	71.8	267.9	25.2	4.1	3.9	12.8	1.8	1.1	#	1220	Grant West
Std. dev.	72	113	1042	21	43	28	1.0	12.4	0.8	0.1	0.2	0.7	0.3	<.1		80	Grant West
Mean	1195	4231	7779	814	976	703	101.8	131.8	22.5	4.3	5.9	11.7	2.2	1.2	#	1257	Kings Overl.
Std. dev.	87	124	656	32	29	27	2.0	10.1	0.5	0.1	0.2	1.0	0.1	0.1		93	Kings Overl.
Mean	1256	3861	15030	1104	1052	803	83.4	209.6	25.6	5.4	5.3	15.0	2.2	1.4	#	1600	Redw. Canyon
Std. dev.	19	42	1498	48	47	43	2.1	6.5	0.9	0.1	0.5	1.1	0.2	0.1		131	Redw. Canyon
Letharia vulpina																	
Mean	1694	4099	3339	729	290	192	65.9	137.9	16.0	2.3	3.9	7.1	0.7	0.7	#	823	Grant North
Std. dev.	59	224	110	14	52	32	2.8	3.5	1.0	0.1	0.1	0.9	0.1	0.3		64	Grant North
Mean	972	3640	3411	776	282	192	58.5	152.2	21.6	2.2	3.0	9.4	0.7	0.5	#	1053	Grant West
Std. dev.	189	193	102	103	48	33	2.7	19.7	0.3	0.1	0.1	1.1	0.2	0.1		49	Grant West
Mean	1218	3862	2286	699	354	251	87.9	78.0	18.5	2.3	4.7	6.9	0.7	0.6	#	850	Kings Overl.
Std. dev.	86	141	140	15	31	24	5.1	1.5	1.0	<.1	0.2	0.6	0.1	<.1		30	Kings Overl.
Mean	556	2486	2355	538	361	266	98.4	53.3	26.2	2.9	4.2	9.8	1.0	0.6	#	913	Redw. Canyon
Std. dev.	16	62	130	25	30	22	11.4	3.7	1.5	0.1	0.3	0.6	0.2	0.1		12	Redw. Canyon

#= two or more values at or below detection limit; not included in calculations

Table 3. Comparison of 1984 and 1985 analyses
Means of values in ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Year
H. imshaugii	1727	5140	10404	1147	1497	1184	84.9	124.6	30.5	5.5	6.3	15.1	2.9	1.7	0.3	1682	1984
H. imshaugii	1260	4127	12275	957	928	668	86.9	181.3	24.0	4.5	5.0	12.3	2.0	1.2	#	1345	1985
L. vulpina	952	3353	1986	648	362	266	52,4	93.5	18.8	2.4	4.9	9.5	1.1	0.7	0.2	885	1984
L. vulpina	1110	3522	2848	686	322	225	77.7	105.4	20.6	2.4	3.9	8.3	0.8	0.6	#	910	1985

#= two or more values at or below detection limit; not included in calculations

1985 analyses for comparison.

All of the levels found in the Kings Canyon lichens are within typical limits for similar lichens although there are no literature reports on analyses of either of these species. For most elements the levels from the 1984 report are comparable to those for 1985. Al and Fe are higher in H. imshaugii in the 1984 analysis and Ca is higher in the 1985 analysis of L. vulpina. The higher levels could be due to blowing dust but the data do not show that any one locality is worse than another within the same year. All of the other elements show similar values when comparing the analyses from the two years.

The sulfur levels in lichens tested range from 750 to 1720 ppm for all samples. These levels are near background levels for other lichens listed by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980). Levels may be as low as 200-300 in some species in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of the two species. Letharia vulpina has lower levels of sulfur than Hypogymnia imshaugii. Even when taking these differences into account there is no clear trend in accumulated levels of sulfur. The sulfur levels are comparable for the two years and no one locality in 1985 showed significantly higher levels than the

rest.

From these tables it can be seen that there is no consistent correlation between element levels and location in the park.

CONCLUSIONS

There is no indication that the lichens of Sequoia or Grant Grove 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 area. There are only a few species with known sensitivities 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 than 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.

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APPENDIX I

Collection Localities

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

Kings Canyon National Park

1 - 43 Fresno Co. Grant Grove. Directly north of Gamlins cabin on dry south facing slope; Sequoia forest with fir and pine, elev. 6800 ft. 19 July 1985.

44 - 100 Tulare Co. Grant Grove. South on Sequoia Lake Road, from North Grove parking lot, 3/4 mile. West and south facing slopes of Sequoia forest with fir, pine and a few oaks, very dry, elev. 6100 ft. 19 July 1985.

101 - 155 Tulare Co. Grant Grove. West of South Boundary Trail service road, directly off of Generals Highway, north side of Sequoia Creek. South facing slope, fir and pine with azalea understory, elev. 6400 ft. 21 July 1985.

156 - 223 Tulare Co. Redwood Canyon. 1.5 miles from the Redwood Canyon Trailhead, toward Hart Meadow, on the Hart Tree Trail. Granite outcropping overlooking Redwood Canyon, pine and fir with manzanita underbrush, elev. 6200 ft. 25 July 1985.

224 - 282 Tulare Co. Redwood Canyon. 3 miles south of Redwood Canyon Trailhead on Big Spring Trail. West facing slope along Redwood Creek. Sequoia, fir and pine, burned in 1983, elev. 5500 ft. 28 July 1985.

283 - 318 Tulare Co. Redwood Canyon. Area adjacent to the Fallen Goliath Tree, 2 miles south of Redwood Canyon Trailhead on Hart Tree Trail. Sequoia forest with pine and fir, very dry, elev., 5700 ft. 28 July 1985.

Sequoia National Park

319 - 351 Tulare Co. Kern Canyon. NW of the south Kern Canyon Ranger Station, bordering Coyote Creek. Incense cedar, pine and fir with manzanita; very dry and rocky, elev. 6500 ft. 4 August 1985.

352 - 385 Tulare Co. Kern Canyon. NE of the south Kern Canyon Ranger Station, directly north of Soda Spring bordering west bank of the Kern River. Incense cedar, pine and

fir; very dry and rocky, elev. 6500 ft. 4 August 1985.

386 - 406 Tulare Co. Kern Canyon. 1 miles NE of south Kern Canyon Ranger Station on east bank of Kern River. Very rocky and dry, vegetation sparse, elev. 6500 ft. 6 August 1985.

407 - 429 Tulare Co. Kern Canyon. 1 mile NE of south Kern Canyon Ranger Station on east side of Kern River. Very rocky and dry west facing slope against canyon wall. Pine, fir and manzanita; vegetation sparse, elev. 6500 ft. 6 August 1985.

430 - 464 Tulare Co. Kern Canyon. Lower Funston Meadow. West side of trail between the two Lower Funston drift fences on west side of Kern Canyon. Pine,fir and some oak on dry and rocky east facing slope, elev, 6500 ft. 7 August 1985.

465 - 498 Tulare Co. Kern Canyon. A quarter mile south of Rattlesnake Creek on the west side of the Kern River. East facing slope where canyon floor meets canyon walls. Large jumbled granite boulders; very dry, vegetation sparse, elev. 6600 ft. 8 August 1985.

499 - 529 Tulare Co. Kern Canyon. A quarter mile north of Rattlesnake Creek on east bank of Kern River. Rocky and dry with incense cedar, fir, pine and manzanita, elev. 6600 ft. 8 August 1985.

530 - 562 Tulare Co. Kern Canyon. Kern Hot Springs. South bank of Rock Creek at canyon wall. N and NW facing cliff face near bank of creek. Willow, cottonwood, cedar, pine and fir; becoming very dry within a few feet of creek, elev. 8000 ft. 10 August 1985.

563 - 592 Tulare Co. Kern Canyon. Kern Hot Springs. North bank of Rock Creek at canyon wall. S and SW facing cliff. Rock face with a few canyon oak and cacti, elev. 8000 ft. 11 August 1985.

593 - 613 Tulare Co. Kern Canyon. Junction Meadow. 1 mile NW of Junction Meadow on Colby Pass Trail. Granite outcrop north of trail. Very dry and rocky; vegetation sparse and shrubby, a few willow and manzanita, elev. 8600 ft. 12 August 1985.

614 - 634 Tulare Co. Kern Canyon. Junction Meadow. E of Upper Kern Trail, .5 mile from junction of Colby Pass Trail at Junction Meadow. SW facing rocky outcrop with mountain mahogany and manzanita; very dry, elev. 8600 ft. 13 August 1985.

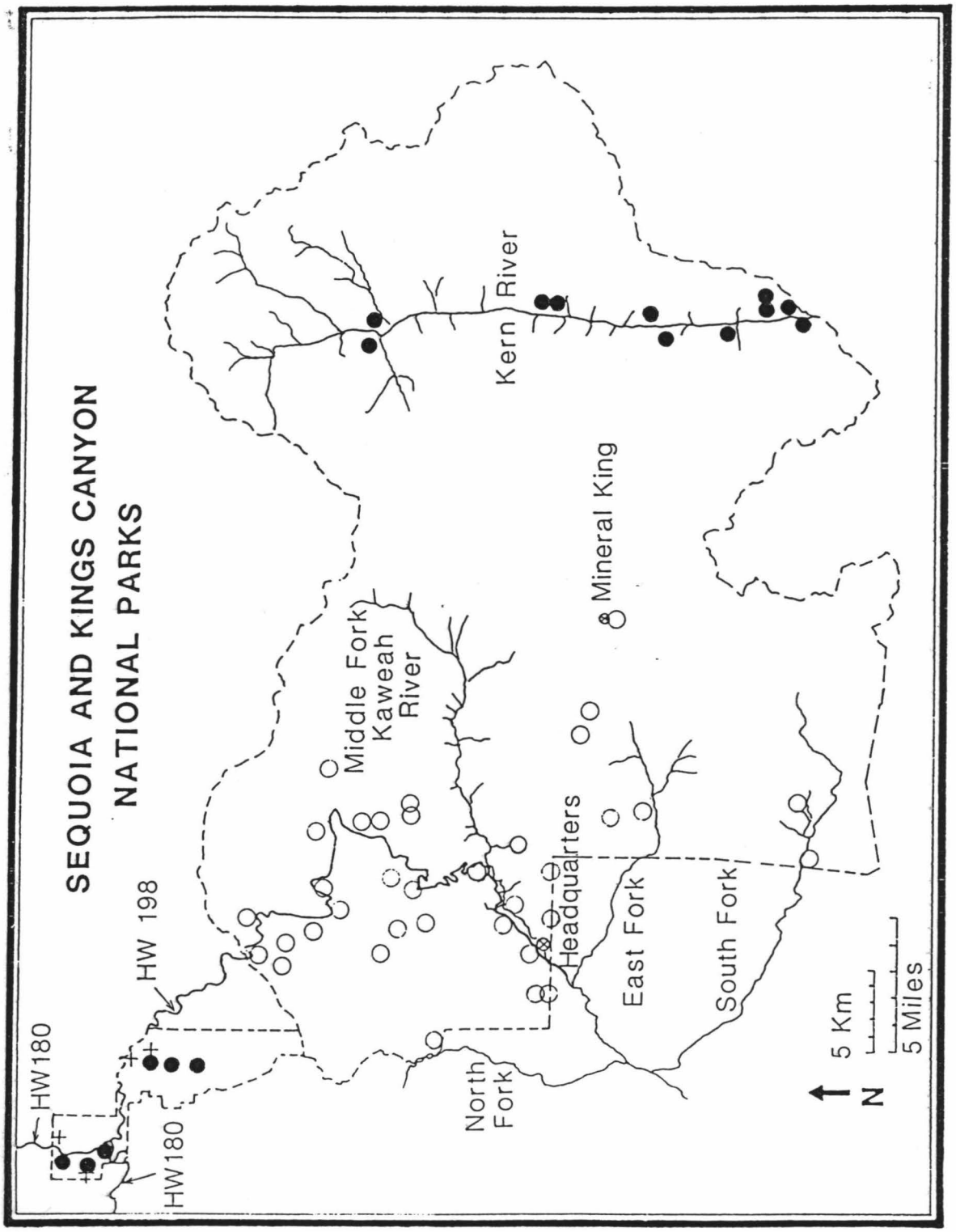

Fig. 1. Open circles are 1984 collection localities, solid circles are 1985 collection localities, + are 1985 elemental analysis localities.

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 and Kings Canyon National Parks 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. Both 1984 and 1985 occurrences are mapped.

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 *Ramalina farinacea* (L.) Ach.

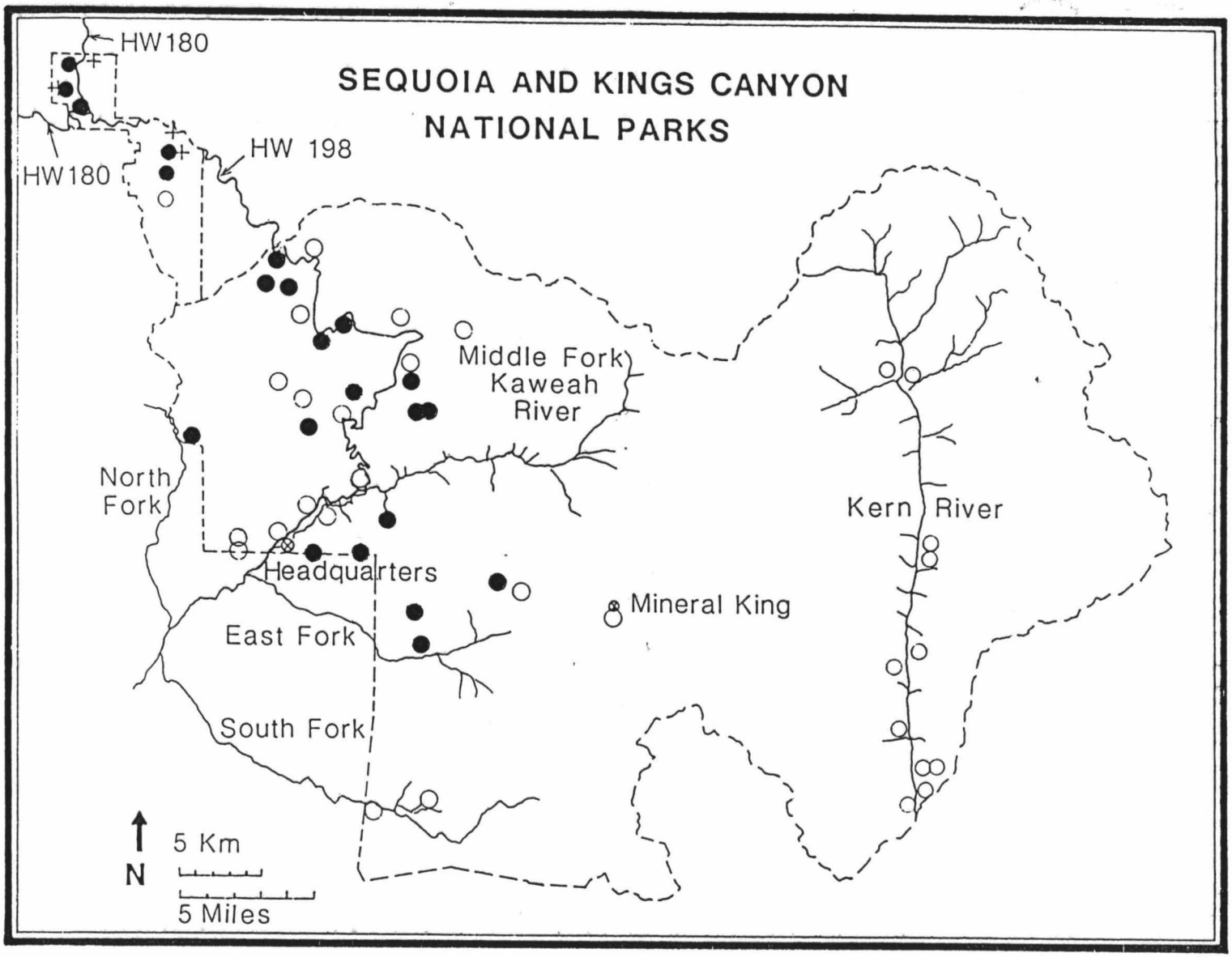

Fig. 2. Caloplaca cerina 1984 and 1985

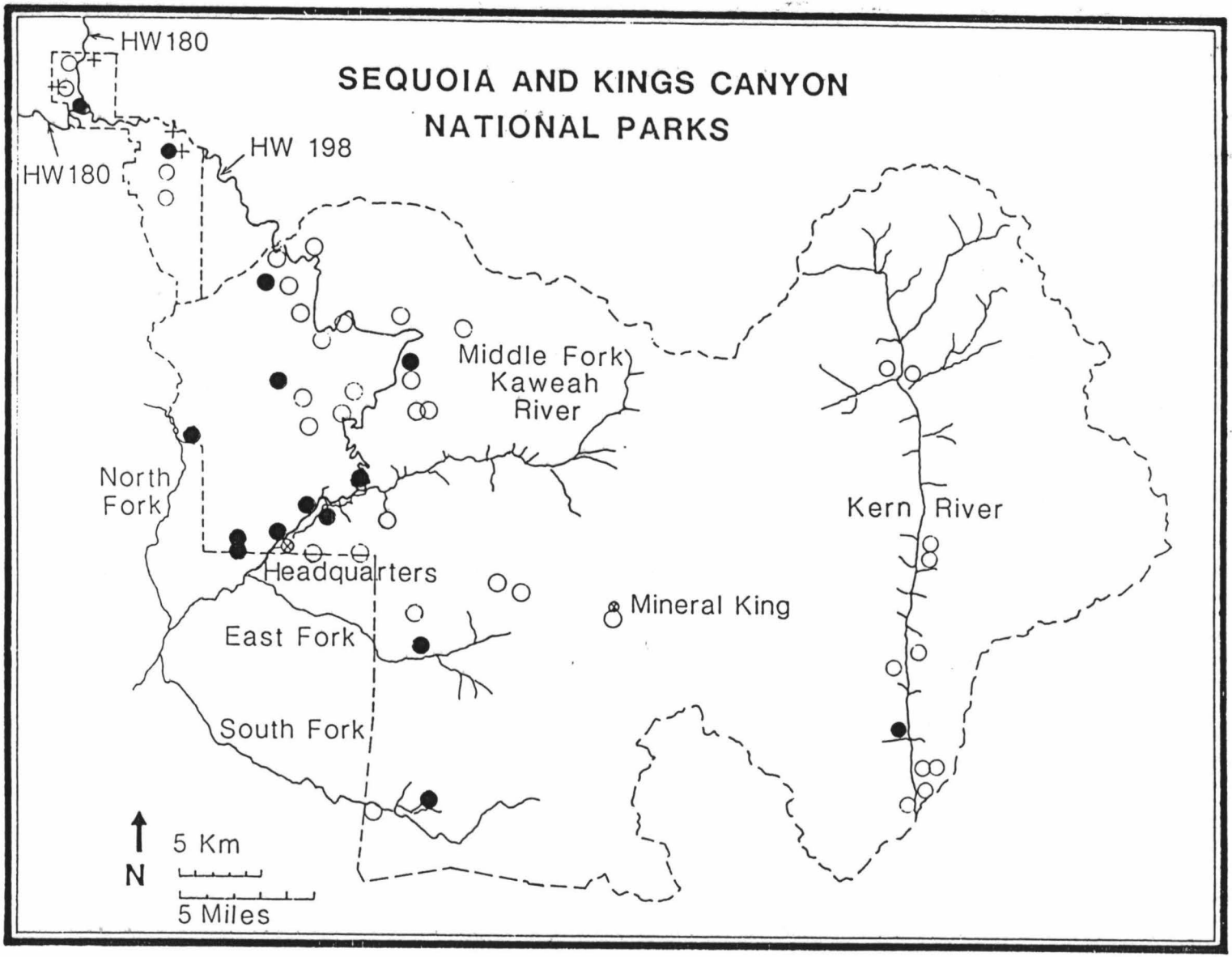

Fig. 3. Candelaria concolor 1984 and 1985

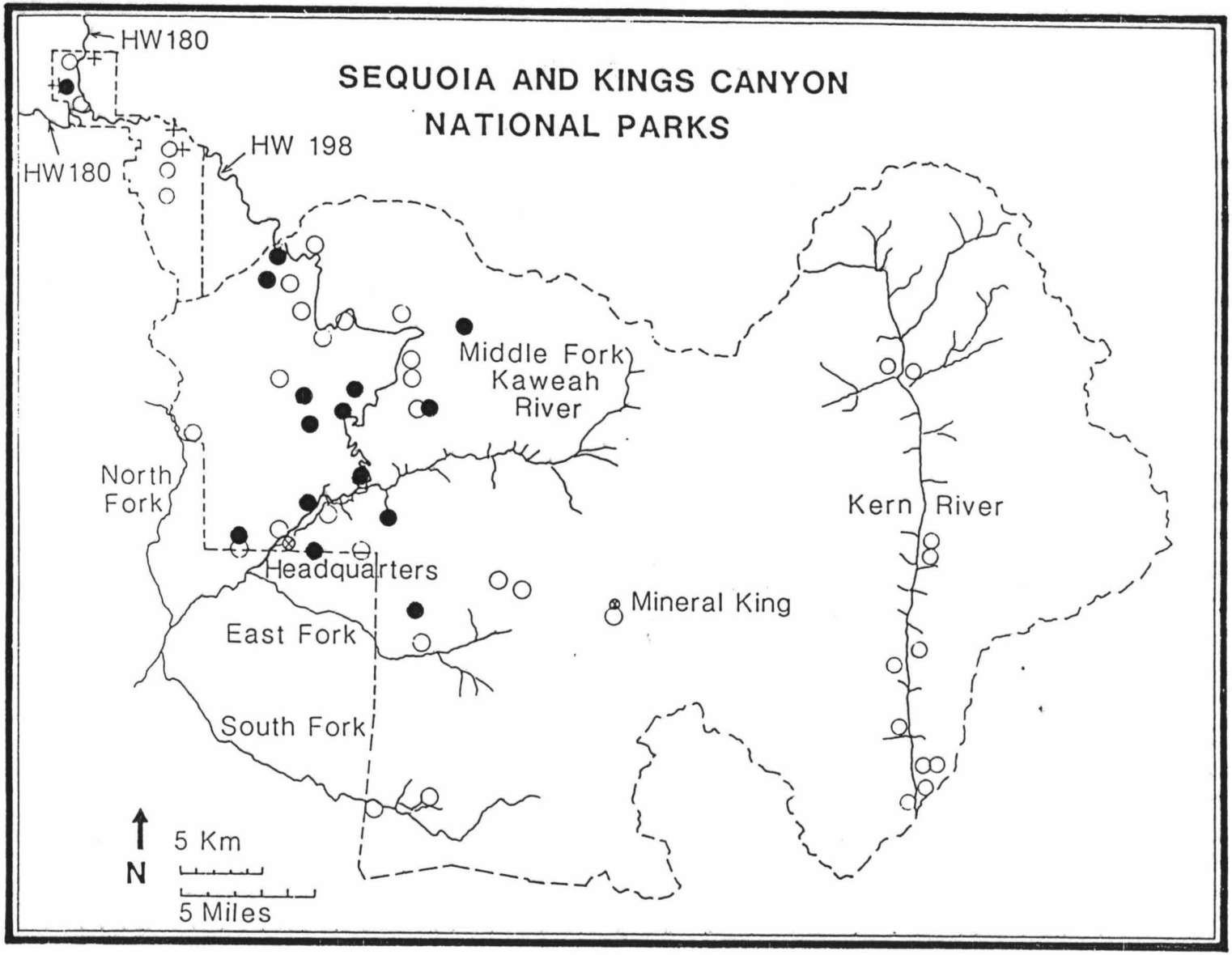

Fig. 4. Cladonia fimbriata 1984 and 1985

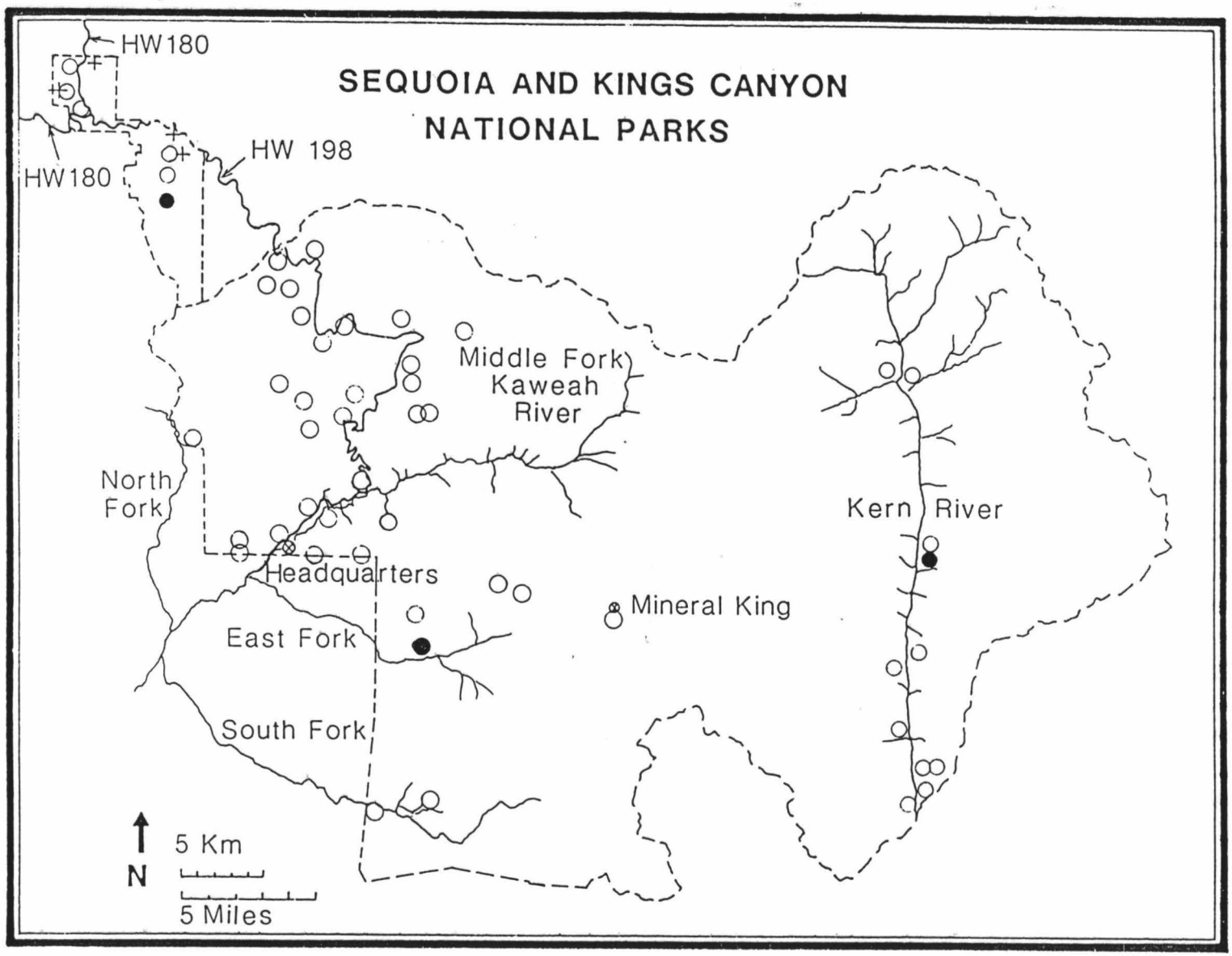

Fig. 5. Normandina pulchella 1984 and 1985

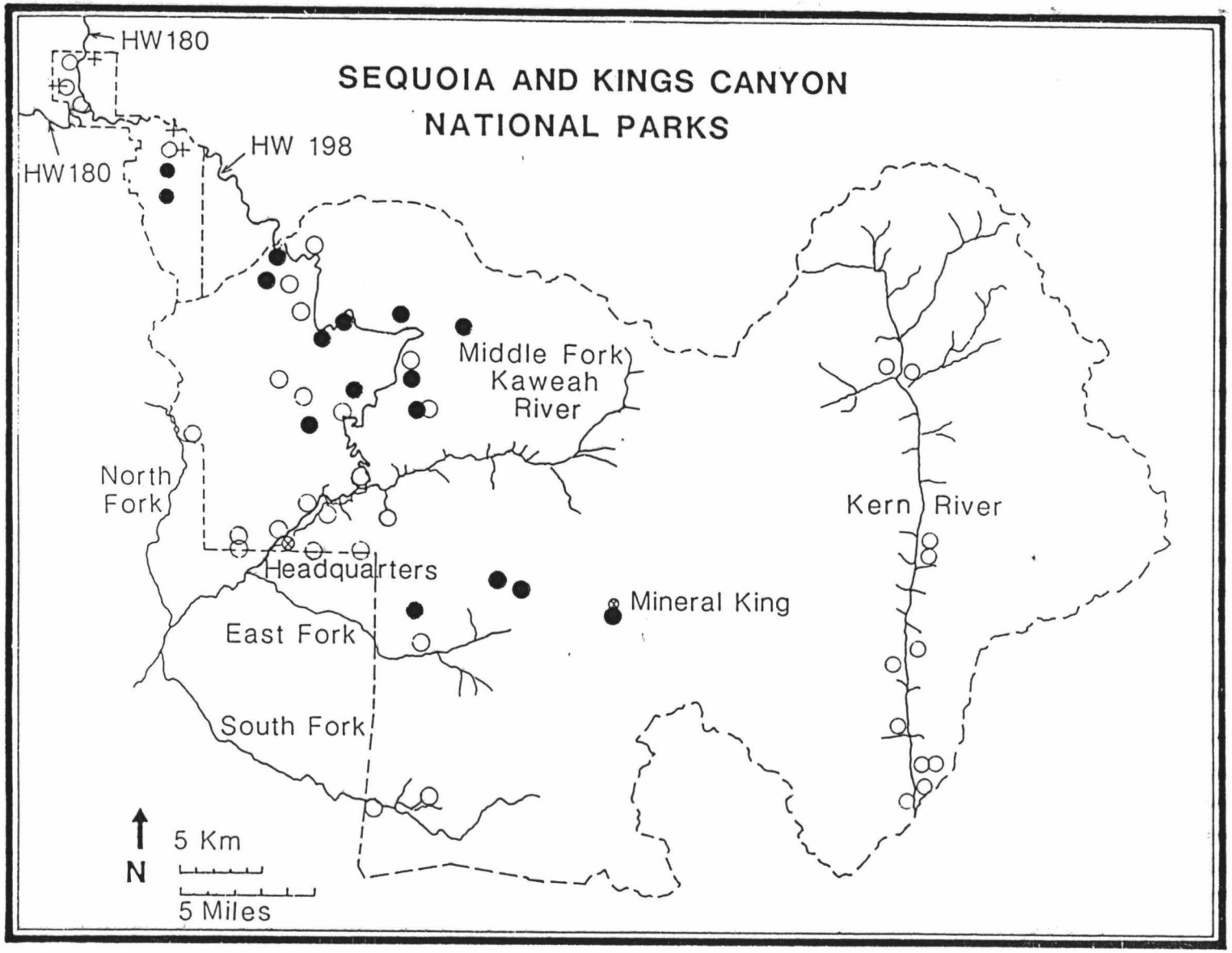

Fig. 6. Ochrolechia androgyna 1984 and 1985

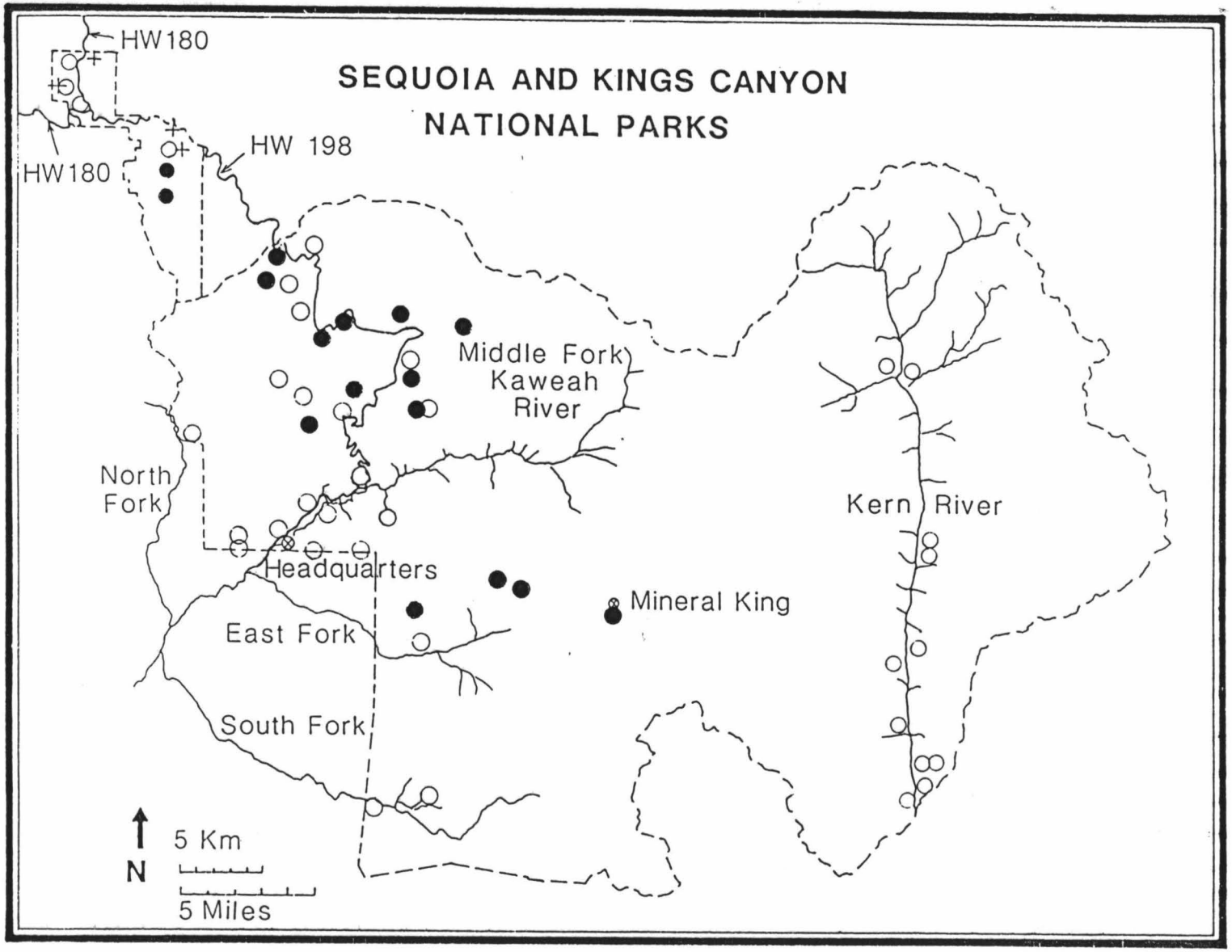

Fig. 6. Ochrolechia androgyna 1984 and 1985

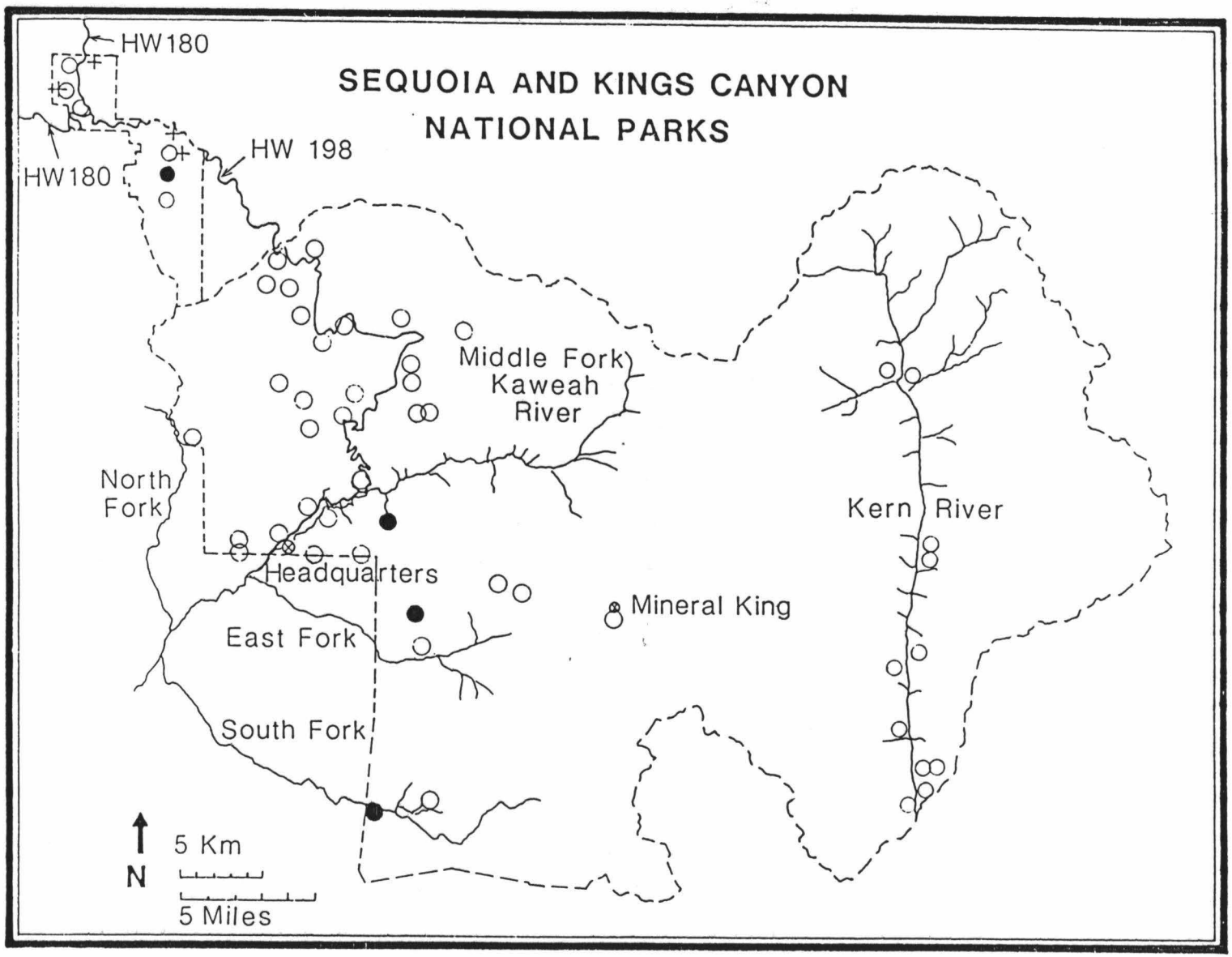

Fig. 7. Ramalina farinacea 1984 and 1985

APPENDIX III

Species listed by localities.

KINGS CANYON NP
Grant Grove
North of Gamlins cabin
Arthonia dispersa
Aspicilia caesiocinerea
Buellia punctata
Calicium adaequatum
Caloplaca cerina
Candelariella rosulans
Candelariella vitellina
Hypogymnia imshaugii
Lecidea auriculata
Lecidea granulosa
Lecidea scalaris
Lecidella euphorea
Leptogium californicum
Letharia vulpina
Massalongia carnosa
Mycocalicium sequoiae
Parmelia subolivacea
Rhizocarpon macrosporum
Umbilicaria phaea

Grant Grove
South on Sequoia Lake Road from North Grove parking lot
Acarospora fuscata
Aspicilia caesiocinerea
Buellia punctata
Caloplaca cerina
Candelariella reflexa
Candelariella rosulans
Candelariella vitellina
Cladonia chlorophaea
Cladonia fimbriata
Hypogymnia imshaugii
Lecanora chlarotera
Lecanora piniperda
Lecidea granulosa
Lecidella euphorea
Letharia vulpina
Parmelia elegantula
Parmelia subelegantula
Parmelia subolivacea
Physcia aipolia
Physcia tenella
Physconia detersa
Placynthiella icmalea
Rhizocarpon macrosporum

Xanthoria candelaria
Xanthoria polycarpa

Grant Grove
West of South Boundary Trail
Aspicilia caesiocinerea
Aspicilia cinereorufescens
Bryoria abbreviata
Caloplaca cerina
Candelaria concolor
Candelariella rosulans
Hypogymnia imshaugii
Lecanora carpinea
Lecanora polytropa
Lecidea atrobrunnea
Lecidea auriculata
Lecidea granulosa
Lecidella euphorea
Letharia columbiana
Letharia vulpina
Massalongia carnosa
Micarea denigrata
Parmelia elegantula
Parmelia subolivacea
Physcia dimidiata
Physcia dubia
Physcia tenella
Physconia enteroxantha
Rhizocarpon geographicum
Rinodina archaea
Umbilicaria phaea
Xanthoria polycarpa

Redwood Canyon
1.5 miles from trailhead on Hart Tree Trail
Acarospora chlorophana
Aspicilia alphoplaca
Aspicilia caesiocinerea
Caloplaca cerina
Candelaria concolor
Candelariella aurella
Candelariella reflexa
Candelariella rosulans
Candelariella vitellina
Dermatocarpon reticulatum
Diploschistes scruposus
Hypogymnia imshaugii
Lecanora carpinea
Lecanora chlarotera
Lecanora hagenii
Lecanora piniperda
Lecidea auriculata
Lecidea glaucopholis

Lecidea globifera
Lecidella euphorea
Leptochidium albociliatum
Leptogium californicum
Letharia vulpina
Massalongia carnosa
Mycocalicium sequoiae
Parmelia cumberlandia
Parmelia elegantula
Parmelia mexicana
Parmelia subolivacea
Parmelia substygia
Phaeophyscia endococcina
Physcia biziana
Physcia caesia
Physcia tenella
Physconia detersa
Physconia enteroxantha
Rhizocarpon bolanderi
Rhizocarpon macrosporum
Rinodina exigua
Umbilicaria phaea
Xanthoria elegans

Redwood Canyon
3 miles south of trailhead on Big Spring Trail
Acarospora badiofusca
Aspicilia caesiocinerea
Bryoria abbreviata
Buellia penichra
Caloplaca yitellinula
Candelariella reflexa
Candelariella vitellina
Cladonia chlorophaea
Dermatocarpon reticulatum
Evernia prunastri
Hypogymnia imshaugii
Koerberia sonomensis
Lecanora carpinea
Lecanora cenisia
Lecanora muralis
Lecanora polytropa
Lecidea aeruginosa
Lecidea anthracophila
Leptochidium albociliatum
Leptogium californicum
Letharia vulpina
Mycocalicium sequoiae
Normandina pulchella
Ochrolechia androgyna
Parmelia elegantula
Peltigera canina
Phaeophyscia endococcina

Physconia enteroxantha
Polychidium muscicola
Rhizocarpon badioatrum
Rinodina exigua

Redwood Canyon
Near Fallen Goliath tree
Aspicilia caesiocinerea
Bryoria abbreviata
Buellia penichra
Caloplaca cerina
Calicium viride
Hypogymnia imshaugii
Lecanora carpinea
Lecanora cenisia
Lecanora chlarotera
Lecanora muralis
Letharia vulpina
Ochrolechia androgyna
Parmelia glabra
Parmelia subolivacea
Parmelia sulcata
Physconia distorta
Placynthiella icmalea
Platismatia glauca
Ramalina farinacea

SEQUOIA NP
Kern Canyon
NW of South Kern Can. Ranger Station along Coyote creek
Aspicilia caesiocinerea
Aspicilia cinereorufescens
Candelariella rosulans
Dermatocarpon reticulatum
Dimelaena thysanota
Lecanora cascadensis
Lecidea atrobrunnea
Lecidea auriculata
Lecidea granulosa
Parmelia elegantula
Parmelia sorediosa
Physcia caesia
Physcia dubia
Placynthiella icmalea
Rhizocarpon bolanderi
Rhizoplaca melanophthalma
Staurothele fuscocuprea
Umbilicaria phaea
Umbilicaria vellea

Kern Canyon
NE of South Kern Can. Ranger Station north of Soda Spring
Aspicilia caesiocinerea

Aspicilia cinereorufescens
Bacidia hegetschweileri
Biatorella microhaema
Candelariella aurella
Candelariella reflexa
Candelariella rosulans
Lecanora cascadensis
Lecanora piniperda
Lecanora saligna
Lecidea atrobrunnea
Lecidea auriculata
Lecidella stigmatea
Letharia vulpina
Parmelia substygia
Peltigera scabrosa
Physcia tenella
Pseudephebe pubescens
Rhizocarpon bolanderi
Rhizocarpon disporum
Rhizoplaca melanophthalma
Umbilicaria cinereorufescens
Umbilicaria torrefacta
Xanthoria polycarpa

Kern Canyon (two localities)
1 mile NE of South Kern Can. Ranger Station on E bank Kern R.
Acarospora badiofusca
Aspicilia caesiocinerea
Candelariella rosulans
Dimelaena thysanota
Lecanora cascadensis
Lecidea atrobrunnea
Lecidea auriculata
Letharia vulpina
Parmelia elegantula
Parmelia mexicana
Parmelia plittii
Parmelia sorediosa
Parmelia substygia
Physcia biziana
Physcia dubia
Pseudephebe pubescens
Rhizocarpon bolanderi
Rhizocarpon geographicum
Rhizocarpon grande
Rhizoplaca melanophthalma
Umbilicaria phaea
Umbilicaria vellea
Xanthoria elegans

Kern Canyon
Lower Funston Meadow
Acarospora badiofusca

Aspicilia caesiocinerea
Bjatorella microhaema
Candelaria concolor
Candelariella rosulans
Dimelaena thysanota
Lecanora cascadensis
Lecanora piniperda
Lecidea atrobrunnea
Lepraria finkii
Parmelia elegantula
Parmelia mexicana
Parmelia substygia
Parmelia sulcata
Phaeophyscia endococcina
Physcia adscendens
Physcia dimidiata
Physcia dubia
Physcia tenella
Rhizoplaca melanophthalma
Umbilicaria phaea
Xanthoria candelaria

Kern Canyon
Quarter mile south of Rattlesnake Creek
Acarospora radicata
Aspicilia caesiocinerea
Caloplaca epithallina
Candelariella aurella
Dimelaena thysanota
Lecanora cascadensis
Lecidea atrobrunnea
Lecidea auriculata
Lecidea granulosa
Lecidella stigmatea
Parmelia cumberlandia
Parmelia disjuncta
Phaeophyscia endococcina
Physcia caesia
Physcia dimidiata
Physcia dubia
Pseudephebe pubescens
Rhizocarpon bolanderi
Rhizocarpon disporum
Rhizocarpon geographicum
Rhizoplaca melanophthalma
Umbilicaria cinereorufescens
Umbilicaria phaea
Xanthoria elegans

Kern Canyon
Quarter mile north of Rattlesnake Creek
Aspicilia caesiocinerea
Aspicilia cinereorufescens

Buellia turgescens
Candelariella vitellina
Dimelaena thysanota
Lecanora cascadensis
Lecanora piniperda
Lecanora saligna
Lecidea atrobrunnea
Lecidea granulosa
Lecidella stigmatea
Letharia vulpina
Physcia dimidiata
Physcia dubia
Rhizocarpon geographicum
Umbilicaria phaea
Xanthoria sorediata

Kern Canyon
Kern Hot Springs, south bank of Rock Creek
Acarospora americana
Acarospora badiofusca
Acarospora radicata
Aspicilia caesiocinerea
Caloplaca stillicidiorum
Dermatocarpon miniatum
Dermatocarpon reticulatum
Lecanora cascadensis
Lecidella stigmatea
Leptochidium albociliatum
Leptogium californicum
Normandina pulchella
Parmelia elegantula
Parmelia subargentifera
Phaeophyscia endococcina
Physconia detersa
Rhizocarpon geographicum
Rhizocarpon macrosporum
Umbilicaria phaea
Umbilicaria vellea
Xanthoria elegans

Kern Canyon
Kern Hot Springs, north bank of Rock Creek
Acarospora radicata
Candelariella rosulans
Dimelaena thysanota
Lecanora cascadensis
Lecanora rupicola
Lecidea auriculata
Lecidea atrobrunnea
Leptogium californicum
Parmelia cumberlandia
Parmelia plittii
Parmelia substygia

Phaeophyscia orbicularis
Physconia detersa
Physconia enteroxantha
Rhizocarpon bolanderi
Rhizocarpon geographicum
Rhizocarpon grande
Umbilicaria phaea
Umbilicaria vellea
Xanthoria elegans

Kern Canyon
1 mile NW of Junction Meadow on Colby Pass Trail
Acarospora radicata
Aspicilia caesiocinerea
Candelariella rosulans
Dermatocarpon reticulatum
Lecanora cascadensis
Lecidea atrobrunnea
Parmelia cumberlandia
Parmelia mexicana
Parmelia plittii
Parmelia substygia
Peltula bolanderi
Physcia caesia
Rhizocarpon bolanderi
Rhizocarpon disporum
Rhizoplaca melanophthalma
Umbilicaria phaea
Xanthoria elegans

Kern Canyon
Junction Meadow east of Upper Kern Trail
Aspicilia caesiocinerea
Candelariella rosulans
Dermatocarpon reticulatum
Dimelaena thysanota
Lecanora cascadensis
Lecidea atrobrunnea
Lecidea auriculata
Parmelia substygia
Physcia biziana
Physcia caesia
Physcia stellaris
Rhizocarpon macrosporum
Rhizoplaca melanophthalma
Umbilicaria phaea
Xanthoria elegans