Fungi, fast food of the forest

A golden-mantled squirrel snacks on hypogeous fungus.

Inset: The long-footed potoroo, a fungi-eating specialist.

Ten years ago, while walking through Washington's Cascade Mountains, ecologist Dr Steven Cork watched a ground squirrel unearth and eat fungi. 'That's interesting,' he thought. 'Why would you want to eat that?'

Cork was on sabbatical at the University of Washington, and his studies weren't centred on the eating habits of squirrels. But he kept wondering why the squirrel selected a food that he understood to be barely digestible, let alone nutritious. Studies by the university's Professor GJ Kenagy, had found hypogeous (below ground) fungi (or truffles) to be a major part of the golden-mantled ground squirrel's diet. Cork then teamed with Kenagy to evaluate fungi as a food source, and discover why the squirrel (*Spermophilus saturatus*) found them so tempting.

The study compared the digestibility of a fungus called *Elaphomyces granulatus*, with a range of other natural plant foods. At that time, hypogeous fungi were known to contain high levels of nitrogen, vitamins and minerals, and to be major dietary items for many rodents and other small mammals. For these reasons, ecologists had assumed they were highly nutritious.

Cork's chemical analysis of *E. granulatus* sporocarps (fruit) confirmed the high nitrogen levels, but found that most was stored in the totally indigestible spores or otherwise protected by the relatively indigestible cell walls of the peridium (outer shell). Even though the squirrels ate the peridium in preference to the spore-laden core, the fungus offered only a maintenance ration, its energy content similar to leaves, but much lower than nuts and seeds.

This finding made the second question more intriguing. If the nutrient availability of fungi was so poor, why did the squirrels like them so much? Well it seems that fungi have evolved as the forest-floor equivalent of fast food: they're abundant, they're ready to eat (much easier than dissecting pine cone), and, to a squirrel's discerning nose, they smell terrific!

Hypogeous fungi have developed these mammal-attracting strategies because they need help to reproduce. 'The fungi produce spores in underground fruiting bodies like little potatoes,' Cork says. 'These smell like garlic or rotten meat.' Animals then spread the spores by breaking them up or eating them and passing them out in their faeces. Cork's study found that squirrels may even assist germination through their digestive process.

Because these fungi form symbiotic associations with trees, their dispersal is important to the forest as a whole. Cork says most forest trees and many other plants form such associations with fungi. The fungi attach to plant roots, their fine strands (hyphae) enhancing nutrient uptake. In return, the tree transfers to the fungi carbohydrates manufactured in its leaves. 'Many trees in north American forests wouldn't grow without fungi,' Cork says. 'And studies in Australian forests have shown that fungi enhance eucalypt establishment and growth.'

Like most ecological relationships, these links have neither beginning nor end. When a forest tree dies and falls, it decays, creating a moist, nutrient-rich environment, ideal for insects and seedlings. But the seedlings also need fungi, conveniently delivered by small mammals, also attracted by the rotting log. Remove the log, the mammals or the seedlings, and complex interaction falls apart, affecting forest health and regeneration.

Learning more about the relationships between trees, fungi and mammals is the focus of Cork's research at CSIRO's Division of Wildlife and Ecology. He has linked up with another ecologist, Dr Andrew Claridge, a post-doctoral fellow with CSIRO and the Australian National University, to study hypogeous fungi and the animals that eat them in Australia's south-east forests. Claridge has spent many years studying fungus-eating mammals in Australia and North America. Their work has focussed on laboratory studies of the long-nosed potoroo, a relative of the endangered long-footed potoroo. They found that unlike squirrels, which are poorly adapted to digesting fungi, the potoroo is a fungi specialist.

'Squirrels and other fungi-eating Australian mammals, such as bandicoots and marsupial mice, don't have the enzymes to digest the fungi efficiently,' Cork says. 'Also, they can't afford the time it takes for this kind of digestion to occur, because their metabolism demands a constant energy supply. Fungi doesn't provide them with enough energy to reproduce. So they also eat more digestible items such as fruit, flowers and insects.

'In contrast, potoroos, bettongs and other "rat kangaroos" have an enlarged stomach, full of the necessary bacteria. And like all marsupials, they have a relatively low rate of metabolism, so can withstand the long digestion period.'

Having discovered this special relationship, Claridge and Cork are expanding their research to surveys of forests in south-east New South Wales. Their goal is to model the environmental variables affecting fungal distribution as an aid to predicting the distribution of fungi-loving animals. They are also investigating the effects on fungi of timber harvesting and fire, what happens when fungi are removed from the ecosystem, and the factors affecting the animals' fungi-eating preferences. All this knowledge will aid the development of conservation strategies for these endangered mammals.

Bryony Bennett