koala conservation status in new south wales

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A review of the conservation status of New South Wales populations of the Koala (Phascolarctos cinereus) leading up to and including part of the 2019/20 fire event.

A report prepared for the International Fund for Animal Welfare (IFAW).

1. EXECUTIVE SUMMARY

This report sets out to objectively quantify the impacts of recent fire events on New South Wales (NSW) koala populations during the Spring and early Summer of 2019, in the context of broader population trends across NSW. Our baseline estimate for the number of koalas in NSW was reliant upon recently published studies which used a process of expert elicitation to derive population estimates for relevant Interim Biogeographic Regionalisation of Australia (IBRA) areas within NSW. However, instead of a focus on numbers *per se*, the review focuses on estimated proportional changes brought about by the fire events, while also giving consideration to changes over preceding generations, in order to place the results in the appropriate International Union for the Conservation of Nature (IUCN) / legislative context.

Population increase, decrease or stability within each bioregion was initially assessed via interrogation of BioNet records and published reports. The location of previously identified Areas of Regional Koala Significance (ARKS) were further considered as a guide to the location of the majority of known koala source populations, which we then considered further by examining survey work across both ARKS and non-ARKS. This initial process identified what appears to be the functional extinction of koalas from the 'Murray-Darling Depression' and 'Mulga Lands' bioregions, as well as substantive declines from the 'South East Corner', 'Brigalow Belt South & Nandewar' and 'Cobar Peneplain & Riverina' bioregions. The estimated proportional decline of the NSW koala population over the preceding three koala generations, but prior to the 2019 fire events, was thus conservatively estimated as a pre-existing 19.82% reduction in population size.

Following on from the above, spatial data on the geographic extent of fire grounds burnt over a ten-week period from October 1st – December 10th 2019 were intersected with bioregion and ARKS boundaries. Given the intensity of the majority of the 2019 fire events thus far, we applied what we consider to be a conservative mortality estimate of 70%, based partly on information from individuals surveying some of the 2019 fire grounds, all of whom reported extreme intensity crown fires.

Seven combined bioregions, namely 'NSW North Coast & South East Queensland', 'Sydney Basin', 'New England Tablelands', 'South East Highlands', 'South East Corner', 'Brigalow Belt & Nandewar' and 'NSW Southwestern Slopes' were impacted by fires up to and including the

10th December 2019, with the combined 'NSW North Coast & South East Queensland' bioregions collectively having 28.88% of their entire land surface burnt. Applying a deductive approach qualified by uncertainty regarding the extent of variation in carrying capacity across individual ARKS, we estimate the 2019 fire events as removing a further 9.46% of the remaining NSW koala population, accounting for previous losses (this equates to 8.70% of the initial population estimate). Communicating this latter outcome in terms of koala numbers, if the estimated numbers of koalas occurring in NSW are correct, it implies that nearly 4,000 koalas across NSW were killed by fires between September and mid-December, 2019.

We consider that our calculations on the matter of population change and the impacts of the initial half of the 2019/20 fire season to be conservative and should thus be considered as a minimum effect, from which a maximum bound can be calculated. To inform this upper limit of uncertainty, we utilized knowledge that several mapped ARKS were data deficient, meaning that it was not possible to make reliable estimates of population trends in these areas. If as a worst-case scenario these ARKS are no longer functional in terms of supporting resident koala populations, this has the potential to increase overall population decline that has taken place by as much as an additional 37.43%. Based on this consideration, we conclude that the NSW koala population has declined by at least 28.52% (lower bound) to as high as 65.95% (upper bound) over the three most recent koala generations, inclusive of the impacts of the fire events up until mid-December, 2019. Importantly, this conclusion does not take into account fire events since the 10th December 2019, some of which are known to have impacted on additional ARKS not taken into account for this report; hence the lower bound will be greater than what we have been able to estimate.

In addition to population loss and consequent range contraction in western parts of the koala's range in NSW, and the impacts arising from the 2019/20 fire season, not yet taken into account are the many hundreds of thousands of hectares of otherwise unburnt koala habitat that have additionally been rendered unsuitable for koalas through water-stress leading to leaf-browning and loss of preferred browse species. The factors driving these dire circumstances for koalas are ongoing; hence any prognosis regarding the future conservation status of the species must adopt a precautionary approach. For these reasons, we consider a measure towards the upper bound of our conservative estimates as the more likely current circumstance for koala populations across NSW such that the species readily

qualifies as endangered, the implications of which in the context of the two key threatening processes that will continue to operate – the progressive impacts of Anthropogenic Climate Change and the High Frequency Fire, are ongoing; this certainty, coupled with the species low reproductive output and a requirement for long inter-fire intervals to facilitate recovery, implies that the risk of extinction is both immediate and significant, thus presenting serious challenges for longer-term survival of koalas in the forests and woodlands of NSW.

2. INTRODUCTION

This report has been prepared on behalf of the International Fund for Animal Welfare (IFAW).

Koalas have experienced declines over large areas of their range even before the effects of the current 2019/20 fire season have been taken into account. Amongst other things, survey work from 107 field sites systematically distributed across southern parts of the Pilliga Scrub, the Warrumbungles National Park and northern parts of Gilgandra Shire in central western NSW during the first half of 2019 informed a conclusion that the Pilliga koalas, which formerly comprised what had been considered the largest population west of the Great Dividing Range in NSW (Paull and Date 1999, Kavanagh and Barrott 2001, DEC 2008), were likely to have become functionally extinct (Koala Likelihood Model (KLM) survey program results - OEH, unpublished data). This followed earlier work by Lunney *et al.* (2017) based on field assessments undertaken in 2014 that koalas in this area had declined by approximately 79% when compared to knowledge collected over the preceding two decades.

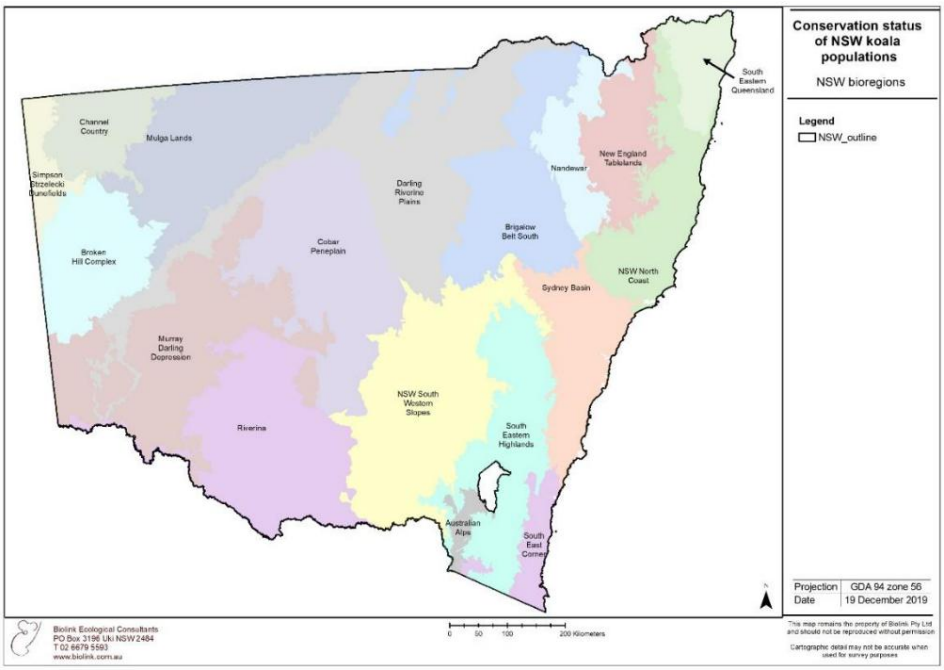
The latter quarter of 2019 has seen a series of unprecedented fire events across NSW, some of which have impacted known Areas of Regional Koala Significance (ARKS) as identified by Rennison and Fisher (2018). Given these considerations and amidst widespread community and scientific concern about the impacts of the fire events on koalas, it was considered timely that a review of the conservation status of koalas across NSW be undertaken.

3. DESCRIPTION OF THE NSW POPULATION

Current distribution

Koalas have historically been distributed along the entire latitudinal gradient of NSW and recorded as far west as Coona Coona Lake in the Mulga Lands (75 km east of Mutawintji National Park), though their density is higher in the eastern portion of the State (Figure 1). One output from the NSW Government's Saving our Species (SoS) Iconic Koala initiative has been the development of a regional koala framework (Rennison and Fisher 2018), the intent of which was to identify regionally significant koala populations using a combination of historical records analyses, underpinned by expert knowledge / opinion. A total of 48 ARKS were identified across NSW, the smallest being Hawks Nest in the Mid-coast of NSW (2,548 ha) and the largest focused around Bungonia in the South East Highlands (354,167 ha).

Approximately 5% of NSW is within an ARKS and these areas are consequently considered to be the current best estimate for the location of the majority of koala source populations.



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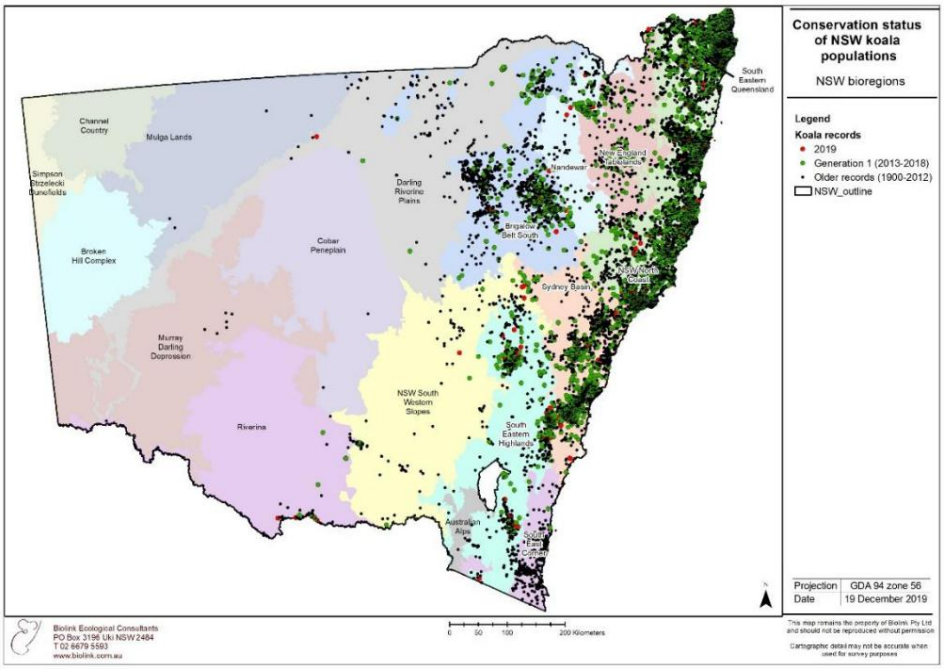

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Figure 1. **(A)** Interim Biogeographic Regionalisation for Australia (IBRA) regions across NSW and **(B)** the distribution of BioNet koala records within 18 IBRA regions, with records from 2019 and the most recent koala generation (2013 - 2018) identified in red and green respectively.

Size of NSW koala population

Adams-Hosking *et al*. (2016) provided population size estimates for Interim Biogeographic Regionalisation for Australia (IBRA) areas in NSW using a process of expert elicitation carried out in 2012. Expert knowledge is regularly utilized to inform listing decisions under the IUCN Red List criteria (McBride *et al.* 2012). The outcomes reported by Adams-Hosking *et al.* (2016) implied that the greater proportion (approximately 53.65%) of the estimated NSW koala population collectively occurred within the NSW North Coast, South Brigalow & Nandewar bioregions, with the South East Queensland bioregion not specifically accounted for. In 2019 Rennison & Fisher reviewed the population estimates for each of the bioregions and suggested that 65.07% of the koala population resides within the NSW North Coast, South East Queensland and South Brigalow & Nandewar bioregions (Table 1). We have used the revised 2019 Rennison & Fisher estimates for this report, which for the most part replicate Adams-Hosking *et al*. (2016), but with the addition of the South East Queensland bioregion estimate. While the population estimates themselves provide for some reflection, they can also be misleading. To this end and instead of a reliance on numbers, we opted to consider the **proportion** of the NSW population within each of the bioregions as the more relevant measure of koala population distribution and abundance.

Table 1. Population estimates of koalas in NSW as of 2012, based on expert elicitation (from Adams Hosking *et al.* 2016 updated by Rennison & Fisher in 2019).

NSW IBRA areas	Mean population estimate	% NSW population
Murray-Darling Depression	55	0.10
South East Corner	2,768	5.10
Cobar Peneplain & Riverina	2,354	5.34
Darling-Riverine Plains	964	1.78
Mulga Lands	711	1.31
New England Tableland	2,771	5.10
NSW North Coast and South East Queensland	24,188	44.59
NSW Southern-western Slopes	2,310	4.25
Brigalow Belt South & Nandewar	11,133	20.51
South Eastern Highlands	1,363	2.51
Sydney Basin	5,667	10.44
NSW	**54,284**	**100**

* Note: the combined NSW North Coast and South East Queensland bioregion estimate was added to Adams-Hosking *et al*. (2016) by Rennison & Fisher (2019).

A brief summary of reporting trends in the NSW IBRA areas, with specific reference to the ARKS of Rennison and Fisher (2018, revised 2019), are as follows:

Murray-Darling Depression

Estimated by Rennison & Fisher (2019) to contain 0.10% of the NSW koala population. A review of available BioNet data for this bioregion reveals seven records, six of which relate to the town of Ivanhoe from 1978 and 1979, with no further records since. There is a single record dated 2004 from the Murray River between Kyalite and Swan Hill which is the last dated record for this bioregion. There are no mapped ARKS.

South-East Corner

Estimated by Rennison & Fisher (2019) to contain 5.10% of the NSW population. A review of available BioNet data for this bioregion reveals 978 records, the majority of which are located in the area between Bermagui and Tathra. There are five records from the most recent koala generation within this bioregion. The South-East Corner bioregion supports two ARKS: Nullica and Murrah.

Cobar Peneplain & Riverina

a) *Cobar Peneplain*

Collectively estimated in combination with the Riverina by Rennison & Fisher (2019) to contain 5.34% of the NSW population. A review of available BioNet data for the Cobar Peneplain component reveals three widely dispersed records covering the time period 1991 – 2004, beyond which there have been no further records. The last confirmed record of a koala was in 2004 from the vicinity of Rankins Springs.

b) *Riverina*

A review of available BioNet data for the NSW section of the Riverina reveals 110 records centered on the localities of, Jerilderie and between Tocumwal and Deniliquin along the Murray River. Records for the most recent koala generation are evident in each of these areas. The Riverina bioregion supports two ARKS: Murray Valley and a portion of the Narrandera ARKS, otherwise situated in the NSW South Western slopes bioregion.

Darling – Riverine Plains

Collectively estimated by Rennison & Fisher (2019) to contain 1.78% of the NSW population. A review of publicly available BioNet data for this bioregion reveals 112 sparsely distributed records dating from 1900 – 2019; records are centered on the area from Lightning Ridge to the western boundary of the Pilliga, though this part of the bioregion does not contain any

records for the most recent koala generation, with the most recent record for this area being from 2007.There are no mapped ARKS.

Mulga Lands

Estimated by Rennison & Fisher (2019) to contain 1.31% of the NSW population. A review of publicly available BioNet data for this bioregion reveals eight widely distributed records across the south-eastern half of the bioregion between White Cliffs and the NSW-Queensland border over the time period 1958 – 1995 which was the last reported record. There are no mapped ARKS.

New England Tableland

Estimated by Rennison & Fisher (2019) to contain 5.10% of the NSW population. A review of publicly available BioNet data for this bioregion reveals 942 records for NSW, with the highest concentration in the Armidale area. The most recent records are two sightings thus far in 2019, both south-west of Armidale, and 17 widely dispersed records from 2018. The New England Tableland bioregion supports two ARKS: Armidale and Severn River NR, in addition to the majority of the Nowendoc ARKS and approximately one third of the Gibraltar Range ARKS.

NSW North Coast and South East Queensland

a) *NSW North Coast*

Estimated by Rennison & Fisher (2019) to contain 15.41% of the NSW population. A review of available BioNet data for this bioregion reveals 34,679 records spanning the bioregion almost in its entirety but with the highest concentration of records located in the areas around Port Macquarie, Hawks Nest, Port Stephens and Coffs Harbour. Records from the most recent koala generation (2013 – 2018) are apparent in all these areas and across the bioregion as a whole.

b) *South East Queensland*

Estimated by Rennison & Fisher (2019) to contain 29.02% of the NSW population. A review of publicly available BioNet data for the NSW portion of the South East Queensland bioregion reveals 15,490 records from 1900 – 2019. Records are distributed across the bioregion, occurring in highest concentration from Tweed Heads to Evans Heads, near Illuka and Grafton.

The NSW North Coast and South East Queensland bioregions collectively support 29 ARKS. NSW North Coast bioregion (19 ARKS): Port Stephens, Girard-Ewingar, Gibraltar Range, Clouds Creek, Coffs Harbour-North Bellingen, North Macleay-Nambucca, Belmore River, Comboyne, Port Macquarie, Wilson River, Barrington, Nowendoc, Crowdy Bay, Hawks Nest, Karuah-Myall Lakes, Khappinghat, Kiwarrak, Wallingat NP, Wang Wuak SF; South East Queensland bioregion (10 ARKS): Southern Clarence, North Grafton, Banyabba, Mt Pikapene, Woodenbong, Broadwater, Far north-east Hinterland, Tweed Coast, Tweed Ranges, Far north-east.

NSW South Western slopes

Estimated by Rennison & Fisher (2019) to contain 4.26% of the NSW population. A review of publicly available BioNet data for this bioregion reveals 301 records spanning the period 1910 – 2019. Records are for the most part sparsely distributed across the bioregion, with a concentration of records from Narrandera, Wagga Wagga, Mudgee and Parkes. There are no records for the most recent koala generation (2013 – 2018) for the areas around Wagga Wagga or Parkes. The NSW South Western slopes have only a single ARK, Narrandara, of which > 80% is located within this bioregion.

South Brigalow & Nandewar

Collectively estimated by Rennison & Fisher (2019) to contain 20.51% of the NSW population.

a) South Brigalow belt

A review of publicly available BioNet data for this bioregion reveals 2,768 records for NSW, spanning the period from 1900 to the present. These records are highly concentrated in the Pilliga region, Warrumbungles National Park, Moree and Gunnedah. There have been no records for the most recent koala generation (2013 – 2018) from the western Pilliga or the Warrumbungles, none for entire Piliga region since 2014 (the closest are two from 2016 in Baradine) and no records from Warrumbungles since 2012. Current records exist (2018 / 2019) for both Gunnedah and Moree.

b) Nandewar

A review of publicly available BioNet data for this bioregion reveals 334 records from NSW. These records span the period 1949 – 2019 and are sparsely distributed across the bioregion, with an area of concentration near Inverell which comprises one third of the records; this includes two records from 2018.

The South Brigalow belt and Nandewar bioregions combined support six ARKS. South Brigalow belt (four ARKS): Gunnedah, Pilliga, Killarney and Moree. Nandewar (two ARKS): Inverell and Kwiambal.

Southeastern Highlands

Estimated by Rennison & Fisher (2019) to contain 2.51% of the NSW population. A review of publicly available BioNet data for this bioregion reveals 2,214 records over the time period 1900 to 2019, distributed widely with concentrations of sightings near Bathurst, Numeralla and Bungonia. There have been no records for the most recent koala generation from that portion of the bioregion west of Canberra, including the areas around Jindabyne, or to the east near Nimmitabel. The Southeastern Highlands supports two ARKS in entirety - Numeralla and Queen Charlottes Creek, in addition to approximately 13% of the Bungonia ARKS.

Sydney Basin

Estimated by Rennison & Fisher (2019) to contain 10.44% of the NSW population. A review of publicly available BioNet data for this bioregion reveals 10,711 records from 1900 to 2019. There have been no records for the most recent koala generation (2013 – 2018) for the areas around Denham and Wollemi National Park as well as several areas along the coastline, notably in the vicinity of Mona Vale and from Royal National Park south to Austinmere. The Sydney Basin supports four ARKS in entirety; Blaxland, Brisbane Water NP, Lower Hunter and Wollemi NP, in addition to 87% of Bungonia ARKS and 17% of Port Stephens ARKS.

4. INFORMING CHANGES TO POPULATION ESTIMATES

To inform on potential changes to current population estimates, we focused primarily on changes that have occurred within the most recent koala generation (2013 – 2018) and especially the impacts of the recent fire events from October – December of 2019. In a

legislative context, a decrease in population size over a preceding three generational timeframe is considered to be of relevance when assessing the threatened status of a species, ergo we extended our timeframe of interest more broadly to the period of 2001 – 2018 when examining relevant scientific reports, in order to assess the potential for changes to population size within this critical time period.

To assess potential population increase, decrease or stability we devised and then followed the decision pathway outlined in Figure 2 and considered changes at the bioregion level, while using the location of the defined ARKS as a guide to where the majority of koala populations were located. In brief, we first searched the records database (BioNet) for areas (both bioregions and ARKS) which lacked records for 2019 and the most recent koala generation (2013 – 2018). We then incorporated information from available scientific reports that contained results of koala survey and / or Area of Occupancy (AoO) estimates. After accounting for pre-existing population declines using these methods, we then assessed impacts arising from the 2019 fire events. Finally, we recognized the potential for population declines in areas for which very little or no data was available. In this way, the bioregions and each of their component ARKS were assessed for potential population changes.

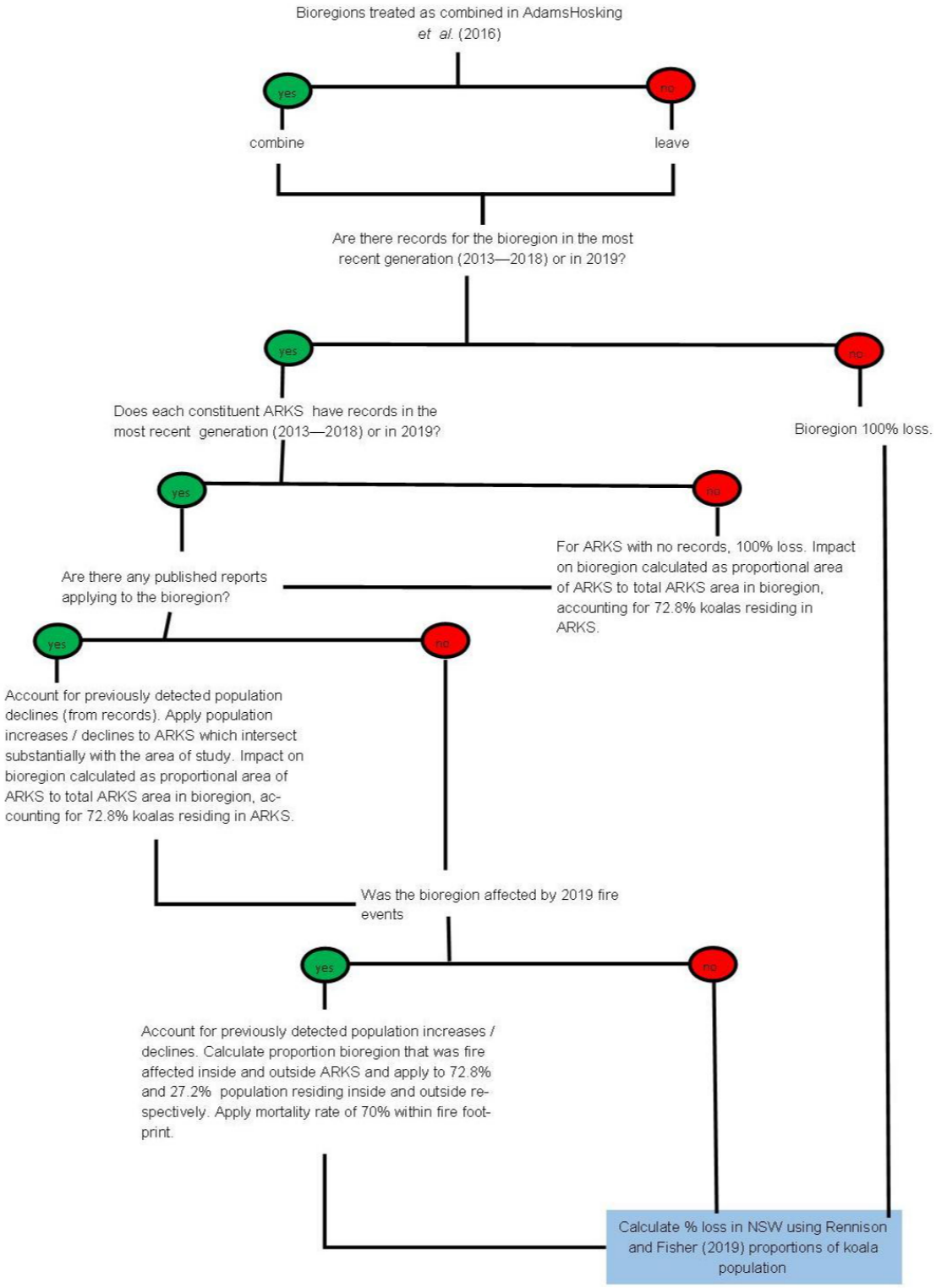

Figure 2. Pathway for assessing changes to population estimates

Bionet Records and Published Reports

Methods – Bionet records

Of the 68,659 koala records for NSW in Bionet, 93.06% (*n* = 63,894) occur within an ARKS boundary as defined by Rennison and Fisher (2018). Due to inherent issues in relying on records to determine the location of populations and in order to inform an estimate of the proportion of koalas actually residing within ARKS, we examined independently derived koala survey data from Port Macquarie – Hastings Local Government Area (LGA) (Biolink 2013). In brief and for purposes of the Biolink (2013) survey, a regularized grid of 350 survey points ≥ 1 km apart, were positioned across vegetated parts of the LGA. Two hundred and ninety-seven (297) of these fell within a defined ARKS and 53 did not. The percentage of those survey locations which evidenced koala activity was 25.25% of survey points within ARKS and 9.43% of survey points outside of ARKS. This leads to an estimate of 72.8% of koalas residing within defined ARKS, a figure which, in the absence of other data sets which could be similarly utilized, we then generally extrapolated throughout NSW for the purpose of this report. Using this approach, potential population loss could then be estimated by considering those ARKS within the bioregion for which there are no koala records for the most recent koala generation. Because records and associated reporting rates are typically known to increase over time, we determined that the absence of records for an entire koala generation would indicate that they no longer persist in that ARKS. The proportional area of a defined ARKS lacking recent records was then considered in relation to the total ARKS area within the bioregion, in combination with the aforementioned estimate of 72.8% of koalas residing within ARKS. By way of example, if an ARKS which lacked recent records accounts for 50% of the total ARKS area within a bioregion, then the calculation of decline is 0.5 x 0.728.

Methods – available reports

Available reports which incorporated koala survey data and / or included estimates of population increase, decline or stability over the preceding three koala generations (2001 – 2018) were used to further inform bioregion level population changes. Calculations were contextualised by geographic location such that changes inside individual ARKS were considered in terms of each ARKS proportional area in relation to all ARKS in the bioregion. The reported percentage decline e.g. from contraction in the Area of Occupancy (AoO) was calculated accounting for an estimate of 72.8% of koalas residing within ARKS. Reports infrequently examine population trends across ARKS specifically, but if they are inclusive of

an ARKS, or a substantial portion of it, then we extrapolated the results of the report to the ARKS itself.

Results

There are three bioregions in NSW which do not contain ARKS but do have proportional koala population estimates (as per Adams-Hosking *et al.* 2016, Rennison and Fisher 2019). The Darling-Riverine Plains has koala records for the most recent koala generation; however, the Murray-Darling Depression has had no records since 2004 and the Mulga Lands have not had a record since 1995. Given the dearth of records we deemed the latter two bioregions to no longer be supporting extant koala populations.

There are 11 bioregions in NSW that contain ARKS. Of these 11 bioregions we combined;

1. Brigalow Belt South and Nandewar
2. NSW North Coast and South East Queensland
3. Cobar Peneplain and Riverina

This was done for consistency with previous population estimates (Adams-Hosking *et al*. 2016).

Records analysis highlighted that five ARKS within bioregions did not have any records for 2019 or the most recent koala generation (2013-2018). Indeed, there were no instances in which there were no records from the most recent koala generation ending 2018, but there was a 2019 record. For this reason, we will refer only to the most recent koala generation and we conclude from this that it is unlikely that populations persist in these localities in order to calculate decline.

An outline of results by bioregion follows, inclusive of findings from available reports.

Brigalow Belt South and Nandewar

The last record of a koala in the Killarney ARKS occurred in 2002, hence there are no records for the most recent koala generation. The Killarney ARKS represents 2.58% of the total ARKS area within the combined Brigalow Belt South and Nandewar bioregions. As we consider this ARKS to no longer be supporting a koala population, this represents a 1.88% reduction in proportional terms.

The study by Lunney *et al.* (2017), demonstrated a 79% reduction in the koala population in the Pilliga forests between the 1990's and 2014, an area that has extensive overlap with the Pilliga ARKS. An additional decline of 20% of the population remaining at that time was detected using repeat citizen science surveys within the time period 2006 - 2015 (Predavec *et al*. 2018). A 2019 study funded by DPIE / OEH to test the Koala Likelihood Model (KLM) further assessed 97 sites across the Pilliga, Warrumbungles and (part) Gilgandra LGAs using scat surveys and found no evidence of koalas. Further to this are an additional six sites that showed evidence of koalas in 2014 which were revisited and were determined to be devoid of any signs of koalas in 2019 (Biolink, unpub. data). It should be further noted that only 7.73% of the 699 records for this ARKS within the most recent three generations were attributed to the most recent generation. It is known that records tend to increase over time and such a low proportion of records in the most recent generation is of relevance. From this collective evidence we conclude that koalas are likely to have become functionally extinct in the Pilliga and Warrumbungles. The Pilliga ARKS contributes the largest land surface to the bioregion and this decline equates to 32.59% of the bioregion.

At 271,800 ha, the Gunnedah ARKS is the second largest ARKS within the Brigalow Belt South bioregion. In 2016 North West Ecological Services used an expert elicitation process to estimate a 50% decline in koala populations in this area (North West Ecological Services 2016). The work of Lunney *et al.* (2012) implied that as much as 25% of this may be due to two extended heatwave events during 2009. Gunnedah has experienced additional heatwaves since this study was completed in 2012, though the effects of these have not been quantified. Regardless, the outcome implies a minimum a 15.50% decline across the bioregion.

Collectively, the reduction in terms of proportional population loss from these two bioregions is 48.10%.

New England Tablelands

Thirty percent (30.36%) of Gibraltor Range ARKS occurs within the New England Tablelands bioregion. The last record of a koala was in 1997, hence no records of koalas have existed in this portion of the ARKS within the last three koala generations and we consider this area to no longer be supporting extant koala populations. The portion of the Gibraltar Range ARKS

situated within the New England Tablelands represents 2.30% of the total ARKS area within this bioregion and this consideration equates to a 1.67% decline across the bioregion.

NSW North Coast and South East Queensland

The remaining 69.64% of the Gibraltor Range ARKS occurs within the NSW North Coast and South East Queensland bioregions. The last known record also occurs in 1997 and we consider this area to no longer be supporting extant koala populations. The portion of the Gibraltar Range ARKS situated within NSW North Coast and South East Queensland represents <0.3% of the total ARKS area within this combined bioregion. Adjusting for the estimate of 72.8% of koalas residing within ARKS results in a proportionally very small decline across the bioregion (0.19%).

The Richmond Valley LGA, which includes large portions of the Banyabba and Mt. Pikapene ARKS, underwent a statistically significant reduction of ~33% in its Area of Occupancy (AoO) from 1996 – 2013 (Biolink 2015a). While this does not align perfectly with the preceding three koala generations (2001 – 2018), we consider it to be broadly indicative given the large degree of temporal overlap. The two aforementioned ARKS combined comprise 9.6% of the total ARKS area within NSW North Coast and South East Queensland and following the assumption that 72.8% of koalas reside in ARKS, this results in a 2.31% decline across the combined bioregions.

Examination of koala distribution and abundance in the Coffs Harbour LGA evidenced a significant reduction of 23% in AoO over the preceding three koala generations (1995 - 2012) (Biolink 2015b). This LGA contains the Coffs Harbour-North Bellingen ARKS almost in its entirety and while the time frame does not align exactly with the current three most recent koala generations (2001 - 2018) there is a large degree of temporal overlap. This ARKS comprises 7.80% of the total ARKS area within NSW North Coast and South East Queensland bioregions and following the assumption that 72.8% of koala reside in ARKS, this results in a 1.31% decline across the combined bioregions.

The Tweed Coast monitoring program evidenced a 37.04% decline in the number of sites showing significant koala activity across the LGA (inclusive of the Tweed Coast ARKS) between 2011 and 2018 (Tweed Shire Council 2018). The Tweed Coast koala population was listed as Endangered by the NSW Scientific Committee in 2014 (NSW Scientific Committee

2016). The Tweed Coast ARKS comprises 0.63% of the total ARKS area within NSW North Coast and South East Queensland and following the assumption that 72.8% of koalas reside in ARKS, this results in a 0.17% decline across the combined bioregion.

Historical records analysis of the area comprising the former Great Lakes LGA including the Hawks Nest ARKS, Wallingat ARKS and Karuah-Myall Lakes ARKS in their entirety and substantial portions of Wang Wauk ARKS and Barrington ARKS was undertaken in 2017 (Biolink 2017a). A decrease of 36% in AoO was noted over the immediately preceding three koala generations (1999 - 2016) across the LGA as a whole (Biolink 2017a). The Hawks Nest Tea Gardens population of koalas is listed as an Endangered population (NSW Scientific Committee 1999). This population has been studied in detail and there is no evidence of a decline in AoO within this specific ARKS over the timeframe of interest. Collectively Wallingat, Karuah-Myall Lakes, Wang Wauk and Barrington ARKS contribute 15.76% of the total ARKS area within the NSW North Coast and South East Queensland bioregions. Overall, this results in a 4.13% decline across the combined bioregions.

Port Stephens ARKS was surveyed during 2017 and 2018 by Biolink (2019) as part of the SoS Iconic Koala initiative by OEH / DPIE in collaboration with Port Stephens Council. The Port Stephens ARKS was found to consist of four purported koala population 'hubs': Tomago, Tilligery, Medowie and Anna Bay. The Tomago hub is now extinct due to the frequent and intense wildfires experienced in this area over the preceding decade (Biolink 2019). The Medowie hub has experienced an 85% decline, again the result of frequent wildfires. The Tilligery Hub was not surveyed for koalas but was preliminarily identified by the proximity of koala habitat to high numbers of vehicle strike records. Before this area could be adequately surveyed it was largely destroyed by two wildfires in late 2018. The Anna Bay Hub is still functional, though currently impacted by high levels of vehicle strike. Using the localized extinction of roughly three of the four component koala 'Hubs', we estimate a conservative 50% decline in the Port Stephens ARKS over the preceding three generations. The Port Stephens ARKS comprises 1.68% of the total ARKS area within NSW North Coast and South East Queensland and results in a 0.61% decline across the combined bioregion.

A report pertaining to the Port Macquarie LGA (inclusive of Wilson River and Port Macquarie ARKS) evidenced a small but significant increase in the AoO of 2.2% (Biolink 2013), and an additional report (Phillips and Chang 2013) for Ballina LGA (inclusive of Broadwater and Far

North East ARKS) shows an increase of 14% in the AoO. Collectively these ARKS contribute 9.43% of the total ARKS area within the NSW North Coast and South East Queensland bioregions and result in a 0.23% increase across the combined bioregions.

There is evidence for population stability in Lismore LGA (inclusive of Far north-east Hinterland ARKS) (Biolink 2017b), and also stability in Kiwarrak and Khappinghat ARKS (Biolink 2019) and the Southern Clarence ARKS (Biolink 2018).

Cobar Peneplain and Riverina

The Narrandera ARK has 18.99% of its area within the Riverina and Cobar Peneplain bioregion. The last koala records for this portion of the ARKS occurred in 2005, hence no records of koalas are associated with this portion of the ARKS within the last koala generation and we consider this area to no longer be supporting a koala population. The portion of the Narrandera ARKS situated within the Riverina represents 36.71% of the total ARKS area within this bioregion. This results in a 26.72% decline across the bioregion.

South East Corner

The Nullica ARKS most recent records occurred in 2004. Of the 201 records since 1900, this is the singular koala record from the most recent three koala generations (2001 – 2018). The Nullica ARKS represents 37.06% of the total ARKS area within the South East Corner bioregion. As we consider this ARKS to be functionally extinct, this represents a 37.06% decline in the ARKS system and hence a 26.98% decline across the bioregion. While it is known that the second ARKS within this bioregion, Murrah, still contains koalas, of the 620 records within this ARKS only two (0.32%) occur in the most recent koala generation with no records since 2016.

Analyses of koala records across the Bega LGA and part of the Eurobodalla LGA, includes the Murrah ARKS. Phillips and Allen (2012) estimated that the distribution of koalas within this area had undergone a 64% reduction in the AoO over the preceding three koala generations (1993 - 2011). While this does not perfectly align with the current preceding three koala generations (2001 – 2018), we consider it to be broadly indicative, given the degree of temporal overlap. At 82,265 ha the Murrah ARKS accounts for 62.94% of the total ARKS area within the bioregion, resulting in a 29.33% decline across the bioregion.

Sydney Basin

While it is possible that Brisbane Water National Park ARKS within this bioregion may still contain koalas, of the 154 records within this ARKS only one occurs in the most recent koala generation, and there have been no records since 2014. The continued functionality is questionable but the potential loss has not been incorporated into the estimate of loss in this part of the report.

An analysis of historical koala records in Campbelltown LGA, just south of Sydney, estimated a 5.19% increase in the AoO over the preceding three generations (Phillips 2016). This LGA includes a small proportion (< 10%) of the Bungonia ARKS, consequently we did not apply population increases across the ARKS as it is not broadly representative of the area.

South East Highlands

The most recent records for the Nullica ARKS occurred in 1993. Of the 12 records from 1900, no records occur within the recent three koala generations (2001 – 2018). The Nullica ARKS represents 6.41% of the total ARKS area within the South East Highlands bioregion. As we consider this ARKS to no longer be supporting a koala population, this represents a 1.38% decline in ARKS system and a 1.00% decline in the koala populations across the bioregion.

Table 2 provides a progressive summary of loss based on the preceding information, the implication of which is that within the last three consecutive koala generations and prior to the 2019 fire events, the NSW koala population had already been reduced by a minimum of 19.83%.

Table 2. Proportional population estimates of koalas in NSW as of 2012, based on expert elicitation ((from Adams-Hosking *et al.* (2016) and further review by Rennison & Fisher (2019)). Data on the extent of decline is expounded upon in preceding sections of this report. In brief, this is calculated based upon the date of the most recent record across the bioregion as a whole and in individuals ARKS within bioregions, in addition to published reports of koala surveys and / or Area of Occupancy (AoO) calculations.

			Records		Reports	
NSW bioregion	Mean population	% NSW population	Bioregion (%)	NSW (%)	Bioregion (%)	NSW (%)
Murray-Darling Depression	55	0.10	100.00	0.10	0.00	0.00
South East Corner	2,768	5.10	26.98	1.38	29.33	1.50
Cobar Peneplain & Riverina	2,354	4.34	26.72	1.16	0.00	0.00
Darling-Riverine Plain	964	1.78	0.00	0.00	0.00	0.00
Mulga Lands	711	1.31	100.00	1.31	0.00	0.00
New England Tableland	2,771	5.10	2.05	0.10	0.00	0.00
NSW North Coast *	24,188	44.56	0.42	0.19	8.29	3.69
NSW Southern-Western Slopes	2,310	4.26	0.00	0.00	0.00	0.00
Brigalow Belt South and Nandewar	11,133	20.51	1.88	0.39	48.09	9.86
South Eastern Highlands	1,363	2.51	1.01	0.03	0.00	0.00
Sydney Basin	5,667	10.44	0.00	0.00	1.17	0.12
NSW Total	**54,284**	**100.00**		**4.65**		**15.18**

The 2019 Fires

Methods

We defined the extent of 2019 fire events as wildfires mapped by the Rural Fire Service (RFS) occurring in NSW over an approximate two month period from October 1st – December 10th 2019 with data on the geographic extent of fire grounds supplied by the Department of Planning, Infrastructure and Environment (DPIE) on November 18th, updated according to boundaries on the RFS website to December 10th. At this cut-off date for our analysis (December 10th), the RFS website advised that there were still 93 fires burning throughout the State.

As detailed in the preceding calculations regarding BioNet records and published reports, we consider that 72.8% of koala populations within a bioregion occur within defined ARKS. The extent of population loss from the 2019 fire events within each bioregion is thus calculated as the amount of each ARKS burnt as a proportion of the total ARKS area within a bioregion

(with 72.8% of koalas residing within ARKS) plus the amount of non-ARKS land burnt as a proportion of the total non-ARKS land mass (with 27.2% of koalas residing outside of ARKS). Evidence for mortality levels in koalas due to wildfires is largely anecdotal and will vary according to fire intensity. Starr (1990) described 100% mortality of a koala population near Port Macquarie, while Phillips, based on impacts associated with the 1994 fires at Port Stephens, estimated an overall 60% mortality of koalas (unpub. data). Given the intensity of the majority of the 2019 fire events thus far, we used what we consider to be a conservative mortality estimate of 70%, based partly on information from individuals surveying some of the 2019 fire grounds, all of whom report extreme intensity crown fires.

In the 2019 fire events, seven combined bioregions were affected, namely NSW North Coast & South East Queensland, Sydney Basin, New England Tablelands, South East Highlands, South East Corner, Brigalow Belt South & Nandewar and NSW Southwestern Slopes. To quantify the effects of the fire we have again treated NSW North Coast & South East Queensland and Brigalow Belt South & Nandewar bioregions together so as to align with the earlier work by Adams-Hosking *et al*. (2016).

Results

The total area thus far burnt in NSW during the 2019 fire events is 2,611,863 ha (as of 10th December) which amounts to 3.23% of the entire NSW land surface. Since the 1902-03 fire year, this scale of fire within a twelve-month period has been recorded on only three occasions: 2002-03, 1974-75 and 1938-39. Over this time period the total amount of NSW surface area burnt ranged from 3.68 - 4.47%. It should be noted that the 2019 fire events do not account for a single entire fire season, as data analysed does not include any fires prior to October 2019, or the events following December 10th 2019. Twenty-seven (27) of the 48 ARKS within NSW experienced some degree of burning during the 2019 fire events, with seven ARKS - Banyabba, Clouds Creek, Crowdy Bay, Gibraltar Range, Girard-Ewingar, Khappinghat and Wollemi National Park, having more than 50% of their total surface area burnt. This knowledge results in 14.72% (617,858 ha) of the entire NSW ARKS being fire-affected. Within grouped bioregions (some which have been assessed together), the seven combined bioregions impacted by the 2019 fire events are outlined below, while Table 3 at the end of this section further summarises the cumulative proportional loss of koalas.

NSW North Coast & South East Queensland

The combined land surface of these two bioregions is 5,647,332 ha. The NSW North Coast and South East Queensland bioregions were the most impacted by the 2019 fire events with 28.88% of the total land surface area being burnt. Fires extended from Mount Nothofagus National Park in the north, to the Tanilba fire in the Port Stephens council LGA in the south. There are 29 ARKS within these bioregions of which 23 were directly affected by fire. These fires equate to 21.29% (519,789 ha) of the combined ARKS landmass within the NSW North Coast and South East Queensland bioregions being burnt. Of the remaining area outside the ARKS, 34.65% was affected by fire. Collectively these considerations equate to a 16.35% reduction in proportional population size across the combined bioregions.

Sydney Basin

The Sydney Basin has a total land area of 3,624,045 ha of which 14.59% (534,167 ha) was burnt, the second highest number of hectares burnt of any bioregion. The Wollemi fire alone contributed 436,072 ha of burnt area (as of December 10th). The 2019 fire events covered 90,268 ha of the ARKS thus far which equates to 15.50% of the total ARKS area. Outside the ARKs area 14.59% of the total land surface area has been burnt; this collectively equates to a 10.66% reduction in proportional population size across the bioregion.

New England Tablelands

The New England Tablelands covers an area of 2,855,781 ha, of which 10.47% (298,860 ha) was burnt. The Nymboida National Park fire, which also affected the NSW North Coast and South East Queensland combined bioregions, was the largest fire in the New England Tablelands contributed 104,650 ha to the total burnt area. This bioregion is represented by four ARKS, all of which had some degree of burning ranging from 28 ha in the Armidale ARKS to 5,820 ha in the Nowendoc ARKS. This results in 6.45% of the ARKS within New England Tablelands being burnt. Outside of the ARKS footprint 10.64% (291,059 ha) of the remaining landmass was burnt. This collectively equates to a 4.50% reduction in proportional population size across the bioregion.

South East Highlands

The South East Highlands is 1,654,149 ha and has thus far (as at 10th December, 2019) been affected by four fires as part of the 2019 fire events. The largest is the Green Wattle Creek Fire which burnt 65,947 ha. There were no ARKS within the fire footprints. A total area of

941,146 ha was burnt, equating to 6.66% of the area outside of the ARKS being burnt. This equates to a 1.27% reduction in proportional population size across the bioregion.

South East Corner

The South East Corner is 1,207,609 ha of which 2.23% (26,979 ha) was burnt by six fire events ranging in size from the 125 ha Currawan fire to the 16,322 ha Murramarang NP fire at Pebbly Beach. All fires were located in the northern part of the bioregion and did not extend below Durras Lake. Two ARKS occur in this bioregion; Murrah and Nullica, neither of which was affected by fire as at the time of preparing this report. Outside the ARKS, 2.51% of the total land surface area has been burnt which equates to a 0.48% reduction in proportional population size across the bioregion.

Brigalow Belt South and Nandewar

The Brigalow Belt South and Nandewar bioregions covers a total area of 7,707,691 ha, of which 0.35% (26,802 ha) was affected by fire. Three fires were recorded within this bioregion; Bedman Downs Road Yetman, Torrington State Recreation Area and Kaputar, which ranged in size from 248 ha to 19,831 ha. None of the ARKS were burnt. This equates to a 0.07% reduction in proportional population size across the bioregion.

NSW South Western Slopes

This bioregion is 8,153,371 ha in size and was only minimally affected by the Wollemi fire, of which 16.95 ha has trickled over the boundary of the Sydney Basin.

Table 3 provides a progressive summary of loss based on the 2019 fire events, which is calculated at 8.70% of the original population estimate. However, if the population was already reduced by 19.82% as calculated in Table 2, this figure increases to 9.46% of the remaining koala population across NSW.

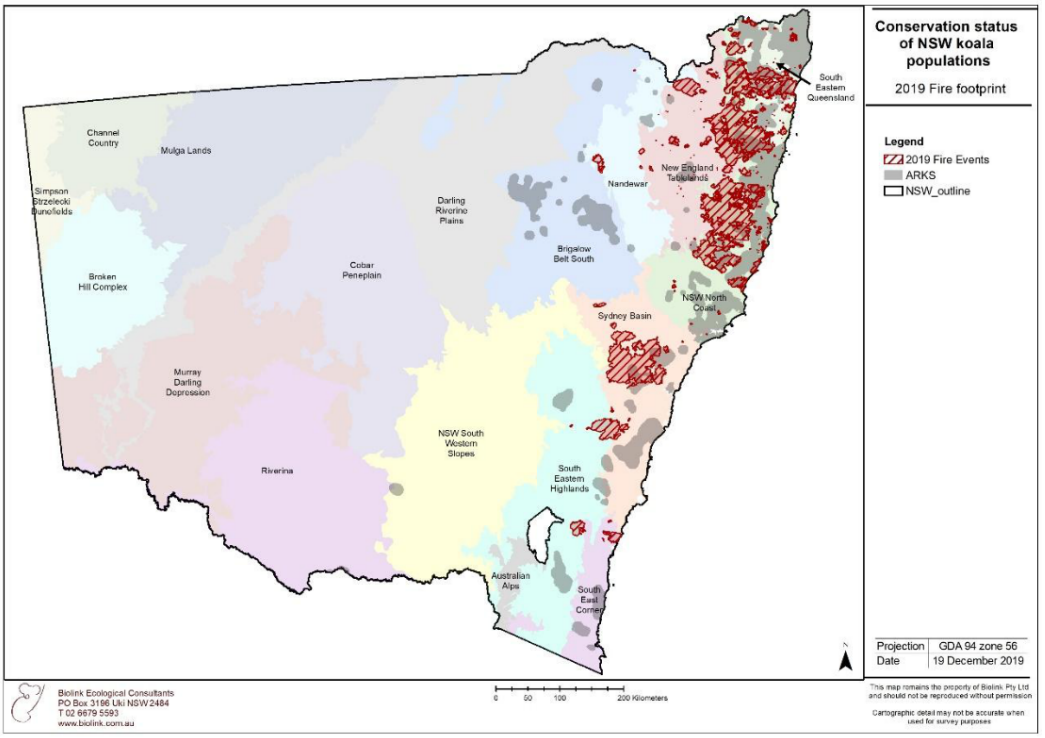

Figure 3. Mapping showing the fire footprint of the 2019 fire events, inclusive of 1st October to 10th December 2019 only, across the IBRA regions.

Table 3. Population estimates of koalas in NSW as of 2012, based on expert elicitation (from Adams-Hoskings *et al.* (2016) as reviewed by Rennison & Fisher, 2019). Data on the extent of decline is expounded upon in preceding sections of this report. In brief, this is calculated based upon the date of the most recent record across the bioregion as a whole and in individuals ARKS within bioregions, in addition to published reports of koala surveys and / or Area of Occupancy (AoO) calculations. Accounting for these losses the impacts of the 2019 Fire Events are calculated according to the size and location of the fire footprint, among other things.

			Records		Reports		Fire	
NSW bioregion	Mean population	% NSW population	Bioregion (%)	NSW (%)	Bioregion (%)	NSW (%)	Bioregion (%)	NSW (%)
Murray-Darling Depression	55	0.10	100.00	0.10	0.00	0.00	0.00	0.00
South East Corner	2,768	5.10	26.98	1.38	29.33	1.50	0.48	0.02
Cobar Peneplain & Riverina	2,354	4.34	26.72	1.16	0.00	0.00	0.00	0.00
Darling-Riverine Plain	964	1.78	0.00	0.00	0.00	0.00	0.00	0.00
Mulga Lands	711	1.31	100.00	1.31	0.00	0.00	0.00	0.00
New England Tableland	2,771	5.10	2.05	0.10	0.00	0.00	4.50	0.23
NSW North Coast *	24,188	44.56	0.42	0.19	8.29	3.69	16.35	7.29
NSW Southern-Western Slopes	2,310	4.26	0.00	0.00	0.00	0.00	0.00	0.00
Brigalow Belt South and Nandewar	11,133	20.51	1.88	0.39	48.09	9.86	0.07	0.01
South Eastern Highlands	1,363	2.51	1.01	0.03	0.00	0.00	1.27	0.03
Sydney Basin	5,667	10.44	0.00	0.00	1.17	0.12	10.66	1.11
NSW Total	**54,284**	**100.00**		**4.65**		**15.18**		**8.70**

Data Deficient Areas

Several of the identified ARKS remain data deficient, meaning that it is not possible to make reliable estimates of population trends in these areas due to a lack of published reports and/or survey work. If these ARKS are no longer functional this has the potential to further impact on the proportional population decline, though it is not possible to quantify the extent.

Methods

BioNet records were interrogated for suggestive evidence of population decline in the most recent generation. For these purposes, a potential population decline was identified if less than one third (33.33%) of the records were from the most recent generation (2012-2018), when compared to the most recent three generations (2001-2018). This metric can point to a possible decline as the number of reported koala sightings tend to increase over time, so it would be expected that at least one third of records would be present in the most recent generation, compared to the two preceding generations.

However, it became clear during analysis that on occasion BioNet records were in conflict with the population changes presented in published reports. By way of example, the Tweed Coast ARKS has 73.02% of records in the most recent generation, compared to the previous two generations. This does not raise red flags for a possible decline. In contrast to this, published reports outline concerns within this ARKS, including a measured decline and the recent designation of the Tweed Coast koalas as an Endangered population (NSW Scientific Committee 2016). It is therefore prudent to consider the potential for decline in an ARKS for which BioNet records are not otherwise raising concern, but for which we have no published information or survey work to indicate otherwise.

We calculated a maximum value of data deficiency by considering the implications if an ARKS which did not have any published information or surveys is no longer functional. In the instance that an ARKS had been considered previously in the report for lack of records, they were not considered in this section. However, if fire impacts in the ARKS were assessed previously in this report, the remaining percentage of that ARKS (unburnt) could be assessed here.

Results

The seven relevant combined bioregions deemed to fall into the data deficient category are discussed further below and the implications collectively presented in Table 4.

Brigalow Belt South and Nandewar

The Moree ARKS had only 5.41% of its records within the most recent generation, indicating a likely decline that has not been taken into account for the purpose of this report. The loss of this ARKS would result in a loss of 3.68% to the collective ARKS within this bioregion, resulting in a further 2.68% loss to the Brigalow Belt South and Nandewar koala population.

The Inverell and Kwiambal ARKS, comprising 6.37% of the ARKS in the bioregion, have no reports or survey work and no evidence of fire. Hence, the lack of reporting from these areas may mask a maximum potential 4.70% decline across the bioregion.

New England Tablelands

The Nowendoc ARKS has 82.12% of it land surface area in this bioregion. The proportion of records in the most recent generation suggests decline, with only 23.33% of records within the most recent generation, compared to the immediately preceding two koala generations. If this ARKS were no longer functional and considering the previous removal of fire effects, then 24.08% of the ARKS system would be lost with a consequent 17.53% loss to the New England Tablelands population.

There are two remaining ARKS that have yet to be considered in this assessment that also don't have any recent reports to refer to: Armidale and Severn River North. These two ARKS contribute 68.24% to the ARKS system, after the effects of fire have been removed. If these two ARKS were no longer functional, they would contribute to a 49.63% decline the koala population.

NSW North Coast and South East Queensland

There are indications that two ARKS in this bioregion appear to be in decline; Crowdy Bay (13.91% records in generation one) and Girard-Ewingar (18.37% records in generation one). If these ARKS were no longer functional, with consideration to the areas already burnt, 1.62% of the ARKS system would be lost and 1.18% of the bioregion population.

There are seven ARKS with no reports or survey work in this bioregion that have not been assessed previously. With consideration to fire and records, as much as 19.77% of this combined bioregion may potentially be affected by declines.

South Eastern Highlands

All three remaining ARKS (Nullica was dealt with in the previous section) in this bioregion show evidence of decline. If all of these were no longer functional, then 71.8% of the koala population would be removed from this bioregion.

NSW South Western Slopes

This bioregion contains a single ARKS, Narrandera. Assuming that it holds 72.8% of the koala population for the bioregion, the lack of reporting from this area may mask a potential decline of the same extent.

Riverina and Cobar Peneplain

The Murray Valley ARKS is one of two ARKS within this bioregion. Narranderra, through lack of records in the last generation, has already been accounted for in this report. The remaining ARKS have no reports or survey work and no evidence of declines. The Murray Valley ARKS contributes 63.29% of the land surface area to the total ARKS system and consequently 46.08% to the koala population in this bioregion.

Sydney Basin

Two ARKS, Brisbane Water National Park and Lower Hunter, have evidence for decline in the most recent generation, with 3.33% and 31.45% of records from the most recent generation respectively. Combined these ARKS would contribute to a 16.98% reduction in the total ARKS in the bioregion, after consideration of fire, resulting in 12.36% of the koala population lost from the bioregion.

Excluding ARKS that have been assessed in other areas of the report, there are three ARKS that do not have reports or survey work. One ARK, Wollemi National Park, has been previously assessed for a fire impact of 5.35%. With the removal of this impact, 63.67% of the ARKS system may be in decline, masked by a lack of reporting. In this instance 46.35% of the koala population in this bioregion would be impacted.

Darling Riverine Plains

Whilst the Pilliga ARK partly extends into this bioregion, only 0.95% of its total surface area resides in this bioregion. We therefore consider that there are no ARKS in this bioregion, and a lack of reporting occurs in this area. This whole bioregion may be in decline.

Table 4 considers the upper bound of the potential koala decline calculated at 65.95% of the entire koala population.

Table 4. Population estimates of koalas in NSW as of 2012, based on expert elicitation (from Adams-Hosking *et al.* (2016) as revised by Rennison & Fisher, 2019). Data on the extent of decline is expounded upon in preceding sections of this report. In brief, this is calculated based upon the date of the most recent record across the bioregion as a whole and in individuals ARKS within bioregions, in addition to published reports of koala surveys and / or Area of Occupancy (AoO) calculations. Accounting for these losses the impacts of the 2019 Fire Events are calculated according to the size and location of the fire footprint, among other things. Finally, areas for which we have inadequate data to assess decline are considered in the context of their potential loss and associated uncertainty as a contributing metric to overall loss.

NSW bioregion	Mean population	% NSW population	% BioNet records	% Published Reports	% 2019 Fire Event	% Indication of Decline	% Insufficient Reports
Murray-Darling Depression	55	0.10	0.10	0.00	0.00	0.00	0.00
South East Corner	2,768	5.10	1.38	1.50	0.02	0.84	0.00
Cobar Peneplain & Riverina	2,354	4.34	1.16	0.00	0.00	0.00	2.00
Darling-Riverine Plain	964	1.78	0.00	0.00	0.00	0.00	1.78
Mulga Lands	711	1.31	1.31	0.00	0.00	0.00	0.00
New England Tableland	2,771	5.10	0.10	0.00	0.23	0.95	2.53
NSW North Coast *	24,188	44.56	0.19	3.69	7.29	1.21	9.67
NSW Southern-Western Slopes	2,310	4.26	0.00	0.00	0.00	0.00	3.10
Brigalow Belt South and Nandewar	11,133	20.51	0.39	9.86	0.01	6.11	0.95
South Eastern Highlands	1,363	2.51	0.03	0.00	0.03	1.80	0.00
Sydney Basin	5,667	10.44	0.00	0.12	1.11	1.40	5.08
NSW Total	**54,284**	**100.00**	**4.65**	**15.18**	**8.70**	**12.31**	**25.11**

Note: All calculations informing each of the preceding sections of this report are available as a protected Excel Spreadsheet that can be supplied on request.

5. ONGOING NATURE OF PRIMARY THREATS

It is of relevance that the two key factors driving the extent of koala population declines that have been detailed in this report are in essence, a) extreme drought likely exacerbated by the inexorable mechanics of progressive climate change (see below) and b) intense wildfires arising from these considerations. The IUCN standards for endangerment, as do State legislative considerations, depend not only on the extent of a populations decline, but also its on-going nature and whether factors contributing to the decline are likely to cease, *vis-a-vis*.

"An observed, estimated, inferred or suspected population size reduction of ≥ 50% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1" (IUCN 2012).

The likelihood of a continuation of significant ongoing declines in the NSW population of the koala continuing to be driven by the preceding factors is considered to be extremely high, if not unavoidable. Climate model projections for the coming decades indicate an increasing risk of below average rainfall for southern and eastern mainland Australia, higher temperatures and evaporation, and below average runoff, with a significant projected increase in frequency of extremely hot years and extremely dry years (CSIRO 2018). Such projections will in turn exacerbate the potential for high frequency fires to become more widespread across the landscape. Both Anthropogenic Climate Change and High Frequency Fires are already listed as Key Threatening Processes (NSW Scientific Committee 2000a, 2000b).

Fire

Fire was identified as the primary driving factor contributing the endangerment of the Tweed and Brunswick Coast Endangered Koala Population, (Phillips *et al*. 2011; NSW Scientific Committee 2016). Fire has also been identified as the single biggest contributor to koala population decline in eastern parts of the Port Stephens LGA (Biolink 2017), while also being implicated as a catalyst in the decline (and now functional extinction) of the Pilliga koalas (Lunney *et al*., 2017; this report), once considered to be the single largest koala population remaining in NSW. The Pilliga has experienced extensive and intense fires since

1997 and surveys in this area have shown that where koalas once existed at high densities they now no longer persist. One lesson from this, amongst others, is that large population size does not in itself afford protection from decline; indeed, the rate at which the Pilliga population has declined from a population in the thousands to functional extinction in little more than 2 decades should provide a sobering reality check of the challenges that lie ahead, while also implying that the threat to extinction is more immediate than we would otherwise consdier. Again, climatic models suggest that wildfires in Australia, and NSW specifically are becoming more intense and with shorter inter-fire intervals (Pitman *et al*. 2007). Given their relatively low reproductive rate, the consequence of more frequent fires is that remaining koala populations are simply not able to recover from one fire event before being subjected to another. There are also implications for changes in habitat suitability with shifts in eucalypt species composition and denser stands of smaller trees (Pekin *et al*. 2009), the latter on the basis of field survey data and biochemical studies already known to be largely unpalatable to koalas.

Other considerations

Eucalyptus dieback is most often a multi-factorial causal agent involving a range of complex interactions between stressors that include climatic extremes, fire and insect outbreaks (Landsberg 1988). It is the matter of climatic extremeness and associated drought that is of most relevance here, and in addition to considerations of the direct impacts of fire as considered for the purposes of this report, extensive tracks of Eucalypt forest and woodlands along the eastern seaboard of NSW have experienced browning off and the associated death of many individuals, presumably due to a lack of water. Preferred koala food tree species such as the grey gums, boxes and other members of the Sub-genus *Symphomyrtus* are impacted by the ecological phenomena. The scale of this loss and/or modification of koala habitat has yet to be estimated but is considerable and likely extends to many hundreds of thousands of hectares. Were the loss of this habitat to be included in the calculations herein, the extent of proportional population loss would only increase.

Limitations and Qualifications

The following limitations and qualifications apply to the material and outcomes presented in this report:

a) The analyses contained in this report rely on several assumptions, the first being the approximate accuracy of the population estimates of Adams-Hosking *et al*. (2016)

and Rennison and Fisher (2019) in terms of the proportions of koala populations found across bioregions. It is noteworthy that Adams-Hosking *et al*. (2016) did not refer to a population estimate for the portion of the South East Queensland bioregion which is situated in NSW, an area stretching from the Queensland border, south to Yamba. While this was rectified by Rennsion and Fisher (2019) to include a South East Queensland estimate, it is not clear how this estimate was derived.

b) There are also qualifications around estimates of the proportion of koala populations occurring within ARKS. The figure used in this report (72.8% of koalas within ARKS) relies on the ARKS system as developed by Rennison and Fisher (2018), contrasted with survey results from a single study across Port Macquarie LGA. Beyond our Port Macquarie study there is a dearth of broad-scale studies that enable koala occupancy data inside and outside ARKS to be compared. There are also uncertainties around how to treat the inevitable variability in koala densities within and across individual ARKS. We acknowledge that koala populations are not evenly distributed across the constituent ARKS within each bioregion. Again, our results appear overly conservative; in the Port Macquarie ARKS, for example, using the approach established in this report which relies on the proportional area of ARKS in combination with the bioregion population estimate, our approach informs an estimated loss of 182 koalas. Survey work and community engagement in this area suggests a much higher number of animals, at least in the order of 300 – 400 based on available density data and the amount of habitat present in the burnt area (Biolink 2013, Cheyne Flanagan pers comm.).

c) Fire boundaries outside those provided to us ("MergedFire_Extent_181119") were obtained from RFS website (https://www.rfs.nsw.gov.au/fire-information/fires-near-me). Small geographical errors may be associated with the display of these boundaries within ARCGIS as they were manually georeferenced using existing shapefiles *e.g.* National Park boundaries, roads, waterways and coastline.

d) Mortality rates due to fire are difficult to quantify due to a lack of access to fire grounds and problems with the identification of remains. Following the 2019 fire in Lake Innes (Port Macquarie ARKS), crews searching for animals in some areas reported that piles of ash are all that remain of koala bodies (Cheyne Flanagan pers.

comm.) and that the overall survival rate was very low. Other indirect *post*-fire impacts may include respiratory disorders, a spike in disease, predation when animals are on the ground and burns which impact an animal's ability to climb and browse successfully. We consider our 70% mortality rate to be conservative while acknowledging that there will be variability across fire grounds. The response of koalas and other animal species *post*-fire is generally better known than their survival rates (Boer 1989, Lunney *et al*. 2004, Sutherland and Dickman 1999).

6. CONCLUSION

This study collated BioNet records, published reports and information on the extent of 2019 fire events to estimate that the NSW koala population has declined by at least 28.52% (and up to 65.95%) over the preceding three koala generations (koala generation ~ 6 years as estimated by Phillips 2000). The extent of this estimated reduction in population size must be considered in the sobering context that the threats that have brought about this circumstance are not just ongoing, but will become more severe. Hence the process of endangerment will be ongoing with an elevated risk of greater numbers of localised extinction events.

The NSW Recovery Plan for the Koala (DECC 2008) lists climate change, vegetation clearing, psyllid and bell miner induced eucalypt dieback, fire and fox predation as the key threatening processes to koalas. With consideration to current and predicted weather patterns, it is likely that the contribution from climate change and fire to the decline of the koala will only increase. Changes in vegetation management as outlined in the *Local Land Services Act 2017* were predicted to result in an increase in the level of vegetation clearing in rural areas due to a provision for lifting the ban on broad scale clearing, no clause to maintain or improve vegetation, self-assessable codes and large portions of exempt land in the central region of the state (Ryan 2017). Since these cumulative threats are likely to be accelerated, there is reasonable basis to predict that the rate of decline of koala populations will continue on at least the same trajectory at least, but most likely accelerate given the overall reduction in population size that has occurred over the last three koala generations, as well as the concomitant habitat modification that has resulted from fire and other drought related considerations.

In NSW the koala is currently listed as a Vulnerable species in Part 3 of Schedule 1 of the *Biodiversity Conservation Act 2016*. Koalas are not currently listed as an Endangered species in Part 2 of Schedule 1, nor are they a Critically Endangered species in Part 1 of Schedule 1. Therefore, this species is eligible for provisional listing as Endangered, while further satisfying additional requirements of the *Biodiversity Conservation Act 2016* and *Biodiversity Conservation Regulation 2017* for an emergency uplisting given the immediate, ongoing and significant threat of extinction in the foreseeable future (*i.e*. within the next 2 - 3 koala generations).

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Appendix A

ARKS divided by IBRA bioregions, showing the cumulative results of records analysis, published reports, fire impacts and data deficiency. Relevant reports that informed the results are noted in the final column.

	Area of ARKS in bioregion	% of bioregion	Last year of records	Total number of records	number of records inGeneration1	number of records 2019	% records in Generation 1(comparedtoGeneration1,2&3)	% ARKS burnt in 2019	change due to report	Reports
Brigalow Belt South & Nandewar			2019	797	254	11	51.11			
Gunnedah	272209.25	39.76	2019	1270	493	8	45.82	0.00	50.00	North West Ecological Services 2015, Lunney et al 2012
Inverell	35039.40	5.12	2018	77	50		74.63	0.00		
Killarney	16507.60	2.41	2002	18			0.00	0.00		
Kwiambal NP	5682.48	0.83	2019	16	1	1	33.33	0.00		
Moree	23553.33	3.44	2014	39	2		5.41	0.00		
Nowendoc	41.04	0.01						0.00		
Pilliga	286137.26	41.79	2019	885	54	1	7.73	0.00	100.00	Steve Phillips, pers comm; David Paull 2011; North West Ecological Services 2016
Darling Riverine Plains			2019	110	17	1	35.42			
Pilliga	2753.17	100.00	2007	2			0.00	0.00		

New England Tablelands			2019	396	80	2	42.33			
Armidale	70448.31	22.11	2018	482	330		72.37	0.04		
Clouds Creek	124.08	0.04						80.10		
Gibraltar Range	2784.57	0.87	1997	4				65.75		
Girard - Ewingar	200.60	0.06						0.00		
Inverell	295.13	0.09						0.00		
Nowendoc	34923.21	10.96	2018	41	7		23.33	16.67		
Severn River NR	12067.58	3.79	2018	19	10		90.91	0.19		
NSW North Coast & South East Queensland			2019	1806	620	130	54.63			
Banyabba	141196.61	5.65	2019	1539	460	179	70.34	73.68	33.00	Biolink 2015
Barrington	157024.27	6.29	2019	718	231	11	54.61	0.24	36.00	Biolink 2017
Belmore River	47956.56	1.92	2019	335	91	3	40.81	3.86		
Broadwater	13754.23	0.55	2019	174	110	1	77.46	0.00	increase 14	Phillips and Chang 2013
Clouds Creek	115072.93	4.61	2019	744	155	24	44.29	82.42		
Coffs Harbour - North Bellingen	190037.44	7.61	2019	3658	995	31	51.88	16.88	23.00	Biolink 2015
Comboyne	220650.40	8.83	2019	938	357	6	55.43	24.61		
Crowdy Bay	17464.13	0.70	2018	224	21		13.91	68.44		
Far north-east	20674.67	0.83	2019	749	473	1	66.62	0.00	increase 14	Phillips and Chang 2013
Far north-east Hinterland	338072.22	13.54	2019	8260	4402	32	62.40	2.51	0.00	stability
Gibraltar Range	6387.01	0.26	1997	34				79.20		
Girard - Ewingar	33749.96	1.35	2018	128	18		18.37	57.20		
Hawks Nest	2548.75	0.10	2018	6490	1012		**15.71**	0.00	0.00	Biolink 2017, Endangered Listing, *
Karuah - Myall Lakes	18826.35	0.75	2018	172	43		31.62	0.00	36.00	Biolink 2017
Khappinghat	18759.30	0.75	2019	189	56	1	43.08	63.20	0.00	Biolink 2019
Kiwarrak	34922.37	1.40	2019	427	241	14	67.70	49.56	0.00	Biolink 2019

Mt Pikapene	92818.35	3.72	2019	313	124	1	67.39	39.91	33.00	Biolink 2015
North Grafton	45708.68	1.83	2019	177	56	1	62.22	6.07		
North Macleay - Nambucca	242008.84	9.69	2019	1591	417	8	64.45	20.17		
Nowendoc	7560.92	0.30	2010	13			0.00	51.45		
Port Macquarie	25133.05	1.01	2019	8379	1530	6	29.57	18.25	increase 2.22	Biolink 2013
Port Stephens	40928.78	1.64	2019	7844	1926	167	54.27	0.08	50.00	Biolink 2018
Southern Clarence	62999.79	2.52	2019	592	290	73	61.44	10.55	0.00	Biolink 2018
Tweed Coast	15399.49	0.62	2019	2256	1372	2	73.02	0.02	37.04	Tweed Shire Council 2018
Tweed Ranges	31821.58	1.27	2018	238	141		71.94	0.00		
Wallingat NP	37791.76	1.51	2018	178	24		27.27	0.00	36.00	Biolink 2017
Wang Wauk SF	170355.74	6.82	2019	863	282	6	51.09	0.74	36.00	Biolink 2017
Wilson River	112426.60	4.50	2019	545	191	4	48.11	34.89	increase 2.22	Biolonk 2013
Woodenbong	174724.74	7.00	2018	591	151		42.42	8.04		
NSW South Western Slopes			2019	97	7	4	16.67			
Narrandera	26075.16	100.00	2019	204	18	1	36.73	0.00		
Riverina & Cobar Peneplain			2019	55	10	3	25.00			
Murray Valley	10537.95	24.66	2019	39	17	1	48.57	0.00		
Narrandera	6111.64	14.30	2005	18			0.00	0.00		
South East Corner			2014	157	3		13.64			Phillips & Allen 2012
Murrah	82265.81	61.38	2016	620	2		0.84	0.00	64.00	Phillips & Allen 2012
Nullica	48436.19	36.14	2004	201			0.00	0.00		
South Eastern Highlands			2019	413	90	12	41.28		32 partial	Biolink/Greenloaning, 2015
Bungonia	46634.43	7.82	2019	130	27	1	27.00	0.00		
Nullica	3317.97	0.56	1993	12				0.00		
Numeralla	116858.33	19.60	2019	525	76	9	16.17	0.00		

Queen Charottes Creek	73471.66	12.32	2019	1134	85	1	24.29	0.00		
Sydney Basin			2019	912	277	16	62.11			
Barrington	9821.04	0.98	2018	93	64		79.01	0.00	36.00	
Blaxland	24854.99	2.49	2018	49	5		62.50	0.00		
Brisbane Water NP	12817.43	1.28	2014	154	1		3.33	0.00		
Bungonia	307532.98	30.80	2019	7678	5685	116	85.53	0.00		
Lower Hunter	115099.70	11.53	2019	296	50	4	31.45	25.11		
Port Stephens	8264.70	0.83	2019	535	38	4	43.18	0.85	50.00	Biolink 2018
Wang Wauk SF	4694.39	0.47	2018	706	7		38.89	0.00	36.00	
Wollemi NP	100299.18	10.05	2019	288	168	4	68.29	61.11		
Australian Alps			1986	2			0.00			
Mulga Lands			1995	8			0.00			
Murray Darling Depression			2004	7			0.00			

Appendix B

Fires from the 2019 Fire Events, divided by IBRA bioregions, showing the total area burnt (ha) and amounts within and outside ARKS burnt.

Bioregion	Fire	Area (ha)	Area within ARKS (ha)	Area outside ARKS (ha)	Area of ARKS (ha)
Brigalow Belt South & Nandewar		12.10		12.10	
	Bedman Downs Road, Yetman	248.22		248.22	
	Kaputar	19831.46		19831.46	
	Torrington State Recreation Area	6722.83		6722.83	
7707691.45		**26802.51**	**0.00**	**26802.51**	**638101.29**
New England Tablelands		32.62		32.62	
	Armidale	133.67	28.40	105.27	
	Bassendean	131.58		131.58	
	Bellingen	92.65		92.65	
	Bundurra	7323.36		7323.36	
	Carrai Creek	65802.73		65802.73	
	Dingo Tops Road, Tapin Tops NP	6373.10	5805.98	567.12	
	Drake	5320.18		5320.18	
	Emmaville Road, Ashford	103.87	22.33	81.55	
	Mitchell Road, Backwater	9200.12		9200.12	
	Nymboydia National Park	104650.42	1038.17	103612.26	
	Nowendoc	3528.73	14.32	3514.41	
	Piggery Road, Red Range	279.62		279.62	
	Pyes Creek Road, Bolivia	3931.57		3931.57	
	Rivertree Road, Rivertree	1165.71		1165.71	

	Single NP	13291.95		13291.95	
	Stanborough	17.84		17.84	
	Tamworth	22.95		22.95	
	Tanners Road, Wollomombi	354.64		354.64	
	Tenterfield	5157.20		5157.20	
	Torrington State Recreation Area	64888.63		64888.63	
	Wandsworth	1684.50		1684.50	
	Washpool NP	5373.00	891.94	4481.06	
2855781.21		**298860.65**	**7801.13**	**291059.51**	**120916.29**
NSW North Coast & South East Queensland		107.09	71.58	35.51	
	86 Crestwood Drive, Port Macquarie	4615.05	4574.16	40.90	
	Armidale Road, Braunstone	29.61	29.61	0.00	
	Ballengarra State Forest	1403.80	1403.80	0.00	
	Barrington Tops	510.12		510.12	
	Bellingen	11398.75	4748.40	6650.35	
	Blyths Road, Bobs Creek	5.91	5.91	0.00	
	Border Ranges	963.92	215.45	748.47	
	Bower Bird Lane, Dondigalong	98.15	98.15	0.00	
	Cairncross State Forest	1.22	1.22	0.00	
	Carrai Creek	436429.34	47848.62	388580.72	
	Carters Road, Stewarts Brook	1809.83		1809.83	
	Cascade National Park	84.17	84.17	0.00	
	Cowarra State Forest	8.48	8.48	0.00	
	Crowdy Bay National Park	13243.66	11957.37	1286.28	
	Dingo Tops Road, Tapin Tops NP	144563.10	41652.67	102910.44	

	Dividing Ridge Road, Huntington	96.30	14.28	82.02	
	Drake	253062.88	88440.40	164622.48	
	Duck Creek Road, Duck Creek	11.22	11.22	0.00	
	Dunggir NP	20899.25	20885.52	13.73	
	Dungog	223.98		223.98	
	Fenry Creek Road, Kings Creek	1.54	1.54	0.00	
	Hat Head NP	1782.28	1782.16	0.11	
	Hillville Road, Hillville	31754.88	29163.65	2591.23	
	Jarrah Road Girvan	1259.17	1259.17	0.00	
	Kumbatine National Park	1041.21	793.30	247.90	
	Llwellyn Road Fine Flower	163.59		163.59	
	Maria River Road, Riverside	1.98	1.98	0.00	
	Martins Creek Road, Paterson	380.76	380.76	0.00	
	Misty Ridge Road, Bellangary	135.26	135.26	0.00	
	Mount Lindsay Road, Legume	2517.30	116.63	2400.67	
	Mt Northofagus NP	8432.69	8432.68	0.01	
	Myall Creek Road	113232.80	71915.98	41316.82	
	Namboydia National Park	412941.19	132826.36	280114.83	
	Nambucca Aboriginal Area	44.91	44.91	0.00	
	Newee Creek	6.01	6.01	0.00	
	Ngambee NR	11450.49	10152.71	1297.77	
	Nightcap	7026.23	7026.23	0.00	
	Nowendoc	14051.19	2497.76	11553.44	
	Orara East State Forest	216.98	216.98	0.00	
	Oxley Highway, Long flat	35105.48	13073.78	22031.70	
	Paddys Flat	37553.01	110.97	37442.04	

	Pillar Valley	36.02		36.02	
	Plomer Road, North Shore	7.42	7.42	0.00	
	Punchbowl	206.58	206.58	0.00	
	Punchbowl Road, Punchbowl	35.21	35.21	0.00	
	Rawdon Island	2.20		2.20	
	Red Hill Road, Cooperabung	2014.55	2014.55	0.00	
	Rivertree Road, Rivertree	689.64		689.64	
	Sandy Swamp Road, Couts Crossing	27.48	13.19	14.29	
	Sherwood Nature Reserve	226.77		226.77	
	Tamban State Forest	325.65	325.65	0.00	
	Tanilba Bay	30.99	30.99	0.00	
	Terrace Creek	1076.28	75.75	1000.54	
	Terragon	308.84	308.84	0.00	
	Tom s Creek Road, Ellenborough	1187.80	945.09	242.71	
	Tooloom	5280.20	5280.20	0.00	
	Tyndale	82.78		82.78	
	Verges Creek	53.37	53.37	0.00	
	Wardell	960.37	960.37	0.00	
	Washpool NP	26192.32	4971.86	21220.47	
	Whiteman Creek	2571.85	2564.30	7.55	
	Wombat Creek State Conservation Area	119.24		119.24	
	Woodford Island	66.50		66.50	
	Yellow Creek Road, Bobs Creek	5.91	5.91	0.00	
	Yuragir NP	20717.56		20717.56	
5647332.45		**1630890.32**	**519789.10**	**1111101.22**	**2441532.52**
Sydney Basin	Goulburn River NP	6208.47		6208.47	

	Green Wattle Creek, Wollondilly	45795.87		45795.87	
	Kurri Kurri	242.23		242.23	
	Murramarang NP, Pebbly Beach	4915.91		4915.91	
	Narone Creek Road, Wollombi	5046.28	4198.00	848.28	
	Ruined Castle, Blue Mountains	1347.91		1347.91	
	Tanilba Bay	70.28	70.28	0.00	
	Three Mile Central Coast	34467.84	5015.33	29452.51	
	Woolemi	436072.45	80984.79	355087.66	
3624045.62		**534167.25**	**90268.40**	**443898.85**	**582264.74**
NSW South Western Slopes	Woolemi	16.95		16.95	
8153371.72		**16.95**	**0.00**	**16.95**	**25844.27**
South East Corner	Kings Highway, Nelligen	184.09		184.09	
	Brimberamala NP	3629.14		3629.14	
	Currowan	125.11		125.11	
	Murramarang NP, Pebbly Beach	16322.53		16322.53	
	Tallaganda NP	5914.24		5914.24	
	Yadboro	804.23		804.23	
1207609.64		**26979.35**	**0.00**	**26979.35**	**130763.93**
South Eastern Highlands	Arkstone Road	818.28		818.28	
	Green Wattle Creek, Wollondilly	65947.69		65947.69	
	Ruined Castle, Blue Mountains	52.40		52.40	
	Tallaganda NP	27328.41		27328.41	
1654149.32		**94146.77**	**0.00**	**94146.77**	**239754.74**

A Review of the Conservation Status of NSW Populations of the Koala (*Phascolarctos cinereus*) leading up to and including part of the 2019/20 Fire Event.

Addendum No. 1 – fire events up to 10th January 2020

1. EXECUTIVE SUMMARY

This report sets out to objectively quantify the impacts of recent fire events on New South Wales (NSW) koala populations during the Spring and early Summer of 2019/20, in the context of broader population trends across NSW. Our baseline estimate for the number of koalas in NSW was reliant upon recently published studies which used a process of expert elicitation to derive population estimates for relevant Interim Biogeographic Regionalisation of Australia (IBRA) areas within NSW. However, instead of a focus on numbers *per se*, the review focuses on estimated proportional changes brought about by the fire events, while also giving consideration to changes over preceding generations, in order to place the results in the appropriate International Union for the Conservation of Nature (IUCN) / legislative context.

Population increase, decrease or stability within each bioregion was initially assessed via interrogation of BioNet records and published reports. The location of previously identified Areas of Regional Koala Significance (ARKS) were further considered as a guide to the location of the majority of known koala source populations, which we then considered further by examining survey work across both ARKS and non-ARKS. This initial process identified what appears to be the functional extinction of koalas from the 'Murray-Darling Depression' and 'Mulga Lands' bioregions, as well as substantive declines from the 'South East Corner', 'Brigalow Belt South & Nandewar' and 'Cobar Peneplain & Riverina' bioregions. The estimated proportional decline of the NSW koala population over the preceding three koala generations, but prior to the 2019/20 fire events, was thus conservatively estimated as a pre-existing 19.82% reduction in population size.

Following on from the above, spatial data on the geographic extent of fire grounds burnt over a fourteen-week period from October 1st – January 10th 2020 were intersected with bioregion and ARKS boundaries. Given the intensity of the majority of the 2019/20 fire

events thus far, we applied what we consider to be a conservative mortality estimate of 70%, based partly on information from individuals surveying some of the fire grounds, all of whom reported extreme intensity crown fires.

Seven combined bioregions, namely 'NSW North Coast & South East Queensland', 'Sydney Basin', 'New England Tablelands', 'South Eastern Highlands', 'South East Corner', 'Brigalow Belt & Nandewar' and 'NSW Southwestern Slopes' were impacted by fires up to and including the 10th January 2020. Applying a deductive approach qualified by uncertainty regarding the extent of variation in carrying capacity across individual ARKS, we estimate the 2019/20 fire events as removing a further 11.62% of the remaining NSW koala population, accounting for previous losses (this equates to 9.86% of the initial population estimate). Communicating this latter outcome in terms of koala numbers, if the estimated numbers of koalas occurring in NSW are correct, it implies that approximately 5,000 koalas across NSW were killed by fires between October 1st 2019 and mid-January, 2020.

We consider that our calculations on the matter of population change and the impacts of the of the 2019/20 fire season up to the 10th January, 2020 to be conservative and should thus be considered as a minimum effect, from which a maximum bound can be calculated. To inform this upper limit of uncertainty, we utilized knowledge that several mapped ARKS were data deficient, meaning that it was not possible to make reliable estimates of population trends in these areas. If as a worst-case scenario these ARKS are no longer functional in terms of supporting resident koala populations, this has the potential to increase overall population decline that has taken place by as much as an additional 37.43%. Based on this consideration, we conclude that the NSW koala population has declined by at least 29.69% (lower bound) to as high as 67.12% (upper bound) over the three most recent koala generations, inclusive of the impacts of the fire events up until mid-January, 2020. Importantly, this conclusion does not take into account fire events since the 10th January 2020; hence the lower bound will be greater than what we have been able to estimate.

In addition to population loss and consequent range contraction in western parts of the koala's range in NSW, and the impacts arising from the 2019/20 fire season, not yet taken into account are the many hundreds of thousands of hectares of otherwise unburnt koala habitat that have additionally been rendered unsuitable for koalas through water-stress leading to leaf-browning and loss of preferred browse species. The factors driving these dire

circumstances for koalas are ongoing; hence any prognosis regarding the future conservation status of the species must adopt a precautionary approach. For these reasons, we consider a measure towards the upper bound of our conservative estimates as the more likely current circumstance for koala populations across NSW such that the species readily qualifies as endangered, the implications of which in the context of the two key threatening processes that will continue to operate – the progressive impacts of Anthropogenic Climate Change and the High Frequency Fire, are ongoing; this certainty, coupled with the species low reproductive output and a requirement for long inter-fire intervals to facilitate recovery, implies that the risk of extinction is both immediate and significant, thus presenting serious challenges for longer-term survival of koalas in the forests and woodlands of NSW.

1. INTRODUCTION

This addendum amends the "NSW Populations of the Koala (*Phascolarctos cinereus*) leading up to and including part of the 2019/20 Fire Event" to include the period from the 10th December 2019 up to 10th January 2020.

The layer used for this intersection was provided by NSW RFS called "NSW Bushfire Burnt Areas 2019-2020" and covered the time period 1st July – 10th January 2020.

Within a single month from the cut-off date of the initial report (10 December 2019), an additional 2,480,387 hectares within NSW had been affected by the fires. This increases the total land area burnt to 5,092,250 hectares. The majority of the additional burnt area is located in the Sydney Basin and South East Corner bioregions. We now report that 11.62% of the NSW koala population has been affected by fires (after declines from reports and records were accounted for); this is an increase of 2.16% from the initial report.

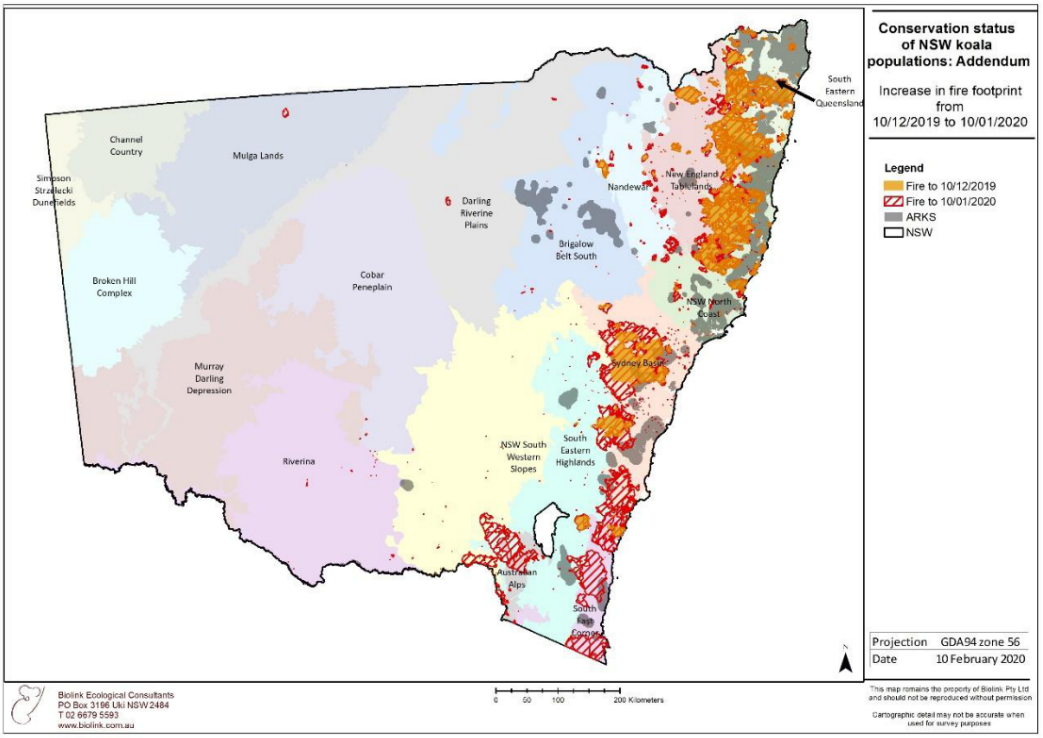

Figure 1. The fire footprint of the 2019-2020 fire events, inclusive of 1st October 2019 to 10th January 2020 (in red dash) and the fire footprint inclusive of 1st October 2019 to 10th December 2019 only, the period covered in the initial report (in orange).

2. DETAILS

South East Corner

The South East Corner had the largest percentage of its landmass burnt in the intervening time period, with an additional decline to the koala population of 14.79% for the bioregion which equates to an additional decline of 0.76% to the NSW population. This single month contributed an additional burnt land area of 34.25% within the Murrah ARKS and 56.41% of the land area outside of the ARKS. This equates to a total of 15.27% decline to the koala population across the bioregion due to fire and 0.78% overall in NSW.

Sydney Basin

The Sydney Basin koala population declined an additional 9.99% within the intervening time period, which equates to an additional loss of 1.05% to the NSW population. Four of the seven ARKS in this bioregion were further affected by fires, ranging from additional declines of 0.05% in Blaxland ARKS to 14.63% in the Lower Hunter ARKS. The area external to the

ARKS was burnt by an additional 22.27%. This collectively equates to a total of 20.65% decline in the koala population across the bioregion due to fire and 2.16% overall in NSW.

South Eastern Highlands

The South Eastern Highlands koala population declined an additional 8.76% within the intervening time period, which equates to an additional loss of 0.22% to the NSW population. Two of the four ARKS, both previously unburnt, in this bioregion contributed to the increase in the proportion of burnt land, with Bungonia having 13.83% of its land area burnt and Numerella having 6.73% of its land area burnt. Outside of the ARKS an additional 30.09% of the land area was burnt. This collectively equates to a total 10.03% decline to the koala population across the bioregion due to fire and 0.25% overall in NSW.

New England Tablelands

An additional decline of 2.46% of the koala population in the New England Tablelands bioregion has occurred. This can be largely attributed to fire in the Nowendoc and Gibraltor Range ARKS, as well an additional 4.65% of the area external to the ARKS being burnt. Overall the New England Tablelands lost 6.96% of its koala population due to fire which equates to a 0.36% decline to the NSW population estimate.

NSW North Coast & South East Queensland

An additional 1.64% decline of the koala population across this bioregion has occurred which represents a additional 0.73% decline to the NSW population estimate for the intervening time period. Eighteen (of the 29) ARKS in this combined bioregion showed some degree of increased burning, ranging from 0.01% - 9.65% at North Grafton and Girard-Ewingar, respectively. The bioregion external to the ARKS was burnt an additional 2.80%. This collectively equates to a total 17.99% decline in the koala population in the bioregion due to fire which equates to 8.02% overall in NSW.

Brigalow Belt and Nandewar

Whilst no ARKS were considered to have functioning populations burnt, 20.44% of the landmass external to the ARKS was burnt. This equates to 0.18% decline of the koala population across the Brigalow belt and Nandewar bioregions which equates to 0.04% of the NSW population estimate.

NSW South Western Slopes

There are not considered to be any functioning ARKS in the NSW South Western Slopes, however there was 1.65% of the landmass external to the ARKS burnt, which previous to this month had not been fire affected. This equates to 0.31% of the bioregion's koala population being fire-affected and a 0.01% decline of the NSW population.

Table 3 (amended). Population estimates of koalas in NSW as of 2012, based on expert elicitation (from Adams-Hoskings *et al.* (2016) as reviewed by Rennison & Fisher (2019)). Data on the extent of decline is expounded upon in preceding sections of this report. In brief, this is calculated based upon the date of the most recent record across the bioregion as a whole and in individuals ARKS within bioregions, in addition to published reports of koala surveys and / or Area of Occupancy (AoO) calculations. Accounting for these losses the impacts of the 2019-2020 Fire Events are calculated according to the size and location of the fire footprint, among other things.

			Records		Reports		Fire		Fire (updated to 10 Jan 2020)	
NSW bioregion	Mean population	% NSW population	Bioregion (%)	NSW (%)	Bioregion (%)	NSW (%)	Bioregion (%)	NSW (%)	Bioregion (%)	NSW (%)
Murray-Darling Depression	55	0.1	100	0.1	0	0	0	0	0	0
South East Corner	2,768	5.1	26.98	1.38	29.33	1.5	0.48	0.02	15.27	**0.78**
Cobar Peneplain & Riverina	2,354	4.34	26.72	1.16	0	0	0	0	0	0
Darling-Riverine Plain	964	1.78	0	0	0	0	0	0	0.01	0
Mulga Lands	711	1.31	100	1.31	0	0	0	0	0	0
New England Tableland	2,771	5.1	2.05	0.1	0	0	4.5	0.23	6.96	**0.36**
NSW North Coast *	24,188	44.56	0.42	0.19	8.29	3.69	16.35	7.29	17.99	**8.02**
NSW Southern-Western Slopes	2,310	4.26	0	0	0	0	0	0	0.31	**0.01**
Brigalow Belt South and Nandewar	11,133	20.51	1.88	0.39	48.09	9.86	0.07	0.01	0.18	**0.04**
South Eastern Highlands	1,363	2.51	1.01	0.03	0	0	1.27	0.03	10.03	**0.25**
Sydney Basin	5,667	10.44	0	0	1.17	0.12	10.66	1.11	20.65	**2.16**
NSW Total	**54,284**	**100**		**4.65**		**15.18**		**8.7**		**11.62**

Appendix A

ARKS divided by IBRA bioregions, showing the cumulative results of records analysis, published reports, fire impacts and data deficiency. Relevant reports that informed the results are noted in the final column. Cells highlighted in yellow indicate an increase in fire impacts in these areas when considering Fire Events between 10th December 2019 and 10th January 2020.

	Area of ARKS in bioregion	%Of bioregion	Last years records	Total number of records	[illegible]	number of records 2019	[illegible]	%ARKS burnt in 2019	%ARKS burnt in 2019 up to 10th Jan	change due to report	Reports
Brigalow Belt South & Nandewar			2019	797	254	11	51.11				
Gunnedah	272209.25	39.76	2019	1270	493	8	45.82	0	0.00	50	North West Ecological Services 2015, Lunney et al 2012
Inverell	35039.4	5.12	2018	77	50		74.63	0	0.00		
Killarney	16507.6	2.41	2002	18			0	0	0.00		
Kwiambal NP	5682.48	0.83	2019	16	1	1	33.33	0	0.00		
Moree	23553.33	3.44	2014	39	2		5.41	0	0.00		
Nowendoc	41.04	0.01						0	100		
Pilliga	286137.26	41.79	2019	885	54	1	7.73	0	0.10	100	Steve Phillips, pers comm; David Paull 2011; North West Ecological Services 2016
Darling Riverine Plains			2019	110	17	1	35.42				
Pilliga	2753.17	100	2007	2			0	0	0.06		
New England Tablelands			2019	396	80	2	42.33				
Armidale	70448.31	22.11	2018	482	330		72.37	0.04	0.04		
Clouds Creek	124.08	0.04						80.1	80.08 *		
Gibraltar Range	2784.57	0.87	1997	4				65.75	97.94		
Girard - Ewingar	200.6	0.06						0	0.00		
Inverell	295.13	0.09						0	0.00		
Nowendoc	34923.21	10.96	2018	41	7		23.33	16.67	27.32		
Severn River NR	12067.58	3.79	2018	19	10		90.91	0.19	0.19		
NSW North Coast & South East Queensland			2019	1806	620	130	54.63				
Banyabba	141196.61	5.65	2019	1539	460	179	70.34	73.68	77.15	33	Biolink 2015
Barrington	157024.27	6.29	2019	718	231	11	54.61	0.24	1.20	36	Biolink 2017
Belmore River	47956.56	1.92	2019	335	91	3	40.81	3.86	3.86		
Broadwater	13754.23	0.55	2019	174	110	1	77.46	0	0.03	increase 14	Phillips and Chang 2013
Clouds Creek	115072.93	4.61	2019	744	155	24	44.29	82.42	85.93		
Coffs Harbour - North Bellingen	190037.44	7.61	2019	3658	995	31	51.88	16.88	20.69	23	Biolink 2015
Comboyne	220650.4	8.83	2019	938	357	6	55.43	24.61	32.09		
Crowdy Bay	17464.13	0.7	2018	224	21		13.91	68.44	71.80		
Far north-east	20674.67	0.83	2019	749	473	1	66.62	0	0.00	increase 14	Phillips and Chang 2013
Far north-east Hinterland	338072.22	13.54	2019	8260	4402	32	62.4	2.51	2.63	0	stability
Gibraltar Range	6387.01	0.26	1997	34				79.2	83.62		
Girard - Ewingar	33749.96	1.35	2018	128	18		18.37	57.2	66.85		

Hawks Nest	2548.75	0.1	2018	6490	1012		**15.71**	0	0.00	0	Biolink 2017, Endangered Listing, *
Karuah - Myall Lakes	18826.35	0.75	2018	172	43		31.62	0	0.00	36	Biolink 2017
Khappinghat	18759.3	0.75	2019	189	56	1	43.08	63.2	69.28	0	Biolink 2019
Kiwarrak	34922.37	1.4	2019	427	241	14	67.7	49.56	49.40 *	0	Biolink 2019
Mt Pikapene	92818.35	3.72	2019	313	124	1	67.39	39.91	42.70	33	Biolink 2015
North Grafton	45708.68	1.83	2019	177	56	1	62.22	6.07	6.08		
North Macleay - Nambucca	242008.84	9.69	2019	1591	417	8	64.45	20.17	23.16		
Nowendoc	7560.92	0.3	2010	13			0	51.45	60.58		
Port Macquarie	25133.05	1.01	2019	8379	1530	6	29.57	18.25	18.84	increase 2.22	Biolink 2013
Port Stephens	40928.78	1.64	2019	7844	1926	167	54.27	0.08	0.32	50	Biolink 2018
Southern Clarence	62999.79	2.52	2019	592	290	73	61.44	10.55	10.55	0	Biolink 2018
Tweed Coast	15399.49	0.62	2019	2256	1372	2	73.02	0.02	0.02	37.04	Tweed Shire Council 2018
Tweed Ranges	31821.58	1.27	2018	238	141		71.94	0	0.00		
Wallingat NP	37791.76	1.51	2018	178	24		27.27	0	0.83	36	Biolink 2017
Wang Wauk SF	170355.74	6.82	2019	863	282	6	51.09	0.74	1.27	36	Biolink 2017
Wilson River	112426.6	4.5	2019	545	191	4	48.11	34.89	36.32	increase 2.22	Biolonk 2013
Woodenbong	174724.74	7	2018	591	151		42.42	8.04	11.27		
NSW South Western Slopes			2019	97	7	4	16.67				
Narrandera	26075.16	100	2019	204	18	1	36.73	0	0.00		
Riverina & Cobar Peneplain			2019	55	10	3	25				
Murray Valley	10537.95	24.66	2019	39	17	1	48.57	0	0.00		
Narrandera	6111.64	14.3	2005	18			0	0	0.00		
South East Corner			2014	157	3		13.64				Phillips & Allen 2012
Murrah	82265.81	61.38	2016	620	2		0.84	0	35.09	64	Phillips & Allen 2012
Nullica	48436.19	36.14	2004	201			0	0	36.00		
South Eastern Highlands			2019	413	90	12	41.28			32 partial	Biolink/Greenloaning, 2015
Bungonia	46634.43	7.82	2019	130	27	1	27	0	13.83		
Nullica	3317.97	0.56	1993	12				0	0.00		
Numeralla	116858.33	19.6	2019	525	76	9	16.17	0	6.73		
Queen Charottes Creek	73471.66	12.32	2019	1134	85	1	24.29	0	0.00		
Sydney Basin			2019	912	277	16	62.11				
Barrington	9821.04	0.98	2018	93	64		79.01	0	0.00	36	
Blaxland	24854.99	2.49	2018	49	5		62.5	0	0.05		
Brisbane Water NP	12817.43	1.28	2014	154	1		3.33	0	0.00		
Bungonia	307532.98	30.8	2019	7678	5685	116	85.53	0	13.57		
Lower Hunter	115099.7	11.53	2019	296	50	4	31.45	25.11	39.75		
Port Stephens	8264.7	0.83	2019	535	38	4	43.18	0.85	0.52 *	50	Biolink 2018
Wang Wauk SF	4694.39	0.47	2018	706	7		38.89	0	1.27	36	
Wollemi NP	100299.18	10.05	2019	288	168	4	68.29	61.11	68.28		
Australian Alps			1986	2			0				
Mulga Lands			1995	8			0				
Murray Darling Depression			2004	7			0				

* These areas show a decline (<1%) in the fire footprint due to drawing errors. It would equate to inconsequential changes overall.