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AND NATURAL HABITATS

**Standing Committee**

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# GUIDANCE FOR THE CONSERVATION OF MUSHROOMS IN EUROPE

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**Content**

## SUMMARY

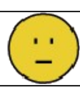
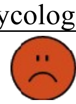
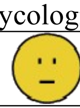
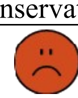
Fungi are no longer treated as an obscure subset of "lower plants", but recognised as their own kingdom with an extraordinary diversity. Fungi are one of the most species rich groups of organisms in Europe, with at least 75 000 species. Of these more than 15 000 species are macrofungi, i.e. they form sporocarps visible to the naked eye.

Fungi are certainly poorly understood and appreciated compared to plants and animals. However, in recent decades, immense advances in our knowledge of the taxonomy, distribution, ecology, and conservation status of European macrofungi, now enable this large component of biodiversity to be appreciated, considered and incorporated into conservation actions at both the national and European level. Most European countries (31) have now produced fungal Red-Lists and more than 5 500 different macrofungi are red-listed in at least one European country. The national red-list evaluations indicate that up to 10-20% of European macrofungi may be threatened. The main causes are unsuitable forest and farmland management and air pollution (eutrophication); however, fungal Red-list analysis rarely seems to be considered in national programmes. Fortunately, the diversity of, and threats to, macrofungi are starting to be considered in a few countries, e.g. for identification and designation of protected areas, development of species action programmes, inclusion in monitoring programmes, and production of management guidelines.

To align fungal conservation with that of other species groups and allow comparison between regions at different scales, the key targets and actions of these guidelines have been arranged to correspond with the five Global Strategy for Plant Conservation (GSPC) objectives. The plant strategy, endorsed by the Convention on Biological Diversity (CBD), is an obvious sister strategy because of the close inter-relationship between fungal and plant diversity. The modified objectives are:

1. Understanding and documenting European fungal biodiversity
2. Conserving European fungal biodiversity
3. Using European fungal diversity sustainable
4. Promoting education and awareness about European fungal diversity
5. Building capacity for European fungal conservation

It is particularly important to ensure the production of a European Red List for macrofungi. Such an assessment will i) enable identification and prioritization of threatened species and their habitats at the European level and hence, ii) enable this knowledge to be effectively considered / implemented in overall national or European conservation strategies and iii) better enable fulfillment of the 2010 Convention of Biological Diversity target. The ECCF aims to produce a European Red-List of macrofungi by 2010, providing funding is obtained.

| Present conservation status of macrofungi in Europe | | | | | |
|---|---|---|---|---|---|
| European checklist | European Red List | No of professional mycologists | No of amateur mycologists | Awareness of fungal conservation | Potential to promote fungal conservation |
|  |  |  |  |  |  |

*This report compiles i) the knowledge of macrofungi in Europe, ii) the state and need for fungal conservation actions within European countries and at the European level, and iii) feasible and required conservation steps. The compilation is based on information from 37 countries within the network of European mycologists interested in conservation issues (European Council for Conservation of fungi, ECCF).*

# 1. INTRODUCTION

Fungi are one of the most species rich and diverse groups of organisms on Earth. They constitute a significant part of terrestrial ecosystems, forming a large share of the species richness and are key-players in ecosystem processes. Fungi were long considered a strange group of organisms, poorly understood and difficult to study due to their largely hidden nature and frequently sporadic and short-lived sporocarps. Hence fungi have largely been neglected and overlooked in national and international nature conservation actions. However, through the research of professional and amateur mycologists and field observations over the last few decades our knowledge of fungi has significantly increased. It is thus now largely feasible to evaluate the present status and future for fungal species and how human activities, such as land management procedures, will affect fungal diversity.

In recent decades, national fungal Red-listing in Europe has revealed that the threats and loss of fungal diversity are as severe for fungi as for other more well-known groups of species, e.g. plants and animals.

A recognition of the important role of biodiversity in supporting human life, and deep concern over its rapid loss motivated the adoption, at the Rio Earth Summit in 1992, of the Convention on Biological Diversity, a legally binding global treaty[1]. The Convention's core objectives are i) the conservation of biodiversity, ii) the sustainable use of its components, and iii) the fair and equitable sharing of benefits arising out of the utilization of genetic resources. The target for 2010 at the global level is 'to achieve a significant reduction of the current rate of biodiversity losses'. The target is addressed even more ambitiously at the EU and at the European level, as to 'halt the loss of biodiversity'.

## The aim of the report

The aim of this report is to summarize the state of fungal biodiversity knowledge for macrofungi in Europe, to report ongoing fungal conservation actions and to identify and suggest additional important actions. An adequate and obvious management question is also whether consideration of the fungi will add important complementary dimensions to biodiversity management or if ongoing conservation actions directed to habitats and other groups of organisms already sufficiently ensure a rich and viable fungal biodiversity in the future.

This report deals only with macrofungi (macro-fungi), an artificial grouping that encompasses species which, irrespective of phylogenetic placement, have sporocarps at least 2 mm in size. Fungi having smaller or no sporocarps are grouped as microfungi. Conservation of microfungi (i.e. the ascomycetes, conidial fungi, rusts, smuts, chromistans, chytrids, myxomycetes and zygomycetes), which comprise a far larger range of species than the macrofungi, has up to now been non-existent, even though there is clear evidence that many of these species too may be endangered: microfungi are orphans of the Rio Convention. A project running from 2008-2010 and funded by the UK Darwin Initiative is attempting to initiate a movement for the conservation of these important and vulnerable organisms[2].

## The fascination, richness and diversity of fungi

Fungi have fascinated humans and been used by them since prehistoric times. They constitute a systematically independent kingdom, the *Fungi.* Fungi are heterotrophic: they depend on other organisms for carbon as they are saprotrophs, mutualists or parasites. The mutualists include mycorrhizal fungi, living together with vascular plants, and lichenized fungi which form permanent double organisms with algae or cyanobacteria, known as lichens. Lichens are commonly handled as a distinct group of organisms and are not dealt with in this report.

The two main groups which contain macrofungi are the *Ascomycota* and *Basidiomycota*. Although most of the *Ascomycota* are microscopic species, it also contains some "larger fungi" cup-fungi, morels and truffles. The *Basidiomycota*, which is a smaller group, mostly comprises macrofungi, including mushrooms and toadstools, bracket fungi and puffballs, although about 30% of its species too are

[1] In 2007, the CBD was signed by 190 parties, including 189 countries and the European Community.
[2] For further information see www.cybertruffle.org.uk/darwin-microfungi.

microscopic. Most macrofungi are decomposers, about one tenth species form mycorrhiza and only a minority is parasites.

Macrofungi have macroscopic and microscopic characters. Like most fungi they are composed of microscopic, elongated chains of cells called hyphae forming a cobwebby structure called mycelium, which grows in soil, wood or other substrata. From this mycelium, they produce macroscopic sporocarps which when fully grown range between a few mm and several dm. In some species sporocarps are short-lived, in others they are persistent and may be perennial. Fruiting in this group (e.g. boletes and waxcaps) is highly dependent on weather conditions and occurrence and abundance of sporocarps may therefore vary by several orders of magnitude between years. Tools to detect and identify fungi directly from soil, wood and plant material using molecular markers have been developed and may give a more appropriate picture of the present fungal community than sporocarp monitoring. However, it is not feasible to conduct molecular surveys on a large scale, while sporocarp monitoring, with a reasonable effort, can be conducted to encompass all fruiting species within large areas. Furthermore, fruiting and production of spores is important for the long term survival of fungal species. Therefore, sporocarp surveys over time are well adapted for evaluating the reproductive fitness of fungal populations.

Modern molecular techniques to identify individual species and describe whole fungal communities (macro- and microfungi) are becoming more accessible to fungal conservation. These techniques, importantly, allow detection of species in the absence of sporocarps and may open up new approaches to fungal conservation in the near future. For example, some species do not produce sporocarps every year. Such species can, however, be detected, if their approximate location is known, through the development of species specific primers and whole community DNA or RNA extraction. Such primers have been developed for many stipitate hydnoid fungi in the UK, and are already being used to increase knowledge of the species distribution and ecology. Community profiling techniques, where individual species are not necessarily identified but where entire fungal communities are detected in a single analysis, are likely to be used more routinely in the future to measure the magnitude and relative impacts of environmental perturbations (e.g. climate change, eutrophication, land management), at lease at a local scale. Those responsible for fungal conservation must be aware of these techniques, liaise closely with academic partners, and be willing to use them to improve the scope of fungal conservation in the near future.

Understanding of fungal population biology has increased considerably during the last few decades and it is now possible to make reliable evaluations of those populations. As with all clonal organisms, fungal individuals consist of a unique genotype (genet). Individual fungi occupying discrete substrata in time and space, e.g. leaves, dung and wood, are dependent on the size and durability of their habitats; they are therefore typically small and often short-lived. In contrast, individual soil-dwelling saprotrophic and mycorrhizal fungi are potentially indeterminate in size and age; they are therefore typically several metres in size and may live for several decades (Tab 1). Fungal habitat requirements have conservation implications. Species with discrete habitats, e.g. wood, need to disperse regularly and to re-establish themselves. They accordingly need a continual supply of their substrata/habitats to maintain populations. In contrast, the primary focus for securing the continued existence of soil-dwelling fungi is to ensure continuity of existing habitats, e.g. unfertilized grass land and old-growth forests.

| Fungal group | Species | Mycelial sizes | Mycelial ages | Ecology notes |
|---|---|---|---|---|
| Wood-inhabiting fungi | *Hapalopilus croceus* | 1 genet/tree | several 100 years | Inhibit coarse old living oaks |
| | *Fomitopsis rosea* | 1 to several genets/log | 1-2 decades | Coarse dead wood of Norway spruce |
| Tree parasite | *Armillaria* spp | > 600 m[a]<br>100 $m^2$ - 1000 ha[b] | centuries to > 1500 years | |
| | *Phellinus weirii* | > 1 km[a] | > 1000 years | |
| Soil-dwelling fungi | *Megacollybia platyphylla* | 150 m[a] | several decades - centuries | Broad-leaved forests |

| | | | | |
|---|---|---|---|---|
| | *Geastrum* spp | 10 m[a] | several decades | |
| Mycorrhizal fungi | *Suillus* spp | 30-50 m[a] | several decades | Pine forest |
| | *Hydnellum ferrugineum* | 10 m[a] | several decades - centuries | old growth forests |

***Table 1**. Examples of sizes and estimated maximum ages of fungal individuals (Worall, 1999; Dahlberg 2001).* [a] *= extent, b = area.*

Most fungi produce spores adapted to wind dispersal, potentially over hundreds of kilometres. However, the most spores settle within a few metres of the parent sporocarp, and in practice many rare species have severe difficulties to spread and establish further than in the immediate vicinity of present populations.

Only a minority of fungal species are common and widespread, while the overwhelming majority of species are less common to rare. Fungal communities are often very species rich, with ecologically specialized component species. Grasslands and forest stands where monitoring of macrofungi have been conducted for several years typically have records of several hundred species of macrofungi. For example, on one 380 ha lowland heath with both planted and seminatural secondary woodlands in Surrey on the outskirts of London 3300 fungal species have been recorded to date. In the Royal Botanic Gardens, Kew, UK (132 ha) almost 2600 fungal species have been recorded. A single coarse beech log commonly hosts more than 50 fungal species and estimates suggest that the roots of individual mature trees host up to 50 ectomycorrhizal species.

**Why consider fungal conservation**

The Convention on Biological Diversity (CBD) aims to embrace all groups of organisms and to secure diversity at all levels; genes – species – ecosystems. It is increasingly being appreciated that a rich and viable biodiversity and environment go hand in hand with human wellbeing.

Fungi form a major part of global biodiversity. Macrofungi and microfungi represent together 10-20% of the total number of species of life. The total number of fungal species is globally estimated to be between 750.000 and 1.500.000 of which only around 100 000 currently are identified and described (Hawksworth 2001; Schmit & Mueller 2007). It is obvious that discovery, characterisation and description of the as yet undiscovered majority of species, and at the same time, improvement in the knowledge of distribution and ecology of those already described represent a major challenge in mycology.

Red-list evaluations produced over the last two decades in almost every European country, together with hundreds of scientific studies addressing fungal conservation questions, indicate that a large portion, probably in the range of 2000 –3000 species of macrofungi throughout Europe are declining and their futures uncertain.

Fungi are rarely considered in national conservation actions and are not considered in any international conservation agreements (e.g. Bern Convention and Habitat Directive). Nature conservation policy in the EU is, for example primarily, directed by the Habitat Directive which aims to secure favourable conservation status in selected habitat types across all member-countries. The implementation however, includes mainly vascular plants and vertebrates, primarily species listed in the Bern Convention. There is no doubt that this programme will be beneficial for many macrofungi and other unrepresented species groups. However, as macrofungi are not considered explicitly, species with particular requirements will undoubtedly be overlooked. In fact no analysis has yet been conducted to determine how efficient conservation actions of today are for macrofungi. This is a short-coming nationally throughout Europe and at the European level.

It is increasingly becoming apparent that the ecological requirements of different groups of species do not fully correlate. Therefore conservation measures based on a certain set of organisms do not sufficiently guarantee the survival of the whole diversity, as has been shown for a number of organism groups (e.g.Virolainen et al 2000; Chiarucci et al. 2005). To meet obligations under the CBD and to secure the diversity of fungi in Europe it is thus of paramount importance regularly to analyse the status of fungi if conservation measures are to be implemented and where there are knowledge deficiencies, to initiate research into appropriate management.

## 2. Material and Methods

The information and discussion in the following chapters are based on

a) a recent compilation of the national state of fungal knowledge and conservation in Europe, b) a questionnaire on the national state of mycological knowledge, number of professionals and amateurs, Red-listing progress, fungal threats and conservation actions that was sent to national mycological representatives throughout Europe in May 2007[3] and c) a discussion within ECCF and the groups of experts on the conservation of Plants within the council of Europe Sept 6th 2007 on earlier versions of this report.

## 3. Knowledge of fungi

Mycology has a long tradition in Europe and hence European knowledge of species, their distribution, ecology and status is the most extensive in the world. With the current level of knowledge, it is feasible to analyse the status of macrofungal diversity in Europe and to set conservation priorities for these fungi as part of national and European conservation priorities. On the other hand, due to the large number of species and the relatively few mycologists, this knowledge (particularly within microfungi) is low, sometimes very low, compared to more well known groups of species.

Taxonomic knowledge is still poorly resolved in many groups of fungi. Each year hundreds of macrofungi are published as new to science in Europe, while other epithets are found to be synonyms of already described species. The increased availability of molecular tools also enables a better understanding and resolution of species concepts in fungi: some taxa previously thought to represent several species may as a result be fused into one species, while in other cases, what was thought to be a single species may now be recognized as, in fact, several different species.

### 3.1 The European level

A challenge for mycology and mycologists compared to other more well-known groups of organisms is the large number of fungal species (Table 2).

| **Organism group** | **Species number in Europe** | **Reference** |
|---|---|---|
| Fungi | > 75 000 | estimate in this report |
| Macrofungi | > 15 000 | estimate in this report |
| Vascular plants | 12 500 | Planta Europa |
| Mosses | 1 753 | Porley et al. 2007. Proceedings to the World Conference on Bryology 2007 in press |
| Butterflies | 8 470 | Karsholt O & Razowski J.1996 The Lepidoptera of Europe, A distributional checklist. Apollo books, Stenstrup |
| Birds | 524 | www.birdlife.org |
| Mammals | 226 | http://ec.europa.eu/environment/nature/conservation/species/ema/index.htm |

***Table 2**. The number of species in Europe in a selection of species groups.*

[3] ECCF, newsletter 14 (2006) can be downloaded together with the answers of the questionnaire at ECCF-webpage, www.eccf.info.

Most European countries have produced checklists of at least some fungal groups (Fig 1, Table 3). Unfortunately no attempt has yet been made to make a checklist or estimate for the likely total number of fungi, or even only of macrofungi, in Europe. By using the relationship between the number of vascular plant species and fungal species, as used for global estimates, between 75 000 – 100 000 fungal species are likely to occur in Europe. The total number of European macrofungi is similarly disputed. Schmit & Mueller (2007) conservatively estimated the expected number to be at least 6300 species, which clearly seems to be an underestimate. Thus both Spain and Norway have estimated their number of macrofungi nationally to exceed 7000 species (Fig 2). We therefore find it likely that the total richness of macrofungi in Europe exceeds 10.000 species and may be closer to 15 or 20.000 species.

Many macrofungi have been described from Europe, and many of these are still known only from Europe. Several are conspicuous and well studied species and should be considered as endemic, e.g. *Pleurotus nebrodensis, Tulostoma niveum; Lyophyllum favrei*. The true extent of European endemism among macrofungi, however, is still not known.

**European Mycological Associations**

***The European Mycological Association***

The European Mycological Association (EMA), a non-governmental organisation, was founded in 2003 to promote mycological activities throughout Europe.

Homepage: www.euromould.org

***The European Council for the Conservation of Fungi***

The European Council for the Conservation of Fungi (ECCF) was founded 1985 and is a network of mycologists throughout Europe interested and active in fungal conservation. Most European countries have representatives in the ECCF and there is usually at least one annual meeting. In 2003, the ECCF prepared a proposal for 33 macrofungi to be included into the Bern Convention. It is currently completing distribution maps of 50 selected European species and is working on a European Red List of macrofungi. Since 2003 the ECCF has been the conservation body of the EMA.

Homepage: www.eccf/.info

## 3.2 The national level

*3.2.1 Species knowledge*

The information about macrofungi varies greatly between European countries. Some have a long and continuous scientific mycological tradition (e.g. Germany, France, Sweden, UK), others have a more recent but strong tradition of mycological studies (e.g. Norway, Poland and Spain), but in several countries knowledge is limited (e.g. Albania, Greece, Portugal). Thirty one European countries have fungal checklists of varying quality or are preparing them (Fig 1, Tab 3). These checklists deal predominantly with macrofungi. The degree to which they encompass the likely number of species reflects differences in national knowledge. For instance the checklists for Ireland, Croatia and Serbia are estimated to include 1/3 of their species richness, while checklists from countries with a stronger mycological tradition (e.g. Switzerland, The Netherlands and UK) are more complete. National estimates of species richness vary between 3 000 and 8 000 macrofungi (Fig 2). Nearly 30 countries also have databases of fungal records and distributions, of which at least 15 are available on-line (Fig 3). A recent development is that records can be reported interactively to some national databases (Denmark, Norway, Sweden, UK, Portugal, Greece[4]) where the records are displayed immediately or soon after recording via a GIS web-application.

In addition some countries have compiled ecological information (species requirements of substrata and habitats) either in ecological catalogues, e.g. Finland and Sweden or in checklists as for example Italy and UK. Extensive knowledge of the ecology of individual species is also available in books, monographs and scientific reports covering many parts of Europe.

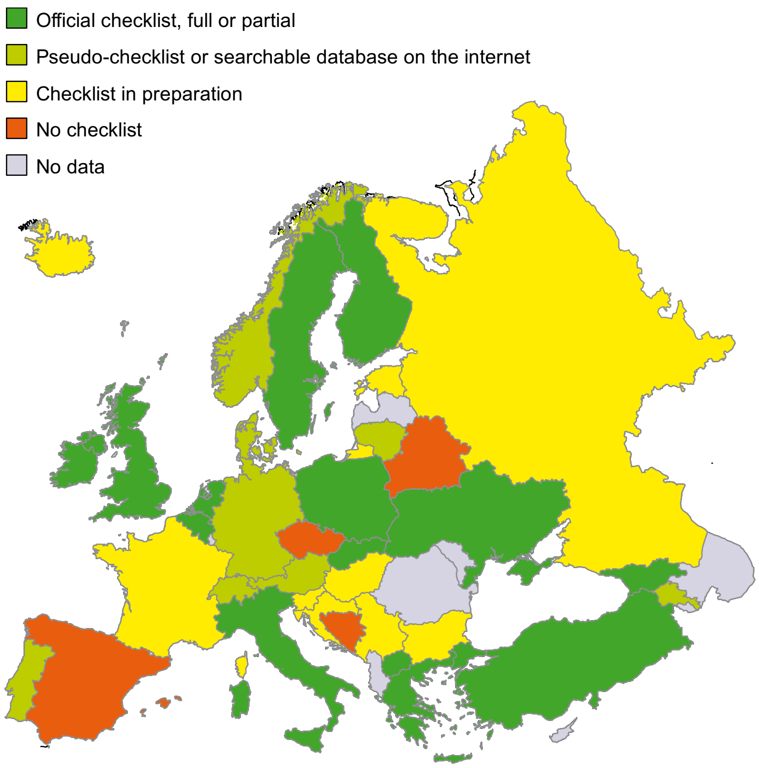



***Figure 1.*** *The presence and status of national fungal checklists in Europe.*

| **Criteria** |  |  |  |
|---|---|---|---|
| **Fungal check-list** | Existing | Pseudo-check-list or in preparation | Lacking |
| **Professional mycologists** | > 10 | 5-10 | < 5 |
| **Amateur mycologists** | < 1/100 000 inhabitants | 2-10/100 000 inhabitants | > 10/100 000 inhabitants |
| **Fungal Red List** | Official, IUCNs criteria from 2001 | Official using national or earlier older versions of IUCN criteria, or unofficial or preliminary | lacking |
| **Consideration of fungal conservation** | Often | Sometimes | Rarely - never |

***Table 3.*** *Compilation of national mycological key-facts. Legend above, Table on opposite side.*

[4] Denmark; www.svampe.dk, Norway; http://www.nhm.uio.no/botanisk/bot-mus/sopp/db-intro.htm#intro, Sweden; www.artportalen.se, Ukraine; http://www.cybertruffle.org.uk/ukramaps/, UK; http://194.203.77.76/fieldmycology/Index.htm.

| Country | Fungal check-list | No of professional mycologists | No of amateur mycologists | Fungal Red-List | Fungal conservation consideration |
|---|---|---|---|---|---|
| Albania | no data | no data | no data | no data | no data |
| Armenia | 😐 | 😐 | 😐 | 😐 | ☹️ |
| Austria | 🙂 | ☹️ | 😐 | 😐 | ☹️ |
| Azerbaijan | no data | no data | no data | no data | no data |
| Belarus | ☹️ | 😐 | no data | 😐 | ☹️ |
| Belgium | 🙂 | 😐 | 😐 | 😐 | ☹️ |
| Bosnia and Herzegovina | 😐 | ☹️ | no data | 😐 | no data |
| Bulgaria | 😐 | ☹️ | no data | 🙂 | 😐 |
| Croatia | 😐 | ☹️ | ☹️ | 🙂 | ☹️ |
| Cyprus | no data | no data | no data | no data | no data |
| Czech Republic | ☹️ | 😐 | 😐 | 🙂 | ☹️ |
| Denmark | 😐 | 😐 | 🙂 | 🙂 | ☹️ |
| Estonia | 😐 | 😐 | no data | 😐 | 😐 |
| Finland | 😐 | 🙂 | 🙂 | 🙂 | 😐 |
| France | 😐 | 😐 | 🙂 | 😐 | ☹️ |
| Georgia | 😐 | ☹️ | no data | ☹️ | ☹️ |
| Germany | 😐 | ☹️ | 😐 | 😐 | ☹️ |
| Greece | 🙂 | 😐 | 😐 | ☹️ | ☹️ |
| Hungary | 😐 | 😐 | 😐 | 😐 | 😐 |
| Iceland | 😐 | ☹️ | no data | ☹️ | ☹️ |
| Ireland | 🙂 | ☹️ | no data | ☹️ | ☹️ |
| Italy | 🙂 | ☹️ | 🙂 | 😐 | ☹️ |
| Latvia | no data | no data | No data | 😐 | no data |
| Lithuania | 😐 | 😐 | ☹️ | 😐 | ☹️ |
| Luxembourg | no data | no data | No data | ☹️ | no data |
| Macedonia | 😐 | 😐 | ☹️ | 😐 | ☹️ |
| Malta | ☹️ | no data | no data | 😐 | no data |
| Moldova | no data | no data | no data | no data | no data |
| Montenegro | no data | no data | ☹️ | 😐 | no data |
| Norway | 😐 | 😐 | 🙂 | 🙂 | 😐 |
| Poland | 🙂 | 🙂 | ☹️ | 😐 | 😐 |
| Portugal | 😐 | 😐 | ☹️ | 😐 | ☹️ |
| Romania | no data | no data | no data | 😐 | ☹️ |
| Russia | 😐 | 🙂 | no data | 😐 | ☹️ |
| Serbia | 😐 | ☹️ | ☹️ | 😐 | ☹️ |
| Slovakia | 🙂 | 😐 | 😐 | 🙂 | no data |
| Slovenia | 😐 | no data | no data | 😐 | ☹️ |
| Spain | ☹️ | 🙂 | no data | 😐 | ☹️ |
| Sweden | 😐 | 🙂 | 😐 | 🙂 | 😐 |
| Switzerland | 🙂 | ☹️ | 🙂 | 🙂 | 😐 |
| The Netherlands | 🙂 | ☹️ | 😐 | 😐 | ☹️ |
| Turkey | 🙂 | 🙂 | no data | 😐 | ☹️ |
| UK | 🙂 | ☹️ | 😐 | 😐 | 😐 |
| Ukraine | 🙂 | ☹️ | no data | 😐 | ☹️ |

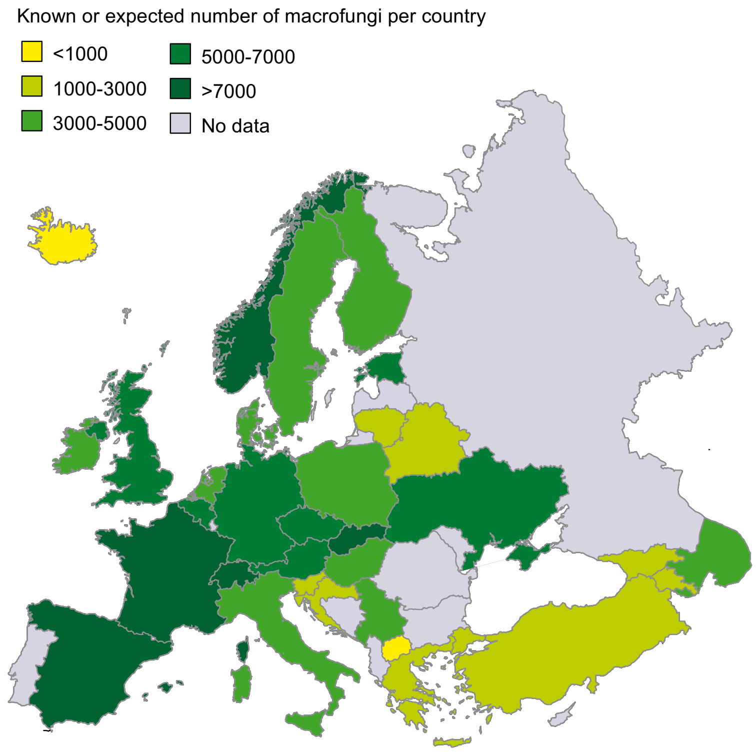



***Figure 2.*** *The number of known or expected number of macrofungi per country.*

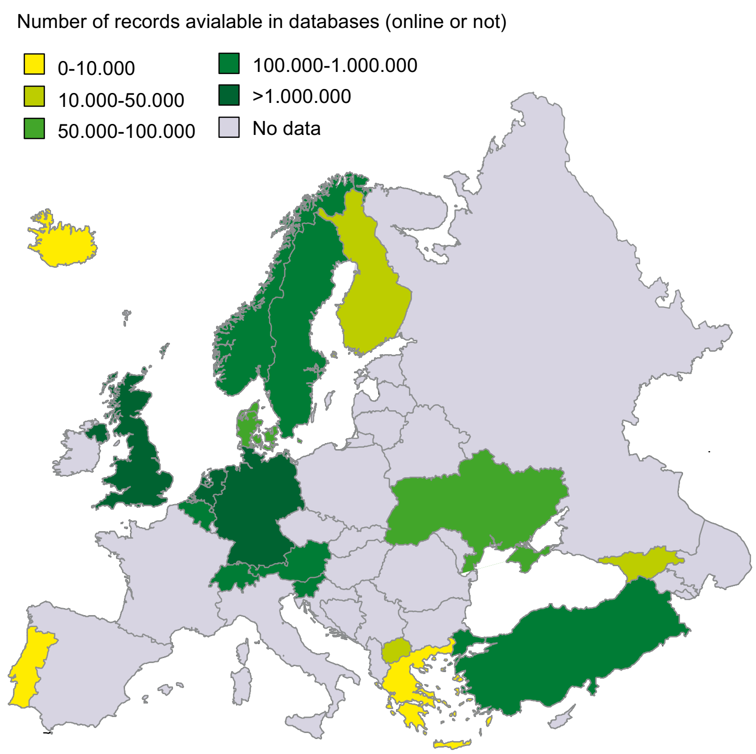



***Figure. 3.*** *The number of records of macrofungi available in databases (online or not).*

*3.2.2 Who knows the fungi?*

**Amateurs and professionals**

Both professional and amateur mycologists are import for fungal conservation (Fig 4, 5). In many countries active amateurs are vital for maintaining knowledge of the distribution and ecology of macrofungi, through their participation in mapping projects etc. Many amateurs are also taking part in red-list assessments, typically in collaboration with professional mycologists.

Many countries have national and/or regional mycological societies (NGOs). In some countries (e.g. Denmark, France, UK ) these are more than 100 years old, while in others they have been formed in the last ten years or so (e.g. Lithuania, Macedonia). There is no clear geographical pattern in the relative proportion of the population involved in fungal NGOs, with Denmark France, Italy, Norway and Switzerland as outstanding examples of countries with large mycological organisations per capita (Tab 3, 4). The variability in organisation degree largely reflects various aims in the national NGOs. In some countries the focus is strongly on experimental science, while in others interest is mainly in picking edible fungi, or in fungal taxonomy, conservation or ecology.

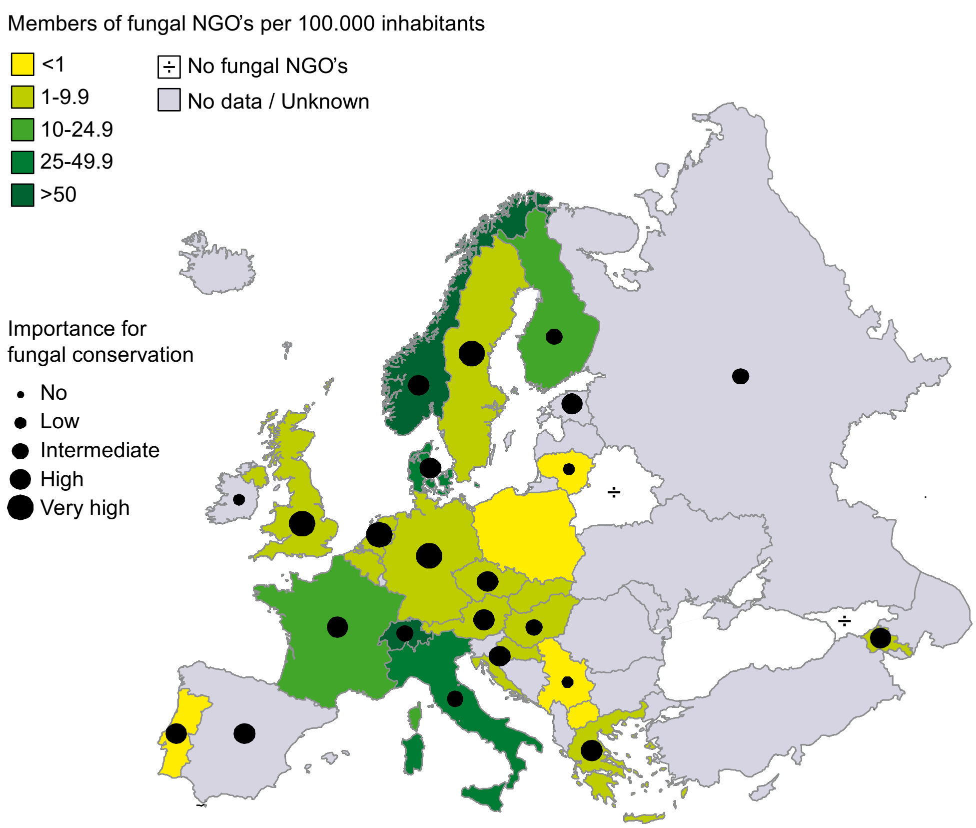



***Figure 4.*** *The number of fungal NGO's per 100 000 inhabitants in the countries of Europe and their perceived importance for national fungal conservation.*

The number of professional mycologists dealing with macrofungi is stunningly low in most countries (Tab 3, Fig 5). Out of 26 European countries evaluated, only six (Finland, Poland, Russia, Spain, Sweden and Turkey) have more than 10 professional mycologists[5] working with macrofungi. Very few countries have mycologists working specifically with conservation mycology. The scarcity of professional mycologists is a serious constraint for effective fungal conservation in several European countries:

[5] Mycologist working with macrofungi, here defined as professional mycologists at universities and at museums working with taxonomy, fungal distributions, field related ecology, conservation but not with fungal physiology, phytopathology and fungal cultivation.

because of the lack of mycological research many crucial questions about taxonomy, ecology and population biology in macrofungi are still to be answered. Also, as a result of this professional deficit, the important interactive, stimulating link between data-collecting amateurs, professional mycologists and conservation bodies is often lost.

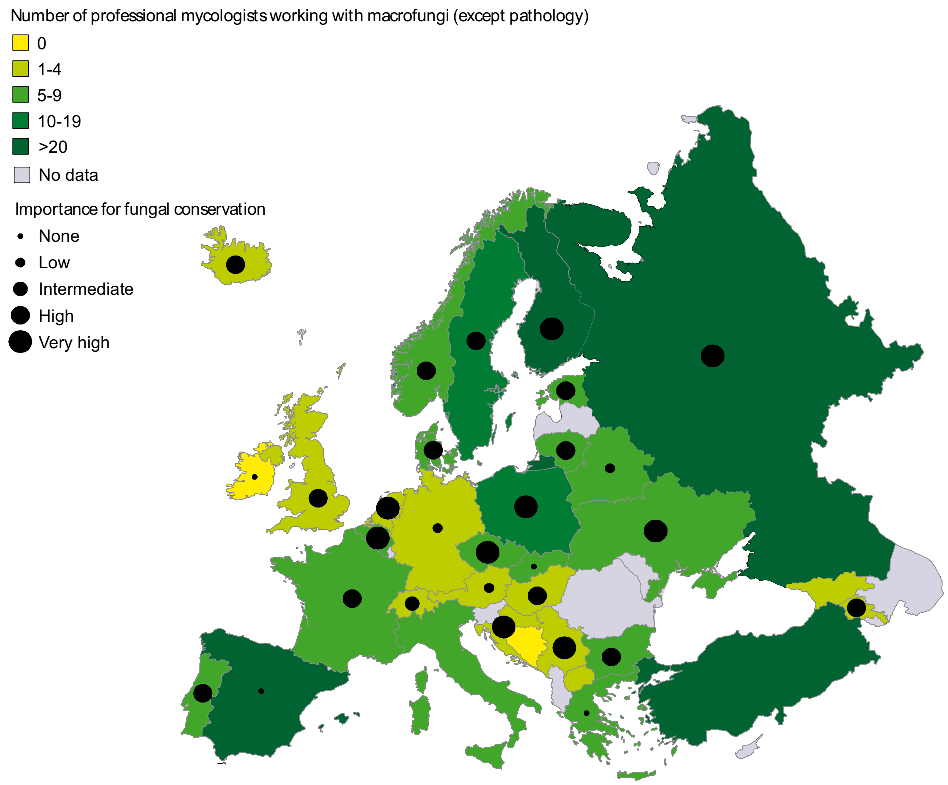



***Figure 5.*** *The number of professional mycologists working with macrofungi and their perceived importance for national fungal conservation actions.*

## 4. STATUS OF MACROFUNGI – FUNGAL RED-LISTS

Reports appeared in the early 1980s of a noticeable decrease in the populations of some species of macrofungi in Europe, i.e. in Germany, the Netherlands and Czechoslovakia. The effects of acid rain and forest die back on fungi, in central parts of Europe were observed, as were changes due to inappropriate forest management and eutrophication of grasslands. In 1988 a thorough analysis of changes to fungal populations due to changed air pollution and changed land use was produced for the Netherlands (Arnolds, 1988). These reports focused the interest of European mycologists, to consider not only acid rain, but also the impacts of changing land use of arable and forest land. These changes include fertilization and cultivation of grasslands, and eutrophication due to anthropogenic nitrogen deposition (See Pegler et al, 1993; Moore et al, 2001 reviews).

### 4.1 Red-listing of fungi

Fuelled by this novel interest in threatened fungi, the national red-lists for fungi began to appear in the 1980s, the first being in 1982 (former German Democratic Republic). By 1992, 11 countries had a published Red List. Currently national fungal Red Lists exist or will shortly be published in 31 countries (Fig 6, Table 2 and 3). Up to 2000, fungal Red Lists were based on a variety of national criteria, which although related to recommendations from the World Conservation Union (IUCN), made comparisons between countries difficult. In the most recent version of IUCN Red-listing criteria (2001[6]) the criteria

[6] www.iucnredlist.org

have been developed and clarified so that evaluation is more easily interpreted, more easily comparable among species group and feasible at different geographical scale. Most fungal Red-Lists published since 2001 are based on these criteria. A working group within the ECCF is presently producing guidelines for fungal Red-listing to facilitate evaluations and to enhance comparisons between different groups of organisms and countries.

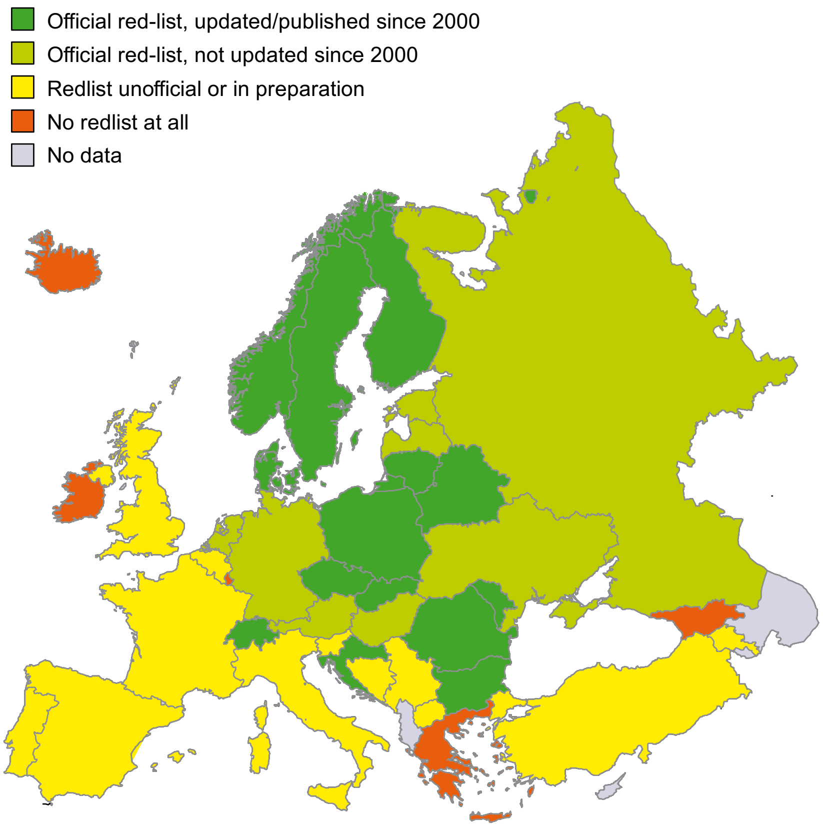



***Figure 6.*** *Red-lists of macrofungi in Europe and their status.*

## 4.2 National fungal Red-lists in 31 countries

Official national fungal Red-List exists in 21 countries and unofficially in 10 countries (Fig 6, Table 3 and 4). The fungal Red-Lists generally have an official status in Central, Eastern and Northern Europe, while they generally are unofficial (or lacking) in most South and West-European Countries. Outside Europe only Japan has produced a fungal Red-List to date. The number of evaluated species and their proportion of the total number of macrofungi present vary significantly between countries. In some countries the aim has been to evaluate as many of the macrofungi as possible (i.e. Denmark, Finland, France, Norway, Sweden, Switzerland) but in the majority the evaluation has been based on a pre-selection of species considered as likely to be threatened. The number of species classified as red-listed varies from 9 (Moldova) to 1400 (Germany). In total, about 5500 fungal taxa are red-listed in at least one country (the compiled total list of all national fungal Red-lists is expected to be posted on the ECCF's homepage before the end of 2007).

| Year | Official National red-lists | Unofficial or preliminary red-lists |
|---|---|---|
| 2007 | *Denmark (3rd, revision not completed)<br>Lithuania (3rd revision)<br>*Switzerland (2nd) | |
| 2006 | *Bulgaria (2nd)<br>*Czech Republic (1st)<br>*Finland (3rd, revision planned 2010)<br>*Norway (2nd revision planned 2010) | Armenia<br>France<br>Montenegro<br>*Spain<br>*UK |
| 2005 | *Croatia (1st)<br>*Romania (1st)<br>*Sweden (4rd, revision planned 2010) | |
| 2004 | *Poland (3rd)<br>*Turkey (1st) | Slovenia |
| 2001 | *Slovakia (3rd) | |
| 2000 | | Belgium (only Flanders) |
| 1999 | Austria (2nd)<br>Estonia (1st, revision planned for 2007-8) | Hungary (1st)<br>Macedonia (official list planned for 2008) |
| 1998 | | Serbia |
| 1996 | Latvia (1st)<br>The Netherlands (2nd, revision planned for 2008)<br>Ukraine (1st, revision planned 2008) | |
| 1992 | Germany (2nd, revision planned for 2008) | |
| 1989 | Malta (1st) | |
| 1988 | Russia (1st) | |

***Table 4.*** *A compilation of fungal Red Lists in Europe and year of the most recent lists. List using IUCN 2001 criteria are indicated by *.*

Early statistics show that roughly 1/3 of the nationally red-listed macrofungi are ectomycorrhizal, 1/3 saprotrophic soil fungi and 1/3 wood-inhabiting fungi (Arnolds & Vries, 1993, based on 11 Red-Lists and 2984 species). This compilation also showed that 74% of the species are mainly found in forests and 9% in grasslands. No more recent compilation exists. In a few countries red-listing of fungi has been carried out and results published together with Red-Lists of all other groups of organisms.

### 4.3 European fungal Red-list lacking

National red-lists are very useful tools for national conservation initiatives and have clearly improved understanding of the status of fungi in Europe. However, they are less useful for conservation initiatives at a European level or for making national priorities based on a larger geographical scale than the individual nation. Red-listed species in a particular country may be at their limit of distribution or for other reasons be more common and not threatened in other parts of Europe. On the other hand, species which are still common and not considered threatened in one part of Europe, may be seriously declining in other parts of Europe. A European Red List is thus necessary to identify which fungal species are threatened at the European scale and thereby to facilitate appropriate conservation priorities at national levels.

A first provisional list comprising species included in more than three national fungal Red-Lists in Europe was made in 1993 (Ing 1993). The compilation and assessment was made by one person and resulted in 278 species of which

- 16 species were assessed to have suffered widespread losses, rapidly declining populations and many national extinctions, and for which a high level of concern expressed.
- 66 species were assessed to have suffered widespread losses, evidence of steadily decline, some national extinctions, and a medium-level of concern
- 114 were assessed to have widespread, but scattered populations, fewer extinctions and a lower level of concern,
- 51 species were assessed as having local losses and some extinction, but mainly at the edge of their geographical range.

Recently the ECCF has initiated a thorough process of red-list evaluation for macrofungi in Europe following IUCN criteria (Tab 5). The project is currently voluntary and unfunded. It aims to produce this evaluation by 2010 and the intention is that the outcome should be similar to the recently published European Mammal Assessment[7] (i.e. the evaluation www available, with illustrated information of status and biology, treatments and management guidelines). A European workshop towards a European Red List was held in 2005 supported by Spain (Andalucía). As a first step all national Red-lists were been put together in spring 2007, resulting in a gross list including about 5500 fungal taxa. The taxonomy and synomyny has since been gone checked, and with the help of mycological specialists throughout Europe all species not obviously threatened at the European level have been removed. The resulting draft list of about 2200 species, which needs closer evaluation is expected to be ready in October 2007. Simultaneously guidelines for fungal Red-listing are being developed to enhance the forthcoming European and also national Red-list processes.

| **Outline for the production ofa Red List of European macrofungi** | | |
|---|---|---|
| **Year** | **Task** | **Progress** |
| **2007** | 1. Project targets identified and organisation outlined<br>2. Compilation of all national European fungal red-lists (about 5 500 species)<br>3. Quick evaluation of which species are likely to be red-listed at the European scale (potentially about 2200 species)<br>4. Fund-raising, about 1 million euro needed<br>5. Fungal red-listing guidelines | Done<br>Done<br>Done<br><br>In progress<br>In progress |
| **Further process provided funding is guaranteed** | | |
| **2008** | Three employed coordinators 2008-2010 will compile the current national knowledge of evaluated species and quantify the area and quality of important habitats at a European scale. To be conducted via questionnaires to all countries combined with open and interactive internet consultation. | |
| **2009** | Red-listing workshops with an evaluation committee of experts and national representatives<br>Internet-discussion of outcome | |
| **2010** | Publication of European Red List as a book and on-line | |

***Table 5.*** *Outline for a European Red List of macrofungi.*

### 4.4 Pleurotus nebrodensis – on IUCN's global Red List

As the compiled knowledge of the state of macrofungi in Europe or on Earth is in its infancy, only one fungus is so far on the IUCN's global Red List, *Pleurotus nebrodensis s.str.,* included in 2006[8]. This mushroom only occurs in northern Sicily, growing in scattered localities in the Madonie Mountains at 1,200 to 2,000m altitude. It is a saprotroph which occurs on limestone pastures containing *Cachrys ferulacea*, a member of the Apiaceae. It is listed as critical endangered (CR) as the area where it is found

[7] http://ec.europa.eu/environment/nature/conservation/species/ema/index.htm

[8] Venturella, G. 2006. *Pleurotus nebrodensis*. In: IUCN 2006. 2006 IUCN Red List of Threatened Species. www.iucnredlist.org.

is less than 100 $km^2$, the population is severely fragmented, and there is a decline in the number of localities and mature individuals. It is estimated that less than 250 individual mycelia reach maturity and produce sporocarps each year. The mushroom is considered the most delicious Sicilian mushroom and the population is in decline due to an increasing number of mushroom gatherers, both professional and amateur, encouraged by the high price 50-70 Euros per kg. Local regulations and a regional legislation prohibiting collections are being prepared. Studies have revealed how the fungus can be cultivated and sporocarps are now being cultivated *ex*-situ locally.

# 5. THREATS TO MACROFUNGI

Intensification and change in land-use, particularly in forestry and agriculture, is the major cause of change and decline of macrofungal diversity in Europe, particularly since 1950 and most severely in southern and western Europe. Together with enlargement of urban settlements, infrastructure and tourist fascilities this has resulted in the decline and loss of previously more widespread and common habitat qualities and subsequent changes in species composition.

The main specific threats identified for macrofungi in Europe are:

- decline and shortage of old-growth forests
- decline in the availability of coarse dead wood
- decline in the number of veteran trees
- impoverishment and decline of old semi-natural and unfertilized grasslands due to fertilization, reforestation and lack of grazing.
- high anthropogenic nitrogen deposition in naturally nutrient poor soils
- increasing habitat fragmentation

In several European countries (e.g. Italy, Austria, Germany, Switzerland) gathering of edible fungi for commercial or recreational purposes has led to a widespread concern about over-harvesting and possible damage to fungal resources. Several countries or regions have introduced legal restrictions on the harvesting of edible fungi. In recent years export of forest fungi from Eastern Europe has emerged as an important income source and worries about the consequences have therefore awareness about their need for conservation in these countries.

Results of a 29 year study in Switzerland (Egli et al, 2005), however, together with earlier studies in the Netherlands (7 yrs), USA (5 yrs) and Poland have clearly shown that there is no detectable reduction in yield of fruit bodies nor of species richness of forest fungi as a result of long-term and systematic harvesting. Harvesting of edible sporocarps may, however, have other negative side-effects; intense trampling and raking of soil litter (for example during harvesting of truffles and matsutake) may destroy and hamper mycelial development of some fungi, and may locally be fatal for them. Long-term effects of lowered spore availability due to harvesting of immature sporocarps may be a problem for species with very small populations, as reported for the globally red-listed *Pleurotus nebrodensis* (4.4).

## 5.1 Land use changes

### *5.1.1 Forests*

Forest ecosystems are the most species rich habitats for macrofungi. The long period of evolution of macrofungi in forests - tens of millions of years - has resulted in a large number of specialized fungi on specific tree species or in certain habitat conditions e.g. particular stages in decay of wood or forest succession. Human influence on European forests over thousands of years has in some parts been very significant, e.g. in respect of grazing, fire and silviculture to produce wood for building and fuel. This has been most intense and for the longest period of time in southern Europe, but is also radical in central, western and northern Europe. However, large scale, new and efficient practices in timber production during the 20th century have dramatically changed conditions in forests throughout Europe. The major changes in most boreal and nemoral forests are an almost total loss of coarse dead wood, and a strong decline in veteran trees and old-growth forests conditions outside protected areas.

**Dead wood**

Coarse dead wood is one of the most important factors for biodiversity in forests. Wood-decaying fungi are key players; they are responsible for the primary decomposition and hence govern subsequent food-webs and play important roles in nutrient cycles. They are necessary from the initial stages of wood decay to the complete disintegration of wood residues and it is estimated that about 50% of forest macrofungi are wood-decomposing. Different types of dead wood, e.g. roots, branches and logs, and their stage of decomposition provide a wide range of niches and hence permit a high diversity of wood-inhabiting fungi.

The abundance and quality of dead wood habitats has changed considerably during the last 100 years in Europe (Jonsson et al, 2005; Heilmann-Clausen & Boddy, 2007). Amounts of coarse dead wood have declined by more than 90% compared to levels in pre-industrial forests, although the actual extent and timing vary between forest regions in Europe. Furthermore, remaining habitats rich in dead wood have become rare and fragmented. Management has increased distances between individual coarse dead wood units within forest stands and at the regional scale surviving areas rich in dead wood typically occur as isolated islands in a matrix of managed forests, farmlands and build up areas. High amounts of coarse dead wood are now only found in protected areas or as yet unmanaged forests.

The decline in amounts of coarse dead wood has resulted in a reduction in population size of many wood-inhabiting fungi. This has been most dramatic for species with a natural low population density (e.g. *Hericium erinaceum*). The change in availability of certain types of dead wood has resulted in a decline in specialist species adapted to them. Conversely, species with broad ecological amplitudes and species adapted to less diminished or even increasing habitats (cut wood, small diameter wood, logging slash, stumps, coniferous wood) have not declined and some may even be increasing.

These trends are reflected in red-lists from several European countries and broadly show that Red-listed wood-inhabiting fungi tend to occur on large diameter decaying trunks or veteran trees.

**Old forest and veteran trees**

Research, red-lists and field-observations have revealed that numerous forest soil-dwelling fungi, whether saprotrophic or ectomycorrhizal, are mainly confined to old growth conditions. The decline of these fungi seems to be because they depend on specific environmental qualities and have infrequent dispersal and establishments strategies. The mycelia of these fungi are long-lived, potentially immortal, and the same mycelial individual may be present on the same spot for a very long time (several decades to several centuries) if conditions are stable. Modern forest management thus favours species that are adapted to disturbance, rather than old-growth conditions. Necessary actions to secure fungal species confined to old-growth conditions are 1) to set aside an appropriate number of protected areas of different forest types and 2) to ensure that ordinary forest management takes nature conservation into consideration, e.g. according to guidelines from Forest Stewardship Council, FSC like leaving veteran trees on clear-cuts which may facilitate ectomycorrhizal mycelium to survive on to the new generation forest.

**Tree species composition**

Many wood-inhabiting fungi are host specific or strongly selective, and regional fungal biodiversity is accordingly dependent on the tree species composition present. Substitution of broadleaf trees (mainly beech and oak) by monocultures of spruce (*Picea abies, P. sitchensis*) and Douglas fir (*Pseudotsuga*) in central and northwest Europe is seen as a key factor in the decline of many host dependent species of beech and oak. Plantations of *Eucalyptus* and *Populus* in southern Europe and also *Robinia* in southeast Europe is causing a major shift in the composition of wood-inhabiting fungi.

Another factor is forest grazing, which has been practised in most European countries for millennia, and may have continuity back to prehistoric times when megaherbivores roamed widely throughout the continent. In countries around the Baltic Sea, wooded meadows have been identified as particularly species rich habitats for fungi, often species considered as threatened due to the strong decrease in forest grazing during the last centaury. In other parts of Europe the impact of forest grazing on fungal diversity is little understood, but at least in the natural fir (*Abies alba*) zone in Central Europe an increase in grazing pressure from wild deer is recognized as problematic because it is tending to hinder regeneration of *Abies* to the benefit of beech and spruce.

*5.1.2 Farmlands*

The intensification of agriculture practices throughout Europe has had large consequences for the diversity of plants, animals (e.g. farmland bird species) and fungi, particularly those species mainly confined to semi-natural habitats. The loss of nutrient-poor grassland due to fertilizer additions (including anthropogenic atmospheric deposition of nitrogen), conversion to arable crops and decreasing animal husbandry leading to forest re-growth, has been particularly serious for grassland fungi.

**Grasslands**

Most grasslands can be considered semi-natural because they depend on management to prevent them developing into scrub or forest. Without the use of artificial fertilizers, most dry grasslands are nutrient poor, because nutrients (phosphorus and nitrogen) are removed by the grazing animals. Grasslands may have a continuity of hundreds or even thousands of years. The history of grasslands in Europe, before animal husbandry began has been much discussed, but there is little doubt that the habitat types reached a maximum in the pre-industrialised farming era, - from the 15$^{th}$ through to the beginning of the 20$^{th}$ century. Since then the area of semi-natural grasslands has decreased dramatically, in many countries by more than 90%. This is partly due to intensification of management (i.e. use of fertilizers) or extensivation (forest planting or regrowth). Significant grassland areas are still present in e.g. Iceland, The Faeroe Islands, UK, Romania and Norway. Nutrient-poor grasslands have a characteristic set of gill fungi, mainly waxcaps, *Hygrocybe* spp., pinkgills, *Entoloma* spp., club and coral fungi and the Clavariaceae.

*5.1.3 Alpine areas*

Alpine areas are less affected by an area-wide human influence than lower regions due to their complex topography. Yet many areas have become more accessible (e.g. opened up through aerial passenger lines) and suffered from the destruction of fragile habitats such as moraine vegetation for ski runs and other recreational infrastructures. As habitats interesting for macrofungi are of very limited area in the alpine zone (snow-beds, moraines and plain rivulets with dwarf willow fungal hosts) the destruction of such habitats has a large impact per unit area. In Switzerland, 6% of all Red-listed macrofungi are confined to alpine areas. Climate change will also gradually affect the extent of the alpine habitat and hence of alpine macrofungi.

*5.1.4 Dunes*

Sandy dune areas, with the typical grassy and shrubby successional stages from bare sand to forest, bear very specialized macrofungi (e.g. *Agaricus devoniensis Gyrophragmium dunalii, Conocybe dunensis, Pleurotus eryngii, Peziza ammophila*). These species are declining and severely threatened in southern Europe through recreational (tourist) use and constructions. Remaining undisturbed dunes need site protection as nature reserves.

*5.1.5 Wetlands*

Most macrofungi are associated with dry or mesic soils, and drainage and lowered water tables have generally been more critical for other groups of organisms than macrofungi. Several types of swamp forest and moors, however, provide important habitat for specific macrofungal communities which have declined in many regions. Alder swamp forests host highly specialized communities of both ectomycorrhizal and saprotrophic fungi (over 100 species). Mixed riverine forests and oligotrophic moors are also important for their specialized fungal communities. The impact of drainage has been strongest in highly populated and intensively managed landscapes. As an example, a case study in four Danish forest districts showed that more than 80 % of all forest wetlands had disappeared since 1857. In the boreal zone, the historical decrease in wetlands has been less dramatic, but is now increasing in many intensively utilized regions.

Moors and bogs with moss carpets of Sphagnum are also characterized by very specific macrofungi (e.g. *Armillaria ectypa, Galerina paludosa, Psathyrella sphagnicola, Omphalina sphagnicola*). Peat extraction in northwest Europe and Russia has led to significant- often still ongoing - loss of peatlands. Consequently European populations of rarer peatland fungi have become small. In addition, anthropogenic nitrogen deposition has recently been recognized as a threat for nutrient poor peat-lands. In Germany over 50 macrofungal species of peatlands are red-listed.

*5.1.6 Urban areas and roads*

The extent of urban areas is increasing throughout Europe destroying forests and farmland. Yet, urban areas with parks and verges along roads offer new habitats especially for isolated trees, which may stand there during their natural life time. Such old trees may be surrogates for the missing old trees in managed forests. Dangers for such old trees are often security regulations for dead wood. Slightly damaged old trees are removed, often exactly the trees with interesting rare and Red-listed fungi.

## 5.2 Air-pollution, eutrophication

*Nitrogen*

The natural shortage of nitrogen in most terrestrial systems has influenced evolution of fungal species and species compositions in fungal communities for millions of years. The natural annual influx of nitrogen, caused by bacterial nitrogen fixation and lightening discharges is typically in the range of a few kilos of nitrogen per hectare, except in locations with nitrogen fixing plants, i.e.. *Alnus* spp, where the annual influx may exceed 100 kg nitrogen/ha. The most densely populated areas in Europe currently receive 50-100 kg/ha and year of nitrogen deposits from man-made sources. This gradual and continuous eutrophication is causing changes in the species composition of fungi. Particularly well documented are major changes of ectomycorrhizal fungi in forests in central Europe and the decline of grassland fungi (Arnolds, 1991; Jordal, 1997). Recent efforts, especially in manure application techniques have started to reduce nitrogen deposition. The perspectives for fungi may therefore be becoming slightly better. In the Netherlands, for example, chanterelle (*Cantharellus cibarius*) was almost unrecorded for many years, but has reappeared and recovered in recent years.

*Sulphur*

For several years sulphur dioxide was recognized as a threat to forest communities, particularly to trees, but also to soil-dwelling fungi. Severe damage to ectomycorrhizal fungal communities was reported in central Europe (e.g. from the Czech Republic, Fellner 1988). Sulphur emissions have, however, decreased by almost 70% since 1980 in Europe and acid deposition is no longer considered a serious threat to biodiversity.

## 5.3 Climate change

All organisms are, to a greater or lesser extent, interdependent on other organisms for their existence. In some cases, for example, a fungus will only be found is a particular plant is present; in other cases, however, the plant may be unable to grow without a particular fungus. Ecosystems may therefore be expected to change according to the sensitivities of their critical species, and it is not prudent to assume that the only critical organisms sensitive to climate change are animals and plants.

The relative frequency of species within habitats may change in response to changing climate. To date there is little concrete information for the fungi. Recent observations from Britain indicate, however, that the fruiting period of macrofungi has already been affected, starting earlier in the season and lasting longer into late autumn due to climate change over the last 30 years (Gange et al. 2007; see also Kreisel H. 2006).

Another possible consequence may be that introduced invasive species or species on the border of their distribution, may be favoured, and it will be a challenge in future to distinguish between alien species which are invasive, and endangered species colonizing new areas as, so to speak, refugees.

## 6. CONSERVATION AND MANAGEMENT OF MACROFUNGI IN EUROPE TODAY

Even though Red Lists for macrofungi exist for most European countries, an obvious message from the questionnaire among mycologists in Europe is that macrofungi only rarely seem to be considered in national nature conservation policies and activities, with a few exceptions, e.g. Andalucia in Spain, Finland, the Netherlands, Norway, Sweden, Switzerland and UK (Tab 3, Fig 8). The main reasons are probably a combination of lack of awareness, lack of political pressure and lack of appropriate information which can be included into general biodiversity measures.

Since species are the main units to be dealt with, conservation depends on good taxonomic knowledge. As species richness is large and numbers of mycological taxonomists low, knowledge of European fungi is significantly less than for plants and vertebrates. Nevertheless some knowledge of macrofungi exists throughout Europe. Major checklists published (e.g. Italy 2005; Turkey, 2007; United Kingdom 2005) or under compilation are major contributions to knowledge of the European mycota and its conservation. In addition concise information about the autecology and habitat requirements together with distribution patterns is increasingly available. This information is critically important for analyses of the conservation status of fungal species and prediction of future population sizes.

### 6.1 Species approaches

*6.1.1 Protected species*

Fourteen countries have fungi protected by law; from 4 species (UK) to 314 species (Croatia) (Fig 7). The extent of protection varies between countries. Commonly picking, selling or destroying protected species is prohibited. In some countries even mycelia and habitats are protected, which at least in theory could have serious implications for land management. In some countries (e.g. Switzerland) regional authorities are bound to enlarge the list with regionally or locally threatened species.

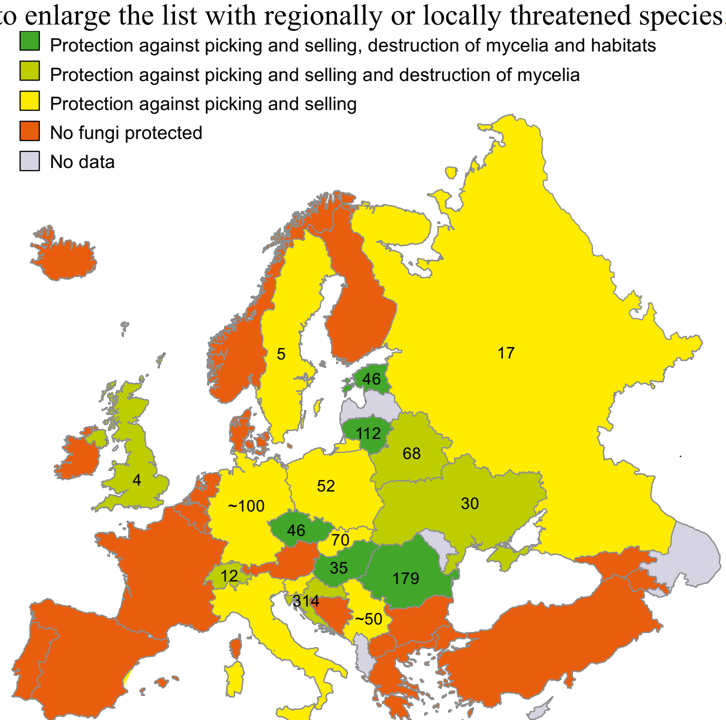



***Figure 7.*** *The number of protected macrofungal species and the level of protection.*

*6.1.2 Action programmes*

Action programmes are an instrument to improve the conservation status of particular species by conservation action through so-called "action plans" (Tab 6). Action plans for selected threatened fungi have been drawn up in six European countries (Czech Republic, Estonia, Finland, Poland, Sweden, UK).

In Sweden national action programmes for 27 non-lichenised fungal species are in force[9] Species have been selected where

a) General nature conservation actions are not sufficient to enhance the conditions,

b) A significant share of the European population occurs in Sweden, and finally

c) They are Red-listed in Sweden and therefore regarded as threatened.

Similarly, the United Kingdom has produced Biodiversity Action Plans for 50 fungal species to conserve endangered species[10]. In Finland action plans are under way for 10-15 species, including mapping, monitoring, detailed information sheets and elaborated concepts of how to subsidise landowners for specific management actions. Estonia has action plans for 19 species, mainly involving monitoring at 56 sites. In Switzerland action programmes are planned for 150 red-listed species with high conservation priority.

| **Conservation tool** | **target group** |
|---|---|
| Increase amount of coarse dead wood left for decay | Wood inhabiting fungi |
| Retention trees in managed forests - trees or tree groups let to grow to maximum age and subsequent decay in the forest | Wood inhabiting fungi and ectomycorrhizal fungi |
| Continued grazing and absence of fertilization in old grass lands | Grassland fungi |
| Reduced nitrogen emission especially in areas with predominantly nutrient poor soils | Grassland and ectomycorrhizal fungi associated with naturally nitrogen poor soils |
| Protection of fungal key habitats | All groups of fungi |
| Species action plans | All groups of fungi |

***Table 6****. General recommendations for management of fungal biodiversity in Europe.*

*6.1.3 Fact sheets of Red-listed species*

In Sweden, fact-sheets for all red-listed fungal species are available with information on taxonomy, morphology, distribution, status, ecology, threat, management guidelines, references to appropriate literature and pictures published on the internet[11]. In Switzerland fact-sheets are being produced for 150 red-listed species with high conservation priority, i.e. species whose populations in Switzerland are considered to be internationally important and for species where conservation actions are feasible and widely accepted (e.g. no pathogenic fungi included). Fact sheets for Red-listed fungi in Norway are presently being produced. The Red Data book of Lithuania includes information on status, distribution, biology and ecology, population size, threats and protection, distribution maps, illustrations of each fungal species.

*6.1.4 Monitoring*

Species monitoring is important to enable trends in population sizes to be ascertained. National programmes are in force for several groups of organisms in many countries i.e. birds, plants, butterflies, snails. Bird monitoring is coordinated at the European level. At least 7 European countries have monitoring programmes for fungi: Armenia (since 2004), Belgium, Czech Republic, Estonia (since 2005), Finland, Hungary (since 2000) and the Netherlands (since 1998). The monitoring programme in the Netherlands has two employed co-ordinators and engages about 350 volunteers involved annually surveying 600 plots). An additional four countries have programmes in preparation.

[9] www.naturvardsverket.se, in Swedish.
[10] www.ukbap.org.uk
[11] www.artdata.slu.se; in Swedish

*6.1.5 Bern convention*

At the European level a proposal was made to include 33 threatened fungi in the appendix of the Bern Convention. The representatives of the Bern Convention recognized the pressing case presented in this proposal, but failed to act on it when it was submitted in 2003. The document for this discussion (Dahlberg & Croneberg 2003[12]) was based on close collaboration between expert mycologists throughout Europe to collect information within a short period of time.

## 6.2 Habitat approaches

*6.2.1 Fungi as indicators of valuable habitats*

There is a long tradition in northern Europe of using selected species of fungi (whether lichenized or not), insects, mosses and other plants as indicators of habitat quality, especially in grasslands and old growth forests rich in dead wood (Heilmann-Clausen & Vesterholt 2007). Suggested indicator schemes for grassland macrofungi have been very important in fuelling a broad interest in this group in several countries. However, they remain largely untested scientifically, and have had limited impact on actual conservation priorities. Attempts to test the relevance of indicator schemes based on wood decay macrofungi in relation to declared or embedded indicator goals (i.e. local forest continuity and/or diversity in other organisms groups) are more numerous, but have yielded inconsistent results. Recent research, however, has moved the focus from local scale processes and has shown macrofungi to be very suitable indicators of dead wood continuity and naturalness. This is especially true at the landscape scale, and indicator species are used as one of several tools in the selection of forest reserves and/or woodland key habitats in several countries (Bulgaria, Czech Republic, Denmark, Estonia, Lithuania, Finland, Norway and Sweden). In Denmark, Finland and Sweden wood-inhabiting macrofungi have been included in the Natura2000 programme for forests, for the assessment of favourable conservation status.

The occurrence of threatened macrofungi and indicator macrofungi are one of several criteria (habitat structure, stand history, occurrence of other indicator species such as lichenized fungi, insects, mosses and vascular plants) used to identify Woodland Key Habitats (Nitare, 2005; [13]). WKH methods are used in Estonia, Finland, Lithuania, Norway, Sweden and will soon also be used in Russia.

*6.2.2 Important fungus areas*

Important Plant Areas (IPA), an initiative from Planta Europa (see www.plantlife.org.) has also been modified and applied in a few countries for fungi. By the 1990s a detailed compilation of the 200 most important areas for fungi in the Netherlands was already published. Furthermore the British Mycological Society (BMS) has published a provisional assessment of the 520 most important areas for fungal biodiversity in the United Kingdom[14]. BMS has also produced reports such as "Waxcap-grasslands – an assessment of English sites"[15] and "Mycologically important semi-natural grasslands of Wales". In central and eastern Europe 20 IPAs contain fungi (Anderson et al. 2005).

At the Planta Europa conference 2003 Estonia, Finland and Italy attempted to introduce fungi into nature conservation by proposing Important Plant Areas from a mycological point of view. Common to the three countries is the aim to be part of a network by co-operating with environmental authorities and botanists to strengthen mycological knowledge in the decision making at different levels. Italy has developed an approach in their selections of IPAs that also considers the national distribution of bryophytes, freshwater algae, fungi (whether lichenized or not) and vascular plants in a multi-taxa landscape approach. .

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[12] The report can be downloaded from http://www.artdata.slu.se/Bern_Fungi/Bern_Fungi.htm

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*6.2.3 Management guidelines*

Conservation practice is often confronted with the need for detailed instructions for the management of a specific site or for specific organisms. In comparison with other groups of organisms, especially birds or orchids, much less knowledge is available for fungi, even for macrofungi. Conservation recommendations for macrofungi are often site protection, but can be more specific for certain groups of macrofungi, e.g. wood-inhabiting and grassland fungi, and can be specifically directed to secure appropriate habitat conditions, e.g. availability of coarse dead wood, availability of adequate mycorrhizal host trees, and care when nutrients are applied. Old growth forest conditions that favour many threatened forest fungal species, can be partly realized by forest management aiming at a multilayered forest structure, diverse in respect to native host trees, leaving retention trees, allowing influx of coarse dead wood, limiting forest floor disturbance and avoiding clearcutting.

An interesting start for clear and specific instructions comes from the Netherlands. Common activities in land-management, gardening and urban planning are critically assessed and classified as favourable or unfavourable with regards to specific fungal needs (Keizer 2003). Disturbance by civil engineering, parking, trampling, and disposal of organic material is seen in general, as unfavourable, whereas removal of autumnal leaf litter and hay in urban areas, extensive grazing, confining exotic plants and especially a continuity of constant management and cultivation methods over many years may favour certain macrofungi.

Management guidelines are also useful in urban areas. In parks and roadside verges the presence of large size logs and trunks will favour rare and interesting decomposers and an avoidance strategy for the accumulation of leaves, dead branches, and remains of pruning or wood chips will favour ectomycorrhizal fungi. Special care should be given to host trees known to harbour many ectomycorrhizal species such as oak and beech, whereas exotic host species should be avoided.

*6.2.4 Protected areas*

The selection and evaluation of protected areas (i.e. national parks, regional parks, biosphere regions, and nature reserves) rarely seems to consider fungal biodiversity (Fig 8). Only in recent years has this consideration started to take place in some countries, mainly in Fennoscandia.

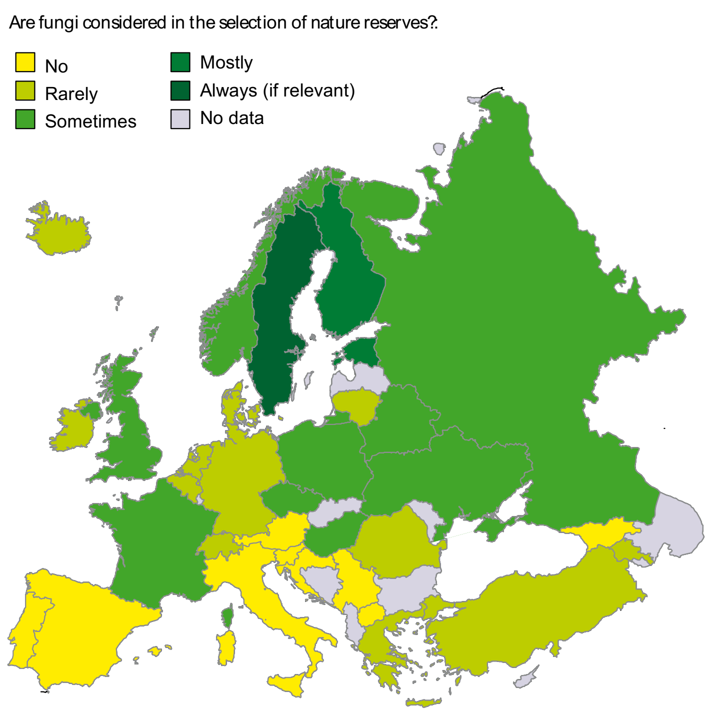


***Figure 8 .*** *The frequency with which fungi are taken into account in the selection of nature areas/protected areas.*

A few examples exist where areas have been set aside predominantly or exclusively because of their mycological values (*Belgium*, at least one grassland site (4.5 ha); *Estonia*, fungal species protection sites for protected species exists since 2007; *Germany,* at least two sites (total areas app. 5 ha); *Romania,* 1 site; *Switzerland,* 6 sites; *UK.* 4 sites of special scientific interest because of rare grassland fungi and 6 old pine sites in Scotland.

*6.2.5 The Habitat Directive*

The Natura2000 conservation programme of the European Union based on the Habitat Directive is highly successful for animals and plants. Natura2000 does not officially include fungi as it mainly is based on habitats of invertebrates, mosses, vertebrates and vascular plants included in the Bern Convention. Nevertheless national implementation of the programme has included fungi in at least three countries. In Denmark 13 wood-inhabiting species are monitored in sample plots in forests. In Sweden 63 macrofungi species are selected as typical species for 8 different forest types. In Croatia 52 important localities for fungi have been selected within the Natura 2000 programme.

# 7. KEY OBJECTIVES AND ACTIONS FOR THE CONSERVATION OF EUROPEAN FUNGAL DIVERSITY

To align fungal conservation with other species groups and allow comparison between continents, key targets and actions of these guidelines have been made compatible with the objectives of the Global Strategy for Plant Conservation (GSPC)[16]. The plant strategy, endorsed by the Convention on Biological Diversity (CBD), is an obvious sister strategy because of the close inter-relationship between fungal and plant diversity.

## 7.1 Understanding and documenting European fungal biodiversity

**GSPC related targets:**

- Developing a working list of European species
- Production of a European Red List of threatened fungi, starting with macrofungi
- Providing methods for fungal conservation based on best practice

The publication of check-lists and an increasing number of mapping projects shows that information about fungi as a basis for conservation action is improving in many European countries (Tab 3, Figs 1 and 3). However, for many fungi, including many red-listed species, the exact ecology and habitat requirements are still not well understood. This lack of understanding is a serious constraint for effective fungal conservation and highlights the current alarming lack of professional mycologists in Europe.

A combination of species and habitat data enables analysis of the most critical threats to biodiversity. If several species groups are included in one analysis, it is possible for each group to identify particular threats that requiring special emphasis. Although other approaches are possible, Red-listing is an important tool to guide this analysis and enables identification of habitat deficiencies. This approach requires that all Red-listed species are classified by habitat requirements and other relevant factors (e.g. life forms, population dynamics, threats, and distributions) and that this knowledge is paired with data on the extent and quality of relevant habitat types. With a joint analysis, the relative importance of different habitat parameters can be identified, and actions to reduce threats and enhance diversity to be coordinated more cost-effectively. So far, no country has made a serious multi-taxa analysis of habitat deficiency based on Red Lists, As a consequence, conservation actions are generally based on fragmentary knowledge, typically restricted to either one organism group, or to habitats but without clear understanding of the species interactions within the habitat.

[16] GSPC objectives and targets have been rewritten in a European context and only targets that are currently thought to be realistic and benefit fungi at a European scale are included. See www.cbd.int/programmes/cross-cutting/plant/default.asp, see also the European Strategy for Plant Conservation www.plantaeuropa.org/

A European Red-List of macrofungi will be of great importance to provide information on the status of macrofungi at the European scale. This will enable actions to be directed to the most threatened macrofungal species and habitats. The European Red-List process has the potential to function as a very important framework, greatly enhancing the quality of fungal conservation in Europe and also on other continents. It will increase the ability of countries to prioritise action on species of national responsibility and act as a powerful tool to increase the profile of fungi as a group deserving conservation action. At the international level, it will be useful to assess whether current priorities and reserve networks are adequate for macrofungi and will help to locate regions and reserves where it is especially important to consider fungi in conservation planning.

ECCF is about to create a Red-listing committee with competencies covering different fungal taxonomic groups and different European regions. Providing funding is secured, two full-time employed staff will co-ordinate the subsequent analyses with input from national mycologists. and staff will also facilitate the Red-Listing assessment. It will be an open process, where it will be possible for participators to comment on and complement the evaluation as it proceeds. The assessment will involve a semi-quantitative classification of important factors for all red-listed species.

**Actions:**

- Improve autecological knowledge and publish methods for fungal conservation
- Secure funding for and produce a European red-list assessment of macrofungi
- Co-ordinate the red-listing of different species groups and analyse habitat deficiencies in order to identify and rank threats to national biodiversity.
- Ensure that a highly competent mycologist is involved with the red-list assessments of macrofungi according to current IUCN criteria.
- Ensure sufficient funding and organization for red-list assessments to take place at regular intervals, every 5-10 years
- Develop a working list of European species

## 7.2 Conserving European fungal biodiversity

**GSPC related targets:**

- Identifying and conserving Important Fungal Areas
- Conserving fungi on land used for agriculture, forestry, recreation and other human activities
- Conserving threatened fungal taxa

**Knowledge of available habitats for fungi:** Knowledge of the extent and quality of many terrestrial habitat types important for macrofungi is improving in major parts of Europe. This is partly thanks to the Natura2000 programme and various national mapping and monitoring initiatives. Such knowledge is important in order to understand threats to fungi with specialist habitat requirements, and to predict future trends in populations. To be relevant for fungal conservation habitat information must be analysed with fungi in mind, and if necessary to be supplemented by recording of specialised habitats that are especially important for fungi, e.g. quantity and quality of dead wood, number of veteran trees, quality and extent of coastal forests and scrubs. In most countries this level of habitat information is not yet available, a failing that is exacerbated by the lack of trained mycologists working in national conservation agencies.

**Actions:**

- Identify Important Fungal Areas (IFAs) and key habitats across Europe
- Develop management plans to ensure protection of IFAs
- Ensure coordination between IFA and Important Plant Area management

- Promote continued grazing and absence of fertilization and tillage in old grasslands
- Reduced nitrogen emissions, especially in areas with predominantly nutrient poor soils
- Promote retention trees in managed forests
- Increase amount of coarse deadwood left to decay
- Ensure funding for mapping and monitoring of IFAs and other important fungal habitats for their quality, conservation status and trends.
- Analyse the Red List and consider appropriate mechanisms to alleviate the threats, this is likely to include a mix of policy measures, protected areas, habitat action and some species-specific actions.

## 7.3 Using European fungal diversity sustainably

**GSPC related targets:**

- Protecting fungi from over-exploitation
- Providing guidelines to enable sustainable livelihoods dependent on fungal resources

There is currently no evidence that harvesting macrofungi has a negative impact on sporocarp production or fungal species diversity. Exploitation may even promote awareness of the cultural and economic value of fungi, which in turn should encourage protection of a valuable resource. However, secondary impacts of harvesting, on both fungi and other species groups, should be considered and guidelines for harvesting developed.

**Actions**:

- Monitor the future impact of harvesting on macrofungi communities
- Develop harvest guidelines to protect macrofungi and associated organisms

## 7.4 Promoting education and awareness about European fungal diversity

**GSPC related targets:**

- The importance of fungal diversity, and the need for its conservation, incorporated into communication, educational and public-awareness programmes

**Public and Political:**

Public and political support for fungal conservation provides the basis for effective fungal conservation. Without this support, there will be little funding or practical habitat management for fungi and conservation will become and abstract paper concept for a small number of fungal experts. Public and political awareness are closely interlinked, with the former acting as a catalyst for the latter.

The education and awareness process is a huge task which requires co-ordination. Leads can include NGOs (e.g. national mycological societies or conservation charities), or government agencies that have a biodiversity remit. Dedicated posts are often required to deliver awareness rising and information services, and these posts require funding.

Awareness raising could include guided walks, interpretative booklets, simple identification guides in local languages and updated floras. In addition, training opportunities should be developed to enable general education providers to introduce fungi to children and adults..

The ultimate aims of fungal education and awareness for the public and politicians should be to:

1. Provide political stimulus for national governments to support fungal conservation activities,
2. Ensure all sectors of society are aware of their impact on fungal diversity and receptive to positive conservation actions,

3. Capture the imagination of, and provide support for, future mycologists

**Land managers:**

It is important that scientific knowledge on biodiversity, and the factors affecting biodiversity, are condensed into practical habitat management guidance for land managers. Although management guidance to maintain and enhance biodiversity exists in many countries, and for many habitat types, fungi are frequently ignored. Thus it is worrying that out of the 34 countries evaluated in this report, 25 (>70% %) indicate that awareness of fungi in conservation management is poor or very poor, and only a few countries have specific guidance initiatives for fungi (Tab 3). Important examples of initiatives that include management guidance are Biodiversity Action Plans (BAPs) for priority species and habitats in the UK and Species Action Plans (SAPs) in Sweden. An approach focusing on important fungal habitats, e.g. dry pine forests or special dead wood habitats, are often of great value. Such an approach is incorporated into some of the Swedish and UK action plans that focus on suites of species associated with certain habitats rather than individual species. This may be a more appropriate way of providing management guidance for very species rich groups such as fungi. Further development of management guidelines to secure fungal biodiversity is needed but will often require research into the population dynamics and ecology of target species. Such research advances the overall understanding of fungal biology but its importance is often underestimated and under resourced. In summary it is an important, national responsibility to:

**Actions:**

- Fund national fungal education and awareness co-ordination posts
- Incorporate fungi into national school education curriculum
- Produce fungal identification guides in local languages
- Organise accessible fungal forays and provide talks in local communities
- Produce practical habitat management guidance and run workshops for land managers
- Promote IFAs and SAPs among all sectors of society
- Support the production of a pan European book/website on the conservation of fungi

## 7.5 Building capacity for European fungal conservation

**GSPC related targets:**

- Ensure that the number of trained mycologists working in fungal conservation is sufficient to implement national fungal conservation strategies
- Networks for fungal conservation activities established or strengthened at national, regional and international levels

**Additional target:**

- Development of national, regional and international fungal conservation strategies to guide the GSPC related targets

Regional, national and European conservation strategies are an important tool to focus efficient fungal conservation efforts. They provide a framework for action and a means of communicating priorities to the general public and politicians. By developing strategies at different geographic scales, actions can be prioritised according to regional requirements and opportunities.

Strategy development also stimulates interaction and co-operation between regional, national and European stakeholders, and helps produce a rational programme for action. Stakeholders may include NGOs (e.g. mycological societies and conservation charities), land managers (e.g. foresters, farmers and local authorities), government agencies and commercial fungal harvesters.

Combining fungal strategies with other species group strategies may help deliver more effective targets and stimulate interaction between a wider range of stakeholders. As an example, Scotland, UK has produced a 'Strategy for the conservation of fungi and lower plants in Scotland', which, in addition to macrofungi, includes actions for algae, bryophytes, ferns and lichen-forming fungi[17].

The key to implementation of these strategies and, in fact, all of the targets recommended in these guidelines, is the training and employment of a sufficient number of expert mycologists. Without experts in fungal taxonomy and ecology and strong networks of interaction between them, the non-professional voluntary sector and land managers, there will be little capacity for fungal conservation across Europe.

**Actions:**

- Develop regional, national and European fungal conservation strategies
- Ensure an appropriate number of professional mycologists working with ecology, population dynamics and taxonomy of fungi in reference collections and universities.
- Ensure that trained mycologists are employed by national conservation agencies
- Support non-professional mycologists who record the distribution of fungi, and secure the necessary level of collaboration with professional mycologists to ensure high data quality
- Produce guidance and run workshops for conservation practitioners
- Increase the number of volunteer recorders for fungi supporting fungal conservation
- Enhance communication and information exchange between scientists and fungal conservationists

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## Appendix 1: Red-List references

All national fungal Red-Lists are compiled and available at the homepage of ECCF, www.eccf/.info.

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