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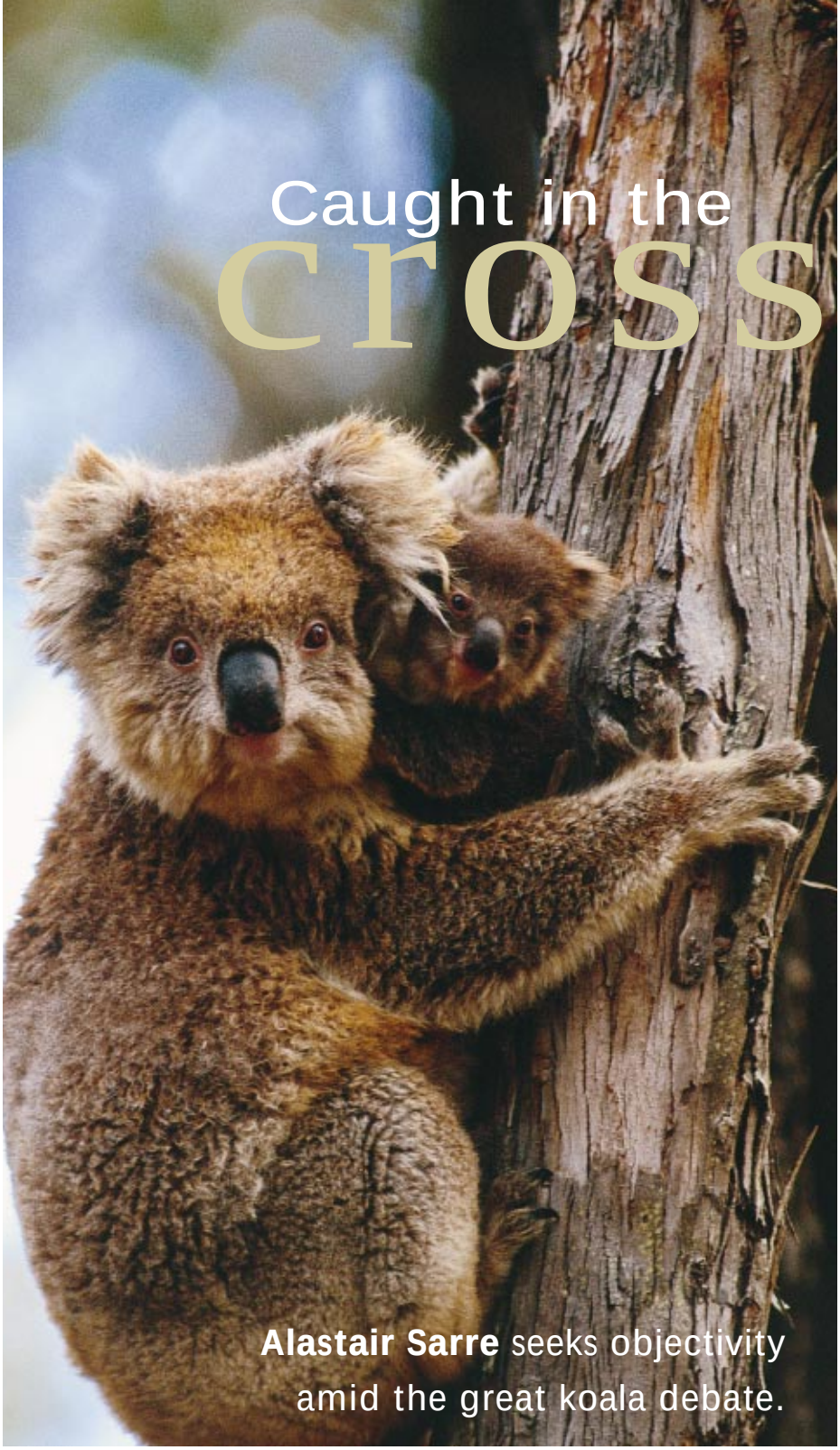

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Caught in the crossfire

Alastair Sarre seeks objectivity amid the great koala debate.

On Barrenjoey Peninsula north of Sydney, a handful of koalas – Australia's most loved, most studied and most controversial animal – struggles to survive. Mauled by dogs, knocked down by cars and pushed out by urban development, this tiny population may well be doomed.

But further south, in Victoria and South Australia, it's a vastly different story. In many populations there, koalas are overcrowding their habitats and killing the trees that sustain them.

The apparent paradox of declining populations and overpopulation is just one element of a debate over koala ecology and management that has smouldered in the scientific, bureaucratic and political undergrowth for years. Flames erupted recently when scientists suggested that excess koalas in Victoria and South Australia should be culled by expert marksmen. Politicians on both limbs of the political gum tree – led by the Federal Minister for the Environment, Robert Hill – howled down the idea.

According to one participant at a koala symposium organised as part of the International Conservation Biology Society Meeting in July 1998, 'there were clearly half a dozen koala camps set up in the auditorium'. It might make great headlines, but heated arguments stemming from entrenched beliefs and values do nothing for the image of science, and even less for koala conservation. Perhaps, say some scientists, the time has come for reconciliation.

Teddy bear syndrome

Of all Australia's unique wildlife, the koala is undoubtedly the star attraction. A recent study estimated that international tourists pay more than $1 billion a year in their efforts to see them, and go crazy when they do. Veteran Victoria-based koala researcher Roger Martin calls it the teddy bear syndrome.

'Koalas look like a babies,' Martin says. 'Their head-to-body ratio is about 1:3, about the same as a one-year-old child when they're sitting on their bum. They trigger a very strong maternal response.'

The koala is probably the only Australian animal with its own lobby group. Set up about a decade ago, the Australian Koala Foundation (AKF) has contributed more than $2 million to koala research. It has also entered the political fray: debates between it and scientists such as Martin have often been ill-tempered and conducted largely in the media.

'Anyone working down here (in Victoria) regards the Australian Koala Foundation as provocative,' Martin says. 'They're not making it any easier for wildlife managers down here to address the problem of overabundance.'

Brisbane-based AKF biologist Steve Phillips is less direct, but equally disappointed about the quality of debate.

‘Koalas may be abundant in one forest but absent from another, despite the presence of similar tree species and environmental conditions.’

‘When we polarise debates like this, it’s the object of the debate that suffers,’ he says. ‘Too many biologists in Australia lose sight of that as they set about undermining their colleagues. All they’re doing is setting back the issues for another few years while politics and our peers try to sort out the mess.’

The habitat debate

Perhaps the perennial issue in the great koala debate is that of habitat: in what kind of bush do koalas live and which tree species do they eat? These may appear to be simple questions, but addressing them on a regional or national basis is fraught with difficulties. To the continued puzzlement of scientists, for example, koalas may be abundant in one forest but absent from another, despite the presence of similar tree species and environmental conditions. In addition, the natural range of koalas extends over much of eastern Australia, from south-eastern South Australia to the edge of the Atherton Tablelands in north Queensland, making generalisations dangerous.

Yet some kinds of generalisation are essential for good koala management. If we can predict the kind of bush that makes good koala habitat, we can set it aside or adapt our management regimes accordingly.

Steve Cork of CSIRO Wildlife and Ecology at Canberra says several approaches have been used to define koala habitat. The most common is based on detailed studies of individual populations: scientists observe a group of koalas, noting which trees they live and feed in. A large number of such studies have produced long lists of eucalypt species considered to be suitable feed trees for koalas. But these lists are full of anomalies: a preferred tree species in one location may be ignored by koalas in another. Cork says such studies can be useful for determining koala habitat in a local area, but not on a larger scale.

Alastair Sarre

Research in the south-east forests of New South Wales led by CSIRO’s Wayne Braithwaite discovered a broad relationship between foliage nutrient content and koala density. At the finer scale, the relationship is complicated by chemical leaf defences that have evolved to protect trees from herbivory.

Another approach is to survey large tracts of forest and correlate distribution with environmental factors, a method used by Wayne Braithwaite and his colleagues in the early 1980s.

Braithwaite, who has just retired from CSIRO Wildlife and Ecology, was given the task of investigating issues of fauna conservation in the south-east forests of New South Wales, then (as now) the focus of a major conservation debate. He and his team used logging crews to collect data on the animals they saw – including koalas, greater gliders, and ringtail and brushtail possums – and then visited sites to assess site conditions. They also analysed the nutritional content of leaves from a range of eucalypts. According to Braithwaite, it didn’t take long for a picture to emerge.

‘Very clearly, foliage nutrient content was the key correlate to the density distribution of these animals,’ he says.

Using information gathered from the surveys, Braithwaite began forming what he calls the nutrient hypothesis, which attempts to explain koala distribution through an understanding of koala physiology and forest ecology.

‘The koala, being a heavy animal, is going to use a lot of energy, not only to maintain itself, but to reproduce,’ he says. ‘Eucalypt foliage is notoriously low in protein, so it seemed to be a reasonable proposition from my point of view that the time-energy nutrient budgets of these animals determined where they could not only survive, but also reproduce.’

Braithwaite reasoned that the best koala habitat was on soils with high nutrient (particularly nitrogen and phosphorus) levels in trees that are highly branched, since these are easier to climb and therefore require the expenditure of less energy.

But while this hypothesis can explain much of the distribution of the koala at a broad scale, it falls down at a finer scale. According to Cork, a koala physiologist, koalas are close to the break-even point at which they run into a simple law of physics.

‘For lots of reasons you would predict that an animal the size of the koala would not be able to utilise a diet such as eucalypt leaves very effectively,’ he says. ‘They’re high in fibre, which means they’re hard to digest, low in energy, low in protein and they’ve got these chemical defences in them which, apart from being toxic, require some energy to detoxify.’

Only large animals could handle such a diet: theoretically, it’s touch-and-go as to whether the koalas are big enough. They do cope, but how?

‘They have a much lower metabolic rate than other animals the same size,’ Cork says. ‘This effectively makes them a bigger animal. In addition, they seem to save energy by not being terribly active, and they have a really effective digestive system that helps them cope with the fibre.’

This explains the famous slothfulness of the koala, but what does it say about habitat? The fact is, says Cork, the koalas’ apparent preference for high-nutrient forests can’t be explained simply on the basis of nutrients, since much of the foliage they don’t eat contains sufficient quantities of nitrogen to sustain them.

So Cork and others started looking at leaf defences. These are chemicals put into leaves by the tree to prevent herbivory, and they are most common in plants growing on low nutrient soils, because such plants can least afford to lose leaves to browsing animals. Cork and his colleagues analysed leaves from forests where koalas were absent and compared them with leaves from forests where koalas were present.

‘Sure enough, we found that the forests where they were present also had high nutrients and low chemical defences,’ he says.

Although this gave a much more satisfying physiological explanation for why koalas

Koalas and other folivores can literally eat themselves sick by consuming sufficient quantities of plant chemical defences called diformyl-phloroglucinols (DFPs). The palatability of certain leaves has been found to relate to their level of DFP compounds.

preferred the high nutrient forests, it didn't improve the confidence with which good koala habitat could be predicted. So its usefulness as a management aid was limited.

Muscling its way into the habitat debate came the Australian Koala Foundation, which developed an approach it calls the Koala Habitat Atlas. This is generated by a geographic information system using data collected in a large number of surveys using koala scats to indicate habitat use.

'One of the things that has dogged the koala debate for many years has been a poor understanding of tree species preferences,' Phillips says. This is partly because of the large volume of anecdotal evidence that is now accepted wisdom, and partly due to what he calls 'a longstanding misconception' in the scientific literature which states that the tree you see a koala in is a food tree.

Phillips claims to have developed a methodology that accurately identifies primary (major) and secondary (less important) food tree species in an area. This information is used with vegetation maps to create maps of koala habitat, usually at the local government scale.

Phillips and his colleagues have mapped about 1.5 million hectares of potential koala habitat using what he believes is the largest koala database in the country. Some 43 000 trees have been assessed at 870 independent sites. He says although the scientific community has been cautious, there are signs that it is beginning to take notice.

'I've had people from CSIRO in particular who have actually sat down for a day and listened and looked at the data and are slowly beginning to appreciate the enormity of what we've achieved,' he says.

But any model that predicts koala habitat based on tree species may encounter a hitch. According to Bill Foley, a nutritional ecologist at the Australian National University, koalas wouldn't know a tree species if they fell out of one.

'Animals discriminate at the level of individual trees, not at the level of taxonomic units,' he says. 'That's hardly surprising.'

Foley bases his comments on work carried out by his team into the feeding preferences of a number of folivores including koalas, greater gliders, and the common ringtail and brushtail possums. By fractionating palatable and unpalatable leaves, the team discovered a new group of plant chemical defences called diformyl-phloroglucinols (DFPs). When folivores consume these compounds in sufficient quantities, they stimulate what Foley calls the 'nausea centre' in the animal's brain. Basically, they stop eating because they feel sick.

'We've done other metabolic work showing that, at least in the short-term, these chemical defences override any other considerations in diet selection for these animals,' he says.

In fact, a model developed by PhD student Ivan Lawler, based solely on differences in the level of a single DFP compound, can explain 86% of the variation in ringtail possum feeding preferences. Another model developed by fellow student Ben Moore explains 75% of the variation in koala feeding preferences.

The level of DFPs is highly variable within a species, leading Foley to surmise that the tree species may be too coarse a scale at which to understand koala habitat.

'Among every eucalypt species we've looked at now for both koalas and ringtails,

‘The koala has a huge distribution . . . It’s probably occupying something like a million square kilometres. I just think it is nonsense to talk about koalas being threatened with extinction.’

there are individuals that are highly palatable and those which are poorly palatable, and a whole range in between,’ he says. ‘This suggests that you can’t reliably identify koala habitat in terms of tree species. There’s substantial variation amongst all species and there’s substantially more variability in habitats than we would otherwise imagine.’

A further complication is that such variability does not appear to be determined by environmental factors, since trees of the same species growing side-by-side may contain vastly different levels of DFPs.

Yet there may be a quick way to assess large areas of koala habitat at this scale. Both Phillips and the ANU research team see potential in a new technology called near infrared spectroscopy (NIRS) as an aid to mapping koala habitat. Using a technique developed by the ANU team, NIRS produces an electromagnetic ‘signature’ that encapsulates aspects of leaf chemistry. This can then be correlated with an animal’s feeding preferences and built into a predictive model. By conducting NIRS via satellite over large areas of bush, suitable habitat at the scale of individual trees can be identified.

‘You would pick areas that are suitable on the basis of nutrients, but in that subset of good, potentially suitable habitat you would then have to start looking at the components that make them unpalatable even if they are of high nutritional quality,’ Moore says.

The jury is still out on the AKF’s atlas. Its biggest weakness, says Cork, is that it hasn’t yet been scrutinised thoroughly by the scientific community, although several papers are in press.

‘Because it’s the AKF, there’s suspicion from various quarters,’ Cork says. ‘Because it hasn’t yet been published in peer review, the problem is compounded.’

But the failure to publish isn’t a criticism limited to the AKF.

‘A large amount of koala research, particularly on habitat, hasn’t been published, or has not been subject to peer review,’ Cork says. ‘And because much of it’s done by foresters or by ecologists outside the forestry profession, they all suspect each other. Without having proper peer review, there’s this conflict situation that’s really hard to resolve.’

This view is endorsed by Lawler.

‘I think it might help reduce acrimony if people would publish, so that at least when they are slinging off they know what they are slinging off at,’ he says.

How many koalas?

Slinging matches are particularly fierce over estimates of the national koala population. The AKF estimates 45 000–80 000 nationally, broken down into 25 000–50 000 in Queensland, 10 000–15 000 in NSW, and 20 000 in Victoria and South Australia combined. According to Phillips, these figures are based on estimates provided by biologists in Queensland and New South Wales that the AKF then used to produce estimates for Victoria and South Australia.

Martin says that the AKF has never adequately explained how it reached its estimates.

‘Where I was taught to do science, the normal way to go about things if you wanted to put an estimate on something, you did some work and you presented your data,’ he says. ‘You gave your professional colleagues some opportunity to criticise it or to see if it was a fair estimate.’

Part of the problem is that koalas are a notoriously difficult animal to count.

‘They’re a widespread, relatively cryptic animal,’ Martin says. ‘And they live in abundances of anywhere from 10 to the hectare, which is what we get down here, to one animal per 200 ha in the brigalow country in central Queensland.

‘So for an animal that is living over such a wide variety of habitats in such a wide range

Habitat loss is the greatest potential threat to koalas, with dogs and cars also taking their toll. *Chlamydia*, a bacterial disease once thought to threaten the survival of the species, is not a significant threat, although it may act as a natural population control mechanism. Another concern is the lack of genetic variation between and within populations.

of abundances, it's hard to assess populations. But I think most people who didn't have the agenda of the Australian Koala Foundation would say there are hundreds of thousands of koalas left in Australia.'

Phillips counters that putting a number on the national koala population is – in any case – largely irrelevant.

'We need to be becoming less concerned about the actual numbers of animals that may be around and more concerned with population trends,' he says. He talks of criteria developed by the International Union for the Conservation of Nature and Natural Resources (IUCN) for determining the conservation status of species. Cork thinks along similar lines.

'Steve Phillips' point is that the number of koalas really shouldn't matter,' he says. 'That's what everyone reacts to, but what should matter according to the IUCN criteria is the rate of change of habitat and populations. According to Steve's data, nationally there is reason for concern. Populations in a large part of the country seem to be declining.'

This brings us to a last point of contention: should the koala be listed nationally as an endangered species under the national Endangered Species Protection Act? Although it has been nominated twice by the AKF – which says the koala faces imminent extinction – it has twice been rejected.

Martin believes the koala is not under any threat.

'The koala has a huge distribution,' he says. 'It's probably occupying something like a million square kilometres. I just think it is nonsense to talk about koalas being threatened with extinction.'

Bill Sherwin, a conservation geneticist at the University of New South Wales, says genetic studies indicate a number of issues that need to be addressed to ensure the continued survival of the species. First, almost all the populations in southern Australia have been established from a single small population on French Island in Victoria. Consequently, there is little genetic variation between and within populations.

'That's a little bit of a worry because there are indications in other species that lower genetic variation can be associated with poorer reproduction and survival,' he says. So far, though, the southern koalas have shown an immense capacity to survive and reproduce, to a point where many populations are killing off their own habitat. Low genetic variation may well become an issue

Koala focus may foil other **leaf eaters**

MANAGING forests for the benefit of koalas could act against the interests of other folivorous marsupials, according to nutritional ecologist Bill Foley.

Popular culture holds that koalas are fussy eaters. Microsoft's *Encarta World Atlas*, for example, reports that the koala is a 'dietary specialist' that eats the leaves of only 'a half dozen species of eucalyptus'. But Foley says that the koala's threshold of intolerance for DFPs (the plant secondary compounds that limit leaf consumption) is much higher than it is for other leaf-munching marsupials such as the ringtail possum and greater glider.

'For this reason, koalas appear capable of eating the leaves of a wider range of individual trees than other folivores,' he says.

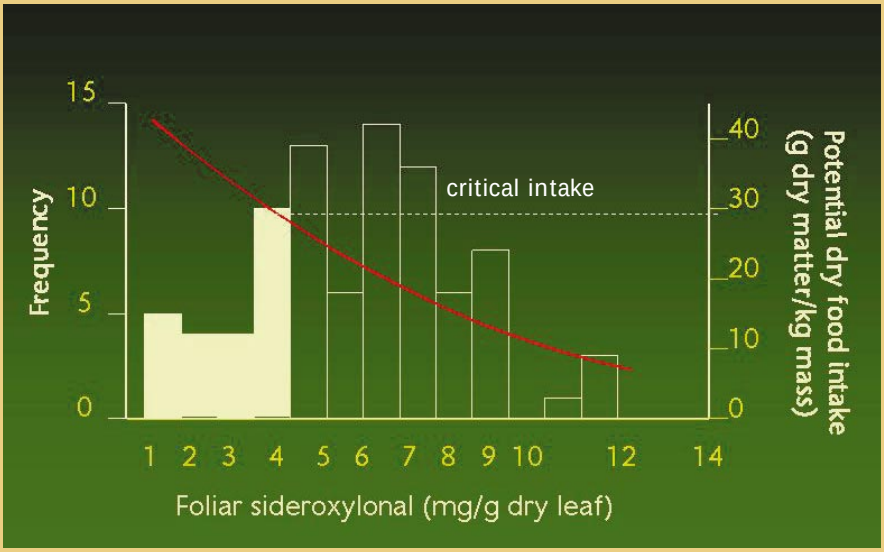
Such a conclusion might not demolish the 'fussy feeder' tag completely, since the animals clearly have discerning tastes when it comes to choosing feed trees, but it could have important implications for wildlife management. For example, koala lobbyists on the north coast of New South Wales advocate a forest management policy that favours *Eucalyptus microcorys* (tallow-wood) because it is thought to constitute an important koala feed tree. But preliminary work by Foley and others suggests that DFP levels in individuals of this species may be skewed towards the high end – often above the threshold of some of the other folivores.

Foley wants to determine intra-species variability in DFPs for tallow-wood across its geographic range before drawing any definite conclusions. But should further investigation support the preliminary work, a management regime developed with only the interests of koalas at heart may be a poor conservation option.

'You might be managing for koalas, but you could be managing against everything else,' Foley says.

More about leaf toxins

Lawler IR Foley WJ and Eschler BM (2000) Foliar concentration of a single toxin creates habitat patchiness for a marsupial folivore. *Ecology* (accepted).



Ivan Lawler and Bill Foley surveyed 87 *Eucalyptus polyanthemos* trees at a 0.5 hectare site near Captains Flat in New South Wales to determine the patchiness of eucalyptus chemical defences. They found that in this single population more than half of the potential food trees could not by themselves sustain a ringtail possum.
In the diagram above, the curved line shows how much food is eaten by ringtail possums at varying concentrations of the defensive leaf chemical sideroxylonal. An intake of 28 grams, the minimum maintenance amount, is represented by the horizontal line. All the trees to the right of where these two lines intersect are unsuitable ringtail possum food sources. The high variability of DFP concentrations within a species suggests that the level of tree species may be too coarse a scale at which to understand koala habitat.

‘If we can’t resolve disputes over koalas, then I doubt we’re going to be able to resolve them for any species.’

should environmental conditions change – due to global warming, for example – but it isn’t holding them back at the moment.

There are other issues. Bearing in mind that a key aim of conservation strategies is to maintain the genetic diversity of a species, Sherwin and his colleagues – particularly Bronwyn Houlden at Taronga Park Zoo – are investigating the genetic diversity of the koala across much of its range.

‘There’s quite appreciable genetic variation between different populations throughout the species’ range on a north-south axis, which is the one we’ve mainly sampled,’ Sherwin says. ‘But there may be variation to some extent on an east-west axis as well. And to maintain the widest range of genetic variation it would be important to maintain populations dotted throughout the range of koalas.’

For this reason, any declines in New South Wales or Queensland are of concern. And some – such as the one on the Barrenjoey Peninsula – appear under threat. In New South Wales, authorities are worried enough to have declared the species ‘vulnerable’ and to have commenced development of a recovery plan. A National Koala Conservation Strategy – in lieu of listing the species endangered nationally – has also been developed.

A point of agreement

Almost all the koala protagonists agree that habitat loss (or what experts will tell you is likely to be habitat) is the greatest potential threat to koalas, with dogs and cars also taking their toll. Most also agree that *Chlamydia*, a bacterial disease once thought to threaten the survival of the species, is not a significant threat, although there is disagreement on its role as a natural population control mechanism.

Protagonists also concede that there is no shortage of information about koalas. Based on what is already known, it should be possible, they say, to manage koalas effectively. In its literature, for example, the AKF reports a ‘formidable information base’ of more than 400 published papers and research theses.

‘The reason for a lot of the conflict is not the lack of good scientific knowledge,’ Cork says. ‘It’s not the sort of thing that’s necessarily going to be solved by coming up with wonderful new models. It arises because of the high stakes over koala habitat because it’s valuable for development as well as conservation.’

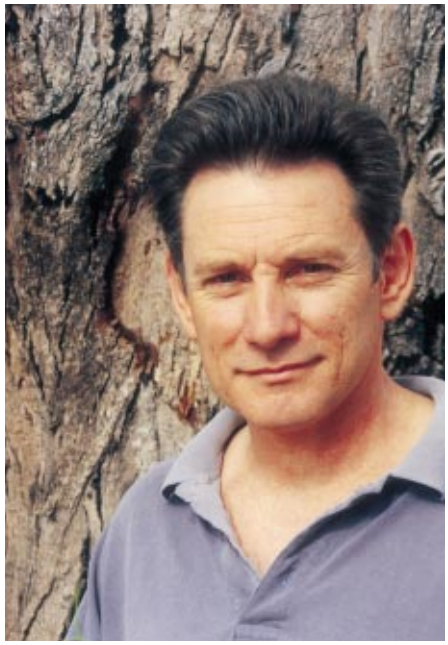
At the end of the great koala debate, it’s refreshing to know that there are some points of agreement. Martin offers an explanation for at least part of the friction.

‘The problem is that biologists coming from different ends of the continent who are dealing with different populations in different types of habitat in different levels of abundance see things differently,’ he says.

‘Roger and I work at opposite ends of the spectrum,’ agrees Phillips. ‘Roger’s worked on *Chlamydia*-negative island populations predominantly; I’ve worked on declining mainland populations predominantly.’

There are political reasons as well. A government-sponsored shoot-out of koalas would be an international public relations disaster for the tourism sector, regardless of its merits as a conservation measure. It wouldn’t do the AKF any good, either, because an ‘endangered’ tag undoubtedly helps it attract funds.

Cork believes that the time has come for an end to the fractious nature of the koala debate. In a special issue of *Conservation Biology* that presents papers from last July’s koala symposium, he and co-authors Ian Hume and Bill Foley liken the koala conflict to addictive drugs. ‘At best they produce short-term relief of symptoms while making the real problem more difficult to solve, thereby creating a dependency on unconstructive behaviour,’ they say.



Alastair Sarre

CSIRO’s Steve Cork and his colleagues say the time has come to end the fractious nature of the great koala debate.

Cork and his co-authors advocate better mechanisms for listening to the concerns of all participants in debates about koala conservation and for allowing them to contribute constructively to the decision-making process. Consensus on some issues may not be possible, but no one argues against an objective debate. It could even advance the cause of conservation on a broader front.

‘The koala is an example of a species that challenges our processes for developing conservation plans,’ Cork says. Being such a high profile species, it could help the community break new ground, creating processes for dealing with conflict that may be transferable to other conservation issues. It’s probably worth a try.

‘If we can’t resolve disputes over koalas, then I doubt we’re going to resolve them for any species,’ Cork says.

Abstract: The distribution of koalas is influenced by chemical defences that have evolved in leaves to prevent herbivory. In one study a new group of plant chemical defences called diformyl-phloroglucinols (DFPs) explained 75% of the variation in koala feeding preferences. DFP levels are highly variable within eucalypt species, suggesting that tree species may be too coarse a scale at which to understand koala habitat. Habitat loss, dogs and cars are the greatest potential threat to koalas. *Chlamydia*, a bacterial disease once thought to threaten the survival of the species, is not a significant threat, although it may act as a population control mechanism. Another concern is the lack of genetic variation between and within populations. Conservation biologists have called for improved mechanisms to enable all interested parties to contribute constructively in the koala conservation process.

Keywords: koalas; population distribution; population dynamics; wildlife management; wildlife surveys; habitats; feeding behaviour; eucalypts; Diformyl-phloroglucinols (DFPs); *Chlamydia*.