WORKING PAPER

Lichens of British Columbia:

Rare Species and Priorities for Inventory

08/1995

Province of British Columbia
Ministry of Forests Research Program

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Citation:
Goward, T. 1996. Lichens of British Columbia: rare species and priorities inventory. Res. Br., B.C. Min. For. and Hab. Protect. Br., B.C. Min. Environ., Lands and Parks, Victoria, B.C. Work. Pap. 08/1996.

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British Columbia, Canada's most westerly province, has a bounty of biological diversity. Its mountains, lakes and rivers, rain forests, wetlands and arid grasslands, and long, rugged coast provide habitats for more species of living organisms than are found anywhere else in Canada. However, this very diversity means that there is much to be discovered about these organisms—their distribution, abundance, habitat requirements, and interrelationships with their environments. Increasing our knowledge of this biodiversity will help us with the complex task of sustainably managing our land and waters.

In 1992 the Provincial Government initiated a co-operative biodiversity research program with funding from the Corporate Resource Inventory Initiative; the British Columbia Ministries of Forests (Research Branch), Environment, Lands and Parks (Wildlife and Habitat Protection Branches), and Tourism and Culture (Royal British Columbia Museum); and the Forest Resource Development Agreement (FRDA II). One goal of this research program is to extend information to scientists, resource managers, and the public through biodiversity publications. These publications are intended to increase awareness and understanding of biodiversity, promote the concepts and importance of conserving biodiversity, and communicate Provincial Government initiatives related to biodiversity. We hope that they will be used as tools for the conservation of British Columbia's rich, living legacy.

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Special thanks are extended to Mike Ryan and Dave Fraser of Arenaric Research and Interpretation for their assistance in the preparation of this report and contract management. Thanks also are extended to Irwin Brodo, George Douglas, Kat Enns, Ted Lea, and Wilf Schofield, who provided technical reviews of the report.

Funding for the production and publication of this report was provided by the Canada-British Columbia Forest Research Development Agreement (FRDA) and delivered through the Corporate Resource Inventory Initiative and the Ministry of Forests IRM research program. Trudy Chatwin co-ordinated the project on behalf of the Wildlife Branch of the Ministry of Environment, Lands and Parks, while Andrew Harcombe, Gail Harcombe, Ted Lea, and Don Eastman contributed in various ways to the production of this report. Thanks are also extended to Evelyn Hamilton, Heather Strongitharm, Susanne Barker, Beth Collins, Alison Nicholson, and Paul Nystedt in the Ministry of Forests for their work in co-ordinating, funding, and producing the report, and to Fran Aitkins and Susan Bannerman for editing it.

Although little information is available on a majority of British Columbia's estimated 1800 lichens, previous studies of 350 foliose and squamulose species permit designation of 46 species as rare. Roughly 90% of these latter lichens occur in lowland biogeoclimatic zones in four of British Columbia's 29 ecoregions, that is, Eastern Vancouver Island, Western Vancouver Island, the Thompson–Okanagan Plateau, and the Columbia Mountains and Highlands. These zones are therefore considered to be of critical importance for the maintenance of lichen diversity.

Eight recommendations are made on behalf of future lichen inventory and research in British Columbia:

1. current funding levels should be maintained for the operation of the University of British Columbia lichen herbarium;
2. funding should be made available for compiling identification keys to British Columbia lichens;
3. an annotated catalogue of lichens should be prepared;
4. a provincial co-ordinator of rare and endangered lichens should be appointed;
5. detailed studies should be initiated on the foliose and squamulose lichens here designated as rare;
6. similar studies should be conducted on a representative sampling of rare saxicolous species;
7. studies on the relation between rare lichens and old-growth ecosystems should receive continuing support; and
8. special emphasis should be placed, especially in the Coastal Douglas-fir, Coastal Western Hemlock, Ponderosa Pine, and Interior Cedar-Hemlock zones, on accumulating lichen data to facilitate future retrospective studies.

The above recommendations are based on the assumption that future lichen research in British Columbia will be driven primarily by the requirements of lichen conservation.

Seven additional observations pertinent to the preservation of lichen diversity are also given:

1. a network of sizeable, well-linked lichen reserves is required;
2. old-growth forests deserve special consideration as critical habitat for lichens;
3. aquatic and semi-aquatic lichens are vulnerable to water pollution;
4. trampling by livestock is highly detrimental to soil-dwelling lichens;
5. agricultural pesticides may have an adverse effect on lichens;
6. the anticipated effect of global warming on lichens requires that entire drainage basins be set aside; and
7. protected areas should be located at distance from factories and other major point sources of air pollution.

What are Lichens?

The vast majority of lichens can be classified as Ascomycetes, or cup fungi. This is the same group to which morels and elf saddles belong. But whereas most cup fungi derive their nourishment from decaying leaves, logs, or other sources external to themselves, lichen fungi "cultivate" their foodstuff among the fungal threads of which they themselves are composed. This foodstuff consists of tiny, photosynthetic algal and/or cyanobacterial cells. Lichens can therefore be thought of as living fungal greenhouses supported by carbohydrates derived from the photosynthetic "crops" growing within them. This accounts for the exposed lifestyle typical of lichens: whereas a majority of other fungi live (except when fruiting) hidden inside the things they feed on, lichens colonize the surface of soil (= terricolous), rocks (= saxicolous), and trees (= epiphytic). Lichens are rightly called the "banners of the fungal kingdom."

The dual nature of lichens has given rise to numerous biological and ecological innovations encountered in few other life forms. Technical accounts of lichen biology and ecology can be found in Hale (1974), Hawksworth and Hill (1984), Lawrey (1984), and Kershaw (1985), whereas Richardson (1975) provides a more popular introduction to lichens. Manuals for the identification of British Columbia lichens include Hale (1979), Thomson (1984), Vitt et al. (1988), Goward et al. (*Lichens of B.C.*, 1994), and McCune and Goward (1995).

The Importance of Lichens

Lichens are a conspicuous component of many British Columbia ecosystems, and often play an important role in the maintenance of ecosystem health. For example, in grassland communities of the Bunchgrass Zone (Meidinger and Pojar, 1991), lichen crusts help to protect the soil not only against erosion, but also against encroachment by annual and biennial weeds (see St. Clair and Johansen 1993). In some portions of the Coastal Western Hemlock and Mountain Hemlock zones, certain species of epiphytic lichens provide a critical source of atmospheric nitrogen (Slack 1988). Epiphytic lichens are also a major source of sustenance for mountain caribou (Edwards and Ritcey 1960), black-tailed deer (McTaggart-Cowan 1945), and flying squirrels (Maser et al. 1985), among other mammals. Many species of birds, moreover, use lichens as nesting material (Richardson and Young 1977), whereas numerous nematodes (Siddiqi and Hawksworth 1982), insects, molluscs, and mites (Gerson and Seaward 1977) rely on lichens for habitat and, in some cases, food.

Lichens are no less useful to humans. Earlier uses have often been superseded by modern technology, but are nevertheless worth recording here. For the native peoples of inland British Columbia, lichens once provided the basis for a "vegetable pemmican" that could be stored for use in times of famine (Turner 1978). Other species supplied a source of colourful dyes, and still others were woven into makeshift footwear and clothing (Turner 1979). Further early applications, especially in Europe, included use as medicines, perfumes, and even alcohol (Llano 1951). The perfume industry in Europe still relies to some extent on lichens collected from rocky shores in the Mediterranean region (Moxham 1981).

These early uses of lichens were familiar to the layman; by contrast, most modern uses are primarily within the domain of scientists. In many parts of the industrialized world pollution-tolerant lichens are being used to monitor changing levels of air quality (Nash and Wirth 1988). Other species concentrate heavy metals and radioactive fallout, and thus provide a convenient measure of environmental contamination, especially by mining activities (Nieboer et al. 1972). Lichens have also proven useful as indicators of environmental continuity, and assist, for example, in distinguishing old-growth forests of different ages (Rose 1976). In arctic and alpine localities, geologists estimate the ages of certain rock-dwelling species to date the retreat of glaciers (Webber and Andrews 1973). Finally, numerous metabolic substances produced by lichens are known to have powerful antibacterial, antiviral, and antitumour properties (Vartia 1974), and are thus useful in medical science. Research in this field is ongoing, and new medical applications are being discovered almost yearly (Yamamoto et al. 1993).

THE STATUS OF LICHEN RESEARCH IN BRITISH COLUMBIA

The latest checklist of lichens and allied fungi of British Columbia appeared in 1987, and listed 1013 lichen taxa (Noble et al. 1987). Since then, however, more than 250 additional taxa have been detected (Goward and Thor 1992; Goward 1994a; Brodo, in prep.; Goward et al. *Notes on Lichens of B.C.*, 1994; Goward, in prep.), and new records continue to turn up each year. This suggests that the actual number of lichen species inhabiting British Columbia is much greater than currently documented—possibly as highas 1800 species. By comparison, the total native vascular flora consists of approximately 2300 species (Douglas et al. 1994). Lichens thus comprise a significant portion of the total floristic diversity of the province.

Whereas British Columbia's vascular plants have received considerable attention from professional botanists for nearly a century, lichenology in British Columbia is still very much a fledgling science. Even to this day, permanent positions in lichenology do not exist in the province, nor do such positions exist in adjacent states, provinces, or territories. Inventory work has thus been performed largely by students and amateurs or by professionals from out-of-province. A brief account of the history of lichen collecting in British Columbia is presented in Noble et al. (1987), and is summarized in the following section.

Given this decided lack of emphasis on lichen research in British Columbia, it is hardly surprising that an informed assessment of the status of a majority of the province's lichen species is still not possible. However, some groups have been more completely inventoried than others. By far the best-documented lichens are foliose and squamulose species, which have been the subject of detailed studies over the past several years. Goward et al. (*Lichens of B.C.*, 1994), in particular, provided detailed accounts of the taxonomy, distribution, and tentative status of approximately 350 lichen species. In keeping with current knowledge of the lichens of British Columbia, the following report will focus primarily on foliose and squamulose species, with special reference to those species considered to be rare and/or endangered.

Preliminary notes will, however, be presented on selected rare fruticose species. Although crustose lichens will be excluded from consideration, there is no reason to suppose that the general patterns reported below do not apply to them also.

PREVIOUS RESEARCH

The first collection of British Columbia lichens dates from 1792, when physician-botanist Archibald Menzies visited coastal North America with Captain George Vancouver. It was not until nearly a century later, however, that John Macoun, ultimately botanist with the Geological and Natural History Survey of Canada (now the Canadian Museum of Nature), assembled the province's first extensive lichen collection. Macoun's collection was eventually published in his *Catalogue of Canadian Plants* (Macoun 1902), and was later added to by collections gathered after he retired to Vancouver Island.

The next major contribution accrued between about 1950 and 1980, when graduate students at the University of British Columbia, mostly under the supervision of Vladimir Krajina, incorporated lichens in their ecological-vegetational studies of different portions of the province. The most important resulting collections are those of Chris Brayshaw, Adam Szczawinski, and Vladimir Krajina himself. These collections, together with those of Wilf Schofield, Teuvo Ahti, Leena Hämet-Ahti, and George Otto, provided the basis for a first checklist of British Columbia lichens (Otto and Ahti 1967).

Recent collections have been made by lichenologists visiting from out-of-province, though most of these specimens are now in herbaria in other parts of the world, especially eastern North America and Europe. Important recent collections wholly or partly held in British Columbia have been made by Teuvo Ahti, André Arsenault, Allen Banner, Fran Benton, Charles Bird, Irwin Brodo, George Douglas, Trevor Goward, Terry McIntosh, Andy MacKinnon, Willa Noble, Karl Ohlsson, Jim Pojar, Mike Ryan, Wilf Schofield, Corine Selby, Susan Stevenson, and Terry Taylor.

The major localities at which foliose and squamulose lichens have been collected in British Columbia are shown in Figure 1. The map is based on an examination of approximately 15 000 specimens on deposit at the University of British Columbia (UBC) in Vancouver, and the Canadian Museum of Nature lichen collection (CANL) in Ottawa. This map reveals that macrolichen collections have been made throughout the province, and have, in fact, sampled all of British Columbia's14 biogeoclimatic zones (Meidinger and Pojar 1991) and 28 terrestrial ecoregions (Demarchi 1993).

Figure 2 depicts the localities of the most detailed lichen inventories conducted to date. It is important to emphasize that only five of the studies listed in Figure 2 (Bird and Bird 1973; Benton et al. 1977; Noble 1982; Goward and Schofield 1983; Brodo, in prep.) attempt to document *all* lichen species occurring within a given area; the rest are based on selective or spotty sampling. Moreover, only four of these studies have been published (Bird and Bird 1973, Benton et al. 1977, Goward and Schofield 1983, Goward and Ahti 1992). Two titles (Noble 1982; Ryan 1991) are available as unpublished theses.

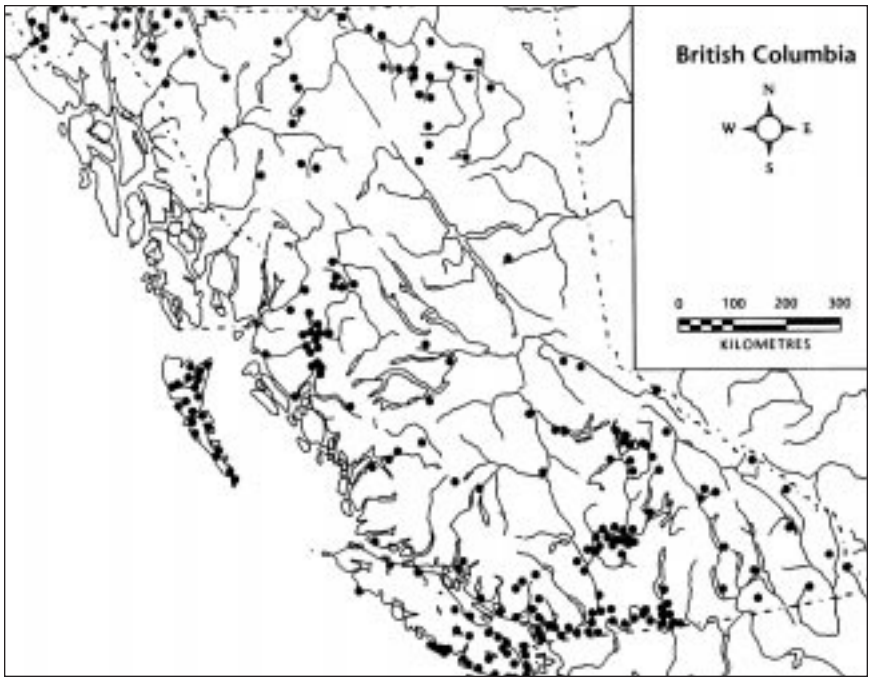
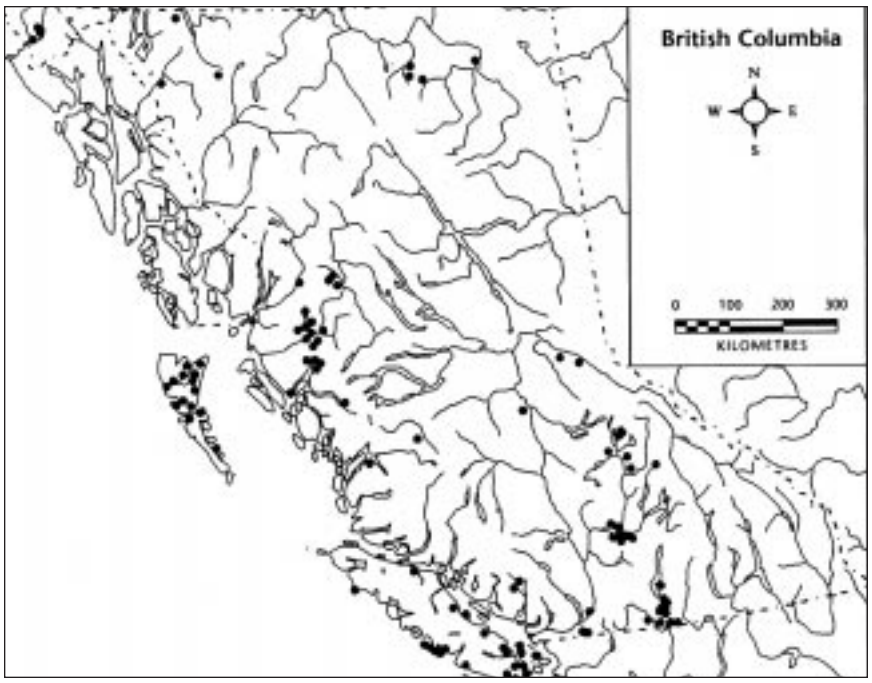


FIGURE 1 *Lichen collection localities in British Columbia (to 1992).*



Primary studies

1. *Brodo (in prep.)*
2. *Goward and Ahti (1993)*
3. *Noble (1982)*
   (Bird and Bird 1973)
   (Ryan 1991)

Secondary studies

4. *Benton, Brodo, and Richardson (1977)*
5. *Brodo (unpubl.)*
6. *Goward (unpubl.)*
7. *Goward and Schofield (1983)*
8. *Ohlsson (unpubl.)*
9. *Otto (unpubl.)*
10. *Thomson and Aht (unpubl.)*

FIGURE 2 *Lichen floristic studies in British Columbia (to 1992).*

Based on the seven studies cited in the previous paragraph (specimens collected in connection with most of the remaining studies are scattered in various herbaria and would be difficult to assemble), exhaustive lichen inventories have been conducted in only three of the province's ecoregions. These are: (1) the Queen Charlotte Ranges Ecoregion (Coastal Western Hemlock and Mountain Hemlock zones); (2) the Queen Charlotte Lowland Ecoregion (Coastal Western Hemlock zone); and (3) the Eastern Vancouver Island Ecoregion (Coastal Douglas-fir zone). Goward and Ahti's (1992) study of (a small portion of) the Columbia Mountains and Highlands Ecoregion is reasonably complete for foliose, fruticose, and squamulose species (i.e., macrolichens), but does not include crustose species.

Notwithstanding these remarks, none of the lichen surveys conducted in British Columbia is exhaustive in the strict sense of the word. To judge from the frequency with which new lichen finds are still being made even in the most intensively studied portions of the province, many decades will pass before the lichen flora of *any* part of British Columbia is fully documented.

CRITICAL BIOGEOCLIMATIC ZONES AND ECOREGIONS

Figure 3 is based on mapping studies of 136 foliose and squamulose lichens that may be considered rare or infrequent in British Columbia. (For a complete listing of the species, see Goward et al. *Lichens of B.C.*, 1994.) These lichens, it will be observed, are essentially distributed over the entire province, suggesting that few, if any, ecoregions are entirely lacking in conservation value for lichens at the provincial level. Although future collecting will undoubtedly lead to changes in status for many of the species included here, the general patterns expressed in Figure 3 are expected to remain unchanged.

Many of the species included in Figure 3 are probably much more common than current knowledge would suggest. This comment applies especially to species occurring over moss, soil, or rock—habitats that are seldom thoroughly examined by collectors. With a few notable exceptions (see below), lichens growing in such habitats are rarely in danger of widespread extirpation by humans. Most terricolous and saxicolous species can thus safely be excluded from further consideration here (see, however, Appendix 2 and "Potential Threats and Habitat Protection," point 6, page 25). Exceptions include: soil-dwelling lichens of arid grassland ecosystems; seaside rock-dwelling lichens; and all species restricted to areas designated for residential development.

Figure 4 is a recasting of Figure 3, but includes only those species believed to be truly rare and/or endangered in British Columbia—a total of 46 lichen species, including two undescribed taxa. These species are arranged below according to the biogeoclimatic zones and ecoregions in which they are presently known to occur. Note that localities followed by a question mark are based on collections made by John Macoun late last century and are of questionable authenticity, due to routine errors in labelling (Godfrey 1977); they have been omitted from the ensuing discussion.

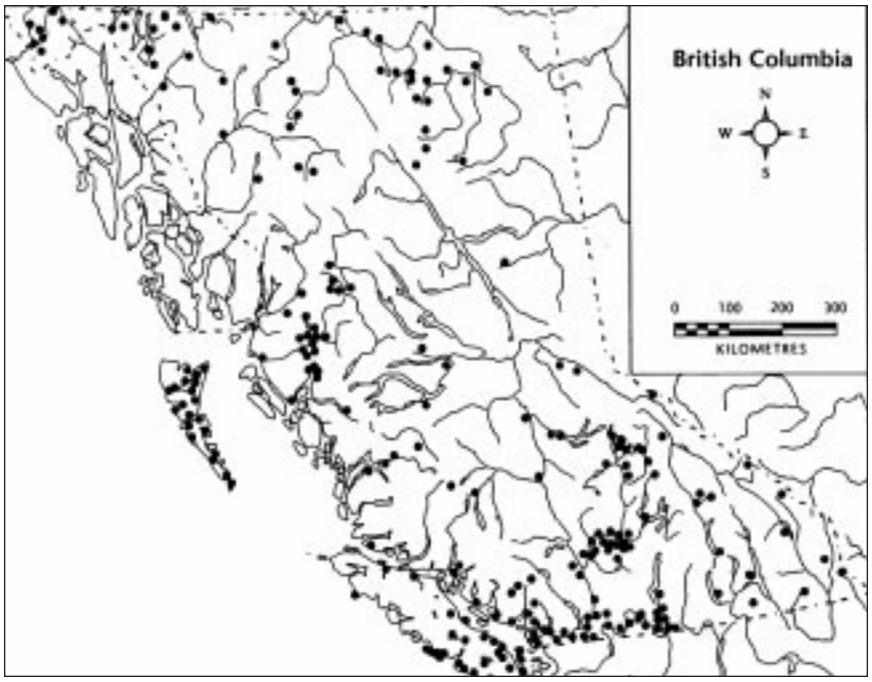


FIGURE 3 *Distribution of 136 rare and infrequent foliose and squamulose lichens in British Columbia.*

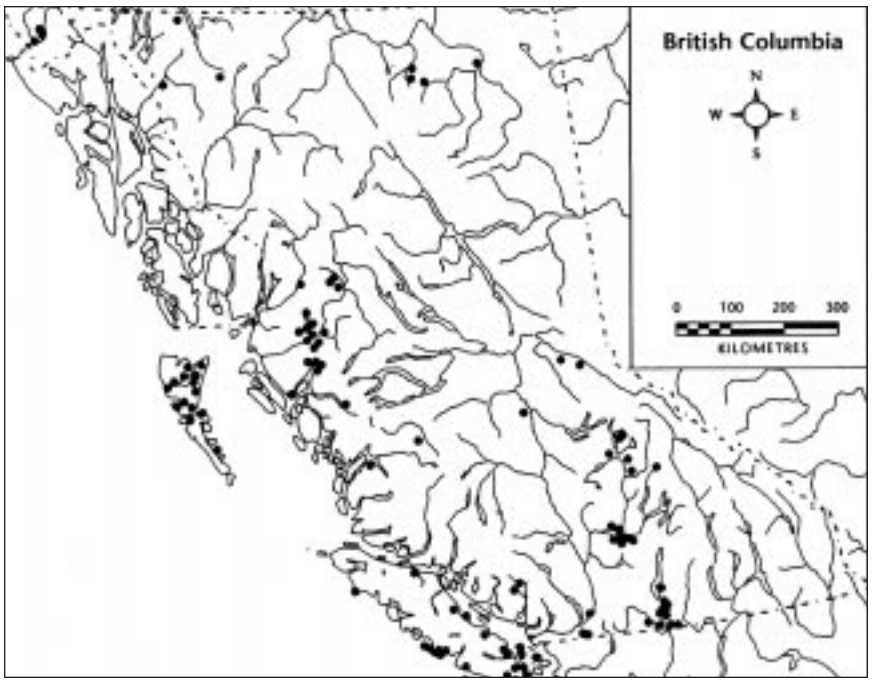


FIGURE 4 *Distribution of 46 rare and/or endangered foliose and squamulose lichens in British Columbia.*

Coastal Douglas-fir Zone
Collema auriforme (With.) Coppins & Laundon?
Collema fecundum Degel.
Collema nigrescens (Hudson) DC.
Flavopunctelia flaventior (Stirton) Hale
Hypogymnia heterophylla Pike
Koerberia sonomensis (Tuck) Henssen
Leptogium furfuraceum (Harm.) Sierk
Leptogium platynum (Tuck.) Herre
Leptogium polycarpon P.M. Jørg. & Goward
Physconia detersa (Nyl.) Poelt?
Punctelia subrudecta (Nyl.) Krog
Waynea californica Moberg

Coastal Western Hemlock Zone
Cetraria californica Tuck.
Collema fecundum Degel.
Collema flaccidum (Ach.) Ach.?
Collema nigrescens (Hudson) DC.
Erioderma sorediatum D. Galloway & P.M. Jørg.
Heterodermia leucomelos (L.) Poelt
Heterodermia sitchensis Goward & Noble
Leptogium brebissonii Mont.
Leptogium polycarpon P.M. Jørg. & Goward
Nephroma silvae-veteris Goward & Goffinet
Pannaria ahlneri P.M. Jørg.
Pannaria laceratula Hue
Pannaria rubiginosa (Ach.) Bory
Parmotrema chinense (Osbeck) Hale & Ahti
Parmotrema crinitum (Ach.) Choisy
Phaeophyscia ciliata (Hoffm.) Moberg
Physcia semipinnata (J.F. Gmelin) Moberg
Pseudocyphellaria rainierensis Imsh.

Mountain Hemlock Zone
Hydrothyria venosa J. Russell

Bunchgrass Zone
Collema sp. 1 (Goward et al., *Lichens of B.C.*, 1994)
Flavopunctelia flaventior (Stirton) Hale
Heppia lutosa (Ach.) Nyl.
Leptogium schraderi (Ach.) Nyl.
Massalongia cf. *microphylliza* (Nyl. *ex* Hasse) Henssen
Phaeophyscia hirsuta (Mereschk.) Essl.
Physcia callosa Nyl.
Physcia dimidiata (Arnold) Nyl.

Ponderosa Pine Zone
Phaeophyscia hirsuta (Mereschk.) Essl.
Physcia callosa Nyl.

Interior Douglas-fir Zone
Anaptychia setifera Räsänen
Collema auriforme (With.) Coppins & Laundon
Phaeophyscia nigricans (Flörke) Moberg

Interior Cedar–Hemlock Zone
Leptogium cyanescens (Rabenh.) Körber
Lobaria retigera (Bory) Trevisan
Nephroma silvae-veteris Goward & Goffinet
Pannaria ahlneri P.M. Jørg.
Phaeophyscia adiastola (Essl.) Essl.
Sticta wrightii (Tuck.)

Engelmann Spruce–Subalpine Fir Zone
Hydrothyria venosa J. Russell

Sub-Boreal Pine–Spruce Zone
Melanelia olivaceoides (Krog) Essl.

Sub-Boreal Spruce Zone
Phaeophyscia hispidula (Ach.) Essl.

Boreal White and Black Spruce Zone
Anaptychia setifera Räsänen
Collema nigrescens (Hudson) DC.
Heterodermia speciosa (Wulfen) Trevisan
Physcia stellaris (L.) Nyl.
Physconia detersa (Nyl.) Poelt

Spruce–Willow–Birch Zone
Melanelia olivaceoides (Krog) Essl.
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia hispidula (Ach.) Essl.
Physcia stellaris (L.) Nyl.

ECOREGION PROFILES OF RARE AND/OR ENDANGERED FOLIOSE AND SQUAMULOSE LICHENS IN BRITISH COLUMBIA

Ecoprovince: Coast and Mountains (nine ecoregions)

Ecoregion: Pacific Ranges
Cetraria californica Tuck.
Collema flaccidum (Ach.) Ach.?
Hydrothyria venosa J. Russell
Leptogium polycarpon P.M. Jørg. & Goward
Pannaria laceratula Hue
Pseudocyphellaria rainierensis Imsh.

Ecoregion: Cascade Ranges
Leptogium polycarpon P.M. Jørg. & Goward
Physcia semipinnata (J.F. Gmelin) Moberg
Pseudocyphellaria rainierensis Imsh.

Ecoregion: Coastal Gap
Erioderma sorediatum D. Galloway & P.M. Jørg.
Nephroma silvae-veteris Goward & Goffinet
Pannaria ahlneri P.M. Jørg.
Pseudocyphellaria rainierensis Imsh.

Ecoregion: Nass Basin
Lobaria retigera (Bory) Trevisan
Nephroma silvae-veteris Goward & Goffinet
Pannaria ahlneri P.M. Jørg.

Ecoregion: Nass Ranges
Collema nigrescens (Hudson) DC.
Lobaria retigera (Bory) Trevisan
Nephroma silvae-veteris Goward & Goffinet
Pannaria ahlneri P.M. Jørg.
Pannaria rubiginosa (Ach.) Bory

Ecoregion: Northern Coastal Mountains
Anaptychia setifera Räsänen
Pannaria ahlneri P.M. Jørg.

Ecoregion: Queen Charlotte Lowland
Cetraria californica Tuck.
Collema fecundum Degel.
Pannaria rubiginosa (Ach.) Bory
Pseudocyphellaria rainierensis Imsh.

Ecoregion: Queen Charlotte Ranges
Collema fecundum Degel.
Leptogium brebissonii Mont.
Pannaria laceratula Hue
Pannaria rubiginosa (Ach.) Bory

Ecoregion: Western Vancouver Island
Collema fecundum Degel.
Erioderma sorediatum D. Galloway & P.M. Jørg.
Heteroderma leucomelos (L.) Poelt
Heteroderma sitchensis Goward & Noble
Leioderma sorediatum D. Galloway & P.M. Jørg.
Leptogium brebissonii Mont.
Pannaria laceratula Hue
Pannaria rubiginosa (Ach.) Bory
Parmotrema chinense (Osbeck) Hale & Ahti
Parmotrema crinitum (Ach.) Choisy
Pseudocyphellaria rainierensis Imsh.

Ecoprovince:
Georgia Depression
(one ecoregion)

Ecoregion: Eastern Vancouver Island
Cetraria californica Tuck.
Collema auriforme (With.) Coppins & Laundon?
Collema fecundum Degel.
Collema nigrescens (Hudson) DC.
Flavopunctelia flaventior (Stirton) Hale
Hypogymnia heterophylla Pike

Koerberia sonomensis (Tuck) Henssen
Leptogium furfuraceum (Harm.) Sierk
Leptogium platynum (Tuck.) Herre
Leptogium polycarpon P.M. Jørg. & Goward
Parmotrema chinense (Osbeck) Hale & Ahti?
Phaeophyscia ciliata (Hoffm.) Moberg
Physconia detersa (Nyl.) Poelt?
Pseudocyphellaria rainierensis Imsh.
Punctelia subrudecta (Nyl.) Krog
Waynea californica Moberg

Ecoprovince: Central Interior (one ecoregion)

Ecoregion: Fraser Plateau
Melanelia olivaceoides (Krog) Essl.

Ecoprovince: Sub-boreal Interior (one ecoregion)

Ecoregion: Fraser Basin
Phaeophyscia hispidula (Ach.) Essl.

Ecoprovince: Southern Interior Mountains (two ecoregions)

Ecoregion: Columbia Mountains and Highlands
Anaptychia setifera Räsänen
Collema auriforme (With.) Coppins & Laundon
Hydrothyria venosa J. Russell
Leptogium cyanescens (Rabenh.) Körber
Lobaria retigera (Bory) Trevisan
Phaeophyscia hispidula (Ach.) Essl.
Sticta wrightii Tuck.

Ecoregion: Western Continental Ranges
Phaeophyscia adiastola (Essl.) Essl.

Ecoprovince: Southern Interior (one ecoregion)

Ecoregion: Thompson–Okanagan Plateau
Collema sp. 1 (Goward et al., *Lichens of B.C.*, 1994)
Flavopunctelia flaventior (Stirton) Hale
Heppia lutosa (Ach.) Nyl.
Leptogium schraderi (Ach.) Nyl.
Massalongia cf. *microphylliza* (Nyl. *ex* Hasse) Henssen
Phaeophyscia hirsuta (Mereschk.) Essl.
Phaeophyscia nigricans (Flörke) Moberg
Physcia callosa Nyl.
Physcia dimidiata (Arnold) Nyl.

Ecoprovince: Taiga Plains (one ecoregion)

Ecoregion: Mackenzie Plains
Heteroderma speciosa (Wulfen) Trevisan

Ecoprovince: Northern Boreal Mountains (four ecoregions)

Ecoregion: Liard Basin
Physconia detersa (Nyl.) Poelt

Ecoregion Northern Canadian Rocky Mountains
Collema nigrescens (Hudson) DC.
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia hispidula (Ach.) Essl.

Ecoregion: Northern Mountains and Plateaus
Melanelia olivaceoides (Krog) Essl.
Physcia stellaris (L.) Nyl.

Ecoregion: Kluane Plateau
Physcia stellaris (L.) Nyl.

An examination of Figure 4 suggests that most of British Columbia's rarest lichens are concentrated in very few zones. This observation is confirmed by the Ecoregion Profiles list: 89% (41 of 46) of the rare and/or endangered foliose and squamulose lichens occur in just 17% (5 of 29) of the province's terrestrial ecoregions (5 of 28) and 35% (5 of 14) of the biogeoclimatic zones. Although these statistics do not take into account the fact that many lichens occur in more than one ecoregion/biogeoclimatic zone, they do help to identify the province's most critical physiographic and ecologic units from the perspective of lichen conservation. The following section lists zones and ecoregions in order of descending priority.

PRIORITY LISTING OF THE BIOGEOCLIMATIC ZONES AND ECOREGIONS OF GREATEST IMPORTANCE FOR LICHEN CONSERVATION IN BRITISH COLUMBIA

A. Biogeoclimatic zones (with numbers of reported rare species)

1. Coastal Western Hemlock (17 species + 1 possible species)
2. Coastal Douglas-fir (10 species + 2 possible species)
3. Bunchgrass (8 species)
4. Interior Cedar–Hemlock (6 species)
5. Boreal White and Black Spruce (5 species)
6. Spruce–Willow–Birch (4 species)
7. Interior Douglas-fir (3 species)
8. Ponderosa Pine (2 species)
9. Sub-boreal Spruce (1 species)
10. Engelmann Spruce–Subalpine Fir (1 species)
11. Mountain Hemlock (1 species)
12. Sub-boreal Pine–Spruce (1 species)

B. Ecoregions (with numbers of reported rare species)

1. Eastern Vancouver Island (13 species + 3 possible species)
2. Western Vancouver Island (11 species)
3. Thompson–Okanagan Plateau (9 species)
4. Columbia Mountains and Highlands (7 species)
5. Pacific Ranges (5 species + 1 possible species)
6. Nass Ranges (5 species)
7. Coastal Gap (4 species)
8. Queen Charlotte Lowland (4 species)
9. Queen Charlotte Ranges (4 species)
10. Nass Basin (3 species)
11. Northern Canadian Rocky Mountains (3 species)
12. Cascade Ranges (3 species)
13. Northern Coastal Mountains (2 species)
14. Northern Mountains and Plateaus (2 species)

15. MacKenzie Plains (1 species)
16. Fraser Plateau (1 species)
17. Western Continental Ranges (1 species)
18. Fraser Basin (1 species)
19. Kluane Plateau (1 species)
20. Liard Basin (1 species)

Amalgamating parts A and B of the preceding list provides a list of British Columbia's most lichenologically critical biogeoclimatic zones and ecoregions:

1. Coastal Douglas-fir Zone (Eastern Vancouver Island Ecoregion)
2. Coastal Western Hemlock Zone (Western Vancouver Island Ecoregion)
3. Bunchgrass Zone (Thompson–Okanagan Plateau Ecoregion)
4. Interior Cedar–Hemlock Zone (Columbia Mountains and Highlands Ecoregion)

These four zones are worthy of special consideration for lichen conservation not only because of the relatively high numbers of rare species they contain, but also owing to the intense levels of disturbance to which major portions of them have lately been subjected. Indeed, some of the most profoundly altered landscapes in the province are located within these regions. In the Coastal Douglas-fir and Bunchgrass zones, extensive logging, grazing, residential development, and/or agriculture have led to the virtual disappearance of many pre-settlement ecosystems. In the remaining zones, logging operations threaten to eliminate, within the next few decades, the oldest (and lichenologically most critical) forest types.

These regions share three further features: (1) they are centred in the southern half of the province; (2) they are at low elevation; and (3) they embrace the driest and wettest expressions of British Columbia's coastal and inland climatic regimes. Given that they thus embrace the maximum possible extremes of moisture, it is hardly surprising that they contain a disproportionately high number of lichens adapted to specialized environmental conditions, many of which tend to be of infrequent occurrence in the province as a whole.

The relative conservation status of the remaining biogeoclimatic zones and ecoregions is less clear. Personal experience suggests that the Nass Basin and Nass Ranges are relatively rich in rare lichens and should be given priority for future study. Also worthy of consideration is the Coastal Western Hemlock Zone in the Queen Charlotte Ranges and Queen Charlotte Lowland Ecoregion; however, these will be treated in Irwin Brodo's forthcoming papers (Brodo, in prep.). The valleys of northwestern British Columbia (adjacent to southeastern Alaska) are also likely to yield several rare species, as are the Interior Douglas-fir and Ponderosa Pine zones in the valleys of the Western Continental Ranges. Furthermore, though little collecting has been done to date in the Fraser Plateau Ecoregion, preliminary field observations suggest that the dry forest zones in the Basin and Chilcotin Plateau ecosections can be expected to support numerous terricolous species of localized distribution in British Columbia. The following biogeoclimatic zones and ecoregions might therefore be added to the above list:

5. Coastal Western Hemlock Zone
   Nass Ranges Ecoregion
   Queen Charlotte Ranges Ecoregion
   Queen Charlotte Lowland Ecoregion
   Northern Coastal Mountains Ecoregion
6. Interior Cedar–Hemlock Zone
   Nass Ranges Ecoregion
   Nass Basin Ecoregion
   Northern Coastal Mountains Ecoregion
   Western Continental Ranges Ecoregion
7. Ponderosa Pine Zone
   Western Continental Ranges Ecoregion
8. Interior Douglas-fir Zone
   Western Continental Ranges Ecoregion
   Fraser Plateau Ecoregion
9. Bunchgrass Zone
   Fraser Plateau Ecoregion

CRITICAL LICHENS

Not all of the lichen species listed on pages 7 to 11 are equally rare, nor are all of them equally threatened by human activity. Notwithstanding that any definitive statement on the rarity or endangerment status of these species must await further field work (see below), it is now possible to assign at least tentative provincial (S) ranks using the Conservation Data Centre ranking system (see Appendix 3). According to this system, species known from five or fewer populations would receive an S1 ranking, whereas species occurring in 6 to 20 populations would be designated as S2. These S ranks are applied here to two groups of lichens in British Columbia: (1) the foliose and squamulose species (also mapped in Goward et al., *Lichens of B.C.*, 1994), and (2) the fruticose species. A few species have also been assigned global status (G1–G5), based on earlier designations by the Rare Lichens Project of the Smithsonian Institute (Pittam 1991).

Critically imperilled (S1)

Collema auriforme (With.) Coppins and Laundon
- over trees near Victoria (the record is based on a Macoun specimen, and is therefore questionable), and in the Robson Valley
- in the latter locality restricted to old-growth forests
- western North America–western Eurasia–eastern Eurasia
- vulnerable to logging (Robson Valley population)

Collema sp. 1, *sensu* Goward et al., *Lichens of B.C.*, 1994
- over mossy soil in grasslands near Kamloops
- distribution unknown; possibly restricted to western North America
- vulnerable to trampling by cattle, and to fire

Erioderma sorediatum D. Galloway & P.M. Jørg.
- over seaside conifers in very humid coastal localities, near Ucluelet, Sayward, and Kitimat

- western North America (also present in the southern hemisphere); in British Columbia at the northern edge of its range
- vulnerable to logging or tourism development

Flavopunctelia flaventior (Stirton) Hale
- over trees and mossy rock near Victoria, and over *Artemisia tridentata* in grasslands near Kamloops
- incompletely circumpolar; in British Columbia at the northern edge of its range
- vulnerable to fire and residential development

Heppia lutosa (Ach.) Nyl.
- over soil in open grasslands near Kamloops and Osoyoos
- probably circumpolar; at the northern edge of its range
- vulnerable to trampling

Heterodermia sitchensis Goward & Noble (G1)
- over seaside conifers near Ucluelet and Tofino, probably restricted to old-growth forests
- western North America; known only from British Columbia
- vulnerable to logging and tourism development

Leioderma sorediatum D. Galloway & P.M. Jørg.
- over seaside conifers near Ucluelet, probably restricted to old-growth forests
- western North America (also present in the southern hemisphere); in British Columbia at the northern edge of its range
- vulnerable to logging and tourism development

Leptogium brebissonii Mont.
- over conifers in open, very humid forests near Ucluelet, also on the Queen Charlotte Islands, probably restricted to old-growth forests
- western North America–western Eurasia; in North America known only in British Columbia
- vulnerable to logging

Leptogium cyanescens (Rabenh.) Körber
- over trees in humid forests near Clearwater and (possibly) Revelstoke
- incompletely circumpolar
- vulnerable to fire or logging

Leptogium polycarpon P.M. Jørg. & Goward
- over deciduous trees near Victoria and near Hope
- western North America; known from British Columbia south to Oregon
- vulnerable to logging, residential development, and possibly fire

Leptogium schraderi (Ach.) Nyl.
- over soil in grasslands near Kamloops and Osoyoos
- western North America–western Eurasia
- vulnerable to overgrazing

Nephroma silvae-veteris Goward & Goffinet
- over conifers near Terrace, Kitimat, and Hazelton; restricted to old-growth forests
- western North America; known from British Columbia to Washington
- vulnerable to logging and fire

Pannaria ahlneri P.M. Jørg.
- over conifers near Terrace, Kitimat, and Hazelton; restricted to old-growth forests
- incompletely circumpolar
- vulnerable to logging and fire

Parmotrema chinense (Osbeck) Hale & Ahti
- over conifers along the west coast of southern Vancouver Island; probably restricted to old-growth forests
- incompletely circumpolar; in British Columbia at the northern edge of its range
- vulnerable to logging

Phaeophyscia adiastola (Essl.) Essl.
- over mossy rocks in Mount Robson Provincial Park
- western North America–eastern North America; in British Columbia at the western edge of its range
- vulnerable to tourist traffic

Physcia semipinnata (J.F. Gmelin) Moberg
- over *Thuja plicata* needles near Chilliwack
- western North America–eastern North America–western Eurasia
- vulnerable to logging and possibly air pollution

Physconia detersa (Nyl.) Poelt
- over trees near Muncho Lake, and also near Victoria (the latter locality is based on a questionable specimen collected by John Macoun)
- probably incompletely circumpolar
- vulnerable to logging and fire

Pseudocyphellaria rainierensis Imsh.
- (G_2–G_3)
- over trees near Kitimat, Masset, Chilliwack, and on the Brooks Peninsula, also formerly near Nanaimo Lakes; restricted to old-growth forests
- western North America; in British Columbia at the northern edge of its range
- vulnerable to logging

Sticta wrightii Tuck.
- over trees in the Robson Valley; restricted to old-growth forests
- western North America–eastern Eurasia; in British Columbia at the southern and eastern edges of its range
- vulnerable to logging and fire

Imperilled (S_2)

Anaptychia setifera Räsänen
- over conifers in the lower Tatshenshini Valley, and near Deception Falls in Wells Gray Provincial Park; locally abundant in the former locality, but rare in the latter
- incompletely circumpolar; in British Columbia at the southern edge of its range
- vulnerable to fire

Cetraria californica Tuck.
- over conifers in humid coastal forests
- western North America; the main range is in British Columbia
- vulnerable to logging

Collema fecundum Degel.
- over coastline rocks
- western North America; the main range is apparently in British Columbia
- possibly vulnerable to oil spills

Collema nigrescens (Hudson) DC.
- over trees in the Coastal Douglas-fir Zone, also north of Terrace and near Muncho Lake (the latter population may possibly represent a separate species)
- incompletely circumpolar
- vulnerable to logging or fire

Heterodermia leucomelos (L.) Poelt
- over seaside conifers near Ucluelet, probably restricted to old-growth forests
- incompletely circumpolar; in British Columbia at the northern edge of its range
- vulnerable to logging and tourism development

Heterodermia speciosa (Wulfen) Trevisan
- over *Populus tremuloides* near Fort Nelson
- western North America–eastern North America–western Eurasia
- vulnerable to logging and fire

Hydrothyria venosa J. Russell
- (G_3)
- over rock in mountain streams
- western North America–eastern North America
- vulnerable to trail development

Hypogymnia heterophylla Pike
- (G_3)
- over seaside *Pinus contorta* near Sooke
- western North America; in British Columbia at the northern edge of its range
- vulnerable to fire and tourism development

Koerberia sonomensis (Tuck.) Henssen
- over seaside rock near Victoria
- western North America–western Eurasia; in British Columbia at the northern edge of its range
- vulnerable to oil spills

Leptogium furfuraceum (Harm.) Sierk
- over deciduous trees, especially *Quercus garryana*, in the Coastal Douglas-fir Zone
- western North America–western Eurasia; in British Columbia at the northern edge of its range
- vulnerable to residential development, and possibly also to air pollution

Leptogium platynum (Tuck.) Herre
- over mossy rocks in the Coastal Douglas-fir Zone
- western North America; in British Columbia at the northern edge of its range
- vulnerable to residential development

Lobaria retigera (Bory) Trevisan
- over conifers near Terrace, Hazelton, and in the northern Columbia Mountains; restricted to old-growth forests
- western North America–eastern Eurasia; in British Columbia at the southern edge of its range
- vulnerable to logging and fire

Massalongia cf. *microphylliza* (Nyl. *ex* Hasse) Henssen
- over soil in grasslands near Osoyoos and Penticton
- western North America; in British Columbia at the northern edge of its range
- vulnerable to overgrazing

Melanelia olivaceoides (Krog) Essl.
- over trees near Atlin, though one questionable record (collected by John Macoun) comes from the Chilcotin
- western North America; in British Columbia at the southern edge of its range
- vulnerable to logging and fire

Pannaria laceratula Hue
- over conifers along the west coast of Vancouver Island and the Queen Charlotte Islands, also near Bella Bella
- possibly restricted to western North America
- vulnerable to logging

Pannaria rubiginosa (Ach.) Bory
- over conifers on the Queen Charlotte Islands and along the west coast of Vancouver Island, also north of Terrace; probably restricted to old-growth forests
- incompletely circumpolar

Parmotrema crinitum (Ach.) Choisy
- over conifers on Moresby Island and along the west coast of Vancouver Island; probably restricted to old-growth forests
- incompletely circumpolar; in British Columbia at the northern edge of its range
- vulnerable to logging

Phaeophyscia ciliata (Hoffm.) Moberg
- over deciduous shrubs on southeastern Vancouver Island and near Fort Nelson
- probably circumpolar
- vulnerable to logging and fire

Phaeophyscia hirsuta (Mereschk.) Essl.
- over rock and deciduous trees and shrubs (including ornamental trees) near Penticton, Okanagan Falls, and at Pavilion Lake
- western North America–western Eurasia

- vulnerable to residential development

Phaeophyscia hispidula (Ach.) Essl.
- over deciduous shrubs and mossy rocks near Quesnel and Muncho Lake, but one specimen also comes (questionably) from Lower Arrow Lake, collected by John Macoun
- probably incompletely circumpolar
- vulnerable to fire

Phaeophyscia nigricans (Flörke) Moberg
- over rock near Kamloops
- western North America–western Eurasia; in British Columbia at the northern edge of its range
- vulnerable to trampling by cattle

Physcia callosa Nyl.
- over rock near Osoyoos and Okanagan Falls
- western North America; in British Columbia at the northern edge of its range
- vulnerable to fire

Physcia dimidiata (Arnold) Nyl.
- over *Artemisia tridentata* near Kamloops and in the Okanagan Valley south of Penticton
- western North America–western Eurasia; in British Columbia at the northern edge of its range
- vulnerable to fire

Physcia stellaris (L.) Nyl.
- over *Populus tremuloides* near Atlin Lake and along the Tatshenshini River
- circumpolar
- vulnerable to fire and logging

Punctelia subrudecta (Nyl.) Krog
- over trees, rocks, and shrubs near Sooke and on the Gulf Islands
- incompletely circumpolar
- vulnerable to residential development

Waynea californica Moberg
- over deciduous trees on the Gulf Islands
- western North America; in British Columbia at the northern edge of its range
- vulnerable to logging and residential development

Historical occurrence

Collema flaccidum (Ach.) Ach.
- over rocks at "Agassiz and Yale" (the record is based on a Macoun specimen from 1889, and is therefore questionable)
- circumpolar; in British Columbia at the northern edge of its range
- vulnerable to logging or road construction

The following species of fruticose lichens are known from very few localities in British Columbia and may, therefore, be considered rare. Further work is required before this status can be applied with any degree of confidence. Many additional species will be added to this list once the appropriate studies have been conducted.

Critically imperilled (S_1)

Acroscyphus sphaerophoroides Léveillé
- over *Picea sitchensis* in an open lakeside fen near Prince Rupert, and over an alpine boulder in the Kitlope Valley
- incompletely circumpolar; a first record for this species in North America north of Mexico
- possibly vulnerable to logging

Agrestia hispida (Mereschk.) Hale & Culb.
- over exposed soil on windswept ridges near Kamloops
- western North America–eastern Eurasia; in British Columbia at the northern edge of its range
- vulnerable to trampling by cattle and recreationalists

Alectoria imshaugii Brodo & Hawksw.
- over conifers in the extreme southern Interior Cedar–Hemlock Zone (e.g., near Nelson)
- western North America; in British Columbia at the northern edge of its range
- vulnerable to logging and fire

Alectoria vancouverensis (Gylenik) Gyelnik *ex* Brodo & Hawksw.
- over conifers, primarily in the extreme southern Coastal Western Hemlock Zone (e.g., near Vancouver, Nanaimo), but also one collection from near Prince Rupert
- western North America; in British Columbia at the northern edge of its range
- vulnerable to logging and fire

Baeomyces carneus Flörke
- over bare soil near a mineral spring in southern Wells Gray Provincial Park
- circumpolar; only one collection known from British Columbia
- vulnerable to fire

Baeomyces placophyllus Ach.
- over moss on an open, north-facing basaltic bluff in southern Wells Gray Provincial Park
- circumpolar; only one collection known from British Columbia
- vulnerable to fire

Chaenotheca cinerea (Pers.) Tibell
- over bark of *Populus trichocarpa* in an old-growth Interior Cedar–Hemlock forest in southern Wells Gray Provincial Park
- western North America–eastern North America–western Eurasia; only one collection known from British Columbia
- vulnerable to fire

Cladonia cyanipes (Sommerf.) Nyl.
- among moss on near-vertical rock faces in open boulder beds in the Interior Cedar–Hemlock Zone (e.g., in southern Wells Gray Provincial Park)
- incompletely circumpolar; in British Columbia near the southern and western edge of its range
- vulnerable, in part, to fire

Cladonia parasitica (Hoffm.) Hoffm.
- over decaying conifer log in open forest, and over cedar shakes of a dilapidated cabin roof in southern Wells Gray Provincial Park
- possibly circumpolar; only two records are known from western North America
- vulnerable to logging and fire

Gyalideopsis alnicola Noble & Vězda
- over *Alnus* in roadside thickets on Saltspring Island
- western North America; reported only from British Columbia
- vulnerable to widening of the road at the type locality

Lichinodium canadense Henssen
- over conifers in humid old-growth Interior Cedar–Hemlock forests
- western North America; known only from British Columbia
- vulnerable to logging and fire

Niebla cephalota (Tuck.) Rundel & Bowler
- reported in Noble et al. (1987), but no specimens have been deposited at any of the herbaria studied; probably over seaside rocks in extreme southern Vancouver Island
- western North America; in British Columbia at the northern edge of its range
- possibly vulnerable to oil spills

Pilophorus nigricaulis Satô
- over rock in open, highly oceanic, coastal, terraced bogs (e.g., on Moresby Island)
- western North America–eastern Eurasia
- possibly vulnerable, in part, to logging

Pilophorus vegae Krog
- over rock in open, highly oceanic, coastal, terraced bogs (e.g., on Moresby Island)
- western North America–eastern Eurasia
- possibly vulnerable, in part, to logging

Ramalina subleptocarpha Rundel & Bowler
- over deciduous trees and shrubs on the Saanich Peninsula and on Mandarte Island
- western North America; in British Columbia at the northern edge of its range
- vulnerable to residential development

Usnea cfr. *florida* (L.) Weber *ex* Wigg.
- over *Acer macrophyllum* in and near Bridal Falls Provincial Park
- possibly incompletely circumpolar; in British Columbia at the northern edge of its range
- vulnerable to fire and logging

Zahlbrucknerella calcarea (Herre) Herre
- over limestone outcrops near Pavilion Lake; also in the southern Rockies
- incompletely circumpolar
- possibly vulnerable, in part, to fire

FUTURE LICHEN INVENTORY AND RESEARCH IN BRITISH COLUMBIA

In the following discussion, it is assumed that future lichen research in British Columbia will be driven primarily by the requirements of lichen conservation. Major emphasis is therefore placed on ensuring the documentation and inventory of those species most vulnerable to human activity.

Background Support

Provincial lichen collection Prerequisite to any future lichen research in British Columbia is the continued maintenance of a centralized repository for lichen collections. The herbarium at the University of British Columbia, which currently houses more than 40 000 lichen specimens, has long served that function, and should be viewed as British Columbia's provincial lichen collection.

Recommendation 1 Funding should be made available at a provincial level to ensure that the lichen section of the UBC herbarium continues to operate at least at its current level (staff: ½ person).

Identification keys The progress of lichen study in British Columbia, as in the Pacific Northwest in general, has been impeded by the absence of any comprehensive set of identification keys to the species. Keys to vascular plants, marine algae, and mosses have long been available, but the first thorough keys to the lichens of any major portion of the Pacific Northwest appeared only in 1994, under the auspices of the British Columbia Ministry of Forests. This identification manual, *The Lichens of British Columbia: Illustrated Keys, Part 1—Foliose and Squamulose Species* (Goward et al. 1994), handles approximately 20% of the total anticipated lichen flora of the province, and provides preliminary assessments of distribution, ecology, and endangerment status of the species.

Recommendation 2 Funding should be made available for the compilation of keys to (and assessments of) the remaining lichen groups (i.e., fruticose lichens and crustose lichens).

Cross-references The most complete summary of lichen diversity in British Columbia is the recent lichen checklist of Noble et al. (1987). Unfortunately, this checklist provides no cross-references to the literature, and hence offers no mechanism by which to evaluate species presence in the province. This lack of cross-references will continue to hamper attempts to summarize our knowledge of British Columbia lichens.

Recommendation 3 An annotated catalogue of the lichens of British Columbia should be prepared. Such a catalogue should be developed concurrent with the identification keys discussed in Recommendation 2, and likewise receive high priority for funding.

Co-ordination No single individual or agency currently has a mandate to supervise and co-ordinate lichen conservation in the province. Such co-ordination is vital, however, to ensure that those species most vulnerable to human activity are preserved.

Recommendation 4 Provincial Co-ordinator of Rare and Endangered Lichens should be appointed. The duties of such a co-ordinator could include: assembling a database of records of probable rare and endangered lichens; encouraging naturalist groups to prepare and maintain species lists in carefully delimited areas; ensuring that the selection of future protected areas is consistent with the requirements of lichen conservation; and co-ordinating lichen conservation efforts in British Columbia with similar initiatives in other parts of North America and Europe.

Field Studies

Inventory of critical areas Although it will be important to ultimately assess the status of all lichens in all parts of the province (ecoregion-by-ecoregion and zone-by-zone), the most urgent task at present is to ensure that no species become extirpated through development, resource extraction, or other human activity. This objective can best be met by focusing inventory efforts on those biogeoclimatic zones and ecoregions considered to be most critical for lichen conservation.

Recommendation 5 Detailed studies should be initiated on the 46 rare foliose and squamulose lichens listed on pages 13–18, based on their occurrence in the biogeoclimatic zones and ecoregions listed on pages 11–12. Ideally, these studies would take the form of COSEWIC-style status reports, though for budgetary reasons it may be necessary to settle for a less comprehensive level of documentation. Fruticose and crustose lichens should be adopted for study only after existing records have been carefully examined and evaluated in connection with Recommendations 2 and 3.

Inventory of rare saxicolous species Notwithstanding Recommendation 5, proposals for lichen inventory outside critical biogeoclimatic zones and ecoregions should not be discouraged; when performed in connection with comprehensive ecosystem research, such studies have the potential to contribute important insights into lichen distribution, as well as into the ecological functions lichens perform in different ecosystems.

Most of the "rare or infrequent" rock-dwelling, or saxicolous, lichens presented in Appendix 2 are assumed to be much more widespread and common than currently documented. To test this assumption, however, it would be useful to study at least a few of these species more closely.

Recommendation 6 A pilot study should be undertaken to assess the endangerment status of selected saxicolous species listed in Appendix 2. This could involve, for example, performing detailed inventories of 10 of the least frequently collected species. Good candidate species would be: *Collema callopismum* (only one specimen recorded to date), *Collema coccophorum* (one specimen), *Collema subparvum* (one specimen),

Neofuscelia subhosseana (three specimens), *Peltula euploca* (three specimens), *Phylliscum demangeonii* (one specimen), *Placynthium flabellosum* (one specimen), *Placynthium stenophyllum* (one specimen), *Placynthium subradiatum* (one specimen), and *Xanthoparmelia planilobata* (two specimens).

Rare lichens and old-growth ecosystems A majority of the species considered in this report are restricted to ecosystems that have remained free of major disturbance over a prolonged period. This aspect of lichen distribution, which appears to apply equally to forest ecosystems and grassland ecosystems, has yet to be adequately documented in North America (Goward 1993), though in Europe it is now well substantiated (Rose 1976). Goward (1993, 1994b) recently discussed the importance of old-growth forests to lichen diversity in British Columbia and observed that epiphytic lichens may be of critical importance as indicators of forest age. Lichen conservation would be well served by further studies along these lines.

Recommendation 7 Studies on the relation between rare lichens and old-growth ecosystems should receive continuing support.

Data for retrospective studies Lichens are highly sensitive to changes in air quality and climate (Nash and Wirth 1988). In many European countries, environmental degradation has already led to the decline or extirpation of numerous species, and similar declines have been detected in some portions of eastern North America. Given that many species can likewise be expected to become less abundant in some parts of British Columbia over time, it is essential that future studies not only document the presence or absence of rare species, but provide a reasonable assessment of their overall abundance. Studies at this level of detail are already providing critical background data for retrospective studies of environmental change in Europe and eastern North America (see, for example, Lawrey and Hale [1981]). To date, however, only a very few baseline studies of this kind have been performed in western Canada (e.g., Goward and Schofield [1983]; Koturi et al. [1985]; Goward [1987]).

Recommendation 8 Special emphasis should be placed on accumulating lichen data so as to facilitate future retrospective studies.

Such studies are of considerable importance in and near urban areas, but are also valuable in regions in which the mining of heavy metals is contemplated. Ideally, they should employ a standardized methodology and should, in particular, make use of a standardized scale of abundance. Numerous abundance scales have been proposed over the years by various authors, including Luttmerding et al. (1990, p. 119).

The following scale has been designed specifically to express lichen abundance in circular plots 30 m in diameter. Plots of this size are usually adequate to detect most of the lichens present at a site.

1 = three or fewer colonies per plot (or up to five colonies if poorly developed)
2 = from four colonies per plot to four colonies per tree or (in the case of ground-dwelling lichens) per 16 m^2.
3 = from five colonies per tree per 16 m^2 to 20% cover
4 = from 21% cover to 50% cover
5 = 51% cover or greater

No thorough review of potential threats to lichens in British Columbia has yet been undertaken, though Goward (1994a) did discuss a few of the more important ones. Based, however, on lichen conservation initiatives in other parts of temperate and boreal North America and Europe, the following observations are probably applicable:

1. Assuming that "island biogeography" theory (MacArthur and Wilson 1967) is applicable to lichens, as to other organisms, lichen diversity in British Columbia will be preserved in the long term only through the creation of a network of sizeable and/or closely linked natural reserves. These reserves should be established so as to maintain maximum genetic variability within species (Scudder 1989). In the very near future, therefore, it will be important to: (a) set aside a province-wide system of many small and some large reserves to act as centres of diaspore production and dispersal; and (b) protect species at the edges of their ranges, as well as at their ecological epicentres.

2. Goward (1993, 1994b) has suggested that the continued existence of many old-growth–dependent epiphytic lichens throughout their present ranges in British Columbia may require long-term forest continuity in the order of 300–400 years. Such lichens are unlikely to persist in plantation forests scheduled for harvesting at 100-year intervals. Selective harvesting may be a viable option in some cases, but this possibility requires considerable study before it can be endorsed.

3. Aquatic and semi-aquatic lichens such as *Hydrothyria venosa* and *Collema glebulentum*, among others, may be vulnerable to water pollution. The strong possibility exists that several such species have already been excluded in the lower stretches of the province's more heavily polluted streams and rivers. Along the coast, shoreline lichens such as *Collema fecundum* and *Kohlmeyera complicatula* may be susceptible to oil spills.

4. Trampling by cattle and other livestock is highly detrimental to terricolous lichens in some grassland ecosystems. No quantitative studies have yet been conducted to assess the impact of trampling on lichen diversity in British Columbia, but Goward (1991, 1992) has summarized the beneficial effects conferred by lichen crusts on grassland communities, and has argued that such studies are badly overdue.

5. Field observations in the south Okanagan suggest that wind-blown pesticide residues may have an adverse effect on lichens in the vicinity of orchards. In fact, lichens are usually completely absent from such areas. Given that several lichens are known to occur in Canada only in this portion of British Columbia, this "pesticide effect" deserves special attention.

6. Lichens lack roots, vascular systems, and any efficient mechanism for water storage. As a result, they tend to be highly sensitive to changes in

microclimatic conditions. This suggests that global warming, if it occurs, will profoundly alter lichen floristics in many portions of the province. For this reason, it might be advisable, where possible, to accommodate upward shifts in lichen zonal boundaries by setting aside the drainage basins of entire streams, from their confluences with lowland rivers to their alpine headwaters.

7. Lichens are among the most sensitive of organisms to various forms of atmospheric pollution, including ozone and sulphur dioxide emissions (Nash and Wirth 1988). It seems likely that air pollution has already excluded some lichen species from portions of the lower mainland (Goward 1994a). In the long term, maintaining lichen diversity in populated areas of the province will be possible only insofar as protected areas are located at a distance from factories and their major point sources of pollution.

INVENTORY TECHNIQUES

A particularly attractive aspect of lichenological studies, at least at the level of basic inventory, is that they need not be costly. To begin with, the necessary tools are few and inexpensive: hand lens, pocket knife, small paper bags, large collecting bags, rock hammer, cold chisel, and an atomizer filled with unchlorinated water. (For further details, see Hale [1979].)

At any given locality, examining two or three plots (of 30 m diameter, as noted above) will usually be sufficient to detect most of the species present. Within each of these plots, however, it is useful to know in advance which of the microhabitats present are most likely to harbour the species being sought—an insight that can only be acquired through long familiarity with lichen ecology.

Ideally, an attempt should be made to collect a sample of all lichen species present at a site, though at a minimum, all of the most common and as many as possible of the least common lichen species ought to be collected. Such mass collections are important both as an adjunct to documenting lichen diversity and distribution, and as a means of recording species that might otherwise be overlooked in the field; such species will often later be detected under the microscope.

In grassland ecosystems, lichen inventories usually require careful searching on hands and knees. By contrast, in forested ecosystems, where many species may grow in the canopy out of reach, it may be necessary to examine the trunks and upper branches of recently fallen trees; the edges of recent clearcuts are useful from this point of view. In the absence of downed trees, searching the branches of standing trees at the edges of small forest openings may be a useful exercise, especially when these are adjacent to marshes, streams, ponds, and other humid, sheltered places.

Finally, specimens collected in connection with future studies should be carefully curated according to standard techniques (see Hale 1979), and deposited with a recognized institutional herbarium. As already noted, British Columbia's largest and most active lichen herbarium is located in the botany department of the University of British Columbia.

The most important collections of British Columbia lichens are located at:

Herbarium
Department of Botany
University of British Columbia
3529-6270 University Boulevard
Vancouver, BC V6T 1Z4
Attention: Olivia Lee

Botany
Canadian Museum of Nature
Box 3443, Station D
Ottawa, ON K1P 6P4
Attention: Pak Yau Wong

Herbarium
Royal British Columbia Museum
675 Belleville Street
Victoria, BC V8V 1X4
Attention: John Pindermoss

Herbarium
Department of Botany
University of Helsinki
Unioninkatu 44
SF - 00170 Helsinki 17 Finland
Attention: Teuvo Ahti

The following individuals have a good knowledge of lichen taxonomy and may be contacted for possible identification or confirmation of lichen specimens:

Irwin Brodo
Botany
Canadian Museum of Nature
Box 3443, Station D
Ottawa, ON K1P 6P4
Telephone: 613 990-6446

Trevor Goward
Edgewood Blue
Box 131
Clearwater, BC V0E 1N0
Telephone: 604 674-2553

Bruce McCune
Department of Botany and Plant Pathology
Cordley Hall 2082
Oregon State University
Corvallis, OR 97331-2902
Telephone: 503 737-1741

Mike Ryan
4467 Wilkinson Road
Victoria, BC V8Z 5C2
Telephone: 604 727-2153

APPENDIX 2 Rare or infrequent saxicolous and terricolous lichens of British Columbia

The following species of foliose and squamulose lichens are considered by Goward et al. (*Lichens of B.C.*, 1994) to be of rare or infrequent occurrence in British Columbia, but were omitted from discussion in the foregoing text for the reasons given on page 5. Most of these rock-dwelling (= saxicolous) or soil-dwelling (= terricolous) lichens are currently known from fewer than 10 localities in the province, though a few rather more frequent species with restricted distributions are also included. The known distributions of most of these species are mapped in Goward et al. (*Lichens of B.C.*, 1994b).

Agonimia tristicula (Nyl.) Zahlbr.
Allantoparmelia almquistii (Vainio) Essl.
Arctoparmelia separata (Th. Fr.) Hale
Arctoparmelia subcentrifuga (Oxner) Hale
Asahinea scholanderi (Llano) Culb. & Culb.
Catapyrenium cinereum (Pers.) Körber
Cetraria agnata (Nyl.) Krist.
Cetraria commixta (Nyl.) Th. Fr.
Cetraria delisei (Bory *ex* Schaerer) Nyl.
Cetraria laevigata Rass.
Cetraria nigricans Nyl.
Collema bachmanianum (Fink) Degel.
Collema callopismum Massal.
Collema ceraniscum Nyl.
Collema coccophorum Tuck.
Collema cristatum (L.) F.H. Wigg.
Collema glebulentum (Nyl. *ex* Crombie) Degel.
Collema multipartitum Sm.
Collema subflaccidum Degel.
Collema subparvum Degel.
Dermatocarpon rivulorum (Arn.) Dalla Torre & Sarnth.
Endocarpon pulvinatum Th. Fr.
Gonohymenia nigritella (Lettau) Henssen
Hypogymnia subobscura (Vainio) Poelt
Lasallia pensylvanica (Hoffm.) Llano
Leptogium burnetiae Dodge
Leptogium subtile (Schrad.) Torss.
Masonhalea richardsonii (Hook.) Kärnef
Melanelia subargentifera (Nyl.) Essl.
Neofuscelia loxodes (Nyl.) Essl.
Neofuscelia subhosseana (Essl.) Essl.
Nephroma isidiosum (Nyl.) Gyelnik
Parmeliella cheiroloba Müll Arg.
Peltula euploca (Ach.) Ozenda & Clauz.
Phaeophyscia endococcina (Körber) Moberg
Phylliscum demangeonii (Moug. & Mont.) Nyl.
Physcia biziana (Massal.) Zahlbr.

Physconia distorta (With.) Laundon
Placynthium asperellum (Ach.) Trevisan
Placynthium flabellosum (Tuck.) Zahlbr.
Placynthium nigrum (Hudson) S. Gray
Placynthium stenophyllum (Tuck.) Fink
Placynthium subradiatum (Nyl.) Arn.
Psora cerebriformis W. Weber
Psora montana Timdal
Psora rubiformis (Ach.) Hook.
Punctelia stictica (Duby) Krog
Rhizoplaca peltata (Ramond) Leuckert & Poelt
Solorina bispora Nyl.
Solorina octospora (Arnold) Arnold
Solorina spongiosa (Ach.) Anzi
Umbilicaria aprina Nyl.
Umbilicaria cinereorufescens (Schaerer) Frey
Umbilicaria krascheninnikovii (Savicz) Zahlbr.
Umbilicaria lambii Imsh.
Umbilicaria lyngei Schol.
Umbilicaria muehlenbergii (Ach.) Tuck.
Umbilicaria nylanderiana (Zahlbr.) Magnusson
Umbilicaria polyrrhiza (L.) Fr.
Umbilicaria rigida (Du Rietz) Frey
Vestergrenopsis elaeina (Wahlenb.) Gyelnik
Vestergrenopsis isidiata (Degel.) Dahl
Xanthoparmelia mexicana (Gyelnik) Hale
Xanthoparmelia planilobata (Gyelnik) Hale
Xanthoria sorediata (Vainio) Poelt

Each element (for example, a species) on the Conservation Data Centre's list is ranked using the system developed over the last 20 years by The Nature Conservancy. This system is now in use in three Canadian provinces, all U.S. states, and a number of Latin American countries. Most government agencies within these jurisdictions have also adopted this ranking system.

Each element is ranked at two levels: global (G) and provincial, or "subnational" (S). The global rank is based on the status of the element throughout its entire range, whereas the provincial rank is based solely on its status within British Columbia. The global rank is established by a biologist assigned to that element by The Nature Conservancy; the provincial rank cannot exceed the global rank.

The status of an element is indicated on a scale of 1 to 5; the score is based primarily on the number of extant occurrences of the element, but other factors such as abundance, range, protection, and threats are also considered if the information is available. Generally speaking, the Conservation Data Centre will track only those species with ranks of 1–3. In addition to the ranks 1–5, there are several letter ranks; all are defined below.

1 = Critically imperilled because of extreme rarity (5 or fewer extant occurrences or very few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction.

2 = Imperilled because of rarity (typically 6–20 extant occurrences or very few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction.

3 = Rare or uncommon (typically 21–100 occurrences); may be susceptible to large-scale disturbances (e.g., may have lost extensive peripheral populations).

4 = Frequent to common (greater than 100 occurrences); apparently secure but may have a restricted distribution, or there may be perceived future threats.

5 = Common to very common; demonstrably secure and essentially ineradicable under present conditions.

H = Historical occurrence; usually not verified in the last 40 years, but with the expectation that it may someday be rediscovered.

X = Apparently extinct or extirpated, without the expectation that it will be rediscovered.

U = Status uncertain, often because of low search or cryptic nature of the element; uncertainty spans a range of 4 or 5 ranks.

R = Reported from the province, but without persuasive documentation for either accepting or rejecting the report.

RE = Reported in error, but this error has persisted in the literature.

? = No information is available, or the number of extant occurrences is estimated.

A = An element (usually an animal) that is considered accidental or casual in provinces; a species that does not appear on an annual basis.

E = An exotic or introduced species to the province.

Z = Occurs in the province but as a diffuse, usually moving population; difficult or impossible to map static occurrences.

In addition to the above ranks, there are four letter qualifiers sometimes used in conjunction with them:

T = Designates a rank associated with a subspecies.

B = Breeding; the associated rank refers to breeding occurrences of mobile animals.

N = Non-breeding; the associated rank refers to non-breeding occurrences of mobile animals.

Q = Taxonomic validity of the element is not clear, or in question.

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