
Monitoring and safeguarding fungal resources worldwide: the need for an international collaborative MycoAction Plan

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The challenge of monitoring and safeguarding the Earth's fungal resources is a daunting one that must be confronted. With only 74-120 K of the estimated 1.5 million fungal species on the planet described and limited human and financial resources, how can we identify priority areas for both systematic research and conservation? Further, what balance should be aspired to between *in situ* and *ex situ* conservation, and how should that be reflected in national and international policy? Mycology has too low a profile and remains an orphan within botany and microbiology; how can that perception be changed? The systems in place for educating new generations of mycologists are also failing; how can that be rectified? While contact between mycologists nationally, regionally, and globally has improved remarkably in the last two decades, concerted action on a scale hitherto not attempted is necessary to address these fundamental questions. Some actions for inclusion in a potential new international initiative designed to start to redress some of these key issues are suggested. The proposals include actions needing to be taken by individuals through to ones meriting coverage in international intergovernmental treaties: many are accompanied by targets and datelines. This contribution is intended to serve as a draft action plan (MycoAction Plan) for discussion, elaboration, and revision by the whole mycological community – working under the auspices of the International Mycological Association (IMA). It is envisioned that there will be plans for action from the worldwide (MycoAction Worldwide Plan) to the personal (MycoAction Personal Plan).

Key words: biodiversity, conservation, human resources, mycology, science policy, sustainability

Background

Fungi permeate and are crucial to almost all aspects of human well-being and ecosystem health. Yet, despite their enormous and undisputed significance, fungi can be regarded as orphans within biology: lacking close relatives, misunderstood, unnamed, excluded from family events, ignored or overlooked,

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with few carers, and inadequately provided for (Hawksworth, 1997). This is not a new problem; indeed it is something the British Mycological Society started campaigning to redress as early as 1944 (British Mycological Society, 1949). During the periods I served as Secretary-General or President of the International Mycological Association (1977-94) and Director of the International Mycological Institute (1983-97), I became keenly aware of the need to redress the balance. But we are not dealing with a single issue, and must face three kinds of challenges: (1) our identity amongst biologists, botanists and microbiologists; (2) the need for a defined and agreed mission; and (3) ensuring pertinent action at the corporate and personal levels (Hawksworth, 1995).

Later, and being aware of the suggestions already made by Subramanian (1982, 1992), I tried to identify the challenges facing mycology in Asia (Hawksworth, 1996): recognition, raising the awareness of the importance of fungi; identity, establishing mycology as a subject distinct from botany and microbiology; organization, developing a cohesive regional body able to speak for the whole of mycology with a common voice; ignorance, how to confront the issue of huge numbers of undescribed species; resources, improving the effectiveness of the existing collection and human resources; and action, deciding what action to take and developing prioritised plans.

Here I wish to explore these issues further and extend them, by proposing the establishment of an international collaborative MycoAction Plan. The Plan presented here is intended as a draft to stimulate debate and encourage action at a variety of levels: the worldwide, regional, national, and personal. It aims to monitor and safeguard fungal resources worldwide, using the word ‘resources’ in the broadest sense to encompass natural, human, and collection resources.

Resources

Natural Resources

With only 74-120 K of the estimated 1.5 million fungal species on the planet described (Hawksworth, 2001), and limited human and financial resources, how can we identify priority areas for both systematic research and conservation? As the current rate of description of new fungi is only about 1100 species each year, a total inventory is impractical within any reasonable time scale; 1290 years at the current rate. Further, the problems of inventorying all fungal species in a particular site is daunting, requiring teams of mycologists with complementary expertise working over decades (Hawksworth *et al.*, 1997; Rossman *et al.*, 1998). If we continue to just

describe species from any locality as they come to our attention, then we are not going to have enough data to make judgements as to which sites are most important and which species are endangered for generations. This issue has been considered by several mycologists who have concluded that some sort of rapid assessment, perhaps using selected groups of fungi, is the way to proceed (e.g. Hawksworth *et al.*, 1997; Cannon, 1997; Hyde and Hawksworth, 1997). Further, it has been suggested that priority in biosystematic work should be accorded to groups of organisms that have keystone roles in ecological processes, have value as bioindicators, or can contribute to improved sustainability (Hawksworth and Ritchie, 1993).

Human Resources

Mycology has too low a profile and remains an orphan within botany and microbiology; how can that perception be changed? The systems in place for educating new generations of mycologists are also failing: how can that be rectified? Sadly, mycologists have been even less successful in asserting their identity than for example, entomologists or microbiologists (i.e. bacteriologists and virologists) with the result that university Departments of Mycology are almost unknown – I can think of none in Europe. This means that there will be few chairs guaranteed to be occupied by mycologists and that universities with strong groups of mycologists will occur by chance rather than planning, and so wax and wane with no long-term commitments to the discipline. More importantly, it means that there will be no first degrees in mycology, and few diploma or master's courses; exceptions being in applied fields such as medical mycology, fungal biotechnology, and plant pathology.

Just how many mycologists there are worldwide is difficult to determine, although we know that 498 were authors of new scientific names for fungi in 1992 (Heywood, 1995). An analysis of mycological society memberships, which would include all kinds of mycologists, residing in tropical countries gave numbers between 0 and 297 per country (Hawksworth, 1993). However, these do not include many researchers that either use fungi as model organisms while focussing on general biological phenomena, or the even more numerous scientists working in various aspects of applied mycology. While numbers are elusive, it is clear that they are incommensurate with not only the numbers of fungi, but also their importance to human well-being and the maintenance of key ecological processes.

In the absence of much formal training in mycology, teaching aids such as books, CDs, and films are of particular importance. While the internet has made a huge difference, and books are increasingly also available on CDs (e.g.

Kendrick, 2000; Vaidya and Lamrood, 2001), the paucity of textbooks and identification manuals in different languages and their high cost remains a particular hurdle. However, if an attractive product can be generated, sources of funding to enable copies to be distributed free of charge to schools can sometimes be secured, as in the case of 'How the Mushrooms got its Spots' (Assinder and Rutter, 2002).

For the professional and keen amateur, there is also the issue of access to scientific publications. While the number of mycological journals is increasing, many countries lack their own outlet for research results. Journals published elsewhere are often expensive and include limited material of immediate regional or national relevance. On-line access to existing journals is not the answer as that is often as expensive as the printed copies, and on-line only journals have yet to gain general acceptance in the scientific community. This is an issue which needs to be addressed at the regional and national levels.

Collection Resources

Dried biosystematic reference collections of fungi are kept in numerous institutions, but curation levels vary markedly and specimens can languish for centuries without study or even their label data being made accessible electronically. The numbers of fungal specimens held worldwide is uncertain; the major plant and fungal herbaria together hold over 279 million specimens (Heywood, 1995), of which perhaps 5%, i.e. 14 million, are fungi. Firmer information is available on genetic resource collections, data from the world's microbial (including fungal) collections being compiled by the World Federation for Culture Collections World Data Center on Microorganisms (Heywood, 1995) which hold fungi under over 19 000 names; not allowing for synonyms and anamorphs within that data set, this suggests that around 27 % of the already known species, but only 1.3 % of the estimated world species, are represented. How safe, and how representative that resource, is questionable. Many culture collections lack the lyophilization and liquid nitrogen storage procedures necessary for long-term preservation, and numerous species are represented by only single isolates when we know that many fungal 'species' embrace several distinct genotypes and cryptic biological species, let alone so-called 'special forms'. While some countries have numerous biosystematic reference and genetic resource collections of fungi, many have few or none. The necessity of having national depositaries is crucial to the documentation and understanding of a nation's natural fungal resources and to making it available for screening for potentially beneficial attributes.

There is also the issue of the balance that should be aspired to between *in situ* and *ex situ* conservation with so many fungi awaiting discovery, and how should that be reflected in national and international policy? As so many fungi are linked with plants, the areas of greatest conservation value for fungi are likely to be the longest-established priority sites for particular plant communities. However, this may not always be the case, and may not be commensurate with protecting particularly vulnerable fungal species which may occur in 'unlikely' habitats such as roadsides. IUCN-The World Conservation Union does have separate committees devoted to fungi and lichens, but so far they have not been especially active, particularly when compared with those working on birds, reptiles, mammals or plants. However, *in situ* conservation of fungi is now being debated (Moore *et al.*, 2001). In the UK, not only have Biodiversity Action Plans have been developed for various species in conjunction with and largely funded by the statutory conservation agencies, the first steps to identify important fungus areas have been taken (Evans *et al.*, 2002). A code of conduct for mushroom pickers has also been agreed by various interested parties and widely distributed (Anon., 1998). The establishment of a national Fungus Conservation Forum comprising a variety of interested organizations has been a stimulus to this enhanced attention to fungus conservation in the UK, and may merit emulation.

Draft MycoAction Plans

In order to start to address the problems mycology faces in relation to its perception and resources, and to initiate debates at a variety of levels, I suggest that MycoAction Plans are developed at a range of levels, with actions grouped according to the key themes of collaboration, promotion, education, and conservation. The exemplar actions identified and suggested datelines (where relevant) are intended to stimulate discussion and will need to be refined, ratified, and developed in detail by the appropriate bodies or individuals.

Worldwide MycoAction Plan

Actions at this level are the mandated responsibility of the International Mycological Association (the Section for General Mycology of IUBS). Some of these actions may need the establishment of new *ad hoc* committees with finite terms devoted to completion of tasks delegated to them.

Collaboration

- Ensure representation at all IUBS General Assemblies (every three years).
- Organize four-yearly International Mycological Congresses (IMC's), successive IMC's being in different continents.
- Compile world directories of organizations, institutions, collections, and specialists, for publication in hard copy (every 4-5 years; cfr. Hall and Minter, 1994), and on the worldwide web (updated monthly).
- Facilitate the organization and operation of the four regional groupings and associations of mycologists established or recognized by the IMA: Africa, Asia and the Pacific, Europe, and Latin America.
- Ensure that all national mycological societies are aware of the IMA and encourage them to become organizational (if not sustaining) members.
- Resolve the relationship between the IMA and IUMS Mycology Division by the next IMC in 2006.
- Organize a three-yearly meeting between key officers of the IUMS Mycology Division, International Commission on the Taxonomy of Fungi (ICTF), International Congresses of Plant Pathology (ICPP), International Society for Human and Animal Mycology (ISHAM), International Lichenological Association (IAL), International Society for Mushroom Science (ISMS), International Commission on Yeasts and Yeast-like Organisms (ICYO), and other 'fungal' bodies recognized by IUBS or IUMS.

Promotion

- Issue an annual hard-copy newsletter (i.e. restart *IMA News*) for distribution to all IMC participants and through national societies, re-starting in 2004.
- Develop the IMA home-page on the web and update at least monthly, to include hypertext links to other pertinent web pages and mycological resources of all types.
- Ensure mycologists are involved in international initiatives relating to biodiversity (e.g. DIVERSITAS), conservation (IUCN, UNEP), and genetic resources (FAO, WFFC).
- Prepare and make available to international and national funding agencies a brochure on the importance of fungi to human welfare and environmental health (by 2005).

Education

- Establish a working group by the end of 2004 to produce a series of key elements to be included in mycological course modules to be available by 2006.
- Develop and endorse a series of codes of practice for the maintenance and operation of fungal genetic resource collections (cfr. Hawksworth *et al.*, 1990; Aegerer *et al.*, 2000), mushroom collection (cfr. Anon., 1998), good taxonomic practice (cfr. Sigler and Hawksworth, 1987), and good cultural practice (cfr. Crous, 2002), with a view to having all revised and endorsed by the next IMC in 2006. After adoption, publication in a wide range of mycological journals should be arranged.
- Extend the system of IMA awards to include: (1) a new medal for younger (under 35 years) mycologists with the first to be granted at the IMC in 2006; and (2) a modest annual research/travel grant scheme (e.g. two of US\$1000), also for younger mycologists, be announced at and start from the next IMC.

Conservation

- Agree a list of priority fungal groups to be surveyed in rapid assessments of sites by the end of 2003.
- Develop a list of criteria requiring consideration for determining sites of greatest scientific importance for fungal conservation by the end of 2004.
- Compile a list of specialists willing and able to undertake identifications (and indicating which are free of charge and which are not) and make this available at least on-line *via* the IMA home page but also ideally as a book (cfr. Holmgren and Holmgren, 1992) by the next IMC in 2006.
- Initiate a discussion between the 4-6 major world service culture collections to determine the scope for developing complementary accessions policies (e.g. by sponsoring a closed meeting during the next WFCC congress).

Regional MycoAction Plans

The concept of encouraging the development of a series of regional mycological groupings was developed at IMC2 in 1977, but little progress was made until the elected IMA officers endeavoured to stimulate action in the

1980s. The IMA Committee for the Development of Mycology in Asia, had its origins at a meeting held in the Genting Highlands in Malaysia in 1986 (Tubaki and Yokoyama, 1987), following on from a workshop on Applied Mycological Research in the Tropics held in Singapore in 1985 under the auspices of the UNESCO Asian Network for Biological Sciences (Subramanian, 1986). The next congress was held in Seoul in 1992 (Korean Mycological Society, 1992), and the following one in Taiwan in 1995. A directory of Asian mycologists was compiled by Chung (1994). Subsequently, there have been several different congresses in the region; the Asia-Pacific Mycological Congresses on Biodiversity and Biotechnology series started in Thailand in 1998 (Jones, 1999), then met in Hong Kong in 2000 (Hyde, 2001), and is now being held in Kunming.

The first regional conference in Africa was held in Mauritius in 1990 (Hennebert, 1994), the second in Egypt in 1992, and the third in Zimbabwe in 1995 when the African Mycological Association was established (Mibey, 1996). The African group published a directory (Buyck and Hennebert, 1994) and adopted the *African Journal of Mycology and Biotechnology* (199X on) edited from Cairo as its official journal.

The Latin American regional group, the Asociación Latinoamericana de Micología, was established in 1990. It produced a directory of mycologists (Anon., 1993), and has held congresses in Cuba in 1993 and 1996, Venezuela in 1999, and Mexico in 2002. The Mycological Society of America (MSA) acts as the North American counterpart. The European region is covered by the ongoing series of European Mycological Congresses which meets every three years, the next being in the Ukraine in 2003; this series has traditionally had a macromycete focus.

Collaboration

- Organize a regional conference covering all aspects of mycology every 3-4 years, never meeting in the same country at intervals of less than 12 years.
- Compile directories of mycologists and collections in the region and publish these in hard copy (every five years) and(or) on the worldwide web (updated at least annually).
- Encourage the development of national mycological societies within each country in the region, and ensure that all countries are represented on the regional committee.
- Ensure representation on and involvement in appropriate regional initiatives (e.g. UNESCO Biosciences Networks).

- Liaise closely with the IMA, sending at least an annual report on activities.

Promotion

- Prepare at least an annual newsletter.
- Develop a website which is updated at least annually and with links to the IMA site and any national sites in the region.
- Identify possibilities for collaboration in regional initiatives, for example programmes of Development Banks or the EEC (cfr. Microbial Information Network Europe).

Education

- Arrange regional training courses and specialist workshops with outside funding, aiming at holding one every two years.
- Develop teaching aids in languages of the region, including translations of course modules developed by the IMA.
- Translate any codes of practice produced by the IMA into languages of the region and ensure their distribution.
- Develop and secure funding for exchange visits between mycologists in the region.
- Identify industrial or other sponsors for awards to younger (under 35 years) mycologists sufficient to facilitate study-visits overseas, aiming to have these available for competition by 2005.

Conservation

- Identify potential sites of major conservation importance for fungi in the region by 2010.
- Explore possibilities for collaboration between specialists in the region to work towards an All Taxa Biodiversity Inventory (ATBI) for one site in the region.
- Conduct an assessment of the available biosystematic and genetic resource collections of fungi in comparison to the needs of the region (cfr. Subramanian, 1992) by 2005, and explore ways of securing funding to enhance collections to meet regional needs.

National MycoAction Plans

Many of the suggestions made here will require funding from governmental or intergovernmental agencies, aid organizations, conservation agencies, industry, or as part of proposals to development banks.

Collaboration

- Establish a national mycological society to include those working on all aspects of pure and applied mycology by 2005 if none already exists, and seek membership of the IMA.
- Actively recruit mycologists of all kinds to membership of the national society, preparing a leaflet for distribution by 2006.
- Organize an annual scientific meeting, with invited and offered papers, posters, and social events (e.g. annual dinner), ideally in a different town each year.
- Compile a directory of mycologists in the country and their specialisms.
- Encourage the formation of specialist groups of mycologists and local fungus groups.
- Liaise with and contribute to the activities of the relevant regional mycological group and of the IMA.
- Organize an annual meeting between officers of national scientific societies with complementary interests in the region (e.g. those concerned with biodeterioration, biotechnology, botany, ecology, medical mycology, microbiology, plant pathology).

Promotion

- Identify government and other national bodies on which mycologists should be represented and facilitate such representation.
- Make contacts with key scientists and government officials in a position to promote mycology.
- Explain by letters to key personnel in universities, government departments of education, environment and science, conservation agencies, and museums, that fungi are more closely related to animals than plants and that they should be independent from and not subsumed within departments or actions relating to botany, plants, or even microbiology (bacteria and viruses are in different domains, let alone kingdoms). Ongoing

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- Appoint a Press Officer responsible for alerting newspapers, radio, and television stations to items of potentially wide interest involving fungi.
- Arrange a touring exhibition on the importance of mycology to be displayed for six months in each of a series of museums, starting in 2004.
- Prepare and seek sponsors for the publication of posters on the importance of fungi to human welfare and ecosystem health for issue by 2005.
- Establish a home page on the worldwide web by 2006 with links to regional and other national pages.

Education

- Identify speakers able to make presentations on different aspects of mycology in the country's language and make that list available to natural history societies, schools and universities.
- Assess the extent of postgraduate training courses in the country by the end of 2003 and arrange discussions of the problem with senior Department of Education staff in 2004.
- Award a certificate and modest cash prize for the best oral presentation and(or) the best poster given by a postgraduate student at the annual meeting of the society.
- Arrange workshops on specific topics, including techniques, at least every three years.
- Plan an annual field excursion, and also a visit to a centre conducting mycological research (in association with the annual meeting).
- Ensure any codes of conduct produced by the IMA are appropriately distributed in the country.

Conservation

- Compile and publish a national checklist of fungi recorded in the country by 2010.
- Implement a national fungal recording scheme, if none exists, by 2006.
- Seek and ensure representation on national conservation bodies.
- Establish a national fungal conservation forum, including professional and amateur bodies as well as government environmental agencies by 2005.
- Identify areas of major importance for fungal conservation in collaboration with government conservation agencies by 2010.

- Select a site for an all taxa biodiversity inventory (ATBI) for fungi in the country and identify specialists to help, and collections to deposit voucher material in.
- Conduct a survey of biosystematic reference and genetic resource collections in the country, including numbers of isolates/specimens and species represented and an assessment of their condition and how they relate to national needs by 2007.

Personal MycoAction Plans

The key action plan on which each of us needs to reflect carefully. Each mycologist's will be different to varying degrees, as we all have different skills and potential roles. These will consequently be highly personalized and individually tailored.

Collaboration

- Join the national society in 2003, where one already exists; if not consider with colleagues how an inaugural meeting might be set up to establish such a society.
- Identify ways of contributing to the activities of the national society and discuss them with society officers in 2003.
- Make contact with at least five other mycologists in your town or district during 2003, encouraging them also to join the society.

Promotion

- Prepare an article for a non-mycological journal every 2-3 years.
- Give one talk each year to non-scientists, for example gardeners or naturalists.
- Write one item or letter for a local newspaper or magazine each year.
- Identify and approach 2-3 people who might be able to sponsor mycological activities each year.
- Devote two hours each week to the above activities.
- Never use terms such as 'plants', 'microorganisms', or 'flora' in relation to fungi.
- Do not submit search papers for publication to botanical, microbiological, or plant science journals (unless on plant-fungal or bacterial-fungal interactions).

Education

- Take on at least one postgraduate student each year as a supervisor or co-supervisor.
- Give one talk (and where possible practical session) each year to undergraduates and postgraduates, contacting local colleges and universities to make them aware you are available for this.
- Lead a local field excursion for both students and naturalists.

Conservation

- Contribute to the national fungal recording scheme, sending in records of groups which you are familiar with, submitting at least 100 records each year.
- Adhere to codes of conduct when collecting fungi produced by the IMA or national society.
- Deposit voucher specimens or cultures in secure collections.
- Identify sites of most mycological interest in your district and communicate these to the national fungus conservation forum.

Prognosis

An Action Plan to encourage the exploration of microbial diversity was proposed by IUBS/IUMS, termed Microbial Diversity 21, in 1991 (Hawksworth and Colwell, 1992). This had a 14-point action plan relating to inventorying, conservation (*in-* and *ex-situ*), and information networks. As part of this programme, major reviews of microbial diversity and its relevance to ecosystem function were held in 1993-94 (Allsopp *et al.*, 1995; Colwell *et al.*, 1996), and the Biodiversity Information Network (BIN21) was established in 1992 (Kirsop and Canhos, 1995). Inputs were also made into the DIVERSITAS programme, initiated by IUBS but later run by the International Council of Scientific Unions (ICSU) in collaboration with UNESCO (Diversitas, 1996), but significant funding was not forthcoming and the only tangible mycological fruit to date has been a manual on methods for studying soil organisms (Hall, 1996). A series of actions to strengthen microbial biosystematics in Europe was also compiled (Hall and Hawksworth, 1996), but progress on what has been extremely limited.

With hindsight, Microbial Diversity 21 was perhaps too ambitious for its time, but more significant may have been the lack of a sufficiently committed constituency of researchers able or willing to devote the time needed to secure

funding for and implement many of the action points. At the British Mycological Society's symposium on Aspects of Tropical Mycology in 1992, I considered the outlook good, provided that the necessary organization and planning could be effected by 1995 (Hawksworth, 1993). That date was indicated because there was a window of opportunity presented by funding agencies anxious to sponsor activities in support of the Convention on Biological Diversity, but sadly no major primarily mycological initiatives were secured in that time-frame – although the mycological component of BioNET and its regional loops (Jones, 1994) continues to spawn a satisfying number of training, collection enhancement, and database projects funded by various bodies (e.g. the UK Darwin Initiative, Swiss Development Corporation).

We can be satisfied with the increased profile of fungi now achieved in biodiversity science (e.g. Schulze and Mooney, 1994; Heywood, 1995; Raven and Williams, 2000) and international systematic initiatives (e.g. Blackmore and Cutler, 1996; Rodriguez, 2000). However, we must now build on this recognition, if yet another opportunity is not to be exploited to its full potential. And recognize that this is something in which each of us has to be proactive. We must not assume that action will be taken by 'somebody'; if we do we will find it is taken by 'nobody'. To take the enhancement of mycology to the next tier, I am convinced that we need a series of concerted actions from the global to each one of us. The suggestions made here for actions at different levels, and the time frames where appended, are intended as drafts for discussion and refinement; and they are surely far from exhaustive. If the IMA, each regional and national mycological group, and each of us here today or who read this text, debate and reflect on its contents and consider actions to be taken it, will have fulfilled its aim.

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