Researching our tropical rainforests

Inside the rainforest, at Mt Speck National Park, north of Townsville.

It is perhaps fitting in our bicentennial year to mention a distinguished personage not unconnected with this fair nation's origins — to wit, one Captain James Cook — and record a seemingly rather trivial incident connected with him that rarely makes it into the history books. In 1770 the intrepid explorer climbed to the top of a grassy hill in what is now far northern Queensland in order to seek a possible passage out of the reef for his ship 'The Endeavour'.

Cook described the hill in his journal and marked it on a map. His originality perhaps wearing rather thin by this stage in his journey, he called the knoll simply Grassy Hill, and it lies outside what is now the aptly named settlement of Cooktown. What is so remarkable about all this is that today most of the grass has gone from Grassy Hill. Instead, tropical rainforest clothes its lower flanks and gullies, and eucalypt forest covers the top.

A photograph of the hill taken in 1914 shows that the upper part was still grass-covered; aerial photos taken at various intervals over the last 40 years show the invasion of the remaining grassland by eucalypts from lower down, and the expansion of the rainforest outwards from protected gullies. This sequence of changes on Grassy Hill has been documented by Dr Geoff Stocker, formerly of CSIRO's Tropical Forest Research Centre in Atherton, some 200 km to the south.

Staff at the Centre comprise a team of scientists studying Australia's small but valuable area of tropical rainforest (when we mention rainforest in this article it will refer to tropical rainforest, most of which occurs from Townsville to Cooktown), and one of several important conclusions to emerge from their work is that the borders of the forest are not fixed and unchange-

A cassowary — an important disperser of large seeds — and, below, a pile of cassowary dung from which seedlings of the silver quandong have grown.

The coppery brush-tailed possum and the male lovely wren — denizens of our tropical rainforest.

able. As the Grassy Hill story illustrates, rainforest can expand and is doing so, quite naturally, in some areas.

The dynamics of rainforest expansion and contraction are worth studying because the forest itself is so important. Although all the tropical rainforest in Australia makes up just under 0·1% of our land area, within it live 30% of our marsupials, 60% of our bat species, 30% of our frogs, 23% of our reptiles, 62% of our butterflies, and 18% of our birds — as well as more than 25% of all our plant genera (see the box on page 20).

The fact that the wet tropics are an unusual environment in this dry continent, coupled with their biological richness, gives them an intrinsic aesthetic value and hence a potential for recreation and tourism. Some of the rainforest is also managed for timber production — a well-established industry. Conflicts between the different types of 'value' put on rainforest are therefore bound to arise. To manage this resource properly for as many uses as possible requires a lot of information about a very complex, interdependent, and tightly connected system of plants, animals, soils, and climate.

One of the difficulties we face in trying to understand this system is time. Although a few rainforest trees may live for 'only' 20–30 years, the majority have life spans covering hundreds of years, and need a long time before they reach the stage where they can set seed. Because of these immense generation spans, the whole system is very ponderous. Just as a giant supertanker at sea takes a considerable period to get back on course if its direction is changed, any problems in this system may take decades to show up. A lifelong study gives us just a peek — a tiny slice of the rainforest's existence, from which we try to deduce its behaviour and predict its response to environmental changes and disturbance.

Because of this limitation, it may appear to us that the system is very stable, whereas in fact over the course of the centuries the forest may well be subtly changing and slowly evolving.

Birds and bees, bats and beetles

It's impossible to understand the life of a rainforest without knowing how pollination and seed dispersal take place. The need to get together for reproduction and for dispersal of the resulting offspring forces plants to make use of some outside help.

Many rainforest plants produce fleshy fruits. Mr Tony Irvine, of the Atherton Centre, along with Dr Mary Willson (of Illinois University), has estimated that, out of a sample of 774 tree species in northern Queensland rainforests, about 84% produce fleshy fruits. This compares with less than 30% of the species in south-eastern Australia.

These fruits can attract hungry animals, and their seeds hitch a ride on the outside or in the intestine of the animals and may be regurgitated or defaecated away from the parent plant. This serves the dual purpose of avoiding competition between struggling seedling and well-established parent, and of allowing the forest species to spread.

The abundance and great diversity of fruit-bearing trees mean that the rainforest can support a good number of fruit-eating animals, mostly birds and mammals — and many of the latter are bats. (Reptiles are few in Australian rainforests and, as far as we know, none eat fruit.)

Now, just as the plants need the animals to act as seed vectors, so the animals require the fruit as a food source. In rainforest, the generally short seasons for most of the trees are so staggered throughout the course of the year that at any given time you will usually find a few species fruiting. Certain times of year are worse than others for the fruit-eaters, but they can generally get by, provided a sufficient variety of fruit-producing plants are present.

Some animals can only use a rather narrow range of plants. But very limiting 'one to one' relationships — where only one animal species eats the fruit of just one tree — don't seem to occur in Australian rainforests, although they are known in other parts of the world. However, some plant species are more important than others because the timing of their seed set means that they can maintain fruit-eaters during lean periods. If human or natural actions reduce the population of these crucial species, then many fruit-eaters will become locally extinct, which may have serious consequences for the other trees that these animals also act to disperse.

Some birds, including parrots and pied currawongs, forage in the rainforest but roost elsewhere. They therefore deposit seeds outside the forest, which is particularly important in helping to spread the rainforest.

It's also possible that a tree may rely on only one animal to disperse its seeds, although that animal may be broad in its tastes. Loss of the animal species may be disastrous for the tree.

We know that in some of these northern Queensland rainforests cassowaries — giant flightless birds like emus — are responsible for eating certain enormous fruits, which no other birds or mammals are able to tackle. (Work by Mr Frank Crome, Dr Stocker, and Mr Irvine has confirmed that cassowaries depend largely on the fruit of rainforest trees for their survival, and that passage of a seed through the gut of these giant birds does not usually affect its germination — see *Ecos* 43.) Loss of cassowaries from an area would therefore mean that any trees there that produce very large fruit would lack an effective means of dispersal.

Such trees may carry on living for hundreds more years, but would be unable to spread. They may not necessarily die out completely, however. Even though the seeds may not survive in the soil long enough to await the death of the parent, some stunted seedlings may persist — inhibited from successful development during the life of the parent either by lack of light or, in some cases, by the parent tree's production of an inhibitory substance from its roots or foliage.

Perhaps paradoxically, some of the animals introduced by Europeans, and so long thought of as pests, may be able to fill certain vacuums and act as useful seed vectors for large-fruited trees. Pigs are an example.

Because they live so much longer than their animal dispersers, trees may lag behind in responding to any changes. For example, animals may become extinct in an area because of climate change during the course of a few thousand years, which represents many generations for the animals but only a few for a tree, and will thus be an insufficient period for it to evolve a new type of fruit suited to the dispersers that remain.

Some trees in our rainforest produce large fruits with, as yet, no known dispersers. Might large animals, now extinct, have roamed the forests in the past eating

Most of the tropical rainforest grows between Townsville and Cooktown.

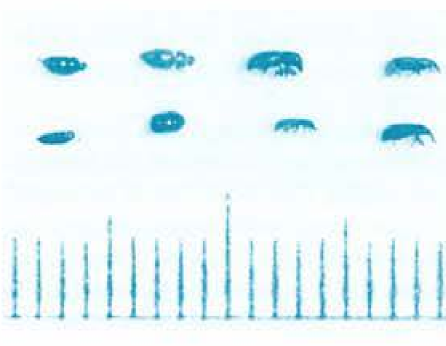
these fruits? Who knows? Although fossil finds in central Queensland have shown that large mammals and birds existed in Australia in the recent geological past, we cannot be sure that they were rainforest-dwellers.

For pollination, trees may use a wider range of animals than for seed dispersal. Many types of insect, as well as birds, bats, possums, and marsupial mice, can act as agents. Recent work by Mr Irvine, in collaboration with Dr Joseph Armstrong of Illinois State University, U.S.A., has shown that very small insects, mainly beetles less than 3 mm in length, are responsible for pollinating several rainforest species that we previously thought were wind-pollinated.

This may be important to the conservation of some areas. If the populations of the tiny beetles succumb to insecticides, then the reproduction of certain rainforest trees — at the moment we are not sure how many may use beetles for pollination — may cease.

Of course, you would not expect insecticides to penetrate deep into a large forest, but much of our tropical rainforest exists in relatively small, isolated fragments separated by agricultural or urban areas. Aerial spraying of a field could conceivably contaminate an adjacent forest fragment.

Some of the micro-beetle pollinators of *Myristica insipida* (the nutmeg). The scale bar shows size in millimetres.



Studies of pollination are also important when considering the possible cultivation and horticultural use of certain forest species. Many exotic fruits originated in rainforest, and we can be sure that some remain there waiting to be found and carefully bred into a suitable form (see the box on page 17). But the plants will be unproductive if the plantation area lacks the right pollinating agent, native to rainforest.

This happened in South American Brazil nut orchards, where scientists showed that the necessary pollinating insect required a sheltered environment for part of its life cycle. The solution was to keep an area of rainforest next to the orchard.

Fire and the edge

Our tropical rainforest can sometimes end abruptly. (It doesn't always; in some parts, it can merge slowly into a different vegetation type.) Of course, it is geographically confined by climate — rainfall and temperature must be high — but climate doesn't change within a few metres and yet, as suddenly as that, dense, wet rainforest can give way to tall, open eucalypt woodland. A difference in soil types seems the obvious explanation.

To check this possibility, Mr Greg Unwin, also of the CSIRO Centre in Atherton, analysed the soil types under the two vegetation communities. He found that no significant change occurred at the boundary, although rainforest may be more complex and richer when growing on basalt soils. However, the top layer of rainforest soil was richer in nutrients than the soil in eucalypt forest, mainly because of the accumulation of a layer of litter that would have burnt in the eucalypt areas. The difference is therefore an effect of the forest type present rather than a cause of it. In defining the borderline, he found that a more important feature was fire.

Although our rainforest lies within what we call the wet tropics, the rainfall does not in fact occur throughout the year, as it does in the truly equatorial tropics, but is quite seasonal. During the drier months — June to November — fires can easily take hold in grassland or in the understorey of the eucalypt woodland. According to Mr Unwin, the occurrence of fire and the local topography together determine the position, and to some extent structure, of the ecotone — the transition zone from one vegetation type to another.

Tall grass becomes flammable during the dry season. If fire ignites the grasslands, it will destroy any small seedlings propagated from nearby rainforest. Thus rainforest

Forest food

As tropical rainforest is so rich in plant species, it is not surprising that among them are some that could be developed as food plants. (This is in addition to the valuable timbers and other products, such as rubber, that come from the world's stock of rainforest trees.)

Several popular fruits (like bananas) and nuts (such as the Brazil nut) are derived from tropical forest plants that have undergone selection for the traits we find desirable — usually increased size and palatability. Obviously the products of 'new' plants found in the forest may also benefit from some selection to enhance their potential, but before deciding on improvements we face the problem of identifying what is edible in the first place.

In Australia we are lucky: the Aborigines have identified many edible plants — for example, the kernels of two Queensland tropical rainforest trees. Mr Tony Irvine, of the Atherton Centre, has investigated the food potential of these plants.

The result is the re-discovery of two very pleasant types of nut — the Atherton nut, or 'black-and-tans', from the tree *Athertonia diversifolia*, and the Kuranda quandong (not related to the quandong fruit of the inland) from *Elaeocarpus bancroftii*. The nuts must be removed from within their fleshy fruits, and can be eaten fresh, or dried and then kept.

Mr Irvine's travels in the forest and knowledge of Aboriginal lore have enabled him also to identify scientifically some edible fruits with unusual flavours. The lemon aspen, for example, is a small white fruit with a very refreshing taste. We can eat it raw, although some may consider it a little sharp, and it certainly makes excellent marmalade. Also tart, the native tamarind has an orange flesh and is rather more acid; however, it has a flavour that, when sweetened a little, would go well in a cordial.

By contrast, *Buchanania arborescens*, which has no common name, is a tree that produces sweet, black, stone-bearing fruits. It belongs to the same plant family as cashews and mangoes. Another sweet fruit, tasting similar to a cherry, comes from *Eugenia reinwardtiana*.

Figs are well known and popular — and we have several species of fig tree, one of which produces edible sweet brown fruit two or three times a year. The tree's

A 2-year old tree of *Eugenia reinwardtiana*, already bearing its sweet cherry-like fruit.

botanical name is *Ficus copiosa*, which means literally 'plentiful fig'.

To close the list of those native rainforest food plants we currently know of, we should include the Davidsonian plum — a large, garishly coloured fruit with a blue skin and bright red flesh. Before eating this one, you need to remove the irritating hairs on the skin. It is decidedly acidic and you may prefer to use it for jam or wine, as the early European settlers did.

(Having tried some of the above fruits and nuts in the course of his research for this article, your *Ecos* correspondent can personally recommend them.)

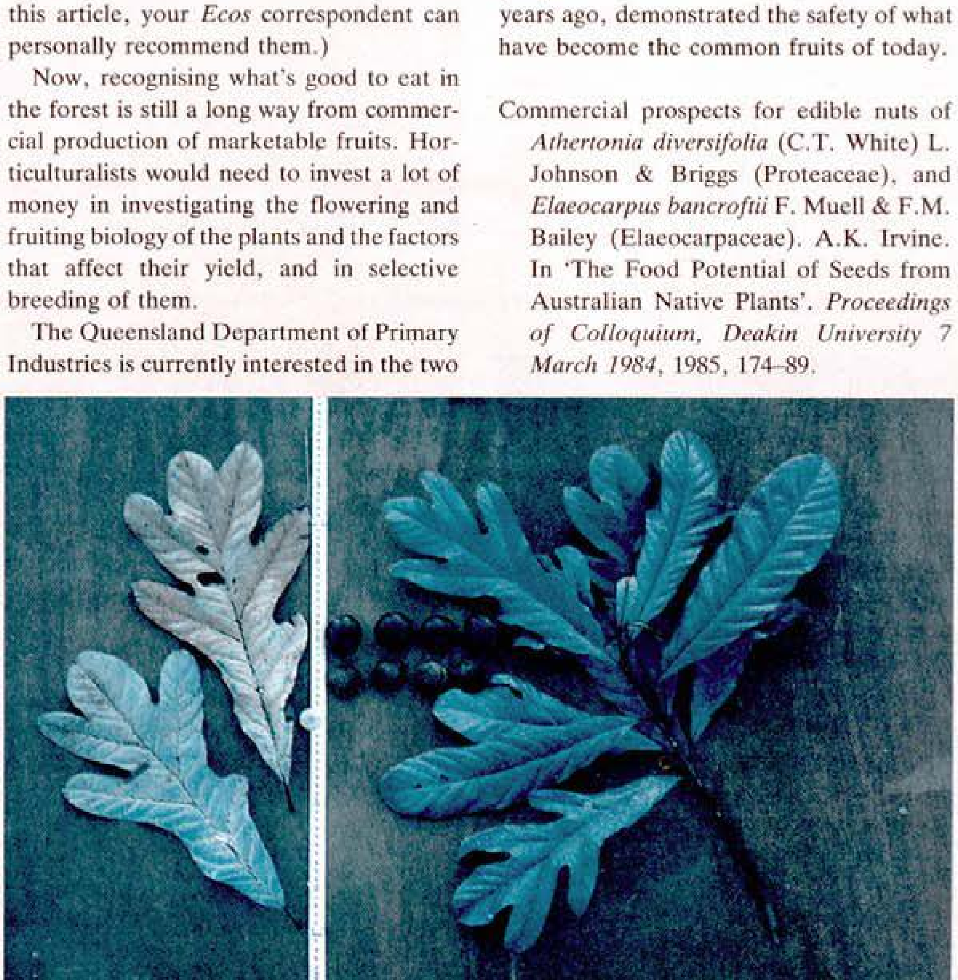
Now, recognising what's good to eat in the forest is still a long way from commercial production of marketable fruits. Horticulturalists would need to invest a lot of money in investigating the flowering and fruiting biology of the plants and the factors that affect their yield, and in selective breeding of them.

The Queensland Department of Primary Industries is currently interested in the two edible nuts, but recognises the problems involved in placing a new product on the market. Macadamia nuts, from a tree native to southern Queensland and northern New South Wales, required many years of developmental work before they became a commercial proposition. Sadly, most of this occurred in Hawaii, following the collection of macadamia seeds by Americans who recognised their potential earlier this century. Although Australia is now producing them, many of the world's macadamias still come from Hawaii! Let's hope Australia won't miss out again.

Athertonia has some advantages over macadamia trees. The fruit ripens more evenly and the shell cleaves into two halves, which may make it easier to remove. And Athertonia could be used for more than just its nuts: the tree itself has attractive foliage and form, which may make it popular as an ornamental, and the flowers attract the domestic honey-bee.

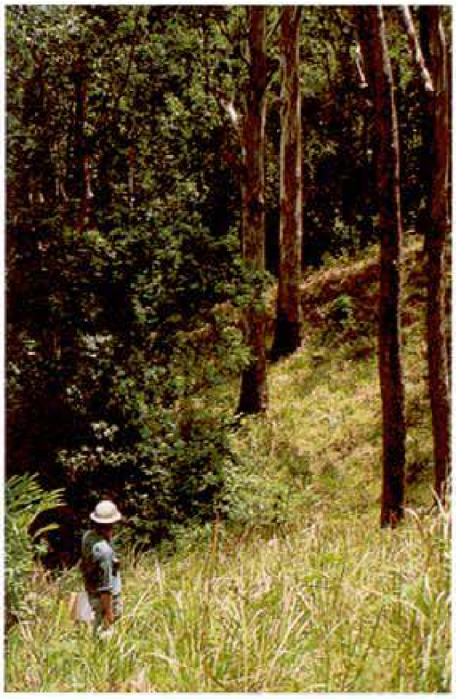
In his research, Mr Irvine has, unfortunately, not gone personally unscathed. On one occasion he became very sick after eating less than 1/2 gram of a fruit that he was investigating. The occasional accident such as this is more or less unavoidable if you really want to discover new sources of food. The rest of us are lucky — we needn't worry about poisoning every time we bite into an apple or banana, thanks to brave people like Mr Irvine who, thousands of years ago, demonstrated the safety of what have become the common fruits of today.

Commercial prospects for edible nuts of *Athertonia diversifolia* (C.T. White) L. Johnson & Briggs (Proteaceae), and *Elaeocarpus bancroftii* F. Muell & F.M. Bailey (Elaeocarpaceae). A.K. Irvine. In 'The Food Potential of Seeds from Australian Native Plants'. *Proceedings of Colloquium, Deakin University 7 March 1984*, 1985, 174–89.



The leaves and edible nuts of the tropical rainforest tree *Athertonia diversifolia*.

Right: **Just how sharp the rainforest boundary can be is seen in this aerial photo. The tall, undisturbed rainforest, with its many different hues of green representing the crowns of various species, is on the left; the open eucalypt forest, with sparse crowns and the yellow dried grass understorey, is on the right.**



The abrupt edge: tall open forest of *Eucalyptus grandis* with a grassy, fire-prone understorey is on the right; rainforest is on the left.

But the border can change; here, young rainforest is encroaching on what was a grassy open forest. The tall poles of *Eucalyptus grandis* are surrounded.

cannot get a hold and expand into a grassy area. A regular, usually annual, burning pattern may become established.

A fire raging in a grassy patch will seldom invade adjacent rainforest, however. With its thick canopy, rainforest can remain moist even in the dry season. The edge may be damaged by fire, but can quickly recover. Fire burns best uphill because the warm air rises and dries out the fuel in advance of the front, and also because the wind tends to carry flames and embers upwards. This further protects rainforest around deep gullies.

Fire is one of the factors (local topography and microclimate are others) that can influence the boundary layer. Here a fire of moderate intensity burns rapidly upslope through the grassy open forest, toward the rainforest edge. Most trees of the open forest and many of the rainforest edge are adapted to this and can regenerate by coppicing.

Although grass can tolerate regular burning and will grow back in the following year, it can't invade the rainforest because light is in short supply beneath the dense canopy. So, a stand-off results — until eucalypts get involved.

Eucalypt seedlings may establish in grassland and survive fires. Then, in the absence of regular burning, the growth of shrubs will eventually shade out much of the grass and the frequency and intensity of the burns will decline. In northern Queensland, tall, open forest composed of *Eucalyptus grandis* may grow in a narrow band adjacent to rainforest. Where fires are irregular, some rainforest species can invade.

After decades, the result, as Mr Unwin has observed, is a hybrid of young rainforest dotted with some tall *E. grandis* specimens. Eventually the old gums die and, as seedlings cannot grow up because of the low light intensity, we are left with pure rainforest, where previously there had been grassland or open woodland.

So rainforest can certainly expand within its broad climatic confines, and the CSIRO scientists think that the sequence outlined above is what must have happened at Grassy Hill. Quite possibly the grass cover

Rainforest flowers — here, the inflorescence of the Queensland maple, famous for its timber and, right, the tree *Syzygium cormiflorum*, which produces flowers and then fruits along its trunk.

there was maintained by the Aborigines who used fire often in order to chase animals out. As the Aboriginal population declined or moved away, following European settlement, so the regular burning on the hill would have ceased and the grassland was doomed.

Climatic influence

In from the humid coast, the Atherton Tableland on which the Research Centre lies is also home to some tropical rainforest. (It held even more in the days before European settlement.) At an elevation of about 700 metres, the tablelands are cooler and receive less rainfall than the coast, and the rainforests contain pockets of eucalypt woodland. Dr Stocker and Mr Unwin have observed that these pockets usually occur downwind of swampy areas that, in winter, can form frost hollows. Frost-browned sedges in the hollows become fuel for fires in the following dry season. The scientists think that their burning then enables eucalypts to establish adjacent to, but downwind of, the swampy areas.

But tropical rainforest, once established, does not necessarily remain forever. The latitudes in which it lies are subject to cyclones. These are a feature mainly of the coastal forest, as the storms tend to lose intensity as they move inland.

Wherever a cyclone hits, however, the forest will suffer damage. Crowns may blow off, or whole trees may fall, bringing others down with them. The resulting destruction deposits a large amount of litter, and leaves gaps in the canopy that allow sunlight to dry out the forest floor.

The dry fuel becomes a fire risk and, compounding that fact, cyclones often precede a spell of hot dry weather. The result is that fires can rage within a rainforest. This does not fit well with the idea of the lush, wet, green jungle, and it is certainly true that fire in a rainforest is not common, partly because the frequency with which any given area of forest suffers badly from cyclone devastation is not high.

If fire does occur within the rainforest, however, it can result in growth of grasses, which increases the likelihood of further fires, and also ensures that they will be more intense. A regular burning pattern, where only grasses survive, could assert itself.

Dr Stocker believes that Grassy Hill was quite possibly forested before Cook's time, and then a cyclone, coupled with regular Aboriginal burning of the resulting grassy areas, converted it. Now, with the decline in burning, it has gone full circle.

This may not always happen. After a fire the rainforest could regrow by coppicing. Whether it did so would depend on the intensity of the fire, and the type of weather afterwards. (Good rains would help.)

Disturbance

Even before the passage of a cyclone, the thick, shady canopy at the top of a rainforest contains gaps. Under 'natural' conditions, death and collapse of trees create variously sized gaps that together may make up about 10–15% of the area of a forest. Furthermore, lightning strikes, landslides resulting from excessive rain, and even the occasional drought periodically disturb and damage parts of any forest.

One of the important facts of any disturbance is that more light passes through to areas previously in deep shade. However, different disturbances will affect the rainforest in different ways.

Small chinks in the canopy, such as those caused by a broken branch, are often filled by the sideways expansion of other trees' foliage into the new space. A gap resulting from the loss of an entire crown will provide a chance for trees lower down, until now suppressed by lack of light, to grow up into the canopy. A gap extending to the floor of the forest can appear when a tree falls or is cut, often damaging others or taking them down with it. In such cases, expansion of existing crowns in the canopy above will not fill what is a relatively large vacant space.

To find out more about what happens then, Dr Mike Hopkins has been studying the characteristics of certain seeds, which can remain viable in the soil to form a 'soil seed bank'. (How this relates to the response to disturbance should fall into place shortly.) Many of the seeds that can last in the soil come from trees called pioneers, which make up about 10% of the 800 or so tree species in our tropical rainforests.

The pioneers are characterised — in general — by a shorter life span (only about 20–70 years) than is usual for rainforest trees, fast growth, and the production of large numbers of small seeds (only a few millimetres across) in succulent fruits. The seeds are nearly always dispersed by vertebrates — particularly birds — and are most

What makes a rainforest?

Some scientists say that rainforest has no precise definition, but certainly the image it conjures up — of a humid environment dominated by a closed canopy of trees — is accurate enough.

Other features include the presence of strong but flexible vines winding their way up trees, and epiphytes — that is, plants that grow on others without actually being parasitic. Many of these are ferns and orchids that grow high up, often in a fork between branches, where dead leaves, dead insects, and water have created a type of soil humus. The epiphytes borrow another plant's support to enable them to reach the light.

Another important characteristic is the presence of many different species of tree — as opposed to an area of sclerophyll woodland that usually has only a few *Eucalyptus* species.

Ground level in undisturbed rainforests is usually sufficiently clear for walking to be possible, although not always easy; but in a gap the dense growth of seedling trees, vines, and herbaceous plants will tend to impede you.

The structure of rainforest and the species within it vary considerably with climate. (Of course, soil type, topography and other factors also determine the presence and structure of rainforest.) The warm and the cool temperate forests lack vines, but may have ferns. In general, the more tropical the rainforest, the larger are the leaves of the plants within it.

Dr Len Webb and Mr Geoff Tracey, at Atherton, have classified the many different types of rainforest that occur in Australia.

But what is so special about rainforest and why should we conserve it?

Your answer partly depends on who you are. For scientists, one of the main reasons is that we haven't yet studied the tropical rainforest enough to gain a full understanding of what is there, and how the whole complex system works. (It may well be that we will never achieve such a full understanding.) We already know that it contains a species resembling the originator of the genus *Eucalyptus* — and the more we can learn about this, the better we will understand our eucalypts.

Primitive forms of other plants are also represented in our tropical forest. Study of them helps shed light over the evolution of land plants, going back more than 400 million years.

Many animal species, too, live only in our rainforests — in this regard, marsupials are particularly important, as Australia is the only country in the world where they exist in such a range of different species and in such numbers, and it is our responsibility to prevent their disappearance. We can best do so by preserving their habitat.

Arguments of a more selfish nature are also important. For some people, the rainforest is a tourist attraction that could form the basis of an industry — and is doing so. The forest is also a source of various products other than timber, which may be important. It would be foolish to destroy it before we have had time to evaluate the potential of its plants, both as novel food sources in their own right and as 'new blood' to hybridise with some of our existing highly selected, and hence often disease-prone, cultivars.

The idea of finding important drugs in a readily usable form in many plants is a long shot, but already a scientist from the National Cancer Institute in the United States has shown that a compound isolated from the seeds of the subtropical rainforest tree *Castanospermum australe* (the Moreton Bay chestnut) can keep alive human lymphocytes infected with the AIDS virus. Maybe this won't lead anywhere, but we'd never have known if the tree had not existed. (Fortunately, the tree in question is not in danger of extinction.)

For some people, one of the most telling arguments for conservation is that 'a thing of beauty is a joy for ever'. Apart from Australia and New Guinea, we know of nowhere else in the universe where we can find tree-kangaroos, white lemuroid possums, dusky rat-kangaroos, Hercules moths (with wing spans of a quarter of a metre), and *Austrobaileya scandens*, one of the most primitive flowering plants in the world, closely resembling plants that lived 120 million years ago. Now that we are confirming the lifeless hostility of the rest of the solar system, it would be a shame to lose all that!

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unusual because they can survive in the soil without germinating for years, whereas seeds of most rainforest trees remain viable only a few weeks.

The stimulus for many pioneer seeds to germinate appears to be a change in the intensity and quality of the light falling on them, sometimes coupled with an increase in the temperature and possibly a decrease in the humidity — all associated with the creation of a gap in the forest. So, are pioneer species important — because of their long-lived seeds — in regenerating rainforest when a gap appears? Most specialists now think they are. But what actually happens out in the field — or, rather, in the forest?

Dr Hopkins and Mr Andrew Graham conducted an investigation in tropical forest near Innisfail, and found that seeds naturally stored in the soil could germinate in gaps to provide seedlings at a density of 200–300 per sq. m. Most of these seedlings represented pioneer species, or early secondary ones.

Of course, plenty of seeds died, either before or just after germination, but in general the numbers of dormant seeds remaining in the soil declined as the size of the gap increased. The highest number of successful germinations occurred with gap sizes of 170–500 sq. m. Larger gap sizes saw a slight fall-off in number, and very small gaps — of the order of 30 sq. m — showed very few successful germinations. Undisturbed soil under a healthy canopy produced none at all.

Large gaps brought about fewer successful germinations because of greater mortality of the seeds or very early seedlings. The scientists believe this is because, in a large exposed area, the extremes of temperature and humidity at ground level become too great. For example, they showed that exposure to 60°C for 1 hour can kill many of the seeds in the soil. Open ground could easily reach such a temperature on a clear day in summer. However, in 'medium-sized' gaps, the nearby rainforest trees provide some shade to prevent complete drying out of the soil, although the necessary change in light levels still happens as no trees grow directly overhead.

Why the lack of seedling survival in very small gaps? The scientists have an answer for this too. They suspect that it derives from the fact that the seeds of the pioneers are small, with scant reserves, and therefore the seedlings are themselves small and weak. They need a good supply of sunlight, which, depending on the season and hence the angle of the sun, they may not always get in a very small gap. Furthermore, observations by the scientists during heavy rain suggest that large drops, accumulated on leaves far above, can fall and dislodge small seedlings.

The role of the pioneers

The pioneer species and their large quantities of small, long-lived seeds perform a valuable service for rainforest. Wherever a 'wound' appears, the germination and rapid growth of pioneers forms a sort of 'scab' to cover over the affected area, protecting it from erosion or, sometimes, the incursion of grasses. Some pioneers also have roots that can fix atmospheric nitrogen into an organic, usable form — a generally useful attribute.

Also, sunlight and high temperatures on exposed soil tend to increase the rate of oxidation of organic material. Pioneer species, by virtue of the speed with which they can grow to form a canopy over the bare areas, may perform a useful job in helping to retain nutrients.

(Recent work by Dr Gavin Gilman, Dr Dennis Sinclair, and Mr Ron Knowlton, of CSIRO, with Mr Murray Keys of the Queensland Department of Forestry, has shown that, in an area disturbed during the process of selective logging, the soil levels of nitrogen, calcium, magnesium, and potassium, although initially reduced, recovered to their pre-disturbance levels, over the whole site, after 4 years. The quantity of organic carbon in the top 10 cm, however, remained depleted by 15%.)

But an area full of pioneer species is not a true rainforest. It lacks the necessary structure and diversity. Once the pioneers become established, other trees — more shade-tolerant — may germinate and, in time and with sufficient light, may grow. After 60 or 70 years, as the pioneers die off the other trees replace them in the canopy. Fortunately, though, the pioneers leave a legacy of their seeds in the soil, ready to respond to a new disturbance. At any time, only a few pioneer trees are scattered within a forest, representing places where small disturbances, like tree fall, have occurred. Nevertheless, as disturbance of one sort or another is always present somewhere, so pioneers have constant opportunities to grow and disperse their seeds.

The existence of pioneer species that can form a scab over a wound seems to be the rainforest's way of responding to local injury. Of course, the scab is temporary. How long will it be until the original forest,

Cyclones can cause severe, but fairly localised, devastation, such as that seen here in lowland rainforest near Babinda. Stems are smashed, large trees uprooted, and canopy vines blown down.

in all its richness, will form again in a cleared area? Dr Hopkins' work in subtropical rainforest has led him to suggest a figure of about 800 years — a long time for us, but certainly not for a rainforest. The important point is that the system can regenerate, and will certainly do so following the particular types of disturbance with which it has evolved to cope.

But the pioneers are not enough by themselves to regenerate the original forest. The vast majority of forest trees do not have their seeds stored in the soil, for the simple reason that their seeds only remain viable for a period of a few weeks. For these species to recolonise an area, a source of fresh seed must be nearby. With an increase in the extent of disturbance, the likelihood that such a seed-source forest will be close enough and will contain representatives of all the necessary species — and that they will all be at an age to breed — greatly declines. Furthermore, if the seed-source forest itself suffers disturbance, or wholesale clearing, then the regeneration process stops before it has finished.

The result is called stagnant (because it is not changing) secondary regrowth. It will never reach the state of 'maturity' that existed before, and certain species will be lost from that area for ever.

Human activity can produce large gaps, and has often fragmented the forest — such that seed-source areas may lie far away from regenerating areas. But if we ensure that in the future our activity produces gaps similar to those that may occur naturally, will it not be possible to log the rainforest selectively — taking out a certain proportion of trees, evenly distributed, rather than clearfalling — and have it regenerate so that our exploitation of it can continue?

To answer this, we have to remember how long it will probably take until an area has completely regenerated. Firstly, can an industry afford to wait that long? And secondly, are the gaps produced by logging really akin to those resulting from natural disturbances?

In the logging process, after a tree is felled it has to be removed. This involves carting it out (which can rip the soil) and making tracks and roads — themselves intensive disturbances that can expose the subsoil to erosion. Also, the relative concentrations of nutrients are altered in the disturbed topsoil. Bulldozers can compact the soil (the precise degree depending on the soil type), which reduces drainage and soil aeration and makes life difficult for growing roots. And finally, removing trees permanently takes away some nutrients from the system.

When a tree falls naturally, it rots on the ground, slowly releasing nutrients into the soil all around it — nutrients that can be used again. Contrary to our expectations when first seeing the lushness of rainforest, the soils on which it grows are often rather poor in nutrients. Compared to a temperate forest, a tropical rainforest keeps a fairly large part of its nutrients up in the trees (the amount varies with different nutrients and soil types), and depends on efficient recycling for new growth to occur.

Just as a farmer cannot forever take from a field without leaving it fallow or fertilising it, so it is probable that we could not continually remove trees from a forest without eventually depleting it of nutrients. More research is necessary on this point, but it seems that, to maintain the yield, it would be necessary to look upon the forest more as a farming system, and replace stolen nutrients. Doing that may prove expensive (as may repairing physical damage to the soil!), but with rainforest so scarce on our continent any timber taken from it perhaps deserves to be priced very highly — a fact that would also reduce the demand.

At the moment, we just don't know enough to answer with confidence what we can do to rainforest without causing damage.

Before leaving the pioneers, let's make one final point: if they have such marvellous physiological attributes as rapid growth, should we not make use of them? In fact, many grow well commercially, and they are good for rehabilitating degraded areas. Balsa — the very light wood — is a pioneer

Lake Eacham on the Atherton Tableland. The sediment at the bottom of this deep lake contains a pollen record of the vegetation that has grown in the region over tens of thousands of years. From this, we know that the lake was not always surrounded by rainforest as it is now.

from the Amazon, and another pioneer, *Acacia mangium*, is used for timber in South-East Asia. The only problem with pioneers is that many of them are relatively small trees.

Fragments

It may seem paradoxical, but many rainforest species are naturally rare in the very areas in which they occur in greatest abundance. This is because the presence of so many species of tree in any one area leaves little room for many individuals of one of those species. In other words, species diversity is high, but individual density can be low. This is important when we come to consider the best way of preserving the rainforest in all its richness. If we set aside reserves of too small an area they will not contain representatives of all the species — and several individuals of a species need to be present to assure it of a sound future.

Animal populations also require a minimum area to ensure maintenance of species diversity. We don't yet know enough about the size of such an area, but we have a clue from this interesting example from overseas: the rainforest on Barro Colorado Island (in Panama) was isolated by the rising water of Lake Gatun in the early part of this century. The island is 15·6 sq. km in area, but, although this may seem large, by 1970 22% of the bird species originally present had disappeared.

Much wildlife in rainforests is restricted to it. When forest is cleared, nothing similar to the original conditions remains. The fauna will be unable to survive in the new habitat — be it agricultural or grassland — that replaces the rainforest. By contrast, when we chop down the trees of an open woodland, little change occurs to the ground cover, and the animals that live there can continue to do so after the felling. A divided rainforest may mean complete separation and hence isolation for the creatures of the forest fragments, whereas the fauna of an open woodland are often able to move from one fragment to another across grassland not dissimilar from that at the base of their wood.

The past and the future

Thanks to the abundance of pollen produced by so many rainforest species, we can trace the history of our tropical forests back thousands of years. Pollen has been continuously falling into long-lived lakes and accumulating in the bottom sediment. Using cores we can now retrieve it and, by viewing the preserved pollen grains, can identify many of the species that produced them. (The sculpted patterns on the outside of the grains are often species-specific, although it takes an expert to identify them.)

Dr Don Walker and his team at the Australian National University in Canberra have been sampling in the lakes of the Atherton Tableland. The pollen record, combined with other data, suggests that rainforest vegetation has been growing on the Tableland at least since 200 000 years ago. But the important point is that this forest has not been there continuously. For a period of 20 000 years — from 27 000 to 7000 years ago — the pollen present did not come from rainforest species. The dominant vegetation then was woodland and savanna.

Nor was the rainforest that did occupy the area for so long of a fixed changeless type. For the bulk of that time it differed very much from the forest we have known in the recent past. (Certain species can be traced almost continuously throughout the time span, but the species associations changed.)

The important concept to come away with is that the present rainforest is not an unchanged relict from time immemorial. These findings are repeated elsewhere in the world, too. Some scientists have estimated that 20 000 years ago the world's rainforest occupied only one-quarter of the area that it does today. We know that the earth's climate has often changed, and it seems likely that this has influenced the area conducive to rainforest survival. Many millions of years ago, Australia was a wet continent, and forests covered most of its area. As the climate changed, so forests died out in all but the wettest regions. In this sense, today's rainforests represent the descendants of the original Australian forest millennia ago.

In more recent times, which we can follow with pollen analysis, many researchers believe that the forest in northern Queensland underwent a period of contraction. This seems to have finished about 70–100 centuries back. Small pockets of the old rainforest probably survived the hard times in more suitable areas, such as protected gullies or particularly wet mountain-tops, which we call refugia. Conditions of the last few thousand years have been suitable for rainforest expansion, and, in undisturbed areas, that is happening right now.

Human interference has long affected rainforest; there is little doubt that regular Aboriginal burning regimes prevented its establishment in some areas. Currently humans do more than merely prevent its establishment — we are actively removing or changing what is there. It is encouraging that Grassy Hill has become a rainforest hill in the last 200 years — but 200 years hence how much of what is for Australians a very unusual and special ecosystem will remain in our land?

Roger Beckmann

More about the topic

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