A Global Perspective on the Status of Lichens and their Conservation

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Abstract
Information from replies to a worldwide questionnaire is used to identify and locate current lichen information, including areas where at present there is little information or interest in lichens. The distribution of lichen-rich environments across the globe, their conservation status in regional, national and international terms and the threats identified by respondents in a range of climatic, environmental and human population conditions are discussed. Lichenological evidence for environmental change at global and regional levels is illustrated by current literature and research projects identified by respondents. These will also be used to illustrate the importance of lichens as monitors of changing conditions in a wide range of ecosystems.

Keywords: lichens, conservation, protected areas, biodiversity

1 Introduction
The formation of the International Committee for the Conservation of Lichens (ICCL) in Båstad (Sweden) in 1992, highlighted our lack of information on lichen conservation even within the countries represented in the membership of the International Association for Lichenology (IAL). As a preliminary means of identifying current practices and problems, a questionnaire was devised (Appendix I) and distributed to IAL members in 57 countries in December 1993. The questionnaire was devised to be equally applicable for site or regional information and to identify threats on a specific or general level.

2 Results
77 replies from 33 countries were received (Appendix II) containing information on 267 sites (Fig. 1). This paper is based on replies, literature and projects that we have received, from which examples have been chosen in as many fields as possible.

The data are at present on a relational database (Paradox 4.1) at the Natural History Museum, in files on: site and country data, contributor, research projects and bibliography. The last is hardly started yet, but the rest are completed for all answers contributed. Maps of sites and threats have been kindly contributed by World Conservation Monitoring Centre (WCMC) in Cambridge, using the same format as their International Union for the Conservation of Nature (IUCN) publications.
2.1 Distribution of replies

The distribution of sites or regions identified by respondents as being of conservation interest for lichens (Fig. 1) indicates that there are large areas where no information has been contributed. This is due to several factors:

1) absence of IAL members in e.g. African and Asian countries
2) existence of independent conservation networks which makes abstraction of information at the level of the questionnaire difficult e.g. Australia
3) absence or restriction of information on lichens or conservation e.g. Asian countries, African and many South American countries.

The majority of lichen sites identified are in temperate and boreal zones, and few are in the wet and seasonally dry tropics, where there are extensive areas of forest forming a major component of the planet's vegetation (see Bailey 1989). Is this because lichens are the dominant life-form in extreme environments where they are a conspicuous component of the vegetation or are these biomes undescribed lichenologically? Biodiversity is frequently assessed in numbers of taxa identified. Figures in Global Biodiversity (Gal-loway in Groombridge 1992) suggest that lichen diversity is lowest in tropical countries, but recent assessments of the lichen flora of Papua New Guinea indicate that the low number may be due to inadequate sampling of tropical regions. In 1956 the lichen flora of Papua New Guinea was less than 250 (Szatala 1956), in 1986, 145 genera and 500 taxa were known (Streimann 1986), and by 1992 the species number has been doubled again (Aptroot and Sipman, manuscript). Many of these additions are undescribed species. In the seasonally dry tropics in Thailand 226 taxa have been found in published records.
Aguirre-Hudson and Wolseley: A checklist of lichenised fungi recorded from Thailand. In prep.), and this has now been increased to c. 400 corticolous taxa found in limited areas of the north of Thailand. New records include conspicuous macrolichen genera of Cetraria, Menegazzia, Platismatia, Pseudocyphellaria as well as many crustose genera (Wolseley and Aguirre-Hudson 1995a, 1995b, in press). Many more are crusts which may remain undescribed and unidentified for many years to come. Distinguishing areas of high diversity, and protecting these areas is a priority, especially in remote regions where species distribution is not known or new species may yet to be described.

2.2 Selection of sites

The inclusion of sites or regions in the answers to the questionnaire was based on lichen interest, and not on the existence of national or international recognition of Protected Areas. Although many of the sites coincide with existing Protected Areas in practice this is largely coincidental as criteria for selection of these may not coincide with lichen interests. There is also a confusing number of different names describing protected areas in different countries. The International Union for the Conservation of Nature (IUCN) proposed a system of ten categories classified according to site interest and objectives for management (IUCN 1994b), and ranging from strict nature reserves where access was restricted, national parks, to sustainably managed resource areas. The present list of sites of International importance or Protected Areas (IUCN 1994a) is based on a combination of the United Nations list of National Parks and Reserves, Ramsar sites and World Heritage Sites (where countries are signatories to the conventions), and the Biosphere Reserves which were selected to represent global biotopes and species diversity as part of the international scientific Man and the Biosphere programme. Criteria for inclusion in this list state that areas should be >1000 ha, that management objectives are clearly defined and that the authority for management is at government level. Lichen-rich sites may or may not be defined by respondents within the larger area of an international Protected Area, but respondents sometimes targeted smaller lichen-rich sites within the larger reserve as in Nanda Devi Biosphere reserve (Upreti, India). Smaller high-priority lichen sites, where relict or rare species may be restricted to small areas or atypical vegetation, may be excluded from protected status (Kuusinen 1995, same vol.; Coppins and O’Dare 1992). Within the European Community the Corine programme (Commission of the European Community 1991) is compiling an inventory of all sites of conservation interest in member countries, irrespective of their size, conservation status or legislation. However this does not ensure that specialist groups get included in site-evaluation, especially where lichen-rich sites fall within a non prioritised vegetation type as in the atlantic facies of Quercus petraea woodlands. There is a vast difference when it comes to site evaluation in tropical areas where information is only available on a few groups (frequently faunal) (MacKinnon et al. 1986). In Tasmania the existence of World Heritage Areas has encouraged the making of inventories, and this has been achieved for a limited number of sites within existing World Heritage Areas (Kantvilas, Tasmania).

If existing protected areas are the basis for investigation, what proportion of the lichen flora is included within the protected areas? In the Ukraine, Kondratyuk and Nvortskskaya (1995, this vol.) have looked at proportions of lichens in protected areas and

shown that it is highest in the Steppe zone of the plains and in the mountainous regions of the Carpathians and lowest in the Forest-Steppe zone on the plains. Their information is drawn from published (3 lists) and unpublished lists (3 for national parks and 7 for reserves) for what is still only a small proportion of the protected areas. The mountainous regions also support 29 Red Data Book species as compared to 10 on the plains of the Ukraine. Chile is rich in National parks and protected areas, many of which are in remote little populated areas only reached with difficulty. The 66 National Parks and protected areas occupy 13,725,125 ha (IUCN 1994a), and of these Galloway distinguishes 8 as having an exceptionally rich lichen flora. These include areas of great remoteness with rich lichen florae such as the glacial wilderness of Laguna San Rafael (Galloway 1992), and a further site at Chuscheno in Valdivia that has been known for the richness of its lichen communities since the early 1940's but which is not included in the IUCN list. This is a type locality for many lichens and without protection is threatened by increasing logging (Galloway, New Zealand).

2.3 Lichen-rich habitats falling outside usual conservation categories

It has long been recognised that ancient forests of temperate and boreal regions have a particular structure and associated lichen flora that includes genera that may be rare but widespread in these conditions such as species of Lobaria, Pannaria, Nephroma, Sticta, Lecanactis, Schismatomma and Calicium (Rose 1976, 1988, 1992; Cieslinski et al. 1992).

These forests were formerly associated with much higher populations of herbivores that maintained open and gladed situations within the forest structure where lichen diversity was high. Such communities are now largely restricted to ancient man-made parks and hunting reserves where conditions have not changed over long periods of time (Harding and Rose 1986), or to areas where the traditional management of forest as wood pasture has continued (e.g. parklands and Royal forests in Britain, dehesas in Spain). This has allowed the survival of epiphytic species long after their natural open forest habitat has disappeared. However because these sites were to some extent managed and not 'natural' they are frequently left out of conservation lists, and in Britain have only recently been accepted as candidates for Sites of Special Scientific Importance (Harding and Rose 1986). Species associated with scattered ancient trees regularly appear in lists of disappearing or endangered species across the world. A similar situation is found in India, Madagascar and many Asian countries, including Japan (Kashiwadani and Kurokawa 1995, this vol.), where religious taboos have allowed the survival of undisturbed and relict forest in sacred groves. There are many countries where a change in ancient agricultural practices, such as removal of grazing may endanger terricolous lichen species that are characteristic of an open community (e.g. Spain; Tasmania, Brown et al. [1994]; Britain).

Man-made sites may also provide sites for rare or restricted lichen species, such as mining spoil heaps, which may be the habitat for rare metal-tolerant lichens (Purvis 1985, 1993; Wirth 1972; Thor 1993; Huneck, Germany), or undisturbed ancient edifices such as churches and tombstones which in Britain support c. 300 species or 18% of the British lichen flora (Chester, pers comm.), and this applies to many other areas of Europe especially in such areas where prehistoric man has left large monuments as at Carnac in
Brittany or Stonehenge in Britain. We do not know how many of our lichen species are associated with human settlements or long-established management patterns, but this pattern may also be found in the tropics. In a Karen-managed forest in Doi Inthanon National Park, Thailand (IUCN category II) at c. 900 m altitude management ensured the retention of the largest trees as seed stock, and continuity of moist environmental conditions within the forest to allow regeneration. Lichens were abundant on slender saplings and on old trees and included several rare species of macro-lichen new to Thailand (WOLSELEY and AGUIRRE-HUDSON 1995a, 1995b, in press).

3 Threats

Although threats identified by respondents varied with country and habitat, most of the threats are directly or indirectly associated with the rapid increase in human population and its requirements. HOLDGATE (1994) points out that the world population was 5.3 billion in 1990 and is expected to be 10–12 billion within the next century, with growth focused on South and East Asia and Africa. This is reflected in the replies, e.g. 23% of the protected sites in South Africa are threatened by urbanisation (Fig. 5, Wessels, South Africa). Increase in industrialisation in Asia has resulted in potential rapid increase in air pollution about which we have as yet little environmental evidence. The threat from agricultural production has increased with the expansion of cash aid to projects in marginal land areas. This has recently happened in Spain since joining the EC, as CAP agricultural policy encourages grant-aided reclamation and conversion of formerly marginal land. This now includes drainage of lowland heaths and intensive afforestation programmes.

3.1 Air pollution

Industrialisation has followed the increase in population, and air pollution has become an increasing threat, so that 24% of respondents identified it as a threat to lichen communities. Although this is still concentrated in Europe and America, the pattern is changing with increasing pressure on the third world countries to industrialise, as shown by the prediction of future problem areas (RODIE and HERRERA 1988) (Fig. 2).

The use of lichens as indicators of atmospheric pollution associated with production of oxides of sulphur and wet deposition of the acids has been widely developed in Europe and the American continent where industrialisation has been occurring over the last 150 years (e.g. FARKAS et al. 1985, in Hungary; FARMER et al. 1992). This questionnaire has highlighted the continuing affect of atmospheric pollution in areas of the globe where information is now becoming available. The literature in Poland is extensive, and charts the loss of sensitive species from reserves that are affected by long range air pollution. Białowieża biosphere reserve (47.5 km²) is situated within an extensive area of forest reserve (1250 km²) and has been protected by law since 1921 and is the largest strict forest reserve in Europe. A comparison of selected species shows the extinction of sensitive species between 1953/5 and 1982/9. 75% of the genus Bryoria are extinct within the park and 60% of Usnea species (CIESLINSKI et al. 1992). The decline in health of Lobaria pulmonaria is observed, and can typically be illustrated by material in Britain in the Lake
District where thallii are reduced to fragmented sterile lobes on bare bark or amongst mosses.

The distribution of sites affected by air pollution (Fig. 2) also shows the distribution of areas where population and industrial growth are taking place at the moment. Long range pollution, or events such as the release of radioactive compounds into the atmosphere, have now produced international concern over the control of pollutants, and initiated lichen monitoring projects in many other countries such as Turkey (BARTH and DUTHWEILER 1988). Present studies on accumulation of radioactive compounds in lichens in Turkey provide evidence of the environmental effects of radioactive pollution (TOPCUOGLU et al. 1992).

3.2 Habitat destruction

Habitat destruction may occur in any environment, and was identified as a threat in 90 (34%) sites. Of these, destruction of old or natural forests accounted for 57 or 63% of the sites (Fig. 3). In many places we cannot even estimate this loss, but it is certain that it has been accelerating rapidly in this century (GRADSTEIN 1992; MACKINNON et al. 1986). Removal of forest cover in all regions of the world has caused the loss or near extinction of many epiphytic lichens. At the same time the use of lichens as indicators of ecological continuity to identify relict forest communities has been developed; indicator species being dependent on the presence of ancient native trees and uneven-aged forests (ROSE 1976, 1992; KUUSINEN 1995, this vol.; GOWARD 1994). Recent developments in the USA towards Forest Ecosystem Management (ROSENTRETER 1995, this vol.), and in Canada termed New Forestry (Land Management Reports 71 and 72, 1991) have stressed the importance of the use of lichens as monitors of the healthy conditions of the forest en-
Loss of old forest is well documented as a threat in Europe and North America, but in the tropics the loss of large areas of lowland forest has already occurred, with little or no documentation of lichens. Thailand is a typical example where forest cover was estimated at 60% of the land area in 1950 and in 1988 was estimated to be between 12.2–26.4% of the land area (Belcher and Gennino 1993). This includes large areas where the former species-rich evergreen forest has been replaced by a species-poor fire-tolerant deciduous forest, and where lichens can be used to indicate the time scale on which this has been happening (Wolseley and Aguirre-Hudson 1995a, 1995b, in press). Recently the most rapid loss in Thailand has been occurring in the fagaceous montane forest above 1000 m, where already many new records for epiphytic lichens for the country, now exist in isolated pockets of undisturbed forest. The montane forest, if undisturbed, has been found to be one of the most lichen-rich and diverse forests throughout the tropics (Sipman 1989; Wolfe 1993; Wolseley et al. 1994). In these unexplored areas, where information is scarce or absent, we need to develop techniques of rapid survey using indicator taxa that can be used to identify and locate species-rich areas. Rapid assessment techniques using flowering plants have been developed in Australia and New Zealand, but at present these methods do not include lichens (Brown et al. 1994).

3.3 Fire

Fire occurs naturally wherever seasonally dry climates occur, and where there is fuel in the form of dry vegetation. In many habitats such as boreal heaths and monsoon tropical forest these may be associated with a rich lichen flora (Fig. 4). In some situations lichen-rich heaths may be maintained by fire and exclusion of fire favours the invasion of phanerogamic vegetation and the loss of the lichen community (James and Rose, pers.
3.4 Tourism

Tourism is identified as a threat in 25% of sites, an increasing number of these occurring in formerly inaccessible areas such as the former USSR. This reflects the increasing demand for access to unspoilt areas and the corresponding pressure on fragile lichen communities, where growth is slow and maximum damage occurs during the growing season. Lichen communities are often rich in exposed areas above the tree line on mountains, and these areas may experience increased pressure during warm and cold seasons where ski stations have been developed. This problem is identified in many countries in Europe and America and also includes such places as Puyehue National Park in Chile where the loss of lichen sites threatened by fire (from replies to questionnaire).

Comm.). Continual use of fire as a management tool may result in a shift in environmental conditions towards a drier climate (Christensen 1993) and a loss of diversity (Wolseley and Aguirre-Hudson 1995a, 1995b, in press). In a recent report on threats to Australian lichens fire was identified as a major threat to lichens (Stevens 1995). Fires are most destructive to vegetation that is not fire-adapted, as in temperate heaths e.g. Isle of Man, and moist montane vegetation in the tropics or southern temperate regions e.g. Tasmania. Where lichens are strongly associated with a forest type, loss of the forest will also result in loss of associated lichens and their replacement with lichens characteristic of disturbance (Wolseley and Aguirre-Hudson 1995a, 1995b, in press).

Fires may also be associated with increased tourist pressure in areas where the dry season coincides with the tourist season. In 26% of the sites threatened by fire, tourism was also a threat, especially in Cladonia heath and coastal communities where trampling and/or fire in the growing season may do considerable damage to terricolous lichens. In Europe coastal heaths are at risk e.g. Isle of Man, Spain, in the tropics evergreen forest in seasonal monsoon areas where fires coincide with tourist pressure e.g. Thailand, and in boreal zones e.g. Canada, Russia.
of major areas of lichen diversity and type sites has occurred with the development of ski-fields (Galloway, New Zealand).

Coastal areas also come under threat through tourist development, and this is often concentrated in areas where lichen diversity is high such as the European coasts (Barréno, Spain), where a combination of tidal regime and rock type have allowed the development of rich lichen communities.

3.5 Climate change

Global warming was only mentioned in two countries, probably because national conservation groups can do little about this large scale international problem. However climate change associated with the movement of the El Nino currents has been observed in Chile where the unusually rich coastal fog communities of cacti and lichens are disappearing (Follmann 1994). In the antarctic where lichens represent a large proportion of the flora and where the ozone hole is largest, lichens are being used as long term monitors of these changes (Kashiwadani, Japan; Lewis-Smith, UK).

Other habitats that may suffer from the effects of global warming include montane communities, especially those containing rare species that are relicts of colder climates. Furthermore rising sea levels will obliterate those areas of coast with rich lichen communities, as in Europe. The European rocky coast supports a great diversity of lichen communities that are also relicts of warmer climates. These would be endangered with a rise in sea level.

3.6 Agriculture

Agriculture is identified as a threat in a wide range of situations, in 26 sites or 9.7% of all sites. Threats ranged from eutrophication caused by inorganic fertilisers, to reclamation, and changes in management which may also include changes in grazing routine leading to scrub invasion or coarse grasses and loss of terricolous species (Brown et al. 1994). Overgrazing is a threat to terricolous species in boreal zones and in South Africa. In densely populated areas of Europe the affects of agricultural chemicals on lichen species and communities are being investigated (Vandobben 1993).

The demands of developed nations for timber and agricultural products have had far reaching effects especially where grant-aid has made it possible to reclaim areas of land that were formerly considered marginal. This is becoming obvious in Spain where recent entry to the EC and the Common Agricultural Policy is causing threats from both intensive agriculture and forestry in formerly unspoilt areas where low grazing routines and diverse land management supported species-rich lichen communities. This is associated with other damaging activities such as dam building and irrigation schemes. Change in long-standing agricultural practices such as removal of grazing may alter the habitat to coarse grasses and scrub which is detrimental to terricolous lichen communities as happened in Britain with the loss of the rabbit population.
3.7 Multiple threats

One of the striking results of this questionnaire is the number of sites where multiple threats are occurring, this being characteristic of densely populated areas or where rapid increases in population are occurring. South Africa provides a good example of this (Fig. 5) (Wessels, South Africa), where loss of habitat from deforestation or urbanisation may be combined with air pollution over a large area, resulting in species extinction.

Fig. 5. Multiple threats – a changing situation in South Africa (from replies to questionnaire).

4 Species protection

Red Lists (THOR 1995, same vol.) are frequently not available in countries where rapid changes are occurring. The preparation of Red Lists is dependent on information on the distribution of species in a country. Lichens are only specifically protected in 13% of sites identified by respondents, mainly in European countries, Russia and Japan where there is already a considerable body of knowledge in existence (e.g. Wirth and Oberholzer 1990). In 30% of sites respondents asked for help either as surveys, literature or funds and these are widely distributed throughout the world.

5 Conclusion

The large number of responses to the questionnaire, together with literature and site information reflects the urgency of the situation, particularly in countries where there is little available information on lichens, even at the macro level, and where sites are being lost before they are documented. The evidence shows that there are lichen-rich sites that are
do not fall within the usual conservation categories, and that threats to these sites are mainly associated with human activities or recent changes in established management patterns.

Following the Rio Summit in 1992, the Convention on Biological Diversity was signed by 153 countries. A significant result of this is the recognition of the need to identify diversity in all groups at a national and international level. A recent publication on Biodiversity Challenge (Wynne et al. 1995) has stressed the targeting of both rare species and habitats under threat, especially where there is insufficient knowledge on the distribution of rare taxa. Lichens are frequently in this category in many parts of the world, and we need to develop techniques of rapid survey, combined with the targeting of identification of indicator taxa to be used in assessing new areas. The production of keys and literature, that can be used by local people to estimate lichen diversity, will facilitate the location of species-rich areas before they are lost. The importance of establishing regional and international information sources towards more effective lichen conservation is emphasised by Smith (Manuscript). The database set up as a result of the questionnaire provides a basic list of researchers and conservationists interested in lichens, together with literature and research projects, and the beginning of site dossiers for lichen-rich sites. An expansion of this information base will enable us to target priorities at the regional and international level, to collaborate in research projects, and to produce a bibliography of available literature and research projects that can be used to protect lichen interests.

Acknowledgements
I would like to thank all respondents for the information and literature that they provided, the Natural History Museum, London for providing facilities, Göran Thor for his support and contribution to the questionnaire, Harriet Gillett and Charlotte Jenkins at the World Conservation Monitoring Centre for producing the maps, and Christoph Scheidegger for initiating and carrying out publication of the symposium.

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Appendix I

Information concerning lichens and lichen-rich habitats

Questionnaire
In order to facilitate compilation of a database please answer all questions even where negative or unknown.
If you respond on separate sheets please specify question number and letter.

1. Are there any sites of conservation status in your region/country where lichens form a major component of the site?
   a) Country
   b) State or Province
   c) Name of site
   d) Geographic locality, give Lat/Long as near as possible + projection if possible.
   e) Conservation status of the area (e.g. national park, wildlife sanctuary or other).
   f) major lichen habitats present (e.g. rainforest, montane, desert etc).

2. Are any of these sites of internationally designated? Please specify.
   (e.g., world heritage site, Biosphere Reserve, Ramsar site etc.).

3. Are any of these sites threatened?
   if so by what? (e.g., air pollution, habitat destruction, fire, agriculture/fertilisers, over collecting, tourism).

4. Do you need help to.
   a) investigate the sites?
   b) prepare a conservation plan?

5. Is there a marked decline of lichens in a region of your country that you know about?
   If so, which species (or groups) and/or ecological groups have decreased?

6. Is there a Red Data List for lichens in your country, or one being prepared, or in the region where you have studied lichens?
   If it is not published please send us a copy.
   If it is published please give full reference.
   If neither exist are there any lists of rare species?

7. Can you identify the major threats to lichens in
   a) these regions?
   b) your country?

8. Is there anything written (besides Red Data Lists) about changes in the lichen flora in the regions listed above, or in your country?
   Please include full references.

9. Is there any research going on at your institute, in NGOs or societies about changes in lichen flora caused directly or indirectly by man?
   If so please give name of researcher, affiliation, title of project, brief descriptions.
Measures for protection of lichens

10. Are lichens in general or any lichen species protected by law in your country? If yes, please provide references to laws.

11. Are lichens explicitly protected in nature reserves and/or national parks in your country?
   a) by general management policy e.g., collecting prohibited or by permit.
   b) by specific species management policy.

12. Is there any research carried out in connection with protective measures for lichens?

13. Do you know of any other persons involved with nature conservation who should receive this questionnaire?

Please return completed questionnaires to: Pat Wolseley, Botany Department, The Natural History Museum, Cromwell Rd, London SW7 5BD, U.K. as soon as possible, and at least by Jan 30th to allow time for data processing.
Tel no: 071.938.9351
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Please give your name and address, phone no. fax no and e-mail address if possible.
Appendix II

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