An Ecological Approach to Koala Conservation in a Mined Landscape

D Lunney[1], J Lemon[2], M S Crowther[3], E Stalenberg[4], K Ross[5] and R Wheeler[6]

ABSTRACT

Gunnedah, in north-western New South Wales (NSW), including the town, the surrounding Liverpool Plains and the Pilliga forests to the west, are currently the subject of intense mining interest for coal and coal seam gas. Achieving positive outcomes for koala conservation on mined landscapes will require a sound grasp of koala ecology; and local knowledge of koala movements, tree choice and associated threats to the continued survival of koalas, particularly roadkill from increased mining infrastructure. This requires a research-oriented approach to testing ideas applicable to the long-term survival of koala populations. Our recent koala research in NSW has shown that, in 2006, Gunnedah had the largest koala population west of the Great Dividing Range, and the only population in NSW that was expanding. That prompted us to instigate a detailed study in 2008 - 2011 to determine, *inter alia*, whether the koalas were using trees that were planted in the 1990s to cope with rising soil salinity. Our GPS-tracking has shown that regrowth trees as young as ten years old can attract koalas. In 2009, the demise of about a quarter of the local koala population from an intense heatwave gave us a foretaste of how habitat and climate change interrelate at the landscape scale. We are now examining the optimal combinations of tree choice, and patch size and shape, for habitat restoration. This will be relevant to local coal seam gas and coal mine proposals, and ongoing mitigation actions. The Senate enquiry of September 2011 on the koala and demonstrated the intense public interest in the survival of this iconic species. Its subsequent listing for Queensland and NSW under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* further raises its profile and obligations for management of koalas and their habitat. It will take considerable effort to manage the Liverpool Plains koala population for the next 50 years in the face of extensive land-use changes from mining, and the attendant threats from road kill, compounded by the new threat of climate change manifesting itself as an increased frequency of heatwaves and more severe droughts. This paper describes the research that underpins these conclusions, identifies some of the research approaches needed, argues for working strategically now, rather than try to patch up matters after the event, and presents a set of guides for environmental plantings.

INTRODUCTION

Gunnedah, in north-western NSW, including the town, the surrounding Liverpool Plains and the Pilliga forests to the west, are currently the subject of intense mining interest for coal and coal seam gas, both for and against. It is front page material in the local paper, the *Namoi Valley Independent*, and it is an issue on national television. The public debate is certain to escalate as mining proceeds. This paper discusses a significant dimension to the debate – the future of the koala populations of the Liverpool Plains and the Pilliga forests. The communities of Gunnedah and the Liverpool Plains are proud of their koalas. The flags flying in the main street of Gunnedah proclaim it to be the 'Koala Capital of the World'. There are long-standing koala conservation initiatives being carried out by a wide range of authorities and community groups across the region, and a high level of community awareness of koalas and the issues that they confront. To the extent that mining will impact on the success of these initiatives, there is certain to be strong community resolve to protect koalas from the growing list of threats that they face both locally and across the region.

To ensure that the flags keep flying will require well-informed ecological responses. It is essential to understand where the koalas occur around Gunnedah, what threats they face, what management actions have benefitted the local

1. Senior Principal Research Scientist, Office of Environment and Heritage NSW, Department of Premier and Cabinet, School of Biological Sciences and Biotechnology, Murdoch University, Perth WA 6150. Email: dan.lunney@environment.nsw.gov.au
2. Natural Resource Project Officer, Office of Environment and Heritage NSW, PO Box 20, Gunnedah NSW 2380. Email: john.lemon@environment.nsw.gov.au
3. Lecturer, School of Biological Sciences, Heydon-Laurence Building A08, University of Sydney, NSW 2006. Email: mathew.crowther@sydney.edu.au
4. Project Officer, Office of Environment and Heritage NSW, Department of Premier and Cabinet. Email: elly.stalenberg@environment.nsw.gov.au
5. Project Officer, Office of Environment and Heritage NSW, Department of Premier and Cabinet. Email: karen.ross@environment.nsw.gov.au
6. Project Officer, Office of Environment and Heritage NSW, Department of Premier and Cabinet. Email: robert.wheeler@environment.nsw.gov.au

koalas, and how the community can contribute to sustaining the koala population of Gunnedah Shire and the Liverpool Plains. Conceptually, this responsibility reaches across the landscape and encompasses the obligations of large groups and entities, such as farmers and miners, local councils, the Catchment Management Authorities (CMAs) and State Government departments. In 2011, the Senate conducted an enquiry into the national status of koalas (Commonwealth of Australia 2011) which resulted in a great deal of publicity and controversy surrounding koalas throughout the country, and now that the koala is listed federally as a threatened species then the Commonwealth Government will also become an active participant in land use decisions and rehabilitation. This will add to the NSW Government's interest in koala conservation where the koala has been listed as a threatened species under NSW legislation since 1992 and is currently subject to a NSW koala recovery plan (DECC, 2008).

This paper is also directed to individual actions, including property management, the care of sick and injured koalas, and participation in surveys of koala presence. This approach is based on the recognition that koalas are mobile animals that are dependent on an optimum set of tree species in which to feed or take shelter, and koalas will traverse open paddocks and cross busy roads to reach the trees that they depend upon (DECC, 2008; Commonwealth of Australia, 2009; Crowther *et al*, 2009; Lunney *et al,* 2012). This approach goes beyond habitat conservation and rehabilitation on specific properties to take into account the dynamics of a population of koalas and all its needs. Habitat conservation and restoration is essential, but it is not enough. If we are to maintain a population of koalas in Gunnedah and across the Liverpool Plains, and indeed, the entire Namoi CMA, particularly the Pilliga forests to the west of Gunnedah, then we need a dynamic, landscape-scale approach. Such an approach is possible, and this paper outlines some of the major steps required, based upon recent local koala research, particularly our 2008 - 2011 study of the restoration of koala habitat in Gunnedah. The paper is a guide to managing a regional koala population in a landscape about to be transformed by coal and coal seam gas mining. It is preferable, in our view, to write such a paper now, even though our work is still underway, rather than wring our hands in ten years and lament that we did not speak about this crucial and emerging subject.

The foundation of this paper is a research project recently conducted by the team from the Office of Environment and Heritage (OEH) (2008 - 2011), under a NSW Environmental Trust Grant won by the Liverpool Plains Land Management (LPLM) in 2008, entitled: '*Restoring Koala Habitat in Gunnedah: Building on a 1990 Success*' (Lunney *et al,* 2012). Not only did this project demonstrate the value for koalas of the trees planted for soil conservation and habitat purposes in the 1990s, but it also foreshadowed two emerging problems for koalas (Lunney *et al,* 2012). These are the impact of heatwaves and drought, and the issue of the koala disease Chlamydia, including its impact on breeding success of koalas. An additional threat is that of the coal mining industry reducing koala habitat, fragmenting what remains, and increasing the risk of koala deaths from vehicles as mine infrastructure increases. These provide a timely warning of the potential for combined impacts from predicted climate change and other threats for wildlife in the region. Thus, while tree planting and restoration has benefitted the koala population, its future is not assured unless these new issues are understood so that future restoration can be approached strategically. Strategic restoration would be more focused on which tree species to plant, and in what soil types, and would determine which planting patterns will provide the most benefit for koalas in the hard times, such as heatwaves and droughts, in a landscape modified by intensifying land uses. It is also necessary to incorporate other species, ie integrated plantings that benefit a wide range of native fauna, not just koalas.

The next step following from the research so far is to study the Gunnedah koala population over an even longer time frame than the 20 years in the OEH study of 2008 - 2011. That study examined the success of the 1990s plantings and found that koalas use trees as young as ten years old, and that plantings will contribute to koala conservation in a relatively short period of time. A more comprehensive project would extend back to first settlement in the region, from the time of explorer John Oxley in 1819 to the present to arrive at recommendations to manage the landscape and koala populations into the future, until at least the changes brought about by coal mining have stabilised at a point where there is a good assurance of a long-term future for the koala population across the Liverpool Plains and the Pilliga. The scientific underpinning for such a future must be ecological, with a crucial social component that involves the community. It must also have the practical component of working with existing legal requirements, relevant authorities and the land owners to maximise the benefits for all parties, while still holding to the view that the flags in Gunnedah should be maintained between generations of Gunnedah residents and visitors to the town.

There are two new players on the scene in 2012 – the Commonwealth Government and the coal and coal seam gas mining industries. On 30 April 2012, the Commonwealth Government listed the koala as vulnerable in NSW and Queensland, under the *Environment Protection and Biodiversity Conservation Act 1999*, thereby formally involving the Commonwealth in major decisions affecting the survival of koala populations, which will include major mining industries. The coal mining industry, including coal seam gas, is about to transform the landscape of the Liverpool Plains, and elsewhere in the Namoi CMA region, particularly the Pilliga forests, which are, or were, the centre of a major koala population in north-western NSW. Available information points to a drastic decline in the Pilliga population in the last 15 years. Along with the koala population on the Liverpool Plains, the Pilliga koala population made up the major component of the inland koala population of NSW and made the Namoi CMA region a critical area for inland koalas in NSW (Crowther *et al*, 2009; Lunney *et al*, 2009). The spotlight is now being thrown on these koala populations and their future. Mining and koala survival are thus linked. The approach we advocate is to take a regional landscape approach to population management. This will involve not only habitat mapping, preservation and replanting, but also detailed demographic studies so that present and future populations of koalas survive. We point to this critical feature because habitat mapping, preservation and planting give no assurance that a koala population will endure. Although the rapid assessment techniques of identifying koala habitat by koala pellets (droppings or dung) under trees can cover a large area quickly, they cannot assess the trends in koala numbers and the causes of the changes, other than patterns of habitat change. If coal mining and koalas are to co-exist, then a robust strategy for koala conservation is essential. That strategy will need to take in all elements in koala population biology, not just habitat identification and management. We now take a step back to say how we arrived at these conclusions, then proceed to make a series of recommendations so that others can see the steps and comment on our proposals.

THE LIVERPOOL PLAINS LAND MANAGEMENT/ OFFICE OF ENVIRONMENT AND HERITAGE STUDY OF KOALA HABITAT RESTORATION 2008 - 2011

Context and aims

In a major NSW state-wide koala survey in 2006, Gunnedah and the Liverpool Plains were identified as a rare bright spot in NSW because the koala population was expanding, against the state-wide trend (Lunney *et al,* 2009). The environmental plantings under the 'Bearcare' program in the 1990s, planted by landholders as part of a landscape project to combat soil salinity, improve biodiversity benefits and reduce soil erosion, may have contributed to this result, and it had always been intended that there would be follow-up research of koalas' use of these plantings.

A subsequent investigation (Crowther *et al,* 2009) showed that, although the four CMAs in the north-eastern part of NSW carried the same list of issues facing koalas, each CMA had a different ranking for the various threats. This pointed to the need for local solutions within each CMA, and even within parts of each CMA, indicating that there is no simple formula to managing koala populations. These findings led to a detailed project on the Liverpool Plains where we worked property by property, koala by koala, and tree by tree. This project involved radio-tracking koalas throughout Gunnedah and the Liverpool Plains to investigate their use of different habitats and how and when they moved across the land.

The primary aim of the project was to investigate koala movements to determine tree choice, with particular reference to their use of the environmental plantings (see Appendix 1). However, a critically important additional element was brought into the study while it was under way. Extreme weather – heatwaves in late 2009, near the end of a long drought, introduced a major climate change element. The opportunity was taken to examine the impacts of these events on local koalas in relation to deaths of koalas during the heatwaves, reduced breeding rate, and the disease Chlamydiosis becoming visibly manifest in the local koala population (Lunney *et al,* 2012).

Methods

The koala is a cryptic species and can be difficult to observe directly in the field. The standard methods employed to survey koala habitat have relied on surveys of koala dung (ie pellets, or scats) under trees. While this is a simple and easy means to detect koala presence and tree use, it does not provide information on the reasons why koalas use particular trees, or information on how often koalas move across the landscape and in what weather conditions. Koalas will mostly move at night and spotlighting or continuously following individual animals using radio-tracking collars can track these movements. The number of 'fixes' or sightings during a spotlighting survey are limited as the method relies on the koalas facing the spotlight, or on observers being able to visually discern their fuzzy grey outline. Continuous radio-tracking surveys overcome this limitation as koalas are tracked detecting the radio frequency emitted by a transmitter attached to the animal, however, these studies require considerable time and resources for little reward as only one or two koalas can be continuously tracked by each researcher at any one time. In addition, there are safety issues and other difficulties of radio-tracking at night, consequently radio-tracking is almost entirely limited to daytime, and therefore to trees selected for daytime shelter, not necessarily for food.

We used global positioning system (GPS) tracking of koalas using custom-made (Sirtrack®, Hawkes Bay, New Zealand) tracking collars to assess the use of the landscape by koalas at a local scale. Over the three years of the project (2008 - 2011), we fitted 51 koalas with tracking collars that included state-of-the-art GPS units to record the location of each koala every four hours, including through the night. The collars were therefore designed to collect vastly more night data concerning koala movements than researchers would be capable of in the field. Furthermore, many koalas were tracked simultaneously. The collars were also fitted with an in-built radio transmitter which enabled the research team to periodically check the koalas to gauge their condition and to locate them at the end of study period (maximum six months per koala) to remove the collars. At this point, the GPS data were downloaded. Detailed health checks were also conducted on the animals captured in 2008, 2010 and 2011.

Results

The GPS collars were extremely successful and provided accurate, reliable and continuous data on koala movements throughout the tracking period. The data were insightful in demonstrating that koalas actively use the trees that were planted by landholders in the 1990s. They show that koalas are moving considerable distances across the landscape, with movement of three to four kilometres over several weeks being a common occurrence. This includes movements to and from landholder-initiated tree plantings, between plantings, and between old paddock trees and trees along fence lines and remnant tree patches (Figure 1). Koalas therefore capitalise on the success of the plantings by using the full diversity of habitat resources available.

The data show that koalas are not walking randomly across the landscape, but along the edges of paddocks, roadsides, railway tracks and travelling stock routes (TSRs). The use of isolated paddock trees has been a striking finding and shows that koalas are frequently walking across open paddocks. The level of use of roadside reserves and railway track corridors by koalas highlighted by this study is a major concern, as road-related injury is one of the highest causes of koala death or entry into care.

Detailed information on the trees koalas visited was obtained by locating the animals two to three times during the tracking period. A sample of trees used by koalas on, respectively, Gunnedah Research Centre (Table 1) and Emerald Plains, was measured for species, size and other structural characteristics. Most frequently used species in this dataset are the red gums (*Eucalyptus camaldulensis, E blakelyi*), an ironbark (*E sideroxylon*), and the cypress pine (*Callitris glaucophylla*). The larger Casuarinas on the lawn at Gunnedah Research Centre were frequently used, while the smaller *C cristata* in the plantings had no scats. None of the kurrajongs (*Brachychiton populneus*) had scats present, but they were mostly smaller trees. Overall, close to half the sampled trees were used by koalas at some stage. Koalas were found regularly in non-eucalypt trees such as white cypress pine and wilga (*Geijera parviflora*), possibly because these trees provide considerable shade and protection against weather extremes.

Discussion

Over the three years of study (2008 - 2011), we collected detailed data on the koalas' movements and showed that they move frequently from ten to 20-year old tree plantings, through paddocks, to isolated older trees and to remnant woodland stands. Koalas were frequently found to have walked distances of several kilometres and used plantings

FIG 1 - Close-up of an air photo of the movement patterns of one koala on one property (Emerald Plains) showing the locations (yellow dots) determined every four hours from the GPS data from the collar on the koala, and the yellow lines show the dots joined sequentially. The green patches are scattered regrowth and old trees near the farm sheds.

TABLE 1

Percentage of trees sampled on Gunnedah Research Centre with koala scats present.

Species	Number with scats present	Total no of trees examined	Use rate (% of trees of that species with scats present)
Eucalyptus camaldulensis	21	26	81%
Callitris glaucophylla	19	24	79%
Eucalyptus sideroxylon	12	17	71%
Casuarina sp sample 5 – large trees on lawn	11	17	65%
Eucalyptus blakelyi	10	16	63%
Eucalyptus mellidora	15	25	60%
Eucalyptus albens	11	19	58%
Eucalyptus populnea subsp. bimbil	15	31	48%
Angophora floribunda	5	17	29%
Acacia pendula	2	14	14%
Acacia salicina	1	8	13%
Brachychiton populneus	0	25	0%
Casuarina cristata	0	17	0%
Total numbers of trees sampled	122	256	48%

along fence-lines, train tracks and roadsides. This shows how far koalas move regularly to gain access to preferred trees and locations, but this movement renders them vulnerable to collisions with cars and trains. Importantly, it also shows that koalas are amenable to using tree plantings such as those originally planted by landholders in the 1990s as part of projects to combat soil salinity, improve biodiversity benefits and reduce soil erosion. Koalas capitalised on the success of the plantings by using the full diversity of habitat resources available. This is a significant finding because until now the

view that young trees, or saplings, could provide valuable koala habitat had yet to be confirmed. This study confirms the value, even in the short term, of planting feed and shade trees to contribute to sustaining Gunnedah's koala population and allowing the koala population to increase, and helping to mitigate the impacts of habitat loss and fragmentation across the rural landscape.

This restoration study made a number of fascinating findings and raised new questions, and it consequently received wide exposure in the local, state and even national media (Lunney *et al*, 2012). We maintained continuous working relations with the landholders in the area, particularly the owners of Dimberoy, Turon Park, Emerald Plains and Pine Cliff, as well as the Crown land at the Gunnedah Resource Centre. We also received considerable support from a local veterinarian (David Amos). We have discussed the need for an appraisal of long-term changes in koalas on the Liverpool Plains with the Gunnedah Historical Society, but that follow-up study is yet to commence. Gunnedah Shire Council and the Namoi Catchment Management Authority have indicated that they will draw on the recommendations from the study to help with their management and planning responsibilities. Currently, Gunnedah Shire Council is developing a Comprehensive Koala Plan of Management, which will materially assist council and the community to conserve koala habitat, habitat being the central focus of such plans under NSW planning legislation. The continued interest and support shown by these local organisations, land owners, local media and the broader community was one of the most rewarding aspects of the project.

Capitalising on the success of the 1990s plantings

We have produced, or are still working on, a number of public, scientific and policy papers, conference presentations and posters, public talks, media releases and numerous feature articles from this project. This paper, including the recommendations and supplementary material attached, are intended to assist managers of public and private lands, particularly lands to be mined, in the management and restoration of koala habitat, while reducing the vulnerability of koalas to existing and future threats.

We are currently planning the next stage in the project, for which funding is yet to be found. This research will comprise a collaborative study, including OEH, University of Sydney, industry and local agencies, to examine the new issues raised from this study so far, namely, climate change and disease, coal and coal seam gas mining and the capacity of the Gunnedah koalas to adapt to these new and ever-increasing threats.

The project findings have led us to develop recommendations for future plantings and landscape management. The koala movements are being modelled against land use and vegetation cover to further refine the recommendations and to draw inferences regarding the importance of planting size, shape, and tree species composition, and in relation to other features in the landscape such as proximity to water bodies, remnant woodland patches and roads.

New questions

Climate change and disease

In addition to meeting our original aims of establishing the value of the 1990s plantings, our study has uncovered a number of previously unforeseen, but increasingly important, issues that the koala population, and indeed other wildlife species inhabiting the region, will need to face in the future. We refer to the novel, but pervasive threat of increasing extreme weather events as a consequence of climate change, which is a recognised key threatening process (Lunney and Hutchings, 2012), in conjunction with other threats, including disease. These issues identify the need for a next phase of the study: to examine the capacity of the Gunnedah koalas, and land managers, to adapt to the long term with new and rising threats.

Heatwaves in November and December 2009 occurred just before the end of an intense, prolonged drought. The heatwaves lasted around 15 days and during this time, two of the collared koalas were taken into veterinary care to be revived through rehydration and then re-released. Two additional tracked animals succumbed to the heat in the field. Koalas were observed displaying extraordinary behaviour to overcome dehydration in the intense heat (Figure 2 shows a dehydrated koala drinking from a bottle during the heatwave), and a number of deaths of wild koalas were recorded by landowners, the local veterinarian and members of the public. After scaling up our observations of the collared koalas and taking into account evidence from interested landholders, we estimate that about 25 per cent of koalas died locally.

FIG 2 - John Lemon offering a drink to a dehydrated wild koala. The koala left the place of the tree where it was sheltering to take the water. Photo by Dan Lunney, December 2009.

Over the course of the project, the region also experienced a major flood. The impact of floods on koalas is yet to be determined, and no previous studies have been conducted on the impact of floods on koalas from which to draw comparison. However, it is unlikely that the floods would have benefitted the koalas. On the contrary, the floods almost certainly restricted movements, limited feeding opportunities, and may have weakened the koalas thereby rendering them more vulnerable to disease and predation. These examples foreshadow the potential impact of climate change on koalas as the severity and frequency of natural disasters and extreme weather events increases as predicted. The study also highlights the role of land managers in helping safeguard koalas against these events, such as by providing trees that give shade and maintaining free water to prevent koalas becoming dehydrated during a heatwave.

Health checks of each koala captured were conducted over the course of the study. Koalas were captured and collared for three consecutive years in spring and two consecutive years in autumn. This allowed for an analysis of the trends in breeding success for the population. The percentage of females with young declined between October 2009 and October 2010. In 2010, the health of the population appeared

to have also declined, and this enables us to predict that the number of young leaving the pouch would decrease even further (Lunney *et al*, 2012) Pathology testing in 2009 of local animals captured for this project confirmed the presence of Chlamydia, a sexually transmitted infection which has been known to cause infertility in koalas (M Krockenberger and J Griffith, University of Sydney, see also Lunney *et al* (2012) for more details). Mounting evidence suggests that the incidence of infection is increasing in the population. This area had previously been considered to be free of chlamydia because there had been no overt signs of the disease. The decline in health of the population and the decrease in numbers of females with young are likely to be the cumulative effect of the heatwave and the increase in chlamydial infection throughout the population. These examples foreshadow the potential impact of extreme climatic events, such as heatwaves and droughts, on the region's koalas which, in conjunction with other threats such as habitat loss and degradation through development (especially on the scale anticipated as a consequence of mining), predation by dogs, and deaths on the roads (especially with more mining traffic) and railway lines that pass through koala habitat, have the potential to cause catastrophic population decline.

Mining

To a large extent, mining on the Liverpool Plains and the Pilliga forests is a relatively new threat to koalas in the region. Most of the mining activity is in the form of proposals but we now know enough about koala ecology and the local area to give a reasonably accurate forecast of the impact of coal mining and coal seam gas extraction on the koala populations in these two vital locations. The threats from mining fall into three categories: loss of habitat and fragmentation of what remains; additional mortality threats from increased vehicle and train traffic; and bushfires in the Pilliga. What the heatwave of 2009 demonstrated is that a population of koalas under stress can show an increase in the debilitating disease chlamydia, with reduced fertility as a result (Lunney *et al*, 2012). Without knowing the exact extent of future coal mining proposals, the apparent scale of the operation is sufficient for us to conclude that these important regional populations will be threatened by mining. The population of koalas in the Pilliga was estimated to be about 15 000, 15 years ago (Kavanagh and Barrott, 2001) but researchers familiar with the area and its koalas, including Rod Kavanagh and also OEH ecologist Harry Parnaby, have observed that the koalas now appear to be rare in the Pilliga (Kavanagh and Parnaby, 2012). That loss can be largely attributed to an extended drought and the extensive fires of 2006. Therefore we cannot rely on the Pilliga koala population to recolonise a depleted koala population of the Liverpool Plains if that were to occur. A more important conclusion is that a large, apparently robust population of koalas, such as in the Pilliga forests, can collapse. With this knowledge, and given that mining has not yet begun is major expansion phase, now is the time to take a strategic approach to managing the koala populations of Liverpool Plains and the Pilliga forests. By strategic, we mean knowing how the population moves across a large area irrespective of property boundaries. It is our view that the populations of koalas on Liverpool Plains and the Pilliga Forests need managing, and their long-term survival will depend upon how we manage the land as it is being used, such as through mining, how it is rehabilitated and on what timetable; at least decades and presumably up to a century.

APPLICATION OF RESULTS

The study in Gunnedah, on which we are basing our current conclusions and recommendations, commenced prior to the release of the 2008 NSW Koala Recovery Plan and National Koala Conservation and Management Strategy 2009 - 2014 (DECC 2008; Commonwealth of Australia 2009). The Recovery Plan states that Gunnedah is one of the specified priority locations for study, so the results for our study will feed back into the NSW recovery process for koalas. This highlights that the findings have application at state and national levels by building greater understanding of the koala's ecology and therefore contributing to its conservation.

This project is primarily intended to feed into the shire-wide management of koalas across all land tenures in Gunnedah. For Gunnedah to maintain its claim to be the 'Koala Capital of the World', it will need to have a koala management plan that dovetails with the 2008 NSW Koala Recovery Plan and the National Koala Conservation and Management Strategy 2009 - 2014, and have its own Comprehensive Koala Plan of Management under State Environmental Planning Policy 44. This plan is currently being prepared, and our research will assist in its implementation.

To the extent that mining proceeds across the Liverpool Plains and alters the landscape, there will need to be a major undertaking to conserve, remediate or replace koala habitat affected by mining. The scale of the mining foreshadowed is of considerable international proportions and we can predict that mining and associated infrastructure (eg pipelines, roads, railway lines) will remove koala habitat, cause fragmentation, create physical barriers to movement and increase the threats of cars and trains, and possibly dogs, with an increasing mining-related population on what are now rural lands. On the positive side, we can advise that strategic and well-planned plantings of the appropriate tree species will help to restore koala habitat, remediate disturbed lands and provide additional koala habitat within the time frame of ten to 20 years from planting, provided the plantings are well planned and protected from stock during the establishment stage. A nursery for local trees would be beneficial, but a nursery for koalas while mining is underway, as suggested in one newspaper article, does not make ecological sense.

Recommendations for planting and land restoration on the Liverpool Plains

Based on our research to date on koalas' selection of trees and threats to koalas, we have produced the following recommendations for tree planting programs.

- Tree species: planting tree species of local provenance to provide appropriate food and shade habitat for koalas. Feed-tree species that should be planted include particularly: River Red Gum (*E camaldulensis*), Poplar box (*E populnea*), Yellow Box (*E melliodora*), Pilliga Grey Box *(E pilligaensis),* Blakely's Red gum (*E blakelyi*), and White Box (*E albens*). Shade tree species include Belah *(Casurina cristata),* Kurrajong (*Brachychiton populneus*), Wilga (*Geijera parviflora*) and White Cypress Pine (*Callitris glaucophylla*). Tree preferences for one of the locations is shown in Table 1 and it is noted that not all locations across the Liverpool Plains contain all of the species of trees.

  Planting a mix of these species within one planting can further encourage koalas by providing a range of food and shelter choices, particularly important during times of extreme weather conditions. It is also imperative to avoid monocultures of trees, that would constitute what is known as a perverse outcome (Steffen *et al*, 2009). It is essential that the plantings are well watered and protected

from stock in order to become established and grow successfully.

- Connectivity: consideration should be given to the location of new tree plantings in relation to existing woodland remnants, other plantings and to sources of water. New environmental plantings need to be close to remnants and other plantings and direct linkages should minimise the need for koalas to cross open paddocks, roads, and across backyards where they will be vulnerable to vehicles and dog attack. Planting trees along creek-lines and near sources of permanent water will result in trees with higher leaf-moisture and denser foliage for shade, thereby creating valuable koala habitat during droughts and heat waves.
- Road side plantings: the tracked koalas were frequently found moving along road-side and train-line plantings. Trees along road reserves can increase the risk of mortality due to vehicles, as they encourage koalas to spend more time near roads to feed, shelter and to use the linear plantings as corridors to other areas of habitat. To reduce this threat, trees should not be planted next to roads.
- Risk of dog attack: wild and domestic dogs are a significant cause of koala death and mortality, particularly near urban areas and within townships. Landholders should be aware of the risk to koalas from farm dogs and, if necessary, should not plant trees near house paddocks where koalas may be at higher risk from attack.

PLANS FOR FUTURE RESEARCH

The study has uncovered new, but important questions about the potential for the Gunnedah koala population to adapt to the novel impacts of climate change and disease. Our proposed next stage of the project is to focus on the 'tree stage.' This will involve detailed collection of specific characteristics of trees used by koalas including species and structural attributes, and the features of the landscape the koalas visited at different times, seasons and importantly, during extreme weather events. We are currently applying for further funding to undertake a more in-depth and longer-term study to investigate the new questions raised in this project. This research would comprise a collaborative study with university scientists, industry, local agencies and the community to examine impacts of climate change and disease on the population, and to further explore how managers can capitalise on the success of the 1990s tree plantings in order to reduce vulnerability to these threats. In addition, the Pilliga koala population would need to be considered in conjunction with that of the Liverpool Plains in the long-run as forming part of a metapopulation of koalas in the Namoi CMA. They have been historically viewed as discrete but if both are subject of climate change and mining simultaneously and one population is ultimately the source of recruits for the other, then they need to be considered together.

Historical enquiry

When the major survey for koalas in Gunnedah was undertaken in 1990, it was recognised then that the large population in Gunnedah was a phenomenon of the previous ten to 15 years. The immediate question is: where were the koalas between the time that Oxley walked into the area in 1819 and 1990 when the koala population was burgeoning? The reason this question is so important is that the local experts, such as the local veterinarian David Amos and the koala carer Nancy Small, note that they rarely saw koalas in the late 1970s. It was not till the 1980s that koalas started to become common. One implication from this circumstance is that the koala population could dip down to rarity without us having grasped what it is that drives the longer-term changes – the decade by decade changes. The approach taken would be that of historical ecology, an area that the authors have been working on for a quarter of a century, including having established a network of environmental historians to assist in these enquiries.

Adaptation strategies for climate change and mining

We have demonstrated that the 1990s tree plantings were important for providing additional habitat for koalas, but in our research we have uncovered additional issues which are generic for all koalas, namely extreme weather and disease. It is arguable that these threats will overwhelm the positive impact of the plantings in increasing the local koala population, but without the plantings, the impact of extreme weather and disease may have been much worse for the local koala populations. The current threats to koalas will be exacerbated by the loss of habitat from mining, so while rehabilitation will be required to sustain the koala population, before rehabilitation can take place, or reach its threshold for being useful for koalas, there needs to be a management strategy that sustains the koala populations through the bottlenecks that will be created by mining. To underpin the approach to managing the koala population through both a changing climate and intensifying land use, we envisage a research project comprising three components.

We firstly want to study koalas' habitat selection in a changing climate, by measuring the structural and compositional characteristics of trees, patches and landscapes that koalas select during different climatic conditions. We would measure, among other attributes: vegetation type, density, species composition, patch size and the availability of water. Secondly we want to study the links between soils, leaf nutrition and habitat selection by koalas, by assessing leaf nutritional status of the trees that koalas select during different climate conditions, and the soils on which they grow. Thirdly we want to track, on a landscape scale, the epidemiology of the Chlamydia disease throughout the Gunnedah koala population and determine the potential impact of the disease on the population in the context of climate change, the restoration of the landscape and the links among the various rural properties and town.

This project would contribute to the development of a more effective restoration program and koala management plan. This will deliver a long-term benefit in providing quality habitat to ensure koalas are able to adapt to a changing climate and a mined landscape.

The Pilliga forests

The Pilliga forests, 100 km to the west of Gunnedah, are the largest inland remnant of box-ironbark mixed-eucalypt forest in Australia. During the 1990s and until 2005, this forest was regarded as holding the best population of koalas in NSW, with estimates of up to 15 000 koalas (Kavanagh and Barrott, 2001). By any standards, this is, or was, a large population. From recent observations, experienced Pilliga researchers now consider the koala to be extremely rare in this forest. The cause of this decline is potentially of great significance for the koalas of the Liverpool Plains and the remainder of the Namoi CMA. A project outline of current survey and historical investigation has been prepared and could be implemented should funding be available.

CONCLUDING COMMENTS

The koala is a threatened species in NSW, and a Species Recovery Plan was officially launched in 2008 (DECC, 2008). The koala is now listed as a threatened species under Commonwealth legislation, but it is of such iconic importance that there is a National Koala Conservation and Management Plan 2009-2014. In addition, the 2011 Senate enquiry on the health and status of the koala in Australia made it clear that there is widespread concern about the future of koalas in Australia, and great public interest in the matter. Since the proposed coal mining and coal seam gas mining on the Liverpool Plains and the Pilliga forests poses a major threat to the two best clusters of koala populations in NSW west of the Great Dividing Range, it is crucially important to maintain these population, and not allow them to fade as mining proceeds. In NSW, there is a planning instrument – State Environmental Planning Policy No 44 Koala Habitat Protection (SEPP 44) – which provides a formal planning mechanism for local government to conserve koala habitat. Gunnedah Shire Council has recently committed to prepare a Comprehensive Koala Plan of Management for Gunnedah under SEPP 44, which will provide planners with options to address existing and foreshadowed threats, particularly threats to koala habitat. However, while koala habitat is a critical element in conserving koala populations, it is not sufficient on its own. To guide management decisions will require a sustained scientific study, which we characterise as comprising: field-based sampling of koala movement patterns, tree and habitat selection, koala health, population (principally distribution) and causes of change in the population; data interpretation and analysis including landscape mapping and modelling; and write-up for publication in scientific journals and for policy specialists and general readership.

It is also our view that these issues need to be made a matter of widespread public knowledge. Scientists, planners and land managers who have specific requirements comprise only a small proportion of the people interested in the long-term future of koalas in Gunnedah. A distinct component of any major koala study needs to promote education and awareness of the findings. Part of that objective would be to show how community participation can contribute substantially to conserving koalas on private lands, both urban and rural, and on public lands including TSRs, road edges, railway and telecommunication easements, reserves, and corridors of trees planted specifically as community exercises in maintaining biodiversity across a large rural landscape. Many local people have a profound concern about the koalas in their community.

The koala is such an iconic species that people often refer to 'their' koalas, with the implication that there are many target groups for this project, ranging from the town of Gunnedah and the rural landowners of the Liverpool Plains to the entire Australian population, who are concerned about the health, status and sustainability of Australia's koalas. Accordingly, this initiative will strike a chord with groups all the way from Connadilly Street in Gunnedah to Commonwealth Avenue in Canberra. We have identified some specific target groups, at each level of government:

- *Local*: community groups include the Shenhua Koala Community Reference Group, the Koala Reference Group and councillors in Gunnedah Shire Council, Namoi CMA, local Landcare groups, rural landholders and members of the LPLM. The OEH team has worked with Namoi CMA on a koala project in 2006 - 2007 and with LPLM in 2008 to 2011. In addition, both LPLM and OEH have given stories to the local newspaper, the *Namoi Valley Independent*, thereby demonstrating openness to communicating findings and being open to comment.
- *State*: the target groups interested in this matter at a state level will include those groups concerned with the effectiveness of the 2008 NSW Koala Recovery Plan, Landcare groups, farming groups, mining interests, and land-use planners. Most of these groups have local interests in a number of sites while holding the state picture in mind, because that is where many of the decisions relating to landuse and wildlife management are made. The target groups also include the Office of Environment and Heritage NSW, which has land use and wildlife management responsibilities.

  (Note: our OEH team is a part of a State government agency with responsibilities for managing fauna and threatened species, such as the koala. This team was part of the 1990 study of Koalas and Landuse in Gunnedah Shire (locally known as Bearcare; Smith, 1992). This team also conducted a state-wide community survey in 2006 which found that the Gunnedah koala population was expanding, in contrast to the state trend of declining local koala populations (Lunney *et al*, 2009). Determining the reasons why the Gunnedah population should be expanding led to the recent joint study with the LPLM. This study found that the plantings had benefited Gunnedah's koalas; however the study also found that new threats, particularly those associated with climate change, may jeopardise the sustainability of the koalas on the Liverpool Plains in the long-term. Further, if habitat loss and fragmentation were to increase as a result of mining and associated infrastructure, along with losses from vehicles, then this would represent a new dimension to the issue of sustainability of the local koala population.
- *National*: there is an immediate interest by the Federal Parliament in the sustainability of koala populations nationally, as evidenced by the 2011 Senate enquiry into koalas. The Senate Committee's findings included specific recommendations for concerted action from all levels of government, and that private landowners, private individuals and companies will also need to contribute to the collective effort to conserve Australia's koalas. The reason that there will be emphasis on private effort is because most koalas, at least in NSW, occur on private land, particularly the richer agricultural lands that support the specific trees, those with leaves with higher nutrient levels, that koalas are dependent upon.

The Commonwealth Government was already well aware of the impending problems for the koalas by the mid-1980s when it helped fund a national survey of the koala, where each state ran its section of the program. The OEH team on this paper conducted the NSW koala survey in 1986-2007. By 1996, the Commonwealth Government had recognised the need for a national koala conservation strategy, which was formally adopted in 1998, updated by the 2009 - 2014 National Koala Conservation and Management Strategy. These strategies, having been publicly negotiated, have served as a working guide for all levels of government. This provides consistency, and has encouraged networking amongst koala researchers and wildlife managers. The OEH team is a member of the national Koala Research Network, a network of scientists from a range of universities, government agencies and other organisations. The limitation of a national approach is that it may miss the particular combination of threats and opportunities in any one locality. Consequently, effective action is most likely to occur locally and most likely to be useful if the state and national pictures are clearly in mind.

Long-term and sustainable populations of native fauna, especially those that are iconic, threatened, or are of economic value, is an aspiration of rural communities. The koalas of Gunnedah fit this category perfectly because Gunnedah was identified in the 2006 state-wide survey of koalas as the most substantial population west of the Great Dividing Range, and was the population that showed the greatest expansion over the previous 20 years. Further, the koala was used as the standard-bearer in the 'Bearcare' program, run jointly by the then Soil Conservation Service and National Parks and Wildlife Service. The program primarily aimed to plant trees and shrubs to prevent rising soil salinity, but had a secondary objective to benefit koalas, because many of the trees planted were koala trees and expanded their habitat. The joint LPLM and OEH program 2008 - 2011 has demonstrated that this was a well-conceived and successful program. The initiatives proposed in this paper capitalise on that community commitment by recognising that when a program offers many benefits, and can work cooperatively with the rural landholders, it can generate goodwill towards sustaining koala populations through land-restoration programs that include koala conservation objectives. There is acknowledged community interest and concern about the potential for increased mining for coal and coal seam gas around Gunnedah and the Liverpool Plains and the Pilliga forests. The wider NSW community also needs the koala management guidance that can be obtained through this initiative as a case study.

ACKNOWLEDGEMENTS

We are indebted to David Walker of the Liverpool Plains Land Management for his sustained co-operation since winning the Environmental Trust Grant in 2008; the landholders who allowed access to their properties for this study; David Amos, veterinarian in Gunnedah; Nancy Small koala carer Waterways; and those who were part of the field program, particularly George Madani, Jessica Bryant, Jo Griffith, Mark Krockenberger and Melissa Retamales and the GPS and technical advice from Anni Blaxland-Fuad and Allan Peatman of OEH.

REFERENCES

Commonwealth of Australia, 2009. National Koala conservation and management strategy 2009-2014, Commonwealth of Australia, Canberra.

Commonwealth of Australia, 2011. Status, health and sustainability of Australia's koala population, Senate Environment and Communications Committee, 3 May 2011.

Crowther, M, McAlpine, C, Lunney, D, Shannon, I and Bryant, J, 2009. Using broad-scale community survey data to compare species conservation strategies across regions: A case study of the koala in a set of adjacent 'catchments', *Ecological Restoration and Management,* 10(S1):88-96.

Department of Environment and Climate Change (DECC), 2008. Recovery plan for the koala *(Phascolartos cinereus)*.

Kavanagh, R and Barrott, E, 2001. Koala populations in the Pilliga Forests, in *Perfumed Pineries: Environmental History of Australia's Callitris Forests* (eds: J Dargavel, D Hart and **B** Libbis), pp 93-103 (Australian Forest History Society).

Kavanagh, R and Parnaby, H, 2012. Personal communications.

Lunney, D, Crowther, M, Shannon, I and Bryant, J, 2009. Combining a map-based public survey with an estimation of site occupancy to determine the recent and changing distribution of the koala in New South Wales, *Wildlife Research,* 36:262-273.

Lunney, D, Crowther, M S, Wallis, I, Foley, W J, Lemon, J, Wheeler, R, Madani, G, Orscheg, C, Griffith, J E, Korckenberger, M, Retamales, M and Stalenberg, E, 2012. Koalas and climate change: A case study on the Liverpool Plains, north-west NSW, in *Wildlife and Climate Change: Towards Robust Conservation Strategies for Australian Fauna* (eds: D Lunney and P Hutchings) (Royal Zoological Society of NSW: Sydney).

Lunney, D and Hutchings, P (eds), 2012. *Wildlife and Climate Change: Towards Robust Conservation Strategies for Australian Fauna* (Royal Zoological Society of NSW: Sydney).

Smith, M, 1992. Koalas and land use in the Gunnedah Shire, NSW National Parks and Wildlife Service, Hurstville, New South Wales.

Steffen, W, Burbidge, A A, Hughes, L, Kitching, R, Lindenmayer, D, Musgrave, D W, Stafford Smith, M and Werner, P A (eds), 2009. *Australia's Biodiversity and Climate Change* (CSIRO Publishing: Collingwood).

APPENDIX 1 – A GUIDE TO SUCCESSFUL TREE ESTABLISHMENT FOR ENVIRONMENTAL PLANTINGS

The establishment of trees on farms and other sites can be used to achieve multiple outcomes including: stock shade and shelter, timber products, soil conservation, salinity mitigation, biodiversity benefits and improved soil health. Whether you are planting shelter-belts or tree lots, the key to successful tree establishment is forward planning. The most common failures in the establishment of trees are a lack of preparation, a lack of moisture and poor weed control. By following a few simple steps these problems can be overcome.

- Exclude stock – to establish a healthy and productive tree stand, treat the area as if you were planning to plant a crop or pasture. After selecting the site it is extremely important to exclude stock. Too often, the efforts that are put into correct establishment procedures are wasted by allowing stock access to the site. Fencing the site and excluding stock prior to site preparation ensures that damaging soil compaction cannot occur and that trees and shrubs are protected from the outset.
- Deep ripping – tree lines should be deep ripped six to 12 months ahead of planting. The best time to do this is during the summer months when the soil is dry as this will help shatter any compaction layer or plough pan. Deep ripping should be approximately 60 - 70 cm deep in a single rip line. It is often advisable to do the initial rip and then rip again in the same line until the required depth is reached. This method suits clay soils but if the soil type is loamy then two rip lines can be placed 20 - 30 cm apart to enable better soil moisture penetration and water retention.
- Weed control – it is crucial to spray out weeds during the six to 12 months prior to planting. A break between spraying and ripping is preferable, as this allows for root release and results in a less cloddy tilth. If the area to be planted is a cropping paddock, retain the stubble and spray with glyphosate as you would for a zero till fallow. If it is a grass paddock, then a strip of two metres should be sprayed out along each rip line. Follow up weed control is also essential after planting. Use of residual chemicals for weed control is not ideal but where there is no alternative, Simizine and Goal can be used. Seek professional advice before using residual chemicals. Selective use of glyphosate around the tree and within the row is extremely effective and cost efficient, however,

care needs to be taken so that the trees are not affected. A shrouded two metre boom mounted on a AWD quad bike to apply low volatile 2, 4D amine to control broadleaf weeds can produce excellent results. This is a deliberate strategy to allow native grasses to re-colonise the site and has been trialed and proven at the Gunnedah Research Centre and on numerous other sites across the state.

- Species mix – a range of native tree and shrub species should be used that are appropriate for the location. Be guided by the native species that occur within close proximity and on similar soils and landscape positions to the site being planted. There may be occasions where non-endemic native species may need to be incorporated in the planting. Always seek advice before selecting the species mix. It is best to plant these in such a way as to promote a diverse canopy and this will provide multiple benefits. I often use a mix of up to 16 tree and understorey species.
- Planting density – row spacing and distance between trees and shrubs is crucial. Generally the intermixing of trees and shrubs is the best option to produce a less regimented planting. Trees and shrubs in these plantings are often planted too close together and far in excess of the density of naturally occurring native woodland communities. This will depend on the topography, soil type and annual rainfall. For example, where the annual rainfall is 650 mm/a, spacing the rows seven metres apart with six metres distance between trees/shrubs within the row works out at approximately 200 stems/ha and allows the trees to grow relatively unimpeded. Such a planting density also allows native grasses to re-colonise and provide sufficient ground cover between the trees and shrubs. In farm forestry situations where plantings range from 600 - 1200 stems/ha, bare ground can result. Block plantings are preferable to two, three or four row windbreak plantings..
- Planting – planting of tube-stock is done manually, and a planting shovel with a tapered end is the preferred tool. Planting guidelines can be obtained from State Forest Nurseries and tube-stock suppliers. In most situations, particularly in the drier rainfall areas, it is a sensibleoption to form a dished area around the plant to allow rainfall to collect and be retained. If the soil type is prone to water-logging then the depth of the dished area should be minimal. Mortalities from weed competition and lack of moisture tend to be more of a concern than water-logging. When establishing larger areas the use of machine driven planters is another option but site preparation can be quite different than the methodology described here. Seek expert advice if using this option.
- Watering – normally an initial watering immediately after planting the tube-stock is required. This will depend on stored soil moisture and if significant rain is imminent. Depending on soil moisture and climatic conditions, another one or two water applications may be required. This is generally enough to ensure successful establishment, even in a drought year. UV treated plastic tree guards need to be used with the bottom turned inside up to capture rainfall. This creates a microclimate that favours the tube-stock, particularly during the summer months. It is also recommended that approximately ¼ bale of hay, (more if hay is not a limitation), be placed around the tree guard because this suppresses weeds and conserves moisture. It also makes it easier to spray around the tree with glyphosate. The taller UV guards and three bamboo stakes are definitely preferable to milk cartons as they can be used two to three times which reduces the cost of establishment. They also make it difficult for hares and rabbits to damage the tube-stock. Sometimes kangaroos and wallaroos may also damage the trees, especially during drought years.

Other agencies such as State Forests, Landcare, Greening Australia and Greenfleet have their preferred methods. However, the method outlined above has the advantage that it is relatively cheap, simple and effective and has been proven at a range of sites across the sheep/wheat belt of NSW.