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Fungal conservation issues: recognising the problem, finding solutions

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Nonbiologists may be excused for questioning whether microbial diversity is really under threat. At a superficial level, micro-organisms seem to be tolerant of almost any set of conditions thrown at them. Also, they appear to have reproductive capacities able to generate populations of truly astronomic numbers in very little time. However, that *is* a superficial understanding and any belief that microbial species are not threatened is simply wrong.

James T. Staley of the University of Washington gave his answer to the challenge 'Microbiologists are not concerned with endangered species, are we?' in a commentary published in 1997 (Staley, 1997). His simple answer to this question is 'Yes, some microbial species are threatened', but the argument Staley develops is interesting and has some valuable points for mycologists to ponder. Even though the commentary was written largely from the bacteriologist's point of view, Staley mentions lichens and fungi so it is clear that he does include even the mushrooms and toadstools within his definition of micro-organisms. This is useful for us as we attempt in this brief introductory chapter to highlight and provide cross-references to the wide variety of aspects of fungal conservation that are included in this book. We are not alone in the belief that such topics are important!

Indeed, Staley puts the level of importance very high. Micro-organisms produced the original biosphere of Earth. 'Not only have they made conditions suitable for the evolution and existence of macroscopic life forms, but they also continue to drive and profoundly influence many of the essential biogeochemical cycles' (Staley, 1997). Furthermore, most of the present-day biodiversity among the eukaryotes is microbial, being generated by the protists, algae and fungi. Bacteria, of various sorts, provide the biodiversity within the prokaryotes, of course. So the consequence is that 'the tree of life is largely a tree of microorganisms . . . much

of the diversity on Earth is microbial with the plants and animals appearing as small, terminal branches' (Staley, 1997).

This fundamental importance of micro-organisms can hardly be doubted, so why is there so little general interest in conservation of microbes? Staley (1997) puts this down to something he calls 'kinship', claiming that humans share strong kinship with many animals and plants, a kinship which can blossom into fondness for closely related and 'warm and fuzzy' animals. Microbes, though, are generally too small to be noticed much by humans, even though human lives are daily more closely intertwined with microbes than with any other organisms. Further, microbes evoke negative feelings because they are associated with disease and spoilage. Finally, there is a general ignorance about the degree to which our daily lives depend on the beneficial activities of many microbes – from sewage sludge through to agriculture, and the making of bread, and antibiotics and other life-saving drugs. 'Because microorganisms rank so low on the kinship scale, the demise of a microbial species is not an emotional issue for humans' (Staley, 1997). We do not expect many to rally to a cry to 'Save the whale's intestinal microbes'!

Staley (1997) suggests that the general phenomenon is that a micro-organism is threatened when its ecological niche is threatened. Consequently, 'the most satisfactory manner in which to preserve the organisms is through protection of the environment and thereby the natural community itself' (Staley, 1997). However, Staley acknowledges that 'we have described so few species; many species may be threatened whose existence are still unknown.' And his final conclusion is that 'Our knowledge of microbial diversity . . . is so meagre that we do not yet know if and when most species are threatened. . . . Our very inability to answer the question of threatened microbial species cries loudly for the need for microbial systematists and ecologists to begin to address the exciting challenges regarding our knowledge of the extent of microbial diversity on Earth' (Staley, 1997).

That brings us to the first point we wish to highlight from this book. It is most succinctly stated by David Minter in Chapter 16 (p. 193): 'In many parts of the world mycologists are an endangered species. It follows that fungal conservation can only occur if mycologists are conserved.' But other authors express similar opinions. Régis Courtecuisse (p. 10) puts it this way: 'Incidental problems and questions around inventories which have to be considered are (a) promoting the conservation of taxonomists themselves . . . ' and Eef Arnolds (p. 77) like this: 'It is obvious that conservation of fungi depends on the input of mycologists. But at present it

seems to be also the other way around: the future of mycologists depends on their input in conservation.' The root problem is that our level of ignorance is so great that we do not have the numbers of experts needed to make serious contributions to knowledge of species sufficiently quickly to conserve those species. 'Taxonomists are scarce because of a shift in academic programmes toward molecular systematics and ecology' (Randy Molina *et al.*, p. 39). One might also add that for several years now funding agencies around the world have been operating a similarly skewed funding policy. Mycological research is rarely funded, anyway, because a lower value judgement is placed upon it than is applied to similar research on lower animals or lower plants. Another aspect, perhaps, of the lack of kinship to which reference is made above. In the long term these attitudes must change and the importance of the kingdom of fungi recognised sufficiently to assure equitable funding for its study. To a very large extent this is a matter of public education and several of our authors mention this. Régis Courtecuisse mentions the need for public education (Chapter 2, p. 14), and David Moore and Siu Wai Chiu claim that 'Education is the key' in China (Chapter 9, p. 118).

It will take a long time for an education policy to result in significantly more experts with attitudes changed sufficiently for the value of fungal biology to be fully appreciated. In the meantime we have the real world to deal with – a real world in which those mycologists who do exist may be prevented from making a full contribution by poor infrastructure or political and economic isolation. David Minter, in Chapter 14 (p. 164), illustrates how effective voluntary help (in this case through provision of second-hand computers) together with intergovernmental assistance (through the UK Government's Darwin Initiative Programme) is enabling Ukrainian mycologists to complete the databases and surveys that are essential to effective national conservation policies. He tells a similar story in Chapter 16 (p. 192), although in this case Cuban mycologists are suffering the inevitable shortages and isolation resulting from a unilateral economic blockage imposed by the USA. Again, provision of resources (another Darwin Initiative Project) enables local mycologists to progress towards a national fungal conservation strategy.

For more immediate input, particularly to projects under way now, 'The depleted ranks of classical fungal taxonomists can be augmented, however, by a cadre of experienced parataxonomists, people with less formal schooling in mycology, who are trained and gain significant experience in fungal identification' (Molina *et al.*, Chapter 3, p. 39). Similar ideas, perhaps, emerge from the Dutch experience in raising interest which Leo Jalink and

Marijke Nauta suggest makes it evident that 'managers need clear instructions' about mycologically valuable sites (Chapter 6, p. 90).

If the information is provided, landowners, managers and administrators have considerable sympathy for including fungi in their conservation management. Indeed, it seems a sensible strategy for mycologists to be proactive in establishing collaborations with those involved in land management and, especially, with groups concerned with conservation of other organisms (see Martin Allison, Chapter 12, p. 144). There is certainly no excuse for mycologists being short of cogent arguments for inclusion of fungi in conservation schemes. Randy Molina *et al.* (Chapter 3, p. 23) detail the four themes that need to be emphasised when 'educating land managers . . . is vital'. Additional ready-to-use material can be found in Chapter 17, in which Cannon *et al.* discuss, largely from the point of view of population ecology, 'Why are fungi difficult to conserve' (p. 198) and 'Why are fungi important' (p. 199).

We know very little about fungal population biology; in fact, even less about fungal population genetics. Randy Molina *et al.* (Chapter 3, p. 25) discuss the role of fungi in communities and describe projects aimed at determining the population genetics of representative species (p. 33). Related to this is the detailed analysis of the population biology of *Lentinula edodes* that shows how the traditional cultivation method in China (especially outdoor cultivation accompanied by harvesting at maturity) is likely to endanger both the cultivars and the wider gene pool of the wild mushroom (David Moore and Siu Wai Chiu, Chapter 9, p. 113).

The main tools available to the fungal conservationist are outlined first by Régis Courtecuisse (Chapter 2, p. 10) to be inventories (checklists), mapping programmes, and Red Data lists. These being the crucial aspects of fungal conservation, they appear in some guise in all chapters. Particularly helpful discussions can be found in Chapters 3 (p. 35), 4 (p. 70), 5 (p. 83), 6 (p. 90), and 17 (p. 202). Eef Arnolds (Chapter 4, p. 66) also discusses the species concept – an important issue for any survey, whilst Molina *et al.* (Chapter 3, p. 43) describe 'habitat modelling' as a tool in conserving fungal resources. Examples of survey work are given in Chapters 3 (p. 19), 5 (p. 81), 6 (p. 89), 7 (p. 95), 9 (p. 111), 10 (p. 120), 11 (p. 136), 13 (p. 156), 15 (p. 177), 16 (p. 182), and 17 (p. 197).

Surveys and mapping programmes culminate in the production of Red Data lists. Although 'Red Data' in this phrase usually carries with it the danger connotation commonly linked with the colour red, it's important to remember that in this case the word is an acronym, the full phrase being Rarity, Endangerment and Distribution Data lists. This *is* important

because the full phrase shows explicitly the amount of information which is required to make the judgement about whether or not to include a species in a Red Data list. Red Data lists are discussed to some extent in most chapters, especially those already highlighted as dealing with surveys. However, Maria Ławrynowicz (Chapter 7, p. 96) shows how different national Red Data lists can be integrated to reach wider conclusions, while Giuseppe Venturella and Salvatore La Rocca (Chapter 13, p. 156), and Heikki Kotiranta (Chapter 15, p. 177) illustrate how local surveys can be compared, on the one hand with an international Red Data listing, and on the other hand with international Red list categories.

Conservation strategies emerge at a variety of levels and provide examples which might be applicable elsewhere. Molina *et al*. (Chapter 3, p. 20) outline the US Federal laws regulating forest management, mentioning the different goals of the different agencies involved. A different set of conflicts (and their resolution) discussed by Martin Allison (Chapter 12, p. 153) is that which can arise 'within conservation management when one group of animals or plants is favoured above another.' Vincent Fleming (Chapter 18, p. 209) details the UK response to the *Convention on Biological Diversity* – essentially the administrative mechanics of conservation in the UK. Below the governmental level, David Moore (Chapter 20, p. 223), and Marijke Nauta and Leo Jalink (Chapter 21, p. 242) show how two national mycological societies (the British and Dutch mycological societies respectively) have reacted and developed programmes aimed at conserving fungi. In Chapter 19 (p. 219) Alison Dyke reports how a purely voluntary code of practice has been established directly by the groups involved in wild mushroom harvesting in Scotland. A range of wild harvested fungal fruit bodies command prices that make them worth shipping over intercontinental distances, as discussed by David Arora (Chapter 8, p. 105), so this code of practice may be applicable elsewhere. In contrast, the commercial harvest of edible forest mushrooms is controlled by Federal laws in the United States (Molina *et al*., p. 46, and see Eef Arnolds, p. 76).

The Scottish Mushroom Forum's code of practice (Table 19.3, p. 221) is one of several examples of specific advice and instruction included in this book. Others are a 'set of summary statements' for use when 'planning and conducting conservation efforts for fungi' (Molina *et al*., Chapter 3, p. 54); some management guidelines from Leo Jalink and Marijke Nauta (Table 6.2 and Table 6.3, p. 93); and British Mycological Society codes of practice (Chapter 20, p. 235).

With these, and other, explicit pieces of advice based upon practical experience, we hope that this book will make a *constructive* contribution to

fungal conservation. It is a global problem and we include examples from Finland in the North to Kenya in the South, and from Washington State, USA, in the West to Fujian Province, China, in the East. Our authors identify threats faced by fungi of all types. Inevitably, even though 'It is probably true to say that the majority of fungi would be describable as "microfungi"' (Paul Cannon *et al.*, Chapter 17, p. 197) descriptions of work with larger fungi – truffles and mushrooms – tend to predominate. The balance, of course, is governed by the research which is being done and the research interests of those doing it.

Our authors also suggest solutions ranging from voluntary agreements, through 'fungus-favourable' land management practices, and on to primary legislation. We have to stress that this book cannot give ready-made solutions to all the problems that might arise concerning conservation of fungi. What we have assembled is a set of descriptions of how far we have got with conservation of fungi, with some focus on the bottlenecks that remain, and with a range of guidelines that may help in improving conservation of fungi in the future. The bottom line, though, is quite clearly that 'Conservation of fungi is, like conservation of other organisms, in the very first place conservation of their habitats combined with adequate management' (Eef Arnolds, Chapter 4, p. 72). Save the world and we'll save the fungi with it. Conserve the fungi and your one and only planetary home will be equally safe.

Reference

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Current trends and perspectives for the global conservation of fungi

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Introduction

For rather more than a year, the specialist group for fungi within the Species Survival Commission (SSC) of the International Union for the Conservation of Nature (IUCN) has been revived after interruption in its activities between 1995 and 1998. As a member of the European Council for the Conservation of Fungi (ECCF) standing committee, I shared with my ECCF colleagues the regret that fungi were no longer taken into account within the IUCN. So we decided to take advantage of the June 1998 *Planta Europa* meeting, in Uppsala, to establish new contacts with the IUCN and to revive this specialist group.

Within the new specialist group for fungi, the ECCF serves as the main framework since it has accumulated much data and experience on the topic since 1984. But I am also trying to federate further mycologists involved in conservation outside Europe so that the group will consist of a genuinely enlarged and international network.

In this chapter I will give a brief description of the present global state of knowledge concerning fungal conservation and indicate the main priorities we should consider for the future. Of course, this owes a great deal to the ECCF heritage, especially through the decisive contributions from some of its members, such as Eef Arnolds and others. I also received feedback from some members of the new group but I do not claim that the literature survey is in any way exhaustive and I do realise that some points may not be represented here. The specialist group of which I serve as chairman is currently still 'under construction' and we attach great importance to communication between all people who are interested or involved in fungal conservation and depend on them for further information.

Current status and problems

Conservation status of fungi

Fungi are very seldom legally protected. Such a situation does exist in Slovakia, where 52 species have a 'special legal status', enabling managers to prevent damage to their habitats (Lizon, 1999). Where no legal status is available, some voluntary efforts have been made to produce codes of practice or have advisory documents published, stressing the importance of fungal conservation and summarising the recommendations to achieve that. This has been done, for example, in Switzerland (Egli *et al.*, 1995), and in the United Kingdom (English Nature, 1998; and see Chapters 18 to 21).

Nevertheless, even without a legal conservation status, Red Data lists have been published, or are currently in preparation, in many countries, especially in Europe. This demonstrates the increasing concern of mycologists for this topic. At the same time, more and more nature managers pay increasingly greater attention to fungi.

So, the idea that fungi may be threatened and deserve special attention to their conservation is now well established, at least in Europe, where books and symposia have been devoted to the topic in relation to environmental problems (Frankland, Magan & Gadd, 1996; Rotheroe, 1996*a*). But this is not yet true everywhere.

Current problems

The main threats and causes of decline in fungi world-wide can be categorised as resulting either from global, or specific or local problems. Air pollution, considered globally, may influence fungi through the greenhouse effect producing a slow climate change, as well as exerting an indirect effect through modification of vegetation. Such changes might threaten climate-sensitive species and/or favour the development of more thermophilic taxa which could in turn act as alien competitors against native species. The balance between parasites and their hosts might also be changed (Lonsdale & Gibbs, 1996; Pettitt & Parry, 1996). Some northward migrations have been demonstrated in recent years, especially in the western part of Europe. Elevation of the sea level could also become a problem for species inhabiting coastal ecosystems (Rotheroe, 1996*b*). Another global problem widely recognised to be of paramount importance in the decline of fungi world-wide is the destruction of habitats and the dramatic felling of forests, particularly in the tropics, but also representing a poten-

tial problem in more temperate or even sub-boreal to boreal forests.

Some problems with a more local or specific effect on fungi include: air pollution, which, whatever the scale, causes well-documented species decline; deposition of various pollutants, leading to soil modifications (the mechanism of which is not clearly understood); accumulation of metals and other pollutants interfering with fungi, either macrofungi (Ing, 1996) or microfungi (Boddy *et al.*, 1996; Magan, Smith & Kirkwood, 1996). Fragmentation of habitats is also a major problem. It has been shown (e.g. Chaumeton, 1994) that fragmentation of habitats makes it difficult for some species to maintain normal population. Such a situation often results from forest cutting, urban extension, evolution of land uses and change of agricultural practices. In particular, modern agriculture increasingly uses chemical treatments that can give rise to various kinds of environmental modifications. This problem is especially well documented in Europe for grassland fungi, both macromycetes such as *Hygrocybe* spp. (Rotheroe *et al.*, 1996) but also soil fungi (Bardgett, 1996). A more specific problem concerns edible species. When harvesting is done by individuals or families, it seldom leads to concern for survival of the species (Egli, Ayer & Chatelain, 1990). On the other hand, the commercial harvesting of the same species causes great concern, as is evident from the numerous publications on the subject, especially in North and Central America (Pilz & Molina, 1996, 1997; Palm & Chapela, 1997; Rowe, 1997). This is a controversial topic. Some people claim that heavy harvesting is harmless (Arora, 1999*a*, 1999*b*) and others claim the opposite (Rotheroe, 1998), depending mainly on the harvesting tools, but also taking into account the longer term, for which we have insufficient background knowledge to know what will really happen in the future. Furthermore, there is currently little scientific evidence about the impact of harvesting on the mycelium itself and more studies are needed on that topic. Suggestions for voluntary and regulatory control have been published also in Europe, such as Switzerland (Keller, 1991), the United Kingdom (Leonard, 1997*a*,*b*) or some parts of France. ECCF members from eastern Europe complain about the ecological damage caused to their forests by commercial harvesting of edible fungi that are exported to western Europe (see, for example, Ivancevic, 1998; Pop, 1998). Further problems arise from the harvesting of edible chanterelles (in part undescribed species) from Africa, tonnes of which are imported each year into France, for example. A similar problem may be faced by the decorative tropical polypores that are used in floral compositions. We need to know more about the actual places and conditions of harvesting of these species.

What can we do?

Looking at these causes of fungal decline, we might feel discouraged because, as fungal conservationists, we have no opportunity to manage global warming or global forest felling. Nor are we likely to have much influence on the politics that affect agricultural practices or industrial pollution. It is not even clear how we should handle the harvesting of edible fungi because important economic interests are involved – commercial interests, of course, but sometimes also at the individual family level, thus involving a social dimension in the problem. What we can actually do, at our 'mycological level', concerns fungi in the field, and is related to our knowledge about the ecological and heritage value of fungi. The 'heritage' dimension of fungi in this context refers to their potential for indicating the holistic natural value of a given site or habitat in a way that integrates many inputs including historical, nature management, biodiversity, and conservation aspects. It is our task to popularise the value of this heritage quality of fungi and to use it as a force in nature conservation. For that, we have some useful tools at hand.

Our tools

First are inventories. In most of the countries of the world, what are basically lacking are checklists of fungi. This is not only true of tropical or developing countries, but also of the first world's great nations. The situation is even worse at the continental level. A project to initiate a European checklist has been urged by the IUCN and is currently being considered by the ECCF for funding in the near future. The first priority in our tasks as fungal conservationists is to promote fungal inventories. Incidental problems and questions around inventories which have to be considered are (a) promoting the conservation of taxonomists themselves, (b) developing arguments in favour of such inventories, (c) using a reasonable consensus taxonomy which is discerning enough to maintain the ecological bioindicative value of the taxa recognised.

Second are mapping programmes. Inventories provide an idea of the fungal diversity: mapping programmes should yield useful information about the rarity of species, their eventual decline and finally their heritage value. Mapping is the second important task we must promote as fungal conservationists. Inventories and mapping programmes are intimately connected, of course. Mapping programmes are conducted in many countries where inventory data are sufficient, as well as some in which inventory