The heat is on for Australia's forests

The Greater Blue Mountains Area owes its blue haze to the highly flammable eucalyptus oil released into the atmosphere in response to heat. More than 100 eucalypt taxa have been recorded here

Australia is currently in the throes of its worst drought in living memory, with all but the far northwest affected. Between 1910 and 1999, the country saw an average increase in temperature of 0.7°C, most of which occurred after 1950. Projections by the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) based on climate models indicate an increase in average annual temperatures ranging from 0.4°C to 2.0°C by 2030 and as much as 1.0°C to 6.0°C by 2070. Evaluating future trends in rainfall remains more difficult. This change in climate regime raises a special concern for forests, where the impact of higher temperatures could heighten the risk of more frequent, intense and destructive wildfires, and decimate biodiversity.

The Greater Blue Mountains and The Wet Tropics of Queensland are two of the sites profiled in *Case Studies on Climate Change and World Heritage*, published by UNESCO's World Heritage Centre in April. Separated by over 2700 km, these two Australian sites are poles apart in many ways: the former ecosystem is made up of temperate eucalypt forests, the latter of tropical rainforests and mangroves. Yet both will be highly vulnerable to Australia's warmer and drier climate in the 21st century.

In 2003, Lesley Hughes from Sydney's Macquarie University argued that it was difficult to plot the impact of climate change in Australia on the broad range of species, due to the lack of sufficient baseline data from which to work. Studies carried out since however on vulnerable alpine and forest ecosystems point to a significant reduction in the numbers of many species and the probable extinction of some.

Perhaps the most vulnerable vertebrate species is the Mountain Pygmy Possum (*Burramys parvus*), whose life cycle requires sustained alpine snow cover. It is estimated that a 1°C rise in temperature would eliminate its bioclimate and a 2°C increase would eliminate the bioclimate of five other alpine species. Given that migration to an environment that has more snow cover is not an option, it is likely that such species will be driven to extinction.

In drier woodland ecosystems of Western Australia, a 0.5°C increase in temperature would reduce the habitat of all frogs and mammals by 28% and a 1°C increase would see the shrub species *Dryandra* become extinct or shrink to small pockets. Again, with only a 1°C increase in temperature, Hilbert *et al*[11] estimate that highland rainforest will decrease by around 50%. This is critical, given the importance of these ecosystems for many of the country's endemic vertebrates.

Moreover, the fragmentation of habitat associated with small protected areas like World Heritage sites often provides limited opportunities for migration to more compatible environments.

The Greater Blue Mountains World Heritage Area is home to the endangered Brush-tailed rock wallaby (left) and Tiger Quoll (right). Their habitats and life-support systems could be profoundly impacted upon by climate change and the increased frequency and intensity of forest fires

One of the world's most fire-dependent forests

The eucalypt forests of Australia, including those of the Greater Blue Mountains in the southeastern state of New South Wales (*see map overleaf*), are among the most fire-dependent forest ecosystems in the world.

Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics. Other sites at risk include the Kakadu wetlands, southwest Australia, sub-Antarctic islands and the alpine areas.

IPCC (2007)[12]

The Greater Blue Mountains World Heritage Area consists of over 1 million ha of sandstone plateaux, escarpments and gorges covered largely by temperate eucalypt forests. Comprised of eight protected areas, the site was inscribed on the World Heritage List in 2000 for its representation of the evolutionary adaptation and diversification of eucalypts in post-Gondwana isolation on the Australian continent *(see box overleaf)*.

Another justification for the site's inscription on the World Heritage List is that it hosts 120 rare or threatened species, including 114 endemic taxa and evolutionary relict species like the Wollemi pine, which have persisted in highly restricted microsites.

Eucalyptus oil highly flammable

The blue haze of the Greater Blue Mountain Area, from which it derives its name, is caused by the highly flammable eucalyptus oil being released into the atmosphere in response to heat. Many species of eucalypt, banksias and other native flora have become so adapted to fire that they only release their seeds after burning has taken place, the ash compensating for the often nutrient-poor soils.

There is usually a high rate of regrowth of eucalypts and banksias within the first three years following a major fire. However, a second hot fire, during that stage in the regeneration process, can lead to severe stress and a loss of species diversity by killing plants before they have matured sufficiently to produce seeds.

Consequently, if the interval of intense bush fires moves from long cycles of 10–20 years to below 6 years, there will be a significant decline in the diversity of the major eucalypt species and other flora of the region, a change that would have serious consequences for the ecosystem integrity of the area.

Studying fire behaviour

Several strategies are being developed to protect the Greater Blue Mountains from the adverse impact of wildfires in the context of a changing climate. The first is to implement more informed policies through greater research into fire behaviour and its ecological impact, especially following the terribly destructive fires of 2002 that led to the establishment of a Bushfire Cooperative Research Centre in December 2003.

The second strategy concerns the use of controlled or mosaic burning to limit the risk of intense and ecologically destructive fires, appropriately designed to take into account the specific ecosystems involved. As the Greater Blue Mountains border the rapidly expanding suburban boundaries of Sydney – Australia's largest city with a population of 4.3 million – there is a real risk of conflicting policy priorities between the protection of urban property and biodiversity conservation.

The gradual emergence of fire-adapted species

In Australian ecosystems, like others that have evolved in relation to 'Mediterranean type' climatic conditions, fire has been the selective mechanism over a very long time-frame. However, in Australia, fire became a more important factor around 100 000 years ago, with the drying of the environment at the end of a major ice age.

This resulted in the decline of the country's megafauna (large animal species) and the emergence of more fire-adapted species. Fire was to become an even more significant feature of the landscape with the arrival of the first Aboriginal inhabitants around 60 000 years ago, who used fire to manage the landscape.

These two factors meant that the fire-sensitive species, such as beeches, pines, tree ferns and sheoaks, along with wet rainforest species, gave way to the more fire-dependent eucalypts and banksias. This was also associated with the emergence of sclerophyll forests[13] and greater erosion of topsoil leading to the silting of coastal regions and the emergence of mangroves. For the Aboriginal population, the use of 'fire stick farming' to manage and clear the landscape was both a means of preventing extremely destructive fires and controlling the movement of game. Such cultural practices as mosaic burning over many thousands of years were to shape profoundly the Australian landscape.

As a result of reduced precipitation and increased evaporation, water-security problems are projected to intensify by 2030 in southern and eastern Australia.

IPCC (2007)

Rising temperatures could force species up the mountain

Rising temperatures may threaten flora and fauna in the very limited parts of the Greater Blue Mountains that are wetter

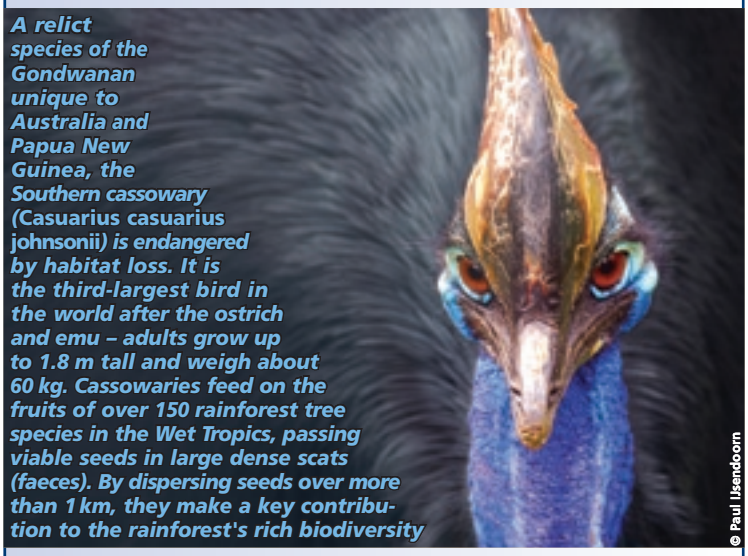
Two red-barked snow gums (Eucalyptus pauciflora). Unique to Australia's southeastern alpine regions, snow gums are especially threatened by climate change

The Wet Tropics: a biodiversity hotspot

A second case study in Australia concerns The Wet Tropics of Queensland World Heritage Area, which stretches along the northeastern coast of Australia for some 450 km (*see map*). It is made up of tropical lowland and upland rainforests and thickets, vegetation complexes, mangroves and sclerophyll forests and woodlands. These ecosystems host a particularly extensive and diverse array of plant and animal species, including a high proportion considered as endemic, evolutionarily significant, rare or threatened (*see box*). It was these features which justified its inscription on the World Heritage List in 1988.

This remarkable ecosystem is threatened by rapid changes in temperature and rainfall, as many species in this area are unable to keep pace with rapid climate change.

For about half of the species modelled, a warming of 3.5 °C – corresponding to the average projected scenario – may lead to the total loss of their core environment; for the remaining species, range sizes are likely to be reduced on average to 11% of the current area. Even a 1°C increase in mean air temperature will lead to a significant decline in range size for almost every endemic vertebrate in the Wet Tropics of Queensland.



A relict species of the Gondwanan unique to Australia and Papua New Guinea, the Southern cassowary (Casuarius casuarius johnsonii) is endangered by habitat loss. It is the third-largest bird in the world after the ostrich and emu – adults grow up to 1.8 m tall and weigh about 60 kg. Cassowaries feed on the fruits of over 150 rainforest tree species in the Wet Tropics, passing viable seeds in large dense scats (faeces). By dispersing seeds over more than 1 km, they make a key contribution to the rainforest's rich biodiversity

Vertebrates living in these isolated tropical mountain rainforests may become trapped with nowhere to go, in response to the projected changes in climate. Many species could be lost in the Wet Tropics of Queensland within the next 50–100 years, including a number of frogs, mammals, birds and skinks. The extent of biodiversity loss will depend on the rate and timing of climate change.

Australia's Marine and Tropical Scientific Research Facility is conducting research to formulate feasible, proactive management initiatives on a regional scale in response to projected climate change. This research programme, which benefits from substantial funding from the Australian government, will refine present climate change models and scenarios to verify which species and ecological communities are most at risk, the long-term effects of these threats and their geographical distribution, how climate change might interact with other threats such as clearing, fragmentation, fire, weeds and feral animals; and whether, or where, some areas may provide continued habitat, or new areas of habitat, in the future.

Concerning the Wet Tropics World Heritage Area specifically, the James Cook University in Townsville, Queensland, has established a Centre for Tropical Biodiversity and Climate Change Research that will focus its efforts on the impact of climate change on the biota of the Wet Tropics of Queensland.

and at a higher altitude, by forcing species to move up the mountains and reducing the availability of water. Yet one of the attributes of the site relevant to its listing under natural criteria is the variability of vegetation in response to decreasing temperature across an altitude range of 100 m to 1400 m.

For example, the upland swamps of the Greater Blue Mountains contain some unique species that are adapted to seasonally waterlogged soils. These species are at risk of being displaced by species tolerant of drier soils. Upland swamps also provide habitat for the endangered skink *Elamprus leuraensis* and the Giant Dragonfly. Their ability to retain and slowly release water also contributes to the survival of threatened plants, such as *Microstrobus fitzgeraldii* and *Epacris hamiltonii*, which have adapted to permanently moist habitats. Swamps currently at the lower end of the suitable rainfall spectrum would be most vulnerable to contraction due to changes in rainfall and/or evaporation associated with climate change.

Evidence of climate change still anecdotal

Much of the evidence of the impact of climate change on the ecosystems of the Greater Blue Mountains is anecdotal for the moment and has not been supported by adequate, systematic research. It is reported for example that at least one eucalypt species, *Eucalyptus corpulens*, related to the Snow Gums of the alpine regions, no longer grows in the Blue Mountains region. Some horticulturists and botanists attribute this to climate change.

Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia ... due to increased drought and fire.

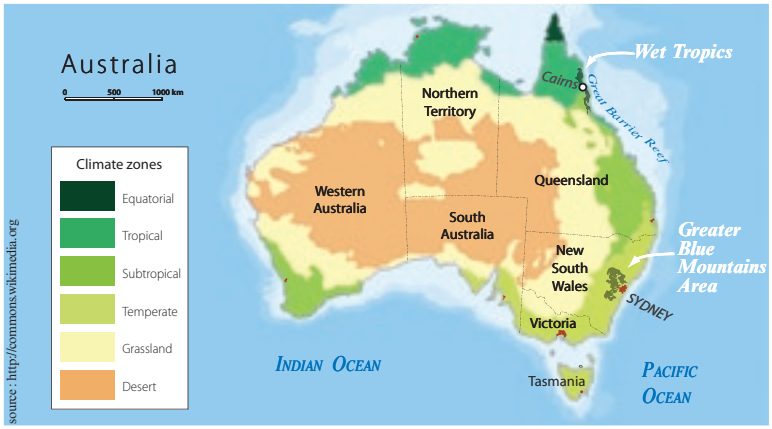
IPCC (2007)

There is also evidence of a lasting impact of the intense bush fires of 2002–2003, where normal regrowth of eucalypts has not occurred in the upper Greater Blue Mountains region.

The spread of the soil pathogen *Phytophthora* is having a serious impact on a number of plant species in the mountains. Plant stress due to drought, erosion and the movement of soil due to extreme weather are believed to be some of the causes for its spread and impact on many vulnerable plant communities. There is evidence of greater long-term stress on hanging swamps[14] and the invertebrate species that depend upon these swamps, due to hotter and drier conditions. However, it is difficult to substantiate the claim that climate change is the cause, due to the lack of adequate research.

A better understanding for better protection

Several research projects into the impact of climate change on the Greater Blue Mountains are being conducted under the auspices of the Australian Greenhouse Office, the New South Wales Department of Environment and Conservation and the Blue Mountains World Heritage Institute. The topics under study include the impact of climate change on biodiversity and ecosystem functions (terrestrial and aquatic), synergistic effects on other threats like invasive species and risks posed by bushfires to people and property.



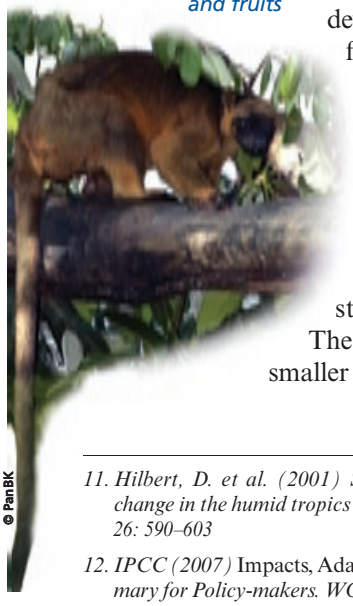
*The Strangler Fig (*Ficus virens*) is one of the largest trees in tropical north Queensland. It germinates atop another tree, its seeds often being dispersed by birds. As it grows, it drops its roots until it "strangles" its host. This adaptation gives the Strangler Fig a distinctive height advantage in the competition for sunlight, which can only be reached by growing above the dense tree canopy*

With other partners, the Blue Mountains World Heritage Institute is undertaking a three-year research project between 2007 and 2010 to assess a range to threats to the region's ecosystems, including climate change.

The Institute is also establishing collaborative research programmes with other research institutes in France and the USA to share research and techniques for addressing extreme weather conditions, more frequent drought, greater fire risk and other impacts of climate change.

If the time-frames of the present climate change models are correct, we have very little time left to develop and test mitigation strategies for conserving both natural and cultural World Heritage sites. It is imperative that international agencies encourage developed countries with research capacity to engage in appropriate local and collaborative international research to support mitigation strategies as soon as possible. The window of opportunity may be smaller then we think.

*The Wet Tropics is home to Lumholtz's Tree-kangaroo (*Dendrolagus lumholtzi*), which stands less than 60 cm tall. A nocturnal, solitary animal, it spends most of its time in the tree canopy feeding on leaves and fruits*



Nothing is a substitute for tackling CO_2 emissions

While there are now better methods for fighting bushfires and managing some of their more damaging impacts, this is not going to be a substitute for addressing the underlying problem of CO_2 emissions. What is needed is much greater public awareness of the real costs to present and future generations of the loss of biodiversity and ecosystem services that are presently taken for granted.

John Merson[15]

Read: Case Studies on Climate Change and World Heritage*: http://whc.unesco.org/en/othermaterials/*

With thanks to Yacoub Raheem from the World Heritage Centre

A long evolution in isolation

The Wet Tropics region is home to about one-third of Australia's 315 mammal species, including unique green possums, fierce marsupial cats, kangaroos that climb trees and rare bats. As well as relatively common Australian mammals like the platypus and wallaby, the Wet Tropics is home to 13 mammal species found nowhere else in the world. All but two – the endangered Tropical Bettong (*Bettongia tropica*), and the Mahogany Glider (*Petaurus gracilis*), a possum – are rainforest dwellers. These include two tree-kangaroos (*see photo*), a rat-kangaroo, four ringtail possums and a melomys (native rat).

Some of the Wet Tropics rainforest species have close relatives in New Guinea and Southeast Asia. When Australia became isolated after the break-up of the supercontinent of Gondwana [Ed: Australia separated from Antarctica about 67 million years ago], it drifted northward. About 15 million years ago, it bumped into the Asian continental plate. This collision allowed an exchange to take place between two sets of animals and plants which had evolved in isolation. Asian flora and fauna, including many placental rats, moved into Australia. At the same time, Australian species moved north. Many of them colonized New Guinea, a new high altitude land mass created by the 'bow wave' of Australia's northerly drift. As a result, some of the unusual mammals of the Wet Tropics also live with Australia's northern neighbours, including the Long-tailed Pygmy Possum in Papua New Guinea and the tiny Tube-nosed Insectivorous Bat (weighing just 8 g) in Southeast Asia.

Source: Wet Tropics Management Authority: www.wettropics.gov.au/pa/pa_mam_info.html

11. *Hilbert, D. et al. (2001) Sensitivity of tropical forests to climatic change in the humid tropics of north Queensland.* Australian Ecology *26: 590–603*
12. *IPCC (2007)* Impacts, Adaptation and vulnerability. *Executive Summary for Policy-makers. WGII Fourth Assessment report. April. Lesley Hughes, cited in this article, was the lead author of the chapter on Australia and New Zealand and a contributing author to the chapter on ecosystems: www.ipcc.ch*
13. *The leaves on plants in sclerophyll forests contain a lot of woody tissue, making the build-up of top soil very slow*
14. *A shallow swamp with a wealth of plant life. Constant saturation creates anaerobic (oxygen-starved) conditions in the soil, inhibiting the decomposition of dead plant material, which accumulates as peat. Peat acts as a sponge, retaining rainwater for later slow release*
15. *Author of a case study on the Greater Blue Mountains World Heritage site, an abridged version of which was published in* Case Studies on Climate Change and World Heritage, *Blue Mountains World Heritage Institute: j.merson@bmwhi.org.au*