Characteristics and uptake of simulated natural cavities for Major Mitchell's Cockatoo in Slender Cypress-pine.

Year 1 results from spring 2014 surveys

Department of
Environment, Land,
Water & Planning

Report Title: “Characteristics and uptake of simulated natural cavities for Major Mitchell’s Cockatoo (*Lophochroa leadbeateri leadbeateri*) in Slender Cypress-pine.”

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Cover photographs: Adult female Major Mitchell’s Cockatoo at a natural nest cavity entrance (Grant Harris ©).

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Executive Summary

Following the February 2014 mallee bushfires, works were undertaken in April 2014 to create simulated natural cavities (SNCs) within standing Slender Cypress Pine (*Callitris gracilis murrayensis*) (Callitris) trees at Pine Plains, Wyperfeld National Park. This work was designed as a support for the region's Major Mitchell's Cockatoo (*Lophochroa leadbeateri leadbeateri*) (MMC) population. MMC are listed as a threatened species on the Victorian *Flora and Fauna Guarantee Act* (1988). In addition, the loss of cavity bearing trees has been listed as a threatening process under the same legislation. Consequently this work not only seeks to replace recently monitored tree cavity losses but also to create a reduction and eventually a reversal in the projected losses into the future.

The study area contains the largest known breeding population for MMC in Victoria, and has been the site of long term monitoring of this species (Hurley & Mott, 2005; and Hurley, 2006a, 2011) and broad scale habitat restoration programmes to support the natural regeneration of Callitris woodlands (Sandell, 2011).

The breeding population at Pine Plains has continually declined over the last 15 years. The population is under increasing pressure following the February 2014 fires that removed 93% (77 of 83) known cavity-bearing trees within the affected area. This lead to a prediction that the population faces extinction within decades if intervention is not taken (Hurley & Harris, 2014).

The rationale behind methods developed in the simulated cavity project, the tree selection methods and construction details were outlined in (Hurley & Harris, 2014, 2015). Briefly, simulating cavities within suitable Callitris trees was intended to replace cavities lost due to fire, storms and decay (Hurley & Harris, 2014). Further, it is expected these new, simulated cavities will require less maintenance, and offer higher thermal stability than nest boxes (Hurley, 2006b).

This report assesses the extent to which the constructed cavities actually simulated natural cavities in the same region, and the efficacy of the SNCs as an alternative nesting site. We also consider the recent fire and Galah cull as additional influencing factors on MMC cavity use.

This analysis is based upon data collected during Spring 2014. A cohort of 91 natural cavities and 26 SNCs form the primary data source. Five nest boxes were also included in the sample; the small number of these precludes meaningful comparisons, so we combined data from SNCs and nest-boxes. We have assumed that study trees were selected randomly relative to nesting species, spatial location (particularly with reference to the 2014 fire scar) and physical characteristics. The control-treatment design is important as there is limited published data on MMC in natural cavities, with peer reviewed work to date focussed on Western Australian populations (Saunders *et al.*, 1982; and Rowley, 1990).

Evaluation objectives and questions

The evaluation questions consisted of four themes, covering the physical structure of the simulated cavities, their success rate as breeding sites and the influence of other factors such as the Galah removal and fire. The analysis addresses specific questions under each theme, as listed below.

Ability of excavated cavities to simulate natural cavities

1. Do the excavated cavities physically simulate natural cavities?
2. Are the dimensions of those excavated cavities not used by MMC for nesting in 2014 different from those that are occupied?

Success of excavated cavities for breeding

3. Will Galahs and/or MMC occupy excavated cavities?
4. Are the excavated cavities occupied with similar frequency by MMC as the natural cavities?
5. Are the clutch sizes, hatching rates and brood sizes comparable between excavated and natural cavities?

Efficacy of Galah cull

6. Will MMC occupy excavated cavities once Galahs have been removed?

Impact of fire

7. Are cavities (natural and SNC) within the 2014 fire scar occupied in the same proportions as those outside of the fire scar?

Key results

The results of this first year of monitoring can be summarised by the following key findings:

- The SNCs generally mimic natural cavities in the physical dimensions measured, confirming the findings of (Hurley & Harris, 2014) and reflecting published cavity dimensions for MMC and Galahs (*Eolophus roseicapilla*) (Saunders *et al.*, 1982; and Rowley & Chapman, 1991). However, the SNCs measured were significantly deeper and longer, with a significantly larger entrance area (all significant at the p<0.01 level).
- There was no significant physical difference detected between the occupied and non-occupied SNCs.
- Sixty-eight (72%) of all (natural + SNC) 95 cavities were occupied, with MMC being the dominant species overall (34 MMC pairs, 23 Galahs and 11 other).
- Of the 24 SNCs, 13 (54%) were occupied in the 2014 breeding season. Four of these were occupied by MMC, eight by Galahs and one by an Australian Kestrel (*Falco cenchroides)*.
- MMC occupied 17% of the SNCs and 42% of the natural cavities. Despite this seemingly large difference, the small sample size (and consequent large confidence interval) meant that the difference in occupancy probability is not statistically significant, based on 2014 data alone.
- There is no evidence that the SNCs perform any worse than natural cavities or nest boxes when it comes to breeding success and they may support larger brood sizes (based on Galah data).
- Breeding was successful (defined as one or more nestlings fledging) for ~50% the occupied SNCs. One of the four occupying MMC pairs successfully bred in SNC compared to 71% in the natural cavities. The very small number does not allow us to determine if this is a genuine difference. Galahs occupying SNCs bred successfully in 50% of cases (4/8) which compared favourably with natural cavities (successful breeding in 60% of cases).
- This study confirmed that MMC will reoccupy cavities after Galah removal, supporting the findings of the study in (Hurley, 2008).
- We found no evidence that occupancy rates in any cavity type were significantly changed by the cavities location relative to the 2014 fire scar. However, the high rate of occupancy of SNCs within the fire scar (*n* = 12) compared to those outside of the fire scar (*n* = 1) strongly suggests that SNCs within the fire scar serve as a replacement of trees lost in the fire.

Recommendations

1. Repair/augment SNCs on an annual basis
2. Add new SNCs and next-boxes across the fire scar of 2014
3. Pre-spring cull of Galahs at SNCs for next four years, and
4. Survey SNC and natural cavity occupancy and breeding results for the next four years.

Introduction

The family Psittacidae (parrots) has the highest number of threatened species of any bird family (Bennett & Owens, 1997; and IUCN, 2014). Approximately 30% of all parrot species are threatened globally. Most parrots are obligate secondary hollow (cavity) nesters thus their breeding success is closely related to the availability and quality of nest cavities. The Major Mitchell's Cockatoo (*Lophochroa leadbeateri leadbeateri*) (MMC) is a threatened species listed under the *Flora and Fauna Guarantee Act* 1988 (*FFG* Act) in Victoria and its largest known breeding population occurs in Pine Plains, Wyperfeld NP (Hurley & Cheers, 2012). This species is a semi-arid zone specialist and this particular population is dependent upon cavities in large old Slender Cypress Pine trees (*Callitris gracilis murrayensis*) (Callitris) for breeding and roosting (Hurley, 2006b; and Garnett *et al.*, 2011). Long term monitoring of this breeding population has recorded a concurrent reduction in the number of breeding pairs and the number of suitable cavities over the past two decades (Hurley, 2011; and Hurley & Harris, 2014). Competition from Galahs for the remaining suitable cavities has also increased over this time (Hurley, 2008). These twin threatening processes provide the basis for the field work undertaken.

To address both of these threatening processes, in 2014 an integrated programme was initiated to excavate new cavities in standing Callitris and prior to the egg laying season remove Galahs attempting to breed in Callitris in Pine Plains. This report provides an evaluation and assessment of this project. The evaluation questions consisted of four themes, covering the physical structure of the simulated cavities, their success rate as breeding sites and the influence of other factors such as the Galah removal and fire. The analysis addresses specific questions under each theme, as listed below.

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Project Rationale

Pine Plains was incorporated into Wyperfeld National Park in 1989 in part due to the significance of its habitat value to Major Mitchell's Cockatoos (LCC, 1989). Conservation efforts can be grouped into two categories, a) proactive landscape restoration and b) targeted reactive interventions. The former actions includes track rationalisation, total grazing control to encourage regeneration of young Callitris, targeted weed spraying and rabbit warren ripping and ongoing bushfire control strategies (DSE, 2008; and Sandell, 2011). The latter actions include, for the conservation of Major Mitchell's Cockatoo, long-term monitoring of the survival of and ageing of Callitris, the trialling of nest-boxes, annual spring counts (1995-2012) of the MMC breeding population and the targeted removal of Galahs competing for nest cavities (Gibson *et al.*, 2008; and Hurley, 2008, 2009, 2011). While the proactive conservation actions are important for the restoration of this semi-arid woodland vegetation community the ongoing loss of cavities and continued competition for these formed the rationale for this project. Supplementing the supply of cavities with nest-boxes has been very successful as a short term conservation intervention for some threatened species [e.g. Gouldian Finch (*Erythrura gouldiae*) (Brazill-Boast *et al.*, 2013) Mediterranean Storm Petrel (*Hydrobates pelagicus*) (Libois *et al.*, 2012) and Scarlet Macaws (*Ara macao macao*) (Olah *et al.*, 2014)]. However, strategies and the cost-benefit analyses for supplementing cavities for cavity dependent fauna can be a contentious issue (Spring *et al.*, 2001; and Lindenmayer *et al.*, 2002; and Harley & Spring, 2003; and Harley, 2006; and Klein *et al.*, 2007; and Lindenmayer *et al.*, 2009).

Long term monitoring (1995-2012) of nest occupancy by MMC at Pine Plains has recorded a continuous decline in this breeding population and in the number of tree hollows (cavities) available for breeding (Hurley, 2011). This monitoring of large hollow bearing Callitris at Pine Plains has recorded an annual loss of 3.2% of know nest trees over 14 years from 1995 to 2008 (Hurley & Harris, 2014). Over the same time period, competition for the remaining cavities for nesting has increased from being historically negligible to significant by Galahs (*Eolophus roseicapilla*) (Hurley, 2008). To determine the key threats and prioritise conservation actions the Department of Environment, Land Water and Planning's (DELWP) Actions for Biodiversity Conservation (ABC) database is a spatially explicit database used as a conservation action planning tool (TNC, 2007) to identify threats and prioritise locations and actions for each population of a threatened species in Victoria (DELWP, 2015). Within this database a Bayesian network analysis model was developed to illustrate how the threats are operating and the possible conservation actions required to address these threats. From this analyses two priority threatening processes were identified operating simultaneously on this population. These being a) the loss of suitable cavity bearing trees and b) increasing competition during the spring breeding season for the remaining suitable cavities.

The conservation management responses to each of these can be classified into either long term, strategic or short term, critical maintenance actions. The land manager, Parks Victoria under State and federal government funded projects continues to address the first process (Sandell, 2011). That is the long term strategic issue of enhancing tree regeneration through total grazing control to produce a new generation of cavity bearing trees (Sandell, 2011). However, Callitris do not form suitable cavities until they are 50-70 years old (Gibson *et al.*, 2008). So the second threatening process can be addressed by increasing the number of available cavities. In the short term this is undertaken via conservation actions: a) direct removal of the competitors, b) installing nest boxes and/or c) excavating cavities from scratch in standing trees. The first two actions have been undertaken previously with mixed success. The targeted culling of Galahs at cavity bearing trees prior to egg laying in 2007 was found to result in a 40% increase in the number of MMC breeding in the same year (Hurley, 2008). Four nest boxes were installed in 2009 and within 3 years these were all occupied by Galahs (Hurley, 2009; and Hurley & Harris, 2014). So it was considered worthwhile to determine if SNCs within standing trees would be more readily occupied by MMC. Finally, a large bushfire impacted on 60% of the area covered by Callitris at Pine Plains in February 2014. This removed 93% (77 of 83) known cavity-bearing trees within the affected area. This represents a serious threat to the viability of this breeding population, increasing the priority of trialling SNCs in the remaining Callitris within the fire effected areas.

Methods

This section provides an overview of the data provided for analysis and the statistical analyses undertaken.

Data review

The analysis used five data sets:

1. Cavity and breeding data (2014)
   This data set included data on tree and cavity dimensions, occupancy and breeding success. Representing a consistent method across natural and simulated cavities, it is our primary data set for analyses.
2. Historical cavity data (1999) from Hurley (2006b)
   This historical data set contains a number of trees subsequently destroyed by fire. We used cavity dimension data from the historical set to augment the natural cavity data in the 2014 set for comparison of physical dimensions against the SNCs.
3. Historical breeding data (1998-2012)
   Breeding data from this historical set has been used for comparisons of breeding performance between MMC and Galah.
4. Galah cull dataset (2014)
   Data on locations of trees where Galahs were culled and subsequent occupancy of these trees. This was used to establish the impact of Galah removal on cavity re-occupancy and breeding.
5. Arc GIS map layers of fire scar (2014)
   These were used to quantify the impact of the fire scar on the foraging area around each cavity (and to determine subsequent impact on occupancy and breeding).

Tree and cavity data

There were 125 cavities surveyed (7-12 October and again 5-10 Nov 2014). This included 91 natural cavities, 26 SNCs, five nest boxes and three potential/but unsuitable cavities. Twenty-seven cavities were removed from analyses, considered unsuitable for breeding by large parrots, at the start of the survey period. This included physical failures (e.g. cavity floor rotted through, truck broken at cavity entrance) and those cavities requiring further augmentation/restoration to be suitable for nesting. This left a cohort of 71 natural cavities, 24 SNCs and five nest boxes for analysis in this study.

To assess the degree to which the SNCs mimic the dimensions of natural hollows, we also made use of data from 55 natural cavities measured in 1999.

The available physical cavity data is summarised below.

Table 1 Physical cavity data dimensions and the "availability" and source of data and explanatory notes describing the dimension of tree cavities in *Callitris*.

Dimension	Availability		Explanatory notes (adapted from Hurley & Harris, 2014)
	1999 data	2014 data	
Entrance above ground	Y	Y	Distance of base of nest entrance from the base of the tree in metres
Entrance diameter max	Y	Y	In centimetres.
Entrance diameter min	Y	Y	In centimetres.
Entrance area	N	Y	Calculated value (cm^2). We used the Maximum and Minimum entrance diameters to calculate the equivalent elliptical area, via (Entrance Area = (π/4)*DiamMax*DiamMin)
Depth to floor	Y	Y	Distance from base of entrance to chamber floor (cm)
Stem diameter at nest	N	Y	Diameter of tree trunk at height of entrance (cm)
Chamber length	N	Y	Maximum diameter of chamber (cm)
Chamber width	N	Y	Minimum diameter of chamber (cm)
Chamber diameter (average)	N	Y	(Max-Min)/2
Wall average	N	Y	Wall thickness was defined as measuring the diameter of the trunk at the level of the nest chamber floor, then subtracting from this the average of two internal diameters of the nest chamber floor. This figure was then halved to give the average thickness of the nest chamber wall.

Breeding success data

Breeding success was surveyed using the following definitions:

Nest Occupied	Was the nest occupied by a breeding pair at any time? (Y/N)
Clutch size	Number of eggs observed
Brood size	Number of hatchlings observed
Nestlings Fledged	Number of nestlings fledged from nest
Breeding Successful	Did the nest result in one or more fledged birds? Allowable values are Y, N, Breeding not attempted, Unknown

Fire data

The Wyperfeld National Park was affected by fire in February 2014. Forty of the cavities in this study were classified as fire affected by DLEWP staff, based upon on-ground field observations recorded one month after the fire. Trees were classified as fire affected if they were burnt or killed by the fire and/or where there was clear evidence of fire up to and around the tree.

In addition, we made use of spatial polygons from mapping the area to provide an overarching indication of the fire scar (Galey, 2014). A small number of trees were classified as fire affected, despite being located just outside the mapped fire scar region.

Statistical methods

Given the small sample size, we approached the analysis in two ways: exploratory data analysis tools (e.g. tables and boxplots) and simple hypothesis testing (t-tests, binomial tests and non-parametric comparisons). The U test was used to assess distribution overlap between factors (Cohen, 1988). Data was assessed and transformed, if necessary, to ensure that the underlying assumptions of the tests held (e.g. normality assumption of the t-test).

Interpreting box plots

The charts below use bloxplots to visualise and compare distributions (Tukey, 1997). The image at right shows a set of data values on (left of image) and demonstrates how the distribution of this data can be visualised as a box-plot (right of image).

The box contains 50% of all data values (technically the box denotes Tukey's upper and lower hinge). The horizontal line in the middle represents the median of the distribution. If the median line is not in the middle of the box, it indicates that the distribution is skewed.

Points beyond the 'whiskers' are considered outliers. Where there is sufficient data, we employed boxplots that were 'notched' around the median. The notches are technically set to extend to ± 1.58 *IRQ/$\sqrt{n}$, where IRQ is the interquartile range and n is the number of observations (Chambers *et al.*, 1983). The notched range is generally analogous to the 95% confidence interval about the median (but does not require the same assumptions about the shape of the underlying distribution as the confidence interval about the mean). If the notches of two boxplots do not overlap, this is strong evidence that the two medians are significantly different.

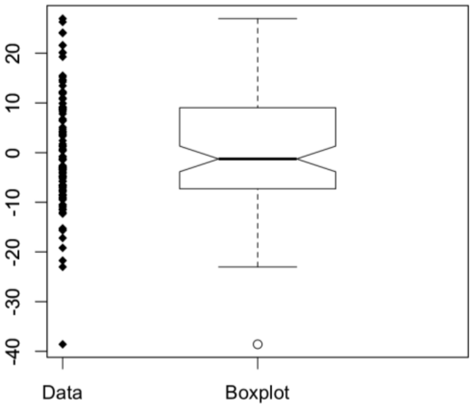

Figure 1 Sample boxplot using dummy data to illustrate how the distribution of points "data" determines the proportions or shape of the "Boxplot".

Results

Ability of excavated cavities to simulate natural cavities

Key questions 1 & 2

1. Do the excavated cavities physically simulate natural cavities?
2. Are the dimensions of those excavated cavities not used by MMC for nesting in 2014 different from those that are occupied?

General, multi-species studies of cavity use in birds and mammals have found evidence that physical cavity and nest box dimensions influence cavity choice (McComb & Noble, 1981; and Newton, 1994). It is also logical that providing effective simulated breeding cavities requires cavities that mimic the dimensions of natural cavities. We evaluated the 2014 cavity work on this basis by comparing the distributions of SNC dimensions with the full set of available natural cavity data (1999 and 2014). Where a particular measurement was not captured in the historical dataset, we restricted our comparison to just 2014 survey data.

Comparing SNC dimensions with natural cavities (1999 & 2014)

Figure 2 and Figure 3 compare the distribution of key dimensions between natural cavities and SNCs. Where sufficient data was available, we have used notched boxplots to provide a visual cue to the difference in the two medians. However, for very low data counts, the uncertainty in the median (represented by the notch) extends past the ‘box’ and the charts are not easily interpretable. In these cases we have reverted back to standard, un-notched boxplots.

Figure 2 and Table 1 suggest that the SNCs are significantly deeper (t=-3.97, p=0.001) on average, and significantly longer (t=-2.81,p=0.009). In addition, there is only a 2% overlap in the natural and simulated distributions for depth (Cohens U1 = 0.98). There is around 9% overlap in measurements of chamber length (U1=0.91).

SNCs also have significantly larger entrance area (t=-2.98, p=0.008).

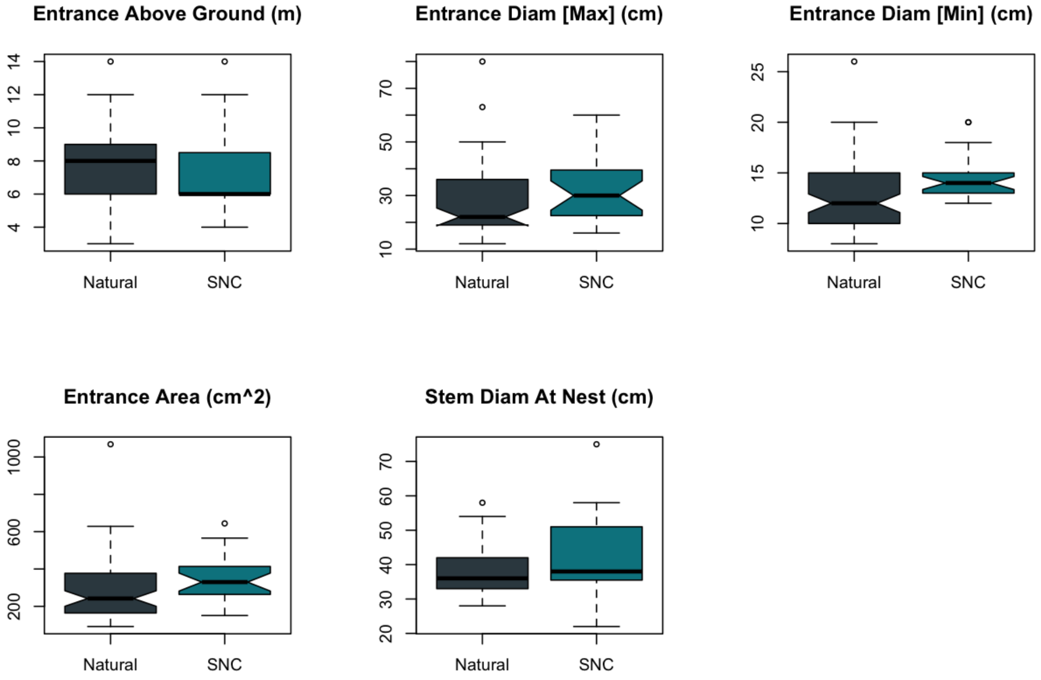

Figure 2 Boxplots comparing external dimensions of natural and SNCs. Box plots are of the height of the lowest rim of the nest entrance above ground level, the entrance maximum diameter (generally equates to the height of the entrance), the entrance minimum diameter (generally equates to the entrance width), the entrance area I calculated by the formula (Entrance Area = (π/4)*DiamMax*DiamMin), the stem diameter at nest is measured using a diameter tape measure at the level of the nest chamber floor.

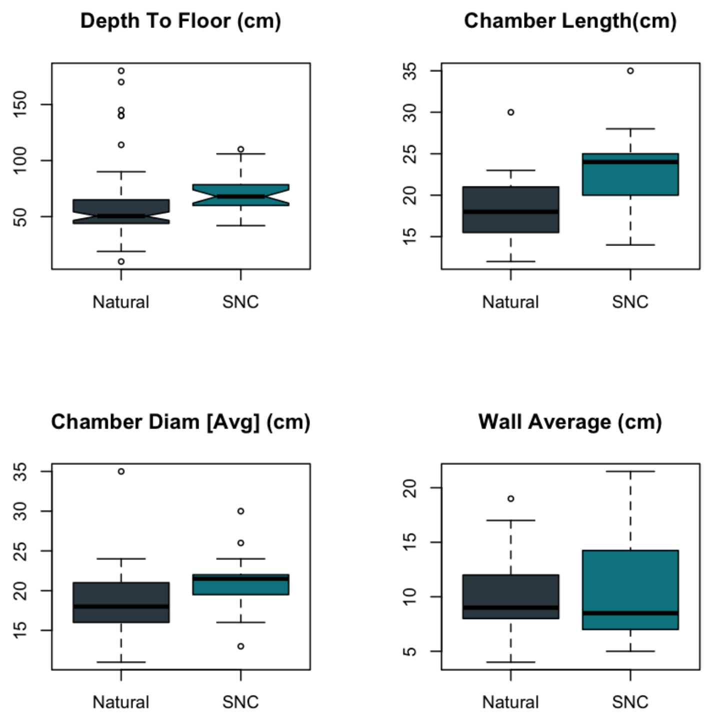

Figure 3 Boxplots comparing interior dimensions of natural cavities and SNCs. The depth to floor is the distance from the lower rim of the nest entrance to the nest chamber floor, the chamber length and width are the maximum and minimum diameters of the nest chamber floor, the chamber diameter [avg] is the average of the two chamber floor diameters and the wall average is the average wall thickness at the level of nest chamber floor.

Table 2 Significance testing results for comparison of SNC dimensions with 2014 and historical natural cavities.

Dimensions	Mean (Natural/SNC)	Observations (Natural/SNC)	t-test		Cohen's U test U1 (proportion of non-overlap of distributions)
			t	p	
Exterior					
Entrance above ground*	6.6/7.8	78/23	0.67	0.5	0.42
Entrance diameter (max) *	22.4/26.5	65/24	-1.862	0.068	0.79
Entrance diameter (min) *	13.4/15.6	74/24	**-2.838**	**0.006**	**0.92**
Entrance area^	199/310	65/24	**-2.602**	**0.012**	**0.89**
Stem Diam At Nest	39.2/42.8	21/24	-1.015	0.316	0.56
Interior					
Depth to floor*	72.3/65.4	74/24	**-3.967**	**0.0001**	**0.976**
Chamber length*	19.3/22.6	16/24	**-2.814**	**0.009**	**0.913**
Chamber width	18.4/20.3	21/24	-1.572	0.126	0.724
Chamber diameter (ave)	19.6/21.4	21/24	-1.640	0.110	0.74
Wall average	10.1/11.5	21/24	-0.445	0.659	0.30

**Technical note: this data required a log-transform to meet the normality assumptions of the t-test. ^This data required square root transformation to meet normality assumptions.*

These differences in entrance size, chamber length and depth are further demonstrated in Figure 4, which shows the distribution of the key differing dimensions. For all these variables, the average values are consistently higher, with less variation around the mean. Entrance area and floor both have truncated distributions for the SNC, particularly at the smaller end of the distributions.

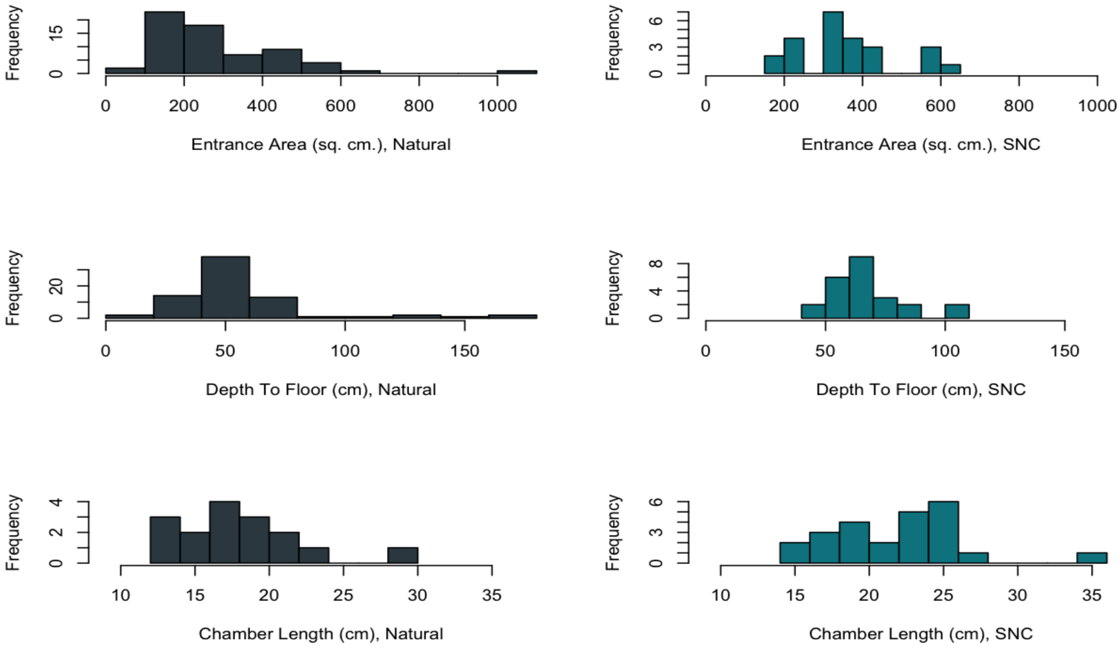

Figure 4 Histograms showing differences in entrance area, depth from the lower rim of the nest entrance to the cavity floor and chamber length is the longest diameter of nest chamber floor for natural cavities and SNCs.

Comparing dimensions of occupied and unoccupied cavities in 2014

It is quite reasonable that the actual physical dimensions of the simulated cavities would be more uniform than naturally occurring cavities. It is arguably more important to investigate whether there is any difference between the dimensions of those SNCs that were occupied and those that were left vacant.

To evaluate this question we consider whether the dimensions of the occupied SNCs differed to the unoccupied. We note that there were only a small number of SNCs (n = 24). While we present boxplots and t-tests in this section, we caution that the small sample size decreases the power to detect a difference, even if one exists (i.e. increases the chance of a type II error). It is still worthwhile to present the analysis, but it should be considered as a baseline finding that can be built upon in future seasons to provide more conclusive results.

Of the 24 SNCs, 13 (54%) were occupied in the 2014 breeding season. Four of these were occupied by MMC (17%), eight by Galahs (33%) and one by an Australian Kestrel (*Falco cenchroides*) (4%).

There was no significant difference detected (at the p=0.05 level) between the occupied and non-occupied SNCs in any dimension.

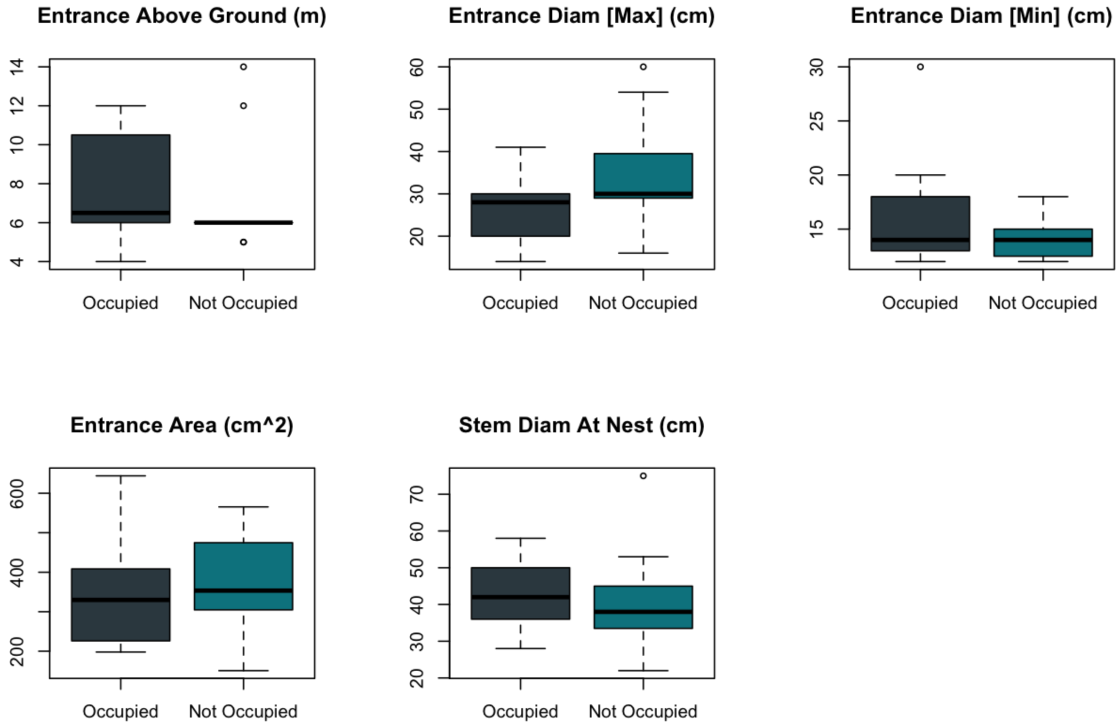

Figure 5 Boxplots comparing exterior dimensions of SNCs by occupancy. Boxplots are of the height of the lower rim of the nest entrance above ground level, the entrance maximum diameter (generally equates to the height of the entrance), the entrance minimum diameter (generally equates to the entrance width), the entrance area I calculated by the formula (Entrance Area = (π/4)*DiamMax*DiamMin), the stem diameter at nest is the trunk diameter at the level of the nest chamber floor.

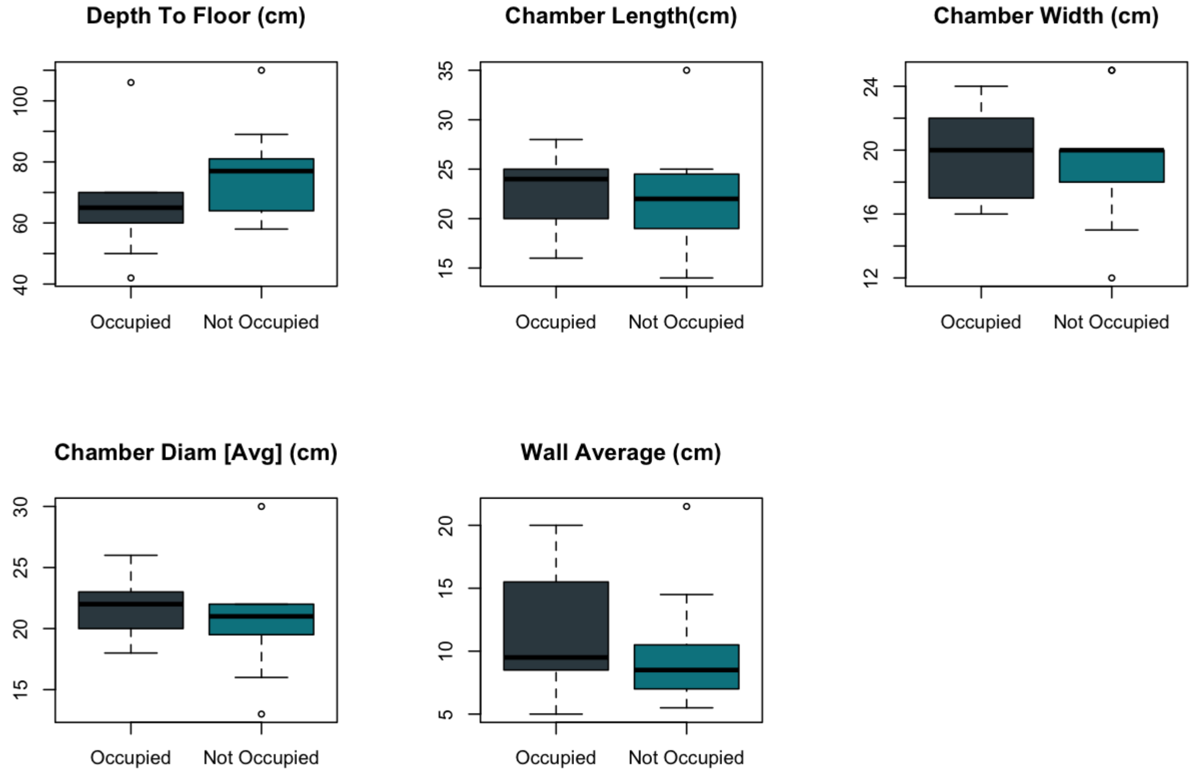

Figure 6 Boxplots comparing interior dimensions of SNCs by occupancy. The depth to floor is the distance from the lower rim of the nest entrance to the nest chamber floor, the chamber length and width are the maximum and minimum diameters of the nest chamber floor, the chamber diameter [avg] is the average of the two chamber floor diameters and the wall average is the average wall thickness at the level of nest chamber floor.

Table 3 Significance testing results for comparison of SNC dimensions against occupancy status

Dimensions	Mean (Occupied/ Not Occupied)	Observations (Occupied/ Not Occupied)	t-test		Cohen's U test
			t	p	U1 (proportion of non-overlap of distributions)
Exterior					
Entrance above ground*	7.8/7.1	12/11	-0.60	0.55	0.38
Entrance diameter (max) *	27.6/34.3	13/11	-1.29	0.21	0.65
Entrance diameter (min) *	15.9/14.0	13/11	1.19	0.25	0.62
Entrance area^	336/374	13/11	-0.67	0.51	0.78
Stem Diam. At Nest	42.8/40.5	13/11	-0.42	0.68	0.41
Interior					
Depth to floor*	65.0/75.6	13/11	-1.85	0.08	0.38
Chamber length*	22.8/22.3	13/11	0.43	0.67	0.65
Chamber width	20.3/19.4	13/11	0.68	0.51	0.62
Chamber diameter (ave)	21.5/20.7	13/11	0.51	0.62	0.78
Wall average	11.4/9.8	13/11	0.80	0.43	0.41

**Technical note: this data required a log-transform to meet the normality assumptions of the t-test. ^This data required sqrt transformation to meet normality assumptions.*

Success of excavated cavities for breeding

Key questions 3, 4 & 5

3. Will Galahs and/or MMC occupy excavated cavities?
4. Are the excavated cavities occupied with similar frequency by MMC as the natural cavities?
5. Are the clutch sizes, hatching rates and brood sizes comparable between excavated and natural cavities?

Occupancy rates of SNC versus natural cavities by species

Sixty-eight of the combined 95 cavities were occupied, with MMC being the dominant species overall (34 MMC pairs, 23 Galahs and 11 other).

The SNCs were occupied by MMC, Galahs and one Australian Kestrel. The natural cavities were also occupied by MMC and Galah, along with a small selection of other species: Australian Kestrel, Red-rumped Parrot, Barn Owl, Boobook Owl, Brush-tailed Possum and feral Honey Bees. For the purpose of this analysis we will ignore these other species. We also removed the five nest-boxes from analysis, though we note that four were occupied by Galahs.

Firstly, it is informative to consider the species breakdown of the occupied cavities (Figure 7). MMCs represent 55% of the population occupying natural cavities, and 31% of the population in SNC, with Galahs dominating the rest of the species mix.

Of the breeding pairs surveyed, 88% of the MMCs were found in natural hollows, compared with 65% of the Galahs (Table 4).

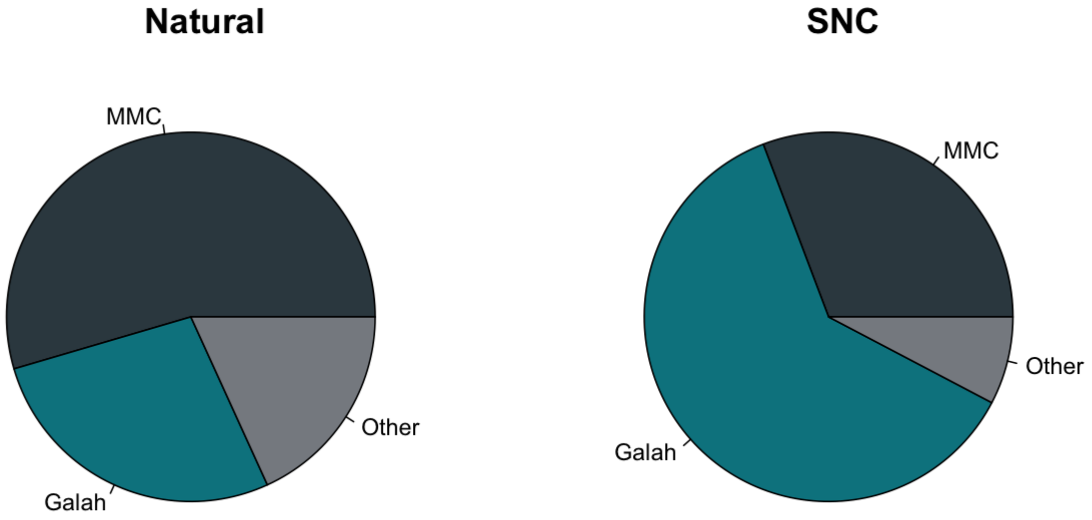

Figure 7 Proportions of each species occupied natural cavities (*n* = 58) and simulated natural cavities (SNC) (*n* = 13) of Callitris in spring 2014 at Pine Plains, Wyperfeld NP.

Table 4 shows the number of the total available cavities occupied by MMC and Galahs. We can use this to estimate the probability of occupation of each type of cavity, with confidence interval estimates calculated using the analytical methods of (Clopper & Pearson, 1934). The likelihood that a natural cavity in the study region will be occupied by an MMC lies between 31% and 55% (mean = 42%). In contrast, the probability that an MMC will occupy an SNC is between 4% and 37% (mean = 17%).

Similarly, we see that the Galahs have an occupancy likelihood of between 12% and 32% for natural cavities and average 44% [22%, 69%] for SNCs. Again, this is not statistically significant.

For all these comparisons, the small sample size results in large (and overlapping) confidence windows. Therefore, while there is an indication that MMCs have a higher probability of occupancy of natural cavities compared to SNC (and vice versa for Galahs), the difference is not significant at the 95% confidence level, based on 2014 data.

Table 4 Number of each cavity type occupied by each MMC and Galah, as well as estimated likelihood of occupation (binomial probability) with relevant 95% confidence intervals in brackets.

Species	Natural		SNC	
	Number occupied	Likelihood of occupation [95% confidence intervals]	Number Occupied	Likelihood of occupation [95% confidence intervals]
MMC	30	42% [31%,55%]	4	17% [5%,37%]
Galah	15	21% [12%,32%]	8	33% [16%,55%]

Breeding success rates between natural and SNC

Forty-five of the available natural cavities and 12 of the SNCs were occupied by either MMC or Galahs. Table 5 shows that breeding was successful (defined as one or more nestlings fledging) at around half the occupied SNCs. One of the four occupying MMC pairs successfully bred (25%) in SNC compared to 71% in the natural cavities. The very small number does not allow us to determine if this is a genuine difference.

We have slightly more information for Galahs. Galahs occupying SNCs bred successfully in 50% of cases (4/8) which compared favourably with natural cavities (successful breeding in 60% of cases). All pairs that attempted breeding in SNCs were successful.

Again, the sample size was too small to formally compare the rate of breeding success, but we have confirmed that MMC breed in simulated cavities, as do Galahs. Confirming whether the success rates differ between cavity types would require further data collection.

Table 5 Breeding success by species, cavity type and counts from the possible of outcomes from the question "Breeding Successful?", Yes, No, Not attempted or Unknown.

Species	Cavity Type	Breeding Successful?			
		Yes	No	Not Attempted	Unknown
MMC	Natural	15	6	8	1
	SNC	1	1	2	0
Galah	Natural	9	2	2	2
	SNC	4	0	4	0

The sample size does not enable us to compare outcomes at different breeding stages for MMC between natural cavities and SNCs (Table 6).

Historical data from the Pine Plains region (*DWELP unpublished data, 1998-2012*) suggests that amongst successful breeding events (those where one or more eggs hatch) Galah brood sizes are not significantly larger than MMC in this region ($\text{mean}_{\text{Galah}}=2.6$, $\text{mean}_{\text{MMC}}=2.3$, df=84, t=1.2, p<0.2). In addition, the Pine Plains MMC brood size is not significantly smaller than that measured in Western Australia (e.g. Rowley and Chapman (1991) found average MMC brood sizes of 2.8).

The mean brood size is different between $\text{MMC}_{(\text{Vic})}$ and $\text{MMC}_{(\text{WA})}$ (t.test, t = -3.1078, df = 104.615, p-value = 0.002427). When we log transform the data first we get the same outcome (t = -3.075, df = 99.322, p-value = 0.002719). Boxplots show that the distributions have the same overall spread, with half of all broods being 2 or 3, and the rest being 1 or 4. But the boxplots suggest the medians could differ (Figure 8).

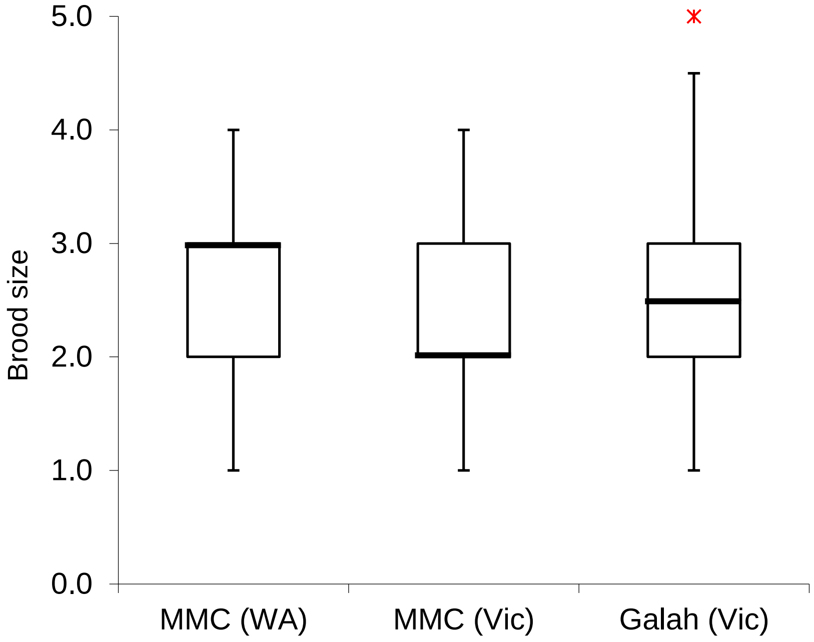

Figure 8 Historic long term brood sizes of MMC (WA) (*n* = 65) at Yangedin, WA, 1978-82 from Rowley & Chapman (1991), MMC (Vic) (*n* = 52) and Galah (Vic) (*n* = 42) at Pine Plains, Vic, 1998-2012. * = an upper outlier.

Collection of data on clutch size was limited in this study because egg laying was initiated earlier than usual the spring of 2014. Most nest content surveys were conducted after hatching so we considered the Galah brood size as a comparison metric, though we caution that only 4 data points are available for SNC/Galahs (Table 6). The performance of natural cavities in 2014 was consistent with historical data from this study site (Figure 9). Each of the SNC cavities performed above expectation, with three of them producing four nestlings, and the other producing three.

Table 6 Sample sizes of breeding metrics measured for natural cavities and simulated natural cavities (SNC) for Galah and Major Mitchell's Cockatoos combined from spring 2014 in Pine Plains, Wyperfeld National Park.

Breeding metric	**Natural**		**SNC**	
	MMC	**Galah**	**MMC**	**Galah**
Clutch Size	6	2	0	0
Brood Size	19	9	1	4
No. Nestlings Dead In Nest	7	0	1	1
No. Nestlings Fledged	14	8	1	4

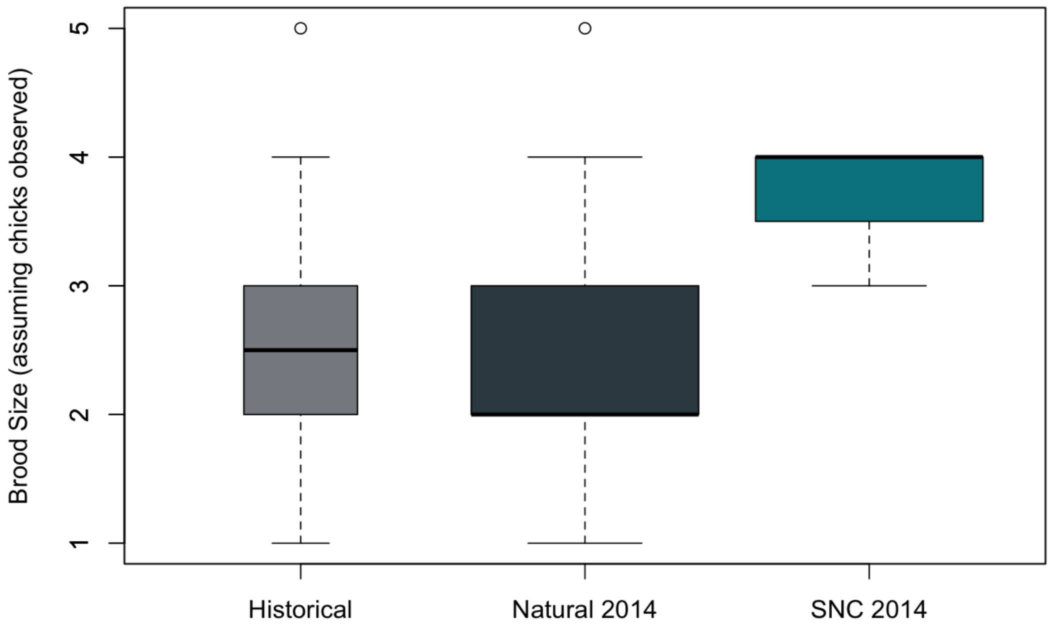

Figure 9 Comparison Galah brood sizes of historical (*n* = 42) data (DLEWP unpublished) with brood size data from the current survey from natural cavities (*n* = 10) and simulated natural Cavities (SNC) from the spring 2014 survey. Note the small sample size (*n* = 4) for SNC 2014. ○ = upper outliers.

Efficacy of Galah cull

Key question 6

6. **Will MMC occupy excavated cavities where Galahs have been removed?**

Hurley (2008) noted a rapid increase in the number of breeding Galah pairs at Pine Plains from 1997 to 2006, and a concurrent decrease in MMC pairs. That study removed 200 adult Galahs from the area prior to the breeding season of 2007, in a control-treatment design (34 trees with removal, 75 without). It found 24% of cavities remained unoccupied, 12% occupied by MMC and the remainder reoccupied by Galahs.

In the current study Galahs were removed from 26 of the study trees, so while there is still little power to quantify patterns, we can descriptively assess whether the patterns identified in Hurley 2008 hold in the current set. Of the 26 trees with Galahs removed 16 were natural cavities, five were SNCs and five were nest boxes. Ignoring cavity type, 22 (85%) of the cavities were reoccupied. The species occupying the cavities are summarised in Table 7.

Table 7 Summary of species occupying cavities after Galahs have been removed earlier in the breeding season of 2014 at Pine Plains, Wyperfeld national park. Listed are the species (by common name), the number of pairs and their percentage of the total of 26 cavities.

Species	Number	Percentage
Major Mitchell's Cockatoo	7	27%
Galah	12	46%
Australian Kestrel	2	8%
Barn Owl	1	4%
Unoccupied	4	15%
Total	**26**	

Four out of the five SNCs were reoccupied, all by Galahs. As in Hurley (2008), the majority of cavities were re-occupied by Galahs. This study confirms that cavities will also potentially be re-occupied by MMC after Galah removal.

Impact of fire

Key question 7

7. **Are cavities (natural and excavated) within the 2014 fire scar occupied in the same proportions as those outside of the fire scar? (i.e. Have the recent fires influenced the occupation of cavity and excavated nests?)**

Thirty-four of the 44 fire affected cavities (77%) were occupied in the 2014 breeding season surveys. This is not significantly different to the 66% (34/51) cavities occupied outside the fire scar. Considering both cavity types together, no significant difference was found in overall occupancy likelihood, based on fire status (logistic model, p~0.25, df=93).

Table 8 breaks down the occupancy numbers by fire and cavity status. Twelve out of the 18 SNCs within the fire affected area were occupied. Of the 13 occupied SNCs, only one of them was in a fire free area.

Table 8 The number (count) of cavities found, available for occupancy by large parrots, fire status, divided by cavity type (Natural or SNC) and the numbers of each occupied or unoccupied.

Fire status	Count	Natural		SNC	
		Occupied	Unoccupied	Occupied	Unoccupied
Fire affected	40	22	4	12	6
Not fire affected	52	33	12	1	6

The lack of a fire effect may be partially explained by the interaction between the foraging areas and the fire affected area. Galahs and MMC are expected to forage, on average, within a 2km radius of their nest (derived from Rowley and Chapman (1991)).

We used a spatial join to map foraging buffers onto the spatial fire scar polygons (Galey, 2014). We then redefined each tree/cavity as:

- Completely within the fire scar – 100% of the foraging buffer is within
- Mostly in – more than 50% of the foraging buffer is within the burned area
- Mostly out – less than 50% of the foraging buffer is within the burned area
- Completely out – none of the foraging buffer with within the burned area.

Employing these definitions, we found that only one tree is classified as completely within the fire scar area (Figure 10). We also found that the occupied cavities are distributed throughout the region; underpinning the statistical lack of evidence for a relationship between fire status and occupancy.

The impact of conservation actions (i.e. creating SNCs and culling Galahs) was factored into a new Bayesian model for the Pine Plains MMC population. Overall the impact of the project was positive. However, but with the threat and asset status so high, only nominal changes were evident from this project (see appendix I).

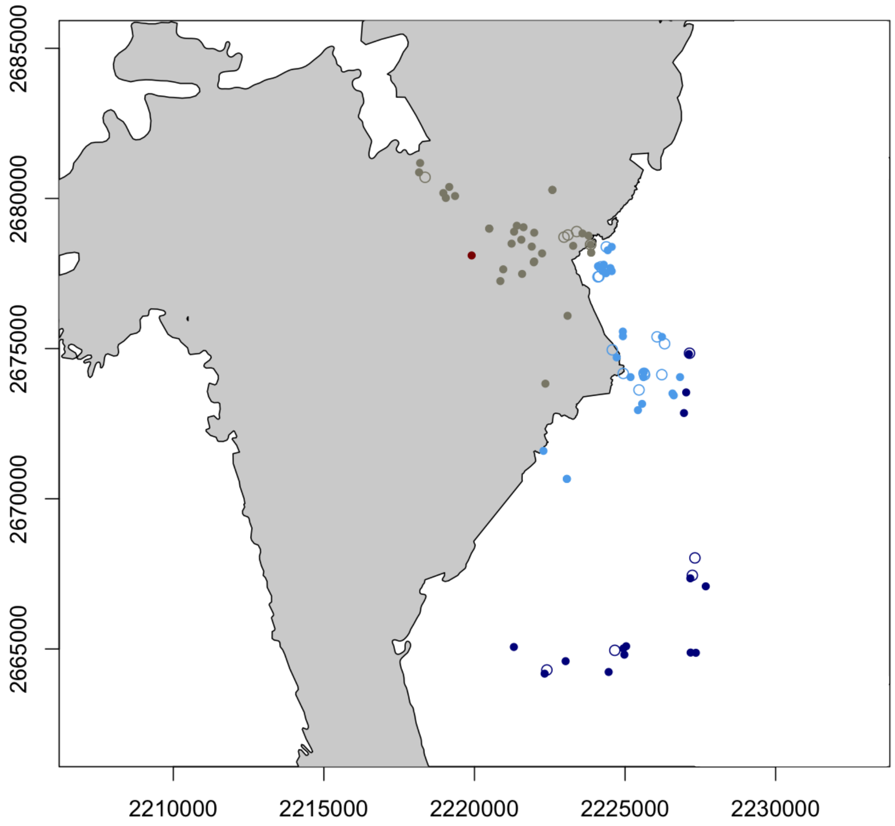

Figure 10 Distribution of surveyed cavity bearing trees, relative to the 2014 fire scar area (grey shading) of Pine Plains, Wyperfeld NP. Filled circles indicate an occupied cavity and open circles indicate cavity not occupied. ● = cavities where the MMC foraging area (2km radius) is completely outside the fire scar, ● = cavities where the MMC foraging area is > 50% outside of the fire scar, ● = cavities where the MMC foraging area is > 50% within the fire scar, and ● = cavity where 100% of the MMC foraging area is within the fire scar.

Discussion and Recommendations

Published studies on MMC are rare, especially for north-west Victoria. In addition, the simulated cavity approach is innovative and not studied to the extent that nest boxes and other augmentations are. Simulated cavities are a logical solution for secondary cavity nesting birds, as they represent a closer analogue to natural cavities. Chimney type cavities have been found to offer more stable temperature profiles and more protection than platform nests configurations (Rockweit *et al.*, 2012).

Nesting preferences can be influenced by physical cavity dimension, inter-species interactions and exogenous factors (e.g. fires reducing nest viability). This highlights the need for direct monitoring of techniques like this, to establish their efficacy 'on-the-ground' and in the face of any regional or species factors.

The simulated cavities broadly resemble natural cavities, but tend toward being slightly deeper, longer and have larger entrances. As one might expect for artificially made hollows, the SNCs tend toward less variation in their physical dimensions than produced by nature. The floor depth and entrance sizes were similar to ranges found in Rowley and Chapman (1991).

The study found a slight preference for occupancy of shallower cavities. Given that MMC have been documented selecting shallower cavities than Galahs (Saunders *et al.*, 1982; and Rowley & Chapman, 1991) future studies should pay attention to emerging patterns between cavity characteristics, occupancy and breeding success. If further augmentation of the cavities were required, they could be made shallower by adding additional wood chips to the base. Preferably, this would also be done in a controlled manner, to collect data from artificially augmented versus bird-modified cavities.

MMC occupied the majority of cavities in the region, with a (sub-significant) preference for natural cavities. Conversely, the majority of SNC take-up was by Galahs. On one season of data, this is an unproven pattern with unknown drivers.

Earlier work has indicated competition maybe a driving factor in this case. It is broadly understood that supply of viable nest sites limits the population of cavity nesting birds and rapid take-up of new sites indicates that there are available birds without nests (Newton, 1994; and Hurley, 2008). Without a full census, or larger statistically sampled survey, we cannot establish estimates for cavity and species populations in the area, so cannot quantify the level of cavity competition.

Pine Plains has experienced steady decline of hollow bearing trees with further significant losses in the 2014 bushfires. There is also evidence that additional cavities will be used, and reoccupied within a season suggesting competition exists at some level. New SNCs were occupied and used for breeding in their first season, with sites reoccupied after culling the resident Galahs. Further, 12 of the 13 occupied SNCs were inside the fire affected area. However, overall occupancy rates did not differ based on fire status.

Therefore species usage patterns for SNC and natural cavities could be driven by a number of things. For example, it is possible that:

- There is competition for hollows and resident MMC pairs outcompete Galahs for their established, natural nesting sites (Rowley & Chapman, 1991), leaving Galahs more likely to take up new SNCs.
- MMCs have been observed inspecting a cavity immediately after Galahs have been removed from it, early in the spring breeding season (Hurley, 2008).
- Galah's outcompete MMC when establishing new nesting sites. Within three years of the installation of four nest boxes in 2009, all four were occupied by Galahs (Hurley, 2011), unpublished survey report) which lends support to this hypothesis.
- Competition is not a primary factor impacting nest occupancy in this area, in which case we expect no inverse relationship in the occupancy by competing species (Gutzwiller & Anderson, 1988). In this case, the preference may be driven more by biological factors/preferences of each individual

species, or simply different population sizes (i.e. a larger surplus Galah population available to take up new sites).

This data set, though small, represents a solid baseline survey of the performance and viability of SNCs to augment the natural supply of breeding cavities for MMC. This data suggests that the SNC mimic natural cavities in most dimensions, are used by MMC and do not have an adverse effect on breeding outcomes. Although this report's findings are preliminary, it has raised interesting patterns in the use of SNC by different species. Regardless of the subtle drivers for SNC use, the management recommendation remains that SNCs are a viable conservation action, are used by MMC (and Galah) for occupancy and breeding.

Recommendations

1. Repair/augment SNCs on an annual basis
2. Add new SNCs and next-boxes across the fire scar of 2014
3. Pre-spring cull of Galahs at SNCs for next four years, and
4. Survey SNC and natural cavity occupancy and breeding results for the next four years.

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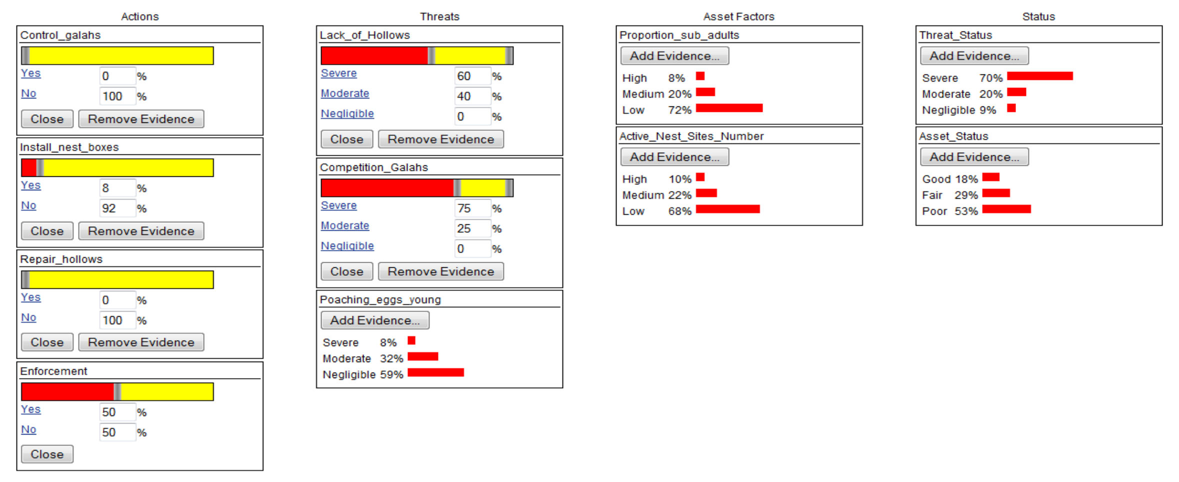
Appendix I

As a result of the information gathered from the VEPP stream 3 project the following changes were made to the ABC Bayesian model for *Lophochroa leadebeateri leadbbeateri* :

- The likelihoods were reconfigured to reflect the changed Threat and Asset Status prior to the implementation of this programme following the bushfire.
- Major reweighting of the current status of each scenario

The consequence of these changes is that the threat status of Major Mitchell's Cockatoo has been increased and the asset status reduced prior to undertaking this project.

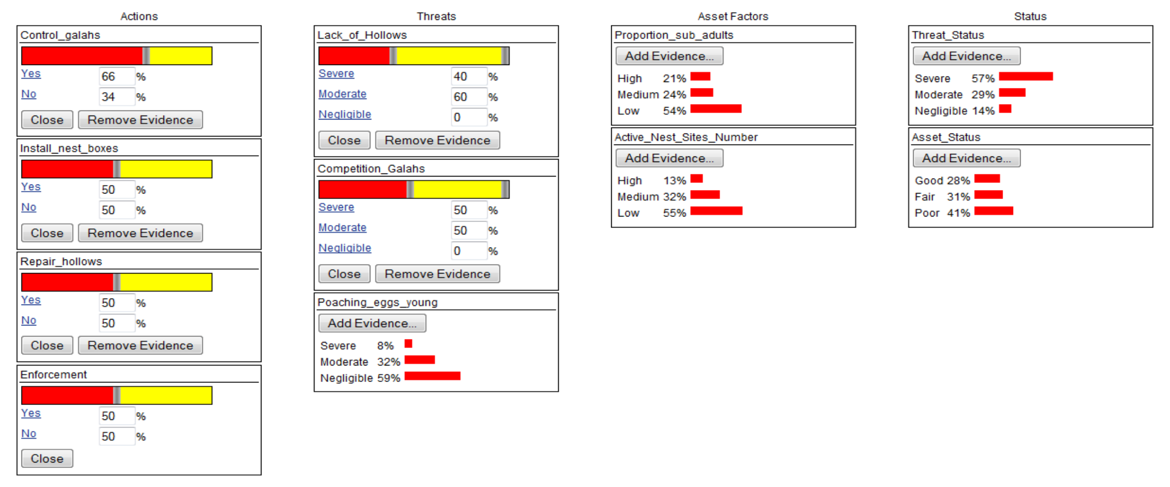
The impact of the project was positive but with the threat and asset status so high only nominal changes were evident from this project.



Control_galahs: Yes 0 % No 100 %
Install_nest_boxes: Yes 8 % No 92 %
Repair_hollows: Yes 0 % No 100 %
Enforcement: Yes 50 % No 50 %
Lack_of_Hollows: Severe 60 % Moderate 40 % Negligible 0 %
Competition_Galahs: Severe 75 % Moderate 25 % Negligible 0 %
Poaching_eggs_young: Severe 8% Moderate 32% Negligible 59%
Proportion_sub_adults: High 8% Medium 20% Low 72%
Active_Nest_Sites_Number: High 10% Medium 22% Low 68%
Threat_Status: Severe 70% Moderate 20% Negligible 9%
Asset_Status: Good 18% Fair 29% Poor 53%

Threat and asset status prior to project works in April 2014

Threat Status	**Severe**	**Moderate**	**Negligible**
	70%	20%	10%
Asset Status	**Good**	**Fair**	**Poor**
	18%	29%	53%



Control_galahs: Yes 66 % No 34 %
Install_nest_boxes: Yes 50 % No 50 %
Repair_hollows: Yes 50 % No 50 %
Enforcement: Yes 50 % No 50 %
Lack_of_Hollows: Severe 40 % Moderate 60 % Negligible 0 %
Competition_Galahs: Severe 50 % Moderate 50 % Negligible 0 %
Poaching_eggs_young: Severe 8% Moderate 32% Negligible 59%
Proportion_sub_adults: High 21% Medium 24% Low 54%
Active_Nest_Sites_Number: High 13% Medium 32% Low 55%
Threat_Status: Severe 57% Moderate 29% Negligible 14%
Asset_Status: Good 28% Fair 31% Poor 41%

Threat and asset status after project works and spring 2014 surveys

Threat Status	**Severe**	**Moderate**	**Negligible**
	57%	29%	14%
Asset Status	**Good**	**Fair**	**Poor**
	28%	31%	41%

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