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Treetop tremors

Herbert River ringtail possum, *Pseudochirulus herbertensis*.

Graeme O'Neill outlines the threat to rare, leaf-eating mammals posed by rising temperatures and carbon dioxide levels.

At the height of the last glacial period 18 000 years ago, the mountain pigmy possum, *Burramys parvus*, ranged widely across the frigid high country of south-eastern Australia.

Natural selection has tuned the metabolism of the tiniest of all Australian possums for survival in the alpine zone. *Burramys* is the only Australian mammal that lives exclusively above the treeline, and is vulnerable to heat stroke when temperatures consistently exceed 28°C.

At the end of the glacial period some 10 000 years ago, the warming climate forced *Burramys* to retreat upslope in pursuit of its comfort zone. Today, it survives in only a few, high altitude 'temperature islands' scattered across the eastern highlands, including Victoria's Mt Bogong and Mt Buffalo, and Mt Kosciusko in New South Wales.

The plight of the mountain pigmy possum epitomises the threat of global warming to Australia's flora and fauna next century. If the region's average temperatures rise by just 1–2°C, the possum's preferred habitat will vanish off the top of the ranges, causing the possum to go extinct.

But *Burramys* may literally be the tip of the iceberg. It's not just in alpine regions that global warming threatens native animals and plants; similar temperature refugia occur at all latitudes, from the tropics to southern Tasmania. And the threat is not just from rising temperatures or changing rainfall patterns.

Ecologist John Kanowski, of the Rainforest Cooperative Research Centre at Atherton, says the temperature-island effect threatens seven rare marsupials restricted to the high-altitude rainforests of the Wet Tropics World Heritage Area in north-east Queensland.

Kanowski is a PhD student at James Cook University, which jointly operates the research centre with CSIRO's Division of Wildlife and Ecology and several other

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Rising concentrations of carbon dioxide in the atmosphere may decrease the digestibility of tree leaves eaten by some rainforest mammals. Two species which may be affected are the green ringtail possum, *Pseudocheirops archeri* (above) and the Lumholtz's tree kangaroo, *Dendrolagus lumholtzi* (below).

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Queensland agencies involved in wet tropics rainforest research. He says the mammals at risk are the lemuroid ringtail possum (*Hemibelideus lemuroides*), the Herbert River ringtail possum (*Pseudochirulus herbertensis*), the Daintree River ringtail possum (*P. cinereus*), the green ringtail possum (*Pseudocheirops archeri*) the coppery brushtail possum, (*Trichosurus vulpecula* ssp. *johnstoni*), Lumholtz's tree kangaroo (*Dendrolagus lumholtzi*), and Bennett's tree kangaroo (*D. bennettianus*).

Abundant populations of the marsupials are found in the relatively cool, misty rainforests between 800 metres and 1600 m on north-east Queensland's highest peaks. Bennett's tree kangaroo also ranges into tropical lowland rainforest below 800 m.

'These are actually temperate-adapted species that lived at lower altitude in cooler times,' Kanowski says.

All have had at least two brushes with extinction in the relatively recent past. At the height of the last glacial period, when *Burramys* was in its heyday in south-eastern Australia, the wet tropics rainforest and its endemic fauna retreated to two small, permanently moist refugia areas in north-east Queensland. They only reclaimed the forests outside these refugia with the gradual return of wetter conditions some 10 000 years ago.

About 5000 years ago they encountered another crisis: a short-lived warm phase that lifted temperatures by about 2°C above those of today. Kanowski believes it likely that this event exterminated the mammals from many lower peaks in the wet tropics, when rising temperatures pushed their favoured habitat off the mountaintops.

Temperatures then declined to today's level, but now there is a new threat: next century, human-induced global warming is predicted to increase average global temperatures by between -0.5 and 4.5°C.

With each 1°C increment, the cool montane tropical rainforests will retreat another 200 m up the mountains between Mossman and Innisfail. Mountains taper with altitude, so a 1°C rise would reduce the area of favourable habitat by two thirds. A 2°C rise would reduce it by 95%.

But Kanowski says a more insidious threat to the marsupials, which are all leaf-eaters, emanates from the very mechanism of global warming: rising concentrations of carbon dioxide in the atmosphere.

As carbon dioxide levels rise, metabolic changes will cause trees to change the balance of proteins in their leaves, and they also will synthesise more tannins. Tannins can potentially inhibit the ability of leaf-eating animals to digest protein; at high concentrations, tannins are actually toxic.

Kanowski says that in a warmer world, the change may force leaf-eating mammals to invest more energy in digesting and detoxifying their leafy diet, a diet that has been marginal since the last glacial period. Rainforest trees that formerly occupied fertile lowland soils have retreated on to rocky granitic soils at higher altitude, which are scarcely more fertile than coarse sand.

Throughout Australia, the diversity and abundance of forest mammals is closely correlated with soil fertility. And if tannin levels in leaves rise in sympathy with carbon dioxide concentrations, it may not just be rainforest marsupials at risk.

Dr Steve Cork, of the Division of Wildlife and Ecology at Canberra, says that several years ago Drs Ivan Lawler, Bill Foley and Ian Woodrow of James Cook University grew *Eucalyptus tereticornis* seedlings in doubled carbon dioxide concentrations, at a range of nutrient levels.

Doubled carbon dioxide always reduced the amount of nitrogen in the leaves and often also increased the levels of tannins and other phenolics, many of which can be toxic to animals. 'Eucalypts grown in low-nutrient environments will use the extra carbon from carbon dioxide to defend their leaves,' Cork says. 'Eucalypts also use their leaf protein more efficiently under high carbon dioxide, so need less leaf nitrogen'.

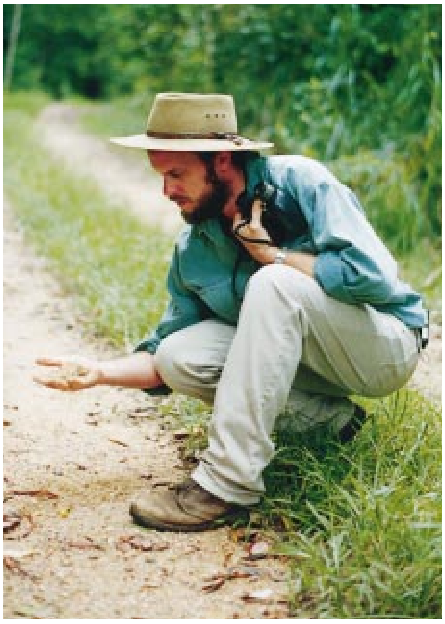
'In higher-nutrient environments, they use it, along with nitrogen, to replace their leaves. In a doubled carbon dioxide regime, leaves of eucalypts in general are likely to contain less nutrients and more carbon-based defensive compounds such as tannins and other phenolics.'

Cork says CSIRO studies with leaf-eating marsupials such as koalas, greater gliders and possums suggest that the ratio between nutrients and defensive phenolic compounds in the leaves is an important factor in their choice of food and habitat (see story on page 13).

'The densest concentrations of koalas, greater gliders and possums are found in eucalypt forests on the more fertile soils, where the ratio of nitrogen to phenolics in the leaves is high,' Cork says. 'The consequence of doubled carbon dioxide levels next century may be that the ratio of nitrogen to phenolics may fall to a point where the leaves in many eucalypt forests where these animal live become virtually inedible.'

Cork says eucalypt seedlings grown in artificial laboratory conditions are not necessarily a reliable surrogate for mature trees. Trees in Australia's eucalypt forests may compensate to a degree, but inevitably, leaf nitrogen and protein levels will decline under a doubled carbon dioxide regime.

Ominously, says Cork, koalas and greater gliders (*Petauroides volans*) are probably already hanging on in sub-optimal habitat in many places, because the forests that once grew on the relatively fertile valley floors have been extensively cleared.



John Kanowski of the Tropical Rainforest Research Centre believes that in a warmer world, higher atmospheric carbon dioxide concentrations may force leaf-eating mammals to invest more energy in digesting and detoxifying their leafy diet, a diet that has been marginal since the last glacial period.

Modelling the battle of the **grasses**

BEYOND the forest, in the grasslands of Australia's semi-arid and arid interior, the ecological balance could also be disrupted as carbon dioxide concentrations rise.

Dr Mark Howden of the Bureau of Rural Sciences is seconded to the Division of Wildlife and Ecology to model the effects of greenhouse warming. He says rising carbon dioxide levels in the atmosphere could change the dynamic balance between C3 and C4 grasses, with accompanying effects on animal species.

C3 and C4 grasses employ different photosynthetic systems. The C4 system, under the current climatic regime, tends to use water more efficiently. An example of a C3 grass is kangaroo grass (*Themeda triandra*); an example of a C4 grass is wallaby grass (*Danthonia richardsonii*).

Howden says a simple competitive index predicts the existing distribution of C4 and C3 grasses. The current line of demarcation – where C4 and C3 grasses are equally represented at the species level, but not necessarily in abundance – runs across the continent at the latitude of Balranald in south-western New South Wales.

North of this line, C4 species become increasingly dominant, with C3 grasses a common component of grasslands as far north as the mulga lands of Queensland, where winter rains allow them to compete. Conversely, C3 grasses are more common south of Balranald, and there are few C-4 species around the latitude of the Victorian coast.

Some previous studies suggest that the doubling of carbon dioxide levels expected in about 100 years from now would result in dominance of the whole of Australia by the C3 grasses due to increased photosynthetic rates. This would have enormous consequences for biodiversity conservation and agriculture. But other studies which have looked only at warming by itself suggest that C4 grasses will just become slightly more dominant in the southern parts of the mainland.

Howden used the predictive competition index in studies which combine both the effects of increased carbon dioxide and the warming which is expected to accompany these increases. These studies suggest that C4 grasses will become slightly more dominant, with the current distributions of C3 versus C4 grasses moving about 250 km southwards. The full impact of such changes needs further study but there are likely to be implications for conservation and agricultural production.

Bandicoot grass (*Monachather paradoxa*) is a C3 grass. Differences in the photosynthetic systems of C3 and C4 grasses will influence their distribution in response to rising carbon dioxide levels in the atmosphere.

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