What happens to biodiversity when clearing fragments native vegetation? A study extending to insects and other invertebrates is providing answers

A close look at biological diversity

Dollar-wise cynics in the conservation movement like to remind us that the Australian government spends more money on opera than on endangered species*. The two commitments could scarcely be seen as competing for funds, but the comparison is not as absurd as it appears.

Fine music and rare mammals both command considerable aesthetic appeal, although more Australians visit national parks than attend opera houses. The study of each provides jobs for highly skilled workers, and both have what the economists call an 'existence value' — that is, worth based not on their usefulness but on a philosophical belief that these things deserve to survive.

Whether one area of government expenditure is more deserving than another is never easy to decide. But taking survival as the criterion, the disappearance of Australian versions of Strauss's *die Fledermaus* is unlikely to threaten the future of this operatic favourite, while the same cannot be said for another sort of 'flying mouse' — the tube-nosed insectivorous bat *Murina florium*, the rarest mammal recorded alive in Australia.

The serious point is that Australia has a very high proportion of endemic plants and animals (that is, species that occur only here) compared with other developed countries, and with it a responsibility to do more in Nature conservation than most nations. According to the federal government's working party on the conservation of biodiversity, seven families of mammals (including those of the koala and platypus), four families of birds and 12 families of flowering plants occur only here. (Bear in mind these are not plants and animals that only differ slightly from overseas counterparts; families are major taxonomic groupings that distinguish organisms as different as a magpie and a honeyeater, or a marsupial mole and a kangaroo.) At the species level, 85% of our vascular plants, 94% of our frogs and 70% of our birds occur nowhere else.

Australia is one of a dozen 'mega-diversity states', so called because collectively they account for two-thirds of the world's species. Unlike Australia, however, most of the other states (Indonesia, Madagascar and Mexico, for example) are poor or developing nations with little money to spare for Nature research.

The global issues of biological diversity — how much there is, why it matters, how to maintain it — have, then, a big potential for Australian involvement. What we do to maintain biological diversity on this continent may have a noticeable effect worldwide on how well humans learn to accommodate the millions of other species that share the planet.

A biodiversity experiment under way near Mt Wog Wog in the south-eastern forests of New South Wales is an important early step. At its simplest level, the study of biological diversity comprises map-making — collecting data to show the geographical distribution of species. That task, in a continent as large and biologically diverse as Australia, is hard enough. The next stage — understanding ecosystem change or how species interact in a habitat or suite of habitats — is daunting, and requires careful survey design and specialised analysis, particularly in the identification of collected specimens. The Wog Wog habitat study, begun by CSIRO in 1985, has this second goal and is perhaps the most ambitious ecological experiment in the world at the moment.

Designed by Dr Chris Margules, of CSIRO's Division of Wildlife and Ecology, the Wog Wog study is attempting to establish the impact of habitat fragmentation on the diversity of life in a eucalypt forest.

Much of Australia's natural environment has already been heavily modified by agriculture, logging and urban development; the habitats of plants and animals have been broken into fragments, reduced to remnants or isolated along roadsides or in railway reserves, cemeteries or pockets of private farmland often destined for clearing. Although Australia has extensive national parks and wildlife reserves (more than 42 million ha), the selection of sites for these has been largely *ad hoc*, with the result that many species and vegetation communities are not represented.

In Victoria, for example, where conservation reserves comprise one-eighth of the total area of the State, and one-third of all public land, habitats associated with grasslands, woodlands and riverine woodlands are still poorly represented in the reserve system. Although the push to set aside land for wildlife is likely to continue, the harsh political and economic reality is that further major additions to the system will be hard-won.

A related problem is how best to manage a reserve once it has been established, especially if it is not as large as scientists would prefer. 'We have to know how to maximise diversity in fragmented habitats and that's something we haven't got a clue about at the moment', Dr Margules says.

For the ecologist the task is to answer questions such as 'How large does a habitat fragment need to be to maintain biological diversity?' or 'What is the smallest population of a species that can be viable?' Dr Margules believes that without these sorts of answers policy-makers may unduly emphasise the need for large reserves or the protection of large populations at the expense of small remnant habitats. The long-term effect, he says, could be that fewer species are conserved than would be using groups of smaller populations or networks of small reserves.

The Wog Wog study is examining whether breaking a habitat into fragments reduces its biological diversity and, if so, whether any reduction in diversity depends on the size of the fragments.

The experiment occupies 25 ha of Forestry Commission land, 17 km south-east of Bombala in southern New South Wales. The land (chiefly 100-year-old eucalypt regrowth) was cleared in 1987 for a pine plantation. Two years before the clearing began, Dr Margules marked out 12 areas of forest that would be left intact after clearing. The 12 'islands' comprise four 0·25-ha, four 0·875-ha and four 3·062-ha areas. Another six areas, with the same size range, were identified in nearby

* $5 million in 1991/92 for Endangered Species Program; $6·9 million for the Australian Opera (source: Federal Budget Statements 1991/92).

State forest to act as controls for the experiment.

Within each 'island' Dr Margules established a number of sample sites on either sloped ground or drainage lines. In an effort to measure 'edge effects', he located half of those sites near the island's boundary and the rest well within it. At each site he set pitfall traps to collect samples of the ground-dwelling fauna, mainly beetles, ants, spiders and scorpions, while arthropods were also collected from the leaf litter. Plant populations were recorded using a vegetation plot method. The experiment has 188 sample sites in all, including some set up between the islands following the clearing.

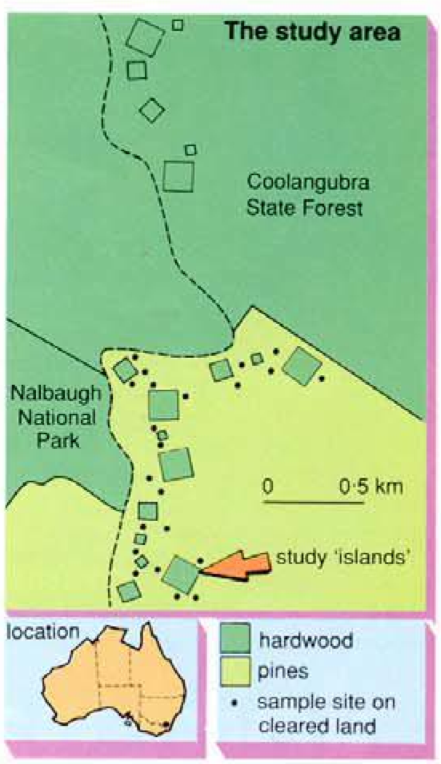
Dr Margules collected fauna samples four times a year for 2 years before the trees were cleared and during the clearing period, and has maintained the collecting for the 4 years since. Plants have been recorded once a year, during the spring. He has also monitored birds, skinks, bats and small ground mammals.

In 6 years of sampling, the experiment has accumulated a vast store of specimens — Dr Margules estimates the total number at about one million — covering a bewildering range of species. If the experiment runs for another 20–30 years, as he expects, it will provide many millions more for examination and classification. The high level of replication in the experiment is important, he says, because otherwise the large natural variation in the forest may disguise an underlying ecological relationship.

Dr John Lawrence, at CSIRO's Division of Entomology in Canberra, has had the job of classifying the beetle specimens, a task he says is not as easy as some assume. From the specimens collected at Wog Wog between 1986 and 1989, he has identified 58 families of beetles comprising about 650 different species, ranging in length from 0·6 mm to 30 mm.

This sampling, from just one small area of unremarkable forest, highlights our lack of knowledge about invertebrates. At least one-third of the beetles, he says, are undescribed in insect taxonomy. The specimens include 75 species of predatory staphylinid beetles that cannot be placed into a known genus.

The samples also contain an estimated 200 species of ants, a similar number for spiders (including two new species of funnel-web), and several species of millipedes, scorpions, skinks and crustaceans. Plant species recorded exceed 220. In all, more than 80% of the animal and plant species collected cannot be named and, according to Dr Margules, most are never likely to be, given the amount of work required.



Eucalypt 'islands' of three sizes in the area cleared for pine planting, and matching sites in uncleared forest, are providing insights into the effects of habitat fragmentation.

Two species under close scrutiny as indicators of the impact of fragmentation are the scorpion *Cercophonius squama* and the Carabid beetle *Notonomus* sp. Observations before the clearing began showed no significant difference in their frequency in different-sized 'islands', or in the inner and outer zones of any 'island'. So any observed change in numbers after 1987 can be confidently attributed to the clearing.

How species are affected will depend chiefly, Dr Margules believes, on their ability to disperse over long distances and colonise new areas. Also, some species may be able to take advantage of new habitat formed on the edge of an island, leading in the short term to an increase in biodiversity. This is most likely to occur on the large 'islands'. Dr Margules expects the species colonising the small and medium-sized islands to be outnumbered by local extinctions.

Preliminary data on beetles show that different species have reacted to

What is biodiversity?

Biodiversity is commonly measured in three ways — by counting species, assessments of genetic variation and analysis of the structure of ecosystems.

The number of life-forms is unknown. To date, scientists have described and named nearly 1·4 million species, including 248 000 plants, 47 000 fungi, 44 000 vertebrates, 31 000 protozoa and 990 000 invertebrates, mainly insects. Scientists estimate the total number of species at between 5 and 30 million.

Genes determine the multitude of physical characteristics of living organisms. The number of genes in an organism can range from less than 10 in viruses to about 1000 in bacteria and 400 000 or more in some flowering plants. A human cell contains about 100 000 genes. The genetic information stored as DNA in such a cell is immense; if the information was reproduced as normal-sized printed text, it would fill a small library. Genetic diversity includes the genetic variations that occur between individual members of a species.

An ecosystem is a functional unit in Nature comprising plants, animals and other organisms, and their relationship with the external world in the form of soil, water and air. Ecosystem diversity can mean either the variety of species within an ecosystem, or the variety of ecosystems in a particular area.

The growth and spread of the human population is threatening biodiversity. The chief causes are the clearing of natural habitat for agriculture, pollution and the over-exploitation of certain species such as edible fish. An American biologist, Edward O. Wilson, estimates that the Earth is losing about one of every thousand species each year, perhaps 1000 to 10 000 times the rate of extinction that existed before humans appeared.

In Australia, nearly 100 plant species have disappeared in the last 200 years to our knowledge, while another 3300 are either rare or threatened. Among animals, 20 Australian mammals have become extinct since European settlement and another 45 are under threat, while the rate of loss among lower vertebrates and invertebrates is not known. The decline in biodiversity is largely due to clearing of forests and woodland for crops and pasture.

the clearing in different ways: some have increased in numbers, others have decreased, and some appear to be fluctuating. Along the edges of the islands, more species appear to be increasing in numbers than not.

The role of invertebrates in the study of biodiversity — and hence environmental impact generally — cannot be over-emphasised. Most of the biological diversity of a forest or woodland can be found in its insects and other invertebrates. Moreover, each invertebrate species — be it predator, fungus-eater or herbivore — represents a unique ecological solution to a fundamental biological problem: how to survive in a hard world.

The study of invertebrate fauna also helps scientists make better recommendations about the management of larger, more appealing species. The intensive effort to save Victoria's faunal emblem, Leadbeater's possum, provides a good example; the Victorian government spends more than 40% of its threatened-species budget on this one animal.

Only recently, researchers found that the possum is heavily dependent for food upon an uncommon species of insect, a web-spinning bush cricket that lives under the peeling bark of the mountain ash trees where the animals make their nests. The insect is a valuable source of protein, allowing the possum to reproduce twice a year. Clearly, efforts to maintain the tiny population of possums will depend to some extent on understanding the availability of the cricket as a food source. And yet, at this stage, we know almost nothing about the insect's biology and whether it too is under threat.

Indeed, biologists have suggested that invertebrates can reflect aspects of a habitat not visible from a typical study of vertebrate species. For example, a study based on the collection of insect species in semi-arid mallee country found that the insects generally displayed a closer relationship with subtle differences in vegetation than did the vertebrate animals. And because there were many more insect species to study (nearly 180 beetle species in this case), their study gave the researchers a much finer-scale analysis of the ecosystems present than was possible using larger animals that have relatively broad habitats. Because of its emphasis on invertebrates, the Wog Wog experiment is expected to produce a much more accurate and complex picture of biological variation in a forest than simpler surveys have revealed.

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More about the topic

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Human pressure

Human population growth and its consequences remain the most vexed issue in the debate on biodiversity.

With its agriculture, Australia currently feeds perhaps 100 million people worldwide and at home. Given the poor soils and unpredictable climate that characterise much of the continent, that is an impressive agronomic achievement, but it comes at considerable environmental cost. The impact is most obvious in the rangelands that make up three-quarters of the area of Australia. According to a CSIRO Division of Wildlife and Ecology report, pastoral farming occupies 63% of all rangelands, while only 3% is protected in national parks and conservation reserves. Not surprisingly, nearly half of the rangelands' original native mammals are no longer found there.

The federal government's working party report on the conservation of biodiversity as it relates to sustainable development, published last year, identifies the destruction of natural habitat as the biggest threat to biodiversity in Australia. The report recommends the urgent establishment of a comprehensive system of conservation reserves for terrestrial, fresh-water and marine environments.

It is quick to point out, however, that many species do not occur in areas likely to be conserved within the proposed reserves. Hence, it says, we need to develop ways to maintain biodiversity outside reserves; this will involve control of exotic weeds and pests, management of remnant habitats areas used in agriculture and timber-getting, the development of agroforestry and alternative farming techniques and the encouragement of community-based conservation programs.

But the biodiversity report makes no mention of human population. What, for example, is the long-term carrying capacity of this country, and of the world? And how efficiently are people using Nature's resources? A 1986 study of global human activities by Professor Paul Ehrlich and colleagues at Stanford University estimated that humans appropriate nearly 40% of the net primary production (NPP) of the Earth's land areas — that is, the total amount of energy fixed biologically, less the energy needed by the primary organisms (chiefly plants). The NPP is a measure of the planet's total food resource.

If the estimate is correct, the implications for biodiversity look rather stark. While one species is reserving 40% of the terrestrial food resource for its own purposes, the other millions of terrestrial species are being asked to survive on the remaining 60%. And if the human population continues to grow at current rates, we can reasonably expect our share of NPP to rise to 100% before the end of the 22nd century — an ecological impossibility.

The Stanford University study, however, makes an interesting distinction between the food needed by humans to survive and the food we waste or consume indirectly. The study estimates the amount of organic material consumed directly by humans or domestic animals at only 4% of NPP — just one-tenth of the energy appropriated by humans. The rest — more than a third of total land NPP — is wasted or denied to other species through the burning of organic material in the clearing of land, the discarded parts of the crop plants we harvest, the land covered over by urban developments etc.

This suggests that the fate of the planet's biological diversity may depend at least as much on how efficiently we exploit the areas not protected in reserves as on what we protect in them.

Human appropriation of the products of photosynthesis. P.M. Vitousek, P.R. Ehrlich, A.H. Ehrlich and P.A. Matson. *Bioscience*, 1986, **36**, 368–73.

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