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Conservation of New Zealand and Australian fungi

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Abstract Until recently, fungi have been omitted from conservation initiatives in New Zealand and Australia, despite their importance to biodiversity, to ecosystem functioning, and to humanity. Whole ecosystem conservation has been assumed to encompass fungi along with other biota. In a renewed assessment of threat status by the New Zealand Department of Conservation, 49 species of fungi have been accorded the highest threat category and are considered to be "nationally critical"; several of these are discussed as case studies. In Australia, ten species and one community of fungi are listed under various legislation at the Federal and State level; case studies of six Australian species are presented. A majority of Australasian fungal species are known from very few collections, often restricting conclusions about their conservation status. Proposals towards effective conservation of Australasian fungi are outlined, and priorities presented for allocation of additional resources.

Keywords conservation; endangered; fungi; legislation; IUCN; rare; threatened

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INTRODUCTION

Fungi are globally the second most diverse group of organisms, behind arthropods. They comprise an entire kingdom, *Fungi* or *Eumycota*, with members also in two other kingdoms, *Chromista* and *Protozoa*. Environmentally, they are key agents of decomposition in all terrestrial ecosystems, cause most diseases of plants, and assist nutrient and water uptake of most plants. Their undisputed importance is further indicated by their contribution to human civilisation through food industries (edible mushrooms, bread, cheese, wine, beer, quorn) and medicine (antibiotics, cyclosporine, nutriceuticals), along with a multitude of interactions with animals (such as vegetable caterpillars and food for endangered potoroos) and humans (such as skin ailments and the devastating Irish potato famine).

While the importance of fungi justifies consideration of their conservation, most conservation initiatives overlook them. Conservation decisions at the species level are sometimes driven more by perceived charisma of the organism than from rationale of repercussions to humanity or to the ecosystem of the loss of that species or group. Relative to the number of species, fungi are one of the most neglected groups of the biota as measured by numbers of taxonomists and collections. Recognition of fungi is hindered because they are often small, ephemeral in terms of fruiting structures, difficult to identify, and associated with some "negative" activities such as death and decomposition, poisonings, and disease. This "bad press" has blinded recognition of the potential conservation needs of fungi that arise through such human-mediated activities as habitat destruction, pollution, excessive harvesting (of edible species), and decline of associated organisms. Recent estimates are that 22–47% of plant species globally are threatened with extinction (Pitman & Jørgensen 2002), and this directly affects conservation of plant-associated fungi.

The recent trend to ecosystem and landscape-based conservation over single-species approaches

(Park 2000) has almost certainly helped conserve "non-target" organisms, but its efficacy for fungi cannot be assured without monitoring of populations of indicator species. In addition, fungi are often considered by conservation agencies to be part of the flora, or even as a "kind" of plant, despite their phylogenetic and biological distinctions. This further dilutes perceptions of their diversity and importance. Comprehensive conservation programmes for fauna, flora, and fungi are the challenge.

Reserves designated specifically for fungal conservation are rare internationally. Conservation initiatives in old-growth forests of the American Pacific North-West, associated with preservation of habitat for the northern spotted owl, pioneered federal protection for fungal species in USA (Pilz & Molina 1996; Molina et al. 2001). The same geographic region was suggested as an appropriate location for the "world's first fungal reserve" promoted by Kendrick (2001). In the UK, the only nature reserve designated to protect mycobiota is a 70-m-long "hedgerow-locality" in Suffolk to protect *Battarrea phalloides* (Dicks.) Pers. (Marren 2001; Moore 2001). Fungi may, however, be noted as significant elements of the biota in some other reserves.

IUCN and RED Data lists

Fungal conservation has a collective voice via the Specialist Group for Fungi, part of the Species Survival Commission (SSC) of the International Union for the Conservation of Nature (IUCN). The 18 members of the Specialist Group (Courtecuisse 2001) represent Europe (8 members), North America (4), Central America and northern South America (4), and Australasia (2). This distribution of members is likely to reflect coarsely the status of conservation of fungi worldwide. Asia, Africa, and most of South America are not represented. Another indication of the uneven distribution of awareness and action in fungal conservation is evident from Moore et al.'s (2001) book "Fungal Conservation: Issues and Solutions". None of the 28 contributors to this book was from the Southern Hemisphere, and the only reference to fungal conservation below the Equator is to the Australian fungal mapping scheme Fungimap.

The first national RED (Rarity, Endangerment, and Distribution) Data list for fungi was published in East Germany in 1982. Since then, 22 European countries have prepared one or more RED Data lists, together comprising about 3000 taxa (Arnolds 2001). These lists vary in numbers of taxa, from 17 for the former USSR to 1655 for the Netherlands, and in status, from official government documents to informal papers. Recently, RED Data lists for macrofungi have also been prepared for Idaho, Oregon, and Washington, USA (Molina et al. 2001).

What is a threatened fungus?

The various categories of threat as agreed by IUCN (2001) are defined by a set of five criteria that are applicable across all biota with the notable exception of "micro-organisms" (IUCN 2001, II, Preamble 1). The concept of "mature individuals" is relevant to four of these criteria, but for fungi and certain other groups assessment of individuals is particularly awkward: "Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g., corals)" (IUCN 2001). The apparent difficulty of categorising fungi according to IUCN standard criteria has certainly added to the slow progress globally in fungal conservation.

Effective fungal conservation depends on an extensive knowledge of the mycobiota of a region and, therefore, is most likely to occur where the science of mycology has been historically strong. Even there, however, practitioners may be reluctant to designate the conservation status of a species in case further evidence indicates that it is not threatened. Marren (2001), for example, cited two species, the devil's bolete (*Boletus satanas* Lenz) and the sandy stilt puffball (*Battarrea phalloides*), which had been promoted for conservation in Great Britain but were later found to be relatively widespread. In a pragmatic sense, it is likely that attention to the alleged rarity of these species was a necessary stimulus to renewed interest in these taxa and development of more informed understanding of their distribution and ecology. Arnolds (2001, p. 72) encouraged mycologists to designate conservation status on the basis of available knowledge: "I consider the international trend for scientific perfection in RED Data lists as a risk to progress in compilation of RED Data lists for fungi and therefore for conservation of the mycota". We also advocate a pragmatic approach to assess fungal taxa using a suite of criteria based on all available information. An alternative approach is to hope that fungal conservation will simply be achieved by protection of habitats for other purposes. This hope carries little scientific credibility when faced with statistics of ignorance of over 90% of the expected global biodiversity of fungi, let alone any knowledge of the critical associations of these unknown taxa with particular habitat type or host(s). Determination of threatened fungi and their inclusion on conservation lists is a first step in raising the profile of fungal conservation and stimulating research on these species.

In this paper, lichenised fungi have not been considered because they have been historically treated among the plants in checklists and floras (such as *Flora of Australia* and *Flora of New Zealand*) and in conservation.

The purpose of this paper is to collate literature and current initiatives in fungal conservation in New Zealand and Australia. These countries are considered together because both have a rich fungal biota, with numerous endemic species; there is a similar historical background and current progress in relation to the study of their fungi; and there are parallel approaches to conservation in general, as through the inter-governmental Australia and New Zealand Environment and Conservation Council (ANZECC). Our aim is to stimulate research and policy debates about threatened Australasian fungi and to promote determination of the threat status of fungi. Case studies for New Zealand and Australia are presented, and a broad strategy is outlined that will lead to effective conservation of fungi, taking into account the huge biodiversity and the relative lack of knowledge and resources. A summary of current initiatives will provide a basis for future comparisons as conservation of fungi gains profile and perceived relevance in the Southern Hemisphere.

NEW ZEALAND

The first formal recognition of the conservation status of fungi by the New Zealand Department of Conservation occurred in 2002 (Hitchmough 2002). Earlier evaluations of threatened taxa did not consider fungi, but the new, revised threat classification system (Molloy et al. 2002) advocated assessment of all New Zealand biota. This classification system was developed specifically for use in New Zealand, reflecting features such as the small size and geographic diversity of the country, the many taxa with small population sizes and naturally restricted ranges, and recent history associated with declines in biodiversity. In terminology, the New Zealand system resembles parts of the IUCN RED List categories (IUCN 2001); for example, the three highest threat categories (within the “Acutely Threatened” division) are designated “Nationally Critical”, “Nationally Endangered”, and “Nationally Vulnerable”, comparable to IUCN’s “Critically Endangered”, “Endangered”, and “Vulnerable” categories. The intention is to classify all taxa that exist in the wild, including fungi and other micro-organisms. In fact, criteria are expressly introduced to facilitate evaluation of fungi:

> “Only those criteria that are appropriate for assessing a particular taxon need be used. For instance, for fungi it would be difficult to assess population size because of the problem of defining the boundary of an individual. In this situation an estimate of area of occupancy may be easier.” (Molloy et al. 2002, p. 22).

To qualify for the highest category of Nationally Critical status, therefore, a taxon must comply with any one of three criteria: population size, area of occupancy, and predicted decline. This first assessment of non-lichenised fungi addressed about 6000 recorded species, 30% of the estimated total of 20 000 New Zealand species. Assessment was biased towards the macrofungi, however, due to inadequate collecting and knowledge of distribution of microfungi. Forty-nine species of fungi (Table 1) were assessed by an expert panel of mycologists as Nationally Critical (Hitchmough 2002), representing 14% of all taxa in this category. A further 16 species were allocated to other threat categories, many of these species being associated with threatened host plants. Over 2500 fungal species are known from fewer than four New Zealand collections in the New Zealand Fungal Collection (PDD, Landcare Research, Auckland), and of these over 1500 are known from only a single collection. Hitchmough (2002) listed 1455 fungal taxa as Data Deficient; these are taxa known from fewer than four New Zealand collections and which, due to a lack of collection, culture, and distributional data, could not be assessed for threat status. These include over 200 species described from New Zealand type specimens but for which no material is held in New Zealand. Fungi comprise 70% of all taxa listed by Hitchmough (2002) as Data Deficient.

Case studies

Among the 49 Nationally Critical fungi, the following species serve as examples of the diversity of taxonomic groups, host relationships, and morphologies. They include macrofungal saprobic species on wood and mycorrhizal species, as well as microfungi on leaves, one on a threatened plant host

Table 1 Nationally Critical species of New Zealand fungi (Hitchmough 2002).

Fungus name	New Zealand collections in PDD
Austrogaster novaezelandiae D.A.Reid	0
Berggrenia cyclospora (Cooke) Sacc.	1
Cantharellus elsae (G.Stev.) E.Horak	0
Chalciporus aurantiacus (McNabb) Pegler & T.W.K.Young	4
Chlorovibrissea bicolor (G.W.Beaton & Weste) L.M.Kohn	1
Chlorovibrissea melanochlora (G.W.Beaton & Weste) L.M.Kohn	1
Chlorovibrissea tasmanica (Rodway) L.M.Kohn	1
Claustula fischeri K.M.Curtis	1
Colpoma nothofagi P.R.Johnst.	2
Cordierites acanthophora Samuels & L.M.Kohn	3
Dichomitus newhookii P.K.Buchanan & Ryvarden	2
Ganoderma sp. 'Awaroa'	3
Gomphus dingleyae Segedin	1
Gomphus novaezelandiae Segedin	1
Gyroporus castaneus (Bull.) Quél.	3
Hysterangium youngii Castellano & R.E.Beever	1
Inonotus chondromyelus Pegler	3
Lactarius maruiaensis McNabb	1
Phallobata alba G.Cunn.	4
Phanerochaete citrina Burds.	1
Phanerochaete corymbata (G.Cunn.) Burds.	1
Phanerochaete luteoaurantiaca (Wakef.) Burds.	1
Polyporus septosporus P.K.Buchanan & Ryvarden	3
Puccinia embergeriae McKenzie & P.R.Johnst.	3
Puccinia freycinetiae McKenzie	1
Ramaria aureorhiza R.H.Petersen	1
Ramaria avellaneovertex R.H.Petersen	1
Ramaria basirobusta R.H.Petersen	2
Ramaria junquilleovertex R.H.Petersen	1
Ramaria piedmontiana R.H.Petersen	1
Ramariopsis avellanea R.H.Petersen	1
Ramariopsis avellaneoinversa R.H.Petersen	1
Ramariopsis tortuosa R.H.Petersen	1
Russula inquinata McNabb	3
Russula littoralis McNabb (nom. illegit.)	2
Russula miniata McNabb	1
Russula papakaiensis McNabb	2
Russula pleurogena Buyck & E.Horak	0
Russula solitaria McNabb	1
Russula vivida McNabb	1
Sarcosoma orientale Pat.	1
Squamanita squarrulosa G.S.Ridl.	2
Thaxterogaster cartilagineus (G.Cunn.) M.M.Moser	1
Undescribed genus (Trichocomaceae)	2
Uredo chathamica McKenzie	6
Uredo salicorniae G.Cunn.	2
Volvariella surrecta (Knapp) Singer	1
Xylaria wellingtonensis J.D.Rogers & Samuels	1
Xylaria zealandica Cooke	1

and the other on a threatened animal host. Although gaps remain in knowledge of the distribution, biology, and ecology of these species, sufficient is known to highlight their threatened status and to encourage future targeted studies of these species. Conservation at the population level, for the genus *Lentinula*, is also discussed.

Polyporus septosporus *P.K.Buchanan & Ryvarden* (*septate-spored polypore, Fig. 1*)

This funnel-shaped, saprobic polypore fungus was recently described as new, based on earlier misidentified collections. It has been recorded in New Zealand from three collections from Auckland and Bay of Plenty* and in Australia from two collections from Tasmania and Victoria (Buchanan & Ryvarden 1998). *P. septosporus* is readily identifiable macroscopically because the pileus and pore surface stain cherry red with 3% KOH. Among polypore fungi globally, it is one of only two species to have septate basidiospores. The other polypore species with septate spores, *Dichomitus newhookii* P.K.Buchanan & Ryvarden, was also described from New Zealand and is listed as Nationally Critical in Table 1.

Ganoderma *sp. 'Awaroa'* (*pukatea bracket, Fig. 2*)

In contrast to the two common, non-laccate species of *Ganoderma* in New Zealand, this endemic, presumed saprobic, laccate species is known from only three herbarium specimens. It is almost certainly a new species (Buchanan & Ryvarden 2000), although Hood (1992) followed Steyaert in identifying it as *G. tropicum* (Jungh.) Bres. The bracket-shaped fruiting bodies are large, up to 34 cm wide, yet recent searches in parts of its presumed range have failed to locate further material. All collections date from 1969 to 1972, on *Laurelia novaezelandiae* (pukatea), from the western Waikato region. Clearing of forests rich in pukatea for farming may have severely reduced the habitat of this species. Although not formally recognised as threatened until 2002, it was recorded as a significant species by the Department of Lands & Survey (forerunner to the Department of Conservation) in its description of Awaroa Scenic Reserve, Waikato (e.g., Anon. 1984, p. 89).

* New Zealand districts follow Crosby et al. (1998).

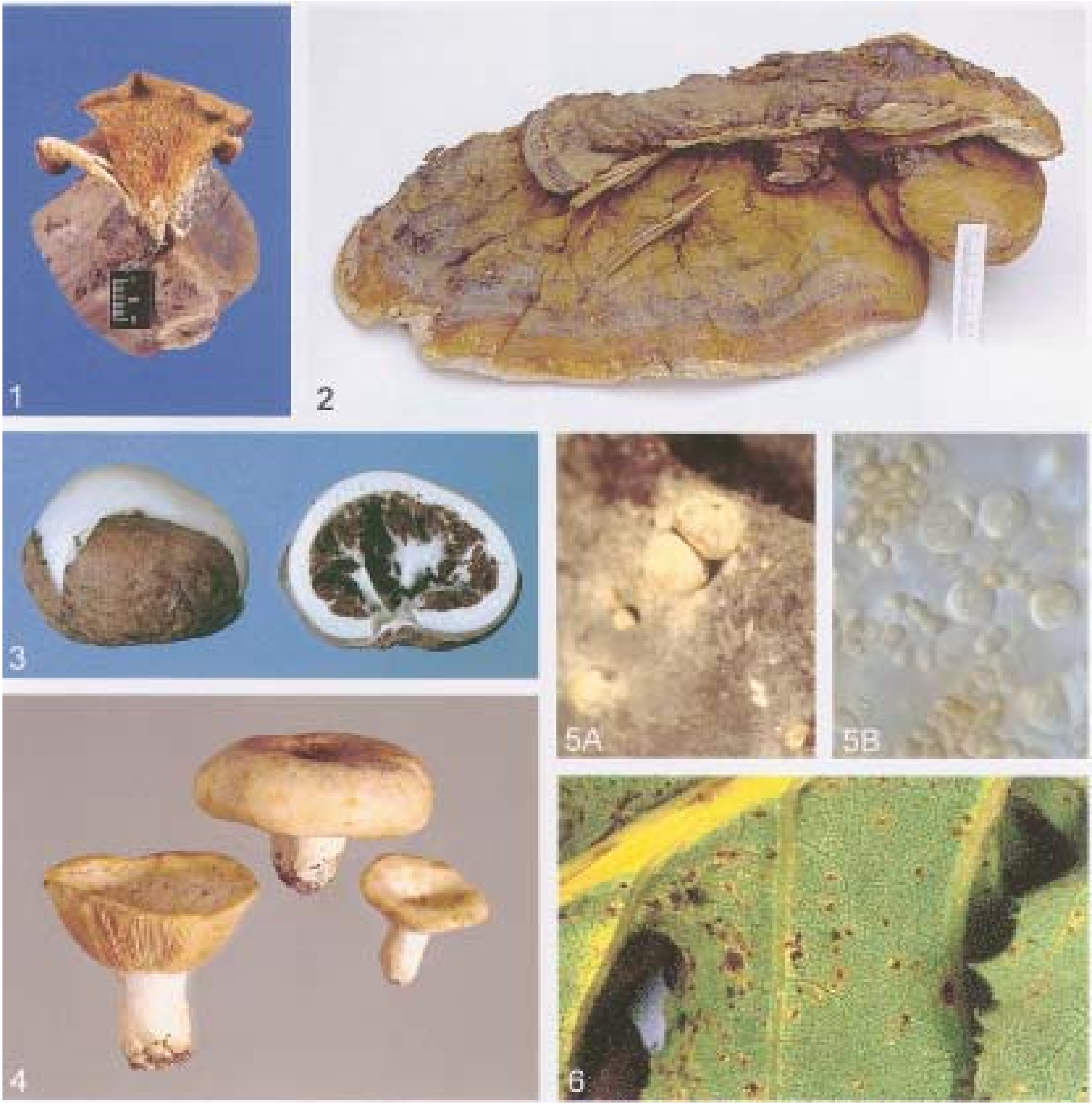

Fig. 1–6 Six New Zealand Nationally Critical fungi. **Fig. 1** *Polyporus septosporus* (PDD 66261, holotype). Pileus and pore surface stain red with aqueous 3% KOH. (Photo: Landcare Research) **Fig. 2** *Ganoderma* sp. 'Awaroa' (PDD 29835). Fruiting body is 34 cm across. (Photo: Landcare Research) **Fig. 3** *Claustula fischeri* (PDD 52012). Fruiting body is truffle-like, 2–3 cm diameter. (Photo: Ross Beever) **Fig. 4** *Russula papakaiensis* (PDD 26605, holotype). Fruiting body is 3.5–7 cm diam. (Photo: Landcare Research) **Fig. 5 A**, Undescribed Trichocomaceae: cleistothecial fruiting body, about 1 mm diam. (PDD 74629) (Photo: Peter Johnston); **B**, Undescribed Trichocomaceae: asci and ascospores (PDD 74629). (Photo: Peter Johnston) **Fig. 6** *Puccinia embergeriae* (PDD 62047), an obligate pathogen of the endangered *Embergeria grandifolia*. (Photo: Eric McKenzie)

Claustula fischeri *K.M.Curtis* (*Fischer's egg, Fig. 3*)

This hypogeous, truffleoid fungus is characterised by the globose to ovoid, hollow fruiting body, 2–3 cm diam. It is known in New Zealand only from Fringed Hill and the Dun Mountain track, Nelson, and from Rocky Hill, Wairarapa, and appears to be associated with *Nothofagus*. At Fringed Hill it is found under *Nothofagus fusca* on a bush margin potentially at risk from fire. Collecting truffleoid fungi is both time-consuming and subject to chance, but the rarity of *C. fischeri* is indicated by a single recent collection among 1500 collections of New Zealand truffleoid fungi representing about 100 taxa (R. E. Beever pers. comm.). The species has also been recorded in Tasmania (Mills et al. 1997).

Its high conservation status is also supported by its isolated taxonomic position; *Claustula fischeri* has been traditionally treated as the sole member of the family Claustulaceae, order Phallales (stinkhorns, etc.). This classification reflects its unique mode of dehiscence; the outer brown gelatinous layer splits open to reveal a pure white, hollow "egg", with a small basal opening. The egg *per se* does not open further and the spores are borne inside the "egg". The natural dispersal agents of *C. fischeri* are unknown, but it is tempting to propose that, along with many other New Zealand truffleoid species, it is adapted to bird dispersal (Beever 1999). The current "Dictionary of Fungi" (Kirk et al. 2001) lists Claustulaceae as a synonym of Phallaceae, but phylogenetic relationships have yet to be evaluated using molecular data.

Endemic Russula *species*

Seven of the 38 species of *Russula* recorded from New Zealand (McNabb 1973) are considered to be Nationally Critical (Table 1). Most of these seven are ectomycorrhizal associates of *Nothofagus* (*Russula inquinata*, *R. miniata*, *R. solitaria*, and *R. vivida*) or of *Leptospermum* and *Kunzea* (*R. littoralis* and *R. papakaiensis* (Fig. 4)). *Russula pleurogena* was recorded on the rotting trunk of *Cyathea* (tree fern). These seven endemic species are collectively known from 11 collections, individually from one to three collections, and each species from a single district. *Russula* species are mostly persistent, easily seen, often brightly coloured mushrooms, and most other species recorded in New Zealand are represented in PDD by numerous collections from several different localities.

Undescribed species in undescribed genus, family Trichocomaceae (*Fig. 5*)

Although presently undescribed, this species appears to represent a new genus of a group rarely collected in the Southern Hemisphere. Its unusual combination of cleistothecial and ascospore features suggests no close relationship with known members of Trichocomaceae (P. R. Johnston pers. comm.).

The species is known from only two geographically separated New Zealand collections (from Northland and Nelson), both on dead shells of unidentified giant land snails. If the fungus is restricted to this host(s), any threat to the snail population (Hitchmough 2002) will present a threat to the fungus population. At present, with increased predation and disturbance resulting in larger numbers of dead giant land snail shells on the forest floor, this fungus may temporarily be more common than usual.

Puccinia embergeriae *McKenzie & P.R.Johnst.* (*Chatham Island sow thistle rust, Fig. 6*)

Pathogenic microfungi might be considered unlikely candidates for threatened status, except where they are obligate associates of a threatened host. *P. embergeriae* is endemic to the Chatham Islands, east of New Zealand, and restricted to the Nationally Endangered host *Embergeria grandifolia* (Chatham Island sow thistle). It has been recorded on only one host population, at Kaingaroa, Chatham Island, but may be more widespread. The rust will have declined, however, as the host plant has become restricted to areas inaccessible to livestock. Both urediniospores and teliospores occur on the host. It is not known whether there is an alternate host on which the rust completes its life cycle (E. H. C. McKenzie pers. comm.).

Lentinula novaezelandiae (*G.Stev.*) *Pegler*

The final case study addresses fungal conservation at the population level, in relation to the agaric genus *Lentinula* Earle from New Zealand and Papua New Guinea (Hibbett et al. 1995). The only indigenous New Zealand member, *L. novaezelandiae*, is not currently considered to be endangered, but research suggests that hybridisation with introduced taxa could lead to a potential conservation threat. *Lentinula edodes* (Berk.) Pegler, the edible "shiitake", is the third most important mushroom globally in terms of production volume (Hall et al. 2003). Most if not all commercialised shiitake strains are of Asian origin (Hibbett et al. 1995) and are distributed worldwide for the shiitake industry. Several genetically distinct lineages of shiitake have been identified in Australasia, with strains from New Zealand (as *L. novaezelandiae*) and one of two sets of strains from Papua New Guinea (as *L. lateritia* (Berk.) Pegler) forming monophyletic groups (Hibbett et al. 1995). However, strains from Asia and Australasia of these monophyletic groups and of other lineages of *L. edodes* sens. lat. were mating compatible (Shimomura et al. 1992). This suggests a potential threat to the New Zealand lineage from imported strains of shiitake, and to sources of future genetic variability for improvement of commercial shiitake strains (Hibbett et al. 1995).

AUSTRALIA

Pascoe (1990) estimated a vast mycota for Australia, comprising 250 000 species, of which about 95% have yet to be formally named (May 1997). For macrofungi, May & Avram (1997) estimated that about 5000 species are currently named and an equal number have yet to be described. Most Australian fungi described in the 19th century remain known only from the type (May 2003), and even for species described in recent times (a sample of all fungi for the period 1980–1993) more than half are known only from the type locality, with 90% known from fewer than five sites (May 1997). For a selection of 443 species of South Australian macrofungi, Grgurinovic & Simpson (2001) found that 22% were known only from the type.

In Australia, the conservation of fungi was considered from a national perspective for the first time by May (1997) as part of a conservation overview of Australian non-marine cryptogams commissioned by Environment Australia, the national environment agency (Scott et al. 1997). For other cryptogam groups (freshwater algae, bryophytes, and lichens) this overview presented lists of rare and endangered species, coded according to the threat categories applied to Australian vascular plants by Briggs & Leigh (1989). For the fungi, however, it was concluded that there was insufficient information to assign any species to threat categories, apart from the fact that most fungi would likely be "Poorly known". Since the 1997 overview there has been little federal government action on the conservation of fungi, apart from indirectly through the continued support of Australian Biological Resources Study for taxonomic work on fungi.

Australia has legislation covering the conservation of threatened species and communities at national, state, and territory level (Scott et al. 1997). The conservation status of Australian plants uses a series of categories modelled on the IUCN standards. The most recent compilation of "Rare or Threatened Australian Plants" (ROTAP; Briggs & Leigh 1996) lists 5031 taxa assigned under the categories "Presumed Extinct", "Endangered", "Vulnerable", "Rare", and "Poorly Known". Numerous species of vascular plants are now formally listed under national and state legislation. Fungi are covered by all relevant conservation legislation, but very few species are formally listed. There are also extensive systems of reserves in each state and territory, and a register of the National Estate. A summary of the ten species and one community of fungi listed under various legislation is presented below, nationally and by states, along with any recent efforts to investigate conservation of Australian fungi. There are no relevant studies for Tasmania, Queensland, or the Northern Territory.

National

The Australian Heritage Commission maintains a register of the Australian National Estate, being places of national significance for a range of values, including scientific significance, as defined by the Australian Heritage Commission Act 1975. Among the more than 11 000 entries in the register, Lane Cove Bushland Park in urban Sydney was recently listed primarily on the basis of the Hygrocybeae (waxcap) community (Kearney & Kearney 2000). More than 20 species are known from the Park, most in warm temperate gallery forest. The nomination to the National Estate was (among several criteria) on the basis of the presence of rare or endangered fungal species (see New South Wales, below).

Fungimap (http://www.rbg.vic.gov.au/fungimap/), a partnership between scientists and community groups, aims to rapidly improve knowledge of the distribution and ecology of selected Australian fungi. Target species were chosen to be readily identifiable in the field by non-experts. Most are illustrated in current field guides, and there is also a CD-ROM guide to target species. With all target species being reasonably distinctive and easily recognised, the relative number of records provides the first large data set that allows quantification of relative rarity.

Among the more than 12 000 records of the 100 target species accumulated since 1996 (G. Evans pers. comm.), several species are represented by less than 10 records, including *Chlorovibrissea bicolor* (G.W.Beaton & Weste) L.M.Kohn, *Claustula fischeri*, *Hypocreopsis* sp. 'Nyora', *Morchella esculenta* (L.) Pers., and *Nyctalis mirabilis* T.W.May. These are prime candidates for formal listing at both state and national level. Fungimap data also help remove species from the Poorly Known category by showing that many of the targets are widespread and relatively common.

Victoria

The conservation status of Victorian macrofungi was reviewed by May & Avram (1997) based on holdings at the National Herbarium of Victoria (MEL). It was assumed the relative number of holdings would be a guide to rarity, and help select taxa for more detailed consideration of threat status. However, most (83%) of the 724 species were represented by five or fewer collections, and, thus, it was not considered possible to distinguish rare species from those merely under-collected. The conservation status of all 529 species represented by five or less collections in MEL was determined as Poorly Known by May & Avram (1997), although it was considered likely that with further data many would turn out not to be threatened. This contrasts with the definition of Poorly Known, as used by Briggs & Leigh (1996), where taxa are "suspected but not definitely known" to be extinct, endangered, vulnerable, or rare.

Taking into account knowledge of biology and ecology, *Morchella esculenta* and *Hypocreopsis* sp. 'Nyora' were considered Vulnerable, and were also listed as such by Cross et al. (2001). However, the two species are yet to be formally nominated for listing under the Flora & Fauna Guarantee Act 1988, which is the threatened species legislation for Victoria. Under this legislation, it is possible to list undescribed species, as long as specimens are lodged in recognised herbaria and the species is accepted by expert taxonomists. Creation of a Flora and Fauna Reserve at Nyora was recommended partly on the basis of the occurrence of *Hypocreopsis* sp. 'Nyora' (May 1994).

Western Australia

In Western Australia, *Amanita carneiphylla* O.K.Mill. and *A. griseibrunnea* O.K.Mill. are listed as Poorly Known Taxa, Priority Two in the Priority Flora List of the Department of Conservation and Land Management, Western Australia (FloraBase: http://www.calm.wa.gov.au/science/florabase.html); no further information on the threat status of these two species is provided. May (2002) analysed the distribution of 491 species of Western Australian macrofungi, looking for evidence of short-range endemism (range of less than 100 km). He found that most species were found also in eastern Australia, and all but five of the 52 Western Australian endemics were known from five or fewer localities. The lack of collections was concluded to be the main reason for apparently restricted ranges, with the exception of two endemic species of *Torrendia* (*T. grandis* Bougher and *T. inculta* Bougher) found only in a small area near Kellerberrin (Bougher 1999). The lack of short-range endemic species of macrofungi in Western Australia contrasts markedly with the situation for angiosperms, where some 75% of the flora is endemic, with many species of narrow range. An important implication for conservation is that narrow-range endemics are by virtue of their restricted range prime candidates for inclusion in conservation schedules. The lack of such species among fungi makes identification of threatened fungi more difficult, since specific threats must be established. It has to be taken into account that restricted species may also be less likely to be collected and described. If a broad range is the norm for macrofungi, there are important questions about the level of genetic uniformity over ranges that span large distances and where subpopulations may have been isolated geographically within this range for considerable time.

New South Wales

The Hygrocybeae community at Lane Cove Bushland Park, Sydney, is listed as an endangered ecological community under the NSW Threatened Species Conservation Act 1995 (Kearney & Kearney 2000). Due to the urban location of the Park and its small size (less than 24 ha), the fungal community is considered to be under threat from a number of causes, such as weed invasion, water-borne pollutants, and trampling. Eight taxa for which the Park is the type locality are listed individually under the Act. *Camarophyllopsis kearneyi* A.M.Young, *Hygrocybe austropratensis* A.M.Young, *Hygrocybe collucera* A.M.Young, R.Kearney & E.Kearney, *Hygrocybe griseoramosa* A.M.Young, R.Kearney & E.Kearney, and *H. lanecovensis* A.M.Young (all known only from Lane Cove) are listed as Endangered, and

Hygrocybe anomala var. *ianthinomarginata* A.M.Young, *H. aurantipes* A.M.Young, and *H. reesiae* A.M.Young (all known within NSW from three or less localities in the Sydney area) are listed as Vulnerable (http://www.npws.nsw.gov.au/news/tscdets/index.html). Kearney & Kearney (2000), who were the driving force behind the nominations, noted the importance in these landmark listings of the involvement of the Sydney Fungal Studies Group in collecting data for and preparing the nominations. They also emphasised the vital contribution of Dr Tony Young (Blackbutt, Queensland), the taxonomic expert in the group. Young (1999) published specifically on the Hygrophoraceae of the Park. The local Council carried out a successful prosecution of persons who permitted waste to pollute the creek along which the Hygrocybeae community occurs.

South Australia

Grgurinovic & Simpson (2001) assessed the conservation status of 443 species of macrofungi from South Australia, by evaluating Herb. AD records, literature, habit, and known distribution. Twenty-two per cent of species were known only from type material, and many had not been collected during the past 50 years. The authors were reluctant to assess any species as Extinct, Endangered, or Vulnerable, the three highest threat categories in the ROTAP system (Briggs & Leigh 1996), but several species were assessed as Rare and many of these are known from a single collection. This approach demonstrates somewhat more caution than that adopted by Hitchmough (2002) for New Zealand species. It also reflects, however, the more disrupted history of mycology in South Australia, with relatively few macrofungi accessioned in AD from 1940 to 1997 (Grgurinovic & Simpson 2001).

Most assessed taxa were collected and studied by J. B. Cleland, who collected extensively in areas of the Adelaide Hills, including Belair National Park. Since 26% of South Australian macrofungi were collected in the 840-ha Belair National Park, Grgurinovic & Simpson (2001) proposed that the Park be listed as an "area of national significance for macrofungi" under the Australian Heritage Commission Act 1975.

Case studies

Six species (only one formally listed) are discussed as examples of Australian rare or threatened fungi. Details are from May (1997) and May & Avram (1997).

Claustula fischeri *K.M.Curtis*

As in New Zealand, *C. fischeri* is very rare in Australia, known from only five sites in Tasmania (Mills et al. 1997). See New Zealand case studies (above) for further details.

Hygrocybe lanecovensis *A.M.Young*

The waxcaps are among the most distinctive of the agarics. *Hygrocybe* is relatively easily recognised in the field, and the species are often distinguished by readily observable characters such as colour, viscidity, and lamella attachment, although microscopic characters are important for some species. The beautiful form and colour of waxcaps means they attract interest and admiration from non-experts. *Hygrocybe lanecovensis* has a brilliant scarlet pileus, contrasting with the pure white, decurrent lamellae (Young 1999). It is known only from Lane Cove Park in urban Sydney. The group has been the subject of intensive taxonomic study by Tony Young over the last decade, based on examination of large numbers of collections and fieldwork throughout eastern Australia. Thus, the rarity of *H. lanecovensis* and the other species known only from Lane Cove Park (or few other sites) is based on considerable survey activity.

Morchella *cf.* esculenta (*L.*) *Pers.* (*Fig. 7*)

Morels (*Morchella* spp.) are highly regarded edible fungi. In south-eastern Australia morels are frequently collected for individual use and for sale at markets, at relatively high prices. There is evidence of illegal harvesting of morels from reserves, sometimes leading to disturbance to the soil when attempts are made to transplant colonies. One morel taxon (in the *Morchella conica–elata* group) is relatively common, and is the taxon most often recorded in field guides and other literature, and through Fungimap. Another morel (in the *Morchella esculenta* group) is very rare, known from only two herbarium collections in Victoria, from Wilsons Promontory and Rosebud (an urbanised area), and is rarely reported through Fungimap or in the literature. May & Avram (1997) considered *Morchella* cf. *esculenta* to be Vulnerable due to its very restricted distribution, its rarity (in contrast with other members of the genus), and the likelihood of collection of fruiting bodies for food (with unknown effects on population viability).

Nyctalis mirabilis *T.W.May* (*Fig. 8*)

This small, grey, agaricoid fungus is currently known from four sites within a 70-km radius in the Central

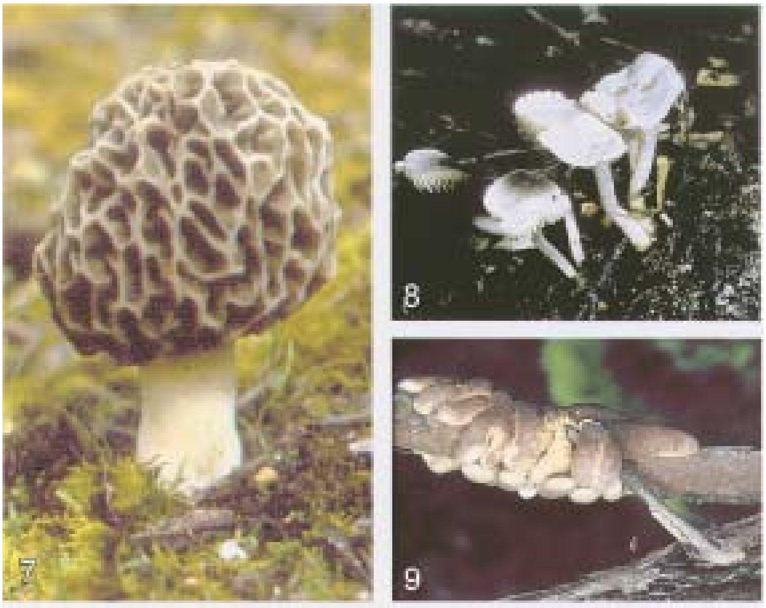

Fig. 7–9 Three Australian threatened fungi. **Fig. 7** *Morchella* cf. *esculenta*. (Photo: Hilary Weatherhead) **Fig. 8** *Nyctalis mirabilis* (MEL 2119136). (Photo: Bruce Fuhrer) **Fig. 9** *Hypocreopsis* sp. 'Nyora' (MEL 2044311). (Photo: Ilma Dunn)

Highlands of Victoria, and a single site in Tasmania (May & Fuhrer 1995). All Victorian localities are within Cool Temperate Rainforest, although the fungus is presently not known from some extensive occurrences of this vegetation type (for example, in the Otway Range). Fruiting bodies of *N. mirabilis* occur only on old fruiting bodies of members of the Russulaceae, possibly on a single species of *Russula*. It is possible for most agarics to survive as mycelia in soil from one season to the next. *N. mirabilis* produces chlamydospores, which may help survival between the appearances of the host. The distribution of *N. mirabilis* may thus be restricted not only by a preference for Cool Temperate Rainforest, but also by the host (if it has a restricted distribution). *Nyctalis mirabilis* is a very unusual fungus that has been seldom collected despite intensive fieldwork in likely habitats, and is certainly rare.

Hypocreopsis *sp. 'Nyora'* (*Fig. 9*)

This fungus is an undescribed member of a genus that is not otherwise known from Australia (May & Eichler 1993). It has been recorded from only three sites in near-coastal Victoria, all of which are reserved but are under increasing pressures due to their proximity to centres of population, from activities such as trail-bike riding, firewood collection, and unplanned fires. The fungus is usually found on stems of *Leptospermum* or *Banksia*, and grows on fruiting bodies of a resupinate species of *Hymenochaete*, upon which it is presumably parasitic. *Hypocreopsis* sp. 'Nyora' occurs only in long-unburned stands of *Leptospermum*. Nothing is known of the regeneration of the fungus after fire. In the field, *Hypocreopsis* sp. 'Nyora' is difficult to spot due to its drab colour, but once seen the distinctive fruiting body that resembles clasping fingers allows ready identification. This fungus was discovered by John Eichler, a member of the Field Naturalists Club of Victoria (FNCV), and there have been a number of surveys by him and the FNCV to attempt to locate further sites. Not only is this fungus very rare, it belongs to a small genus in which another species is threatened; *Hypocreopsis lichenoides* (Tode) Seaver is classified as Endangered in Britain (Ing 1992). May & Avram (1997) considered *Hypocreopsis* sp. 'Nyora' to be Vulnerable (V) due to its limited occurrence (despite surveys), habitat specificity, and known threats, especially inappropriate fire regimes.

Urocystis destruens *McAlpine*

The smut fungus *Urocystis destruens* was described in 1910 from material collected in the Melbourne suburb of Armadale. The host is the lily *Wurmbea dioca* that has most likely since disappeared from

Armadale, although it is widespread elsewhere. In 1991 a single specimen of the fungus was collected from Wattle Park, also a Melbourne suburb. Despite thorough searching on other occasions, no further material has been sighted. The fungus is likely to be relatively rare because the symptom is quite striking and would draw attention. Further observations are required throughout the range of the host to establish the conservation status.

DISCUSSION

The neglect of fungi in conservation initiatives for New Zealand and Australia until recently has been due primarily to a lack of resources, rather than to any intrinsic barriers in the formal conservation process. Fungi are not actively excluded from legislation, nor is there any apparent bias against accepting fungi onto conservation schedules. Much of the drive for fungal conservation so far has come from the involvement of taxonomic mycologists rather than from land management and conservation agencies, although the advocacy for the inclusion of fungi in the threat classification system for New Zealand by Molloy et al. (2002) is an encouraging sign.

Comprehensive assessment of the threat status of species, such as has occurred in New Zealand, is an excellent first step. However, because of the many poorly known species, and the great number yet to be described, action is needed on a number of fronts to bring the conservation of fungi in line with that of more popularly charismatic biota. A comprehensive strategy to address the conservation of fungi needs to encompass the following discussed points.

Threat categories

Internationally, there is a need to re-assess the IUCN threat categories to take into account the peculiarities of fungal biology and ecology, particularly the definitions and practical determination of individuals and generation times. The "Status survey and conservation action plan" recently published for bryophytes by the IUCN/SSC Bryophyte Specialist Group (Hallingbäck & Hodgetts 2000) is an excellent model of how to start this process for fungi. For local legislation, analysis is required on whether rarity *per se* is sufficient grounds for listing, and what level of survey is sufficient to establish rarity and threat status, given the poor information base.

Production and maintenance of RED lists

The excellent foundation of the current New Zealand threat status list needs to be extended to cover all New Zealand fungi. In Australia, there is an urgent need to produce a national threat status list for fungi that includes at least a large sample across taxonomic and trophic groups. A similar method to the way fungi were assessed for the New Zealand list would be most appropriate. Similarly to New Zealand, numerous Australian fungi are likely to be assessed as poorly known, but identification of even a short list of threatened species would be of value. For Australia, fungi also need to be included in state-based lists, although due to the limited resources, wide distribution of many species, and ecological artificiality of state boundaries, a co-ordinated approach is warranted. At both national and state level in Australia, the assessment of threat status and the nomination of species under the various legislations is an area where resources are most needed, and little progress is likely to occur without active support by governments.

RED lists also need to be regularly updated. Significant changes to the species included and to their threat status are to be expected as knowledge accumulates. There has been considerable development of the various editions of the Australian ROTAP list (Briggs & Leigh 1996). It is proposed that the New Zealand threat lists will be reviewed every three years by the relevant expert panels that contributed to Hitchmough (2002).

Intensive studies

Listing of species on conservation schedules is what drives the research, management, and support funding of endangered species, especially of high profile groups such as birds, orchids, and mammals. Once listed, it is hoped that the full breadth of the current conservation apparatus (including research, surveys, recovery plans, and action plans) can be applied to at least some fungi. To what degree this occurs may be the real test of how well fungi are embraced by conservation authorities.

Intensive study is required to determine distribution, population biology, and ecology of threatened fungi. The knowledge of these areas for indigenous fungi is extremely poor. For most species it is restricted to whatever information is included in taxonomic treatments, which may be no more than the locality of occurrence of the type specimen. A strategic approach would see intensive study applied to selected threatened fungi representative of a range of taxonomic and trophic groups. Such studies will be of great value, not only in ameliorating threats to the particular species, but just as importantly as background to understanding what sorts of threats might be relevant to all other fungi. In-depth study across some genera would also be of benefit in allowing a contrast between any factors specific to threatened or non-threatened species.

Collation of taxonomic and nomenclatural information

Authoritative lists of fungi are a vital underpinning to lists of rare and endangered fungi. Australasia is relatively well served by checklists of fungi, with on-line lists available for New Zealand (http://nzfungi.landcareresearch.co.nz) and partially for Australia (http://www.rbg.vic.gov.au/biodiversity/fungi/cat/). These lists need to be kept up-to-date and comprehensive.

Collation of herbarium data

Data on herbarium collections is the foundation of determining rarity, distribution, and ecological preferences. For New Zealand, most fungal specimens are held by the New Zealand Fungal Collection (viz p.3) (PDD), Landcare Research, Auckland, where all specimens are databased with on-line access. In Australia, data are scattered across state and national institutions, but are currently being brought together through a single on-line portal (Australia's Virtual Herbarium, AVH). There are significant collections of Australian fungi at PDD, and broadening the scope of the AVH to all Australasia would be beneficial. For the AVH to be of maximum benefit, all collections must be databased. Responses to date suggest that databasing of fungal collections may be a low priority for some herbaria. There are also numerous collections of Australasian fungi in foreign herbaria such as BPI, IMI, K, OSC, and ZT, although many of these are duplicates of collections in New Zealand or Australian herbaria. Integration of data on such specimens with local databases of New Zealand and Australian fungal collections is desirable.

Mapping schemes

Mapping schemes, such as Fungimap in Australia, have the capacity to rapidly increase knowledge of the distribution of selected species. They also support the surprising level of interest in and enthusiasm for fungi amongst the wider community. Fungimap can be useful for evaluating threat status and for establishing the threat status of poorly known taxa (most of which will probably turn out to be secure). Fungimap also provides large datasets that act as baselines against which to measure any effects of factors such as global climate change. It would be beneficial to establish a New Zealand fungal mapping scheme.

Surrogacy and congruence

For the large number of undescribed and poorly known species, other approaches to conservation must be developed, since it may be a long time before all species are described and their threat status established. Because many conservation decisions are made at the level of the vegetation community, it is vital to establish the degree of congruence between the vegetation community and the fungal community. How effective is vegetation as a surrogate for fungi? If different sites with the same vegetation community also have a similar suite of fungi present, then conserving a proportion of each vegetation community will "drag along" the fungi (even if the inventory of fungi is only partial). If there is not such a good match, then losing examples of even common vegetation types may still result in the loss of some fungi. There is an urgent need for research on the congruence of vegetation and fungal communities. A recent study in Tasmanian wet forest at different stages of regrowth found a good fit between vegetation and fungi, but also some exceptions (Packham et al. 2002). Such studies need to be extended to compare the fungi of different vegetation communities.

Hot spots and habitats

Hot spots are locations or habitats of high diversity for particular groups. Any areas currently known as hot spots may act as mycological arks until comprehensive knowledge accumulates on threat assessment and surrogacy. Known examples in Australia are pockets of wetter vegetation such as Deep Creek Conservation Park (South Australia), Mount Wilson (New South Wales), and patches of cool temperate *Nothofagus* forest in Victoria such as The Beeches. Localities where mycologists have been active may also be hot spots of diversity against a background of low collecting activity, as is the case for the association between mycologist J. B. Cleland and Belair National Park. Most known fungal hot spots are already in conservation reserves, but their significance to fungi needs to be brought to the attention of land managers, and, where appropriate, hot spots need to be listed under relevant legislation (such as has been the case for the Hygrocybeae community at Lane Cove Park).

On a broader scale, the suite of fungi associated with *Nothofagus* in New Zealand and Australia is highly unique and diverse, with more than 800 fungi already known to be associated with the five New Zealand *Nothofagus* taxa (McKenzie et al. 2000). While all indigenous forest types are vital for biodiversity of indigenous fungi, additional habitats of critical importance to fungi include wetlands and grasslands (e.g., for smut fungi on grasses and sedges), sand dunes (e.g., for sand-inhabiting discomycetes and agarics), and thermal regions (e.g., for specialised mycorrhizal fungi on thermal-tolerant plants).

The Australasian region as a whole is also a hot spot, being a centre of diversity of global significance for certain genera and ecological groups of fungi, which would merit closer study from the standpoint of conservation status. Examples are ectomycorrhizal truffleoid members of the Cortinariales and Russulales (Bougher & Lebel 2001) in Australasia, and sooty mould fungi, which are particularly diverse and conspicuous in New Zealand. Although there are currently insufficient data to assess their rarity on a local scale, conservation of these fungi is globally important.

Hosts

Those fungi that are associates of threatened plants are a particular group that merits close attention. Where the hosts are threatened (such as for *Puccinia embergeriae*), obligate fungi that are restricted to the host will be too. The compilation of host lists for pathogenic fungi is near comprehensive for cultivated and exotic plants, but much less so for Australasian indigenous hosts. The same situation applies to mycorrhizal fungi, some of which are host specific at the plant genus or species level. Cross-checking of lists of threatened plants against lists of fungal hosts should be carried out regularly. There is also a need to establish more effectively how narrow or broad is the host range of many indigenous fungi.

Education and profile

Iconic taxa should be used to raise the profile of fungi and their importance in ecosystems with the general public, educators, land managers, scientists, and politicians. Already among listed species are those that are beautiful, interesting, and weird. The connections between fungi and seemingly more charismatic organisms (such as truffles and marsupials, or mycorrhizal fungi and orchids) can also be promoted.

It is likely that provision of common names will have a beneficial effect on the wider dissemination of information about fungi. Common names for Fungimap target species are in development (P. Grey pers. comm.), and it would be appropriate to undertake this process on a wider scale, such as through a subcommittee of the Australasian Mycological Society.

CONCLUSION

The conservation of fungi will always be a challenge because of the huge biodiversity. In relation to the great number of fungi and their undoubted importance for ecosystem functioning, however, a relatively small increase in resources could have a significant effect. To achieve progress on all of the above points, injection of only modest funds on three fronts would be necessary. First, taxonomists are a good investment for conservation since they have already shown initiatives to become actively involved in the issue, and usually have the best first-hand knowledge of the biology and ecology of the fungi they study. Second, addition of any staff with expertise in and responsibility for fungal conservation to government conservation agencies, particularly at a national level, would be of great benefit. Third, the existing synergy between amateur and professional mycologists should be strengthened, since there are many non-experts who can make significant contributions, given some direction and support.

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