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LICHENS AND AIR QUALITY in VOYAGEURS NATIONAL PARK

FINAL REPORT

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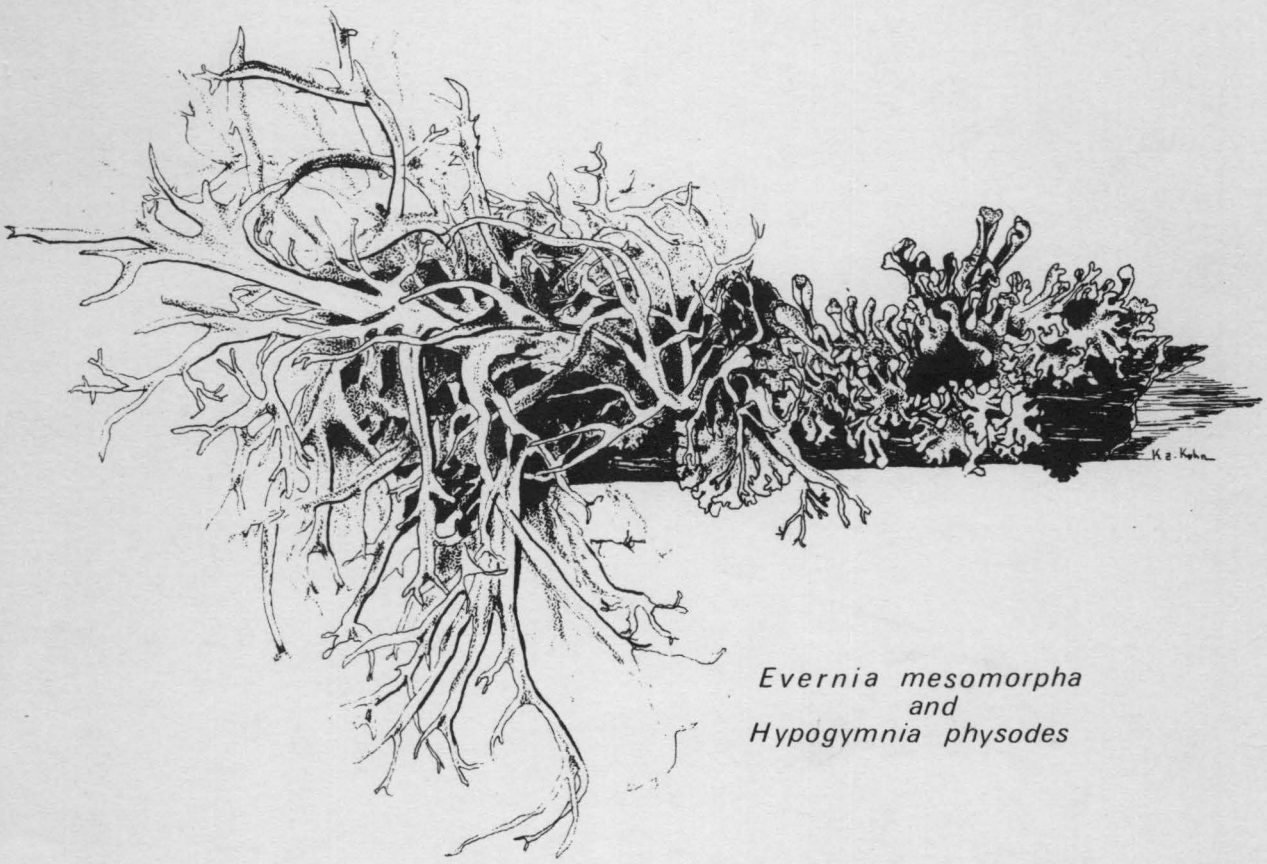

Evernia mesomorpha
and
Hypogymnia physodes

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JUNE 1983

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Final Report

National Park Service
Contract CX 0001-2-0034

National Park Service Contracting Officer
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June 1983

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PREFACE

Under contract USDI CX 0001-2-0034 with the National Park Service, Division of Air Quality, one of the reports to be produced is an evaluation of the lichen flora of Voyageurs National Park for indications of air quality effects and the designation of species that are sensitive to sulfur dioxide which should be monitored for long term air quality changes. This report supplements work originally done under NPS contracts PX 6000-7-0922 and PX 6000-8-0922. All work has been done at the University of Minnesota with frequent consultation with Dr. James Bennett, NPS-AIR, Denver. Susan Miller assisted in the preparation of this report.

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 dewfall. 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 µg/cubic meter (annual average) or by nitrigen oxides at 3834-7668 µg/cubic meter or by other strongly oxidizing compounds such as ozone. 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.

PREVIOUS STUDIES

Wetmore (1981) summarizes previous work in Voyageurs and reports on the studies of the lichen flora done for the National Park Service from 1978 to 1980. Briefly, collections were made at two localities in what is now Voyageurs National Park in 1901 by Bruce Fink. His collections were made before logging so they represent nearly the original lichen flora.

His collections are preserved in the University of Minnesota Herbarium and were restudied and included in the report by Wetmore (1981).

In 1978 and 1979 Clifford Wetmore collected extensively in Voyageurs. Over 8000 collections were made at 128 different localities in the park. At each locality specimens of all species observed were collected. These collection localities are indicated by open circles on the maps. The report to the National Park Service was submitted in October, 1980 and subsequently published and included over 400 taxa of lichens for the park (Wetmore, 1981). Brief comments were included about the disappearance of some species since Fink's collecting. It was noted that there is probably no significant air pollution because the genera Usnea, Bryoria, Evernia and Cladonia were abundant in all parts of the park. The disappearance of species was attributed mainly to logging and the destruction of habitats.

This report supplements the previous report by providing information and discussion of the lichens of the park in relation to air pollution, especially sulfur dioxide.

DISCUSSION OF THE FLORA

Evaluation of the lichen flora of an area by floristic methods can be done by comparing the present lichen flora with historical records to see whether the species most sensitive to air pollution are still present. If historical records are not available, the flora of the area in question can be compared with the lichen flora of a nearby area with similar ecological conditions. The latter method is less accurate

because of the question of whether another nearby area is really comparable. In Voyageurs it is fortunate that there are historical collections made by Fink in 1901 when the area was in its near-virgin state. As stated in the previous report (Wetmore, 1981), only eight species found by Fink were not found by the recent study. These species are: Arthonia dispersa, Buellia alboatra, Buellia dialyta, Caloplaca saxicola, Chaenothecopsis rubescens, Dermatocarpon tuckermanii, Sticta weigelii and Usnea longissima. According to the the list of lichens with known sensitivity to sulfur dioxide (Wetmore, 1983), only Buellia alboatra is listed and it is in the Intermediate category. Based on the known sensitivities of related species, Sticta wiegelii and Usnea longissima are probably in the Sensitive category. Sticta weigelii has not been collected in Minnesota since the forests were logged near the beginning of this century and Usnea longissima is found today only in northeastern Minnesota in old forests and near the shore of Lake Superior. The other species that were not found in the recent study are small, rare species that could have been missed or they are species restricted to old undisturbed forests, which are completely lacking in the park today. Therefore it is not likely that these species have been eliminated by adverse air quality.

A second way of checking for pollution effects is to look at species diversity of the flora. A more diverse flora which includes the sensitive species as well as the tolerant species indicates a lack of pollution while a flora with low diversity

and few sensitive species might indicate the presence of adverse air quality. In using this test it is important to compare the floras of comparable areas with similar ecological conditions and near enough to the areas in question so that species distributions will not be a factor. The lichen flora of Voyageurs is quite diverse and includes many species that are sensitive to sulfur dioxide. It has a lichen flora comparable with other parts of northern Minnesota based on my previous studies in Minnesota and is also similar to the lichen flora of Isle Royale National Park (Wetmore, 1983). Isle Royale, however, is more moist and has much more lake fog than Voyageurs and has more species while Voyageurs is more continental in climate. Likewise, the north shore of of Minnesota along Lake Superior is more moist and has some species not found in Voyageurs. Given its inland position, Voyageurs has a very diverse lichen flora. This again indicates that there is no adverse air quality impact on the lichen flora of Voyageurs.

Another way of analyzing the the lichen flora of an area is to study the distributions of the sensitive species to look for voids in the distributions which might be caused by pollution. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors (Showman, 1975). In Appendix I are listed the species in the Sensitive and Sensitive-Intermediate categories based on the sensitivity list provided in the report on the lichens of the parks (Wetmore, 1983). The following species have been mapped on the base map of collection localities in the park

(Appendix II).

Bryoria furcellata, common on trees
Bryoria trichodes, grows in moist balsam fir forests
Calpolaca cerina, mainly on bark of hardwoods
Candelaria concolor, on tree bark and wood
Candelariella xanthostigma, a rare species
Cladonia fimbriata, a rare species
Dimerella lutea, an uncommon species of wet swamps
Lecidea nylanderi, an inconspicuous crust on pine bark
Lecidea vernalis, grows on moss at tree bases
Lobaria pulmonaria, very sensitive but uncommon, in swamps
Normandina pulchella, a rare species of wet areas
Ochrolechia rosella, growns on pine bark
Opegrapha pulicaris, a rare species
Parmelia plittii, a rare species growing on rocks
Parmelia squarrosa, common on trees and rocks
Parmelia subaurifera, common on trees
Ramalina americana, common, mainly on hardwoods
Usnea filipendula, uncommon in old balsam fir forests
Usnea hirta, common, especially on pines
Usnea subfloridana, common, especially on pines
Xanthoria fallax, on various substrates, not really a sensitive species

Not all voids in the distribution patterns are due to air quality effects. Some species may be too rare to be of value (Showman, 1975) such as Candelariella xanthostigma, Cladonia fimbriata, Normandina pulchella, Opegrapha pulicaris and Parmelia plittii. Some of the localities where a sensitive species is absent may not have suitable habitats or may not have the substrates required by that species. Under present conditions the most likely source of air pollution is International Falls area and the wood products plant there. The western edge of the park is only about 12 miles downwind (east) of International Falls. None of these distribution maps shows any indication that there are voids in the distributions in the western end of the park due to air quality factors. The only exception might be Bryoria trichodes which seems to be

absent from the western part of the park. However, Bryoria furcellata, Lobaria pulmonaria, Lecidea vernalis, Lecidea nylanderi and Ramalina americana are just as sensitive as Bryoria trichodes and they do not show this void in the western part of the park, so the distribution of B. trichodes must be due to other factors. In addition to voids in the distributions, field observations while collecting did not reveal more lichen damage and death in the western part of the park than in the eastern part.

Another method of assessing the effects of air quality is by examining the elemental content of the lichens. Elevated but sublethal levels of sulfur or other elemnts might indicate incipient damaging conditions. At the present time no specimens are availble for chemical analysis but these will be collected and analyzed and the results submitted in a supplement to this report later this year.

CONCLUSIONS

There seems to be no indication of air pollution in Voyageurs that has an effect on the lichen flora. The park has a rich and diverse flora, the species found in 1901 but not in 1980 are more likely absent because of changes in the forests rather than air pollution, the lichen flora includes most of the species found in similar and comparable areas in this region, and there are no voids in the distribution of the sensitive species that are not due to absence of suitable habitats or substrates. This study provides a baseline which can be used in a future study after the new generating plants begin operation in Canada north of the park or after any

further industrial development in the International Falls area.

FURTHER STUDIES

With the construction of the power generating plants in Ontario north of the park is will be necessary to evaluate their impact on the air quality of the park. In order to detect the first subtile effects it would be desirable to have more detailed quantitative data on the present lichen flora. Permanent plots should be established at several places in the park and the lichens quantitatively studied for frequency and cover. Plots should be established in the Kettle Falls area and the Rainy Lake City area as well as in the southeastern corner of the park and perhaps in the Junction Bay area. Since the Thuja and black spruce bogs and the balsam fir forests have the greatest numbers of very sensitive species, the plots should be located in these vegetational types. Additional species should be chemically analyzed to establish a broader base for later study.

SUMMARY

This report is based on the previous thorough lichen collecting done in the park by the present author and a restudy of the historical collections made by Fink in 1901. By all methods of analysis of the lichen flora there is no indication of air pollution on the lichens of the park. The lichen flora is diverse, shows no voids in the distributions of the most sensitive species and the flora includes the sensitive species normally found in comparable areas nearby.

Suggestions are made for the establishment of permanent plots for quantitative study to provide a more sensitive baseline as further pollution sources become established.

LITERATURE CITED

Showman, R. E. 1975. Lichens as indicators of air quality around a coal-fired power generating plant. Bryologist 78:1-6.

Wetmore, C. M. 1981. Lichens of Voyageurs National Park, Minnesota. Bryologist 84:482-491.

Wetmore, C. M. 1982. Lichen decomposition in a black spruce bog. Lichenologist 14:267-271.

Wetmore, C. M. 1983. Lichens in the air quality class 1 National Parks. Report submitted to National Park Service, Air Quality Division, Denver.

APPENDIX I

Lichens Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivety compiled from the literature, the following species in ~~Theodore Roosevelt~~ Voyageurs National Park fall within the sensitive and sensitive/intermediate categories. Sensitive species (S) are those present only under 50 µg sulfur dioxide per cubic meter (average annual). The intermediate category (I) includes species present between 50 µg and 100 µg and the tolerant category (T) is for species present at over 100 µg/cubic meter average annual levels. The S-I group falls between the Sensitive and Intermediate categories and the I-T group is between the Intermediate and Tolerant categories.

Alphabetical List of Species

Sen. Cat.	Species
I	*Arthonia radiata* (Pers.) Ach.
I	*Bacidia chlorococca* (Graewe ex Stenh.) Lett.
I	*Bacidia rubella* (Hoffm.) Mass.
S	*Bryoria furcellata* (Fr.) Brodo & Hawksw.
S	*Bryoria trichodes* (Michx.) Brodo & Hawksw.
I	*Buellia alboatra* (Hoffm.) Branth & Rostr.
T	*Buellia punctata* (Hoffm.) Mass.
I	*Buellia stillingiana* J. Stein.
S-I	*Caloplaca cerina* (Ehrh.) Th. Fr.
I	*Caloplaca holocarpa* (Hoffm.) Wade
I-T	*Caloplaca vitellinula* (Nyl.) Oliv.
S-I	*Candelaria concolor* (Dicks.) B. Stein
I	*Candelariella vitellina* (Ehrh.) Müll. Arg.
S-I	*Candelariella xanthostigma* (Ach.) Lett.
I	*Cetraria orbata* (Nyl.) Fink
I	*Cetraria pinastri* (Scop.) S. Gray
I	*Cetraria sepincola* (Ehrh.) Ach.
I	*Chaenotheca ferruginea* (Turn. & Borr.) Mig.
I	*Cladonia coniocraea* (Flörke) Spreng.
I	*Cladonia cristatella* Tuck.
S-I	*Cladonia fimbriata* (L.) Fr.

S Dimerella lutea (Dicks.) Rev.
I Evernia mesomorpha Nyl.
I Graphis scripta (L.) Ach.
I Lecanora allophana Nyl.
I Lecanora coilocarpa auct.
T Lecanora muralis (Schreb.) Rabenh.
I Lecanora pallida (Schreb.) Rabenh. var. rubescens Imsh. & Brodo
I Lecanora saligna (Schrad.) Zahlbr.
I Lecanora symmictera Nyl.
S Lecidea nylanderi (Anzi) Th. Fr.
I Lecidea scalaris (Ach.) Ach.
S Lecidea vernalis (L.) Ach.
I Lecidella elaeochroma (Ach.) Hazsl.
S Lobaria pulmonaria (L.) Hoffm.
I Mycoblastus sanguinarius (L.) Norm.
S-I Normandina pulchella (Borr.) Nyl.
S Ochrolechia rosella (Tuck.) Vers.
S Opegrapha pulicaris (Hoffm.) Schrad.
I Parmelia caperata (L.) Ach.
I Parmelia exasperatula Nyl.
I Parmelia glabratula Lamy
I Parmelia olivacea (L.) Ach.
S Parmelia plittii Gyeln.
I Parmelia revoluta Flörke
I Parmelia rudecta Ach.
I Parmelia septentrionalis (Lynge) Ahti
S Parmelia squarrosa Hale
I-T Parmelia subargetifera Nyl.
S Parmelia subaurifera Nyl.
I Parmelia subrudecta Nyl.
I-T Parmelia sulcata Tayl.
I Parmelia trabeculata Ahti
I Parmeliopsis aleurites (Ach.) Nyl.
I Parmeliopsis ambigua (Wulf.) Nyl.
I Parmeliopsis hyperopta (Ach.) Arn.
I Peltigera horizontalis (Huds.) Baumg.
I Pertusaria amara (Ach.) Nyl.
I Pertusaria multipunctoides Dibben
I Phlyctis argena (Spreng.) Flot.
I Physcia adscendens (Th. Fr.) Oliv.
I Physcia aipolia (Ehrh.) Hampe
I Physcia dubia (Hoffm.) Lett.
I Physcia millegrana Degel.
I Physcia stellaris (L.) Nyl.
I Physconia detersa (Nyl.) Poelt
S Ramalina americana Magn. ex Hale
I Ramalina dilacerata (Hoffm.) Hoffm.
I Rinodina exigua (Ach.) S. Gray
I Stenocybe major Nyl. ex Körb.
S Usnea filipendula Stirt.
S-I Usnea hirta (L.) Wigg.
S-I Usnea subfloridana Stirt.
S-I Xanthoria fallax (Hepp) Arn.
I Xanthoria polycarpa (Ehrh.) Oliv.

APPENDIX II

Maps of Sensitive Species

Bryoria furcellata, common on trees
Bryoria trichodes, grows in moist balsam fir forests
Calpolaca cerina, mainly on bark of hardwoods
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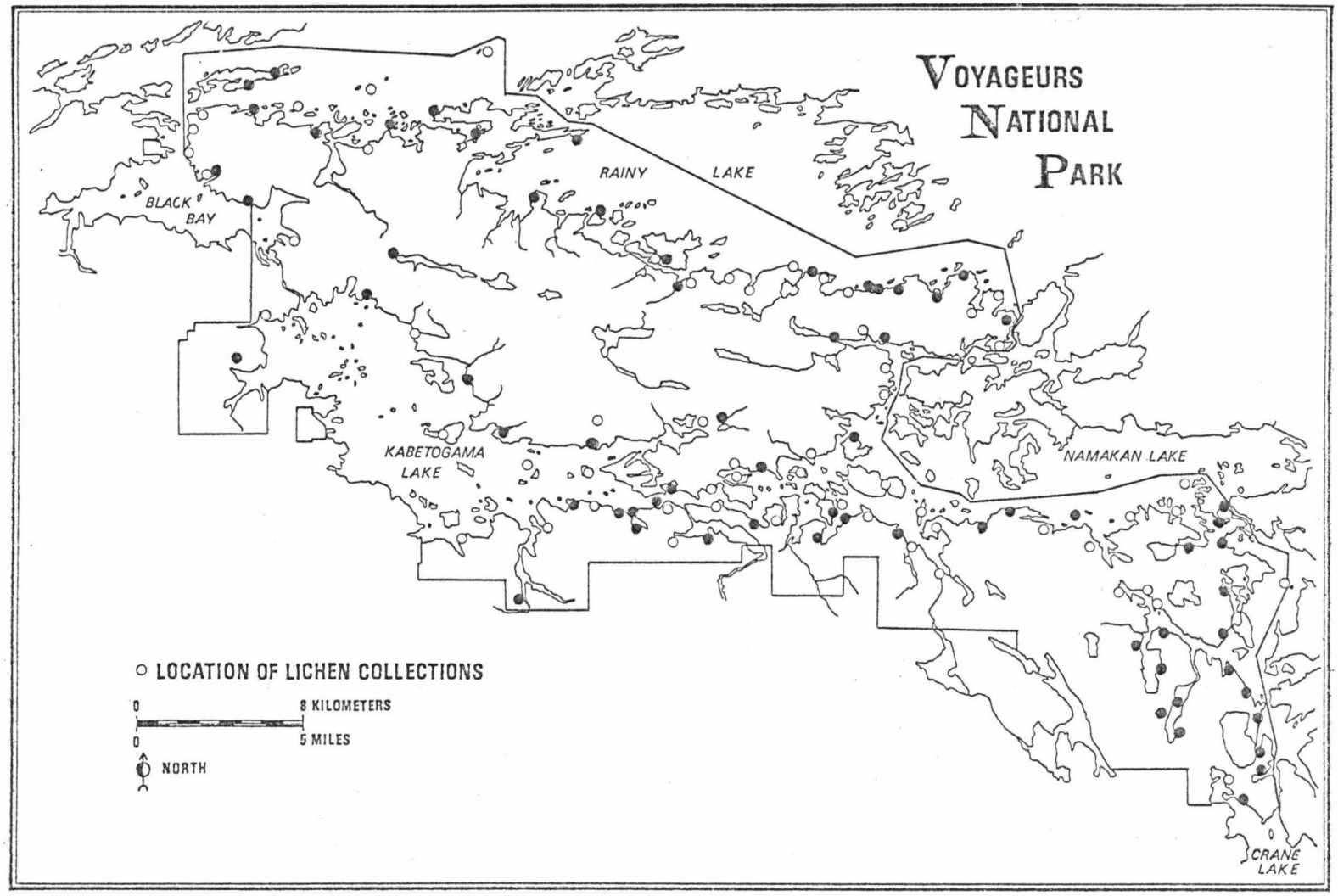
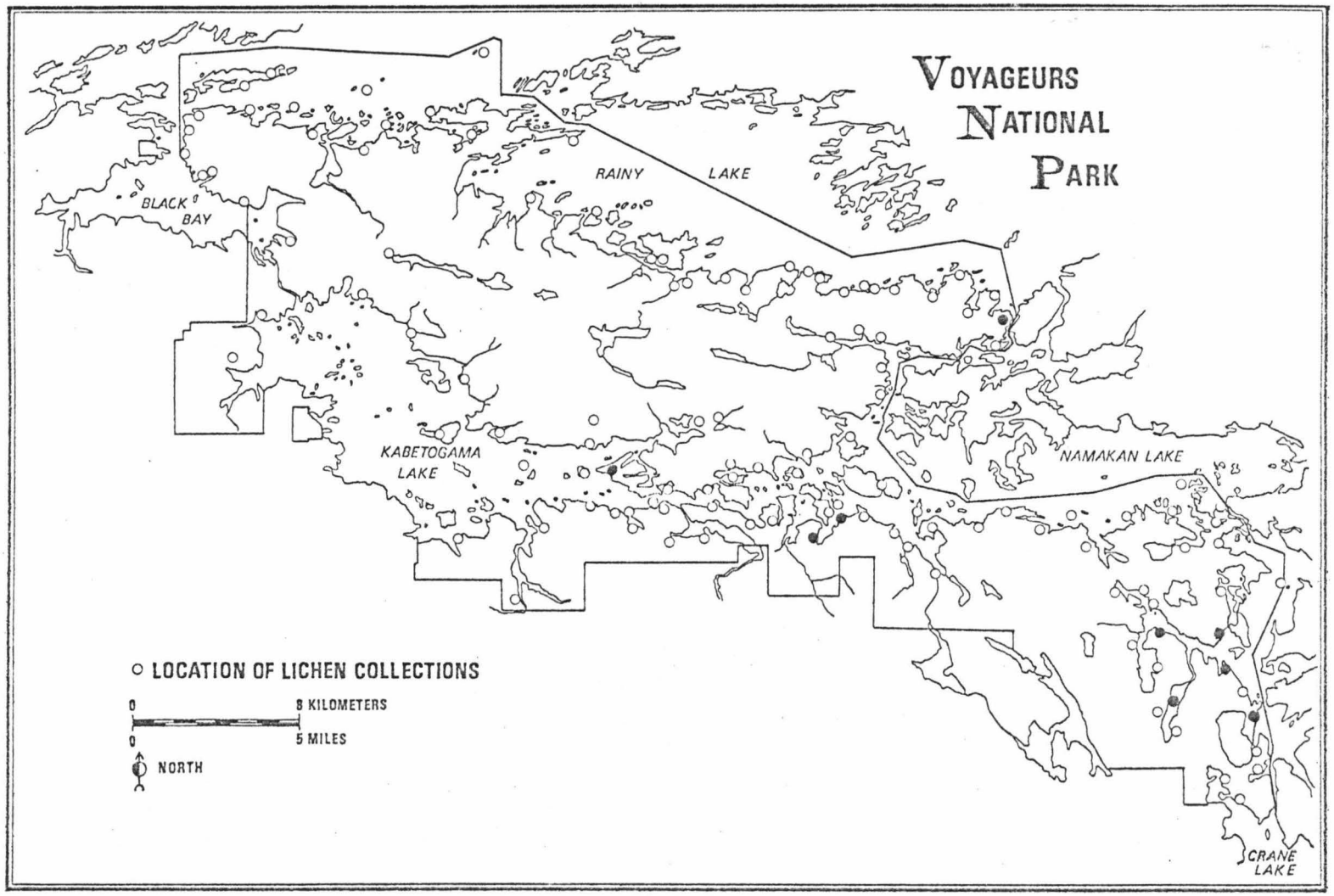
Usnea filipendula, uncommon, in wet balsam fir forests
Usnea hirta, common, especially on pines
Usnea subfloridana, common, especially on pines
Xanthoria fallax, on various substrates, not really a sensitive species

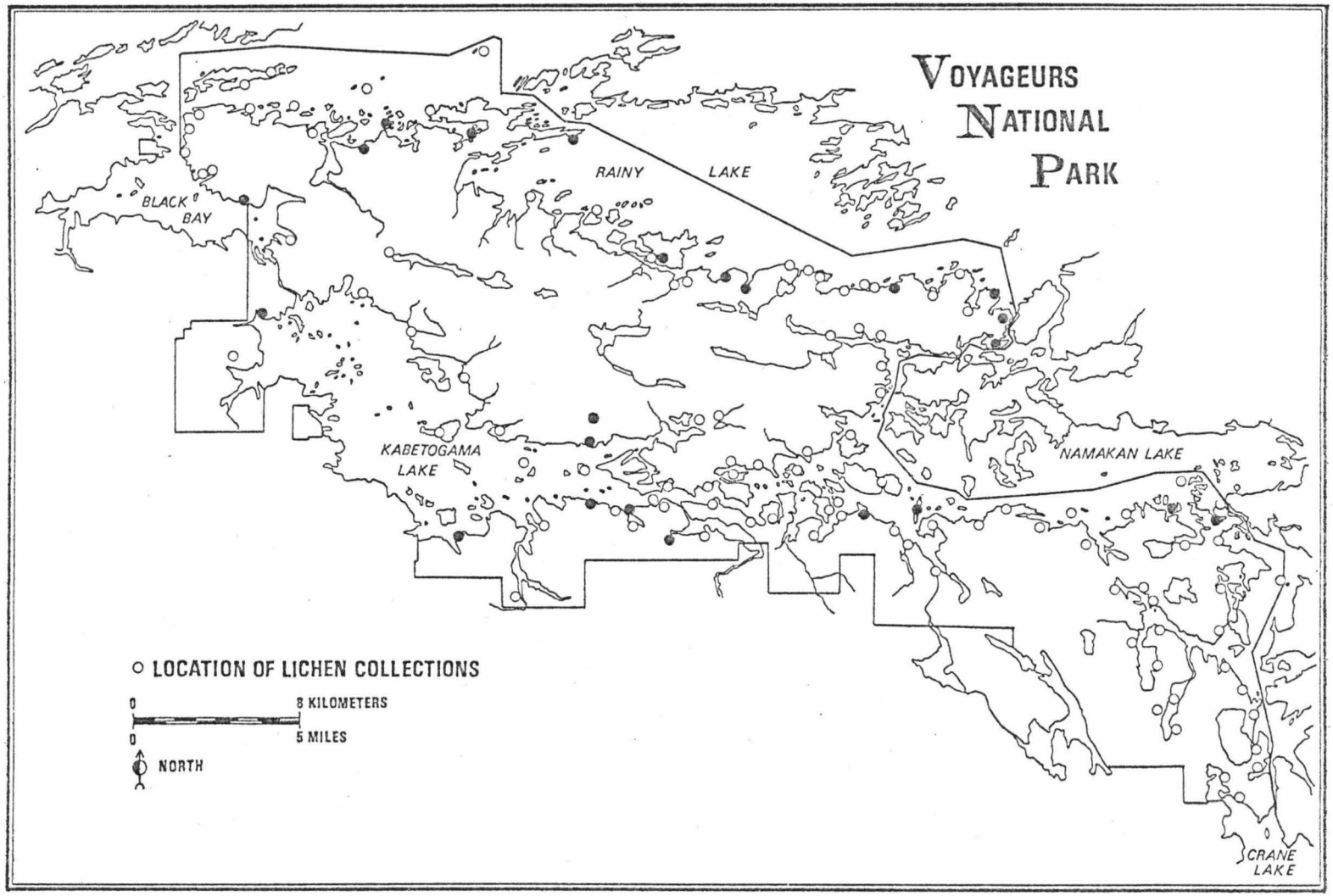
Note: Refer to text for interpretation of these maps and precautions concerning absence in parts of the park.

Bryoria furcellata



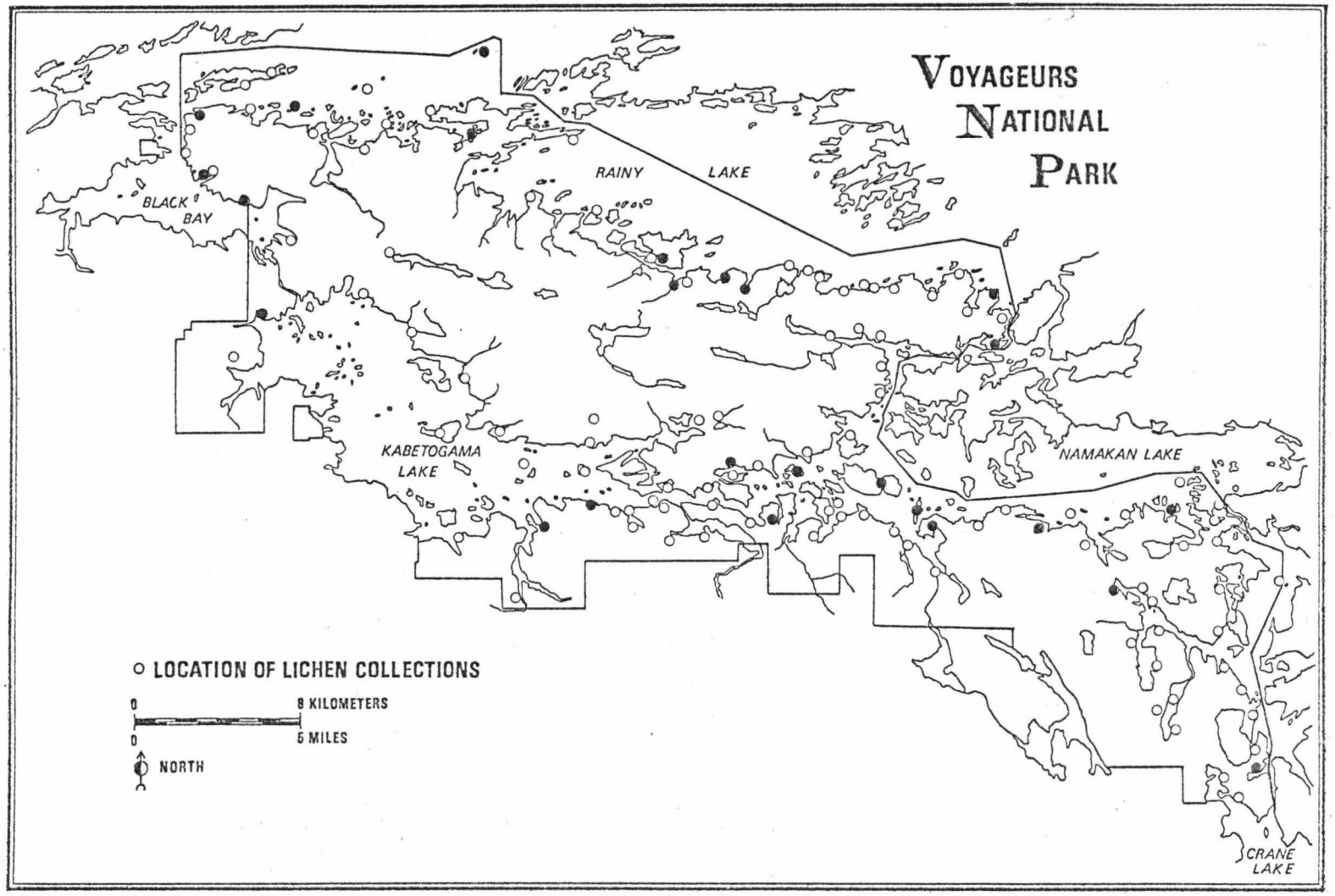


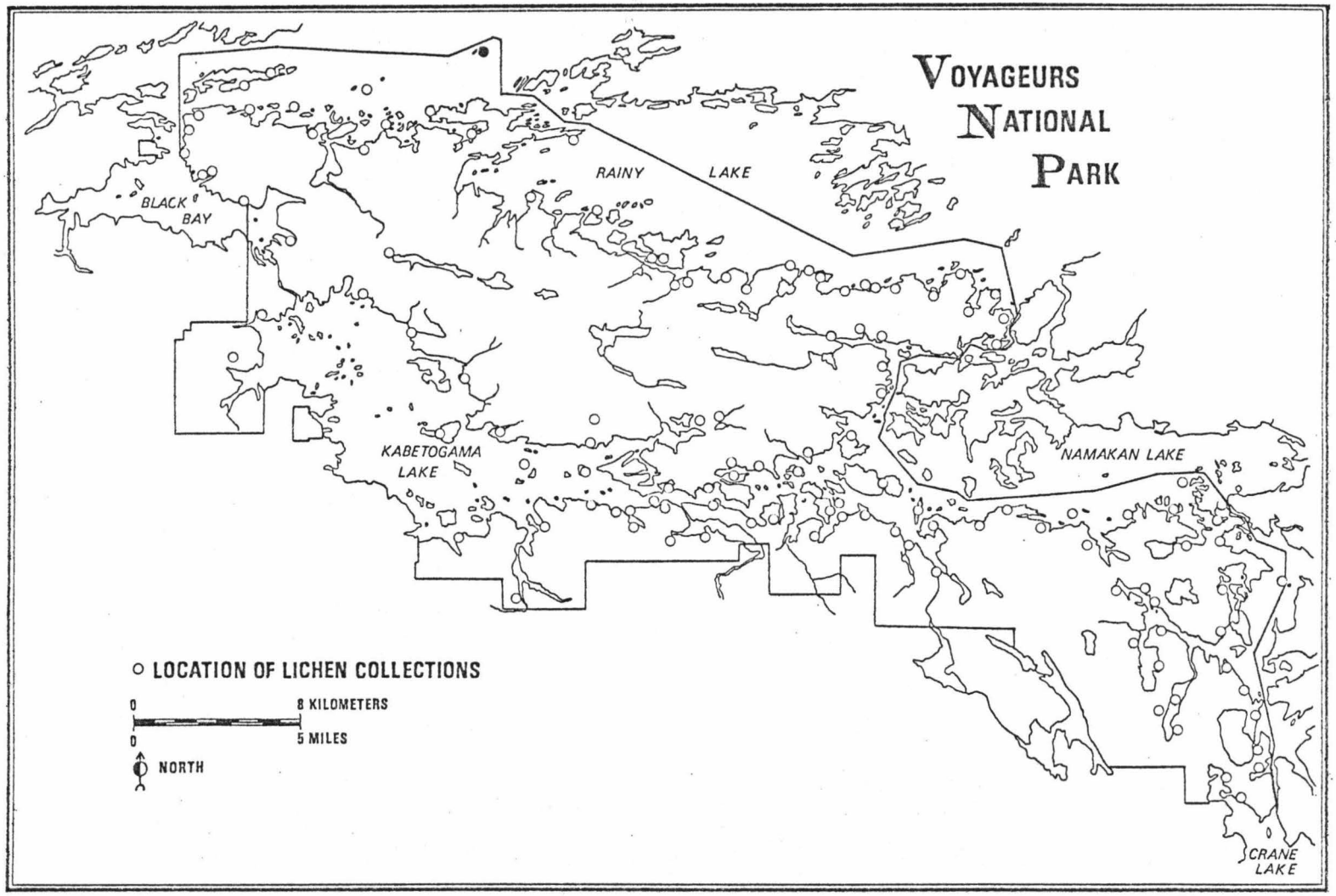
Bryoria trichodes



Caloplaca cerina

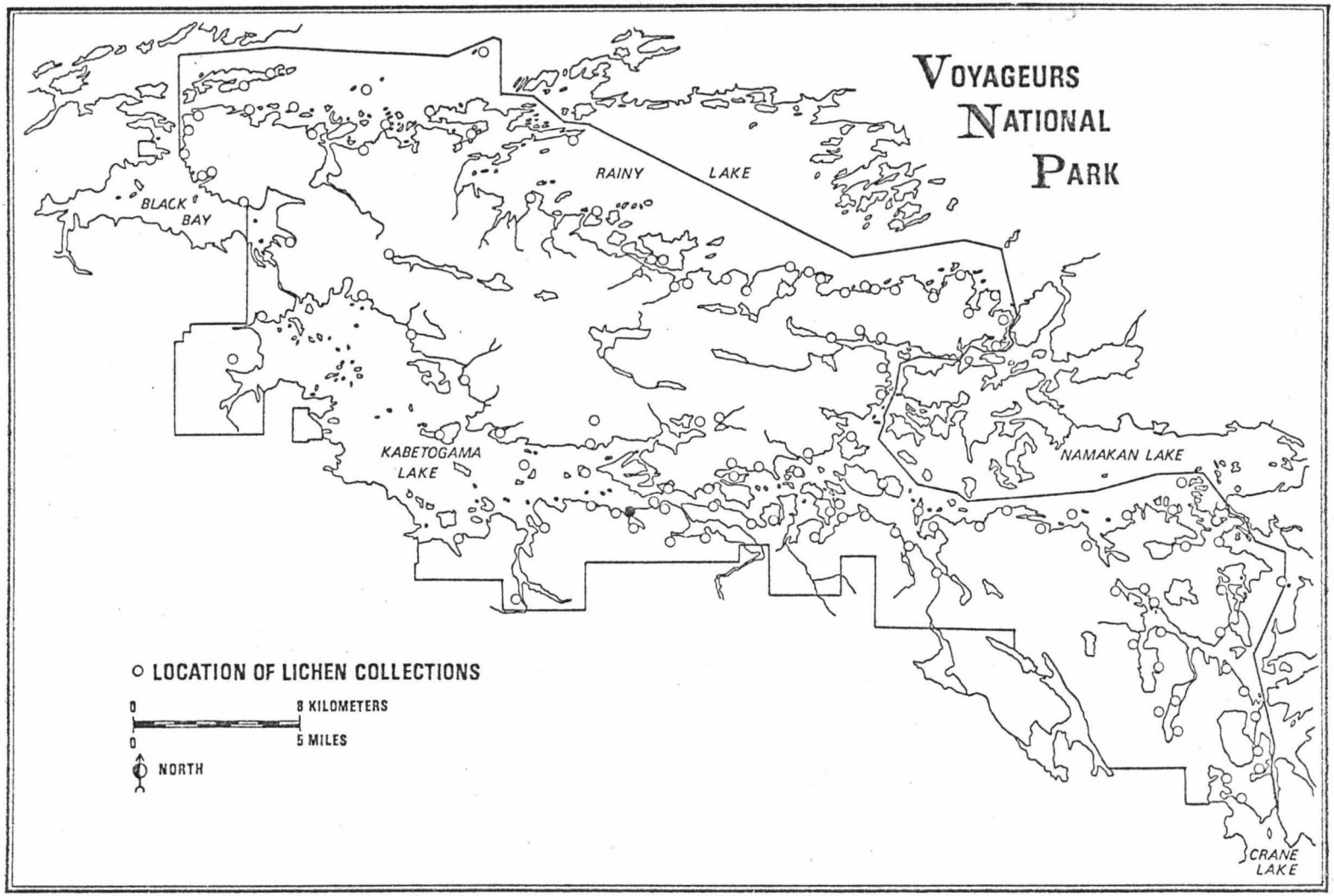
Candelaria concolor



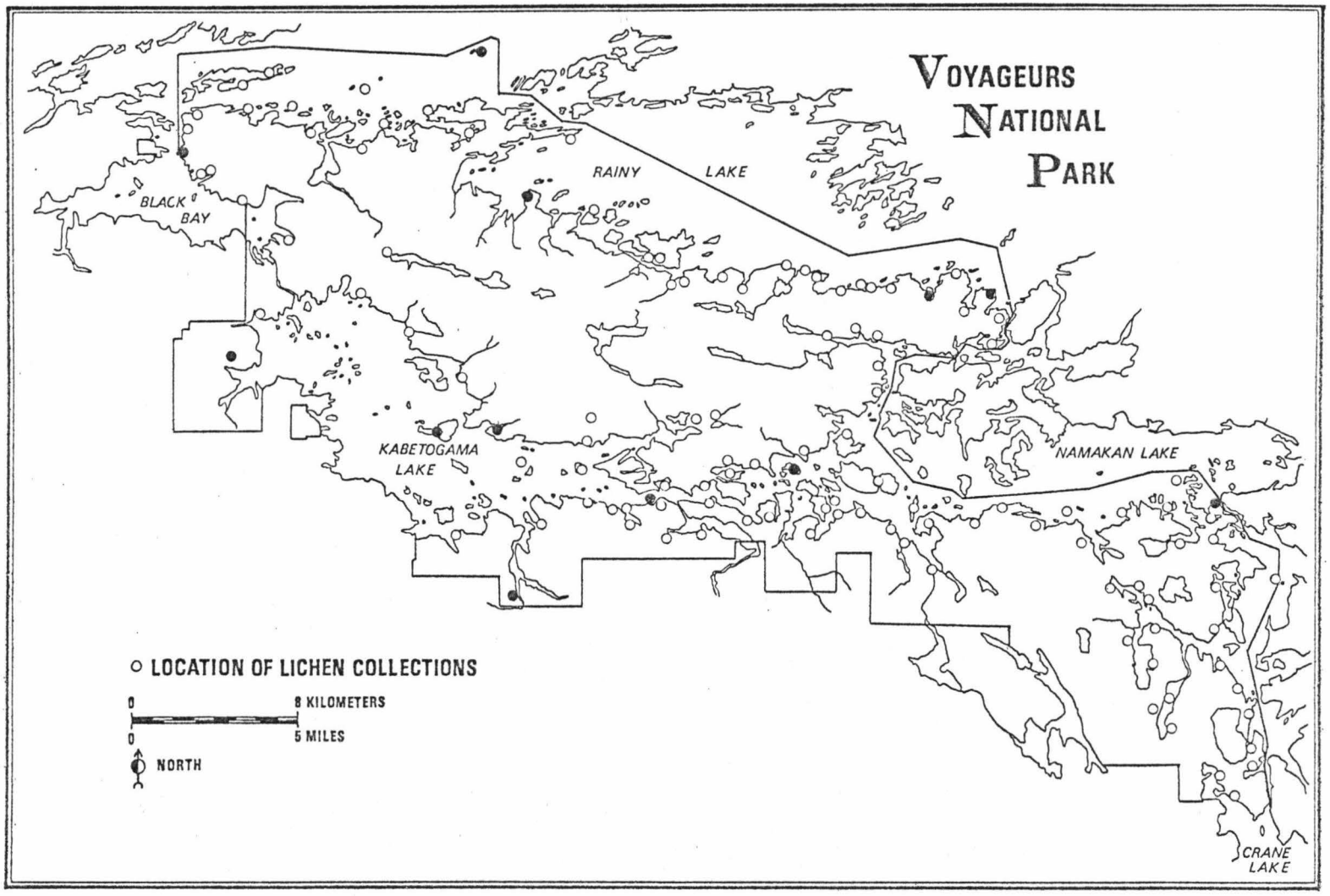


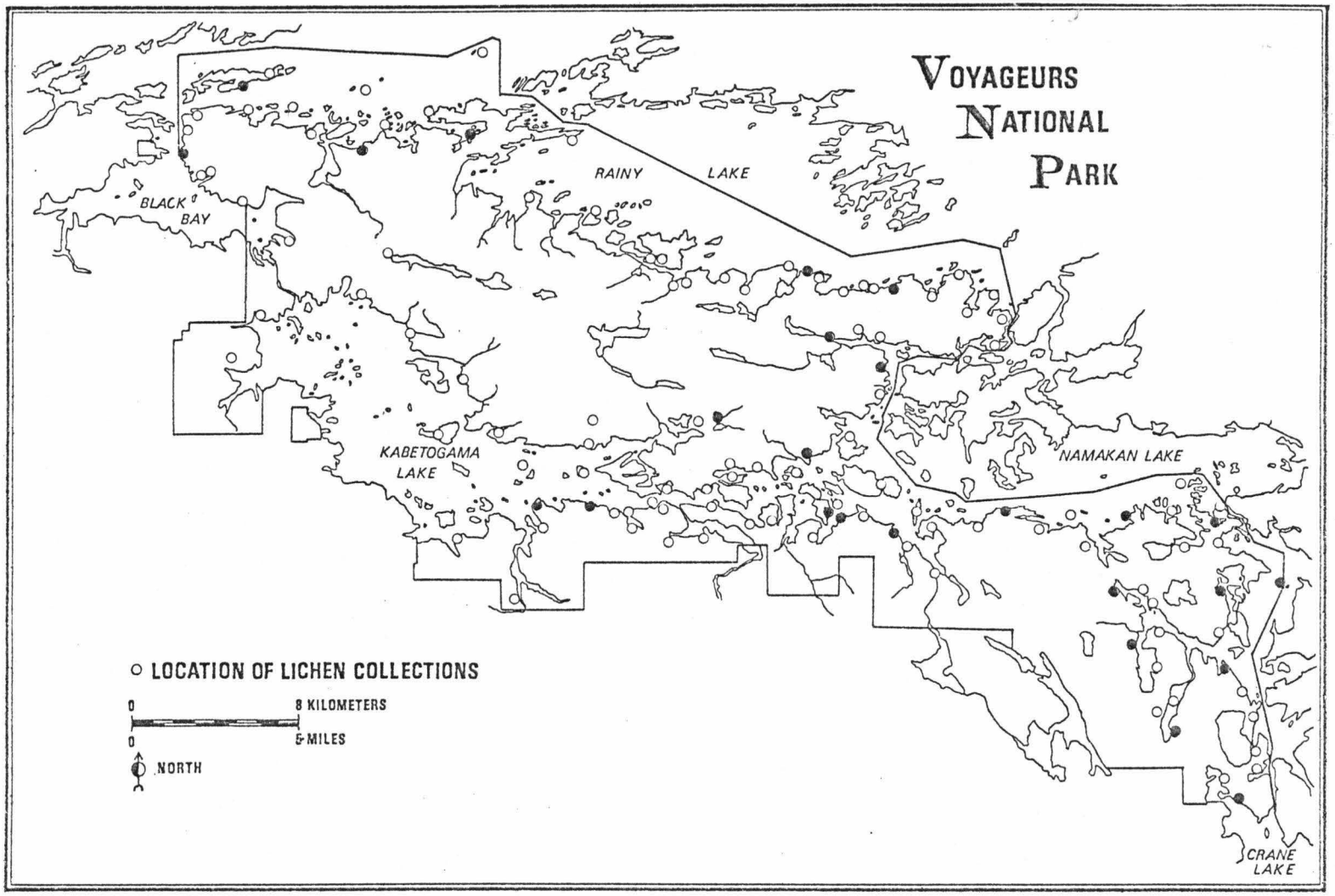
Candelariella xanthostigma

Cladonia fimbriata

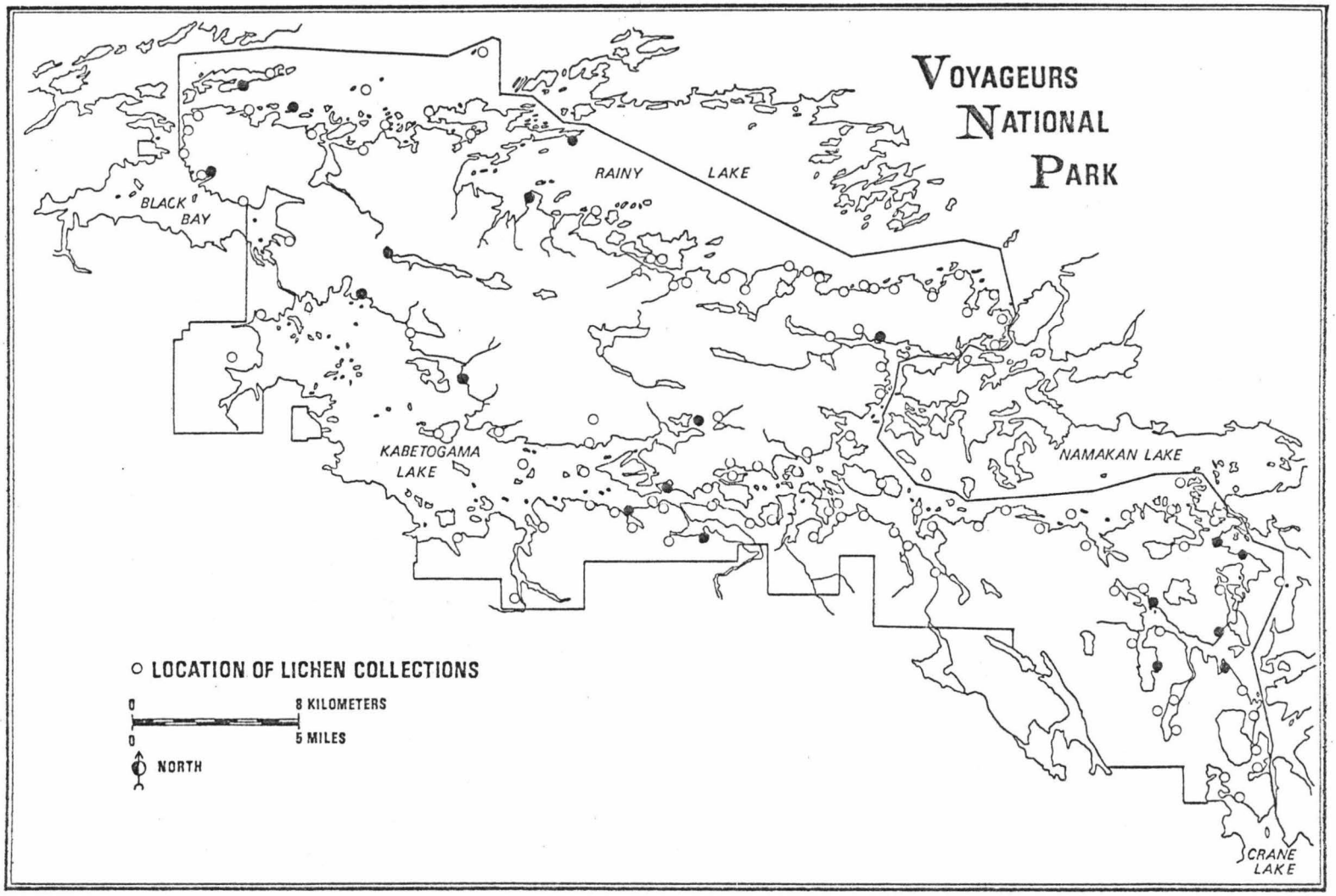


Dimerella lutea





Lecidea nylanderi



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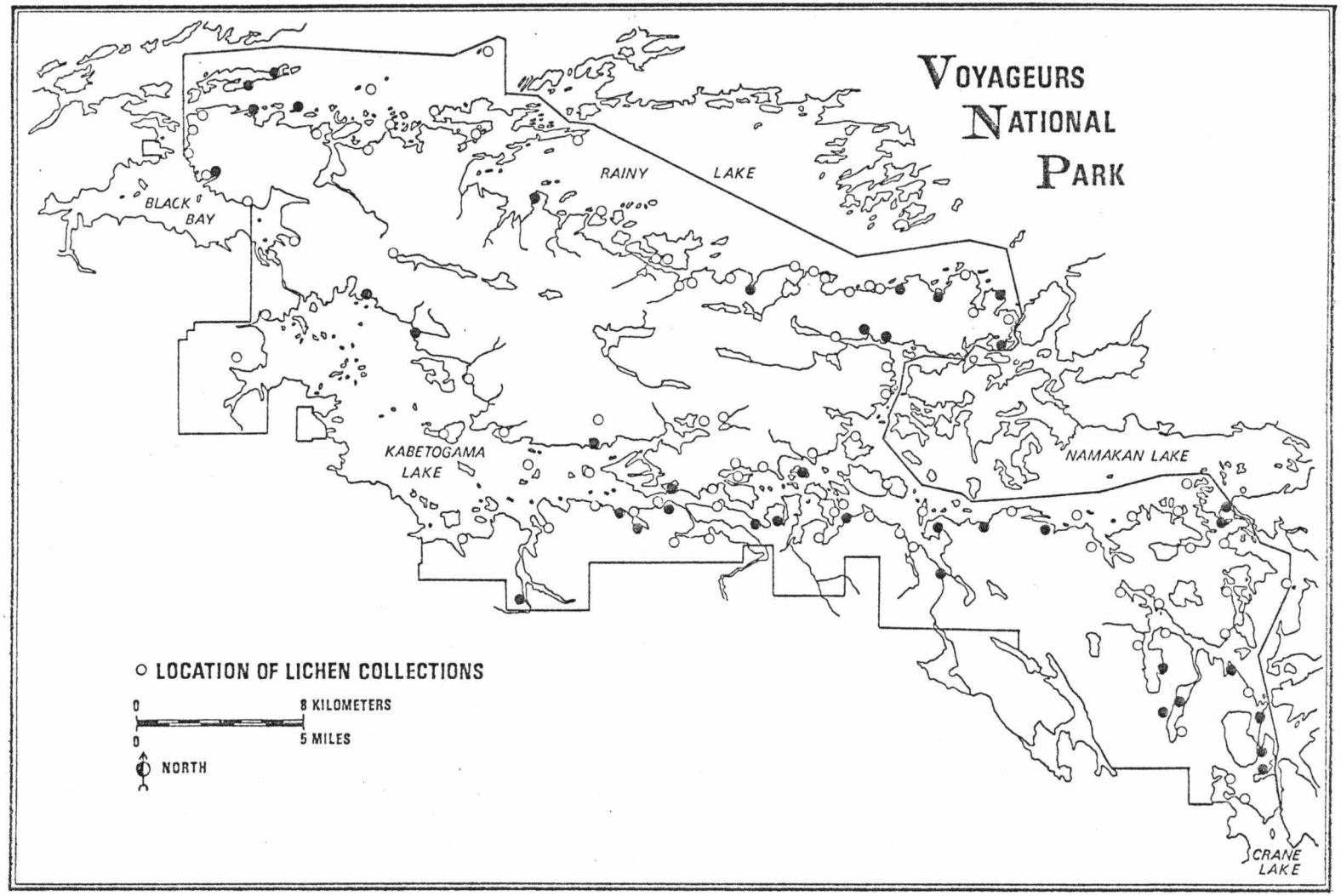
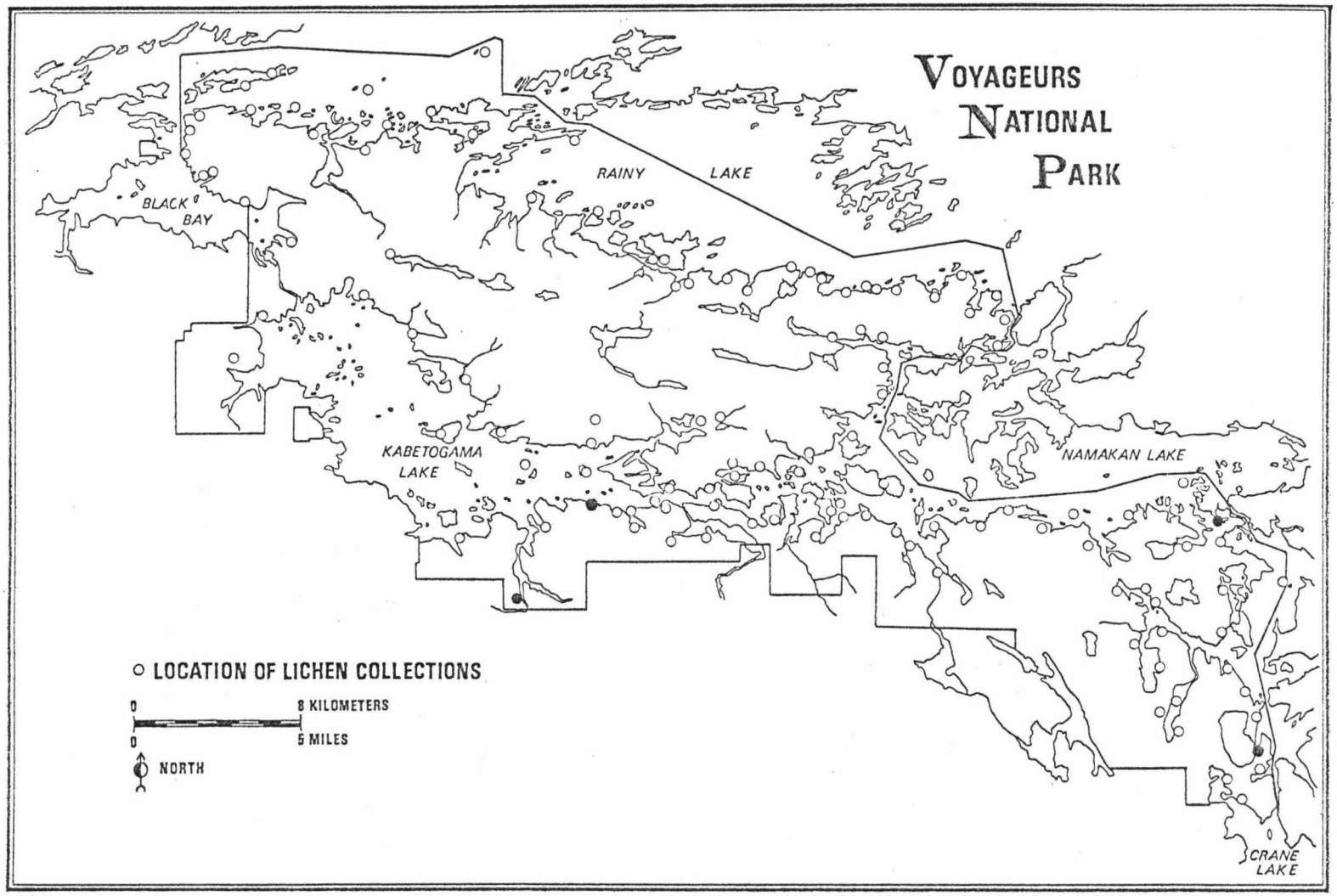
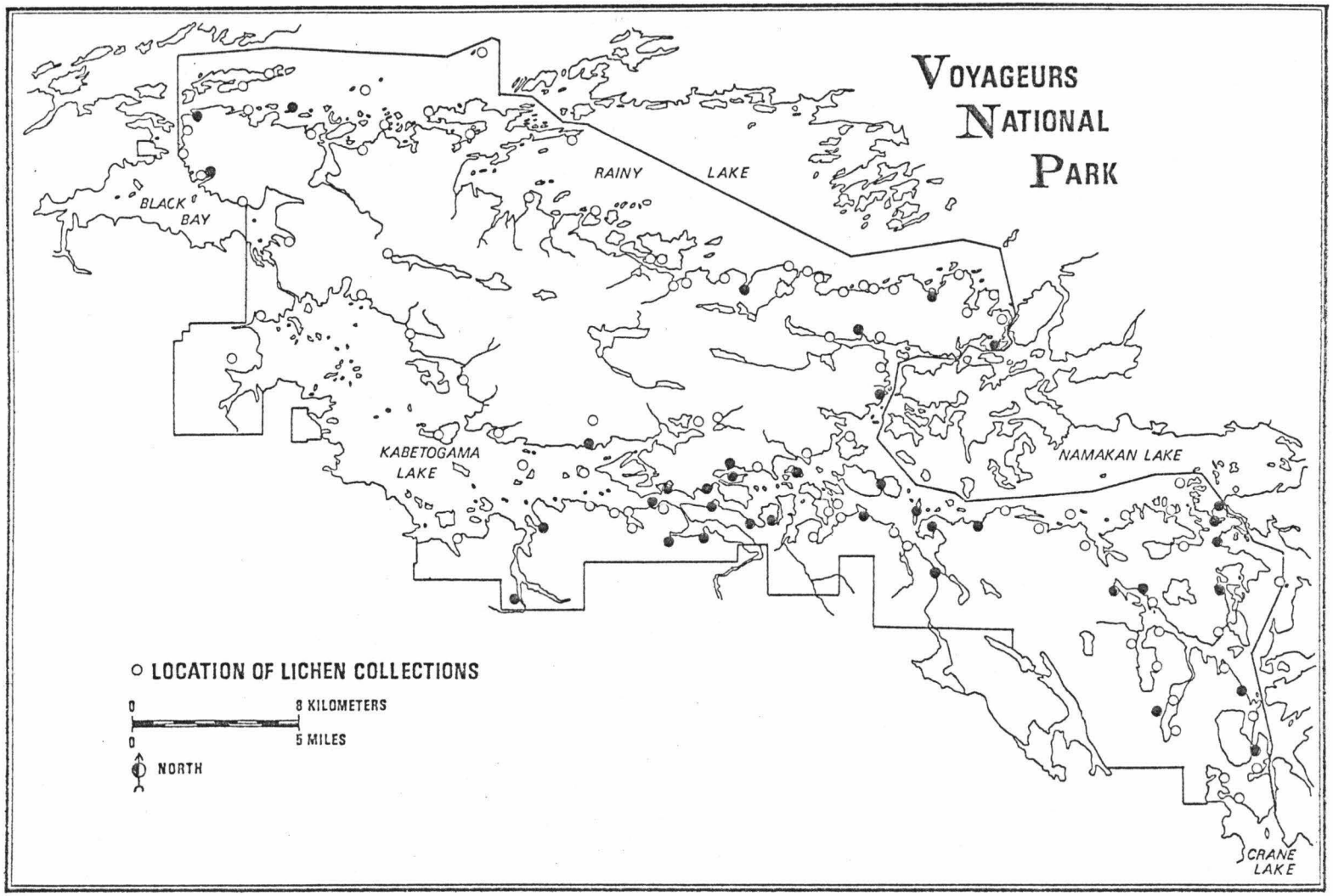


Lobaria pulmonaria

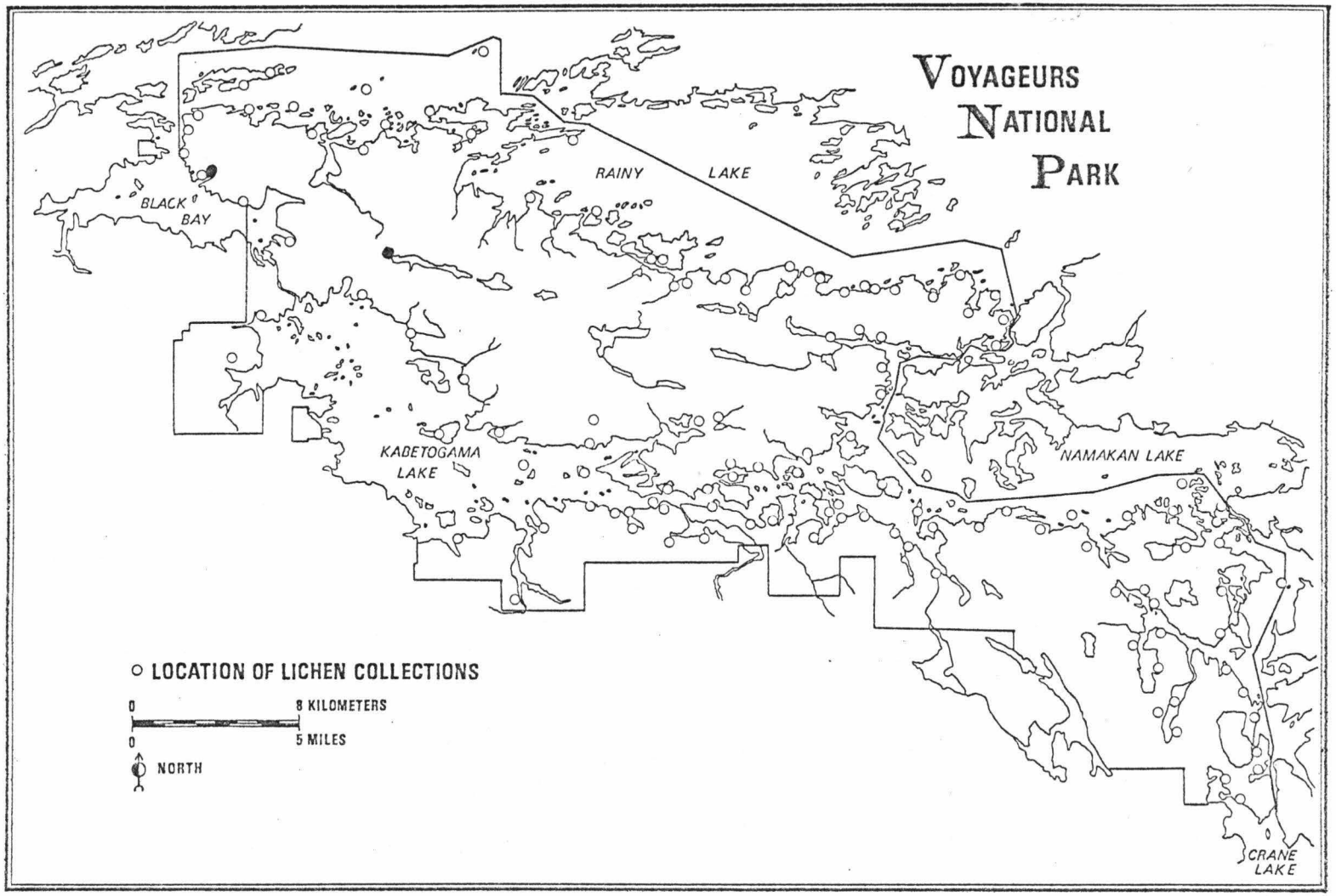


Normandina pulchella

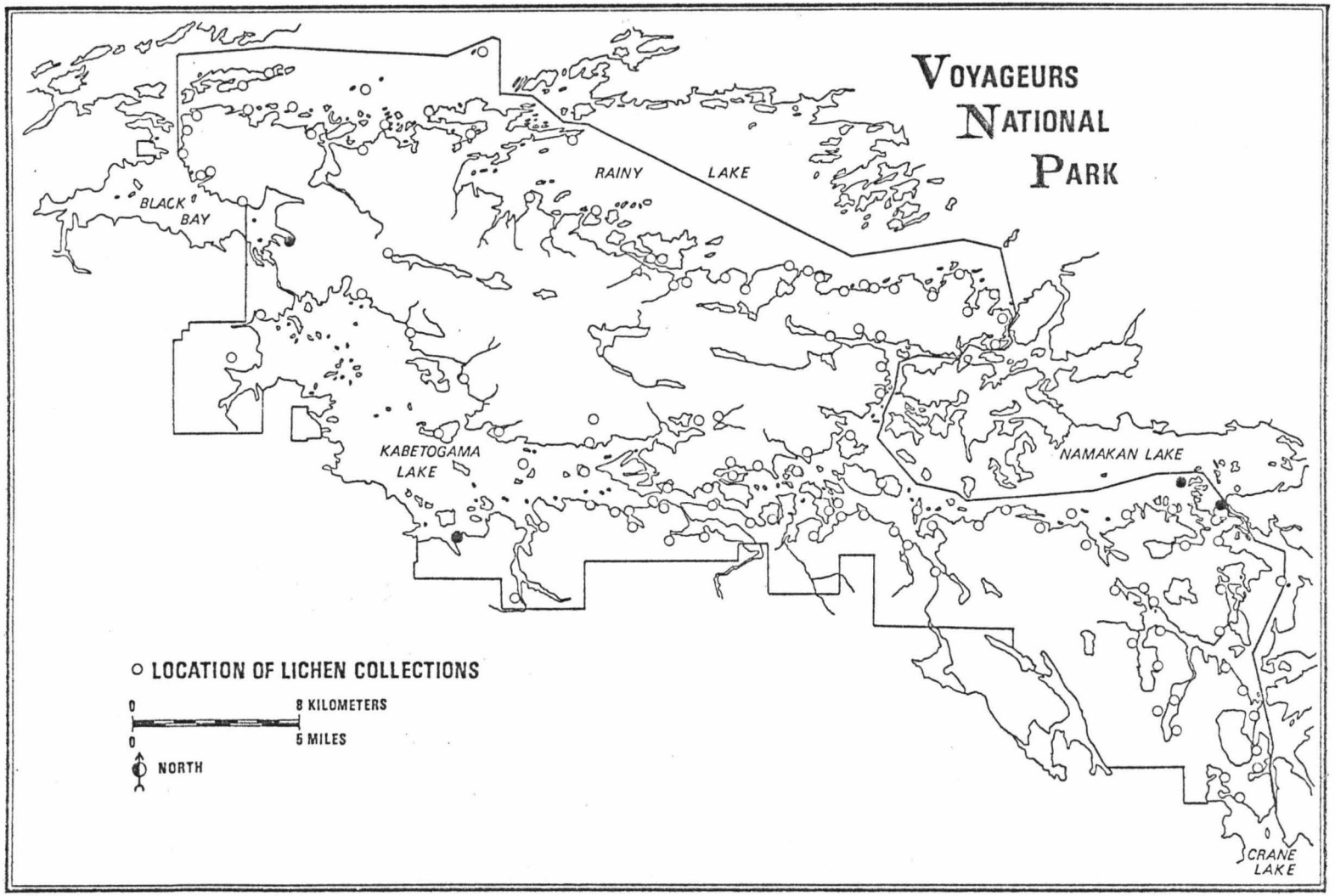


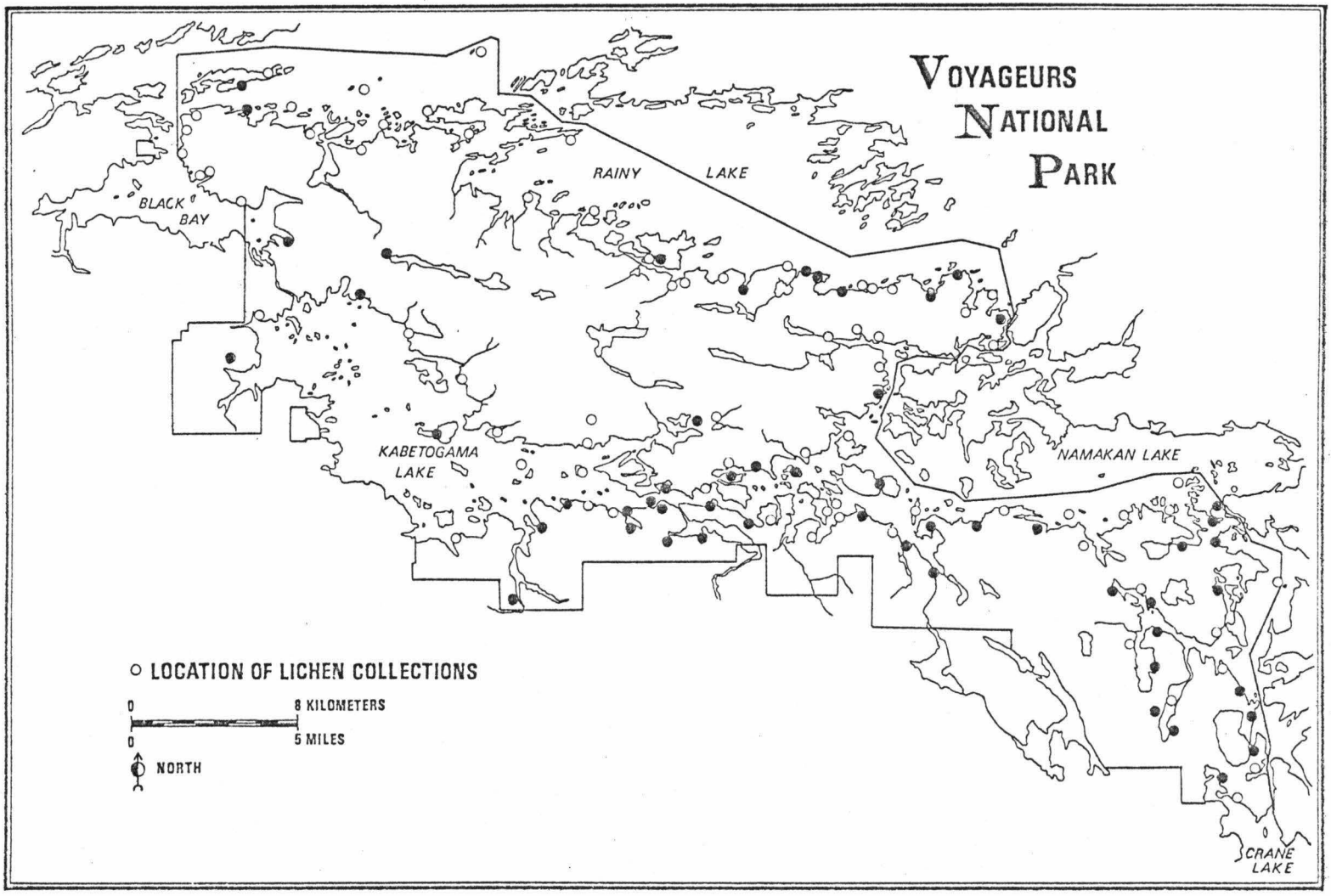
Ochrolechia rosella

Opegrapha pulicaris

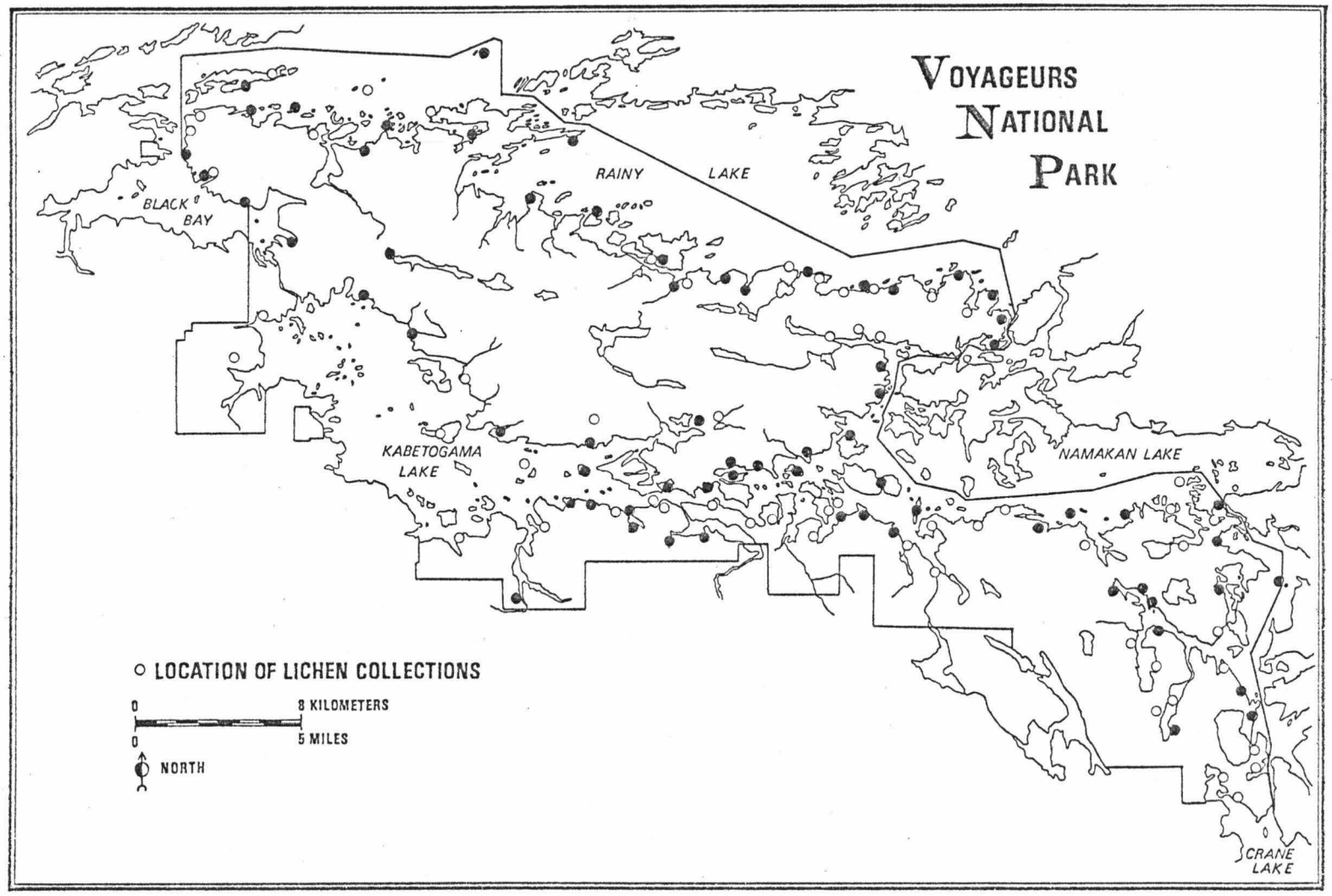


Parmelia plittii

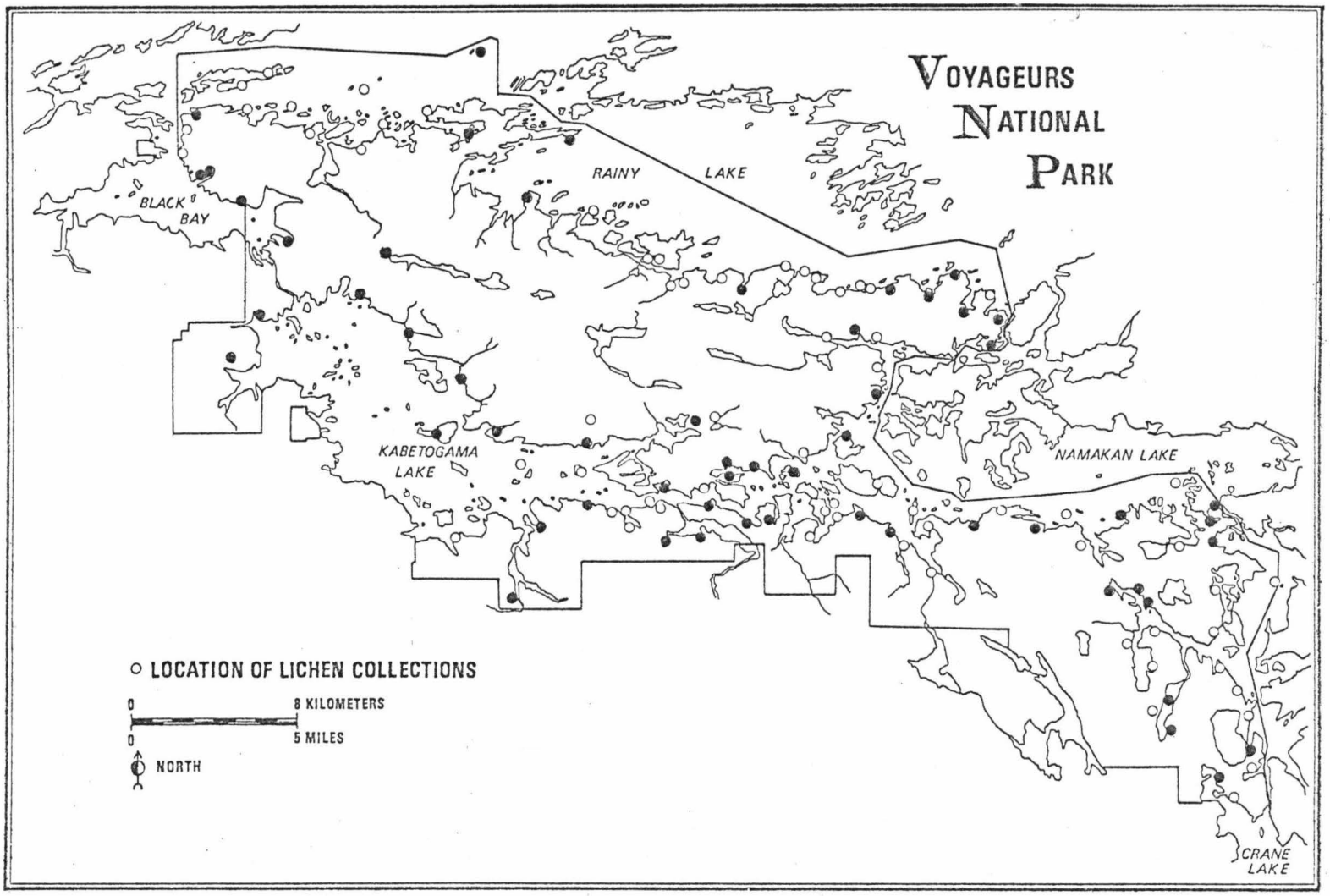




Parmelia squarrosa

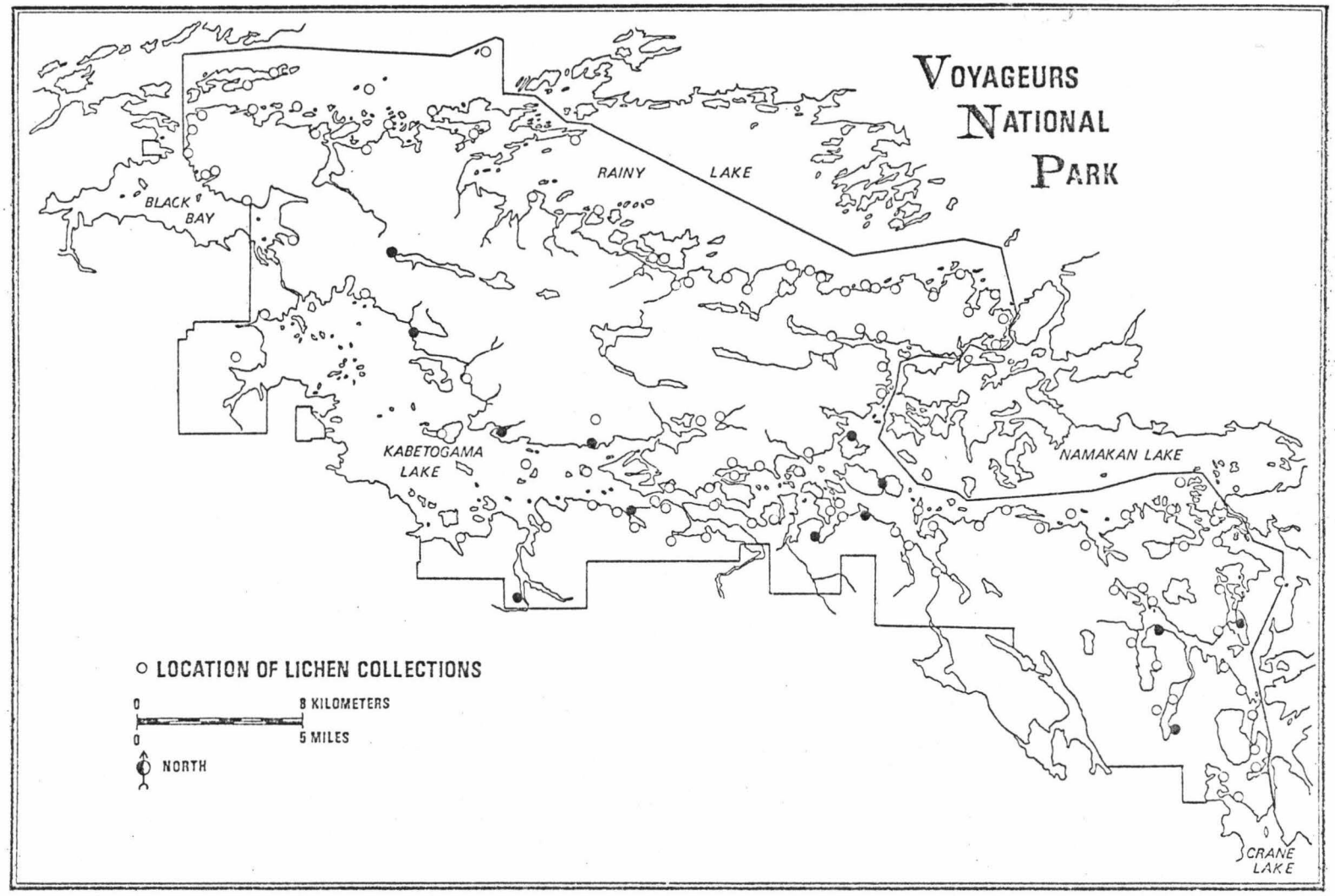


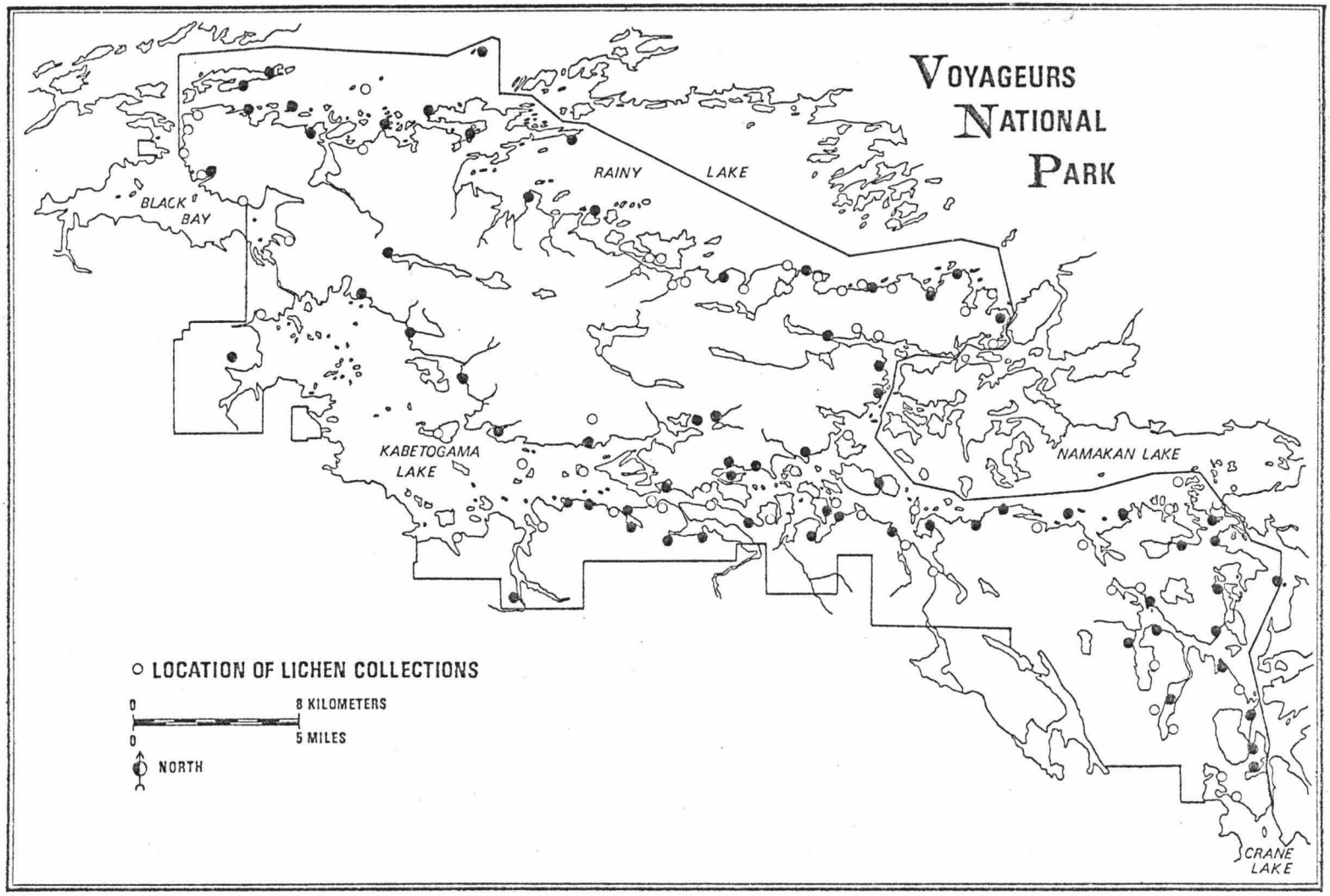
Parmelia subaurifera



Ramalina americana

Usnea filipendula




VOYAGEURS
NATIONAL
PARK
RAINY LAKE
BLACK BAY
KABETOGAMA LAKE
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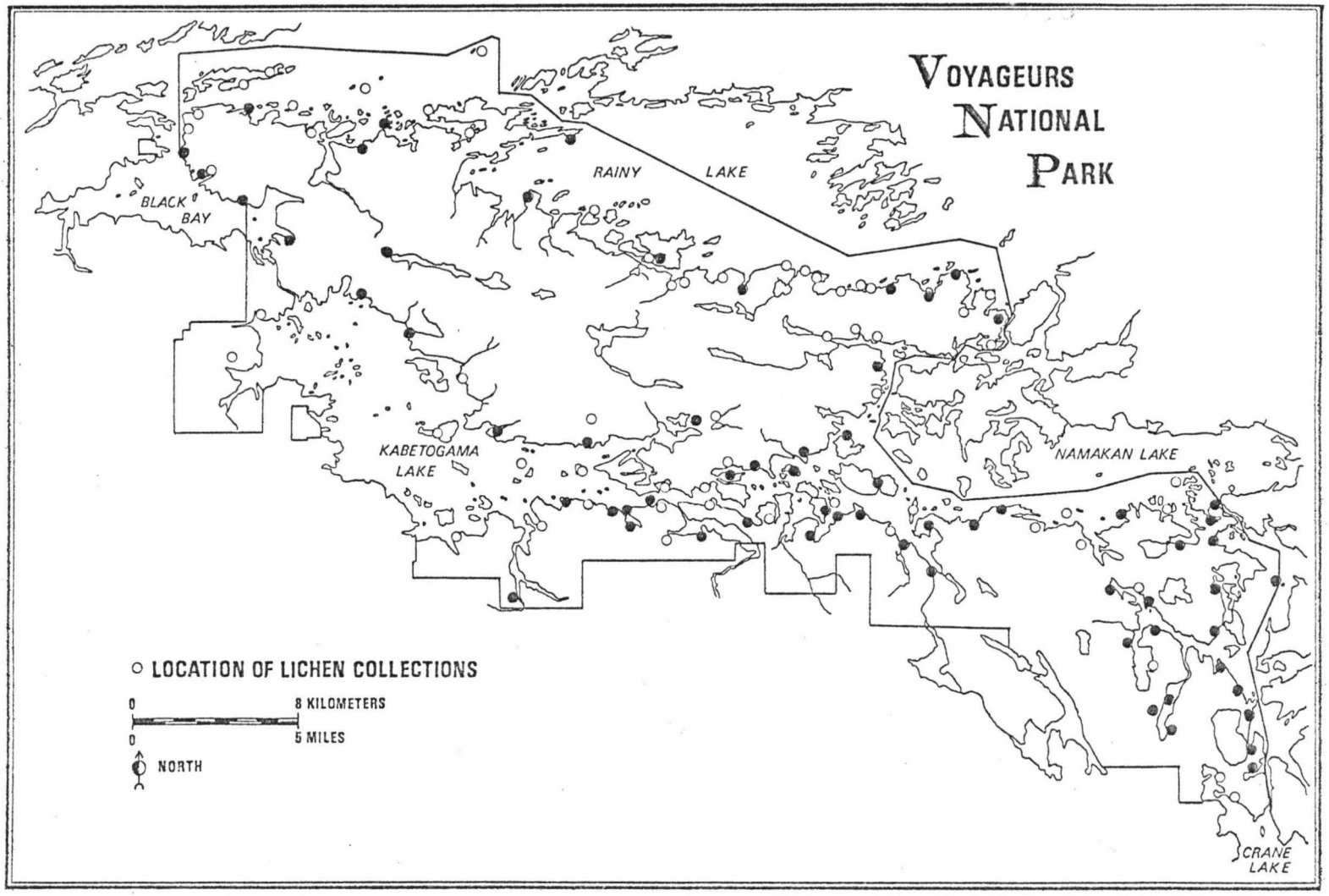
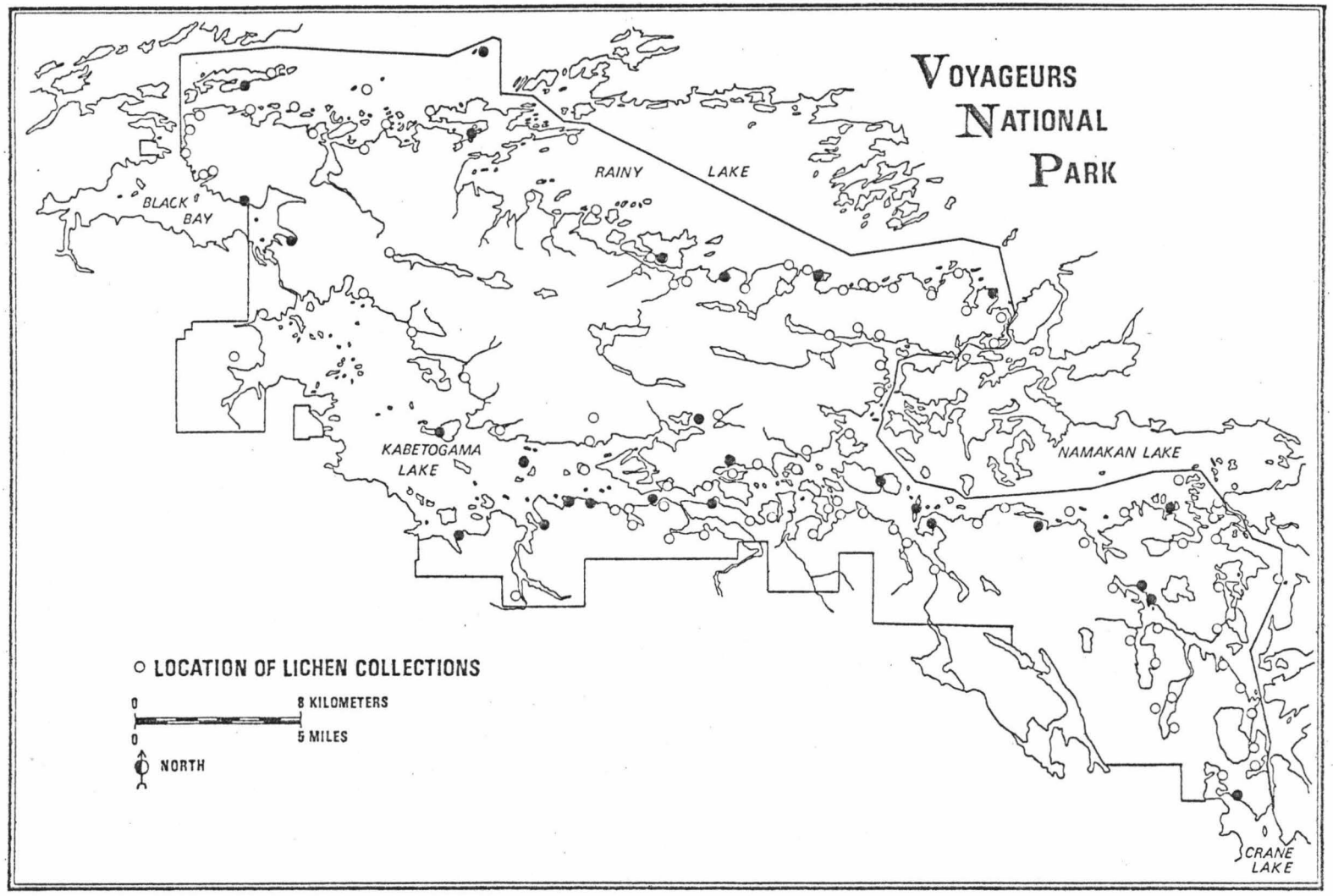
CRANE LAKE
LOCATION OF LICHEN COLLECTIONS
0 8 KILOMETERS
0 5 MILES
NORTH

Usnea hirta



Usnea subfloridana



Xanthoria fallax