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INQUIRY INTO KOALA POPULATIONS AND HABITAT IN NEW SOUTH WALES

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Submission to the Inquiry into koala populations and habitat in New South Wales – Portfolio Committee No. 7 – Planning and Environment

Dear Ms Faerman,

I am a senior lecturer at the Hawkesbury Institute for the Environment at Western Sydney University, where I undertake ecological research, mostly in the broad areas of chemical and nutritional ecology, and plant-animal interactions. This field of research incorporates research into the nutritional quality of chemistry of plants, how this varies with where plants grow, with environmental conditions such as temperature, drought and atmospheric CO_2 concentrations, and with plants' needs to defend themselves from being eaten by herbivores. It also incorporates research into the consequences of variation in plant quality for herbivore nutrition and ecology – I ask, what do herbivores eat, what behavioural and physiological mechanisms have they evolved to cope with the nutritional and toxicological challenges posed by their diets, and how does diet affect the growth and persistence of animal populations across landscapes and in the face of environmental change?

Although I am involved with research into a variety of plant (e.g. pasture species) and animals (e.g. insect) species, eucalypts and koalas are the main focus of my work, and have been for much of my career. I undertook my Ph.D. under the supervision of Prof. William Foley at the Australian National University submitting my thesis "Chemical determinants of diet and habitat quality in the koala" in 2004. In my Ph.D. I demonstrated the importance of a particular class of plant toxins (the formylated phloroglucinol compounds, FPCs) in influencing koala feeding behaviour and showed that the occurrence of these compounds can vary greatly between eucalypt species and populations, by extension altering habitat suitability for koalas. This work was published in Nature, Ecology, Ecological Monographs, Biology Letters and elsewhere. After my Ph.D. I worked for 2 ½ years at James Cook University in Townsville, where I investigated how landscape-scale variation in eucalypt leaf quality drives densities of brushtail possums, and with Jane DeGabriel, showed how leaf protein and tannin concentrations interact to determine the nutritional quality of leaves and consequently, the breeding success, of possums. I then worked for 5 years as a chemical ecologist at the James Hutton Institute in Aberdeen, Scotland, before returning to Australia and my current position in 2012.

At HIE my research program has included research into the effects of climate and atmospheric change on leaf quality, particularly at Western Sydney University's EucFACE

(Eucalyptus Free Air Carbon dioxide Enrichment) experiment; variation and function of the koala gastrointestinal microbiome; the interaction between temperature and the ability of mammals to cope with plant toxins; and the development of new molecular methods to determine which tree species koalas have eaten from the analysis of their faecal pellets. My research has been funded by the Australian Research Council, The Queensland Government, NSW Department of Planning, Industry and Environment and the Natural Resources Commission and others. A full list of my publications can be found here: https://publons.com/researcher/2881648/ben-d-moore/publications/ . I sit on the expert review panel for the (former) Office of Environment and Heritage's Koala Habitat Suitability Mapping Project.

I believe that a robust understanding of the nutritional requirements of koalas and the value of different trees and landscapes to koalas is essential to identifying koala habitat in NSW and to ensuring healthy, sustainable populations. While suitable foliage alone cannot ensure the survival of koalas, it is clear that koalas cannot persist without an adequate and reliable source of nutrition.

Koalas remain absent from vast areas of NSW where the historical record shows that they once occurred. At many locations that have supported koalas in more recent decades, populations have declined. Some populations have apparently shown positive growth trends, at least for periods of time, and koalas are sometimes detected in areas when their presence has previously been overlooked, but the overall trend is strongly one of decline.

We still have more to learn about how the nutritional quality of eucalypt foliage for koalas (and other leaf-eating marsupials) varies across the landscape. Understanding and mapping this (e.g. with remote sensing technologies) will greatly assist in the distinction of suitable and unsuitable potential habitat for koalas, and inform whether koalas are absent from regions because they cannot be supported nutritionally, or because of historical factors such as past hunting, land clearing and fire.

Many well-known factors contribute to this decline, to different extents, around NSW. These include loss of habitat, disease, death from vehicle strike and dog attack, and direct impacts of climate change and extreme weather events, including drought and heatwaves, which are increasing in frequency and severity. In my opinion, climate change and the loss and deterioration of habitat are the most insidious of these drivers. Habitat is lost when forest and woodland is cleared for agriculture or other uses, including plantation forestry; when paddock trees are felled or die of old age and are not replaced; when roadside and urban trees are removed for road widening, safety or aesthetic reasons and not replaced; at least temporarily, after extensive and intense bushfires; when trees are killed by disease and dieback, including bell miner associated dieback. Recent legislative changes that have led to an acceleration of land clearing in NSW are a threat to the sustainability of koala populations, and the recently announced amnesty on past illegal land clearing offences sends a clear message that preservation of habitat is no longer considered a serious matter.

As a research ecologist, I can comment on some subjects and identify useful further research that may help to better understand trends and resource availability for koalas

throughout NSW, as well as the likely impacts of climate and atmospheric change of koalas and koala distribution.

1. Historically, most koala research has studied relatively high-density koala populations, for obvious reasons. Efforts have turned more recently to overlooked, lower-density populations. Understanding the distribution of lower density populations is very valuable to understand the true extent and trends in koala populations and to understand and model how koala populations can recover from future disturbances. New koala populations have been identified by intensive directed research efforts and citizen science in the Southern Highlands and the Blue Mountains, and by the use of acoustic monitoring in NE NSW. Some research groups are trialling the use of drones with thermal cameras to spot koalas, an approach which might eventually be automated. All of these approaches are to be commended, and could usefully be expanded across greater areas.
2. The former Office of Environment and Heritage recently published a comprehensive review of koala food tree preferences for NSW. This thorough and detailed review is a valuable document, but our understanding of koala food tree preferences remains somewhat constrained by the fact that it is based primarily on observations of daytime tree use, which does not always reflect the nocturnal use of trees for feeding.
   With Dr Michaela Blyton (formerly my postdoc, now at University of Queensland), we have developed a new DNA-based method for identifying what koalas have been eating from analysis of faecal pellets. We have received funding to develop and roll out this method across Queensland, and to apply it to understand how koala food choices are affected by regeneration forestry practices in NE NSW. A better understanding of what koalas eat, particularly when the availability of tree species changes, may lead us to revise our concept of what can constitute koala habitat, as well as guiding future tree planting efforts.
3. Climate and atmospheric change can have multiple direct and indirect effects on plants and animals, but much uncertainty surrounds the severity and even direction of some of these.
   a. *Effects on leaf quality.* Both temperature and increasing atmospheric concentrations of CO_2 can act independently and in concert to alter the physiology of plants and the quality of plant tissues as food for herbivores. These produce indirect effects on koalas. Numerous studies have shown that the nutritional quality of leaves is generally reduced by elevated CO_2 , as protein concentrations decline and digestibility decreases. Our EucFACE experiment at Richmond has shown that the foliage of *Eucalyptus tereticornis* (forest red gum, a very important koala food tree in NSW), does not change as much in response to elevated CO_2 as some other tree species studied elsewhere in the world. However, young leaves do show significantly reduced protein concentrations.

      We believe that protein availability is a limiting nutritional factor for koalas, and that young leaf, which has the highest protein concentrations, may be an essential, seasonally limited, nutritional resource. In North Queensland, Jane DeGabriel and I showed that brushtail possums with access to eucalypts with

high concentrations of digestible protein bred successfully year after year, while neighbouring possums with poorer quality eucalypts bred only occasionally.

If we extend these results to koalas, we would predict that reduced protein availability would also reduce the likelihood of successful breeding in koalas, and thus, ultimately, would reduce the likelihood of long-term population growth or persistence. This indirect effect is one that is likely to have extensive detrimental effects on koala populations across NSW, but particularly in more marginal habitats. The effects of increasing temperature and its interaction with elevated CO_2 on nutritional quality are less well studied, but may exacerbate or ameliorate the effects of CO_2 alone. More research is required to understand the effects of climate and atmospheric change on other leaf attributes such as the concentrations of plant defensive compounds (e.g. toxins and tannins) and the total energetic return to koalas associated with different leaf diets, as well as an different eucalypt species growing in different environmental conditions (soil, rainfall, climate). This will aid in understanding how habitat suitability for koalas will change in the future, and where conservation efforts should be directed.

b. As the climate and atmosphere change, not only will the quality of foliage on existing trees change, but conditions may favour the establishment and growth of certain eucalypt (or non-eucalypt) trees and disfavour others. Over a timescale of decades, or less where fire and drought intervene, this may cause a change in the species composition of many of our forests and woodlands, which may favour koalas in some areas but harm them in others. Some efforts have been made to model these changes, using species distribution models that assume that tree species' current distributions are a reflection of the conditions they require for growth and persistence. However, this is not always the case, meaning that a question mark hovers over the reliability of these models. Efforts to improve and validate these model predictions would be valuable.

c. NSW is currently experiencing what is by some measures, the worst drought in its recorded history. In some parts of the state, extensive tree mortality is being reported as a result of the often unprecedented combinations of drought and heat – this is the subject of active research by Prof. Belinda Medlyn, Assoc. Prof. Brendan Choat, and others at my research institute (HIE). On our inland rivers, a particularly important koala food tree, river red gum, is often killed when the flood events they require no longer occur as a consequence of the depletion of water in our rivers for irrigation. Elsewhere, water tables can be lowered by extraction for irrigation and by mining, and this can be expected to reduce the ability of trees to survive drought. These impacts can be expected to have severe and prolonged effects on koala food resources in some areas, such as New England.

In order to better understand habitat suitability for koalas across NSW, these patterns need to be understood, and when conditions allow, plans should be enacted to attempt to establish replacement trees. Unfortunately, droughts like this are anticipated to become more severe and frequent under climate change, and the stress on plants is exacerbated by increased temperatures, meaning that some of these forests may never recover their former condition.

Elsewhere, outbreaks of (often previously unrecognised) insect pests have caused extensive damage to particular eucalypt species in certain regions (e.g. weevils have killed manna gum across the Monaro; psyllids have killed many grey box and forest red gum throughout Western Sydney and the Hunter Valley). These events also appear to be increasing frequency, and in some cases can be directly linked to the warming climate. Needless to say, tree deaths reduce the extent and quality of koala habitat in NSW, and understanding and reversing this process should be a priority.

d. Climate change also produces direct effects on koalas. During extreme heatwaves, which are increasing in frequency and severity, koalas can be killed directly by heat stress. At less extreme temperatures and over shorter periods of time, koalas can cool themselves by evapotranspiration if sufficient water is available. Koalas are best positioned to survive if free water is available in dams and watercourses, and in some areas researchers and trialled supplementing koalas with water at drinking stations. It remains to be seen whether this approach can be feasibly rolled out at scale that will alter the prospects of survival for whole koala populations.

   When free water is not available, koalas must meet their water requirements from the leaves they consume. Previous research has not recognised, however, that heat stress can constrain the ability of koalas to feed and thus obtain the water they need. This is because, first, eating and digesting generates heat, and animals avoid the production of heat when they are already heat-stressed, and second, because high temperatures impact liver function and reduce the ability of koalas to tolerate the toxins found in eucalypt foliage.

   We have recently received funding via the NSW Koala Strategy to better characterise these constraints. The project will also map the water content of foliage, and with these data we will update a previously published bioenergetic model of koala population persistence throughout NSW. This model will take information about the ability of koalas to obtain energy from their diets, and safely dissipate it as heat when required, and model the survival and reproduction of koalas through a variety of projected climate, weather and leaf moisture scenarios. We anticipate that this work will return a much more nuanced picture of the variety of nutritional and energetic circumstances that confront koalas, and how these limit the current and future distribution of koalas. In particular, this should allow the more

confident identification of koala refugia (areas where koala populations persist during challenging periods where they may disappear from other parts of the landscape) and candidate areas for koala translocations and reintroductions. The ultimate endpoint of this work, for which we will seek additional funding, will be to create a live "koala heat stress map". This online tool would feed information about tree distributions and the availability of free water across NSW; near real-time spatial predictions of leaf moisture levels; and real-time weather data into a sophisticated model of koala bioenergetic physiology, to understand when local conditions threaten the survival of individual koalas or reduce the ability of koalas to successfully breed.

The terms of reference ask that the committee address the environmental, social and economic impacts of establishing new protected areas to conserve koala habitat. Retention of forested areas has environmental benefits beyond the protection of the koala. It offers additional biodiversity, carbon sequestration and precipitation benefits. Koalas provide significant economic benefit to Australia via tourism and are highly valued by society. The protection and retention of koala habitat outside of reserves also carries substantial environmental benefits for biodiversity (including koalas). On agricultural lands, the benefits of trees for cooling and offering shelter to livestock can often outweigh the loss of productivity.

Yours sincerely

Ben Moore