An Ecological Reading of the History of the Koala Population of Warrumbungle National Park

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The severe Wambelong fire in 2013 focussed attention on the koalas of Warrumbungle National Park, and highlighted the lack of detailed study into their populations. Here we examine the history of land use and management within and surrounding the Park and how the koala populations have changed through the decades. Before the dedication of the Park in 1953 there was little koala habitat and, at best, a very low-density koala population in and around what became the Park. The koala population grew through the 1970s and 1980s, and by the mid- to late 1990s the Park was known for its strong koala population before the onset of the millennium drought (2001-2009). However, sightings were rare after the drought. The fire compounded the drought, showing that the Park on its own is too small to be a long-term refuge, particularly in an era of climate change. A regional approach to population management is needed, with the Park and the private land surrounding it both necessary for the survival of the local koala population. We have witnessed impact of a severe fire in 2013 on the koala population, although one best understood through an ecological reading of the historical record.

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INTRODUCTION

Warrumbungle National Park was well-known for its koalas (*Phascolarctos cinereus*) in the late 1900s, to the extent that they were a visitor drawcard. Thus, when a severe fire in January 2013 consumed almost all the Park, and much surrounding land, it presented a rare opportunity to examine the impact of an extreme fire on the population. Fire is a recognised threat to koalas (McAlpine et al. 2015; Office of Environment and Heritage NSW 2018), although to date studies of the direct impact of fire are rare (Curtin et al. 2002; Lunney et al. 2004, 2007, Matthews et al. 2016). Therefore, not only was the impact of this fire important for the koala population of Warrumbungle NP, but more broadly for koalas in general.

Warrumbungle National Park, near Coonabarabran in the Central West/Orana region of New South Wales (NSW), lies within the Brigalow Belt South Bioregion and to the south-west of Gunnedah and the Liverpool Plains, which are in the Armidale/north west region of NSW. It is west of the Great Dividing Range and near the western, or semi-arid, limits of the distribution of the koala in NSW (Lunney et al. 2009). Recent koala research in these regions has identified important koala populations, provided details of changes in the populations, revealed the hitherto largely overlooked koala populations west of the Great Dividing Range, and especially the impact of drought (e.g. Lunney et al. 2012, 2017; Crowther et al. 2014; Predavec et al. 2018 Dargan et al. 2019). The significance of drought in this study includes the Millennium drought (2001-2009) (BOM 2015) and the current drought (as of September 2019) with NSW Water (2019) stating that, 'NSW is experiencing one of the most severe droughts on record, with the Central West, Far West and North West regions the worst affected to date.' The impact of drought on koalas was identified in a study by Gordon et al. (1988) and in the review by Reed and Lunney (1990). In western Queensland (Seabrook et al. 2011; Smith et al. 2013) these same negative effects became clear at the same time as research

was underway on the Liverpool Plains (Lunney et al. 2012; Crowther et al. 2014). McAlpine et al. (2015), in their review of the issues for conserving koalas, emphasised that both fire and drought were threats to koala populations. A state-wide NSW koala survey in 2006 found that the koala populations of the northern tablelands and slopes of NSW had increased, in contrast to the rest of the State, where the populations had either declined or remained steady (Lunney et al. 2009). This finding provoked interest in the reasons for the increase, and research since then has found that koalas were exceptionally rare in the 1970s on the Liverpool Plains, increased rapidly through the 1980s and 1990s and had become so locally common that, just after the turn of the twenty-first century, Gunnedah proclaimed itself as the koala capital of the world, with flags flying in the main street carrying that message (Lunney, in litt). This boom, however, was not sustained: subsequent research found that the Millennium drought, which ended in December 2009, had a major adverse impact on the koala population (Lunney et al. 2012). An ensuing study found that the koala population of the vast, half-million hectare, Pilliga forests had declined 5-fold from the mid-1990s to 2014 (Lunney et al. 2017). Further, a repeat citizen science survey of these regions from October 2014 to March 2015, which included Warrumbungle National Park, found that these regional koala populations had declined (Predavec et al. 2018). We are thus dealing with regional populations of koalas that can be rare, rapidly increase over a few decades, and then noticeably sink as the climate changes, and drought and fire impact populations. In the wake of the 2013 fire in Warrumbungle National Park, the idea of 'refuge' populations gained increasing interest, with questions such as whether an area as koala-rich and seemingly secure as a protected area, such as Warrumbungle NP, can be a refuge, and to what extent both reserved lands and private land are needed to conserve regional koala populations.

The koala population of Warrumbungle National Park has been of interest since the first portion of the Park was dedicated in 1953. The history of that knowledge forms a major strand of this study, partly to establish whether there was ever a robust local population, or whether koalas were always rare, or even absent. There had been no detailed scientific studies of the koala population of the Park, or its immediate surrounds, prior to the 2013 fire, so our task in understanding changes over the past century means piecing together a series of observations, comments, records, management considerations and interpreting them ecologically. The Wambelong fire, as the fire of January 2013 is formally known, gained much attention from several quarters, each of which provides us with glimpses and insights of what might have happened to the koala population of the Park as a consequence of the fire. In the context of the ecological history of the region, we can interpret the diverse sources to gain an overall picture of the changes in the koala populations of the Park and the surrounding land. Taken with the regional picture of koala populations, this can reveal possible paths, and impediments, to the recovery of the koala population of Warrumbungle NP.

The question that emerges when the changes in the koala populations are considered since 1953 is what was present before Warrumbungle National Park came into existence. What is also apparent is that the Park was small at the outset, 3237 ha, but by the time of the Wambelong fire had grown to 23,558 ha. This seven-fold increase in area represents much potential for increase in the koala population of the Park as livestock were removed, timber harvesting ceased, and the vegetation allowed to recover. Thus, part of our work was to map this increase in area. Given that there were no studies of koalas before 1953, we therefore had to make use of the historical record to construct an ecological history and interpret the possible status of the koala population in the century or more before the 2013 fire. To complement that approach, and recognising that koalas are mobile, particularly after a fire (Matthews et al. 2016), we expanded our citizen science survey geographically in 2014-5 to encompass a much wider area than the Park itself (Predavec et al. 2018). This allowed us to identify the potential for recolonisation of the Park.

METHODS

Ecological history is a relatively new area of study that straddles the border of ecology and history, drawing on the interpretative skills of each disciple, but with the use of sources that are likely to be unfamiliar with one or other speciality. To an ecologist, there is an appearance of story-telling, meaning that words, not numbers, drive the narrative. To the historian, it can seem most unusual to make extensive use of maps, surveys, accounts by managers, species names, radio-tracking, habitat preference, home-ranges, koalas in care, with the aim of interpreting a landscape under change to provide the basis for determining the continuity of a population of koalas, namely the troughs and peaks of population changes with environmental changes. We have previously undertaken four studies, each in a different location, of changes in populations of

koalas since European colonisation, and the changes have been remarkable, with current populations giving little clue to the numbers and distribution of koalas in the early 19th century (Lunney and Leary 1988; Knott et al. 1998; Lunney et al. 2010; 2014). Among the standout features are the remarkable differences among the four locations, even though each was a coastal population. Unfortunately, with Warrumbungle NP, it is not possible to extrapolate much from these previous coastal studies, since it is west of the Great Dividing Range and in a region subject to intense and prolonged drought and a different history of land use.

The diverse sources of both pre- and post the 2013 Wambelong fire in and around Warrumbungle National Park were primarily: the Coroner's report (2015); the BAAT (Burnt Area Assessment Team) report (2013); NSW National Parks and Wildlife staff members Sue Brookhouse and colleagues; fire severity map, map of plant community types; regional koala surveys, radio-tracking results; and the ecological history of Warrumbungle National Park from sources as distinct as a cadastral map showing the incremental increase in Park size, the writings of Peter and Allan Fox and John Whitehead, the NPA (National Parks Association) Journal, the memory of Alan Morris, and a land-use and cropping map.

From the perspective of examining recent records with an immediate sense of impact on koalas, the Coroner's report is the most telling, but we recognise that it is out of sequence if a timeline were to be constructed. Chronologically, the sequence follows from the presence of stock (sheep and cattle) from the 19th century, with the dedication of Warrumbungle NP excluding stock from the mid 20th century, along with cropping and clearing records, with the growth of the area of the Park from 1953 becoming a factor in that land-use change. The written records of Stanley (1983), (Fox (1996) and of Whitehead (2008) play a role after the Park was dedicated, the NPA journal, and most recently the BAAT report and the Coroner's report.

The oral records from Alan Morris then Sue Brookhouse cover the period from 1964 to just after the fire in 2013, as well as the radio-tracking of a koala released into the Park post fire combined with maps of the vegetation and fire severity. The major regional koala survey of 2014-15 was undertaken explicitly to examine the changes in the koala population from the previous extensive survey in 2006 to gain a regional perspective of change and potential sources of koalas to re-inhabit the Park.

While the chronological approach makes sense from one point of view, it is not necessarily the best way in which to depict the most coherent portrait. The information from Sue Brookhouse provide a vivid contrast in koala abundance to both the fire and the drought and the resulting precipitous drop in numbers. The questions that arise are whether this koala population has suffered such insults previously, and what in fact were the likely population sizes in previous decades, and how long did it take for the populations to recover. The same principle applies to the regional koala populations as both sources of immigrants for the Park and as recipients of koalas from the Park, that is, what was the regional flux of the koala populations across tenures, and did they change in synchrony with those in the Park. Our objective is thus to gain an understanding of the degree of vulnerability and resilience in the koala populations of the region, of which the Park is an integral part.

RESULTS

Coroner's report

We began by examining the Coroner's report (2015). It captures the range of views on the fire and sets the scene as to why this fire is so central to the question of its impact on the koala population. It describes the magnitude of the fire, thus introducing the potential of assessing why the fire would have such a devastating effect on the koala population. The fire was a dramatic change to the landscape, and it spread beyond the Park onto private land. The fact that the NSW Coroner's office became involved also shows the social significance of the event.

The Coroner's report is a key document in describing the fire of 2013. It included a map (Fig. 1), which neatly presents the landscape context of the Park. It is quoted here because its language is written in a style that is not characteristic of scientific writing. Rather, the wording is vivid, and it conjures up a description that allows us to visualise the impact of the fire on any wildlife in its path and serves to set the scene for the scale and magnitude of the fire. (To the end of this section, the material is in quotations marks):

'Introduction (P 8). This is an inquiry under s 30(3) of the *Coroners Act 2009* into a catastrophic bushfire that started on 12 January 2013 at the Wambelong campground which forms part of the Warrumbungle National Park. The fire continued to burn out of control for approximately the next week with parts of the fire burning but contained for a further two weeks. (P 8) As a result of the fire, 56,280.55 hectares (139,072.2678 acres) of National Park and private lands were burned out. Within this area, 53 houses and 113 other buildings were destroyed and most

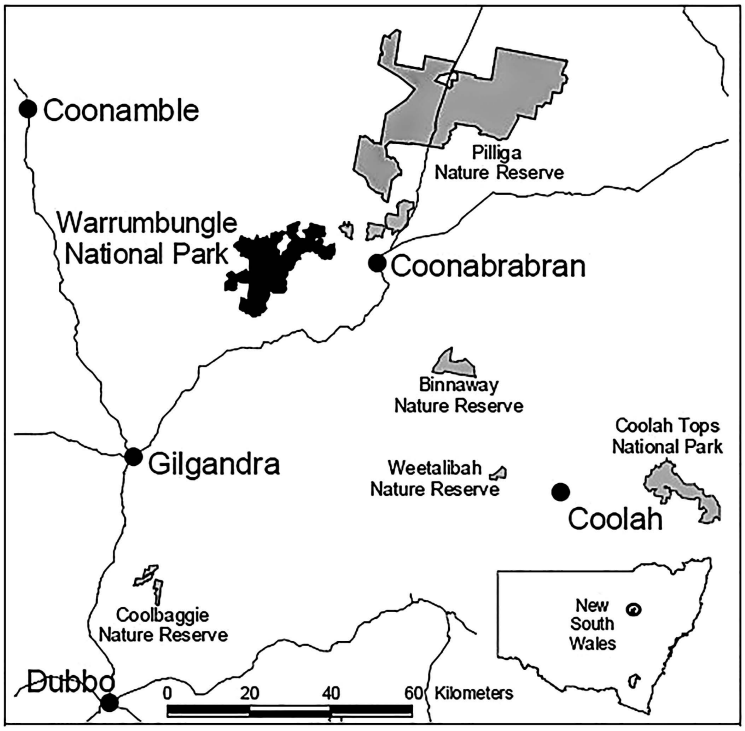

Figure 1. 'Map 1: From NPWS Fire Management Plan Warrumbungle National Park 2001-2006'. This map was included in the Coroner's report on P8.

of the infrastructure in the burned out area was destroyed or damaged. Approximately 95 per cent of the Warrumbungle National Park was burned out.'

(P 8-9) 'At the time, the fire was described by the Deputy Commissioner of the Rural Fire Service, Mr Bob Rogers, as "absolutely ferocious" [ABC 2013]. The devastation wreaked by this inferno was not only on the park and private properties neighbouring it. Farmers lost large numbers of animals and countless wild creatures, including those of threatened and endangered species, must have died as well. Miraculously, although a significant number of people were injured, no human lives were lost. But the fire and the losses it caused have traumatised those who lost property and livestock, and left many in financial jeopardy.'

Fire history

(p 13) **'**Unlike the neighbouring Pilliga Scrub, until January 2013, fires in the Warrumbungle National Park had historically been small and less frequent. In the last 50 years there have been less than 30 fires in the national park. The largest recorded fire prior to 2013 was in 1967 when about 5,000 hectares was burnt. More recently, in 2001 a wildfire burnt approximately 3,000 hectares around Mount Exmouth. According to NPWS, before the January 2013 fire, there had been no listed fires in the National Park since January 2002. This history of contained, comparatively small fires was one of the factors that coloured the assessment of risk by the NPWS officers in January 2013.'

'Conclusions (p 45)._The devastation the fire caused literally had to be seen to believed. Viewing the landscape from the lookout at Siding Springs gave the coronial team a sense of the enormous scale of the fire that reports and maps and photographs cannot give. But it remains very difficult for those of us who were not there to imagine the desperate experience of the people who fought that fire and who lost so much in it.'

(p 46) 'Findings at cause and origin of the fire: s 81 Coroners Act 2009: I find that the fire that broke out at the Wambelong Camp Ground in the Warrumbungle National Park on 12 January 2013 probably originated to the west of the camping ground on one of the banks of the Wambelong Creek. The evidence does not enable me to determine the cause of the fire.' Magistrate Hugh Dillon, Deputy State Coroner, Date of findings: 28 September 2015.

Aftermath

Under the heading, 'How fire ruined the lives of one country town', reporter Tim Barlass in the *Sydney Morning Herald* of 16-17 November 2019, reported that 'After nearly seven years, Coonabarabran residents continue to pay a heavy price.' 'Coonabarabran residents in northern NSW looked on with a sense of déjà vu at the forecast of catastrophic fire danger across the state this week.' The article does not mention wildlife, it has a human focus and one that paints a picture of the severity and impact of the fire beyond the Park boundary.

The BAAT report

The coroner's report did not mention koalas, so the next step was to consider the BAAT report (2013), which explicitly included koalas. In the final report on 2 February 2013 of the Burned Area Assessment

Team (referred to as BAAT, looking at post-fire rapid risk assessment and mitigation), the following statements are informative.

'The Wambelong fire started on January 12, 2013 in Warrumbungle National Park and … Under extreme fire weather, the fire extended over 39,000 ha in one day. The fire extended over a total area of 56,370 ha, including 21,926 ha within Warrumbungle National Park and 34,444 ha in other tenures (private property and Crown Land). Approximately 95% of Warrumbungle National Park was burnt and 76% of it was burnt at an extreme or high fire severity with consumption of most or all shrubs and tree canopies. A post-fire rainfall event estimated at >100 mm in <30 minutes fell on February 1 causing significant flash flooding, debris flows, erosion and asset damage.'

Subsequent research found that 95% was an overestimatemof the area of the Park that was burnt. It was <90%.

'Wambelong Creek…Koala feed trees have been affected severely by the wildfire which may lead to starvation of any remaining koalas. At least one koala has been recorded near Wambelong Creek 18 days post-fire, and short-term supplementary feeding would be beneficial until trees form enough growth to sustain the remaining animals.' A photo was also supplied (Fig. 2, listed as Fig. 25 in the BAAT report.)

Sue Brookhouse

In discussion with one of us (DL) during a Staff Information Day, Coonabarabran, 15 April 2016, Discovery Ranger, Sue Brookhouse recounted her post-fire koala observations in Warrumbungle National Park. Sue identified the most important points as follows: 1. Two weeks after the fire, David Brill (NPWS staff) saw a male koala in a tree in an intensely burnt area along Wambelong Creek about 500 m from Camp Blackman. 2. Another koala was seen and photographed after the fire in the Park; the koala appeared to be male and looked healthy, it was found in unburnt trees in the camping area but, after much searching, was not seen since. 3.The fire was intense in some of the central valley areas, eastern and northern areas of the Park, though it was a cooler burn to the southern side of the park (Grand High Tops). This area was known to have koalas before the fire. The cooler burnt areas were on the mountain range. 4. One koala was seen in a low intensity burnt area at Mount Exmouth, where koalas always had been seen. 5. Two koalas were found in burnt bush just beyond the edge of the Park, near Cenn Cruaich Road, where there was a small population. 6. Ten days after the fire, the first koala was found by the BlazeAid volunteer community group, who then notified Sue Brookhouse. Sue found the second koala. Fire did not burn through this area until a few days after the start of the fire, on the Wednesday. Sue rescued both koalas and took them into care. 7. In the year or so after the fire, about 500 park visitors were asked if they had seen a Koala, but none was seen. 8. One koala was seen in a stringybark at Siding Spring Observatory in an unburnt patch near the telescope. 9. One koala was seen at Mount Exmouth. 10. One koala was seen at Camp Blackman. 11. One koala was seen at Burrumbuckle Mountain on John Knight's property, which was burnt, but probably not badly (as it burned subsequent to the day of extreme fire behaviour). 12. In September 2015, koalas were heard calling at Spirey View and Pincham Trail, which had burnt at night at low intensity. Some cypress trees were unburnt, so koalas possibly survived the fire. 13. Sue, with fellow staff members Steve Tucker, Rebecca Cass and George Barrett-Brown, looked for koalas in Warrumbungle National Park for six months following the Wambelong fire in January 2013, but did not find any koalas. 14. Sue supplied photos of the fire, which are presented in Figs 3a-d.

Figure 2. From BAAT report: 'Figure 25 Koala in burnt tree on land adjoining Warrumbungle National Park (Sue Brookhouse)' Sue's original photo is used here for clarity.

Figure 3. Four post-fire photos in Warrumbungle National Park. 3a (top left). West, looking east on 14 January 2013; 3b (bottom left). West Park entrance, looking east, 14 January 2013; 3c (top right). Burnt area, 17 January 2013; and 3d (bottom rightt). Road through burnt area 6 February 2013. Photos by Sue Brookhouse.

Recent (2019) enquiries and searches

Enquiries in March 2019 by one of us (DL) of Park and Regional staff (May Fleming) confirmed that there had been no new sightings subsequent to those listed above, either by Park staff or visitors. One of us (ME, September 2019), also had not heard of any sightings or records during his many surveys of other fauna species in the Park.

Fire severity and vegetation maps post fire with koala locations

Warrumbungle NP falls within the North Western Slopes botanical subdivision of NSW and the Brigalow Belt South Bioregion. Sixteen vegetation communities, or Plant Community Types (PCTs), occur in the Park, of which 10 (Porteners 2016) are listed as being the primary communities A total of almost 900 plant taxa from 117 families have been recorded in the Park, and of these, 166 taxa are exotic or introduced species. *Acacia* and *Eucalyptus* are the best represented genera (Porteners 2016). Vegetation and fire severity maps assist in interpreting the recovery of the plants and animals in the Park.

Locating the post-fire records of koala locations

To clarify the extent and severity of the fire, the next step was to examine the severity map and the vegetation map of the fire in relation to the post-fire records of koalas. These were superimposed on the fire severity and vegetation maps to both locate the exact sites and suggest areas for future searches (Figs 4 and 5).

Post fire koalas rescue, rehabilitation and release,

Two Koalas (a male and a female) were rescued from just outside the boundary of the Park 10 days after the fire and were taken into care by Sue Brookhouse, who supplied the following details. Both koalas were burnt and had some minor health issues: new claws grew back, the male koala had an issue with one eye which produced more tears after being burnt. The two koalas were held in a large purpose-built koala enclosure with tree trunks for climbing, and the attachment of sprigs of foliage for food and shelter. Both had been checked and tested for *Chlamydia* by veterinary staff at Taronga Western Plains Zoo, Dubbo, and were healthy and *Chlamydia* free. Both koalas were tagged with coloured tags and both were

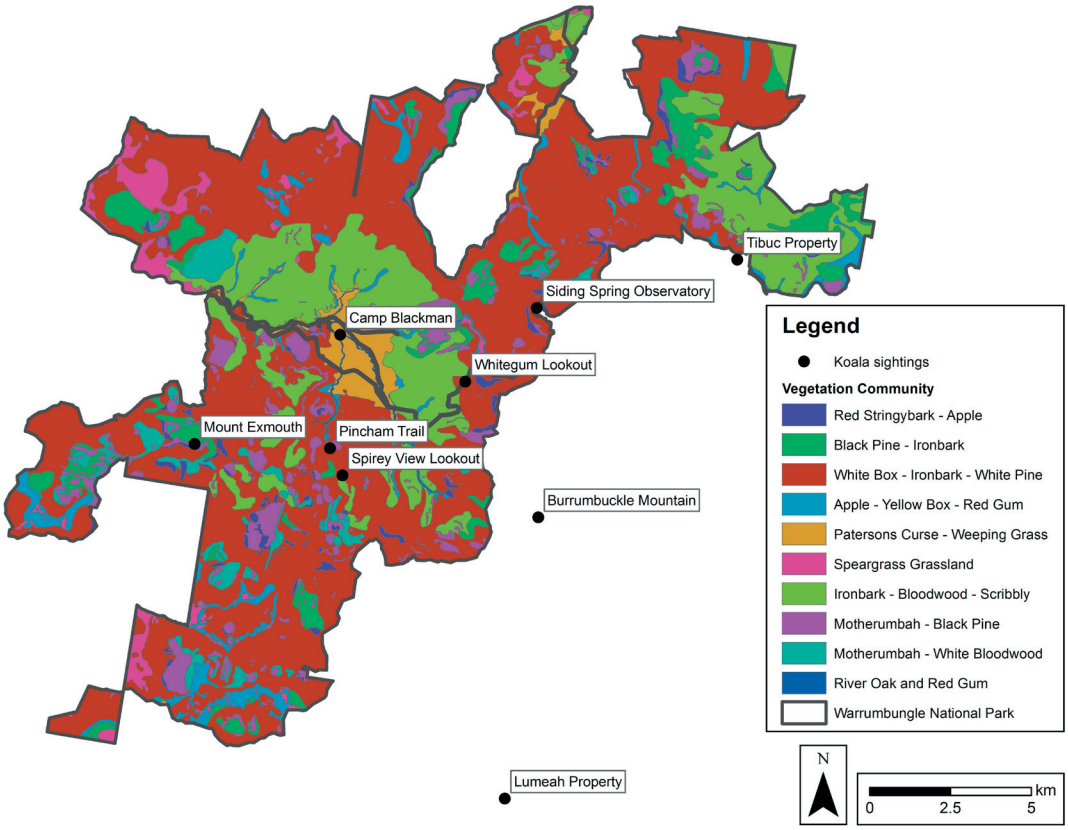

Figure 4: Koala sightings within Warrumbungle National Park following the 2013 fires superimposed on vegetation types.

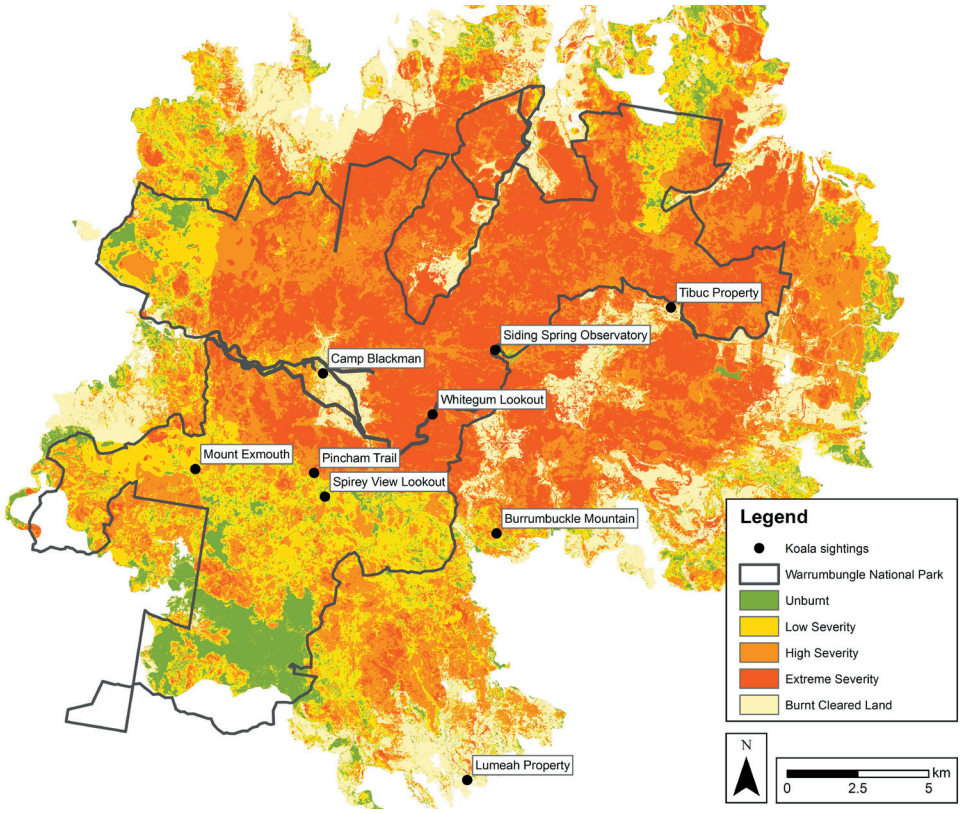

Figure 5: Koala sightings within Warrumbungle National Park shortly after the 2013 fires, superimposed on fire severity map.

microchipped – records are with Western Plains Zoo. At first, both koalas did well in captivity, put on well over 1 kg each, with a weight of 9 kg for the male and 8.3 kg for the female. The female initially had a burnt nose and her claws were gone. However, the male had badly damaged tear ducts and was euthanized nine months after being taken into care. The female was initially looked after in Dubbo Zoo by Jodi Milton for two weeks, before being cared for by Sue at her home. A radio-tracking collar was fitted to the female koala a week before she was released to give her time to get use to the collar. This koala was released into the Park following a long period of recovery (17 months, which, to our knowledge, is a record for an injured koala that goes in care and is subsequently rehabilitated). This rehabilitated koala was released with a collar to enable radio tracking from June 9 to August 29, 2014, when its collar was removed before the battery expired.

The female koala, called Midi (which means missus in Gamilaroi), was pre-released in a redgum which was surrounded with a core-flute enclosure. The location for the koala's release site was chosen for its tree species, access to water and adjacent to where a male koala was observed after the fire (on several occasions). The tree initially selected for the koala had a diameter at breast height (DBH) of about 45 cm. Despite three attempts at holding the koala in place against the trunk for several minutes, the koala was not able to grasp and climb up the trunk. The fluting was then arranged around another redgum which had several trunks, the DBH of each was about 30 cm. The koala was placed at the base of this tree, and it soon climbed, if somewhat ungainly, to a height of 2.5 metres before settling into a fork. Immediately prior to release, we were told that a fox *Vulpes vulpes* had been seen in the immediate area. Cage traps and 1080 baits were set and, as an added precaution, the fluting at the base of the tree was kept in place for three days, and the koala checked several times per night to ensure it was above ground. Day-time searches below the canopy for koala faecal pellets were undertaken. Those pellets were removed. Night-time checks of the koala, under different areas of the tree canopy, showed evidence of browsing, and the daily locations of pellets indicated that the koala had not confined itself to one section of the canopy over the three nights.

The koala was subsequently tracked for a minimum of three times per week. The collar had a Titley brand transmitter, with VHF, but no GPS, so the fixes were day only. In the first week, the koala was tracked and assessed daily. The second week it was tracked and assessed every second day, decreasing to 1-2 times per week. Retrieval from a tree used a purpose-built extendable capture pole with a flag tied to the end and waved above the koala's head to encourage it to descend the tree. Removal of the collar was undertaken after capture, with the koala released back into the same tree.

Initially, this koala preferred smooth-barked red gums with a diameter of about 30 cm. The rough-barked trees, mainly iron barks were much larger and taller which the koala was able to climb confidently and quite often spent the day sleeping in these trees. On very frosty mornings the koala was usually located higher upslope in sunny, sheltered positions. On wet days it would locate mid-slope in a tree with a lot of epicormic growth for protection. Its favourite food trees were Blakely's red gums (*Eucalyptus blakelyi*) and was often seen sleeping in iron barks during the day. The koala returned to its original release site about 1 month after her release. By the time the collar was removed, this koala had covered an area of about 1 square kilometre and appeared to be taking up a similar territory to an old female koala that was occasionally seen at the visitor centre before the fire. The terrain covered included creek-line with sandy loam soil, mainly Blakely's red gum and yellow box; hillside with rocky shallow volcanic soils, with ironbark, tumbledown gum (*E. dealbata*) and black cypress pine (*Callitris endlicheri*), some open country with white box, yellow box and ironbark with volcanic soils and a rocky canyon with tall red gums and casuarinas on Wambelong creek. When the collar was removed, she weighed 0.5 kg more than her release weight of 7.5 kg and was in a healthy condition. The survival of this koala for three months demonstrates that the post-fire stands of trees were sufficient for its survival. Tree selection was consistent with tree choice shown by koalas within the region (Crowther et al. 2014).

The koala was released into an area of high fire severity as shown on the Wambelong Fire Severity map (Fig. 7). It remained in this area for a few days and was seen in redgums, until the fourth day when it had moved to a low fire severity area and was also seen in a redgum (see later for the trees species selected by koalas). The following day, it had moved to a different patch of low severity and remained in the same red gum tree for several days. It then moved through burnt cleared land with isolated trees for a couple of days before being located in what had been a high fire severity area. For the next month, the koala moved between high and low severity patches. It then returned to near where it was released, but in a burnt cleared area. The koala continued to move around in this area for a week, before moving to a high severity area. The locations are shown in Figs 6 and 7.

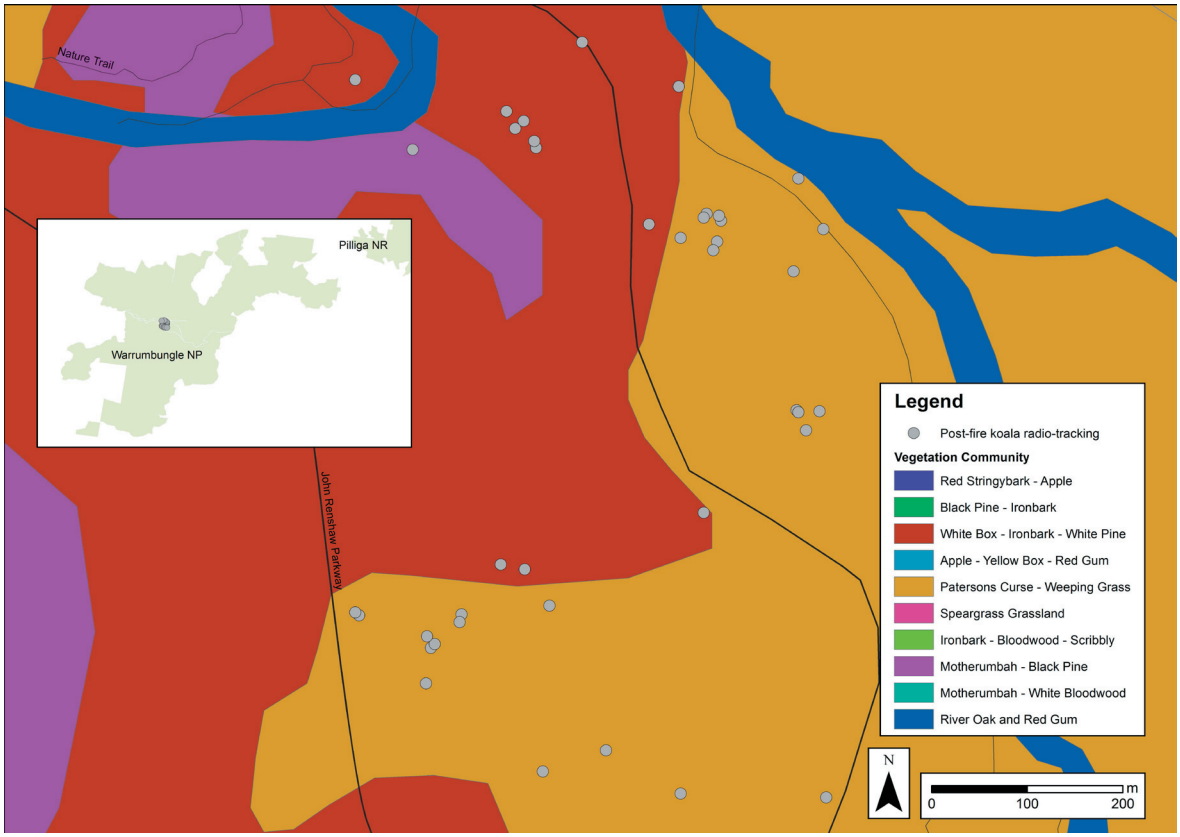

Figure 6. Koala locations determined by radio-tracking in 2014 superimposed on the vegetation map.

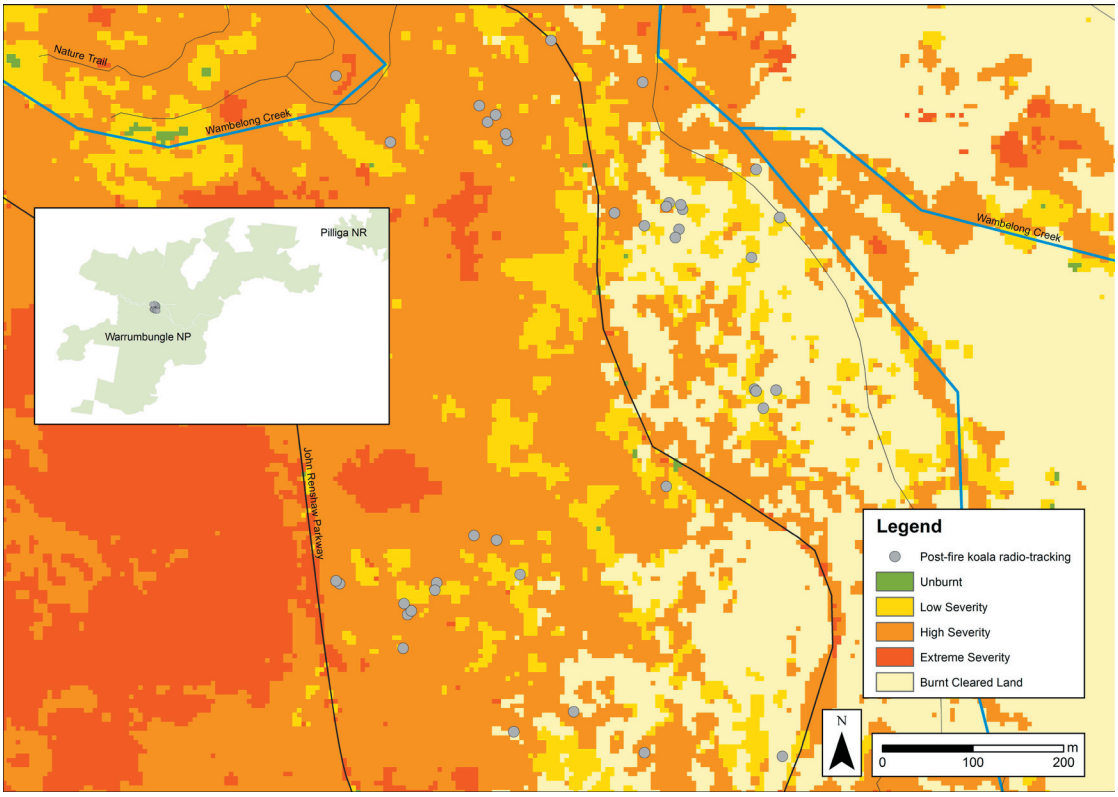

Figure 7. Locations of radio-tracked koalas (shown in grey dots) in 2014 on the fire severity map.

Regional surveys in 2006 and 2014-15

The realisation that koalas were seen just post-fire, but not subsequently, raised the distinct possibility that the koala population in the Park had been lost. Thus, if the Park's population was to recover, koalas would have to come from beyond the Park's boundary. Given that we had a large state-wide postal (citizen science) survey in 2006 (Lunney et al. 2009), which identified the importance of the north-west for koala population, we therefore had the opportunity to redo a section of this survey to see where koalas were now located. The new survey was conducted in 2014-15 and reported in Predavec et al. (2018). Here we have included relevant parts of the maps from both these citizen-science surveys to show the relevant koala locations before and after the fire (Figs 8a-b). What is noticeable is the low number of locations in and around the Park, including nearby post-fire locations on private land that may serve as potential sources of immigrants.

History of the increasing size of Warrumbungle National Park

Warrumbungle National Park was one of the first National Parks to be dedicated in NSW. The initial dedication, in 1953, comprised 3437.40 ha. In 1967, at the time of the passage of the NSW *National Parks and Wildlife Act 1967* and the formation of the NSW National Parks and Wildlife Service, the area had increased to 6239.04 ha. In the ensuing years, the Park continued to increase incrementally. The dates of the increments and the areas are shown in Fig. 9 and Table 1.

The concept of national parks was still novel in NSW in the post war years, so the selection and dedication of land for national parks was unusual, with the relevant records now difficult to find, and thus worth recording when found, as in the case for Warrumbungle National Park. Specialised investigative skills are needed to understand the land-use coding, read the maps and the gazettal notices and piece together a map with the relevant files to portray the tenure history of the land. It was not until 1967, when the NSW National Parks and Wildlife was formed, that record keeping and access became more regular. Nevertheless, Cathy Johnson, Project Officer - Land Information, Reserve Establishment in NSW National Parks and Wildlife

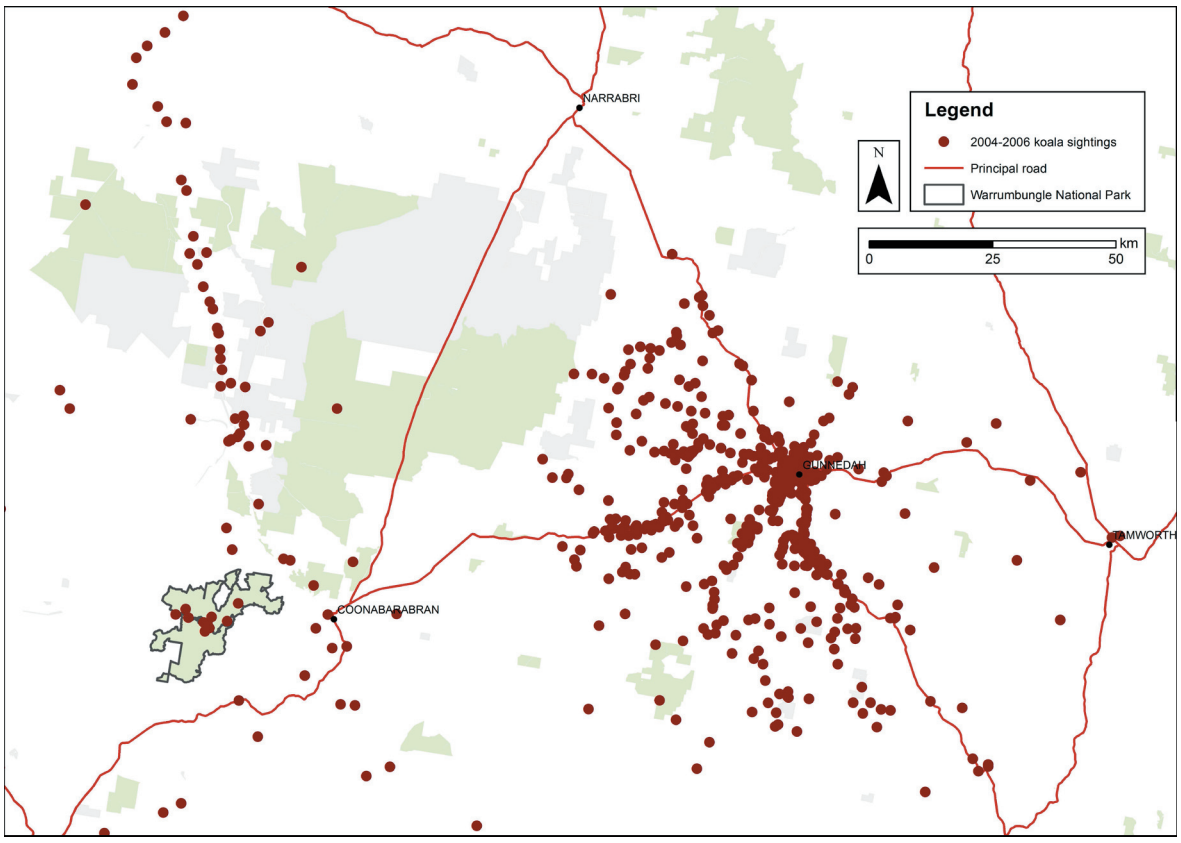

Figure 8a. Community survey for koalas in 2006. The dark red dots represent koala sightings made between 2004 and 2006.

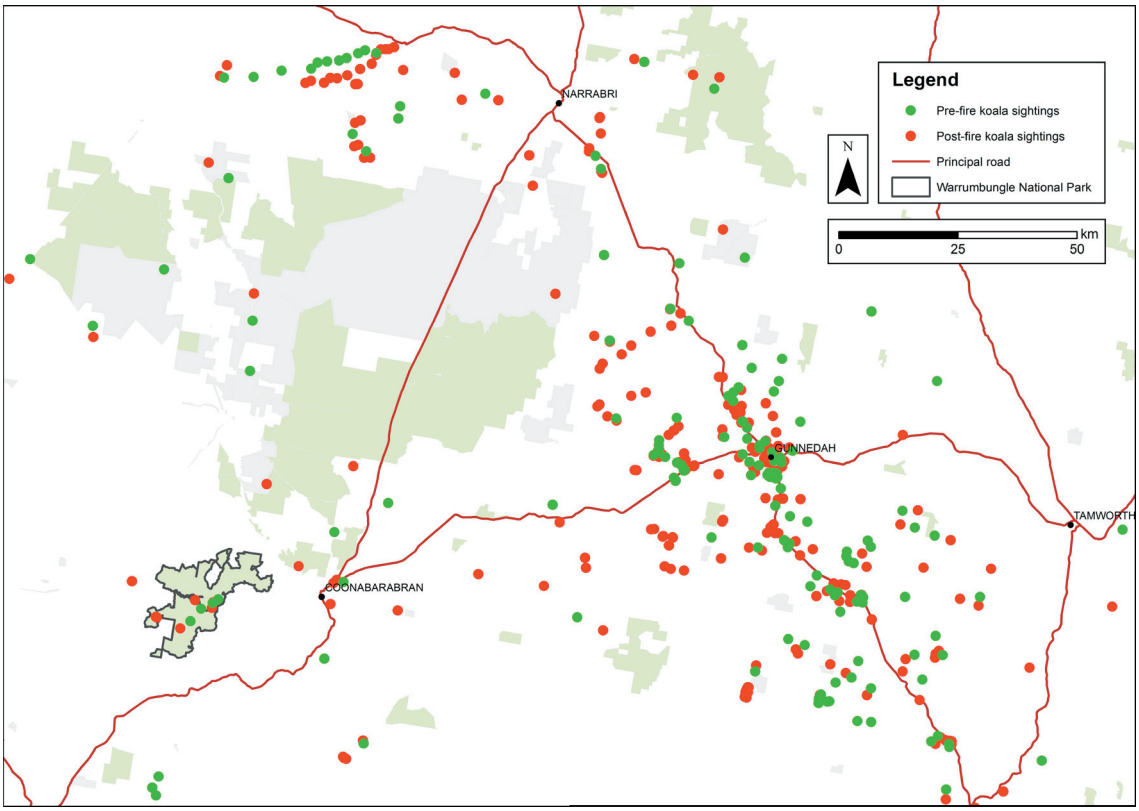

Figure 8b. Community survey for koalas in 2014. The green dots represent koala sightings made before to 2013 and the red dots represent sightings in 2013 to 2015.

Service, succeeded in finding the early information identifying that Warrumbungle NP was gazetted as a Reserve for Public Recreation on 30 October 1953. The newspaper article in the *Gilgandra Weekly* on 9 November 1953 confirmed the 30 October 1953 date. There are two gazette notices, one withdrawing existing Crown Lease for Public Recreation, folio 3617 (it was these two areas that formed the reserve in 1962). The Crown leases were withdrawn under Section 233 of the *Crown Lands Consolidation Act 1913*. The other gazette notice, folio 3628, reserved the lands for public purpose/public recreation under Section 28 of the *Crown Lands Consolidation Act 1913*. Cathy noted that the gazette notices refer to Ms 1783 Do 1783-3030 so she used this plan to create the shapefile in the Diagram – Warrumbungle NP with 1953 boundary. The gazette notices refer to the blue, red, green and brown hatching on the MS plan. In addition, Cathy found a Sydney Morning Herald article from 7 August 1954 where the Minister for Lands announced 14,000 acres as Warrumbungle NP (the gazette notices total 13,985 acres). The most recent addition in 2011 brought the total to its current (2019) size of 23,558 ha (its size at the time of the Wambelong fire).

Ecological history of Warrumbungle National Park

The koala population of Warrumbungle National Park has been of interest since the first portion of the Park was dedicated in 1953. The history of that knowledge forms a major strand of this paper, partly to establish whether there was ever a robust local population, or whether there were in fact few or any koalas. There had been no scientific studies of the koala population of the Park, or its immediate surrounds, before the 2013 fire, so our task in understanding change over decades means piecing together a series of observations, comments, records, management considerations and interpreting them ecologically. The Wambelong fire of January 2013 gained much attention from several quarters, each of which provides us with glimpses and insights of what might have happened to the koala population of the Park as a consequence of the fire. As with the ecological history of the region, we need to interpret diverse sources to gain an overall picture of the how the changing landscape may have impacted the koala population of the Park.

The concept of national parks being important for fauna conservation had not yet taken hold by 1953, indeed, fauna conservation has long been a contested

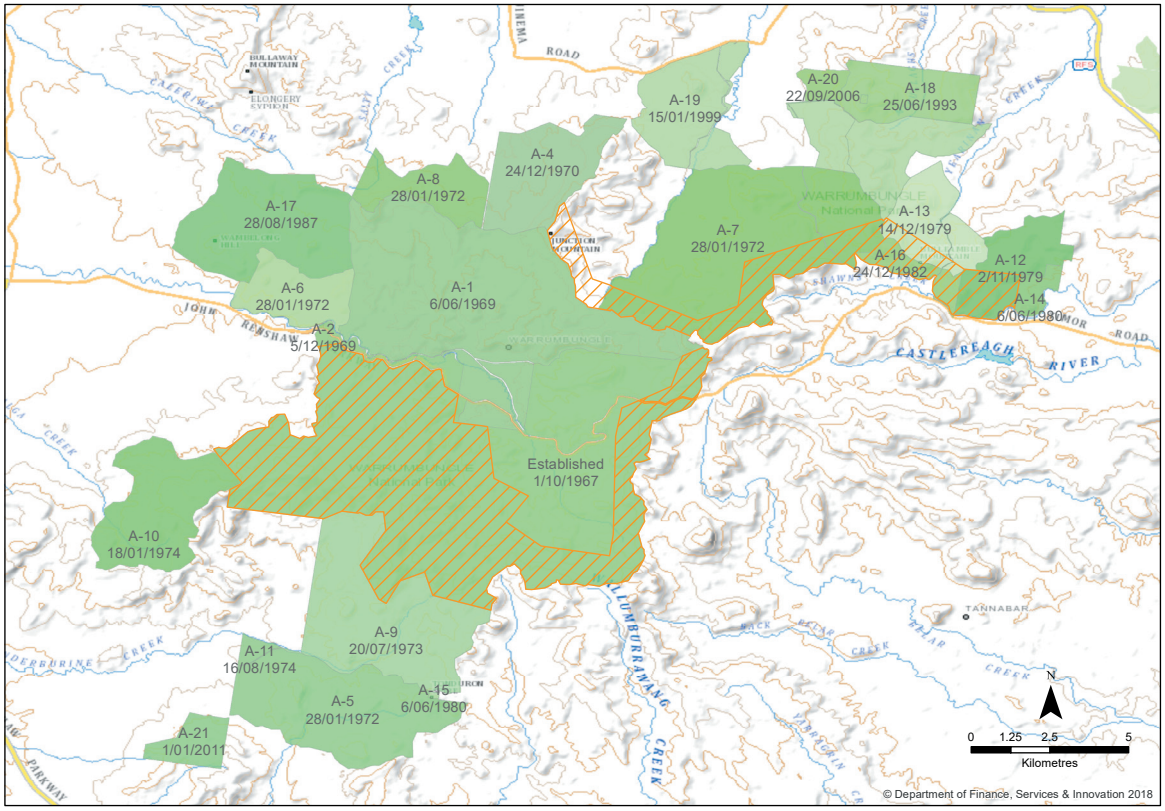

Figure 9a. The incremental increase in Warrumbungle National Park since the dedication of the initial parcels of land in 1953, shown in orange hatching. The outline is the area of the Park in January 2013. The accompanying Table 1 shows the additions to Warrumbungle National Park from 1/10/1967, which is the date of the passage of the NSW National Parks and Wildlife Act 1967. The prior dedications of Warrumbungle National Park were under a preceeding Act.

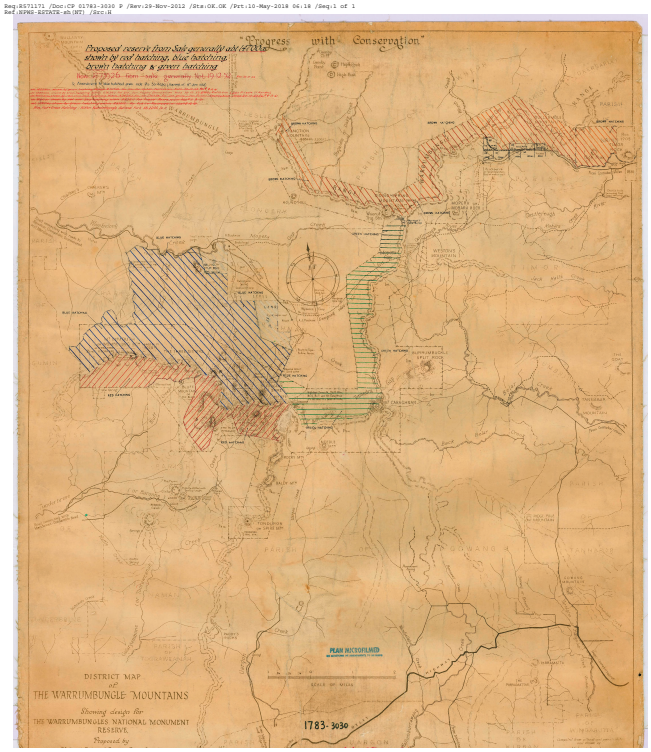

Figure 9b. Original map showing the initial designation of Warrumbungle National Park in 1953 (area shown in hatching; the different colour hatching refers to different prior owners). The unusual shape of the Park follows the Warrumbungle Mountains. Mr Allen A. Strom, a Balmain Teachers' College lecturer said of the Park, 'While we are gratified to see this park founded at last, we are critical of its ridiculous, drawn-out shape. It is about 18 miles in length, but narrows down to less than a half-mile in places' (Article by Kanangra, SMH 1954).

(8684) • Sydney, 30th October, 1953.

WITHDRAWAL FROM SETTLEMENT LEASE FOR PUBLIC RECREATION.

IT is hereby notified, for public information, that in pursuance of section 233, Crown Lands Consolidation Act, 1913, the Crown lands hereunder described are hereby withdrawn from Settlement Lease 11-5, Coonamble, held by Agnes Gale, for the purpose of a Reserve for Public Recreation.

F. H. HAWKINS, Minister for Lands.

LAND DISTRICT—COONAMBLE; COONAMBLE SHIRE.

Settlement Lease 1911-5, Coonamble; Agnes Gale.

Parish of Naman, county of Gowen, part portion 14, area about 2,300 acres, being the part of Settlement Lease 1911-5, shown by red hatching on plan Ms. 1,783 Do. G. 1,961-1,797 R. P. 53-4,236.

Figure 9c (above). The public notice in the New South Wales Government Gazette No. 196 that was the beginning of Warrumbungle National Park, whereby land was withdrawn from settlement and reserved for public recreation on October 30, 1953.

WARRUMBUNGLE NATIONAL PARK

RESERVATIONS GAZETTED

The Minister for Lands, Mr. F. H. Hawkins, has advised all technical details and considerations have now been completed for the Warrumbungle National Park and full details given for the publication of the necessary reservations in the Government Gazette of October 30.

Mr. Hawkins pointed out the matter involved considerable preparatory investigation, both field and office, prior to the preparation of a detailed submission for consideration in August 1952, when approval was given for a certain course of action.

This action envisaged the withdrawal of substantial areas from existing leases under the Crown Lands Act, with a view to the reservation for the purpose of public recreation. It was also necessary to protect these lands from alienation and to remove any danger of disposal of any portion of them.

After notice was given to the affected lessees of the intention to withdraw from their leases and reserve the lands for recreation each of the lessees made representations with the views to variation of the areas said Mr. Hawkins, and this involved further investigation and consequent delay in reaching finality.

The present position is, concluded the Minister, all technical details and considerations have been completed and full preparations have been completed for the necessary reservations. Following this reservation of the land for the purpose of public recreation, consideration will be given to the question of appointment of trustees for the care, control and management of the park. — ("Coolabaraman Times").

Figure 9d (right). An article in the Gilgandra Weekly on November 19, 1953 describing the process of creating Warrumbungle National Park, plans for which were submitted in August 1952.

Table 1. The gazetted additions to Warrumbungle National Park since the establishment of the NSW National Parks and Wildlife Service in 1967. Information supplied by Cathy Johnson, Project Officer - Land Information, Reserve Establishment in NSW National Parks and Wildlife Service. The 6232 ha on 1 October 1967 is the size that the Park had reached on the date of the formation of the NSW National Parks and Wildlife Service.

Reserve for Public Recreation gazetted on 30 October 1953 and known as Warrumbungle NP.

Establishment & additions under NPW Act.

Entry Type	Date	Hectares
Established	1/10/1967	6232
A-1	6/06/1969	3421
A-2	5/12/1969	2
R-3	12/06/1970	-2
A-4	24/12/1970	859
A-5	28/01/1972	1429
A-6	28/01/1972	520
A-7	28/01/1972	2562
A-8	28/01/1972	462
A-9	20/07/1973	1605
A-10	18/01/1974	1076
A-11	16/08/1974	9
A-12	2/11/1979	559
A-13	14/12/1979	581
A-14	6/06/1980	136
A-15	6/06/1980	6
A-16	24/12/1982	195
A-17	28/08/1987	1263
A-18	25/06/1993	620
A-19	15/01/1999	1664
A-20	22/09/2006	114
A-21	1/01/2011	248

ideal in the management of national parks (Lunney 2017). National parks have nonetheless increased in their value for fauna conservation in NSW as their number, area and diversity has increased (Lunney et al. 2017). In contrast, Nature Reserves in NSW, dedicated under the *Fauna Protection Act 1948*, explicitly included fauna and research (e.g. Nadgee Nature Reserve, dedicated in 1957, see Lunney et al. 2013). When Warrumbungle National Park was first dedicated, it was managed by a Trust, which was responsible to the NSW Department of Lands. In contrast, the Fauna Protection Panel managed matters under the *Fauna Protection Act 1948,* and the Chief Guardian of Fauna reported to the NSW Chief Secretary's department. The two were merged by the NSW *National Parks and Wildlife Act 1967*, and the *Fauna Protection Act 1948* was repealed with the passage of the *NSW National Parks and Wildlife Act 1974.* Howard Stanley (1983) published a useful administrative history of the Park. These details are germane to the management of fauna, and national parks, in the first years of Warrumbungle National Park management. Fortunately, we were able to draw on the memory of Alan Morris. who initially worked for the Fauna Protection Panel then later as the manager of the Park. Alan's account provides one of the key elements in constructing a history of the koala population up to 1983. Similarly, Discovery Ranger Sue Brookhouse, who took koala walks in the Park from 1995, and was still working through and beyond the 2013 fire, enabled us to follow the story of the major fluctuations in the koala population of the Park.

The question that emerges when the changes in the koala population are considered since 1953 is what was present before Warrumbungle National Park came into existence? What is also apparent that the Park was small at the outset, 3237 ha, and was 23,558 ha at the time of the fire. This seven-fold increase represents a potential for more koalas to be included within the Park that were previously on grazed private land. Thus, part of our work was to map this increase in area. In turn, this raises the question of what was the likely size of the koala population before 1953. Given that there were no studies of koalas, we therefore relied on the historical record to construct an ecological history and interpret the potential status of the koala population for a century or more before the 2013 fire. However, we did not take the history beyond the latter part of the 19th century because the records are rare and any search would need to construct a regional picture and interpret the early European land use of the Park from the broader picture, as had become apparent from the records that we had obtained. The Aboriginal pre-history of the area, and the knowledge of the wildlife, and koalas in

particular, was beyond the scope of this study, but it is an important area of investigation and recording.

National Parks are associated with the concept of a large natural area, although many had earlier land uses that were inconsistent with natural areas. Warrumbungle National Park is an example of a park with a history of intensive grazing, other than the steepest areas that make it such an attractive place to visit. Frank Hurley's magnificent photo of 1910 shows cattle grazing, and the cleared lower half of the steep slopes of what was identified in the original caption as the Warrumbungle Mountains (Fig. 10). The country was also well known as sheep country. At this point in the story, one of us (DL) has a family connection.

During WW II, men from the land joined the armed forces, with the shortfall in labour filled by women who joined the Australian Women's Land Army (ABC 2012).. DL's mother was part of the Land Army, and was sent to work on 'Avon Hills', a property owned by Gordon Blackman. The property was near what is now the centre of the National Park. Her tasks included working with sheep and killing foxes. As a child, DL was taken to visit the property. His father still remembers it well: when DL asked him whether there were any trees, his answer was a clear "no" (April 2019). DL's father, who worked in the wool industry as a research scientist, remembers Gordon Blackman recounting that, when he was a small boy, his father showed him an unusual animal. His father thought that it might be a rabbit. DL's father remembers Gordon Blackman saying that by the next year 'there were a million of them'. One of the detailed old local maps shows a line, marked in 1892, saying 'boundary of rabbit infestation area'. We are thus constructing a picture of a landscape grazed by stock since well before the end of the 19th century, then with a grazing impact exacerbated by rabbits for over half a century before the Park was dedicated. We now cover the details of the historical record of the koalas of the Park, starting with the most recent, and travelling back through the decades until the picture is

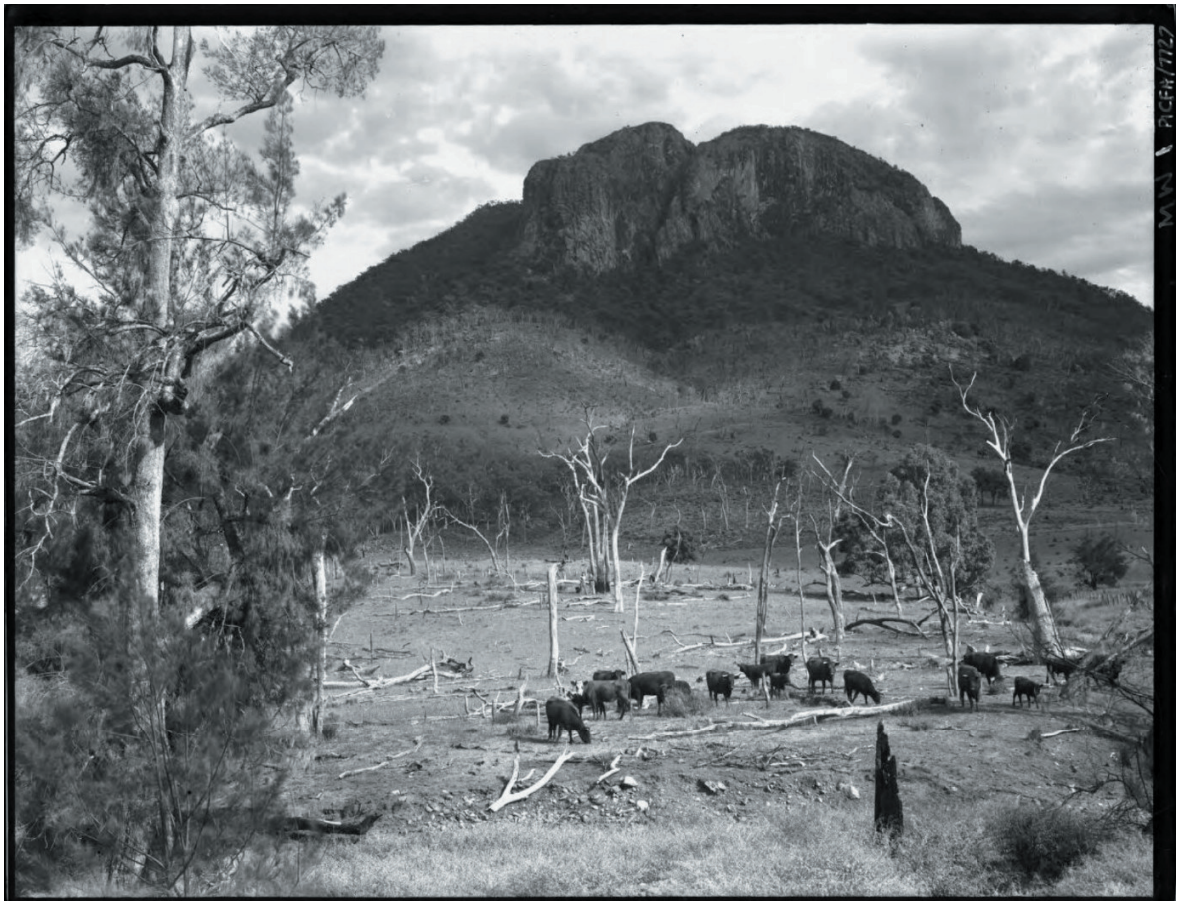

Figure 10. Frank Hurley, 1910 Scene on Tannabah Station (Knights), Coonabarabran, Devon cattle, in the Warrumbungle Mountains, NSW. Reference number nla.obj-160145117. Permission to use this photo granted by the National Library of Australia

clear as to whether or not there was a koala population on the land now designated as Warrumbungle NP at the time of its dedication as a park.

Sue Brookhouse

The information on the koala population of the Park in the period 1995-2013 is principally derived from the NPWS staff member, Sue Brookhouse, who worked in the Park Visitor Centre and regularly spoke with visitors to the Park. Sue Brookhouse initially discussed the status of koalas in the Park with DL on 15 April 2016 at a staff information day in Coonabarabran on the fire, and subsequently by phone to DL and IS in the following weeks. Sue's account is summarised as follows:

Koalas were very commonly sighted in the park prior to the 2001-2009 (Millennium) drought. The Park received approximately 40,000 visitors per annum before the fire and the feed-back of koala locations and occurrence was mainly from visitor reports. When DL asked Sue, 'Out of 500 people, how many would not have seen a koala?' Sue replied that 'Only 10 out of 500 people would not have seen a koala in the Park'. A koala sightings book was kept at the park visitor centre and received one or more sightings most days before the drought This information was (unfortunately) lost when the visitor centre burnt down in the Wambelong fire. Sue ran koala walks for the Discovery program and always saw koalas on the Pincham Trail towards the Grand High Tops and on the Wambelong Nature Trail (not far from the visitor centre). Up to 2001 (pre-drought), Sue took koala walks along the Pincham Trail and Northern Fire trail (especially the valley floor), as well as around Mount Exmouth, The Woolshed, the Visitor Centre, Canyon Picnic Area, Camp Blackman and Whitegum Lookout, where koalas were seen regularly. Other sites where koalas were common were around the old Visitor Centre site, Camp Blackman and Mt Exmouth. Koalas were widespread – the valley floor as well as on the higher elevations – Grand High Tops and Exmouth where pockets of richer soil with redgums and volcanic ash appeared. Their main food source in the Park was predominately any redgum species*; Eucalyptus blakelyi, E. dwyeri, E. dealbata, E. camaldulensis*. Other species were; Apple Box *E. bridgesiana*, Narrow-leaved Ironbark, *E. crebra*, Yellow Box *E. melliodora*, Mugga Ironbark, *E. sideroxylon,* and *E. volcanica.*

During the 2001 to 2009 millennium drought, koalas were found dehydrated and suffering from various cancerous tumours and retrovirus - most subsequently died. Koala numbers dropped drastically and some of those that remained were showing signs of the disease Chlamydia, possibly brought on by periods of hotter than normal temperatures and stress of the prolonged drought. Sightings were rare after the drought, but there were several locations where koalas were still seen before the 2013 fire: Pincham trail, Strathmore homestead, Tara Cave Trail, Camp Blackman and Mt Exmouth.

Between 2001, and up until the fire, Sue estimates that 80% of koalas were lost due to drought. When DL asked Sue, in the period just before the fire, 'How many people out of 500 would have seen a koala?' Sue replied that 'Only 10 out of 500 people would have seen a koala'. (Thus, in terms of seeing a koala, the visitors' response had declined from 98% to 2%.) After the fire, visitors were asked if they had seen a koala, and of about 500 people, none said they had seen a koala in the Park.

Allan Fox

Warrumbungle National Park visitor guidebook

Allan Fox, a hero of the conservation movement in NSW (e.g. Lunney et al. 2013), was raised in Coonabarabran. When DL first met Allan in 1970, he was the chief wildlife officer in the NSW National Parks and Wildlife Service and DL was a newly appointed education officer. Allan had joined the predecessor organisation, the NSW Fauna Protection Panel, in 1965. Allan wrote the foreword to (his son's) Peter Fox's (1996) guidebook 'Warrumbungle National Park', and Peter Fox's comments on koalas can be taken as a reflection of his father's long-term knowledge, and affection for, Warrumbungle National Park.

Under the heading, 'A plantation for koalas' (Fox 1996, p37), there is a curious story of koalas. Excerpts from that account are as follows: 'The koala was once thought to be extinct in the Park, primarily as a result of disease, over-hunting and bushfires. The Park Trust decided in the early 1960s to recolonise the mountains with koalas imported from Victoria. As part of this scheme, a plantation of Manna Gums (*Eucalyptus viminalis*) was established beside Camp Pincham to provide the new immigrants with food and a secure environment. As fate would have it, soon after the trees were planted, local koalas were discovered already living elsewhere in the Park (albeit in small numbers). The re-colonisation project was abandoned, and the plantation has since become the site of the carpark at the start of the mountain trails. We now know that Koalas are present in healthy numbers in the Park, and an ongoing monitoring program is in place.'

NPA journal

In a special edition of the *National Parks Journal* of February 1964, focussed on Warrumbungle National Park, under the heading of 'Fauna' (p 19) the text notes that: 'in 1960 (30/9), the Park was gazetted as Wildlife Refuge No. 3. (The Wildlife Refuges scheme has existed since 1948 and is one of the longest-running schemes in Australia that supports conservation on private and public land. DPIE 2020). Near Camp Pincham, from 14-20th July, 1963, some two hundred Koala Food Trees were planted, as the first step in creating a breeding station.' Later, on the same page, the text reads: 'Some animals will have to be found almost by chance. Koalas, for example, were seen for the first time in several decades purely by chance – and then, because of an aroused interest, at least three more sightings were made in as many months on Exmouth spurs.'

John Whitehead

In his valuable and painstaking history, 'The Warrumbungles' Whitehead (2008, p 252), under the heading, 'The Warrumbungle National Park 1955 to 1966 Trust control', describes decisions recorded in the Trust minutes. (Before the formation of the NSW National Parks and Wildlife Service in 1967, each National Park was an independent entity, managed by a Trust and the Trust was responsible to the NSW Department of Lands. After the formation of the Service, Trusts were phased out.) The minutes of 28th February 1960 record, under the heading: 'Koala Trees'. 'Trees have been ordered for the koala sanctuary. I have asked Strom [head of the Fauna Protection Panel] to consider the possibility of siting the plantation between the creek and the road near the Canyon area. This would most materially assist maintenance of the trees in dry times, and would, I imagine be helpful for care of the bears (goodness) in due course.'

From the Trust minutes of 1969 (Whitehead 2008, p 266), under the heading 'Koala Sightings', the text is scathing on the matter: 'Ranger Duggan reported that six (6) koalas were seen inside the Park outside the so called Koala enclosure. So here we have a situation where a great deal of time and effort was spent on establishing a system that really wasn't needed. I am surprised that Strom and his fauna experts did not investigate the presence of Koalas in the area before committing to the installation of the enclosure. As more sighting reports were recorded it quickly became evident that there were large populations of Koalas in the Park and also in the adjacent Pilliga forests and Nature Reserves. The enclosure was literally a 'white Koala'.' This comment clashes with those of the previous sources from the 1960s that stated koalas were rare. A degree of caution needs to be taken when interpreting such comments on a cryptic animal, and the context here matters. There was an apparent clash between the Trust and the Fauna Protection Panel, and one can surmise that the language was exaggerated.

By 1969, one record claims that there were large populations of koalas in the Park, but that remark needs to be weighed against the bitter comment at the time that: 'I am surprised that Strom and his fauna experts did not investigate the presence of Koalas in the area…' Putting the two points together, it can be surmised that there was a koala population in the Park, but it was unlikely to have been large. Ranger Duggan's report of six koalas is hardly a record of a large population. The assertion that there was a large population of koalas in the Park can be seen as an exaggeration to ram home the hostile comment by one organisation - the Park's Trust - about Strom and his fauna experts from another organisation – the Fauna Protection Panel. We can now read "large populations of koalas" as the more likely being, just "koalas" and reject the opinion of a larger population.

In the Trust minutes of 1970, Whitehead (2008, p 289) writes, 'At last the Trust realised that the Park and district had its own population of Koalas. The text of the minutes reads as follows: 'Koala Sanctuary to be let go. RESOLVED that because of the apparent increase in koala population that there was no need for a regeneration centre and that the notice be taken down.'

Under the heading 'Mammals and marsupials', Whitehead (2008, p85) recounts that in 1983 on a NSW Department of Education media trip to the top of Mount Bullaway [immediately northwest of Warrumbungle NP on the Baradine road], 'we found many koalas in the mountain gums on the mountain top. Bob Smith, the owner [of the property] had counted over 40 koalas at that time. They appeared to be a healthy tribe of mountain koalas.' The possible reason for such a large number, Whitehead adds, was the steep cliffs surrounding the plateau preventing access by predators.

Howard Stanley

The vision of a Warrumbungle national park was first proposed in 1936, with Myles J. Dunphy, as secretary of the National Parks and Primitive Areas Council writing to the district survey at Tamworth on 23rd September 1936 putting the case for a national monument for the "Warrumbungles National Monument Reserve" (Stanley 1983, p 2-3). Howard Stanley was the assistant director (administration) of the NSW National Parks and Wildlife Service when

one of us (DL) joined the NPWS in 1970. He wrote a number of histories of the administration of national parks. He noted in his administrative history of the Park that by the time the necessary surveying work had been completed World War II delayed further action. Stanley writes about further correspondence and the political figures involved, concluding with the details of the areas reserved which became the Warrumbungle National Park in 1953. Stanley added (p 14) that, "after a patient wait of 17 years the hopes and dreams of the National Parks and Primitive Areas Council were realised." Almost all of his 52 page history is on administrative matters, with only a one mention of wildlife, that being one sentence under the heading 'Koala plantation': "In the early 1960s koalas were discovered in the Park and at the suggestion of Mr. Trustee Strom a plantation of suitable trees was established in the Park with considerable assistance of Mr Strom and the Fauna Protection Panel (Stanley 1983, p 32-33)."

Of considerable ecological interest was the inclusion of an extract from the *Sydney Morning Herald* of 13th November 1967, under the heading: 'Fire destroying 13,000 acre National Park' (Stanley 1983, p 40). The opening line of the text in the Herald stated: 'About 10,000 of the 13,000 acres of Warrumbungle National Park, south-west of Coonabarabran, have been destroyed by fire. Stanley (1983, p 42) picked up the story again with quotes from the *Sydney Morning Herald* of 15th November 1967: 'Fire was raging out of control last night in the Warrumbungle National Park, south-west of Coonabarabran, and there seems little hope of saving the Park. The fire which has been burning for 18 days flared up again yesterday under a 30 m.p.h. north westerly. The Park's Senior Ranger, Mr. C. Hormann estimated that only 2000 acres of the Park's 15,400 acres remained unburnt last night. The remaining 2,000 acres would be burnt out by the morning unless the wind changed.'

We thus have a foretaste of the 2013 fire in the Park, largely burnt out, but in 1967 there was no mention of the koalas in relation to the fire, yet we know from Stanley's earlier entry that koalas were present in the early 1960s. We also have no record of fire severity, but we do know from our current work on the 2019-2020 bushfires that, in the low severity burns, there is about an 80% survival of koalas. We can surmise that part of the koala population in the Park would have been killed by the fire, but some koalas would have survived. Even so, a loss of part of a small population would have been a setback. There is also no record of whether the fire went beyond the Park boundary, or whether the neighbouring properties had koalas. Nevertheless, we can look back and reasonably conclude that sufficient numbers survived for the koala population to continue to grow for over the next three decades until the onset of the millennium drought in 2001 and the Wambelong fire of 2013. We can also make the more general observation that koalas are animals of importance for Park managers and the Park visitors, and thus gain a mention in an administrative history that is otherwise not concerned with fauna or ecological matters.

Alan Morris

Recollections by Alan Morris AM of koalas in Warrumbungle NP 1964-83 were conveyed by Alan in an email exchange with DL between April and June 2019, and only very lightly edited here for publication.

> In my role as Wildlife Officer with the Fauna Protection Panel 1964-1968, then with the NPWS 1968-1974, I was regularly in the Warrumbungles as Allen Strom, Chief Guardian of the Fauna Panel, was a Trustee of the WNP and I sometimes visited with him, and at other times visited the Park as Field Officer to discuss Koala Management and other issues as the Park was a 'Wildlife Refuge' and the Fauna Protection Panel could spend money there, in particular on koala management.
>
> When I first joined, and the Park was only about 8000 acres, 3000 ha, few koalas were seen, and sheep grazed across much of the land that is in the park these days. The koalas seen were suffering from Chlamydia, supposedly carried by sheep? [We note the contrast with other statements saying the population was healthy, but we cannot resolve the matter, just record it. We also note that Alan Morris was familiar with this disease.] So the Trust, with the Fauna Panel's financial support, constructed an area near Camp Pincham with a koala-proofed fence and established a plantation of 'Koala food Trees', eucalypts known to be koala food trees, but not necessarily local to the area, including Manna Gums! Once the trees were high enough, a number of koalas (maybe 4), from elsewhere (but I don't remember where), were released there with the intention of release into the Park.
>
> I can recall camping one night in my car, pre 1970, at Camp Pincham, which was at the very [southern] edge of the boundary of the Park, and a shooter was shooting the roos that were coming in onto the property to eat the new wheat on 'Strathmore', that at the time was still private property. By the time I moved to Coonabarabran. 'Strathmore' was part of the Park, and the old homestead had been made into a prison farm, where the prisoners were used to construct the Grand High Tops Walking Trail!

At that time, i.e. pre-1970, I did not see koalas in the Park, there in the wild. The koalas were thought of as 'rare' pre 1970. I only have vague recollections of the pre 1970 era, so cannot recall anything about koalas on the adjoining private property. I do remember the problem with the koalas and Chlamydia and I can picture one being cared for re Chlamydia, before joining the Fauna Protection Panel in August 1964, I knew nothing about it. But within a few months, it had become a hot topic in my life as the koalas at Sir Edward Hallstrom Reserve at Cowan, possibly the ones at the Sea-Acres Wildlife Life Refuge at Port Macquarie, and some out at the Warrumbungles as per the comments of Allen Strom at the time, would appeared to have been afflicted! I remember it being an issue! I would have been relying on the comments of others, but I did go to Cowan on a number of occasions in those days and I would have been shown the symptoms (a Macquarie Uni research activity?).

By 1975, once I came to live at Coonabarabran, and the NPWS had resumed and or purchased most of the hill country east of Tooraweenah, such as Guneemaroo, and removed domestic stock, and doubled the Park size, koalas were then easy to see. Koalas were particularly common around the Lookout as you first entered the Park from the east; in the Wambelong area; the grand High Tops walk; and Burbie Canyon. The koala proof fence had been removed by then because koalas were then considered to be much more common.

During the period 1975-1983, there were virtually no wildfires in the Park, only one along the boundary with the 'Strickland' Property on the western boundary... although there may have been some small lightning strikes. However, there were some big fires in the Pilliga particularly in 1978, 1981, so there was no need to take any action to manage the koalas in the Park. (When I moved to Sydney in 1983, I was followed by John Gerritsen (for two years), then Rod Holmes and then Greg Croft.)

During my time at Coonabarabran, I remember that koalas were regularly seen in the Pilliga, particularly Pilliga West SF & Merriwindi SF, west of Baradine and Kennebri, where they could be found feeding in Pilliga box and ironbark country. Koalas were also seen along Terridgerie Creek and around Terridgerie Lagoon feeding in red gum and Pilliga box, and that was the case through the 1980s and 1990s as well.

I would have described the population of koalas in Warrumbungle NP and the Pilliga in my time 1975-1983 as 'moderately common', and if I was taking some visitors out to the Warrumbungles for the day during that time, we would expect to see at least one koala to show them. It was not uncommon to see a koala round Terridgerie Lagoon when bird watching.

The Coonabarabran District was established by the NPWS in 1975 and I was the first Senior Ranger 1975-1983. The District included the LGAs of Wellington, Coonabarabran, Coolah, Dubbo, Narromine, Warren and Nyngan, and included the Macquarie Marshes NR, Wongarbon NR, Quanda NR, Binnaway NR, Warrumbungle NP and Pilliga NR. Initially it included Narrabri (Mt Kaputar NP) and Cobar (some Crown lands near Gundabooka), but in due course Cobar and Narrabri got their own Senior Ranger (Bob Moffatt).

Initially I had no direct management role in the Warrumbungle NP as it was still under the control of the Trust, as the Chairperson of the Trust was Mr Quinton, who was also the campaign manager for Jack Renshaw, the local member of Parliament for Castlereagh, and he was NSW State Treasurer, and eventually Premier, and Mr Quinton did not want to give up his control of the Park! The WNP Trust was the last one to go in about 1978. Nevertheless, I was involved in various activities in the Park, and so regularly visited in both private and public activities. Dick Duggan was the senior of the two rangers employed by the Trust, and later became Senior Ranger for the District when the Trust was dissolved and I was the District Manager.

Land use

The cropping, clearing and thinning in the district, as described here, is based on Australian Bureau of Statistics reports, presented as the percentage of the reporting district with sown crops (including grasses) in a given year. Fallow and ploughed but unplanted areas were generally not included. Reporting districts were either counties or LGAs. Ringbarking was recorded, as well as additions to area under crops for some time periods and areas preparation for cultivation. From the regular 5-yearly updates, we selected the year 1920, as it is typical of the use of the land in the decades before the Park was established (Fig. 11). It is apparent from this figure that the land was intensively used for agriculture, and that clearing was widespread. What is not apparent is what parts of the landscape were not used, though it may reasonably be inferred that the more fertile, better watered lands were the first to be used and were the most intensively used, which is the land most preferred by koalas. However, we note that in many parts of the Warrumbungles, the ridges - in contrast to

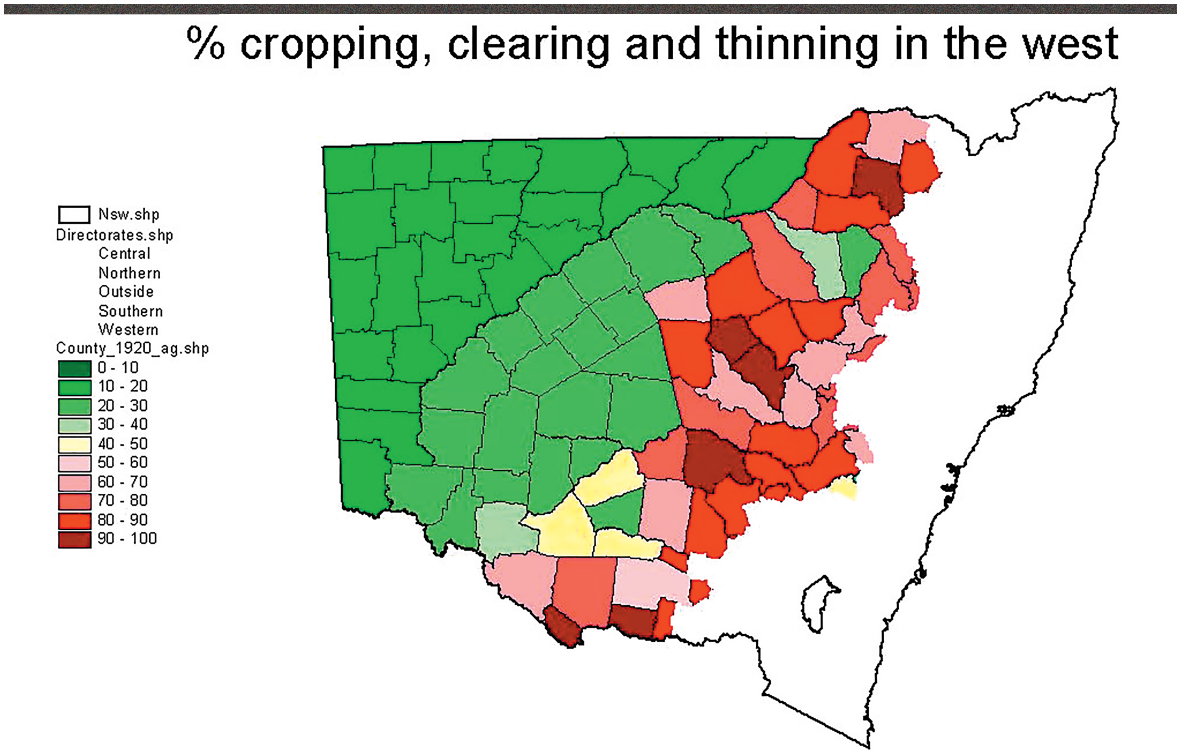

Figure 11. Cropping, clearing and thinning in the west is based on Australian Bureau of Statistics reports for the year 1920. The map shows that the region was largely cleared and used well before Warrumbungle National Park was dedicated.

ridges elsewhere - are relatively fertile volcanic soils. Given observations of koalas on ridgetops could this mean that koalas were persisting in the more rugged, less visited country of the Park.

During the 1890s, and the first years of the 20th century, a serious threat for koalas was the fur trade in NSW (Lunney and Leary 1988; Lunney et al. 2016, the latter paper includes details of the trade in koala skins in the Sydney markets). There is local evidence that the NSW trade in marsupial skins had local agents (Lunney in litt.). Given the close proximity of remaining koala habitat even today to local towns and settlements, it is a reasonable assumption that the local koala population of the land that became the Park and surrounds was subject to shooting for skins as a supplement to local incomes. This would have been especially the case given the economic depression of the 1890s.

DISCUSSION

The primary aim of this study was to assess the koala population of Warrumbungle National Park in the context of an ecological interpretation of the history of use and management of Park and surrounding area. The 'ferocious' Wambelong fire of January 2013 remains vivid for anyone who was there at the time and its impact was severe, affecting about 90% of the Park, as well as much of the neighbouring land. Immediately after the fire a few koalas were seen, but over the next six months of searching, not a single one was seen, and none seen in the subsequent seven years. This means that not only has the Park's koala population disappeared as a consequence of the cumulative effects of the fire and drought, but so has the population in the surrounding burnt private land, arguably to very low numbers given that no koalas have moved into the Park from nearby properties in the seven years to the time of writing this paper. The impact of was apparently on the koala population itself, not that the post-fire habitat was unsuitable, as shown by the persistence of the koala released into the Park in 2014 into burnt habitat, and previous studies on koalas post-fire (Lunney et al. 2004; 2007; Matthews et al. 2007, 2016). More significant was the major regional decline in the koala population due to the drought.

The 2014-15 regional citizen science survey showed that koalas were present in and near

Warrumbungle National Park both before and after the 2013 fire, but that throughout the region, koalas declined over the 2006 – 2014-15 period. This confirms that, before 2013, koala populations were shrinking in and around the Park, as well as in the wider region. Thus a broad-scale environmental change was underway, most obviously from the extraordinarily dry conditions.

Between 1970 and 1995, koalas in the Park increased from uncommon to common, as in our study of the koala population of the Pilliga forests (Lunney et al. 2017). The koala in 1995 was a common sight in the Park, and remained so until 2001, when the Millennium drought hit. Just before the fire in January 2013, koalas had already dwindled to rare. Although these are qualitative records, there being no other estimates, we nonetheless have a clear picture of a koala population that was still present, but at a low ebb just before the fire.

An appreciation of the land-use changes, particularly those relevant to koalas, enables us to see the impact of the fire in perspective and, although evident, that it is much less significant than the pre-existing decline due to the drought. A pivotal point is the relatively recent dedication of a national park in the Warrumbungle Ranges. At the time of the initial dedication of the Park in 1953, there was little koala habitat and, at best, a very low-density koala population in and around what became the Park. By 1995, when Sue Brookhouse was taking koala walks in the park, koalas had become common. When more than a century of change is considered, it can be seen that the 1995-2001 period, when the koala was a familiar sight, was unusual. There are just enough reports to sketch a history of change, beginning with the record of koalas from the late 19th century.

There are several striking features of the record of the koala populations in and around Warrumbungle National Park until 1970. Until the dedication of the first parcel of land as a national park in 1953, most of what would have been the best koala habitat when the first Europeans and their stock arrived, namely the richer soils especially of the lower slopes selected for grazing and near water, became cleared land. The area of Warrumbungle National Park that held a koala population in the decades before the 2013 fire must have been, by and large, regrowth forest on land that had been cleared, and grazed by stock and rabbits. The early debate over bringing koalas into the Park, planting native trees of a non-local species for an intended batch of immigrant koalas, and the view that koalas did not exist in the Park in its early years, is consistent with a population that had been through severe climate conditions with the Federation drought and subsequent droughts (rainfall figure in the Pilliga paper, Lunney et al. 2017) and with a scarcity of suitable koala habitat.

Whether there was sufficient habitat to support a koala population on the land that is now the Warrumbungle National Park is not known. There are no records. However, given that red gums (various species) are commonly found on the soil types of the river flats of the Park, and that these are preferred koala feed trees, it seems likely that the area of possible, or previous, koala habitat remaining ungrazed or uncleared would have been small, whereas the richer, better watered land, the land preferentially selected by koalas, would have been commercially grazed. However, it also seems that at least some koala habitat remained on hilly country and this offers an argument for the persistence of a low density population in the more rugged, uncleared areas.,

Our research in the nearby Pilliga forests (Lunney et al. 2017), as well as our regional citizen science survey (Predavec et al. 2018), indicate that these fluctuations were not confined to the Park: a major contemporaneous decline occurred regionally. The fire occurred when the koala population was already at a low point. Recovery of the Park's population is thus also likely to be limited by the continued small regional populations. These findings show that the koala population of the Park does not exist in isolation, and that a regional approach to koala ecology and management planning is needed.

Surveys for koalas were not undertaken before 1986, and as Reed et al. (1990) record, their 1986-87 survey was the first comprehensive koala survey in NSW, and there was very little background information on which it could draw. The detection of koalas within a decade of the National Park being dedicated in 1953 gives a clue that there was a small resident koala population, and that by 1970, with stock gone from the area, and no doubt the vegetation regrowing, and many additions to the area of the Park, the pre-conditions were set for the koala population to increase as the habitat, especially the preferred koala trees, regrew. We know from the work of Ellis et al. (2017) and Rhind et al. (2018), further north along the Oxley highway, that koalas use regrowth trees as young as 10 years old, although tree choice is complex, with climate and season dictating tree choice in this region (Crowther et al. 2014; Dargan et al. 2019). Consequently, we can now examine the more recent information on the koala population against the background of a habitat that was increasing in size and quality, a park that was growing in size, and a national park with the objective of the protection of fauna with a minimum of threats.

Underlying related questions are to ask about the possible paths to recovery, and identify what constitutes a refuge koala population. A direct study on the impact of fire on a koala population from the coast at Port Stephens (Lunney et al. 2004; 2007; Matthews et al. 2007; 2016) found that koalas returned to the severely burnt forest within three months, and were breeding in the burnt areas one year after the fire. The source was the immediately adjacent unburnt forest, as in the study by Ellis et al. (2017) on the rate of return of koalas to regrowth and plantings on farmland nearer Gunnedah, i.e. the closer the source of colonising animals, the quicker the recovery. Similarly, the fire reported in Curtin et al. (2002) identified the valley was unburnt and served as the refuge from which the koalas could return. Thus, a key to a speedy recovery is the proximity of a source populations. This points to the value of repeating the citizen science survey effort in and around the Park to reveal the current status of the regional populations. On the Iluka Peninsula, on the north coast of NSW, a koala population plunged to extinction, with one of the causes being the loss of the koala population from fire in the nearby national park that was a crucial source of immigrants to the Iluka Peninsula, which itself had not been burnt (Lunney et al. 2002). Although the contrast among these populations across NSW is stark, some general points can be identified. Firstly, the proximity of the koala population adjacent to the burnt area matters. It is also reasonable to assume that the larger the population, the more rapid will be the recovery. Secondly, the concurrent impact of other factors is important, such as predation by dogs in Port Stephens and drought in Warrumbungle National Park. Fire on its own, provided source populations exist close-by, does not cause extinction of koalas. Thirdly, land use history provides insights into the potential causes of population changes. At Iluka and Port Stephens, beach sand mining after WW II caused a major loss of vegetation that was koala habitat, whereas in and around Warrumbungle National Park, land clearing, cropping and grazing changed the landscape dramatically following European colonisation up until the Park was dedicated in 1953. Collectively, these various examples speak to the point that the best koala habitat is also favoured by people, and that retained habitat, such as formally protected areas, and conservation agreements with private landholders, as well as rehabilitated habitat on good soils on reserved or private land, are major ways to conserve koalas. Identifying these locations when the regional populations are low would help identify long-term refuge sites.

The ecological history of the koala population in and around the Park also provides insights into the question of what is a koala population, can it be defined by tenure boundaries and does the history allow a more enlightened interpretation of how to manage such an important koala population as the one in Warrumbungle National Park. Some answers are clear: Warrumbungle NP is too small to conserve a koala population. The nearest major refuge is the Pilliga forest, but even there the koala population has declined markedly over the two decades from the mid-1990s (Lunney et al. 2017). Whereas 10-20 years ago both Warrumbungle NP and the Pilliga forests would have appeared to be substantial koala refuges, by 2019 in the face of prolonged and severe drought, this was no longer so. The pervasive effect of drought is critical. For Warrumbungle NP, the fire compounded the impact of the drought, and has shown that the Park is too small to be a long-term refuge. The impact of this fire supports the conclusion in Predavec et al. (2018) that scale matters. To conserve koalas, private land managed for tree retention is critical to allow koalas to re-inhabit the Park. Given that the post-fire habitat in Warrumbungle NP can support koalas, it can be expected that, with time, koalas will return to the Park. We do not yet have enough information to predict when, but given the low local population, it may be a while. Additional local survey and research would provide critical evidence of the enduring drought and fire impacts. Such study would need to include visitor records, community survey, as well as standard and new scientific survey and study techniques both in and beyond the Park. We argue that research be prioritised and complemented by other methods. We have provided in this paper tantalising glimpses of what may have been. Yet for some aspects we still remain uncertain. Consequently, we stress the importance of well-designed ecological studies would be highly appropriate to investigate these matters.

The current (2019) apparent absence of koalas from the Park, and very low numbers in the region, is the nadir of the regional koala population. What happens next represents a crucial phase in the status and potential recovery of this population. Given the widespread decline of koalas caused by drought, it will be critical to the conservation of koalas to minimise other threats, such as land clearing of prime habitat, logging of preferred food trees, and minimising mortality from other sources.

We also observe that National Parks are not enough for koala conservation, indeed they are not even the key for koala conservation. In the time of drought, and extensive fires, what we can do is concentrate not

only on the other threats, but recognise the central importance of private land for koala conservation. Again, we press the point that the conservation and management of koala populations is contingent on a sustained ecological research program, including novel approaches, such as ecological history as demonstrated in our study of the koala population of Warrumbungle National Park.

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