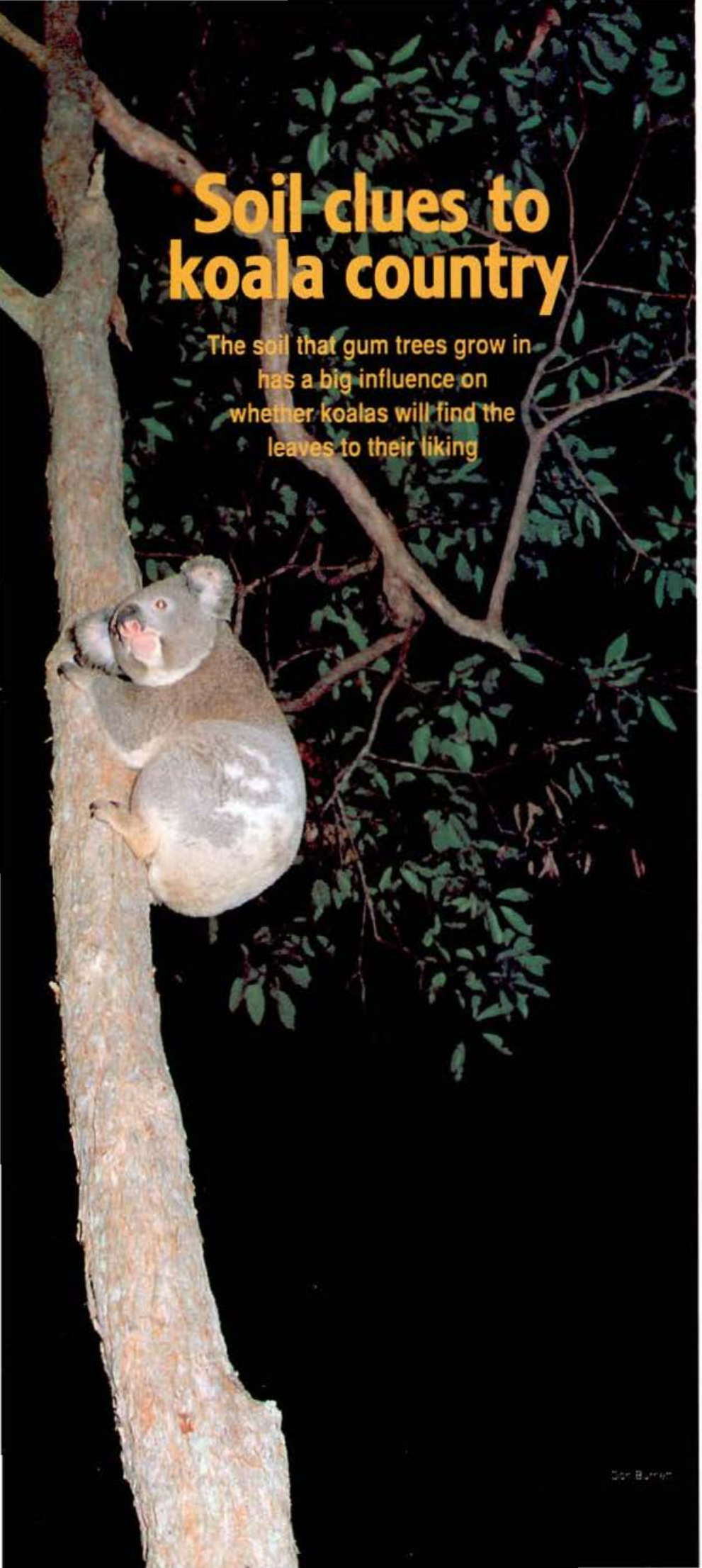


Soil clues to koala country

The soil that gum trees grow in has a big influence on whether koalas will find the leaves to their liking

Twenty years ago, a generation proclaiming that it sought peace and a new vision of the world through a return to Nature — and through the heavy use of what it liked to call 'mind-altering substances' — maintained that koalas were models of peacefulness because they were permanently 'high' as a result of chemical compounds believed to exist in eucalypt leaves.

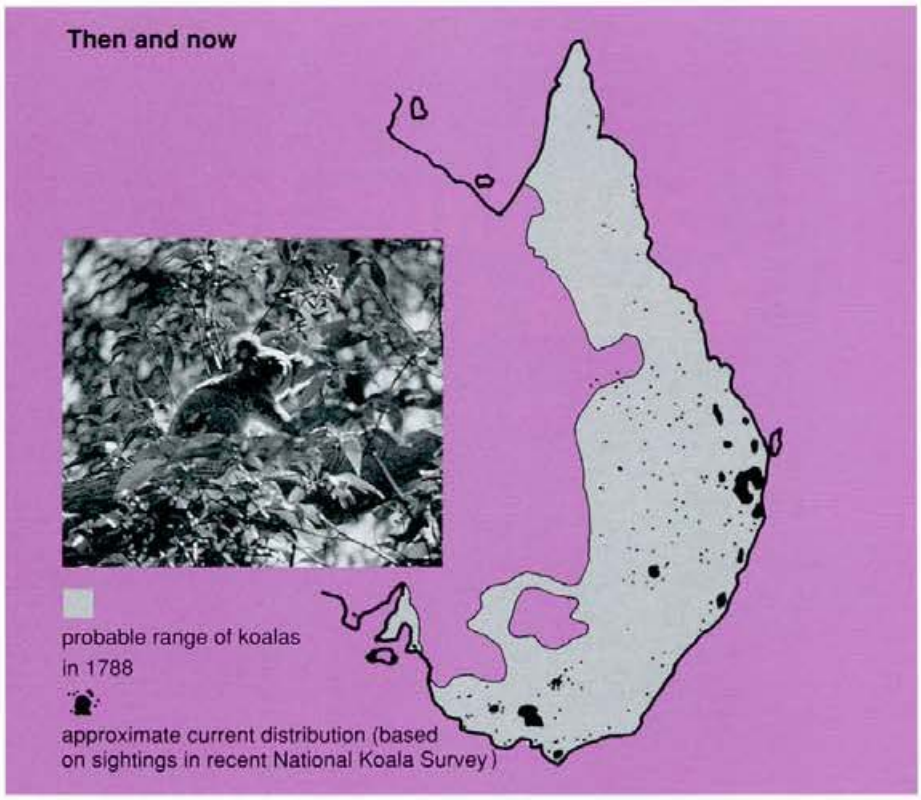
Since then, science has dispensed with the idea that koalas are lost in Antipodean opium dreams: the poor quality of gum leaves as food means that koalas have to devote a lot of time to digesting them (see *Ecos* Nos. 19 and 51), so their inactivity reflects no more than their need to conserve energy while they gain the energy that enables them to eat and to reproduce.

Only recently have we begun to appreciate just how much of a challenge survival is for a koala; and just how inimical is the environment in which it lives. While the Australian bush may lack such obvious dangers as bears, lions and tigers (despite a generous quota of venomous reptiles), it is the scene of a silent war between plants and herbivores.

Plants growing in nutrient-poor soil produce chemical weapons — toxins — as a defence against being eaten, since the poor quality of the soil means they can't mobilise nutrients quickly enough to replace leaves eaten by herbivores such as koalas (or insects, for that matter). On the other hand, plants growing in nutrient-rich soil can afford to lose leaves to predators because they can replace them at a comparatively low energy cost.

Dr Wayne Braithwaite and Dr Steven Cork, of the CSIRO Division of Wildlife and Ecology, have demonstrated the essential importance of resource availability in plant–herbivore relationships in the eucalypt forests of south-eastern Australia — where ancient, infertile soils low in nitrogen and phosphorus have led to what Dr Cork calls an 'evolutionary arms race' between plants that produce toxins (primarily carbon-based compounds called phenolics) and leaf-eaters such as greater gliders and koalas, which counter the plants' chemical defences with complex digestive adaptations.

Koalas in particular have evolved to the outer limits possible for mammals to cope with, much less to overcome, the defences produced by eucalypts. In human beings, for example, the



caecum or appendix is a non-functional offshoot of the large intestine and rarely reaches 10 centimetres in length; in koalas, the same organ (used to separate nutritional from non-nutritional parts of leaves, and to filter out toxins) is up to 2·4 m long.

Dr Cork and Dr Braithwaite say resource availability plays a far greater role in the status, distribution and population dynamics of koalas than, for example, recent outbreaks of chlamydia, the viral disease responsible for large numbers of koala deaths: in fact, chlamydia appears to be an endemic disease of koalas, becoming a threat mainly in response to stress brought about by habitat loss.

A comprehensive understanding of koalas' status based on where they occur, the researchers say, cannot be gained without also considering where koalas do not occur... and why. It seems koalas can only survive in places that have enough nitrogen, phosphorus and other nutrients to counteract the effects of toxins, or where concentrations of leaf toxins are low; and, it also seems, these factors are inextricably linked.

How they are linked is the subject of continuing research by Dr Cork, who is looking beyond the immediate aspects of the relationship between resource availability, toxins and koala survival at the effects of human activity on the species' shrinking range. Over the past several years he and colleagues at the Division of Wildlife and Ecology have conducted population surveys of koalas throughout south-eastern Australia, and have collected leaf samples from various tree species to examine the links between soil nutrients, leaf toxins and palatability, and koala distribution.

In fact, Dr Cork has found that one of the best ways to find koalas is to look not up in the trees but down in the soil in which those trees grow. Ultimately, resource availability means the relative abundance of soil nutrients such as nitrogen, phosphorus and potassium. These exist in a delicate balance that affects the production of toxins and, it seems, that can be affected by forest management techniques. Activities such as burning, fertilising, grazing, logging and road-building alter the flow of nutrients (and water, which carries nutrients to and through the trees) in ways that affect koalas directly.

Most of the optimum koala habitat in south-eastern Australia had disappeared by the beginning of this century (see the map), so the species must now rely on oases of good vegetation set among much larger tracts of sub-optimal or marginal habitat. This situation has led researchers to recognise the existence of a threshold between habitats in which koalas can survive and those that cannot support resident populations. (In most cases, the only koalas found in such sub-threshold areas are young males, which have been ejected from oases 'owned' by older, dominant males that maintain a harem of breeding females.)

Simple food quality is the basic determinant of the threshold. In captivity, an adult koala needs at least 400 grams of high-quality leaves to survive, and larger animals must consume up to 800 g. Wild koalas need more food of high quality because they must use more energy to find that food... and even more food of poorer quality to obtain the same amount of energy.

The palatability and nutritional value — in other words, the food quality — of the eucalypt leaves on which the animals subsist depend on the types and amounts of nutrients available in a particular habitat. The balance of phosphorus, potassium and nitrogen in the soil influences the production of phenolics (significantly, nitrogen, generally present at very low levels, is not used to manufacture these compounds, which are based on abundant carbon). Phenolics represent a 'one-off' energy cost to trees: they require more energy to produce than 'qualitative alkaloid' defences, but they are stable compounds that remain effective for the life of the leaves in which they're stored — and eucalypts produce long-lived leaves.

Qualitative alkaloid toxins are generally produced by faster-growing plants with shorter-lived leaves: while these cost less to manufacture, they break down more rapidly and thus need to be 'topped up' at intervals — which means a continuing energy cost.

Phosphorus is especially important. It is thought to help maintain a neutral pH value within the koala's bloodstream, damping the effects of high acid concentrations that are themselves produced by the koala's physiological efforts to break down toxins.

Koalas excrete a greater proportion of their nitrogen as ammonia than they would if their diet didn't include phe-

nolics, in the process voiding large amounts of hydrogen; they have to get rid of the hydrogen ions associated with high acid concentrations in the blood. Their high level of nitrogen loss means koalas must obtain as much of this vital element as they can from their diet. On the other hand, koalas' low basal metabolic rate — about 50% of the average for placental mammals — means their total nitrogen requirements are lower. Marsupials in general have lower metabolic rates than placental mammals, although South American sloths (also arboreal leaf-eaters, although they are placental mammals) have a basal rate only 20% of the placental average.

Koalas exhibit an understandable preference for leaves that are relatively low in toxins... leaves, that is, with high food quality and from trees that grow on soil with relatively high amounts of nitrogen, phosphorus and other nutrients. While the younger, more succulent leaves koalas prefer are often actually higher in phenolics than older leaves, they are also higher in nitrogen and contain less difficult-to-digest fibre.

Walking a tightrope in an effort to obtain the best possible food, in an environment where limited resources have led most trees to produce food that has built-in defences against predators, has made koalas inherently conservative in their selection of food trees. Commonly, they will eat leaves from individual trees of a particular species while ignoring other individuals of the same species nearby. Koalas in one area may include the leaves of a particular species in their diets while koalas in another location will ignore the same species. Examples of this sort of preference can sometimes seem a little bizarre: for example, *Eucalyptus sideroxylon* is eaten only rarely by koalas in Australia, but is eaten by koalas at San Diego Zoo, California. Dr Cork suspects that the use of fertlisers to enhance this species' growth may make it more palatable.

A conservative approach to food selection further reduces the species' chances of survival in habitats that are under increasing pressure from human activity. Forestry may seem contra-indicated in this situation, but Dr Cork's research suggests that carefully monitored and highly selective forestry could, on occasions, be of some benefit to koalas.

A degree of tree removal could enhance food quality for the animals, reducing competition for resources and releasing water and nutrients to younger trees... which could then produce larger numbers of the kinds of the young, succulent leaves koalas prefer.

However, this benefit must be weighed against the effects of removing the shelter on which koalas and other wildlife depend. Those effects include not only the immediate, direct effects of disturbance, but also the longer-term effects of the lag between tree removal and the appearance of regrowth and the impact of logging on soil nutrients and forest growth rates — factors that must be understood if forestry, farming and koalas are to co-exist.

Carson Creagh

More about the topic

Polyphenols and the distribution of arboreal folivorous marsupials in *Eucalyptus* forests of Australia. S. J. Cork. In 'Plant Polyphenols: Biogenesis, Chemical Properties and Significance.' (Plenum: New York, in press.)

Resource availability and plant antiherbivore defense. P. D. Coley, J. P. Bryant and F. S. Chapin. *Science*, 1985, **230**, 895–9.

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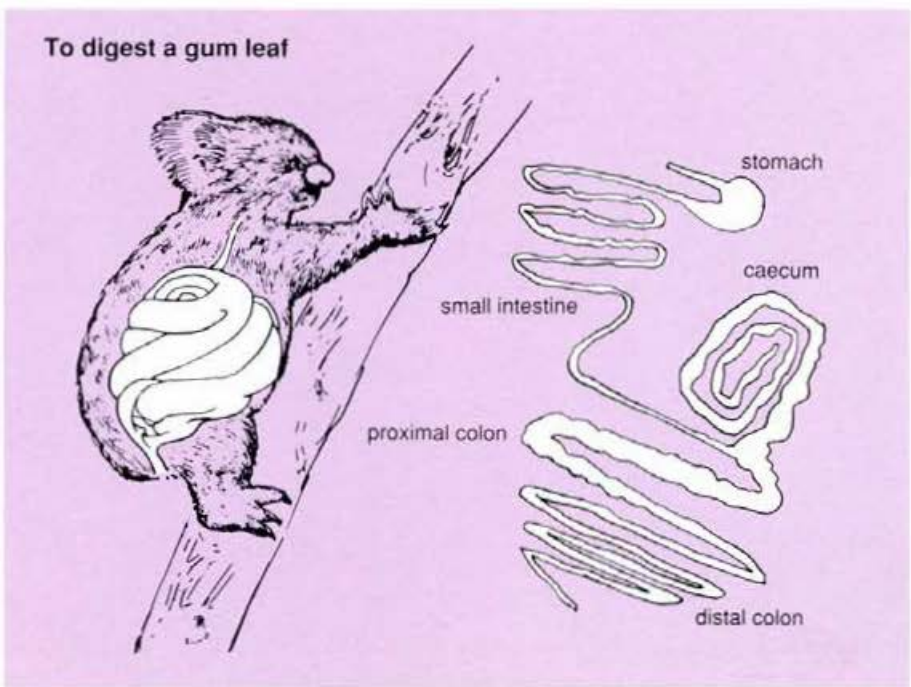

The caecum, the koala's much larger equivalent of our appendix, plays a vital role in gum-leaf digestion — filtering out toxins and separating nutritional from non-nutritional parts of the leaf.