MONITORING LICHENS FOR CONSERVATION: RED LISTS AND CONSERVATION ACTION PLANS

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1. Specific problems for the conservation of lichens

1.1. THE MUTUALISTIC WAY OF LIFE

Lichen-forming fungi are mutualistic symbiotic organisms. The mycobiont coexists with one or more algal or cyanobacterial photobionts. Conservation biology of lichens deals, therefore, with more than one organism, although it is the fungal partner, or mycobiont, which is generally the target for conservation. It is also the mycobiont which determines the systematic position of lichens.

The indeterminate pattern of growth of multicellular fungi has enabled lichen fungi to adopt an astonishing array of growth forms, and, as poikilohydric organisms, to occupy microniches not available to most other life forms. Many species have evolved a requirement for substrates (e.g. sheltered tree bark, large old logs, dry decaying wood) that are themselves by-products of advanced succession in more dominant ecosystems. Such species are often sensitive to various forms of anthropogenic disturbance, including intensive agricultural and forestry management.

In keeping with their need to secure nutrients mostly from their immediate environments, e.g. atmospheric dust, rainwash, lichens are highly efficient accumulators of environmental impurities. Many species are, therefore, highly sensitive to air, water, and soil pollution. Some species have suffered catastrophic decline in industrialised regions as a result of these pollutants. With the introduction of industrial smokestacks in the 1970s, these declines have become established over large geographic areas [77].

1.2. WIDE DISTRIBUTION – DISJUNCT AREAS

The incidence of circumpolar distributions is much higher in lichens (and other cryptogams) than in most other macroscopic organisms, including plants, mammals, and

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birds. At boreal latitudes, nearly 60-70% of all macrolichens occur more or less around the world in suitable habitats [1]. Unfortunately, widely distributed species tend to receive a low priority for conservation, even in portions of their range where they are truly endangered. This tendency can be highly detrimental to conservation of organisms, such as lichens, in which species concepts are not yet fully settled. Certainly at least some taxa currently believed to be circumpolar will eventually be shown to contain two or even several more geographically limited entities.

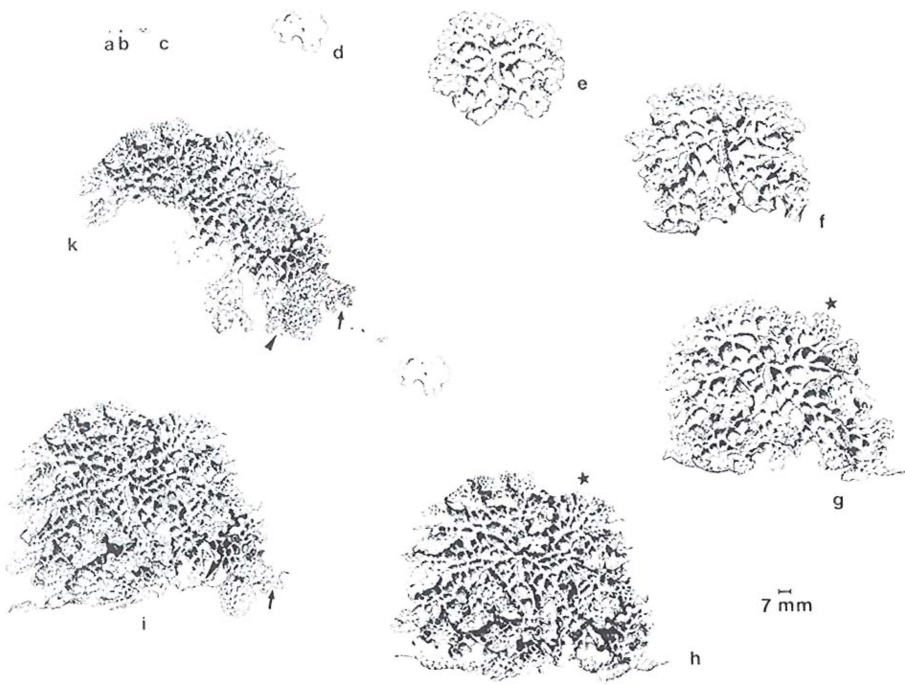

Figure 1. Thallus development in Lobaria pulmonaria*: a: Isidioid soredia are released from an adult thallus and attach on a suitable habitat. b: Development into stratified, spathuliform juvenile thalli within 1 year. c: After 4 years, isidioid soredia have developed into thalli only about 2 mm broad. d: After about 5 years, the early stages of lobe differentiation can be observed. e: At about 8 years, laminal growth by secondary meristems leads to the formation of foveae and ridges. f: After about 14 years, soralia develop at the thallus margins and on the laminal ridges, while upwards-growing lobes become canaliculate, and downward-growing lobes are spoon-shaped. g: Meristematic growth zones of lobes growing upwards often divide into three daughter meristems (see ★). h: First apothecia are formed on ridges of lobes growing downwards. i: Marginal soralia inactivate meristematic growth zones (arrow) of old lobes. These stop growth but continue to produce diaspores. k: Parts of the thallus can get lost and old lobes often form marginal and laminal regenerative structures (arrowhead). Figure after [54].*

1.3. LONG GENERATION TIME

Lichens are poikilohydric organisms and in many habitats they remain in an anabiotic state for much of each year. Further, the photobiont biomass is mostly very low and net production is accordingly low, at least as compared with that of higher plants. This low productivity often correlates with slow growth rates and, in some cases, exceptionally long life spans. Although only limited data are available on longevity in lichens, the extrapolated maximum age of saxicolous species in hot and cold deserts is greater than 500 and several thousand years, respectively [7, 35]. Though the lifespans of most epiphytic lichens are probably much less, some individual thalli are certainly able to persist for a century or more, an interval commensurate with the "lifespans" of the trunks and branches on which they grow. Longevity is likely to be important especially for species in which reproduction is initiated only after a prolonged juvenile phase (Figure 1); it is also certainly crucial for the maintenance of rare species in which an inability to recolonise efficiently is limiting (see below) (Figure 1).

1.4. ECOLOGICAL CONTINUITY

The tendency of many rare lichens to have long generation times, coupled with inefficient mechanisms of dispersal, makes them dependent on habitats with a low intensity and frequency of disturbance [48, 49]. Favoured habitats include rock outcrops, talus slopes, and primeval forests with a low incidence of fire and other stand-replacing events. Yet extensively managed habitats can also sometimes support such species dependent on ecological continuity [75]. Examples include pasture woodlands with a low tree harvesting intensity, and xeric terricolous habitats with low levels of competition from vascular plants as well as from the animals that graze them.

1.5. SURVIVAL OF SMALL POPULATIONS THAT ARE NOT REALLY VIABLE

Fragmentation of forested landscapes can entrain dramatic declines in many forest-dwelling lichens. Widespread and common species have become discontinuous, especially during the past century, the ranges of many formerly widespread and common species have become discontinuous, with the resulting populations becoming increasingly reduced in size. This tendency can create a high potential for genetic bottlenecks - an observation especially applicable to epiphytic species associated with old-growth forests. Although forest fragmentation has in many regions been occurring for a century or more, this interval in fact represents only a few generations of epiphytic lichens associated with old-growth forests. Conditions permitting the original establishment of such species may no longer exist. In Europe, both the medieval landscape and its characteristic epiphytic lichen cover are now largely relictual; even the most stringent efforts to preserve the remaining old stands are unlikely to prevent the loss of yet more old-growth-associated lichens.

1.6. CLONAL POPULATIONS OF SOREDIATE/ISIDIATE SPECIES

Vegetative dispersal is the sole means of propagation for many epiphytic and terricolous species. Clonal populations, therefore, are probably rather frequent in lichens. European lichenologists have noted a gradual reduction in the production of apothecia during the past two centuries, at least in some regions [11, 50]. Although lichen population biology is poorly understood at a molecular level, studies on *L. pulmonaria* indicate that fertile populations are genetically more diverse than sterile populations. At the same time, however, high genetic diversity is not necessarily prerequisite to the development of luxuriant populations [78]. Indeed, small and declining populations of *L. pulmonaria* may actually support a rather high genetic diversity.

2. Monitoring for rare and endangered species

Current efforts to conserve rare and endangered organisms generally involve data generation from one of two very different approaches. The first of these can be referred to as the habitat or ecosystem approach, while the second is appropriately termed the species-based approach [26]. The ecosystem approach will not be discussed here (for a summary, see [26]).

Species-based conservation involves, as a first step, the careful monitoring of individual taxa. The objective here is to identify those species warranting high priority for conservation. Once the endangerment status of such species has been thoroughly documented, conservation and recovery plans can be developed [26]. In recent times, and under the guidance of IUCN, this approach has led both to the development of Red Lists, i.e. lists of quantifiably rare and endangered species, and to the preparation of status reports. In both cases, national procedures often follow the IUCN guidelines with specific adaptations to regional or national levels and requirements [19, 21]. The following chapter provides brief discussions of both theses approaches, the first of which is widely used e.g. in Europe, while the second has been applied most notably by Canada. We recognise that other, somewhat intermediate approaches exist, but lack of space prohibits their inclusion here (for a summary, see [43]).

3. Red Lists

Early attempts to categorise species-at-risk according to the severity of the threats facing them date from the 1960s (for discussion, see [26]), though they bear little resemblance to current practices. The general aim of a modern Red List is to provide an explicit, objective framework for the classification of species according to their risk of extinction [30]. More specifically Red Lists are intended to:

- provide a system that can be applied consistently by different people;
- improve objectivity by providing clear guidance on how different factors affecting risk of extinction should be evaluated;
- provide a system that will facilitate comparisons across widely different taxa;
- give people using lists of threatened species a better understanding of how individual species were classified.

A wide range of data is required, most of it quantitative, to achieve the desired level of objectivity. The information needed for a Red List is specified in the criteria, and the degree of extinction risk is given in the threat categories. In the case of inconspicuous organisms particularly (including most crustose lichens), the available data are inadequate for the development of Red Lists, and specific monitoring projects must be designed to collect the required information.

3.1. THE THREAT CATEGORIES

Candidate species can be assigned to any of three "threat" categories, i.e. critically endangered (CR), endangered (EN) and vulnerable (VU). All of these categories are recognised as conferring "threatened" status upon the species in question. Species that have disappeared worldwide are considered extinct (EX). Species surviving in botanical gardens but not in the wild are considered extinct in the wild (EW), while species no longer occurring in a country or region are considered regionally extinct (RE) [19, 21]. A near threatened category (NT) is reserved for species that do not qualify for a threatened category at the present time but are expected to do so in the near future. Taxa which neither face serious decline nor have a restricted area of occurrence are classified as least concern (LC). Species for which additional data are needed in order to determine an appropriate Red List status are called data-deficient (DD). Finally, species not considered during a Red List project are referred to as not evaluated (NE) [31]. All taxa listed as critically endangered qualify also for vulnerable and endangered, and all listed as endangered qualify also for vulnerable.

3.2. THE CRITERIA

The IUCN has adopted five criteria intended to reflect varying forms of risk faced by declining species. Criterion A is related to past and future reductions in population size, while criterion B estimates the risk arising from both continuing decline and a small area of occurrence or occupancy. In criteria C and D, the focus is on small populations which additionally suffer ongoing decline or in which all individuals are in one subpopulation. Finally, criterion E considers the risk of future extinction. A more comprehensive discussion can be found in the official text published by IUCN [31].

3.3. THE PARAMETERS

Red List criteria are determined according to a variety of parameters. These are discussed below. Definitions of the parameters as used in IUCN [31] are given in italics, followed by explanations on how each parameter can be used in a lichenological monitoring project.

3.3.1. *Population and population size (criteria B and C)*

In the Red List literature a population is measured as the number of mature individuals of the taxon.

This measure, unfortunately, is hardly applicable to lichens, in which many species are inconspicuous, and are likely to be found only by chance. Even in careful surveys of lichen diversity the proportion of the total flora reported is often determined by the amount of time spent examining plots. Obviously, the number of "counted" or extrapolated individuals is mostly a rough estimate, intended primarily to provide a lower limit of population size. If repeatability of a monitoring program is desired, it is often useful to neglect thalli smaller than a given minimum length or diameter. For example, when monitoring for biodiversity on 100 m^2 permanent plots thalli smaller than 5 mm in diameter were excluded [56].

For endangered macrolichens, very detailed counts of individuals have often been reported. In Newfoundland, a threatened population of *Erioderma pedicellatum* was investigated both by amateurs and by foresters. Here the resulting population size of about 3000 individuals was used to defend a high conservation priority for this species, including mitigation measures in future management plans [41, 51]. Nevertheless, in the case of many crustose species, as well as some macrolichens (e.g. mat-forming and pendulous fruticose lichens), it is often impossible to delimit a separate individual. To some extent, this problem can be solved by adopting the concept of the "functional individual" (Hallingbäck, *pers. comm.*), especially for epiphytic lichens, which depend for their survival on the continued existence of the host tree. Because the single most important cause of death for epiphytic lichens is the death of their phorophyte host, all conspecific thalli inhabiting that phorophyte can for practical purposes be considered a functional individual. This approach makes population studies of epiphytic lichens relatively easy because mortality of the lichen functional individual can then be related to the mortality of the phorophyte [55].

Another approach to estimating the population size in lichens is to measure a species' abundance or biomass; for example, the summed length of thalli has been used as a measure of population size for *Usnea longissima* [16]. Of course, a precise estimation of population size is important for rare species only; and when time-consuming censuses are performed for highly localised species, this focus is very useful in the preparation of Red Lists. For more common species, however, extrapolation from representative surveys is usually sufficient for a rough estimate of regional population size. For example, the Swiss national population of *Hypogymnia physodes* has recently been estimated to consist of at least 1.608×10^9 individuals [53].

3.3.2. *Number and size of subpopulations (criteria A, B, C and D)*

Subpopulations are defined as geographically or otherwise distinct groups in the populations between which there is little genetic exchange.

The size of a subpopulation seems to us rather subjective; it depends on practical aspects of the area being considered. For example, the British Red List is based on a national gridwork consisting of 100 km^2 squares [10] while in the Swiss counterpart, subpopulations were considered to occupy a range of about 400 km^2 [53]. However, because many lichen species are rather poor dispersers and because even rather small areas can therefore be assumed to support independent populations, it may be useful to adopt subpopulation areas somewhat smaller than this.

3.3.3. *Mature individuals (criteria A, B, C and D)*

Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g. single pseudopodetia in Stereocaulon*).*

Problems related to the concepts of individuals are discussed under the parameter "population".

3.3.4. *Generation time (criteria A, C and E)*

Generation time is the average age of parents of the current cohort (i.e. new-born individuals in the population).

In lichens, generation time can therefore be defined as the average age at which a thallus has produced diaspores (i.e. whether ascospores, isidia, soredia, or thallus fragments) which led to the establishment of a succeeding generation. For convenience a period of three generations is used in the assessment of Red List status. Generation time can of course differ considerably among lichen species. Foliicolous species, for example, are usually short-lived. Competitive epiphytic species live considerably longer and usually die only upon the death of their phorophytes (see above). This observation holds true not only for the functional individual but also for individual thalli, which can persist for many decades, notwithstanding reported high rates of biomass turnover. However, depending on climatic conditions and the maximum age attainable by a phorophyte in different parts of its range, generation time can vary considerably even within a given lichen species. The estimated generation time for *L. pulmonaria* in Central Europe is probably several decades because significant diaspore production commences only at about 35 years of age, afterwards continuing for many decades [55]. For the purpose of Red List status, at least a century would be required for *L. pulmonaria* to attain its third generation. This corresponds well with the upper time limits usually considered in Red List designations, which is set at 100 years [31].

3.3.5. *Reduction (criterion A)*

A reduction is a decline in the number of mature individuals of at least the percentage stated under the criterion over the time period specified, although the decline need not be continuing.

In regions with a long tradition of lichen floristics and well-curated lichen collections, historic decline is one of the most powerful criteria for developing Red Lists. This parameter has been used in a semiquantitative way in most traditional Red Lists. However, with the modern, more quantitative definition of this criterion, it becomes difficult to compare past with present, because the methods used in early surveys usually differed considerably from those employed today. Only recently, for example, has it become possible to survey an entire country or region over a short period of time [72]. Modern surveys also tend to be much more intensive than their earlier counterparts. For example, analysis of a selection of well-known macrolichens in Switzerland has shown that many species thought to have undergone reduction in the past actually now occur at a greater number of sites than had formerly been documented. Anticipating this result Scheidegger *et al.* [53] included in their study several species for which no evidence of past reduction could be deduced. The ratio of historic to modern collections was then used to correct for different levels of sampling intensity between past and the present surveys. The same authors also found that surveys of subpopulations gave better results than did analyses of the collection sites [52]. Difficulties such as these are significant only in regions in which sampling intensity is not uniform. Elsewhere, in regions with a more complete knowledge of past distribution it is possible to accurately estimate reduction by simply revisiting previously known sites [66].

3.3.6. *Continuing decline*

A continuing decline is a recent, current or projected future decline, which is liable to continue unless remedial measures are taken.

The quantitative estimation of a continuing decline requires an intensive monitoring of the target species. If these direct measures are not available, then an indirect estimation via the decline of the habitat area or habitat quality is possible. However, it is often difficult to find data for specific lichen habitats.

3.3.7. *Extreme fluctuation*
Extreme fluctuations can be said to occur in a number of taxa when population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude.

Extreme fluctuations are likely to occur in rare ruderal species. Although this parameter seems not to play an important role in epiphytic lichens, it may be more significant in the life cycles of some foliicolous or terricolous taxa with both short generation time and high turnover rates.

3.3.8. *Severely fragmented*
The phrase "severely fragmented" refers to the situation in which increased extinction risk to the taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations.

This is a very important parameter in lichens. Many regional Red Lists and floras report taxa that occur on single trees [10] or on a few boulders [3].

3.3.9. *Extent of occurrence (criteria A and B)*
Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary drawn to encompass all known, inferred or projected sites of present occurrence of a taxon.

Because most lichen species are rather widely distributed, at least relative to the maximum allowable area of coverage for Red List status, only a few endemic species (see [18]) are likely to qualify for a listing under this parameter. When preparing a regional Red Lists, however, extent of occurrence can be important to document, especially in the case of subpopulations at their ecological limit.

3.3.10. *Area of occupancy (criteria A, B and D)*
Area of occupancy is defined as the area within its "extent of occurrence, which is occupied by the taxon".

According to IUCN protocol, this parameter can be estimated by summing the areas of grid cells in which the target species occurs. Mapping units for national surveys can vary significantly from region to region, e.g. whether a 10'x6' [minutes] grid [37, 68, 74], a 10x10 km grid [10, 17, 27] or a 20x20 km grid [15]. All of these grid units, however, are larger than the 50 km^2 area required for a CR listing under criterion B. A finer grid system is therefore required to determine the area of occupancy with a suitable degree of resolution.

In a recent national survey of epiphytic lichens of Switzerland, Dietrich [15] determined area of occupancy from a random sample where one observation represented 50 km^2. This level of resolution, however, is practical only when the area being surveyed is comparatively small. Even in a country the size of Switzerland, 826 observation plots were needed. A much larger number of plots would be required in most other countries, though the actual number might be kept to a minimum through habitat stratification. For example, habitat types with depauperate lichen floras are unlikely to support rare and endangered lichens, and need not be surveyed.

3.3.11. *Location (criteria B and D)*

The term "location" defines a geographically distinct area in which a single threatening event can rapidly affect all individuals of a species.

The actual size of a location varies according to the nature of the threat(s). In regions subject to industrial air pollution, the size of a location can be in the range of several hundred km^2. The geographic extent of a location also depends on forest and landscape management practices. In regions with predominantly small-scale management, a reasonable size for a location is 1 ha [53].

3.3.12. *Quantitative analysis (criterion A, E)*

A quantitative analysis is defined here as any form of analysis which estimates the extinction probability of a taxon based on known life history, habitat requirements, and any specified management options.

Along with expected declines due to habitat loss, a high degree of fragmentation into small populations is a typical response especially of epiphytic lichens. The latter response will lead to even greater future declines. However, the estimation of this decline is often hampered by lack of data, which are needed for a population viability analysis (PVA). Although it is unlikely that life cycle data can be collected for more than a handful of species, PVA can be carried out for some flagship species of high conservation relevance. Further, such a PVA could allow lichenologists to estimate the future decline of ecologically similar species, such as competitive late-stage species of the *Lobarion* communities.

3.4. DATA COLLECTION AND SAMPLING DESIGNS

Data collection for a Red List project involves careful monitoring, i.e. 'intermittent surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm' [28]. For any given species, the norm can be defined in terms of population size, geographic delimitation or degree of fragmentation. When undertaking a Red List project, it is crucial that the following sequential set of criteria be addressed from the outset: purpose, method, analysis, interpretation, and fulfilment [73].

3.4.1. *Purpose: what is the aim of the Red List project?*

Red List projects aim at checking the status of all lichen species or of a subset of them, e.g. the macrolichens. Follow-up, by contrast, is usually undertaken in order to detect significant changes in species status since the first Red List. Here the goal is to determine to what extent conservation measures (or other factors) have arrested earlier declines. This often involves revisiting historical sites of rare species and searching for hitherto overlooked or new sites.

In order to avoid loss of time and energy, the specific objective of a particular surveillance programme must be decided in advance, i.e., whether it is intended to provide baseline data for: (1) future Red List assessments, (2) mapping projects, and/or (3) biodiversity studies. Survey frequency and data reliability should also be specified at the outset. It is important to ensure that a high degree of reliability can be attained, as between-crew errors are relatively frequent in monitoring programs that focus on species richness [40].

3.4.2. *Method: How can the parameters for Red List criteria be measured?*
The (cost) efficiency of any large-scale monitoring programme is decisively influenced by its sampling design [58]. Attempts to monitor lichens for Red Lists must cope with the problem of how to provide representative information on rare and endangered species. The presence of rare species can often not be predicted with precision and it is usually through the field knowledge of an experienced lichenologist that rare species are found. Although this "sixth" sense for rare species can be learned, it nevertheless remains highly subjective and depends on a viable lichenological tradition. Unfortunately, field knowledge is now generally in decline in many countries, even where outstanding traditions in lichen floristics have formerly existed [37].

The vast majority of lichen species now considered to be endangered were formerly much more abundant than they are today (see [10, 53, 63, 76]). This trend seems likely to continue into the foreseeable future, at least for some species groups, e.g. cyanolichens and calicioids. It is, therefore, important to apply Red List criteria not only to rare species but also to species that, though widespread and common today, may become the threatened species of tomorrow. To be of greatest value in the long term, a sampling design should therefore include assessments of all species, especially as regards frequency occurrence. It should also take into account the requirement of statistical analysis for random sampling. Too often the importance of random sampling is underestimated, with the result that many population estimates are nearly worthless [61].

From the wide variety of sampling methods available [12], the most useful for the purpose of monitoring biodiversity is the stratified random sample approach, in which a region is subdivided into strata, and each stratum is then sampled randomly [73]. In one recent Red List project involving epiphytic lichens, for example, the study area (Switzerland) was stratified into 5 geographical strata, 2 vegetation formations and 6 altitudinal strata [14]. Biodiversity surveys must often remain very incomplete, as there is time to visit only a small fraction of the total study area. Between-replicate sample variation is most easily minimised when very small sampling units (e.g. 500 m^2) are monitored. Using this approach common and widespread species are well represented, though localised species (e.g. species restricted to rare habitats or invariably scarce when present at all [46]) could easily be missed. Nevertheless a recent survey of 826 small (500 m^2) permanent plots, a fraction of $1x10^{-5}$ of the study area, yielded more than 60% of total regional epiphytic lichen richness [15].

If only a few specific habitats are disproportionately rich in rare species, then a stratification for these habitats could contribute to an even more effective sampling design for rare taxa. However, habitats potentially occupied by rare lichens typically cover a very broad geographic range. Collecting data specifically for rare species is therefore more efficiently accomplished by examining larger mapping units. In this case, lichen-rich habitats are more likely to be visited and monitored in the context of systematic traverses and intelligent random meanderings [59]. This method is very effective especially in areas where target species have previously been reported and where more detailed surveys are intended to add information on population size and delimitation. What is more, experience has shown that the "intelligent random meander" approach is more highly regarded by amateur lichenologists (who often carry out the majority of lichen monitoring) than the more standard "small plot" approach.

3.4.3. *Analysis: how are the data handled?*
Akçakaya *et al.* [2] have recently developed the software programme RAMAS Red List (http://www.ramas.com/), which assists in the calculation of Red List status. Even so, each project will have its specific interpretation of parameters, which will require customised methods for data analysis. In all cases the general characteristics of monitoring data such as trend, cycle and noise [73] have to be distinguished. While it is true that cyclic trends in lichen populations have not yet been reported, noise and trend still remain to be separated - not an easy task in the case of these long-lived organisms.

3.4.4. *Interpretation: what might the data mean?*
IUCN protocol has established firm guidelines for interpreting field data in the context of Red List assessments (see [31]). Though it is beyond the scope of this paper to discuss these interpretations in detail, we can observe that the ecological and evolutionary significance of Red List status is supposed to be universal for all groups of organisms. For example, an 80% reduction in beluga whales should theoretically have biological implications and evolutionary consequences equivalent to those that would attend an 80% reduction in *Lobaria pulmonaria*. Unfortunately this assumption, though precautionary, is difficult to apply meaningfully, for it seems to require that species concepts should be uniform and equivalent for all taxa on earth, which is so far not the case.

3.4.5. *Fulfilment: when will the aim have been achieved?*
The goal of conservation politics related to Red Lists can be roughly summarised as follows: Sustainable management of natural resources and conservation measures for threatened organisms should both make Red Lists shorter and shift the red listed species downwards to lower threat categories. The goals of monitoring for Red Lists will therefore be achieved as soon as no species qualify for the Red List criteria.

3.5. STRENGTHS AND LIMITS OF RED LISTS

Over the past 15 years national Red Lists have been published for many countries and natural regions; for a review, see [63], [4, 5, 6, 8, 9, 10, 20, 29, 32, 33, 34, 36, 38, 42, 44, 45, 47, 53, 57, 60, 62, 64, 65, 67, 69, 70, 71]. At the same time, a preliminary global Red List has been compiled [62]. These Red Lists constitute a most valuable source of information. Nevertheless, Red List protocol has undergone major changes during this period. The earliest Red Lists were often prepared by one or two regional authorities who were able to apply threat categories rather consistently across their local flora. This approach, however, made it difficult to align Red List designations across political boundaries. A major advantage of the new IUCN Red Lists protocol is its greater emphasis on quantitative estimates of regional or global risk. Rarity and vulnerability of populations at the national level are thus now intended to reflect the probability of regional extinction. This emphasis builds on the strength of earlier Red Lists by ensuring greater interregional compatibility, and thus making possible a more broadly based assessment of at-risk status.

4. The status survey: A case study

4.1. COSEWIC: A CANADIAN APPROACH TO AT-RISK DESIGNATION

By world standards, Canada is a sparsely populated country in which natural ecosystems remain largely intact. Until recently, the impact of human activity in most regions of the country has been negligible, and conservation efforts have accordingly tended to receive low priority. Nevertheless, no fewer than 12 species of mammals, birds, fish, and molluscs formerly endemic to Canada are known to have gone extinct within the past century, while another 15 species have lately disappeared within the Canadian portions of their ranges [13].

Responsibility for rare species conservation in Canada is shared between two levels of government. Provincial and territorial governments have sponsored monitoring programmes at a regional level, mostly under the auspices of Conservation Data Centres (CDCS) and Natural Heritage Information Centres (NHICS), while the federal government has taken the lead in promoting monitoring at the national level. To date, however, only the latter initiative can be said to be truly underway, at least as concerns lichens; the CDSS and NHICS have as yet developed no authoritative provincial lichen tracking lists. In the following account, we therefore focus on initiatives conducted at the national level only.

Canada's enormous size and sparse research capacity has prompted the Canadian government to adopt a nationally co-ordinated process for the official designation of endangerment status. Since 1978, the designation of species-at-risk in Canada has been undertaken by the "Committee on the Status of Endangered Wildlife in Canada", widely known as COSEWIC. COSEWIC operates at arms' length from government, though it is funded by the Canadian Wildlife Service. Its purpose is to determine the status of wild species (including subspecies, varieties, and nationally significant populations) suspected of being at risk in Canada. The committee is comprised of representatives from all provincial and territorial wildlife agencies, four federal agencies, three national non-government organisations, and the chairs/co-chairs of various specialist groups. The committee meets annually to consider status reports on candidate species.

In keeping with its name, COSEWIC was originally intended to assign at-risk status to "wildlife" species only, i.e., fish, birds, mammals, reptiles, and amphibians, though vascular plants were informally understood to be appropriate for status designation. In 1994 however, the COSEWIC mandate was expanded to include lichens and mosses, while in 1995 it was expanded again to encompass lepidopterans and molluscs. Thus, though lichens are now included under its aegis, many other organisms are not.

4.1.1. Status reports

The credibility of the COSEWIC designation process rests on the availability of accurate and detailed information on the status of candidate species. This information is assembled and made available through the preparation of lengthy status reports. The format of COSEWIC status reports has been standardised to ensure a high level of documentation for all candidate species. An impression of the level of detail required for the preparation of these reports can be garnered from Table 1.

TABLE 1. Standardised format of a COSEWIC status report.

ABSTRACT

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   - Extant populations recently verified
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   - Biogeographic and phylogenetic history
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   - Climate
   - Air and/or water quality requirements
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   - Dependence on dynamic factors
   - Biological characteristics
6. Population biology
   - Demography
   - Phenology
   - Reproductive biology
7. Population ecology
8. Land ownership and management responsibility
   - General nature of responsibility
9. Management practices and experience
   - Habitat management
   - Performance under changed conditions
   - Cultivation
10. Evidence of threats to survival
    - Habitat destruction or modification
    - Overutilisation of species
    - Disease or predation
    - Other natural or manmade factors
11. Present legal or other formal status

SECTION II: ASSESSMENT OF STATUS
12. General assessment
13. Status recommendation
14. Recommended critical habitat
15. Conservation recommendations

SECTION III: INFORMATION SOURCES
16. References cited in report
17. Other pertinent publications
18. Collections consulted
19. Fieldwork
20. Acknowledgements and knowledgeable individuals
21. Other information sources
22. Summary of materials on file

SECTION IV: AUTHORSHIP
23. Initial authorship of status report
24. Maintenance of status report

Responsibility for commissioning status reports falls to the subcommittee chairs/co-chairs. For lichens, it is the vascular plant subcommittee co-chair who initiates a status report. This is a lengthy process, and involves: 1) developing a priority list of candidate species (see below); 2) securing the necessary funding; 3) contacting and contracting knowledgeable individuals to prepare the reports; and 4) guiding the reports through to completion. Once completed, the reports are subjected to peer review by a panel of lichen specialists within the vascular plants subcommittee. The reports are then submitted to COSEWIC for deliberation at its annual designation meetings. Only then is official at-risk status determined. COSEWIC status reports for vascular plants, mosses, and lichens are based both on existing information and on field-work to establish the validity of earlier literature reports. In the past, COSEWIC designations were meant to reflect the status of candidate species solely within Canada's borders, i.e. without reference to their status in the United States or other jurisdictions. More recently, however, an attempt has been made to consider the "rescue effect", i.e. the likelihood that species, though potentially endangered in Canada, will eventually re-establish from one or more populations outside the country. Species judged to be subject to the rescue effect are now accorded a lower status designation than would apply given strict adherence to the designation criteria.

4.1.2. The threat categories

In the past, COSEWIC has assigned candidate species to one of seven categories, i.e., not-at-risk, vulnerable, threatened, endangered, extirpated, extinct, and data-deficient. More recently, however, COSEWIC risk categories have been modified to reflect advances in conservation biology, and to more closely align with the IUCN categories (see above). Canada's current risk categories can be defined as follows:

- Extinct (X): a species (i.e., including subspecies, variety, or geographically distinct population) that no longer exists.
- Extirpated (XT): a species no longer occurring in the wild in Canada, but extant elsewhere.
- Endangered (E): A species facing imminent extirpation or extinction.
- Threatened (T): A species likely to become endangered if limiting factors are not reversed.
- Special concern (SC): A species judged to be particularly sensitive to human activity or natural events.
- Not at risk (NAR): A species that has been evaluated and found to be not at risk.
- Data deficient (DD): A species for which there is insufficient scientific information to support status designation.

4.1.3. At-risk designation

COSEWIC endangerment status is assigned on scientific merit alone; political, social and fiscal implications are not considered. By the same token, the assignment of at-risk status by COSEWIC carries no legal import; its primary function is merely to draw public and government attention to specific instances of impending extirpation or extinction. This approach of course presupposes that the responsible jurisdictions can be depended upon to act within their mandates to offset these trends. Unfortunately, this has not always been the case.

The assigning of at-risk categories has traditionally been consensus-driven and, in consequence, relatively non-quantitative. This practice has raised concerns regarding possible inconsistencies in the designation of at-risk status across different taxonomic groups. These concerns have lately become more vocal, following recent attempts to secure at-risk legislation in a federal endangered species act. In response, COSEWIC has now adopted quantitative designation guidelines modelled on the IUCN Red List criteria (see above). This move toward a more defensible protocol has extended even to the process of prioritising candidate species for COSEWIC assessment.

4.1.4. Status of lichen conservation in Canada

Initiatives to conserve Canada's lichen flora are at an early stage. Indeed, the first tentative steps toward lichen conservation in this country can be said to have begun only a decade ago, in the early 1990s, when the British Columbia Ministry of Environment commissioned a series of studies on the status of epiphytic lichens associated with old-growth rainforests. Species included in these studies are *Heterodermia sitchensis*, *Hypogymnia heterophylla*, *Nephroma occultum*, and *Pseudocyphellaria rainierensis* [22, 23, 24]. The resulting reports adopted a COSEWIC format (Table 1), and were later "donated" to COSEWIC for status designation. Unfortunately only one of these species, *Heterodermia sitchensis*, was eventually accorded at-risk status as "endangered"; the other species are currently listed as "special concern".

More recently, Wolfgang Maass completed a COSEWIC status report on *Erioderma pedicellatum* [39], a globally rare species restricted in North America to maritime Canada [51].

Another step toward lichen conservation occurred with the commissioning, by COSEWIC, of a report on the rare lichens of Canada. In this report, Goward *et al.* [25] called attention to 112 lichen species considered to be at risk in Canada. Most of these are macrolichens. At least 30 species are believed to be in serious decline, while six species appear to be extirpated in Canada. These are *Alectoria fallacina, Heterodermia hypoleuca, Leptogium azureum, L. byssinum, L. dactylinum, and L. rivulare* - most of which, however, are still present in adjacent portions of the United States.

4.2. STRENGTHS AND WEAKNESSES OF THE COSEWIC APPROACH

The COSEWIC approach has three basic strengths: 1) its high level of scientific rigour; 2) its transparency; and 3) its consistency of approach. Scientific rigour ensures that at-risk status is accorded only to species really in danger of extirpation or extinction - with obvious benefits to the expenditure of public funds on recovery programs. Transparency invites input from sources outside government and industry, thus tending to promote an acceptable degree of objectivity. And finally, consistency of approach allows organisms from a wide array of taxonomic groups to receive equal attention by Canada's committee on endangered species - subject of course to adequate levels of knowledge among taxonomic specialists.

It is also possible to point to at least three weaknesses with the COSEWIC approach. First, COSEWIC embraces only the most charismatic taxonomic groups, all of them macroscopic. As a result, only a small percentage of Canada's total species are currently eligible for at-risk designation. Second, the process of determining species status is very slow and involved, with only 513 designations having been completed in more than two decades. This is testament both to the rigour of the COSEWIC process, and more particularly to the shoestring budgets on which this committee has operated since its inception. Finally, as already noted, COSEWIC status designation has no legal import; it recommends but does not oblige.

What does the future hold for Canada's rare and endangered species? Actually there is reason for cautious optimism. Political pundits predict that the long-proposed federal species-at-risk act will come into effect within the next few years. Should this happen, COSEWIC would receive legal status; and its designations, once ratified by parliament, would result in the mandatory preparation of recovery plans for all species designated as threatened or endangered.

5. Conclusions

Recent methodological developments in the preparation of Red Lists and status surveys have strengthened the reliability of both these approaches to at-risk designation. Ongoing efforts to harmonise the use of at-risk categories will provide a basis for even greater consistency between them. Notwithstanding these positive trends, however, there is not too much reason for optimism regarding the future of lichen conservation. While the power of Red Lists and status surveys to assist in conservation management has increased, their level of acceptance by politicians and conservation authorities continues to lag behind. The practical utility of these tools appears to depend less on their scientific merit than on the cost-effectiveness of the recovery plans that flow from them. What is more, in the harsh bureaucratic reality of conservation practice, the aesthetics of the target organisms are often at least as important as their ecological significance. Unfortunately, lichens are seldom accorded a high ranking for conservation: a state of affairs certainly in part related to their small size, general inconspicuousness, and lack of big brown eyes. Even lichens that have been well documented as critically endangered often fail to receive an adequate level of conservation priority. This unsatisfactory situation is likely to change only when lichens have acquired a higher public profile. Clearly, these organisms have yet to achieve their full potential political import. We urge our colleagues to join us in sharing - with politicians, conservation authorities, the media, and the broader public - our collective sense of the importance of lichens, not only as biological chinking and surpassing models of symbiosis, but also as monitors of ecosystem functioning.

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7. References

1. Ahti, T. (1977) Lichens of the boreal coniferous zone, in M.R.D. Seaward (ed.), *Lichen Ecology*, Academic Press, London, pp. 145-181.
2. Akçakaya, H.R., Ferson, S., Burgman, M.A., Keith, D.A., Mace, G.M., and Todd, C.R. (2000) Making consistent IUCN classifications under uncertainty, *Conservation Biology* **14**, 1001-1013.
3. Aptroot, A., van Dobben, H., van Herk, C., and van Ommering, G. (1998) *Bedreigde en kwetsbare korstmossen in Nederland. Toelichting op de Rode Lijst*, Rapport IKC Natuurbeheer, 29, Informatie- en Kennis Centrum Natuurbeheer, Wageningen.
4. Aptroot, A., van Herk, C., van Dobben, H., van den Boom, P., Brand, A., and Spier, L. (1998) Bedreigde en kwetsbare korstmossen in Nederland: basisrapport met voorstel voor de Rode Lijst, *Buxbaumiella* **46**, 1-101.
5. Aronsson, M., Hallingbäck, T., and Mattsson, J.E. (1995) *Rödlistade växter i Sverige 1995 [Swedish Red Data Book of Plants 1995]*, ArtDatabanken, Uppsala.
6. Arup, U., Ekman, S., Kärnefelt, I., and Mattsson, J. (1997) *Skyddsvarda Lavar i Sydvästra Sverige [Red-listed lichens and changes in the lichen flora of southwestern Sweden]*, SBF-Forlaget, Lund,
7. Beschel, R. (1958) Lichenometrical studies in west Greenland, *Arctic* **11** (4), 254.
8. Carballal, R., Paz Bermudez, G., and Valcarcel, C.P. (1999) *Datos para una "lista roja" de macroliquenes en Galicia*, Universidad Complutense, Madrid.
9. Chabanenko, S.I. (1995) Rare and vulnerable species of lichens in the southern part of the Russian Far East - Primorye and Sakhalin Regions, *Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft* **70**, 147-152.

10. Church, J.M., Coppins, B.J., Gilbert, O.L., James, P.W., and Stewart, N.F. (1996) *Red data books of Britain and Ireland: lichens vol. 1: Britain,* Joint Nature Conservation Committee, Peterborough.
11. Clerc, P. (1999) Les lichens bioindicateurs de la pollution de l'air dans le bassin lémanique, in C. Bertola, C. Goumand and J.-F. Rubin (eds.), *Découvrir le Léman 100 ans après François-Alphonse Forel,* Editions Slatkine, Genève, pp. 123-138.
12. Cochran, W.G. (1977) *Sampling techniques,* John Wiley, New York.
13. COSEWIC (2000) *Canadian species at risk,* Environment Canada, Ottawa.
14. Dietrich, M. and Scheidegger, C. (1997) A representative survey of frequency of epiphytic lichens at the regional and national levels and its use for the Red List of Switzerland, in R. Türk and R. Zorer (eds.),, *Progress and Problems in Lichenology in the Nineties - IAL 3,* Bibliotheca. Lichenologica **68**, J. Cramer, Berlin, pp. 145-154.
15. Dietrich, M., Stofer, S., Scheidegger, C., Frei, M., Groner, U., Keller, C., Roth, I., and Steinmeier, C. (2000) Data sampling of rare and common species for compiling a Red List of epiphytic lichens. *Forest, Snow and Landscape Research,* **75**, 369-380.
16. Esseen, P.A., Renhorn, K.E., and Pettersson, R.B. (1996) Epiphytic lichen biomass in managed and old-growth boreal forests: Effect of branch quality, *Ecological Applications* **6**, 228-238.
17. Faltynowicz, W. (1990) Lichen mapping in Poland, *Stuttgarter Beiträge zur Naturkunde, Ser. A* **456**, 41-42.
18. Galloway, D.J. (1996) Biogeography, in T. Nash III (ed.), *Lichen Biology,* Cambridge University Press, Cambridge, pp. 199-216.
19. Gärdenfors, U. (1996) Application of IUCN Red List categories on a regional scale, in J. Baillie and B. Groombridge (eds.), *1996 IUCN red list of threatened animals,* IUCN, Gland, pp. 63-66.
20. Gärdenfors, U. (2000). *Rödlistade arter i Sverige - The 2000 Red List of Swedish Species. Vol. 2000,* ArtDatabanken SLU, Uppsala.
21. Gärdenfors, U., Rodriguez, J.P., Hilton-Taylor, C., Hyslop, C., Mace, G., Molur, S., and Poss, S. (1999) Draft guidelines for the application of IUCN Red List criteria at national and regional levels, *Species* **31/32**, 58-70.
22. Goward, T. (1996) *Status report on the oldgrowth specklebelly,* Pseudocyphellaria rainierensis, *in Canada,* Committee on the Status of Endangered Wildlife in Canada, Ottawa.
23. Goward, T. (1996) *Status report on the seaside bone,* Hypogymnia heterophylla, *in Canada,* Committee on the Status of Endangered Wildlife in Canada, Ottawa.
24. Goward, T. (1996) *Status report on the seaside centipede,* Heterodermia sitchensis, *in Canada,* Committee on the Status of Endangered Wildlife in Canada, Ottawa.
25. Goward, T., Brodo, I., and Clayden, S. (1998) *Rare Lichens of Canada. A Review and Provisional Listing,* Committee on the Status of Endangered Wildlife in Canada, Ottawa.
26. Groombridge, B. (1992) *Global Biodiversity: Status of the Earth's living resources. A Report compiled by the World Conservation Monitoring Centre,* Chapman & Hall, London.
27. Hawksworth, D.L. and Seaward, M. (1990) Twenty-five years of lichen mapping in Great Britain and Ireland, *Stuttgarter Beiträge zur Naturkunde, Ser. A* **456**, 5-10.
28. Hellawell, J.M. (1991) Development of a rationale for monitoring, in B. Goldsmith (ed.), *Monitoring for conservation and ecology,* Chapman and Hall, London, pp. 1-14.
29. Inoue, M. (1998) Our continual project on Japanese red data lichens. *Lichen - News Bulletin of the Lichenological Society of Japan,* **11** (1), 172.
30. IUCN (1994) *IUCN red list categories. As approved by the 40th meeting of the IUCN council,* IUCN, Gland.
31. IUCN (2001) *IUCN red list categories. Prepared by the IUCN species survival commission. As approved by the 51th meeting of the IUCN council,* IUCN, Gland.
32. Jacobsen, P. (1997) *Die Flechten Schleswig-Holsteins - Rote Liste,* Landesamt für Natur und Umwelt des Landes Schleswig-Holstein, Hamburg.
33. Kashiwadani, H. and Kurokawa, S. (1995) Threatened lichens in Japan, in C. Scheidegger, P.A. Wolseley and G. Thor (eds.), *Conservation Biology of Lichenised Fungi,* Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf, Switzerland, pp. 141-146.
34. Kuusinen, M., Kaipiainen, H., Puolasmaa, A., and Ahti, T. (1995) Threatened lichens in Finland, *Cryptogamic Botany* **5** (3), 247-251.
35. Lange, O.L. (1990) Twenty-three years of growth measurements on the crustose lichen *Caloplaca aurantia* in the central Negev Desert (Israel), *Israel Journal of Botany, Basic and Applied Plant Sciences* **39**, 383-394.

36. Liška, J. (1996) Cervene seznamy lisejniku [Red Lists of lichens], *Severoceskou prirodou, Litomerice, Suppl.* **9**, 53-59.
37. Liška, J. (1990) The mapping of lichens in Bohemia: aims, problems and present state, *Stuttgarter Beiträge zur Naturkunde, Ser. A* **456**, 43-52.
38. Litterski, B., Brandt, B., and Dieminger, J. (1996) *Rote Liste der gefährdeten Flechten Mecklenburg-Vorpommerns,* Der Minister für Landwirtschaft und Naturschutz des Landes Mecklenburg-Vorpommern, Schwerin.
39. Maass, W. (2001) *Status report on* Erioderma pedicellatum *in Canada,* Committee on the Status of Endangered Wildlife in Canada, Ottawa.
40. McCune, B., Dey, J., Peck, J., Cassell, D., Heiman, K., Will-Wolf, S., and Neitlich, P. (1997) Repeatability of community data: species richness versus gradient scores in large-scale lichen studies, *The Bryologist* **100** (1), 40-46.
41. McHugh, S. (1998). *A study of the endangered lichen* Erioderma pedicellatum *in Lockyer's Waters, Newfoundland*, Memorial University, St John's, Newfoundland, Canada, St. John's.
42. Motiejunaite, J. (1999) Checklist of lichens and allied fungi of Lithuania, *Botanica Lithuanica* **5** (3), 251-269.
43. Nicholopoulos, J. (1999) The endangered species Listing Program, *Endangered Species Bulletin* **24**, 6-9.
44. Pfefferkorn, V. and Türk, R. (1997) Rote Liste der im Bundesland Vorarlberg aktuell gefährdeten Flechtenarten, *Vorarlberger Naturschau* **3**, 217-229.
45. Pisut, I. (1999) Chranene druhy machorastov a lisajnikov v Slovenskej republike [Bryophytes and lichens protected by law in the Slovak Republic], *Bryonora* **24**, 27-28.
46. Rabinowitz, D. (1981) Seven forms of rarity, in H. Synge (ed.), *The biological aspects of rare plant conservation,* Wiley, Chichester, pp. 205-217.
47. Randlane, T. (1998) Red List of Estonian macrolichens [Eesti suursamblike punane nimekiri], *Folia Cryptogamica Estonica* **32**, 75-79.
48. Rose, F. (1976) Lichenological indicators of age and environmental continuity in woodlands, in D.H. Brown, D.L. Hawksworth and R.H. Bailey (eds.), *Lichenology: Progress and Problems,* Academic Press, London, pp. 279-307.
49. Rose, F. (1992) Temperate forest management: its effects on bryophyte and lichen floras and habitats, in J.W. Bates and A. Farmer (eds.), *Bryophytes and lichens in a changing environment,* Clarendon Press, Oxford, pp. 211-233.
50. Scheidegger, C. (1995) Early development of transplanted isidioid soredia of *Lobaria pulmonaria* in an endangered population, *Lichenologist* **27**, 361-374.
51. Scheidegger, C. (1998) *Erioderma pedicellatum*: a critically endangered lichen species, *Species: Newsletter of the Species Survival Commission IUCN* **1998** (June), 68-69.
52. Scheidegger, C., Clerc, P., Dietrich, M., Fiore, A.-M., Frei, M., Groner, U., Keller, C., Roth, I., Stofer, S., and Wildi, E. (in prep.): Reduction in national populations of epiphytic lichens assessed from herbarium observations and a national surveillance.
53. Scheidegger, C., Dietrich, M., Frei, M., Groner, U., Keller, C., Roth, I., Stofer, S., and Clerc, P. (2001) Epiphytische Flechten der Schweiz, in C. Scheidegger, P. Clerc, S. Lussi and F. Cordillot (eds.), *Rote Liste der baum- und erdbewohnenden Flechten der Schweiz,* BUWAL, WSL, Bern (in press).
54. Scheidegger, C., Flachsmann, S., Zoller, S., and Frey, B. (1997) Naturschutzbiologie bei Flechten: Konzepte und Projekte, *Kleine Senckenbergische Reihe* **27**, 167-175.
55. Scheidegger, C., Frey, B., and Walser, J.-C. (1998) Reintroduction and augmentation of populations of the endangered *Lobaria pulmonaria*: methods and concepts, in S. Kondratyuk and B.J. Coppins (eds.), *Lobarion lichens as indicators of the primeval forests of the eastern Carpathians,* Phytosociocentre, Kiev, pp. 33-52.
56. Scheidegger, C., Stofer, S., Frei, M., Groner, U., Dietrich, M., Roth, I., and Keller, C. (1999). *Biodiversitätsmonitoring Schweiz: Operationalisieren von Z9 Flechten*, WSL, Birmensdorf, pp. 12.
57. Schöller, H., Cezanne, R., and Eichler, M. (1996) *Rote Liste der Flechten (Lichenes) Hessens,* Hessisches Ministerium des Innern und für Landwirtschaft, Forsten und Naturschutz, Wiesbaden.
58. Scott, C.T. and Köhl, M. (1993) A method for comparing sampling design alternatives for extensive inventories, *Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft* **68**, 1-62.
59. Selva, S. (1998) Searching for Caliciales in the Adirondacks of New York, in M.G. Glenn, R.C. Harris, R. Dirig and M.S. Cole (eds.), *Lichenographia Thomsoniana: North American Lichenology in Honor of John W. Thomson,* Mycotaxon Ltd., Ithaca, New York, pp. 337-344.

60. Shibuichi, H. (1998) Red data list of lichens in Saitama Prefecture, *Lichen - News Bulletin of the Lichenological Society of Japan* **11**(2), 25-26.
61. Sutherland, W.J. (2000) *The conservation handbook: research, management and policy,* Blackwell Science Ltd, Oxford.
62. Thor, G. (1996) ICCL *Preliminary Global Red List of Lichens*, http://www.dha.slu.se/guest/global3.htm, electronic document.
63. Thor, G. (1995) Red Lists - aspects of their compilation and use in lichen conservation, in C. Scheidegger, P.A. Wolseley and G. Thor (eds.), *Conservation Biology of Lichenised Fungi,* Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf, Switzerland, pp. 29-39.
64. Thor, G. (1997) Red-listed lichens in Sweden: habitats, threats, protection, and indicator value in boreal coniferous forests, *Biodiversity and Conservation* **7**, 59-72.
65. Thor, G. (1999) The Swedish lichen Red List 1995, *Graphis Scripta* **11** (1).
66. Thor, G. and Arvidsson, L. (1999) *Rödlistade lavar i Sverige: Artfakta,* ArtDatabanken, SLU, Uppsala.
67. Tønsberg, T., Gauslaa, Y., Haugan, R., Holien, H., and Timdal, E. (1996) The threatened macrolichens of Norway - *Sommerfeltia* **23**, 1-258.
68. Türk, R. (1990) Lichen mapping in Austria, *Stuttgarter Beiträge zur Naturkunde, Ser. A* **456**, 67-72.
69. Türk, R. (1996) *Rote Liste der Flechten Salzburgs,* Naturschutz Beiträge, 18, Amt der Salzburger Landesregierung, Salzburg.
70. Türk, R., Breuss, O., and Üblagger, J. (1998) Die Flechten im Bundesland Niederösterreich, *Wissenschaftliche Mitteilungen aus dem Niederösterreichischen Landesmuseum* **11**, 1-315.
71. Türk, R. and Hafellner, J. (1999) Flechten. Rote Liste gefährdeter Flechten (Lichenes) Österreichs. 2. Fassung, in H. Niklfeld (ed.), *Rote Listen gefährdeter Pflanzen Österreichs,* Austria Medien Service, Graz, pp. 187-228.
72. Urmi, E., Schnyder, N., and Geissler, P. (1990) A new method in floristic mapping as applied to an inventory of Swiss bryophytes, in U. Bohn and R. Neuhäusl (eds.), *Vegetation and flora of temperate zones,* SPB Academic Publishing bv, The Hague, pp. 21 - 32.
73. Usher, M. (1991) Scientific requirements of a monitoring programme, in B. Goldsmith (ed.), *Monitoring for conservation and ecology,* Chapman and Hall, London, pp. 15-32.
74. Wirth, V. (1995) *Die Flechten Baden-Württembergs, 1 & 2,* Eugen Ulmer, Stuttgart.
75. Wirth, V. (1999) Gefährdete Flechtenbiotope in Mitteleuropa, *Natur und Museum* **129** (1), 12-21.
76. Wirth, V., Schöller, H., Scholz, P., Ernst, G., Feuerer, T., Gnuchtel, A., Hauck, M., Jacobsen, P., John, V., and Litterski, B. (1996) Rote Liste der Flechten (Lichenes) der Bundesrepublik Deutschland, *Schriftenreihe für Vegetationskunde* **28**, 307-368.
77. Wolseley, P.A. (1995) A global perspective on the status of lichens and their conservation, *Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft, Birmensdorf, Switzerland* **70**, 11-27.
78. Zoller, S., Lutzoni, F., and Scheidegger, C. (1999) Genetic variation within and among populations of the threatened lichen *Lobaria pulmonaria* in Switzerland and implications for its conservation, *Molecular Ecology* **8**, 2049-2060.