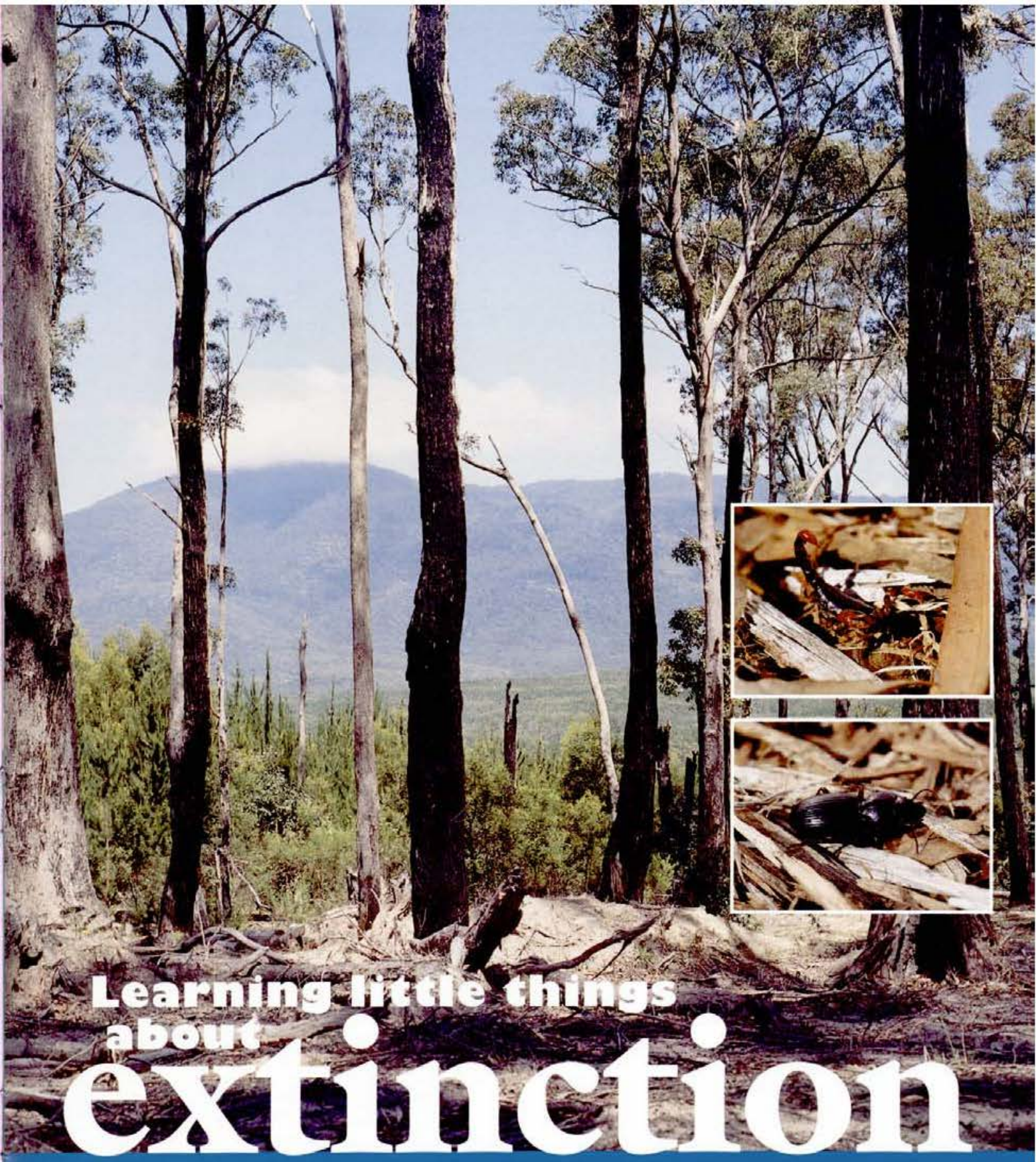


Learning little things about extinction

Main picture: Wog Wog Mountain stands implacably overlooking Chris Margules' remnant habitat patch experiment.

Insets: Hardy residents of the remnant forest, the scorpion (*Cercophonius squama*) and the carabid beetle.

In the mid '80s ecologists began studying the effects of habitat fragmentation on 800 insect species. Twelve years and half a million specimens later, they have to admit that science is not a patch on nature. **Alastair Sarre** reports.

Wog Wog Mountain sits calm, dark and shrouded in cloud, overlooking a battlefield. We're in that most famous of forests in south-east New South Wales, Coolangubra, which has seen so many skirmishes between conservationists and loggers in recent years.

The forest is quiet now; much of it has been made a national park, and the protagonists have moved elsewhere. But nearby, on some odd, square patches of native bush in the midst of pine forest, another battle is going on: the struggle of populations against extinction.

The patches are part of an extraordinary experiment created by CSIRO scientist Chris Margules. The experiment began in 1985, but the battle dates back to January 1788, when Arthur Phillip's motley collection of settlers took their first nervous steps onto the Australian continent.

Axes and saws did the damage early, but in time Australia's European pioneers used a suite of machinery in their charge across the continent. Vast tracts of bushland were cleared and carved into blocks. Embryonic modern Australia stamped its imprint on the landscape so indelibly that you might think the original had vanished completely.

But it hasn't, not quite. Fly over Australia's agricultural and suburban heartland today and you'll see that the open spaces are studded with little patches of bush. They vary in size, from a few trees huddling in the corner of a paddock to larger tracts that take half a minute or longer to fly across. It might remind you of the face of a man who has shaved in a hurry. The tufts he missed have sharp, angular boundaries and they seem vulnerable to the next pass of the blade.

When you realise that these tufts might be all we have left of the original vegetation of an entire region, they suddenly take on special significance. They might be the last strongholds for dozens, hundreds or even thousands of plant and animal species that otherwise could have disappeared when the bulk of their habitat was destroyed.

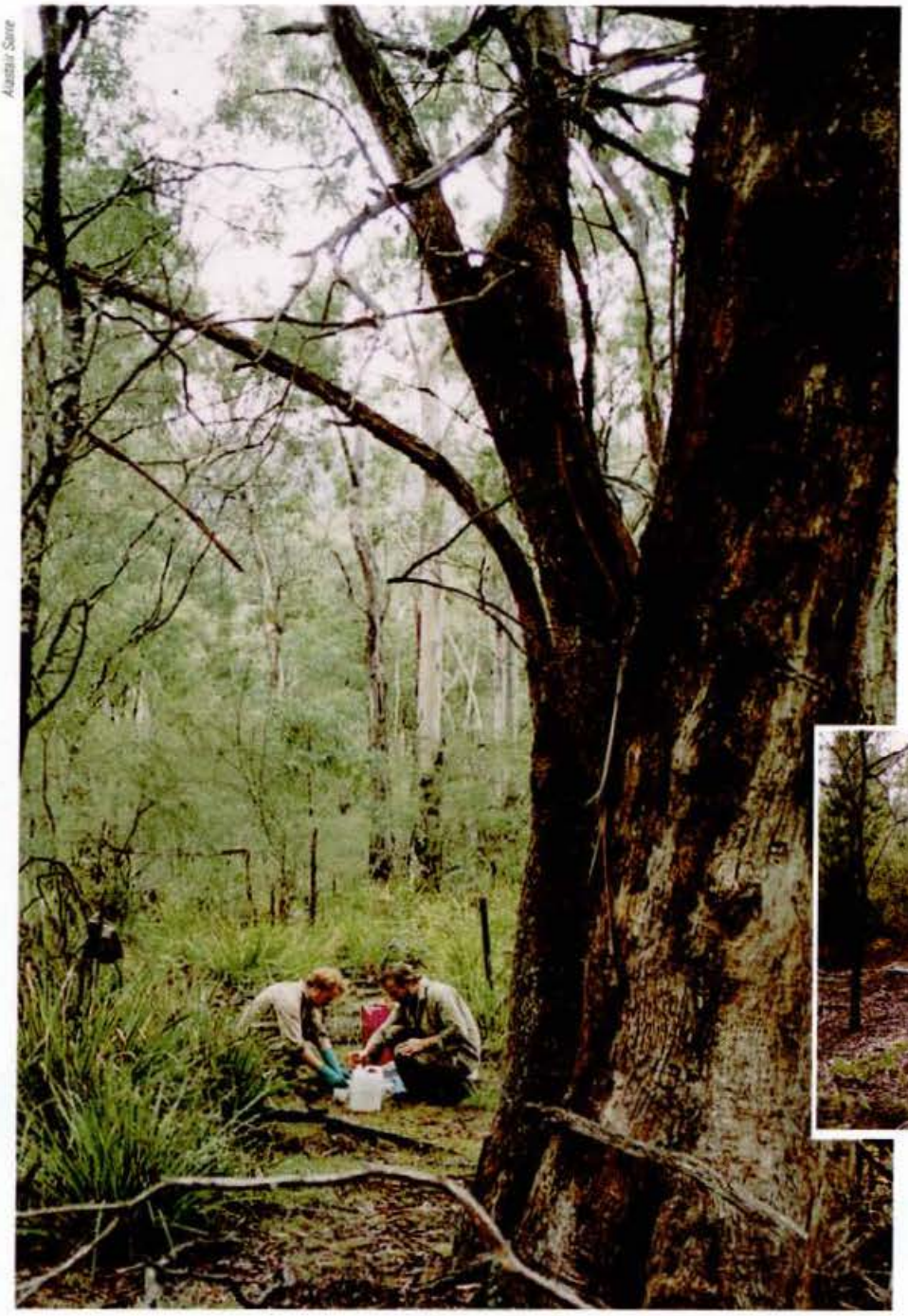
What is happening in these remnant patches of bush? What has the act of fragmentation done to them? Are species persisting, or are they gradually going extinct? What is their conservation value, and how can it be enhanced?

Questions such as these were being asked with increasing urgency in the late 1970s and 1980s. They coincided with debate about an intriguing idea laid out in *The Theory of Island Biogeography*, a book by two leading biologists, Robert H MacArthur and Edward O Wilson.

It was a seminal work that brought about a fundamental change in the science of ecology. The basis of the theory is this: the number of species on an offshore island is a function of the size of the island and the distance it is from the mainland. While species composition might change as species go extinct and others colonise, the total number would stay the same depending on distance and size.

Conservation biologists quickly realised that the theory could have implications for the persistence of species

Alastair Stone



Above: The shoreline of a remnant patch in a pine forest sea some 10 years old.

Left: CSIRO technicians Stuart Doyle and George Milkovits check pitfall traps on a control plot in the national park.

These two aerial views, one taken in 1988 (inset) and the other in 1995, show the changing nature of the pine forest 'sea'.

Science by design

THE complexity and diversity of nature makes it a difficult beast to study. Habitat is variable and can change dramatically in both space and time. Because of this, the science of ecology demands careful experimentation.

One of the most impressive things about the Wog Wog patch experiment is its design. Despite budgetary and logistic limitations, it has several features that help ensure meaningful and useful data.

The first of these is replication. The experiment was designed originally to test the theory that remnant size would determine the number of species that survived fragmentation. Thus, there are three remnant sizes. But what if the effects observed were not an effect of fragmentation but reflected some anomaly in the landscape? Replication – the multiple repetition of treatments – helps protect against this. In the Wog Wog patch experiment, each size class is replicated four times in the treatment and twice in the controls.

The experimental design of the Wog Wog Patch Experiment showing all six replicate blocks, four in a 'sea' of pine forest and two in the Southeast Forests National Park.

The use of controls is the second important feature of the experimental design. To be absolutely sure that an observed effect is due to the treatment (fragmentation), we need to compare what is happening in the fragmented plots with what is happening in the unfragmented landscape. The Wog Wog patch experiment has two replicates of controls in the contiguous forest.

These have already been useful. There was a dramatic increase in the numbers of amphipods collected immediately after fragmentation. The impulse would be to call this a treatment effect: amphipods are favoured by fragmentation. But similar increase was observed in the controls.

In other words, whatever caused an increase in the amphipod population, it was not the fragmentation itself. Indeed, by comparing the increase in the treatments to the increase in the controls, it can be seen that, relative to the controls, numbers in the treatments have decreased. Amphipods are, in fact, vulnerable to fragmentation.

The third element of the design was 'before and after' measurements. Monitoring began two years before the treatment, so it is possible to compare what is present now with what was present before fragmentation.

According to Chris Margules, the inclusion of these three features in the experiment have been well worth the investment in time and money. For a start, they make possible the use of advanced statistical techniques. They have also made the experiment robust enough to cope with the changing aims of the experiment.

The combination of replication, controls and before and after measurements also makes the experiment unusual in ecology.

'In all modesty I don't know of any other long-term experiment like this that is as well designed,' Margules says.

Which makes one wonder about the quality of some of the results that have become articles of faith in science.

'It makes me wonder too,' says Margules. 'I guess replication and other aspects of experimental design often fall into the too-hard basket. People don't think it through. They say, 'well, this is going to cost a fortune, it's going to be too hard to do'. So it gets forgotten.'

In an era where science, and ecology in particular, is being asked to do more with less, scientists must surely be tempted to become even less strict about experimental design. But at what cost to our understanding of nature?

Appreciating the art of biodiversity

Chris Margules.

CHRIS Margules is a soft-spoken man. His ruddy face is framed by a calm, greying beard and he wears half-moon spectacles that suit his thoughtful demeanour. He seems tired by his exertions on a project he has nurtured for well over a decade.

'To some extent it wears me down. It's a very big job to keep it going in the face of funding cuts, but I believe in it strongly. I want it to work,' he says.

Why?

'It's my way of doing something for the biological diversity of the planet. This is my way of contributing, it's as simple as that,' he says. 'I think it's important to understand biodiversity for all sorts of utilitarian reasons but there's another reason which people don't recognise as well as they should.

'It's a bit like a great work of art. You don't just suddenly look at it and it all makes sense. You need to learn a bit about it before you really appreciate it. We know almost nothing about biological diversity but it is there to be wondered at, and we need to learn a bit about it to appreciate it.'

With the experiment likely to extend well into the new millenium, there is plenty more learning to be done. But Margules himself hopes to sign off on it.

'The business of science is the business of guarding your data and making sure you publish it. I don't feel like that about this experiment. The more that can be published out of it the better, fullstop, whoever does it. I would like some bright young scientists to join the project, along with all the funding they need, and kick-start their careers. There is a mine of information here just waiting to be dug.'

That sounds a bit like a call to battle for young ecologists. The fight for our biodiversity is not over yet.

Back at the lab, technician Natalie Barnett painstakingly sorts insects for identification and analysis.

in habitat remnants in cleared landscapes. On that basis, bold statements were made that in a fragmented landscape, a single large reserve would be better than several small ones adding up to the same area. But some had doubts.

'One of the criticisms of this theory was that it dealt with characterless species on featureless plains,' Margules says.

Nobody knew if it would be valid in the real world with real species. There were counter-arguments that smaller reserves summing to the same area as a large reserve would sample more species because, being dispersed, they sampled more of the environmental variation in a landscape.

'At the time this was a big issue in conservation biology,' Margules says. 'So I set up this field experiment to test one of the predictions of the theory, which was that groups of small reserves with more-or-less similar total area to a large reserve will retain fewer species over time.'

Mounting an experiment to test the theory in mainland remnant habitat is not simple. It requires the fragmentation of a pre-existing natural landscape: conservation biologists rarely have the resources or inclination for this sort of thing.

But Margules was lucky. A small company, Kapunda Pty Ltd, planned to clear 100-year-old regrowth forest in the shadow of Wog Wog Mountain in southeast NSW to establish a pine plantation. Margules knew several of the company's directors, and his father was the company's forestry consultant. They agreed to leave fragments of the original forest behind, and what became known as the Wog Wog Habitat Patch Experiment began.

It was perhaps an unparalleled opportunity in ecology. Margules had the chance to design a landscape to test a prediction, and he did so with great care (see story on page 23).

There are six replicate blocks. Each block has one large island of 3.062 hectares, one medium sized island of 0.875 hectares, and one small island of 0.25 hectares. Four of the replicates have been isolated from the native forest, first by clearing and later by an emergent pine plantation. The other two replicates are in contiguous native forest in nearby Coolangubra forest and serve as the control plots.

In the two years before the isolation event, baseline information on the site's flora and fauna was collected.

Above: The pine forest sea is calm in the early morning
Below: Wog Wog Station sits on a rise amidst the pine forest sea with a view across to the flanks of Wog Wog Mountain. It serves as a field station for researchers.

Larger animals were quite rare: for example, there was virtually no evidence of arboreal mammals and only a few species of lizard. Birds were abundant, but it was their foodstuffs that constituted the vast bulk of the diversity and formed the subject matter of the experiment. These were the invertebrates that reside in the leaf litter and soil of the forest; more than 800 species of them, many previously unnamed and undescribed.

There were even two new species of funnel web spider. Venomous?

'Well, they're aggressive,' says technician George Milkovits, who has been with the experiment since early on. 'We know that from tests with a pencil. They will repeatedly attack it and you can see the venom running down.'

For the past twelve years, a team of scientists and technicians have been collecting data. Four times a year, once in each season, Milkovits and another technician descend on the experiment to sample insects.

They do this with plastic coffee cups. A mixture of ethanol and diethylene glycol is poured into each cup which is placed into a plastic sleeve embedded in the ground. Nearly 300 such sleeves are scattered throughout the treatment and control plots. There are also several dozen in the 'sea', the pine forest that separates the islands from the mainland habitat.

The cups are left for a week and then collected, usually with a dozen or more insects and other invertebrates nicely preserved in the fluid at the bottom.

Any one of the cups is likely to contain several species: from shiny black beetles, to hairy-legged spiders, to tiny scorpions. There could be a centipede, a millipede or an amphipod (like miniature shrimps). There might even be a cricket, a daddy-long-legs or several dozen ants. The cups are relayed to the lab and painstakingly sorted, and the specimens are handed to various experts for identification and analysis.

The results of the work are now starting to be seen.

'We're seeing three obvious kinds of responses to fragmentation,' Margules says. 'Species decline in abundance and/or range with fragmentation, species increase in abundance and/or range, or they don't respond. But within those three broad classes of response, there is almost as much variation as there are species. What we're trying to do now is

categorise these responses and relate them to characteristics of the species.'

It may be that declining species have common characteristics that make them more susceptible to the effects of fragmentation. One such characteristic might be flightlessness, because without wings insects may not be able to cross the sea of pines. And this is a problem.

'Complete isolation of a population is bad for it,' Margules says. 'For example, the only two species of beetle that have never been found in the "sea" have both declined in both range and abundance, to a level where some environmental accident such as prolonged drought or fire could make them locally extinct.'

And what of the theory that stimulated the experiment in the first place? So far, it hasn't been tested.

'We haven't seen any species go extinct yet,' Margules says. 'We need extinctions to answer the question, but what we're realising now is that most of these species are incredibly tenacious so that even if they're declining they're not anywhere near going extinct.'

In any case, island biogeography theory receives less currency now than it did when the experiment was designed. While it remains one of the founding theories of modern ecology, its usefulness as an aid to the design of reserve systems is now seen as minimal.

'When you're trying to plan a regional landscape for the twin purposes of conservation and production, you rarely get the option to say: "I think I'll have one big one or a group of small ones summing to the same area". It doesn't happen like that,' Margules says.

Teasing out a clear signal from the natural 'noisiness' of the forest environment is also proving a mighty challenge. Imagine, for a start, the amount of data that need to be analysed. For the insects alone (and there are datasets for plants, lizards and birds, too), 376 samples have been taken four times a year for the last 12 years. If each contains an average of, say, 25 insects, then some half a million insects have been collected, and almost nothing is known about almost all of them.

Added to this is the huge variation within the landscape itself.

'Habitat fragments were once part of the original natural spatial heterogeneity of the landscape,' Margules says. 'They are not necessarily miniature versions of a previously continuous habitat. Each one is unique.'

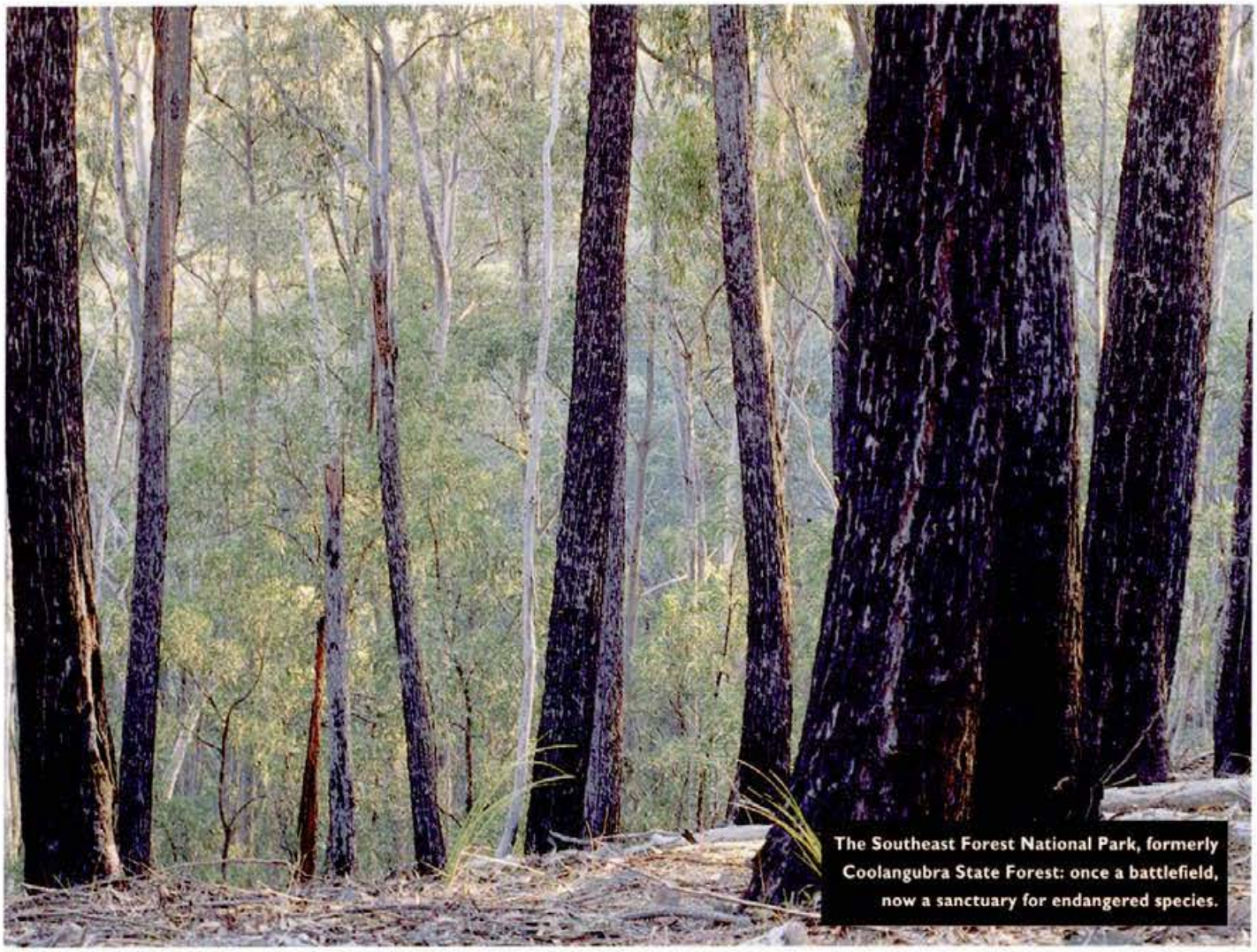
The experiment tried to take this variation into account with as much replication as possible, but Margules admits to underestimating the level of environmental heterogeneity within the landscape.

'We knew there were differences, but we now know that there's much more spatial heterogeneity there than we originally thought. This is really new and useful information for how we conduct the science of ecology.'

It also has implications for the management of biodiversity.

'This level of information about the variation in the landscape suggests that if you want to conserve as much biodiversity as possible, and if you have the option in a fragmented landscape, then you should sample all the very local habitats in the fragments,' Margules says.

'And if you don't have the option, and you rarely do, then we are now closer to being able to say where to expend time and resources on reconstructing habitats.'



The Southeast Forest National Park, formerly Coolangubra State Forest: once a battlefield, now a sanctuary for endangered species.