



September 2009
Vol 25 No 200

Australian Plants



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Front cover: *Hygrocybe erythrocala* Photo: Ray and Elma Kearney

Back cover: Bracket fungi in Lane Cove Bushland Park Photo: Ray & Elma Kearney

This issue is dated September 2009 to maintain sequence. It was, however, compiled in June 2010 and may mention occurrences that occurred between these dates.

Australian Plants articles

Australian Plants is published quarterly to promote knowledge of Australian native plants.

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Australian Plants No. 200 Issue of Volume 25 which comprises issues 198 – 205.
Published quarterly and available nationally in 6,000 copies by the Australian Plants Society NSW Ltd

© Australian Plants Society NSW Ltd 2009 ACN 002680408 ISSN 0005-0008

Printed by Elect Printing, Fyshwick, ACT Print post approved PP226253/00017

Introduction

Merle Thompson

For those interested in Australian native plants and the environments in which they grow what does the term “Fungi” mean?

My first thoughts are of those fascinating plant-like structures which pop up from time to time in garden beds or pots, in the bush and on tree trunks and fallen logs. I have seen some wonderful photographs of brilliantly coloured ones and others of fascinating shape and structure but more subdued in colour. These are, of course, the fruiting bodies and the main part of the organism may be underground.

To other people, fungal diseases which are soil borne and cause the roots of one's plants to rot or diseases of the leaf and stem may be their first reaction.

Both concepts are correct but they only touch on a small proportion of the organisms which are classified as ‘fungi’.

Even though we often think of the fruiting bodies of the “macrofungi” as plants, they technically are not part of the plant kingdom. They are described on the Botanic Gardens Trust, Sydney's website as part of the “forgotten flora” and to quote that website: “... *it has been estimated that Australia has about 250,000 species of fungi, but only about 5% of these have been scientifically described. Yet fungi are essential for breaking down organic matter, retaining nutrients in soils and making these nutrients available to plant roots.*”

In one issue of *Australian Plants* we can only touch on a few aspects of this diverse and fascinating area of study and range of organisms. We have not explored areas such as the role of fungi in medicine, in biotechnology or as food. Nor have we covered fungal diseases of native plants and we have only looked at the fungi in a limited range of areas.

What we hope to have done is to whet your appetite to learn more and to consider the role of fungi in all aspects of your study and enjoyment of native plants.

We start with an overview of what native plant lovers should know about fungi; present some specific types of fungi from a more ‘technical’ viewpoint and look at the types of interesting fungi in a few specific geographic areas as described both by those who have special expertise or experience in the field and by those who are ‘keen amateurs’. Finally, we look at plants which are not fungi at all but ‘true’ plants which mimic the life and appearance of fungi.

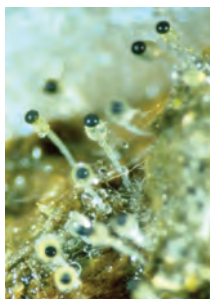


What Should Plant Lovers Know About Fungi?

Peter McGee

Peter McGee is an academic at the University of Sydney. He teaches fungal biology and microbiology. His research concentrates on the role of fungi in sustainable use of resources. The members of his laboratory currently are working on the rehabilitation of soil, restoration of mine sites and the replacement of chemicals in integrated management of pests and diseases.

Have you ever stopped to think about the other inhabitants of this planet? No, not the obvious ones like plants and animals: the other ones, those organisms that are largely invisible. We call them microscopic because we need a microscope to see the most common part of their bodies. Some, like bacteria, encompass huge variation that is only realised when we test their biochemical functions. Others, like the fungi, are more closely related to the visible organisms and they occasionally place their reproductive organs in places where we can and do see them. This issue is about the fungi.



The fungus *Pilobolus* producing its reproductive spore above a surface

And the largest known organism is? No, not a specimen of *Eucalyptus globulus*, nor the blue whale; it is a fungus. This microbe spreads through soil linking trees in a forest that covers some hundreds of hectares. What a paradox! That we have only just realised the size of this fungus is because we can't see the structure and have only just developed techniques to envisage the scale of its spread. I suspect we will be surprised by other discoveries of enormous microbes!

So what are fungi?

The scientific answer indicates that although fungi are similar to plants and animals in having a complex cell structure, the fungi differ by having chitin in the outer wall and having filaments called hyphae which have continuity from cell to cell, thus linking the entire individual. Fungi also have specific biochemical processes that differ from plants and animals. We know that brewer's yeast is a fungus, so cell shape does vary: from single cells to hyphae. Some fungi assume a yeast-like form when under stress and a filamentous form when in normal conditions. The most complex fungal structures are probably the fruiting bodies we call mushrooms. Yet even these complex tissues have a unique structure and development: the hyphae pack together as parallel strands and hyphae elongate to form the fungal tissues. The differences go even

further. At the cellular level, each cell of a fungus (when it has cells) commonly has a single haploid nucleus, sometimes more than one.

The usual animal and plant cell has a single diploid nucleus. The consequence for sex becomes obvious: fungi do that differently as well.

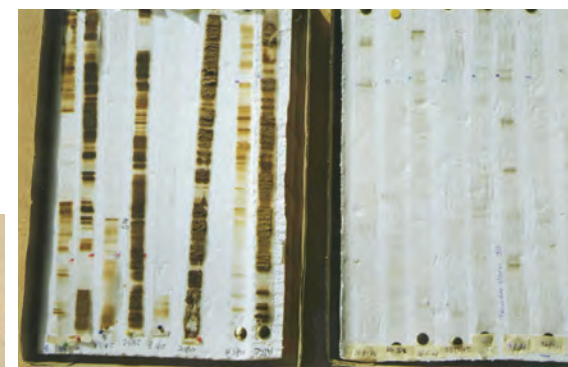
Indeed, fungi feed on the outside. Instead of consuming food and digesting it inside the organism like animals, fungi digest their food outside the organism and then take up the digested materials. By taking up only the food they can use, they leave their waste on the outside and can remain quite slim, enabling utilisation of hidden and complex (and sometimes toxic) materials. So, fungi are usually filamentous, spore-bearing eukaryotic organisms with a haploid lifestyle, extracellular digestion and cytoplasmic continuity.

OK, we know what a fungus is, but why should plant enthusiasts consider fungi? What do fungi do for plants? If we were to ask this question in a school room, the immediate response would "They eat all the plant and animal remains and litter". Well, yes, they do, and fungi are assisted by bacteria in this very important role. However, their functions are much more complex and their specific roles even more important.

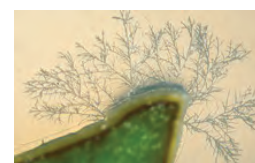
This note will take a look at the big picture and the industrial picture, because they are flip sides of a single coin. By big picture, we mean in ecosystems. Fungi are everywhere.

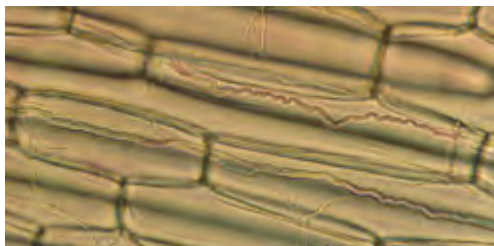
Fungi play an extraordinarily important role in transporting minerals and energy through soil, storing minerals and energy in living cells, transferring minerals to plants and transforming energy into simple and sometimes complex forms. Fungi shape the structure of soil enabling plant roots to penetrate the soil profile and store water yet enabling movement of water through the soil. Fungi may also protect plants from pests and pathogens.

Right: Spores of various fungi collected on a sticky tape from air (left) above a wheat harvest and (right) over a normal garden).



Below: Hyphae growing from a healthy leaf of Banksia.





Neotyphodium growing in a healthy leaf of grass

Claviceps paspalli growing on the seed of *Paspalum*. The upper seeds are colonised by the fungus and the lower ones are not. *Claviceps* releases a chemical that is used in treating migraine.

All photos by the author



We believe the fungus helps protect the host from fungal pathogens and fungi are the most important agents causing disease of plants. These roles are hugely important for the overall stability and resilience of ecosystems and, when the food reserves for fungi decline, we notice that all these functions also deteriorate (except plant disease which increases).

The biochemists among you will know that most microbes have complex biochemical systems that form the basis for many of our modern medicines. The chemicals originally found in fungi are now used in fighting cholesterol (statins), treating bacterial infections (penicillin), making food additives (citric acid), treating timber (cellulase and lignin oxidation) to make paper and transforming materials to food (tofu and soy sauce). Of the twenty most important medicines, ten originally came from fungi. Fungi form the basis of some of the largest global industries including brewing and food manufacture and they contribute in many more industrial processes.

Quite clearly, you should now be ready to sit back and enjoy this exploration of the fungi in your life.

In this issue are articles that tell you about what fungi do. Others will tell you about fungi that fascinate mycologists, amateur and professional alike. Indeed, we will supply you with a place to go to find some more information and allow you to 'meet' people who have been just as fascinated about fungi as you have with plants.

Fungi in Soil

Peter McGee

Fungi are extremely diverse in soil. Up to 5,000 different species of fungi will be found in each gram of soil. Some fungi will be present as spores, some as yeast cells and others as hyphae. Fungi are microbes and, like all microbes, their abundance changes dramatically over time and space. Because of the very high diversity, most species of fungus will be in a dormant state at any one time. Dormancy is broken by the detection of nutrients, such as a flush of energy that moves through soil immediately following rain or the growth nearby of a plant root. Various fungi will respond to the nutrients, grow and quickly drop back into dormancy. The growth of a few fungi will persist if the supply of nutrients continues. Persistence is enhanced if the fungus has access to ongoing supply of nutrients: a growing plant root is one such form of nutrient. Indeed, many species of fungus can be detected in roots, the most common being arbuscular mycorrhizal fungi (AMF). These fungi have the potential to make an on-going contribution to soil activities.

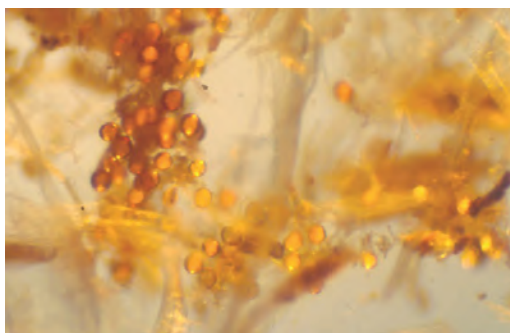
Most species of fungi commonly have brief periods when they are functioning, so their contribution to overall soil functioning will be largely unpredictable and short. The requirement for energy, moisture and appropriate temperatures probably determines when and where fungi are active.

The most abundant fungi in soil are the arbuscular mycorrhizal fungi (AMF). These fungi will be discussed elsewhere. AMF are the most common microscopic fungi in soil. They consist of between 0.1 up to 5m (forest) of hyphae per gram of soil. AMF are obligate associates of the roots of most plants and many plants rely on the fungi.



Effect of the presence of AMF on the growth of cotton seedlings. Those lacking AMF are much smaller and show signs of phosphorus deficiency compared to normal: (left) cotton - no AMF; (right) cotton with AMF.

All photos by the author



Spores and hyphae of AMF recovered from soil washings

- AMF increase plant growth through increased uptake of the immobile minerals particularly P, Zn and Cu, and they protect the plant against toxic concentrations of Mn. The mechanism is complex but it includes modification of the activity of the genes of the host plant, physical extension of the root and modification of soil chemistry.
- The diversity of AMF and plants is directly correlated; that is, the more AMF there is in soil, the more plant species are supported. The mechanism is unclear.
- AMF aggregate soil. They enmesh (0.1 – 5m hyphae per gram of soil) and glue particles through release of gels.
- AMF function as a store of carbon in soil through the creation of anaerobic sites in the centres of aggregates, though stores may be short-lived.

Each group of fungi makes a complex contribution to soil functioning.

Current research is now showing that some fungi produce biofilms in soil. These films enable the fungi to reduce losses of water and maintain beneficial interactions with other microbes. Biofilms consist of a gel rather like jelly in which microbes can release nutrients, leave behind waste that is food for other microbes and communicate by means of chemical signals. The film also reduces penetration by toxins and antibiotics. The biofilm is extremely dynamic, though the dynamism is modified because of the surrounding soil. Loss of water shrinks the biofilm and probably the rate of water loss is increased by the removal of water by plants. Presence of biofilm means that simple experiments in sand do not indicate the complexity of the responses in normal soil. Indeed, our level of ignorance of the soil and what goes on in soil, means that most plant growers still consider soil to be a black box.

We are largely ignorant of the activities of all organisms in soil, though fungi clearly play an important part.

Mycorrhizal Fungi

Peter McGee

We often wonder why healthy looking seedlings from the nursery suddenly sicken and die. Our first thought might be *Phytophthora* or some other root pathogen. Or we think about cut worm larvae, or other insects that eat the roots. However, if we check the roots, what are we to think when they appear healthy?

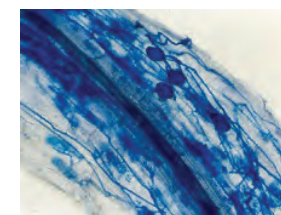
Seedlings in nurseries are commonly fertilised. They appear fresh and green and soft. The seedlings grow well on planting out. That is the whole point of using fertiliser. However, the use of fertiliser must be sustained for the seedlings to continue thriving. Fertiliser use can be difficult to monitor: each species has different needs.

This is where an understanding of mycorrhizas becomes important for the home garden. Mycorrhizas are an association between soil-borne fungi and the roots of plants. Most plants have arbuscular mycorrhizas and many have ectomycorrhizas. Our Epacrid and orchid families have their own types, and then there is *Thysanotus*.

Arbuscular mycorrhizas (AM), orchid mycorrhizas and ericoid mycorrhizas are cryptic: the plant may have mycorrhizas and you would not know unless the root was examined microscopically. Ectomycorrhizas can be seen as swollen root tips: easy to say, difficult to see all the time. Being cryptic or largely cryptic is a major problem. How can the gardener know when these important plant associates are present? Well, you can't without knowledge of what to do and the equipment to do it.

So let us look at what these fungi do. Each type has quite different behaviours and we are still coming to understand the details. This discussion will be brief and you could go to the web site run by the Australasian Mycological Society to obtain more detailed information: (<http://bugs.bio.usyd.edu.au/learning/resources/Mycology/>).

AM fungi are obligate associates of most plants: we culture them only with the roots of living plants. The Proteaceae (*Banksia*, *Telopea* etc) do not become mycorrhizal. The fungi are extremely common in undisturbed soil, widespread and not particularly diverse. Arbuscular mycorrhizas aid in the plant uptake of minerals and water. AM fungi also assist in the development of soil structure and modifying the soil environment making minerals more available.



AM fungus stained blue in the root of *Dichopogon*



Of considerable interest is that AM fungi structurally and genetically modify the way the plant takes up minerals. A colonised plant establishes an exchange region in the root and the fungus determines what enters that part of the root from soil and the root feeds the fungus. Seeds of Australian plants germinating in natural soils become colonised by AM fungi within a few days. The fungus immediately increases plant uptake of minerals especially phosphate. The table below shows the consequence of this increased uptake.

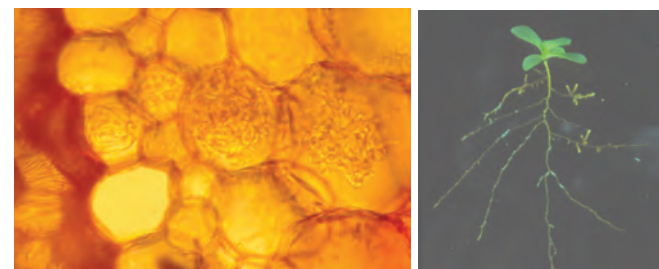
Table 1. Average P distribution in AM and non-AM seedlings of *Acacia longifolia*.

	% phosphate in shoot	% phosphate in shoot
AM seedling	0.05	0.8
Non-AM seedling	0.05	0.04
Fertilised non-AM seedling	0.05	0.7

Note that the fertilised and mycorrhizal seedlings have stored phosphate in the root system, not the shoots. The store of P in roots then feeds the seedling during early growth. Because the fertiliser effect runs out, the only way for a garden plant to cope with low P, is if it becomes mycorrhizal. Most gardens lack AM fungi. You see many plantings of roadside native plants where apparently healthy seedlings have died. The usual reason is because the soil used is artificial and lacks AM fungi and the seedlings have been fertilised. Death is due to the seedling exhausting its internal store of phosphate.

Ectomycorrhizas are formed on many native Australian plants. Each autumn you can see ectomycorrhizal fungi fruiting among the fallen plant materials in a spectacular display of fungal diversity. Trees and shrubs in Myrtaceae, Fabaceae and Sterculiaceae and many herbs and smaller shrubs are normally ectomycorrhizal. The plants can also associate with AM fungi. Ectomycorrhizal plants naturally inhabit our poor soils: we see few ectomycorrhizal plants in rainforest. The Ericaceae are only found in very poor soils. The fungal associates of both have remarkably similar behaviours, even though the root colonisation is very different. The fungi grow into the soil where they digest plant litter thereby accessing both phosphate and nitrogen. The minerals are delivered to the plant. The cycle of minerals from the litter layer to the fungus, to the plant and back again is very tight.

Orchid mycorrhizas are highly specialised. The fungi are required to germinate seed in nature. The fungi then provide the protocorm with its energy and minerals until the seedling starts to photosynthesise. The



Left: Short fat roots of an ectomycorrhiza on *Rodanthe bracteatum*

Far left: Microscopic image of coiling mycorrhizal fungus in the root of an orchid.

All photos by the author

association continues throughout the life of the orchid. The fungus retreats to the skin of the underground structure each year as the orchid dies back. Re-emergence of the 'root' coincides with growth of the fungus.

Some orchids are parasitic on their fungus. These associations are even stranger. The fungus is always also attached to a tree where it forms an ectomycorrhiza. Thus the tree feeds energy to the fungus, which passes some of that energy to the parasitic, achlorophyllous orchid.

Thysanotus forms a specific type of parasitic association with AM and ectomycorrhizal fungi. Roots of seedlings become colonised by fungi, the fungus is retained under the epidermis and the plant sucks much of its nutrients from the fungus. If the fungus is attached to another plant, then Thysanotus will continue. If the fungus is disturbed, then the plant will use up its mineral reserves and then die. The plant is not normally short-lived, only in garden settings where its mycorrhizal associates are severely and continually disturbed.

References To learn more about fungi

Websites

Fungimap www.rbg.vic.gov.au/fungimap

Australian National Botanic Gardens

Australian Fungi Website: www.anbg.gov.au/fungi

www.anbg.gov.au/abrs/lichenlist/introduction.html

CSIRO www.fungibank.csiro.au

Sydney University

<http://bugs.bio.usyd.edu.au/learning/resources/Mycology>

Books

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Dictionary of the Fungi, ed: Kirk, Cannon, Minter, Stalpers

Flora of Australia, Vol 51; Supplementary Series Vol 20 & 21

Fungi of Australia Series, 6 volumes

A Field Guide to the Fungi of Australia, Young, Tony & Smith, Kay

Common Australian Fungi, Young, Tony



A Look at the Lichenised Fungi

Simone Louwhoff

After completing her doctorate on lichens at the Australian National University, in 2000, Simone worked as the lichen curator at the Natural History Museum, London. Returning to Australia in 2004 she worked on lichens for the Flora of Australia - Lichens Series. Currently employed at Monash University, (Victoria) in the School of Applied Sciences and Engineering, she remains strongly interested in lichens.

Fungi are a very varied group of organisms and it is estimated that currently only about 5% are known, as compared to just over 80% of flowering plants. They survive by absorptive nutrition and “lichenising” is just another lifestyle that fungi employ in their quest to fulfil carbohydrate requirements. Some fungi are saprophytic and live off dead organic matter and others parasitise living hosts. Yet another group are mutualistic and form a symbiotic relationship with a partner. Lichenised fungi belong to this last group and the organism they form a partnership with is a green alga, or a cyanobacterium (blue-green alga), or on occasion both. These two or three partners form a little ecosystem called lichen, which functions very successfully. There are at least 13,000 lichen species known worldwide, but some estimates are as high as 30,000! Lichens occur in almost every environment and on many different kinds of substrates. What makes them especially interesting from a scientific point of view is that the organisms making up a lichen represent two or three different kingdoms; the Fungi, Plantae (green alga) and/or Monera (cyanobacteria).

The fungal partner protects the algal partner against dehydration and harmful UV rays. It is responsible for the sexual reproductive structures present on the lichen and mostly for its shape. The algal partner contains chlorophyll and is able to photosynthesise and produce carbohydrates, which the fungus metabolises. A large array of secondary metabolites (at least 700), many unique to lichens, are produced as a result of this. If a cyanobacterium is present, then the fungal partner can obtain nitrogen compounds also, as the former is able to capture and fix atmospheric nitrogen. Although essentially mutualistic, this relationship is sometimes viewed as controlled parasitism. The fungal partner actively promotes the multiplication of the algal cells (its “host”), thereby increasing its carbohydrate supply, but, in many cases, suppresses their sexual reproduction. Whichever way it is viewed, the lichen state benefits both partners as together they are able to colonise habitats that would otherwise be out of their reach.

Water and nutrients are taken up directly across the surface of the lichen. The advantage of this is that lichens are able to survive in areas with very low rainfall, as even atmospheric moisture in the form of fog or dew is sufficient.

The downside is that any atmospheric pollutants present are usually taken up by the lichen also and accumulate in the thallus (main body of lichen). Sensitivity to these polluting air particles appears to vary according to the species. Some lichen species are tolerant of certain atmospheric pollutants. Nitrophilous (nitrogen loving) lichens thrive in nitrogen rich environments caused by ammonia pollution and include species in the genus *Xanthoria* and *Physcia*.

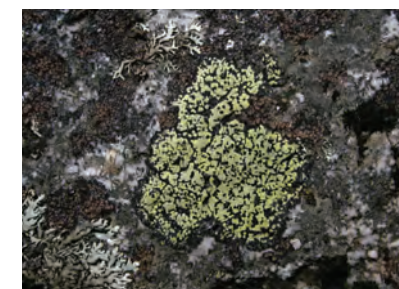
Other lichens are nitrophobes (intolerant of nitrogen) but thrive in highly acidic environments, such as some species in the genus *Hypogymnia*. Some lichens even have a tolerance of heavy metals and can be found growing in the drip zone of copper or iron pipes, or on rocks at mining sites. Lichen species known to be extra sensitive to air pollution can be used as indicators of healthy air.

Many lichens are known to be particularly sensitive to microclimatic conditions too and will only occur in particular habitats.

Lichens grow slowly as compared to most plants and growth rates range from less than a mm per year in the case of the crust-like lichen *Rhizocarpon geographicum* (also called map lichen), but may attain rates of 9 cm per year in the case of some of the pendulous lichens. Some are only a few millimetres in diameter and others reach over 2 metres in length.

The vast majority of lichens belong to the fungal class Ascomycetes (the sac fungi). Most fungi are highly selective, forming associations only with a compatible algal partner. The most common of these belong to the genera *Trebouxia* and *Trentepohlia* (green alga) and *Nostoc* (a cyanobacterium). These can exist in a free-living state as well and particularly *Trentepohlia* is often seen colonising tree trunks as an orange discolouration. In approx 4% of cases, lichens have both types of algal partner.

Lichens play an important ecological role and are used as a food source by vertebrates as well as invertebrates, although the



Rhizocarpon geographicum
Photo: J-M. Porignaux



secondary metabolites are known to deter some potential grazers. Many invertebrates use lichens as camouflage or shelter, which soon becomes evident when looking at them more closely with a hand lens or through the microscope. They are also used by birds as nesting material. Lichens play an important role in soil formation through chemical and physical weathering of rocks. They may also stabilise the soil by forming soil crusts, which reduce soil erosion and can trap water and nutrients and return these to the soil.

According to the most recent Lichen Checklist, on the Australian Biological Resources Study website (Web ref. 1), close to 3,500 lichen species have been recorded for Australia and approximately 34% of these are thought to be endemic. Reportedly, the greatest number of species occurs in Queensland (1,776), which also has most endemics (275 species), followed by NSW (1,468) with 108 endemic species. Listed below are some different habitats and outlines of the more common lichen species found there.

Parks and Gardens. The orange, leaf-like (foliose) lichen *Xanthoria parietina* is very common, as is the grey coloured *Physcia*, which is similar in appearance.

The green-yellow foliose *Flavoparmelia rutidota*, with brown fruiting discs is often seen too. There are also the shrubby (fruticose) lichens, including the small orange *Teloschistes*, and the green *Usnea* (with rounded branches) or *Ramalina* (with flattened or inflated branches).

Coastal regions. There are distinct zones of lichen communities along rocky seashores, consisting first of all of the intertidal zone, which is dominated by the black crustose lichen *Verrucaria* and the black shrubby (fruticose) *Lichina*. Above this, in the spray zone, occur the orange lichens *Xanthoria* and *Caloplaca* (a crust).

The green shrubby *Ramalina* occurs more commonly on vegetation further back and is also common on mangroves.



Teloschistes, *Ramalina*, *Flavoparmelia* and other lichens on fruit tree.
Photo: S. Louwhoff



Pseudocyphellaria and *Sticta* on Eucalypt trunk
Photo: J-M. Porigneaux



Usnea (green) and *Parmotrema* (grey) species
Photo: K. Harris

Arid and semi-arid. The most distinct lichens in these areas are soil lichens, which may form thick soil crusts. Most easily recognisable is the scale-like, salmon-pink to orange coloured *Psora decipiens*, which has black fruiting bodies growing along the margins.

Another common lichen is *Toninia sedifolia*, which has a thallus comprising inflated, dark grey to brown scales with a dusting of “glitter” and are covered in black, rounded fruiting bodies. *Xanthoparmelia semiviridis* is a yellow-green, wandering lichen and, when dry, can be seen curled up into small balls, which can form large windrows.

Rainforest. Species in the foliose genera *Pseudocyphellaria*, *Sticta* and *Lobaria* (all Lobariaceae) can be seen growing luxuriantly from tree trunks and branches. The former two have pin-prick sized holes in their lower cortex (*Pseudocyphellaria* has small tufts growing out of these). *Lobaria* lacks holes but has small root hairs.

Nephroma cellulosum is a lettuce green lichen with a white lower surface and brown fingernail-shaped fruiting bodies at under side of lobe tips. Silver Wattle is often covered in a white crustose lichen called *Pertusaria*.

Many blotchy, leaf-inhabiting lichens occur in rainforest too and *Usnea* drapes from the branches, growing a metre or more in length. “Script” lichens in the family Graphidaceae are common on smooth-barked trees.

Alpine and subalpine. Grey to black, foliose *Umbilicaria* species grow attached to rock by a central holdfast. The hollow, white “vermicelli”-like *Thamnia* is found growing unattached on the ground or among ground vegetation. *Parmelia signifera* is foliose with a thick, dark green to grey-brown roughened thallus, mostly on rock.



Cladonia species
Photo: K. Harris



Menegazzia on rock
Photo: J-M. Porigneaux.

Eucalypt woodland and forest. Various *Cladonia* species consisting of small green stalks topped with, usually, brown or red rounded fruiting structures are common on bark and soil. The initial stages of *Cladonia* comprise only scales and can be difficult to separate from one another.

Small, shrubby lichens with a perforated thallus belong to the *Cladia aggregata* complex and are common on bark, among moss and on soil. The fertile form is more robust with black tips (the fruiting bodies).

Various parmelioid lichens occur mainly on bark and rock, including *Hypogymnia* with hollow, straggling "fingers", hollow *Menegazzia* species with distinct perforations in the upper cortex, and large, foliose, grey *Parmotrema* species, attached by black root hairs.

Reference

www.anbg.gov.au/abrs/lichenlist/introduction.html. Updated 27.08.2009

Agents of Decay – the wood-inhabiting macrofungi

Genevieve Gates

Genevieve Gates has been working on Tasmanian fungi for 12 years. She recently completed her Ph.D. entitled "Coarse woody debris, macrofungal assemblages, and sustainable forest management in a *Eucalyptus obliqua* forest of southern Tasmania. (<http://eprints.utas.edu.au/9593/>). This stimulated her interest in wood-inhabiting fungi although her first love is the family Entolomataceae.

Introduction

Wood decomposition is an integral part of ecosystem functioning as well as contributing to economic losses in the timber industry and in buildings. Wood, in particular dead wood, of all sizes and in different stages of decay, presents a high number of available niches for wood-decay fungi to occupy. These fungi possess powerful cellulolytic and ligninolytic enzymes that break down plant tissue. Three types of wood decay have been distinguished, viz. brown rots, white rots and soft rots. In brown rots, only the celluloses and hemicelluloses are degraded, leaving the lignin part of the wood (Figure 1). White rot fungi attack both the carbohydrate and the lignin components (Figure 2) more or less at the same time and soft rots are usually caused by Ascomycetes (e.g. cup fungi and disc fungi) and Fungi Imperfecti (fungi that do not produce a fruit body). Genera of macrofungi that are otherwise very close can be separated by their ability to cause a brown or a white rot. For example, all members of the genus *Antrodia* are brown rotters and those of *Antrodiella* are white rotters.

The large brackets and conks found on living and dead trees, e.g. *Phellinus wahlbergii* (Figure 3) and *Fomes hemitephrus* (Figure 4), are the sporulating stages of wood-inhabiting fungi that have entered the tree either via the root system or from an above-ground decay entry point caused by branch breakage, fire scars or damage by birds, wood-boring insects and larger animals (Simpson 1996).



Fig. 1 (far left): Brown cuboidal rot

Fig. 2 (left): White pocket rot caused by a resupinate polypore

All photos by the author unless otherwise credited



Fig. 3: *Phellinus wahlbergii* with worms feeding on the surface



Fig. 4: *Fomes hemitephrus*

Some of these fungi need a long time to fruit in a tree or are host specific, e.g. in Tasmania, *Australoporus tasmanicus* is most commonly found in old forests and *Fomes hemitephrus* only grows on *Nothofagus cunninghamii*. An important relationship exists among wood-inhabiting fungi and many invertebrate species as the fungal fruit bodies provide food and habitat for fungus gnats, molluscs, slugs, nematodes, collembolans and coleopterans. In fact, the fruit bodies of old growth specialist polypores have been proved to be important for the persistence of specialist insects (Komonen 2001). Furthermore, the rot of heart-rot polypores is instrumental in producing hollows that shelter birds and small animals.

Not all wood-inhabiting fungi produce large and conspicuous fruit bodies. Corticioid or 'crust' fungi are a cosmopolitan group of fungi that, more often than not, look to the naked eye like a splash of paint on the wood, hence the common name of 'paint fungi'. However, when one examines them under a hand lens or dissecting microscope, diverse hymenial surfaces are revealed and are described as poroid, hydroid, tuberculate, grandinoid, furfuraceous, toothed (simple and phalanged), merulioid and stereoid! These spore-bearing fruit bodies vary in texture and size and may be very thin and cobwebby (arachnoid), felty, pellicular, waxy (ceraceous), gelatinous or firm and corky. They may be sub-visible and appear as a greyish bloom covering a small area of the substrate or they may be a very bright colour or cover a very large part of a fallen tree. The fruit bodies can be formed adpressed to the surface of the substratum or they may be slightly reflexed at the fruit body margin or disc-like, as in *Aleurodiscus limonisporus* (Figure. 5).



Fig. 5. *Aleurodiscus limonisporus*

There is substantial mycelial growth below the surface of the fruit body which can extend far throughout the substrate. Some polypore species, e.g. *Phellinus* spp., also assume a resupinate habit. Resupinate fungi are able to colonise woody substrates of all sizes from small thin twigs to very large diameter coarse woody debris in all stages of decay.

The fruit bodies of wood-inhabiting fungi have varying structures to survive in adverse conditions. *Ganoderma australe* and *Phellinus wahlbergii* form fruit bodies that persist for many years and are capable of producing spores for many years. The fruit body is structured to reduce rates of evapotranspiration by increased bulk and hairy or lacquered surfaces. The tough leathery fruit bodies of *Stereum* spp. are able to survive extremes of temperature and fluctuations in moisture content. Some Ascomycota species, e.g. *Hypoxylon bovei*, *Hypoxylon hians*, *Hypoxylon diatrypeoides*, *Hypoxylon howeanum*, *Xylaria castorea* (Fig. 6) and *Nitschkia* sp., have hard melanised outer crusts (which offer protection against ultra-violet radiation) and gelatinized matrices that serve as a water store in dry conditions. Such species with persistent fruit bodies able to resist desiccation will be present for much of the year including the hot dry months. However, once the spores are discharged, only the shells of the ascoma (fruit body) remain unless new fruit bodies are produced.



Fig. 6. *Xylaria castorea*
Photo: Michael Pilkington

Soft bodied genera of wood-inhabiting fungi, e.g. the 'jelly fungi' such as *Calocera*, *Exidia*, *Dacromyces* and *Heterotextus*, have been shown to be perhaps the most efficient macrofungi at rehydrating and resuming spore dispersal, a significant survival strategy.

Wood-inhabiting fungi are threatened by natural and anthropogenic disturbances which result in a loss of habitat and substrate. In Australia, the most common form of natural disturbance is wildfire. Anthropogenic disturbances include the loss of habitat due to intensive forestry operations (which include the added threat of salvaging dead wood as biofuel), land clearing for agriculture and urban development. Illegal collecting of firewood has also led to a decrease in the quantities of dead wood in dry sclerophyll forests. Tidying-up procedures by property owners also remove available substrate that supports wood-decay macrofungi.

Conservation of wood-inhabiting fungi focuses on protecting habitat and ensuring the maintenance of adequate quantities of dead wood





in varying decay stages. Natural habitat with different-aged stands of living trees of native composition should be as large as possible to protect, in particular, the heart-rot fungi that have a long and diverse history of decay.

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Aphid colonised by *Beauveria*
Photo: Peter McGee See article on next page



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Fungi and Insects

Peter McGee

So you thought your insects were able to avoid fungi? Well, this brief article aims to show you where the interaction is important.

Just like all organic matter, insects are a good food source for some fungi and inevitably some fungi live on insects. Where the insect is killed by a fungus, the fungus is called an entomopathogen.

The life cycle of entomopathogens can be simple, but recent research suggests it is far more complicated than entomologists thought. They might also have to become mycologists as well. It is not evident that the commonly used entomopathogens *Metarhizium*, *Lecanicillium*, *Beauveria* and *Isaria* have a stage where they live in plants.

How do insects contact the fungi? This is not yet clear. We spray spores at insects and thus contact is made. This does not happen in the wild. It is most likely that insects walking through dead or dying plant materials contact spores of the fungi and then become colonised. Indeed, the presence of entomopathogens in plants may deter insects from feeding and those that feed may have reduced reproduction. Stay tuned! You may find in a few years that you will not need to use dangerous chemicals to reduce insect attack on your plants: fungi living in your plants may do it for you.



This is not a
decoration:
*Aspergillus
parasiticus*
growing from a
plague locust

All photos by the
author



Fungi In The Restoration Of Ecosystems

Peter McGee

What is an ecosystem? Each of you lives in an ecosystem. For instance, the urban environment can be thought of as an ecosystem, its shape and activities determined and supported by (mostly) human activities imposed upon the existing environmental framework. Other ecosystems might be farmlands and natural bush lands. Note that natural bush lands might be those found in tropical environments, or wedged within a suburban conglomeration. The key to understanding ecosystems is that they are complex temporarily, structurally and functionally: they have an enormous diversity of organisms that ultimately depend on the plant communities for energy entering that ecosystem.

Human activities have been responsible for the loss of function and biological diversity in many ecosystems.

Perhaps the most appalling losses are associated with the need for food and clothing. Some 80% of all farm lands have lost significant amounts of topsoil through erosion. Minerals have leached from the soils and in some areas salinity has increased. The consequence of these changes is that we have reduced productivity and, especially because of our increasing global population, an increased need for food. These demands increase pressures on our soils and our ecosystems.

The response to ecosystem degradation must be multifaceted and complex. It might include social aspects such as regulation of populations, migration and increased efficiency of food supply and usage. Responses may also be biological. Many different attempts to restore degraded ecosystems have concentrated on severely damaged systems in order to better understand the processes underlying successful restoration.



Consideration of plants is extremely important, but not enough by itself.

Without considering the complex biology, plant restoration is limited and ultimately unsatisfactory. As I hope you can now see, even if you have enough money, restoration might

An abandoned mine site in NSW



A site used to bury urban waste after preparation for revegetation



Limited recovery from seed scattered on a prepared sandstone site

be impossible unless sensible goals for restoration are set and plans developed and implemented in a logical and scientifically valid manner.

The fungi have a role in the restoration of ecosystems. The functions contributed by microscopic fungi include:

- Transport minerals and energy through soil
- Function as a biological store of minerals and energy
- Degrade organic matter and release CO₂
- Transform materials such as glucose to complex materials including polyphenolics such as melanin
- Increase plant uptake of minerals
- Aggregate soil
- Regulate water-holding capacity of soil
- Protect plants from pests and pathogens
- Cause plant disease via direct invasion and production of plant toxins
- Contribute to animal nutrition.

Fungi make a complex contribution to ecosystems

Growth of the entomopathogen *Lecanicillium lecanii* (from the leaf of cotton)

All photos by the author





Listing of Australian mushrooms under State & Commonwealth legislations

Ray and Elma Kearney

Ray and his wife, Elma, as amateur mycologists and executive members of the Sydney Fungal Studies Group Inc., were responsible for the listing, under the Conservation & Endangered Species Act of NSW, of a community of fungi for the first time in Australia. In addition, 9 new species in the fungal assemblage of over 25 fungal species were listed and finally, the habitat - the Lane Cove Bushland Park - was gazetted with its listing on the Register of the National Estate. Both are recipients of numerous awards. Ray retired from the Department of Infectious Diseases and Immunology, University of Sydney on 31 December, 2006 where he had been head for seven years.

Knowledge of fungi (mushrooms) still remains extremely limited. They have a kingdom of their own, separate from plants and animals and have a vital role in the ecosystem and life-support systems. Misunderstanding persists in government environmental bureaucracies at State and Federal levels where fungi are erroneously assumed to be plants.

Fungi are no less threatened than plants and animal species and have also become endangered by default - through inefficient administration, ignorance of their ecology, or simply because too few seem to have the interest, authority or responsibility for taking constructive action to safeguard them. The introduction of e.g., 'Bio-banking' can pose a threat to endangered fungi by legislation that favours developers against responsible mycological stewardship. Governments generally have no formal system of documenting fungi other than by community volunteers.

The following account illustrates how initiative and analytical insight of amateur mycology enthusiasts, as members of the Sydney Fungal Studies Group (SFSG), when coupled with the skills of a professional taxonomic mycologist (Dr Tony Young), can achieve landmark decisions for conservation of fungi at Local, State and Commonwealth levels of Government.

Lane Cove Bushland Park (LCBP)

LCBP is a warm-temperate wet sclerophyll forest and measures approximately 800 metres long and about 300 metres wide. (Fig.1). It is evergreen, hygrophilous in character in the upper portion and rich in lianes. Epiphytes are relatively common on tree trunks, especially in the upper tributary of Gore Creek. The gallery rainforest at the bottom of the valley is

surrounded by steep-sided ridges and gullies which carry run-off rainwater into the tributary of Gore Creek and empties into Sydney Harbour.

LCBP records a rainfall of more than 1200 mm, the wettest months being January to July. Extremes of temperature are infrequent: average maximum summer temperature is around 24°C and the average minimum 18°C. Average winter temperatures are: maximum 16°C, minimum 7°C. Why is this bushland so special?

LCBP is the location of at least 35 species (previously 27) in the tribe Hygrocybeae (waxcaps). This Hygrocybeae Community has been legislated under the NSW Threatened Species Conservation Act, 1995 as endangered along with nine *holotype taxa* as either endangered or vulnerable. In addition, LCBP has been listed on the Register of the National Estate by the Commonwealth Heritage Commission as a site of national significance based principally on its mycological assemblage. These successful prototype listings set a precedent for mycology in Australia and depended also upon the exemplary support of Lane Cove Council.

The Park's diverse landscape comprises a wide variety of vegetation complexes. It is in the gallery rainforest that has a north-south aspect between sloping hillsides, which govern shade and heat in autumn and winter, where the majority of waxcap species are found.

The major rock types, Wianamatta shale and Hawkesbury sandstone, give rise to two distinctly different types of soil. The unusual combination of both soil types, coupled with the topography of the site, has created a range of unique habitats and ecosystems, which support the colourful waxcap species. By 1997, more than 20 different waxcaps had been documented photographically by amateur mycologists Ray Kearney and his wife Elma.

Scientific documentation in the Applications



In 1998, Dr Tony Young received grants from the Australian Biological Resources Study to undertake studies on Hygrophoraceae along the eastern seaboard of Australia, including Tasmania.

Fig 1. Lane Cove Bushland Park
All photos by the authors



The authors drew his attention to their unofficial records of the waxcaps in LCBP in 1998 and marked the beginning of the formal identification and classification. In January 1999, two applications were submitted by Ray and Elma, on behalf of the SFSG, to the Scientific Committee established under the *NSW Threatened Species Conservation Act, 1995*.

Hygrocybeae Community listed as an endangered

The first application sought a determination to list the Hygrocybeae Community of LCBP as an Endangered Ecological Community. An extract of the Final Determination as legislated on 3 March, 2000 is reproduced as follows:

Final Determination

"The Scientific Committee established by the Threatened Species Conservation Act, has made a Final Determination to list the Hygrocybeae Community of Lane Cove Bushland Park as an Endangered Ecological Community under Part 3 of Schedule 1 of the Act. Listing is provided for under Part 2 of the Act.

The Scientific Committee has been found that:

1. The Hygrocybeae Community of Lane Cove Bushland Park is an assemblage of more than 20 species of fungi in the family Hygrophoraceae (Fungi, Basidiomycota, Agaricales, Hygrophoraceae).
2. The following species have been recorded in the community Table 1

<i>Camarophylloopsis kearneyi</i>	<i>Hygrocybe anomala</i> var. <i>ianthinomarginata</i> (Fig.3)
<i>Hygrocybe astatogala</i>	<i>Hygrocybe aurantiopallens</i>
<i>Hygrocybe aurantipes</i>	<i>Hygrocybe austropratensis</i>
<i>Hygrocybe cantharellus</i>	<i>Hygrocybe cheelii</i>
<i>Hygrocybe chromolimonea</i> (Fig.2)	<i>Hygrocybe erythrocala</i>
<i>Hygrocybe graminicolor</i>	<i>Hygrocybe helicoides</i>
<i>Hygrocybe involutus</i>	<i>Hygrocybe irrigata</i>
<i>Hygrocybe kula</i>	<i>Hygrocybe lanecovensis</i> (Fig.4)
<i>Hygrocybe lewellinae</i>	<i>Hygrocybe mavis</i>
<i>Hygrocybe miniata</i>	<i>Hygrocybe reesia</i>
<i>Hygrocybe sanguinocrenulata</i>	<i>Hygrocybe stevensoniae</i> (Fig.5)
<i>Hygrocybe taekeri</i>	<i>Hygrocybe virginea</i>

Other species in the Community have been collected but remain undescribed and unclassified, and other Hygrocybeae may be present."

Dr Chris Dickman Chairperson, Scientific Committee

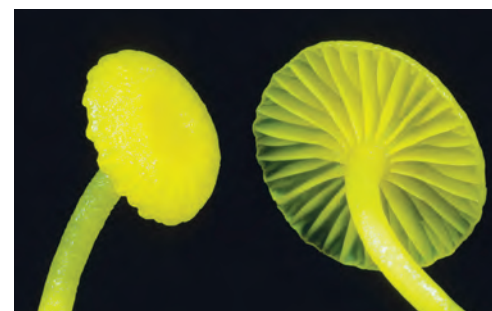


Fig 2 *Hygrocybe chromolimonea*



Fig 3 *Hygrocybe anomala*
var. *ianthinomarginata*



Fig 4 *Hygrocybe lanecovensis*



Fig 5 *Hygrocybe stevensoniae*

Since then, the Hygrophoraceae has been separated into four genera. Three species have also been added to the numbers of species in this assemblage:

Hygrocybe collucera (Fig. 6 below), *Hygrocybe griseoramosa* and *Hygrocybe rubronivea*



Listing of new species of Hygrocybeae of LCBP

The second and subsequent applications to the Scientific Committee nominated the nine holotypes of Hygrocybeae including *Camarophylloopsis kearneyi* as Rare Native Species of LCBP within the meaning of Schedule I (endangered), Part I of the *Threatened Species Conservation Act, 1995*.

The holotype species and the Final Determinations are:

<i>Hygrocybe anomala</i> var. <i>ianthinomarginata</i>	vulnerable
<i>Hygrocybe aurantipes</i>	vulnerable
<i>Hygrocybe austropratensis</i>	endangered
<i>Hygrocybe collucera</i>	endangered
<i>Hygrocybe griseoramosa</i>	endangered
<i>Hygrocybe lanecovens</i>	endangered
<i>Hygrocybe reesia</i>	vulnerable
<i>Hygrocybe rubronivea</i>	vulnerable
<i>Camarophylloopsis kearneyi</i>	endangered

Listing on the Register of the National Estate

On behalf of the SFSG, the authors prepared for Lane Cove Council, (the owner and manager of LCBP) an application to the Heritage Commission based upon the conservation value ranked of national significance, according to Rald's system (Table 2 - see end of article).

The Australian National Estate has more than 11,000 entries of cultural and natural heritage places which have special value on the basis solely of specific criteria.

However, following amendments to the *Australian Heritage Council Act 2003*, the Register of the National Estate (RNE) was frozen on 19 February 2007, which means that no new places can be added, or removed. The Register will continue as a statutory register until February 2012. Thereafter all references to the Register will be removed from the *Environment Protection and Biodiversity Conservation Act 1999*. The RNE will be maintained after this time on a non-statutory basis as a publicly available archive.

Each of these three initiatives was strengthened by the supporting scientific and photographic documentation. These initiatives allowed mushrooms to be legislated for the first time, at all levels of government i.e., Commonwealth, State and Local as significant to conservation.

Scientists accept that extinction is an integral part of the process of natural selection. However, whilst some species are rare and the assemblage of fungi in LCBP is threatened and endangered, the best way to safeguard the rare species is to ensure the conservation of the biotic community. Rarity is not of itself a cause for concern. Some species are inherently rare, often because they occupy a highly specialised ecological niche. But few species can survive outside their natural habitat. None of the species of Australian Hygrophoraceae has been artificially cultured.

Since these listings an additional eight species have been identified as new or unclassified.

Rald's classification for conservation has been up-graded (Rald, 1985/ Vesterholt et al. 1999). A collection of greater than 22 species of Hygrophoraceae in one location ranks the site of International Significance. LCBP clearly fulfils this ranking with at least 35 species.

In Europe, *waxcaps* are found in a variety of *nutrient*-poor grasslands which are either grazed or mown. In North America they occur in woodlands. However, in LCBP, they occur in a range of habitats e.g., soil, leaf mulch and moss in a warm-temperate wet sclerophyll forest.



Most of our knowledge comes from the recording of the fruiting bodies (carpophores), which appear mostly in autumn and winter, peaking late June to mid-July in the LCBP. The majority of the fungal organism is the *underground mycelium*, which is difficult to study. Unlike some mushrooms, waxcaps do not grow on dead wood. All the species of waxcaps from LCBP produce white spores, despite the colour of the fruiting structure.

How long the mycelium lives or takes to develop before fruiting or what triggers fruiting is unknown. Some of the rare species may not be rare but simply fruit more rarely as DNA analysis suggests there is a poor correlation between fruiting bodies and the mycelia. Thus species whose fruit bodies are only very sparsely recorded can be widespread below ground. Neither controlled back-burn nor bushfire appears to affect fruiting of waxcaps as do consecutive droughts.

Threats

In Australia, there have been no formal studies of the nature of 'threats' on species of waxcaps found here. Overseas, the presence of waxcaps in grassland is a marker for low air/soil pollution. The greatest overseas documented threats are:

1. Loss of semi-improved grassland through development
2. Seeding and application of chemical fertilisers or pesticides as well as ploughing
3. Abandonment leading to colonisation by weeds and scrub

Overseas, the conservation of waxcaps grassland is dependent on maintaining the *low nutrient status* of the grassland. Inputs of fertilisers such as nitrogen *reduce* the species richness of grassland fungi. It is noteworthy that LCBP was formerly 'Kelly's Flat' where cattle grazing on grassland was its former use and may have been critical in establishing the conditions for its current waxcap assemblage.

A suggestion is that *Hygrocybe* spp. originally evolved in grassy woodland glades and that historic deforestation (in Britain and Europe) and agriculture has in effect expanded the habitat of these fungi. If this is true, then the assemblage in LCBP assumes even greater importance i.e., the assemblage is consistent with a more 'primitive' woodland glade adaptation rather than that of grassland – and largely pre-dates the widespread use of inorganic fertilizers, pesticides and other chemicals. The effect of inorganic fertilizers on fruit-body production is known to be immediate.

An application of ammonium nitrate fertilizer will cause a 4-fold reduction in fruit-body production. Lime or calcium carbonate inhibits the fruiting development of waxcaps. In the LCBP, sewage contamination of the creek will lead to high nutrients and chemical contaminants are positively detrimental.

In the UK, another consistent feature of habitats where waxcaps occur is the presence of *moss* cover. Recent overseas data indicate the waxcaps are humic saprotrophs where nitrogen-enrichment is a growth inhibitor. This suggests that their optimum survival in nitrogen-poor soil is met by having biochemical mechanisms that allow them to access nitrogen from organic humus. Any addition of nitrogen then is toxic that may favour a shift in balance between the soil bacteria and fungal mycelium.

Waxcaps do not like being enshrouded with tall grass or weed vegetation. Overseas reports indicate that the type of grazing animal (rabbit/sheep/cow) is not a factor in waxcap diversity. However, creatures, such as ants, that burrow and disturb the soil are detrimental. Another factor found to be damaging is trampling by inhibiting the fruiting, by up to 50%.

Regarding restoration of habitat, we simply do not know whether re-colonisation involves incoming airborne spores or re-growth from residual patches of mycelium. Our attempts to 'transplant' waxcaps either by fruiting structures or by spores have uniformly failed. To date, there is no report of a mycorrhizal association between waxcaps and vascular plants.

Of vital importance is that this conservation project has enlisted the support of Lane Cove Council and the local people, without whose active collaboration – and, wherever possible, participation – little of permanence would be achieved. Being active participants in these collective processes is only a beginning to give mycology a quality resonance.

Table 2: Conservation Importance of Waxcap sites.
Rald (1985) / Vesterholt *et al.* (1999)

Conservation Value	Total <i>Hygrocybe</i> taxa	Number of taxa in a single visit
International importance	22+	15+
National importance	17–21	11–14
Regional importance	9–16	6–10
Local importance	4–8	3–5
No importance	1–3	1–2

Fungi of South Australia

Pam Catcheside, all photos by David Catcheside

Pam Catcheside is an Honorary Research Associate at the State Herbarium of South Australia. She is also editor of the Fungimap Newsletter. Fungimap is an Australia-wide non-government organisation devoted to improving knowledge and conservation of Australian macrofungi.

The driest State on the driest continent does not sound a favourable habitat for fungi. Nevertheless, South Australia with its arid lands, mallee country and dry and temperate woodlands provides a variety of environments for a rich array of fungal species.

Since 1997 David, my husband, and I have been surveying and collecting fungi in parks and reserves in most parts of the State. We have deposited over 3,000 collections of fungi in the State Herbarium of South Australia (AD) and run the Adelaide Fungal Studies Group whose enthusiastic members also collect and document fungi found on our forays.

Some of our more distant collecting sites are in desert and arid lands. The fungi living in these dry, sandy soils have to endure limited water availability, nutrient-poor soils and extreme temperature variation. Although their mycelium, the vegetative part of the fungus, is underground and protected, the above ground fruit bodies need to be adapted to the dry conditions.

The puffball is one of the commonest forms of fruit body. The puffball contains a powdery spore mass which is dispersed when wind, raindrops or animal movement dent the sides of the puffball resulting in the release of spores through an apical pore, the stoma. The casing of the puffball is usually dry and papery or almost woody which results in a lower water requirement and reduced evaporation rate. The more or less spherical shape of the puffball means there is a reduced surface area to volume ratio resulting in a reduction in the rate of water loss in comparison to that of an umbrella-shaped mushroom.



The Tulostomas, stalked puffballs (Fig. 1), are the most common species in these dry areas. Their stipes (stems) are usually underground, only the puffball exposed on the surface. The exoperidium, the outer skin, is

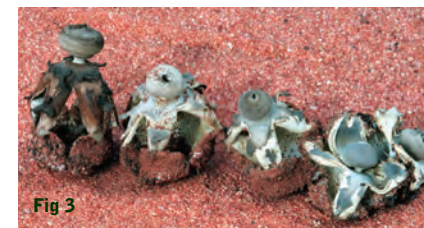
composed of a mixture of sand and hyphae (fine tube-like threads) and remains at the base of the ball, forming a sand collar.

The sand collar of members of the genus *Disciseda* forms a saucer under the spore case (Fig. 2). The whole resembles an acorn or hazelnut, hence they are sometimes called Acorn Puffballs. *Discisedas* become detached from the substratum and are blown by wind or washed by rain to new locations. The mass of the sand collar serves to keep the puffball upright and helps spore dispersal from the small apical stoma.



Species of *Geastrum*, Earthstars, are also common in dry areas. These are puffballs in which the exoperidium has split into a number of pointed rays, usually 5 - 10, to form a star-like base under the inner spore case, the endoperidium. This star base, like the sand collar of the *Discisedas*, keeps the fruit body upright and the stoma pointing upwards.

The exoperidial "star" of Arched Earthstar *Geastrum fornicatum* (Fig. 3) arches upwards and raises the inner puffball, resulting in increased height and thus greater opportunity for spore dispersal by wind.



Other puffballs bear their spore cases on high stalks, also improving the chances of effective spore dispersal. The Tall Stiltball, *Battarraea stevenii*, *Chlamydopus meyenianus* (Fig. 4) and the Black Powderpuff *Podaxis pistillaris* are large, desert dwelling stalked puffballs.

However, not all dryland fungi are puffballs:

Gyrophragmium inquinans is more like a dry, woody mushroom with a conical cap.

Fungi in moister environments show a greater variety of form and colour. One area with a rich fungal diversity



Montagnea arenaria (Fig. 5) has a small daisy-like cap.



is a short walking trail in Deep Creek Conservation Park, a park approximately 100 km south of Adelaide. The vegetation is *Eucalyptus obliqua* woodland with *Xanthorrhoea semiplana* and *Pultenaea daphnoides* understorey. Approximately 250 species of larger fungi have been recorded from this site (Catcheside & Catcheside 2008) including the delicate shell-like cream-pink *Marasmiellus affixus* (Fig. 6) which has a terrible wet-nappy smell and grows along rotten twigs and branches. Deep Creek is the only place in South Australia where we have found this little fungus although it is more common in higher rainfall areas of other States.

Similarly, the tiny pale blue umbrellas of Pixie's Parasol, *Mycena interrupta* (Fig. 7 below left), and the small pinkish-ochre branching candelabra of Fairies' Castles, *Artomyces piperatus* (= *Clavicornia piperata*) (Fig. 8 below right) are found in few other places in South Australia.



Pagoda Fungus, *Podoserpula pusio* (Fig. 9 right), with its pale salmon pink caps arranged in tiers around a central stalk, is another fungus that is found only in moister habitats. In mid-winter the soil is often carpeted with the yellow discs of *Discinella terrestris*, the brilliant red-pink finger like clubs of *Clavaria miniata* emerge from the leaf litter and even truffle fruit bodies such as the rather slimy yellow *Protoglossum luteum* with its chocolate coloured gleba, the inner spore mass, may poke up above the soil.



Flinders Chase National Park (at the western end of Kangaroo Island) and the adjoining Ravine des Casoars Wilderness Protection Area, cover an area of almost 75,000 ha. (See www.parks.sa.gov.au/flinderschase/index.htm)

Vegetation types there include low open shrubland with Dryland Tea-tree, *Melaleuca lanceolata*, open woodland with Sugar Gum, *Eucalyptus cladocalyx*, Brown Stringybark, *Eucalyptus baxteri* and South Australian Blue Gum, *Eucalyptus leucoxylon* ssp. *leucoxylon* as well as *Banksia marginata* and *B. ornata* heath. This large area of remnant vegetation has a very rich and diverse assemblage of macrofungi. Between 2002 and 2007 we recorded almost 300 species of larger fungi including more than 20 species of Amanitas with their rounded to flattened caps adorned with warty or thin veil fragments, white to cream gills, stipes clothed with a skirt-like, membranous ring and stipe bases encased in a basal sac, the volva.

There are Inkcaps whose thin black gills may deliquesce into black fluid as they age; brightly coloured cortinars of purple, yellow, orange, brown and white; wiry-stalked but delicate bells of *Marasmius* species; brackets, both gilled and pored; jelly and club fungi; little brown mushrooms galore; soil- and wood-inhabiting discs; more than 20 species of truffles that fruit underground and many more. The devastating bushfires of December 2007 burnt approximately 95% of the Park but the fungi are amongst the first colonisers, carpeting the blackened soil with masses of pink and brilliant orange or clusters of brown-black discs, most of which are not seen except after fire.

There are also the oddities: the fungi about which one gets excited because they are strange or rare.



Beaton's Clubs *Underwoodia beatonii* (Fig. 10 above) with their waxy, blackish-grey columns can hardly be called beautiful and are found only occasionally.



A new species of stalked truffle, *Cribbea turbinispora* (Lebel & Catcheside 2009) (Fig. 11 – left), was discovered in Karte Conservation Park, a dry, sandy park in mallee country, far from southern Queensland and northern New South Wales where other members of the genus have been found.

The fungal kingdom provides not only beauty and strangeness but its members perform essential roles: as recyclers of organic matter, as soil remediators, as symbiotic partners with an estimated 90-95% of all plants. So when I observe a little *Mycena* I enjoy its prettiness, but also think of its rotting and returning of nutrients to the environment. The knowledge that a handsome *Amanita* is collecting water and nutrients for the benefit of its plant partner, receiving sugars from the photosynthesising plant in return, gives the satisfaction of recognising a mutually beneficial relationship.

Catcheside PS, Catcheside DEA (2008). A Fungal Hotspot: Stringybark Walking Trail, Deep Creek Conservation Park, South Australia and the Conservation Status of its Macrofungi. *Journal of the Adelaide Botanic Gardens* 22, 9-30.

Lebel T, Catcheside PS (2009). The truffle genus *Cribbea* (Physalacriaceae, Agaricales) in Australia. *Australian Systematic Botany*, 22, 39-55

Significance of fungi in vegetation communities in coastal south east New South Wales

Text and photos by Robin Corringham

'As one continues through the stages of study over many years, appreciation of our native plants grows. They don't stand alone. I looked about and fell into ecology which led to Kingdom Fungi. It's a natural progression. Will you come with me for a short while?'

Fungi in the wild in South East New South Wales have only recently been systematically recorded. As in the wider world there are many times more fungi than plants and it is now popularly understood that fungi are more than an ephemeral curiosity.

The mushrooms, earth stars, corals and puffballs that we see are spore-bearing bodies rising from a vast network of fine feeding filaments largely invisible beneath the ground, or within living or dead organisms above. In our area fungi occur mainly from late February into June, possibly depending on the timing and amount of rain from January and subsequent humidity. Always vulnerable to general climate and weather changes, in this district as in many places, the appearance of fungi fruit bodies is unpredictable.

While rain may appear to be the trigger for fruit production, other edaphic factors of soil and topography, which with land use, influence vegetation community design, combine to be a major influence on the distribution of species. In any discussion of plant communities the presence and role of fungi cannot be neglected. Biotrophic fungi have an intimate relationship with a wide range of trees, shrubs and smaller plants, while saprotrophic fungi, with other decomposers, convert dead tissue to essential nutriment.

Chatham Park, Tuross Head, is a small littoral rainforest reserved in a suburban context. In addition to recording fungi over a four year period, 2002-05, answers were sought for the question of a catalyst for fruiting. Over the four seasons there was an unevenly diminishing rainfall which was not accurately reflected in the numbers of fungi appearing. However, in the fourth, and driest year, fungi on wood substrate, particularly lying wood, showed a significant rise in numbers while common soil substrate genera were not seen. This trend may have been due to moisture retention in the litter/log layer from light rain which did not penetrate the deep mulch.

In each year saprotrophs were the majority - in the last year only two



species known to be mycorrhizal were identified. These quite elementary observations beg questions of whether fungi fruiting body appearance may be an indicator of the health of the vegetation community.¹ Or is it business as usual in the great underground engine room?

Many of the species recorded at Chatham Park were not found, nor was there a disproportion of saprotrophs, in a comparison/contrast survey at Meringo, 10ks south of Moruya, on a rise within sight of the sea. Here, two adjoining sites were studied, each of about four acres and each within the broad definition of Endangered Ecological Communities. Site 1 is disturbed Dry Grass Forest on basalt-derived soil with *Eucalyptus tereticornis* and *E. bosistoana* dominants. Site 2 is minimally disturbed Sand Forest on an old dune system with ancient *E. pilularis* dominant.

On both plots 2007 was a vintage year with a total of 169 species recorded. About 25% of these were not identified. On Site 1 there were masses of soft creamy *Collybia butyracea* and *Lepiota kammala*, with big coarse *Phylloporus rhodoxanthus* (pictured) near every *Acacia mearnsii* and *E. tereticornis*. These were not seen on Site 2 where there were thirteen species of *Amanita*, many growing near *E. pilularis*, contrasting with Site 1 where only three *Amanita* were recorded. This, and other examples, (*A. punctata* was recorded adjacent to *E. pilularis* at Chatham Park) leads to the inference that there is a number of fungi which has a mutual relationship specific to a particular vegetation community or a member of that community. The two sites shared only 12% of the named fungal species found. Forests have specialized types of communities which include not only specific plant species, but their growth stages, the fallen trees and parts of these, all intrinsic to its ecology.²



The number and variety of mushrooms at that season created such a display that one must have intruded and trampled (Gulliver in Lilliput) on a world of thin white threads of mycelium which is the largest component of a fungus. Growing and spreading as a member of a community, simple sugars are taken from their plant partners which receive mineral nutrients in return. It was a short

Entoloma virescens

time of Tolkien dimension with metre patches of fascinating earth stars, *Geastrum triplex*, sticky, stately, brown cap atop white stemmed *Xerula radicata*, sky blue *Entoloma virescens*, an oval metre of pale *Panellus pusilus* on the trunk of a superb *E. bosistoana* which also supported seventy four *L. kammala* radiating from its base. The 2008 follow-up recorded very few fungi despite 363mm rain in the fruiting season but only 11 mm pre-season in January.

The mushrooms and other forms we recognise belonging to Kingdom Fungi are more allied to animals, but slime moulds, which are usually discussed with fungi, are aligned to Kingdom Protocista. Teresa Van Der Heul has been doing pioneer work recording and photographing these in a short rainforest gully in Bodalla Forest. The gully is covered in rotting mossy logs and detritus, a rich habitat which supports an array of weird forms and wonderful colours, often so small as to be hard to see. Several species are first discoveries.

Informal surveys have also been done at Gulaga (Mt. Dromedary) in Gulaga National Park. This is a unique volcanic mountain extensively mined in the nineteenth century. In this southern rainforest, which merges into wet sclerophyll on the higher slopes, there has been a vigorous 100 year regrowth. In a good season fungi are abundant in the deep, moist ground litter and fallen debris. At their different stages of growth mushrooms and slime moulds are each a food source and habitat for insects such as flies and beetles, arthropods and slugs. Potoroos, bandicoots and lyre birds are recorded eating small underground fungi (truffles).

While site specificity was recorded at the Meringo location, there is a big group which may not be so particular with species common to many broadly described soil and vegetation types such as 'pasture' or 'eucalypt forest'. In the former one may expect to see *Agaricus* spp.. *Cyathus stercoreus* may be on herbivore dung including dung of grazing kangaroos. The generic description of 'eucalypt forest' will have a range of fungi from tiny, fragile *Mycena* spp. and the exquisite *Cortinarius albobolacius*, to big bunching *Gymnopilus junonius* (food for slugs and flies) - pictured above. And where the feral pine trees grow there is a good chance of observing its soulmate *Suillus*.





Presently, the enthusiasts who are generously contributing to knowledge of fungi are at an exciting stage of discovery because in the South East Region of New South Wales, and, as far as the writer knows, these records are among the first. There are thousands more to be found. There is an urgent need to know what and where are our regional fungi. They well may be lost before they are discovered. Fungimap, Royal Botanic Gardens, Melbourne, is mapping Australia-wide the natural distribution of this most important of living organisms. Locally, the Herbarium of the Eurobodalla Regional Botanic Gardens, Batemans Bay, holds 800 collections of fungi from its catchment.

1. *The Chatham Park Fungal Survey 2002-05* N.Baxter, R.Baxter, R.Corryingham.
2. *Informal Survey of Macrofungi occurring in Two Neighbouring Locations at Meringo 2007*. R.Corryingham

Other fungi species in survey area



Coprinus disseminatus



Macrolepiota dolichaula



Trametes versicolor



Bolotellus emodensis



Podocypha petalodes



Dermocybe sp



Paecilomyces farinosus



Calocera sp on *Casuarina glauca*



Ramaria subaurantiaca

Fungi and orchids

Cathy Powers

Cathy is a photographer who lives within the foothills of the Brisbane Ranges. She has spent many hours roaming the National Park taking wonderful photos. Terrestrial orchids are her favourite subject.

A sweeping statement could be made about fungi – ‘Without FUNGI many inhabitants of our world would be non-existent including flora, fauna and even us, humans’.

Whenever I think of fungi, I have visions of a little pixie sitting atop a toadstool.

Obviously this indicates the era of my childhood. Mature age has changed that perspective and retirement has allowed for a hobby of macro photography and orchids. How does this relate to fungi you might ask? Well, while looking close to the ground for small terrestrial orchids it is amazing what other subjects one finds to photograph.



Part of my interest with orchids lies in the interaction between orchids and pollinators. Orchids, beautiful and interesting, are some of the most devious plants when it comes to attracting a pollinator. They use appearance, odour, structure and even nectar to attract the insect. One orchid type that may use this deception of appearance/structure or odour (similar to fungi) to deceive insects is the Helmet Orchid.



Helmet Orchids (*Anzybas*, *Corybas* & *Corysanthes*) are pollinated by fungus flies and, to this end, may mimic fungal growth. Flowers of some species have a fungal type odour. The orchids grow in damp areas during the winter months when there is an abundance of fruiting fungus and the flowers are usually small, close to the ground and can even have the appearance of small toadstools.

Corybas acutiflorus



Corysanthes diemenica



Corysanthes incurva

Fungi have learned to live without chlorophyll, cannot produce their own food and are recognised by their lack of green.

Saprophytes are also without chlorophyll and the *Gastrodia* species (Potato Orchid - pictured) is one of the few listed as completely saprophytic. It is leafless and lacks green; the large fleshy rhizome rarely has roots but instead has patches of hair-like fungus. The orchid is dependant on this fungi to act as an intermediary allowing communication with the soil to enable absorption of water, mineral salts and carbon compounds.



An established fact is that terrestrial orchids require a mycorrhizal fungi to exist. It is not visible to the naked eye, like all microfungi, but still exists in the soil. The relationship between orchid and fungi starts from the very beginning of the orchid's existence.

Another known fact is that orchid seeds are some of the smallest of plant seeds. Their tiny size and corresponding light weight facilitate wind-aided dispersal but this benefit comes at a cost. An example of this is the *Dipodium roseum* (Rosy Hyacinth Orchid - pictured).

The seeds are so minute that they have almost no nutrients to support the growth of an embryo.

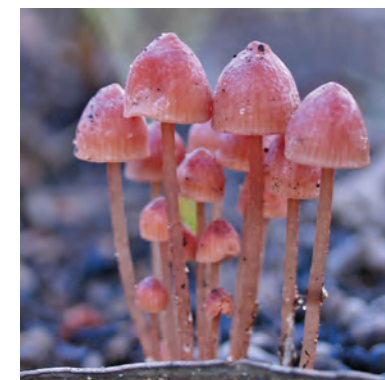


Orchid seeds

Because they cannot germinate and grow on their own, they rely on certain fungi to supply water and nutrients.

Something to consider when it comes to deception is with the fungi relationship. It appears that the fungi gain nothing by assisting the orchid – it is purely a one-way street.

The question posed for further study would be 'Why does the fungi act in such a way?' At least some of the fungi involved colonize and decompose decaying wood. Could the orchid 'trick' the fungus into inserting its growing filaments into its seed and roots by mimicking the chemical cues provided by the decaying wood? Food (pardon the pun) for thought and possible investigation by others who use microscopes instead of cameras to search for answers.



Myco-Mimicry

Don Gover, Additional material by Merle Thompson

Don Gover is Secretary of the Sydney Fungal Studies Group Inc

The diversity of life forms found in both the fungal and plant kingdoms provides a high probability that similar physical life forms, will be found in both kingdoms.

The oldest known fossil fungus is probably from the Devonian (417 to 354 Million Years ago) from Aberdeenshire, Scotland.

While the fungi evolved quite early, it was the appearance of flowering plants about 125 million years ago and the advent of parasitic plants, both having similar lifestyles, that has given rise to the convergent evolution of some fungi and plants.

The eons since their first appearance has allowed both fungi and plants to radiate into all manner of lifestyle niches. To survive in that niche, a primary need for any organism is to have a fitness such that it fulfills the necessary functions for it and its progeny to survive in that niche.

As such, the generation and dispersal of propagules for an organism is an important reproductive function; in order to maintain the species, extend the existing habitat range and also to spread genetic variability, when it occurs, throughout the population.

Dispersal may be achieved by the physical mechanisms of gravity, wind, water and animals. Also, many organisms may have active mechanisms to generate and affect release of their propagules, which are then dispersed by these external agencies.

To fulfill its reproductive function an organism's fruiting body needs to utilise these dispersal agents and to be positioned and have a structure such as to allow the fruiting body of the organism to be exposed to these external physical agents.

Many macrofungi have a structure that provides the function of elevating the spore-bearing part of the sporophore to a position, generally above soil level, where the spores may be exposed to external dispersal agents.

Vascular flowering plants that parasitise the roots of host plants mimic closely the lifestyle of many macrofungi and, similarly, need to have their flowers exposed to these above ground agents for pollination and dispersal.

Many parasitic flowering plants are in the Family Balanophoraceae, which may be generally described as being: 'plants that are monoecious or dioecious, attaching to the roots of trees and shrubs by a tuber, which may contain only parasite tissue or mixtures of host and parasite. Slender rhizomes grow from the tuber and form haustorial connections to the host roots. The inflorescence is above ground, arising endogenously within the tuber. Leaves are spirally arranged, without stomata, scaly. Flowers are minute and numerous - some of the smallest flowers in the angiosperms. They are achlorophyllous, need to expose their flowers to external pollinating and dispersal agents and generally are low growing'.



Balanophora sp.

These characteristics mimic quite closely those of many mycorrhizal macrofungi and, as such, the flowers of these plants mimic not only the physical appearance of some macrofungi but have also attractants for pollination vectors.

It was reported in the Sydney Fungal Studies Group Inc.(SFSGI) Newsletter, Vol. 13, No. 5. 2001, that *Thismia clavarioides*, a new species and fungal mimic, was found at Morton National Park near Bundanoon, New South Wales.

The SFSGI Newsletter, Vol. 14, No. 2. 2002, reported that the flowering plant *Balanophora fungosa*, a fungal mimic, was found at Mosman Gore Queensland.

Myco-mimic Parasitic Plants

[Ed: *Thismia clavarioides* was formally described in *Telopea* 9(4) 2002: *Thismia clavarioides* (Thismiaceae), a new species of Fairy Lantern from New South Wales by K.R. Thiele and P. Jordan. This article provides a key to differentiate the species from the other two known species in Australia – *T yorkensis* and *T Rodwayi*. *T yorkensis* is known from two collections from rainforest on Cape York Peninsula in North Queensland.

Thismia rodwayi. (pictured on the next page) has been recorded from widely scattered localities in Tasmania, Victoria, New South Wales, Queensland and the North Island of New Zealand. The NSW and Queensland records are based on a single specimen each, from Werrikimbe National Park (north-eastern NSW) and Kroombit Tops (Queensland).]



Thysanotus rodwayi
Photo: Keith Jesse

Jane Miller of the Blue Mountains APS Group in NSW encountered *Balanophora fungosa* in August 2004.

She wrote: "While I was in Cape York I found some plants which I initially thought were some sort of fungus. The first ones were found very late in the day and had just broken the surface of the leaf litter. A day or so later on a very sunny day we came across more of them only this time they had lifted up from the ground."

Jane's first photo was taken when the plants had just broken the surface. The second is a close-up of the plant after it had become higher above the ground.



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