FUNGI - LIFE SUPPORT FOR ECOSYSTEMS

Fungi are fundamental to the success and health of almost every ecosystem on earth, both terrestrial and aquatic, and essential to the sustainability of biodiversity. However, how often do we consider their existence within a habitat, let alone how conditions could be improved by active encouragement and management of the fungal diversity.

Fungi are perhaps the most unappreciated, under valued and unexplained organisms on earth. When you ask someone to describe a fungus, you will get a variety of descriptions ranging from, mouldy bread and mildew on the bathroom wall, to magic mushrooms and poisonous toadstools. Some enlightened individuals will tell you that fungi are essential for things like bread making, brewing and medicines. However, these are only some of the more visible supporting roles that fungi play. Rarely considered, even in general scientific circles, is that there are many times more fungi than plants on earth, and that each type plays a crucial role in the processes supporting the functioning of major ecosystems.

Fungi are present almost everywhere, in a spectacular array of shapes, sizes and colours, and performing a wide variety of different activities. In 1991 David Hawksworth, a mycologist at Kew estimated the world's fungal diversity at 1.5 million species (equal to the estimated number of all known other living organisms). This was thought at the time to be a radical over estimate, but now other researchers have proposed figures in excess of 13 million. Fungi perform essential roles in every terrestrial, and many aquatic, ecosystems, eg. decomposing dead organic matter to release nutrients, supporting plant life on poor soils by improving the absorption of nutrients when they form mycorrhizal associations with roots, living inside plants as endophytes and forming symbiotic partnerships with algae to form lichens. Any deterioration in fungal populations and diversity can therefore have a considerable impact on ecosystem health, in fact, the loss of lichens from an area is often used as an indication of poor air quality.

What fungi are and how they live provides some insight into the reasons for their significant role in ecosystems. The basic structures of most fungi are microscopic threads called hyphae, which form the active feeding and growing body of the fungus. The majority of the world's fungi are microscopic, and they do not usually produce structures which are visible to the naked eye, unless the hyphae form a thick growth (Often referred to as 'moulds'). However, the most familiar species are those which produce spore-bearing fruit bodies, which are clearly visible to the naked eye. These include puffballs, coral fungi, earthstars, truffles and other forms of mushrooms and toadstools These are the so-called 'larger fungi' or 'macrofungi'.

Some fungi are very adaptable. For example, species of leaf litter decomposers such as the Parasol mushrooms *(Macrolepicta* species*)* and Funnel Caps *(Critoeybe* species*)* which decompose organic matter indiscriminately regardless of source, while others are far more specific and occupy a very restricted niche, like the Ear Pick fungus *(Auriscalpium vulgare)* which is only found on pine cones. There are others that are so geographically and biologically restricted they are considered rare and are now included on endangered species lists. Some fungi are known to have rapidly declined due to pollution and loss of habitat. English Nature is lending its weight to a Biodiversity Action Plan which aims to conserver 40 species across England.

Decomposition and nutrient recycling

One particularly crucial role of fungi is in the transport, storage, release and recycling of nutrients. Nutrient cycling - the continuous supply, capture, replenishment and distribution of carbon, nitrogen and minerals - is fundamental for the ongoing health and vitality of all ecosystems. In woodland ecosystems, a substantial proportion of the nutrients stored, or in various states of flux, is in living and dead organisms, both above-ground and in the soil. Fungi, microbes and fauna may account for much of this nutrient resource in soil, and these organisms work together in a soil based food web to recycle the nutrients. They expedite crucial transfers and transformations of nutrients within micro habitats, including transfer from leaf litter, twigs, branches and logs into soil, and from soil into plants. As a result, soil organic matter and nutrient availability to plants is entirely dependent on the activity of soil organisms such as fungi.

The ability of fungi to decompose major plant components - particularly lignin and cellulose - is the basis of their organic recycling role. Without decomposer fungi, we would soon be buried in litter and debris. They are particularly important in litter decomposition, nutrient cycling and energy flows in woody ecosystems, and are dominant carbon and organic nutrient recyclers of forest debris.

Fungi are particularly valuable in acid soils, where the low pH makes it difficult for the survival of other organic decomposers such as bacteria. Bacteria release nitrogen in the form of nitrate which is easily leached from the soil and therefore lost to surface roots. However, the fungi that break down the organic surface litter release nitrogen into the soil in a form of ammonium nitrate which is less mobile. This could be very important to the successful establishment of young trees and to the sustainability of the ecosystem as a whole.

Mycorrhiza - 'fungus-root'

The transformation of nutrients and their transition from soil into plants is an essential component of ecosystem nutrient cycling which could not be achieved without the fungi. 'Mycorrhizal associations' form fungus-root systems which are far superior to roots alone. Many of the world's plants are partnered by mycorrhizal fungi, both in natural ecosystems and in agricultural or forestry crops. The fungi have a mutually beneficial relationship with the plants, thanks to a two-way exchange that occurs in modified roots known as mycorrhiza, (literally 'fungus-roots').

Carbohydrates from the plant are transferred to the fungus, while soil nutrients such as phosphorus are transported from the fungus to the plant. Mycorrhizal fungi are central to the processes of nutrient capture and recycling for most higher plants in low nutrient soils, as they assist in the acquisition of scarce nutrients and improve their absorption by the plant. Networks of fungal hyphae radiate outwards into the soil from mycorrhizal roots, forming a vast mycelial infrastructure capable of absorbing soil nutrients far more efficiently than plant roots alone.

The fungi act as an extension of the root system, resulting in improved nutrient uptake for the plant. This is particularly important for soil-immobile nutrients such as phosphorus. In woodland soils, where plants compete for available nutrients that may be in short supply, this association can provide a vital support system to help maintain the stability of the ecosystem.

Mycorrhiza are grouped into two main types. Ectomycorrhizae occur predominantly in association with woody plants, including many of the world's major forest trees. The fungus forms a sheath around the fine roots of plants, penetrating between the outer cells, forming a Hartig Net. A diverse range of fungi form ectomycorrhizae, and most of these produce large fruit bodies. The second type, endomycorrhiza do not have a sheath, but the hyphae penetrate both inside and between the plant root cells. Fewer species of fungus form endomycorrhiza than ectomycorrhizae, and endomycorrhizal fungi do not generally produce large fruit bodies.

Among trees, mycorrhizae are a major part of the strategy for capturing, taking up and recycling scarce nutrients, and well over 1000 species of mycorrhizal fungi may be associated with them. Living and dead fungi, microbes and fauna may account for much of the soil nutrient resource in forests and woodlands. Mycorrhizal fungi may also buffer plants against environmental stresses such as disease, for example by protecting plants against pathogens, by increasing host vigour, and by acting as barriers, actively competing against the intruders.

The fungus inside - Endophytes

Still unknown and unexplained, the unseen world of fungi living inside plants as an inconspicuous embroidery of threadlike filaments, provides yet another dimension to the fungal support system. Plants are not just single organisms, they are entire symbiotic systems. Virtually every plant species researchers have examined has fungal endophytes including several fossil plants related to club mosses. We have not even begun to understand the complexities of their relationships. Some are thought to help with the storage and distribution of nutrients and carbohydrates around the plant, while some are pathogens waiting for the time to strike when the conditions are right, others may act to defend the plant by producing toxins that make the plant distasteful to herbivores.

This fungal world within plant leaves, stems and roots, went largely unappreciated until 1977, when researchers found a grass endophyte to be responsible for many livestock poisonings, in both cattle and horses that eat its host, a tall fescue grass. Research in Europe has found 40-70 species of endophyte in 11 different trees and a further 400 associated with grasses.

Endophytes have been found to play a crucial role in the production of extremely beneficial chemical compounds. For example, the cancer-fighting compound taxol, which was originally derived from the Pacific yew, has been found to be a product of endophytic fungi. Some of the most recent research, reported in the New Scientist in April 2000, found not only that multiple endophytes in various yew species produced taxol, but that other fungi in wholly unrelated plants do so too. Since taxol has antifungal properties, particularly against 'water moulds' (not true fungi), it may help keep pathogens at bay and strengthen the plant's defence system. However, a lot more research is needed as taxol may not be the most effective of organic compounds. The potential for finding something far better and much more effective can not and should not be overlooked.

What now ?

Despite their central role in ecosystems and their applications in biotechnology, knowledge about fungi remains at a low level. For example, it has been estimated that only 5% of the World's fungi have so far been discovered, and for most of these, little is known about their biology. If we don't know what they are, how do we know what they do, and what capabilities we could be harnessing? Our lack of knowledge may relate to the inconspicuous nature of many fungi. Most are rarely seen, and those producing conspicuous structures appear fleetingly, at unpredictable and irregular intervals.

The masses of fungal hyphae that spread throughout the soil and into the plants themselves are responsible for keeping the entire ecosystem in healthy order. In the deep layers of organic litter found on the surface of woodland soils, the decomposer fungi and those associated with roots as mycorrhizae, form an interlocking web of mycelium which binds this organic horizon together.

Organisms killed by pathogens contribute organic matter for nutrient cycling. Fungal pathogens of trees produce gaps, contributing to natural ecosystem dynamics, creating cavities in trunks and hollow logs, used by native animals, and accelerating the return of woody organic matter to the soil. Furthermore, some pathogenic fungi are used as biocontrol agents - a good alternative to chemicals for controlling weeds and pests.

Fungi need a constant supply of organic matter to survive and thrive. The nutrient cycle relies on the reintroduction of dead material to provide a constant source for the fungi to decompose. In an existing woodland the organic horizon is topped up each year with falling leaves, but in our parks and gardens, or on new planting schemes, this source of nutrients is either non-existent or is removed as over enthusiastic gardeners remove all the autumn leaves. In these situations the application of an organic mulch becomes very important and will improve the quality and productivity of the soil.

The recognition of fungi in ecosystem restoration and conservation is long-overdue, and accelerated studies on fungi are now needed, not only so that we may learn to harness more of them in more ways, but also to gain a better understanding of how ecosystems operate. Perhaps most importantly, we need to learn how to lessen human impact on ecosystems and to implement more efficient rehabilitation regimes on degraded land.

PHOTOGRAPH F1

(Photograph of - Jew's Ear *(Auricularia auricula-judae)* Photograph taken by Andrew Cowan

This common fungus found on dead wood in broadleaf woodlands, earns the nickname from it's ear-like shape with wrinkles that look like veins and a hairy inner surface.

PHOTOGRAPH F2

(Photograph **Fly Agaric *(Amanita muscaria)*** is often found in association with Birch *(Betula* species.*)*, and could be responsible for the trees success as a pioneer on exposed sites, such as open heaths. The above photograph was taken on the edge of a sandy ride across Limpsfield Chart on the Kent Surrey border, by Andrew Cowan

PHOTOGRAPHS F3 & F6

(Photograph of - Honey Fungus *(Armillaria* species.*)* Photograph taken by Andrew Cowan)

This infamous group of fungal species are the torment of many gardeners. However, only two or three of the known varieties are thought to be actively parasitic and even then for only some of the time.

PHOTOGRAPH F4

(Photograph of - *Ramaria stricta* Photograph taken by Andrew Cowan

This is an uncommon fungus normally found on or near stumps of conifers and broad-leaf trees in late summer to winter. Seen here growing on a woodchip mulch spread across a garden flower bed, the dense mass of white mycelium can clearly be seen as a system of cords foraging for resources within the mulch.

PHOTOGRAPH F5

(Photograph of - Sulphur Tuft *(Hypholoma* species*)* Photograph taken by Andrew Cowan

This photograph shows Sulphur Tuft growing on an old stump. Some Canadian research appeared to indicate that Honey Fungus *(Armillaria* species*)* could be excluded from stumps of felled trees if they were inoculated by Sulphur Tuft.

PHOTOGRAPH F7

(Photograph of the Oak polypore Photograph copyright Martyn Ainsworth)

Oak Polypore *(Piptoporus quercinus)* photographed in July fruiting on exposed oak heartwood of a standing living tree in Windsor Forest its principal UK stronghold- The fruiting bodies are very reminiscent of the Birch Polypore *(Piptoporus betulinus)* in both shape and texture. The colour of the upper surface has been described as similar to creme caramel, but darkening with age. They can appear on trees, in July and August, from just above ground level to a height of 12 metres, on fallen trees, in crevices between root buttresses as well as inside hollow trees. All the fruiting bodies have been found on oak *(Quercus robur)* on dead wood of either a dead or living tree, as individual brackets, in layered tiers or in clusters. Anyone who comes across this rare fungus should contact Carl Borges of English Nature on 01-206-796-666 (carl.borges@english-nature.org.uk), but specimens must not be removed or displaced as they are protected under the Wildlife and Countryside Act 1981.