Burning issues

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Australia's cities impinge upon an ancient landscape shaped by fire. Carina Dennis talks to the researchers who are striving to protect lives and property, while retaining natural fire regimes that nurture the country's biodiversity.

Searing winds, soaring temperatures and smouldering homes — it's summer in Sydney and the suburbs are besieged. In recent months, Australia's largest city has been hemmed by wildfires. Highways have been closed, power lines severed, and scores of houses destroyed.

The need to protect urban areas from incineration is just one reason why fire science is a hot issue in Australia. Much of the country's unique flora and fauna has evolved with fire, coming to depend on the bush periodically going up in flames. But across large tracts of the country, established rhythms of fire and regrowth have been altered by human activities, in some cases stoking uncontrollable conflagrations that threaten lives, property and biodiversity.

Fighting fire with fire may offer the best solution. Controlled fires can be used to reduce the build-up of flammable vegetation, and might also mimic the natural cycles of scorching and regrowth needed to maintain biodiversity. But if fires are to become an effective land-management and conservation tool, scientists must improve their understanding of how complex fire regimes have shaped Australia's ecosystems. "We need a good understanding of how fire behaves in the landscape," says Jim Gould, a bushfire expert with the Forestry and Forest Products Division of the CSIRO, Australia's main national research agency, in Canberra.

But the residents of Sydney and other Australian cities have more pressing concerns. As cities have expanded into bushland, more and more urban dwellers have found themselves living in an extremely vulnerable position. "In Sydney, about 300,000 hectares lie at this urban–bush boundary," says Ross Bradstock, a fire ecologist with the New South Wales National Parks and Wildlife Service.

Recent decades have unleashed some ferocious blazes — 16 February 1983 is remembered as 'Ash Wednesday', after fires swept through the states of Victoria and South Australia, killing 76 people and destroying more than 2,500 homes. During the fires of 1994's dry season in Sydney, four died and about 180 houses were lost. And the fires that threatened Sydney in December 2001 destroyed more than 100 homes.

Time bomb

The Australian bush — dominated by eucalyptus trees — is highly flammable. As the summer wears on, the build-up of undergrowth creates a natural tinderbox. The current drought, which dates from March 2002 and is the worst on record, has exacerbated this volatile situation. Add in the unpredictable variable of twisted individuals who get their kicks from deliberately starting fires, and the suburbs of Sydney and other Australian cities are like incendiary bombs with very short fuses.

With the public demanding action, federal and state governments have increased investment in firefighting equipment and stepped up surveillance. Science has also been called to the frontline, with the announcement in December of a new national Bushfire Cooperative Research Centre, based in Melbourne, which will bring together fire researchers from across the country in a seven-year, A$112-million (US$64-million) programme to investigate better ways of preventing and controlling bushfires, particularly at the urban–rural interface[1].

The centre's main focus will be to support projects directly relevant to those responsible for preventing and fighting fires. For instance, some of the participating scientists have previously revealed how fires can suddenly threaten firefighters' lives following a change of wind direction. A fire that has been advancing for some time in the same direction tends to move forwards in a 'V' shape, with an intense, narrow 'head fire' at the apex. But even a slight shift in wind direction creates a wider, linear head fire. And by analysing fire behaviour under various conditions, CSIRO researchers have found that these linear head fires travel up to three times faster than was previously thought, reaching speeds of up to five kilometres per hour[2]. "This is critical information for good safety training of firefighters," says Gould.

If towering flames that can change direction at a moment's notice weren't enough to contend with, combating bushfires in Australia is made even more difficult by the phenomenon of 'spotting'. Spotfires occur when firebrands of bark are tossed into the updraft of hot air from a fire and are carried ahead of the fire front by the wind. Although other countries have problems with spotfires, the highly flammable bark of many Australian trees makes spotting a particular hazard.

The CSIRO's Forestry and Forest Products Division has developed models of firebrand behaviour to predict spotting distances from different sources of burning bark, under various weather conditions. Using a specially designed wind tunnel[3], the researchers record the 'terminal velocity' — the speed at which the firebrand begins to fall to the ground once

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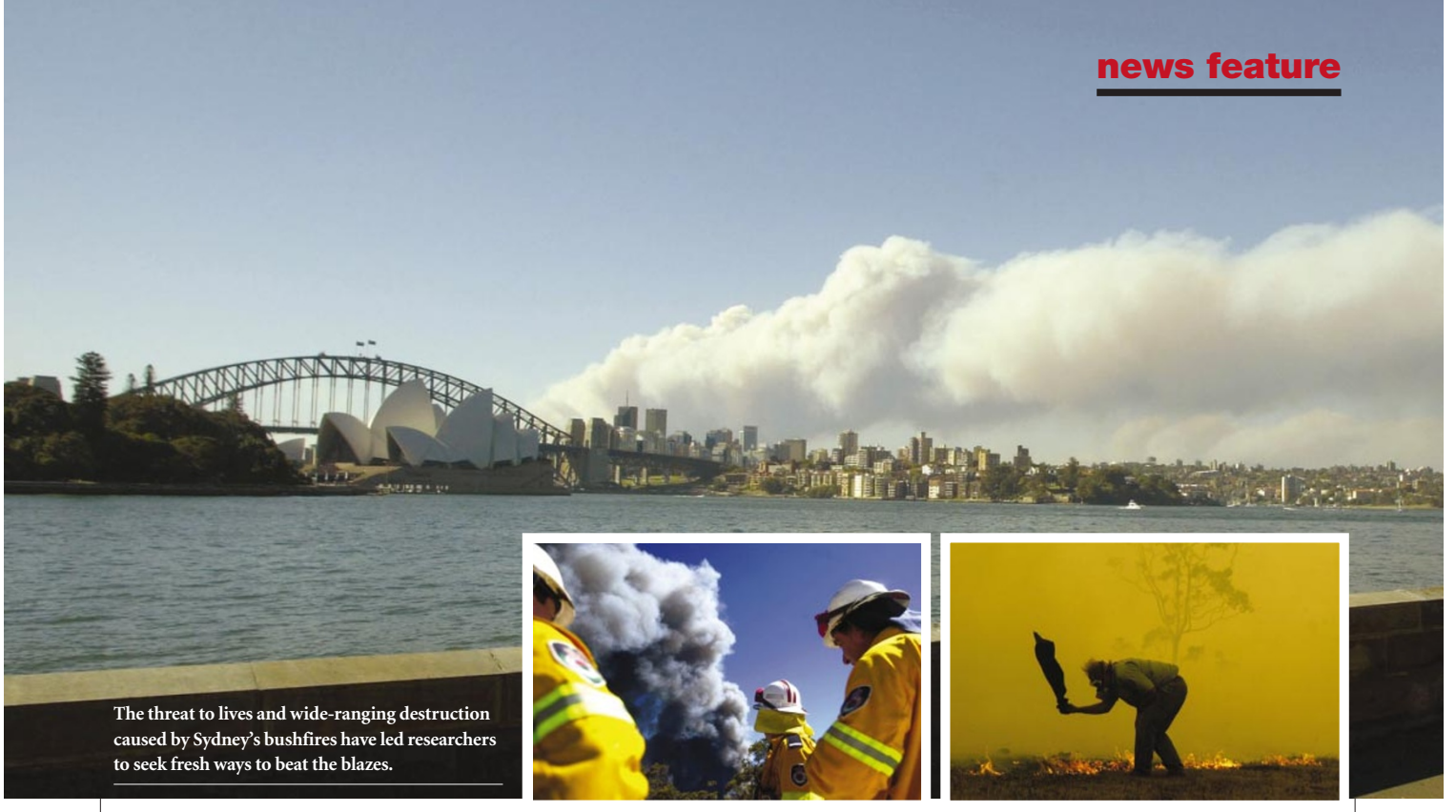

The threat to lives and wide-ranging destruction caused by Sydney's bushfires have led researchers to seek fresh ways to beat the blazes.

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away from an updraft — monitoring the effects of firebrand size and length of time it was exposed to flame. In an initial unpublished study, Peter Ellis has concentrated on the messmate stringybark eucalyptus (*Eucalytpus obliqua*), which is common in southeast Australia and can shoot out huge numbers of firebrands that can travel up to five kilometres. "We plan to develop a database on the behaviour of a number of different bark types," says Ellis.

CSIRO researchers are also recording the distribution of spotfires in high-intensity experimental fires during summer conditions. The eventual goal is to develop a comprehensive spotting model to help firefighters anticipate bushfire behaviour and assist communities in managing vegetation around residential boundaries.

Cutting through the smoke

Modelling fire behaviour is crucial, experts agree. "Fire research needs to go from being a descriptive to a quantitative science," says Michael Reeder, a mathematician at Monash University in Clayton, near Melbourne, who is not part of the new cooperative research centre. Working with a group at the US National Center for Atmospheric Research in Boulder, Colorado, Reeder's team has built a computer model of how a fire behaves under different conditions, including variable topographical and meteorological factors, such as strong winds or high temperatures.

In unpublished work, the researchers have tested their model's predictions against experimental fires filmed with an infrared camera. "We have found that our model agrees with how the fire behaved," says Reeder. But he cautions that the model has so far only been tested for a controlled fire in a lightly grassed, disused airfield. Reeder eventually plans to simulate fire behaviour under more extreme conditions, which would be of most use to firefighters.

Research on extreme fires has determined the maximum blaze intensity that can be safely controlled by ground-based firefighters[4]. Bushfire intensity is characterized by the amount of energy released at the front of the main fire. "The maximum intensity of a directly controllable bushfire is about 3,500 kilowatts per metre," says Gould. Some of the blazes that threaten Australia's cities have intensities of tens of thousands of kilowatts per metre, and can only be held in check by bulldozing firebreaks into the landscape, or by deploying aircraft that can release large volumes of water.

To prevent fires from reaching such intensities, land managers can use prescribed burns early in the season to stop the build-up of dried undergrowth that can fuel an uncontrollable blaze. But the question of how much to burn is a huge bone of contention. Many city dwellers want to increase the amount of prescribed burning to protect their homes. But conservationists argue that burning too frequently can compromise biodiversity, killing the seeds of plants before they have a chance to germinate, and destroying wildlife habitats. A recent study across the state of Victoria suggests that biodiversity is currently suffering from too much fire around settlements and too little in many forests and national parks[5]. "We need to find a balance between maximizing biodiversity and minimizing risk to people and property," says Kevin Tolhurst, a fire ecologist based at the University of Melbourne's Creswick campus, northwest of the city.

Finding the right pattern of burning to support Australian ecosystems is far from simple. "Some species like a lot of fire and some species don't like much at all," says Bradstock, who is fascinated by how distinct ecosystems with very different fire requirements can live side by side. For instance, in the Blue Mountains National Park, west of Sydney, the dry eucalyptus forests that crown ridges and blanket escarpments are regularly singed by bushfires. Yet deep in the gullies, rainforests — including the last refuge of the prehistoric Wollemi pine (*Wollemi nobilis*) — survive by only rarely encountering fire. Modelling the key components of fire and ecology, Bradstock has developed computer simulations to devise appropriate fire regimes for different ecosystems[6]. Under the cooperative research centre, he plans to refine the model by studying the influence of climate, weather and fuel load on fire ecology.

Patched up

Optimal fire regimes won't simply involve prescriptions of fire frequency and intensity — burning needs to be patchy. "You need a balance of young and old vegetation," says Tolhurst. Some Australian animals, such as the pebble-mound mouse (*Pseudomys chapmani*) and the ground parrot (*Pezoporus wallicus*), live on the edges between burnt and unburnt vegetation, seeking food from areas recovering from fire but raising their young in the shelter of unburnt older vegetation.

Tolhurst has just completed an unpublished study of the effects of five different fire treatments across about 50,000 hectares in

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Heated debate: researchers such as Jim Gould (above) are desperately trying to find out more about fire's behaviour. Among other questions, they want to investigate the value of controlled burning (inset).

the Wombat State Forest, some 80 kilometres northwest of Melbourne. The work revealed a complex network of relationships between tree growth, soil nutrients and the abundance of species of insects, birds and mammals immediately after a fire. Ecosystems generally recovered within two years, as long as they weren't entirely razed. "A key conclusion from our study was that recovery from fire is rapid provided there are small unburnt patches left behind," says Tolhurst.

The biggest challenge is quantifying the extent of patchiness needed, which Tolhurst hopes to overcome with computer modelling. But progress may be limited by what is known about the historical pattern of fire in the landscape. "Data on fire histories are sketchy at best," says Malcolm Gill, one of Australia's foremost fire ecologists, who recently retired from the CSIRO's Plant Industry Division in Canberra. He believes that the answer is a national fire-mapping project to record the frequency, intensity and nature of bushfires across the country. This would include extensive satellite imaging and analysis of biological indicators, such as fire scars in trees. But Gill remains frustrated by "the lack of action so far" — and hopes that such an endeavour will eventually be supported by the new cooperative research centre.

Some fire ecologists, meanwhile, feel that the new centre should do more to address the issue of bushfires in northern Australia, where more than 30 million hectares of bush go up in flames every year[7]. "The fires in Sydney are a drop in the bucket compared with the area burnt every year in northern Australia," says Dick Williams, an ecologist with the CSIRO Sustainable Ecosystems Division in Darwin. These conflagrations are thought to be one of the main culprits behind the declining biodiversity seen in the region, but have not attracted the same interest from politicians as the fires threatening southern cities.

Trailblazers

Williams is part of a team headed by Alan Andersen, also at the Sustainable Ecosystems Division, which has conducted one of the world's largest fire experiments to measure the impact of different fire regimes on entire ecosystems over some 250 square kilometres of northern Australia's tropical savanna[8]. Set up in 1988 at the Kapalga Research Station in Kakadu National Park, Northern Territory, the project has monitored the effects of four different fire regimes: absence of fire, annual fires early in the dry season, annual fires late in the dry season, and fires lit progressively through the season. The researchers have been crunching their data since the completion of the experimental phase in 1996. One of the most important findings is that fire frequency — rather than the intensity of individual fires — is the more important determinant of biodiversity. Put simply, too much of the bush is burning too often, destroying vital havens for small mammals and other species.

Worryingly for those trying to protect the region's unique flora and fauna, it seems that the frequency and intensity of bushfires in northern Australia has increased since European settlement. To many experts, an answer to the problem may lie with the Aboriginal people whose small-scale, deliberate burning shaped the landscape after their arrival in north Australia from Southeast Asia more than 40,000 years ago. This 'fire-stick farming' was motivated by the Aboriginal people's own needs. But, in combination with climate change, it may have created a new equilibrium under which biodiversity flourished. Certainly, there is some evidence to support this view: one long-term study of an area with unbroken traditional fire management in Arnhem Land, some 250 kilometres east of Darwin, found that it had a good bill of health in terms of biodiversity[9].

"Aborigines used fire to stabilize an incredibly flammable environment and very unstable situation," argues David Bowman, a landscape ecologist at the Northern Territory University in Darwin. The problem now, he suggests, is that European settlement and agricultural practices have disturbed that equilibrium — returning Australian ecosystems to a volatile 'pre-human' state, in which destructive late-season fires are more common.

Some researchers are now collaborating with Aboriginal groups — which, following successful land-rights claims, own a large proportion of northern Australia's savanna — to reintroduce mosaics of deliberate burning in some areas. But they are working in a political minefield. Australia's racial politics remain fraught, and some cattle ranchers argue that the burning threatens their livelihoods.

Other experts, in any case, are less convinced that the answer to Australia's current bushfire problems necessarily lie with a return to the practices of the people who first managed the bush by fighting fire with fire. "Any blanket statement that Aboriginal burning is best for biodiversity is more ideological than scientific," says Andersen.

But the country's fire scientists agree that the interests of city dwellers and biodiversity alike require a much more comprehensive and quantitative approach to studying the blazes that have shaped the Australian landscape — with the new cooperative research centre representing just the start. "We have to learn to live with fire, whether it be from an economical and social point of view or from an environmental perspective," says Tolhurst. ■

Carina Dennis is *Nature*'s Australasian correspondent.

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