SURVEYS OF DIGGING ABUNDANCE OF THE SOUTHERN BROWN BANDICOOT (*Isoodon obesulus*) IN THE SOUTH EAST OF SOUTH AUSTRALIA: 1998 – 2016

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Cover photo

Southern Brown Bandicoot digging in Lower Glenelg River Conservation Park, 2001 (Mark Bachmann).

Disclaimer

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EXECUTIVE SUMMARY

The Southern Brown Bandicoot *Isoodon obesulus* (right) is a medium-sized, ground dwelling marsupial mammal, once common in south-eastern Australia. The species is threatened with extinction as a result of the cumulative impacts of habitat loss, habitat fragmentation, altered fire regimes and introduced predators, yet the South East of South Australia remains an apparent stronghold for the species, despite all of these influences acting on local populations.

A regional recovery and action plan for the South East of South Australia was completed in 2006 and is currently under review. The review process is reliant on up-to-date monitoring of the status of Southern Brown Bandicoot populations, providing the impetus for the 2016 field study outlined in this report.

The aim of this report was to determine the status of the Southern Brown Bandicoot population across its current range in the South East region of South Australia, during a 3-month period (April – June 2016), by assessing the presence and abundance of the diggings created by the species when foraging (below) and comparing results with previous studies. Digging abundance surveys of the Southern Brown Bandicoot were conducted at Nangwarry, Mt Burr Range and Caroline Forests across its current range in the South East region of South Australia.

Of the 29 native vegetation patches surveyed, three were within Nangwarry Forest and two within Caroline Forest, with the majority (24) in the cluster along the Mt Burr Range. Prior surveys have occurred approximately 9 years apart: 1998/99, 2007/08 and 2016.

The results of the latest round of digging abundance surveys indicate two key findings:

1) **Occupancy** – the detected presence of the Southern Brown Bandicoot within the majority of patches containing the most suitable remnant vegetation for the species in the lower South East – **remains stable**.

Overall, records of Southern Brown Bandicoot patch occupancy have declined slightly from the 2007/08 survey, but remain the same as the 1998/99 survey, with 23 of 29 patches visited across the South East region having confirmed detection in 2016. The Mt Burr Range remains a consistent stronghold for bandicoots based on confirmed rates of site occupancy, while the Nangwarry and Caroline Forests appear to be under duress and may require potential intervention on the basis of repeatedly low occupancy data. Persistence in these habitats should be of immediate concern to biodiversity managers in the South East.

2) **Digging activity** – physical evidence of the amount of feeding behaviour taking place within representative areas of native vegetation, as a surrogate measure of bandicoot abundance – **has declined**.

The pooled digging abundance data in this study indicates that bandicoot occupancy (presence) declines immediately after fire, but returns to near maximum levels around 5 years after fire. Digging activity (abundance) levels peak from around year 7, consistent with earlier studies. On the basis of the data in this study, this period of increased (albeit variable) activity is then sustained for the subsequent 10-15 years, before declining and then plateauing. Also of note, much longer unburnt habitats in some (especially wetter) patches have continued to show evidence of sustained bandicoot activity for several decades after burning, and is not related to fire history.

It is clear from this study that fire management has played a key role in shaping much of the remaining habitat for bandicoots in the South East NRM Region, and that the species is tolerant of a wide range of fire histories. If used judiciously at a scale and frequency capable of achieving a mixture of age classes and successional states, cognisant that habitat becomes increasingly available to the species from 5-7 years post burn, then fire can continue to be used as an important tool for managing the isolated fragments of habitat that remain. Maintaining a mosaic of burn histories also makes the landscape less prone to uncontrolled, hot and widespread bushfires that could have a potentially devastating effect upon entire, now fragmented, populations. However, some long unburned, productive habitats for bandicoots should also continue to be reserved from burning, making it possible to maintain and evaluate different approaches to fire management for the Southern Brown Bandicoot in the future.

Other key final recommendations from this work are for:

- For digging abundance surveys to be repeated at Mt Burr Range sites in 5 years, and at Nangwarry and Caroline sites on an annual or biennial basis to help guide any future management strategies within the updated Regional Action Plan.
- For implementation of more active interventions (translocations / reintroductions) to ensure populations are not lost from the Nangwarry and Caroline sites.
- To protect and maintain the region’s most viable Southern Brown Bandicoot population within the Mt Burr Range cluster of patches, through supporting the regional corridor strategy and giving serious consideration to a program of assisted migration (through translocations).

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1. INTRODUCTION

The Southern Brown Bandicoot *Isoodon obesulus* (Figure 1-1), is a medium-sized, ground dwelling marsupial mammal (head-body length of 280 – 360 mm), once common to south-eastern Australia, south-west Western Australia, Tasmania and far north Queensland (Paull 1995, Zenger *et al.* 2005). Habitat clearing and fragmentation, inappropriate fire regimes and introduced predators have all contributed to the species' decline (Rees and Paull 2000, Brown 2004).

Figure 1-1: Southern Brown Bandicoot Isoodon obesulus. Photo: Mark Bachmann

Mainland populations are now listed as endangered under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999) (Brown 2004, Zenger *et al.* 2005, Brown and Main 2010). The National Recovery Plan (Brown and Main 2010) aims to address these threats by improving our understanding of the species' ecology via monitoring and proposing threat abatement measures such as fire management. In South Australia, the Southern Brown Bandicoot is listed as Vulnerable under the *National Parks and Wildlife Act 1972* (South Australia) and has been recorded in the South East, Mt Lofty Ranges, Fleurieu Peninsula, Kangaroo Island and Eyre Peninsula (Kemper 1990, Paull 1995, Robinson *et al.* 2000, Brown 2004).

In the South East region of South Australia, the species is restricted to the Penola Forest, Mt Burr Forest and Caroline Forest areas in lower South East within a 50km radius of Mount Gambier, as illustrated in Figure 1-2 (Harley 2006, Duff *et al.* 2009). Habitat fragmentation

(Aitken 1983, Graetz *et al.* 1995, Paull 1995, 1999, 2003) caused by land clearing in each of these areas resulted in the creation of disconnected patches of native vegetation (Croft *et al.* 1999), surrounded by pine plantations, which are also in turn surrounded by grazing and cropping land (Paull 1995, Harley 2006). This fragmentation of native vegetation can limit dispersal opportunities for the Southern Brown Bandicoot and increase the risk of populations becoming genetically isolated (Rees and Paull 2000, Li *et al.* 2016).

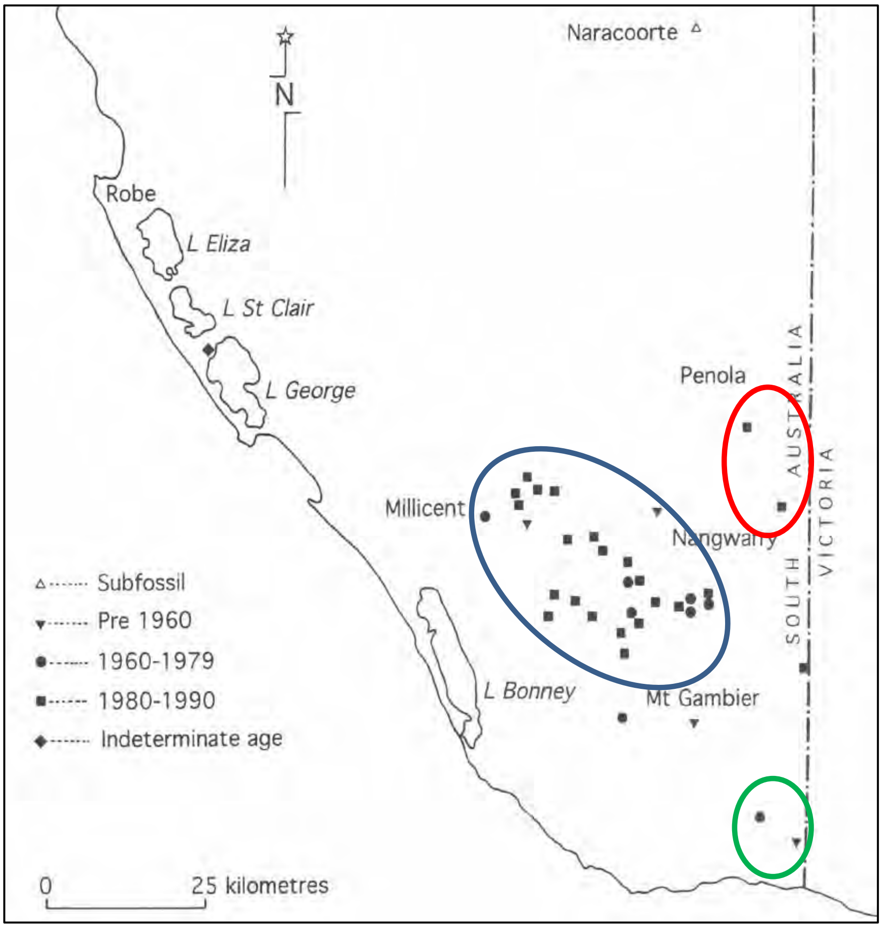

Figure 1-2: Southern Brown Bandicoot distribution in the South East of SA (from Paull 1995), with the three extant population areas shown. Penola - red, Caroline - green & Mt Burr Range - blue.

A regional recovery (or action) plan for the South East of South Australia was completed in 2006 (Harley 2006) and is currently (in 2017) under review. The review process is reliant on up-to-date monitoring of the status of bandicoot populations, providing the impetus for the 2016 field study outlined in this report.

The regional distribution of the species is associated with well-drained, sandy soils with moderate to dense stands of stringybark woodland *Eucalyptus baxteri/arenacea,* bracken *Pteridium esculentum* and heathland, including yacca *Xanthorrhoea* spp. (e.g. Figure 1-3) and tea-tree *Leptospermum* spp. (Paull 2003, Brown and Main 2010).

Figure 1-3: Eucalyptus baxteri heathy woodland with yacca in Dry Creek NFR (Caroline Forest). Photo: Mark Bachmann

In the South East, it is only known to inhabit fragmented patches of moderate to high quality remnant vegetation, while elsewhere in its range the species has also been recorded utilising more modified habitats in closer proximity to humans (Coates *et al.* 2008).

Of note, twenty-four biodiversity corridors in the pine forests of the lower South East are gradually being set aside from production (in stages, as relevant compartment areas are harvested) and being revegetated with native species, as shown in Figure 1-4.

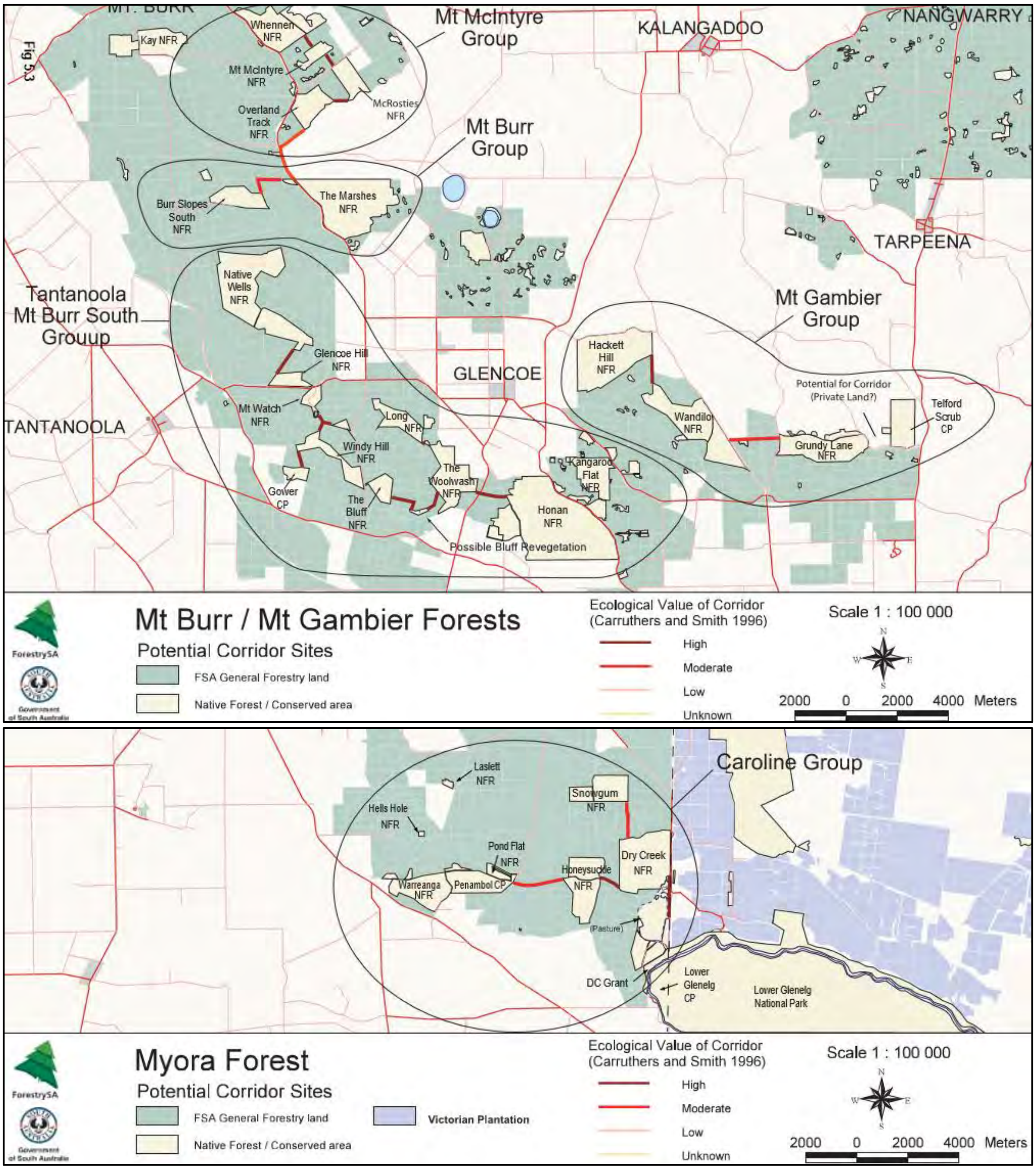

Figure 1-4: Important native vegetation patches and biodiversity corridor locations as original proposed by ForestrySA (Horn 2003)

The goal of this long-term strategy is to facilitate the movement of a range of fauna, with a specific focus on threatened species such as the Southern Brown Bandicoot, between currently isolated patches; aiding recruitment and genetic dispersal between populations

(Horn 2003, Paull 2003). The original proposed locations of the corridors in the Mt Burr and Caroline Forests are shown in Figure 1-4, noting that the precise location of some of these corridors have been slightly altered during the establishment phase to meet operational or practical requirements on the ground.

Fire is another key consideration identified in the literature, as burning frequency has the capacity to significantly alter vegetation structure and composition and hence may have a significant impact on Southern Brown Bandicoot populations (Rees and Paull 2000, Paull 2003), with inappropriate fire regimes identified as a major threat (Claridge 2000). Prescribed burning regimes occur at the majority of sites surveyed in the South East (Harley 2006). Forestry SA manages the variable prescribed burning regime across the compartments (management areas) that each Native Forest Reserve is broken up into, with a variable burn frequency of 3 to 35 years. This creates a mosaic of vegetation age classes and understorey densities, which (on the basis of past outcomes) appears to be compatible with conserving Southern Brown Bandicoot populations. A 15 to 20 year period since fire is often identified as being optimal for the Southern Brown Bandicoot, as burning at shorter or longer intervals may create an inappropriate spatial and temporal arrangement of suitable habitats (Claridge *et al.* 1991, Possingham and Gepp 1996, Paull 2003). In particular, recently burnt sites (up to 4 to 6 years previously) tend to have lower occupancy (Paull 1999).

Further research in the South East region is required to determine the most effective fire management regimes for the Southern Brown Bandicoot as well as other target mammal species, including the Feathertail Glider *Acrobates pygmaeus* (state endangered), Heath Mouse *Pseudomys shortridgei* (nationally endangered) and Red-necked Wallaby *Macropus rufogriseus* (state rare) (Horn, 2003).

2. AIMS AND OBJECTIVES

The aim of this report was to determine the current status of Southern Brown Bandicoot populations across the species' current range in the South East region of South Australia

Specific objectives were:

1. To assess Southern Brown Bandicoot occupancy rates in potential habitats across the lower South East.

2. To document Southern Brown Bandicoot activity in those habitats where the species was found to be present, enabling:

    a. an analysis of changes in site-scale digging abundance across the three survey periods (1998, 2007 and 2016); and

    b. a combined assessment of the relationship between digging abundance and time since last fire, to help understand the relationship between prescribed burning regime and current or potential habitat.

3. METHODS

3.1. Study area

Digging abundance surveys of the Southern Brown Bandicoot were conducted at Nangwarry, Mt Burr Range and Caroline Forests across its current known range in the South East region of South Australia, during a 3-month period (April to June 2016) (Figure 3-1).

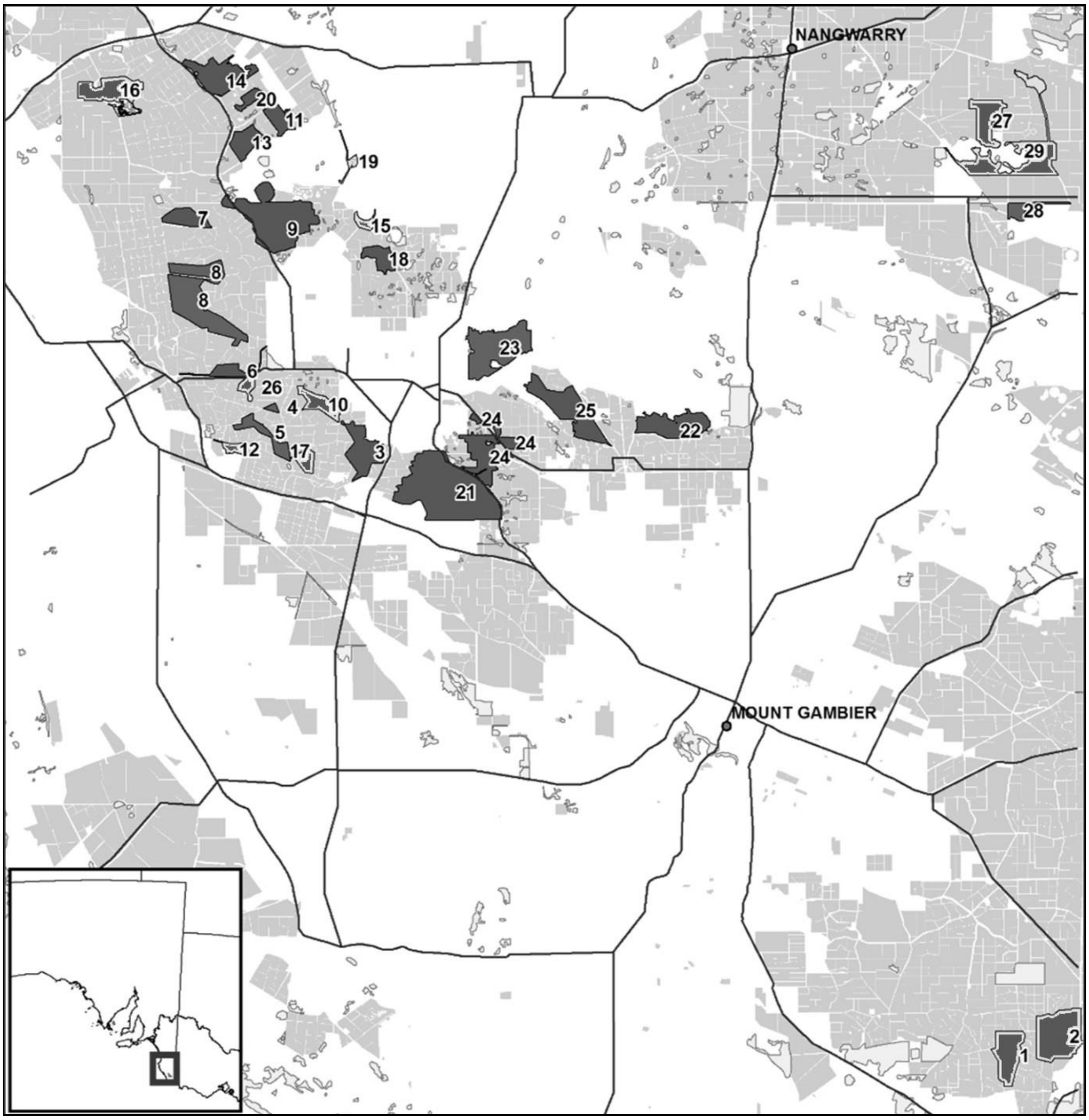

Figure 3-1: The 29 remnant vegetation patches surveyed for bandicoot diggings in 2016. These were: Caroline - Honeysuckle (1), Dry Creek (2); Mt Burr Range - The Woolwash (3), Windy Hill North (4), Windy Hill South (5), Glencoe Hill (6), Burr Slopes South (7), Native Wells (8), The Marshes (9), Long (10), McRosties (11), Gower Conservation Park (12), Overland Track (13), Whennen (14), Lake Leake (15), Kay (16), The Bluff (17), Mt Lyon (18), Brooksbys (19), Mt McIntyre (20), Honan (21), Grundy Lane (22), Hackett Hill (23), Kangaroo Flat (24), Wandilo (25), Mt Watch (26); Nangwarry - The Heath (27), Paltridges (28) and Byrnes (29).

Of the 29 native vegetation patches surveyed, three were within Nangwarry Forest and two within Caroline Forest, while the majority (24) were clustered within the pine forest matrix along the Mt Burr Range (Table 3-1). The three surveys that have occurred have been completed approximately 9 years apart: 1998/99, 2007/08 and 2016.

Table 3-1: The 29 patches surveyed across all survey periods, with number of sites per patch.

Patch (and/or NFR) Name	Locality	Size (ha)	Target no. sites (~1 / 20ha)	Target no. sites (~1 / 40ha)	No. sites surveyed 1998/99	No. sites surveyed 2007/08	No. sites surveyed 2016
Dry Creek	Caroline	419	21	n/a	22	22	21
Honeysuckle	Caroline	258	13	n/a	14	14	13
Brooksbys	Mt Burr	15	1	0	2	2	1
Burr Slopes South	Mt Burr	132	7	3	10	10	3
Glencoe Hill	Mt Burr	65	3	2	5	5	5
Gower Cons. Park	Mt Burr	39	2	1	4	4	1
Grundy Lane	Mt Burr	261	13	7	15	15	11
Hackett Hill	Mt Burr	444	22	11	39	35	22
Honan	Mt Burr	1004	50	25	51	43	25
Kangaroo Flat	Mt Burr	214	11	5	13	9	9
Kay	Mt Burr	214	11	5	13	13	13
Lake Leake	Mt Burr	30	2	1	1	1	1
Long	Mt Burr	120	6	3	9	9	9
McRosties	Mt Burr	105	5	3	7	7	3
Mt Lyon	Mt Burr	85	4	2	8	6	2
Mt McIntyre	Mt Burr	57	3	1	5	4	2
Mt Watch	Mt Burr	47	2	1	5	5	5
Native Wells	Mt Burr	568	28	14	30	28	28
Overland Track	Mt Burr	124	6	3	9	7	3
The Bluff	Mt Burr	71	4	2	5	5	5
The Marshes	Mt Burr	536	27	13	29	25	13
The Woolwash	Mt Burr	245	12	6	15	15	6
Wandilo	Mt Burr	397	20	10	24	23	20
Whennen	Mt Burr	234	12	6	13	13	6
Windy Hill North	Mt Burr	15	1	0	3	2	2
Windy Hill South	Mt Burr	113	6	3	8	8	8
Byrnes	Nangwarry	373	19	n/a	6	6	19
Paltridges	Nangwarry	67	3	n/a	2	2	3
The Heath	Nangwarry	211	11	n/a	5	5	11

Patches ranged in size from 15 ha (minimum) to 1004 ha (maximum), with a mean patch size of 223 ha. All but four of the surveyed patches of native vegetation are managed by Forestry SA (as Native Forest Reserves, which are considered Protected Areas under the National Reserve System). The exceptions include three patches located on private property and one is a Conservation Park managed by the Department of Environment, Water and Natural Resources (DEWNR).

The local climate is characterised by warm summers and cool, wet winters, with an annual rainfall of 650-850 mm (Paull 2003) and mean annual rainfall of 782.4mm (for the period 1950 – 2015, measured at Tantanoola, BOM 2016). Mean minimum and maximum annual temperatures are 8.1 – 19.0°C (for the period 1942 – 2016, measured at Mt Gambier Aero station, BOM 2016). Climate (especially rainfall) drives ecosystem productivity, hence inter-annual (April to March) rainfall variability for Australia over the year of the survey (and the year prior) is a relevant consideration for this report, as shown in Figure 3-2.

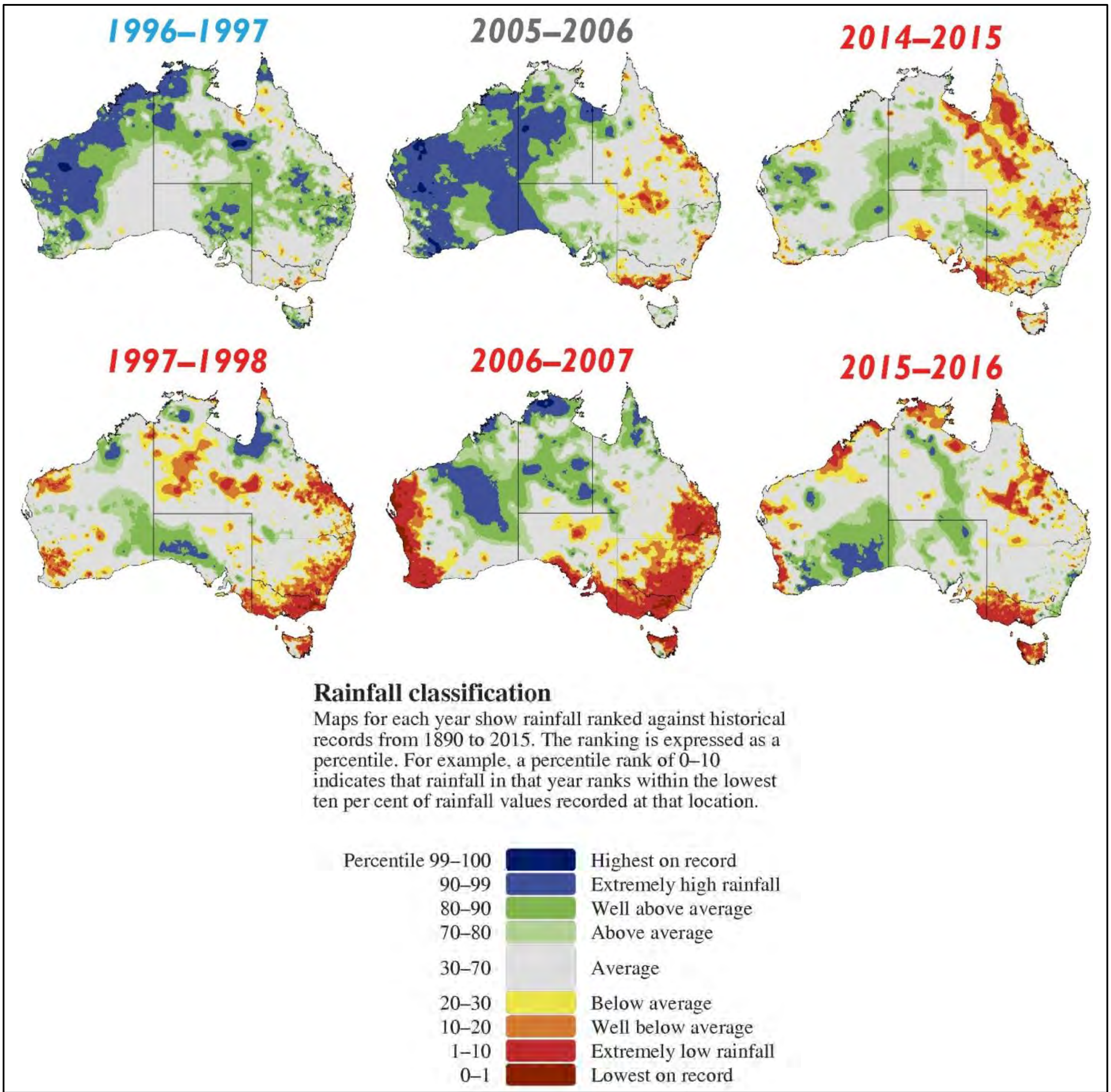

Figure 3-2: Inter-annual (April to March) rainfall variability for Australia during key dates relevant to the three digging abundance surveys, the year of the survey and the year prior.
From: Department of Science, Information Technology and Innovation (DSITI), Queensland Government, 2016.

The three survey years (the bottom row of three maps) were El Niño years, and all resulted in significantly below average rainfall for the South East of South Australia. With the exception of average rainfall in the region the year before the first survey, the next two surveys also took place after below average rainfall years. Hence the climatic conditions were broadly similar between the three survey years; an important variable to be able to largely eliminate when later considering comparative survey results.

3.2. Survey design

In the 1998/99 and 2007/08 surveys, there was generally (on average) a survey site for every 20 hectares (ha) in a patch in the Mt Burr Range, and a slightly lower survey effort within the Caroline and Nangwarry Forests (a site for every 30-40 ha in a patch).

In 2016, (due to time constraints) the survey method was also limited in the first instance to 1 survey site for every 40 hectares in a patch in the Mt Burr Range. The survey was ended at this point if the percentage of sites occupied (showing evidence of diggings within a patch) was at or above the level recorded in the previous survey period (2007/08) in that patch.

However, if the percentage of survey sites occupied in that first round in 2016 was less than 2007/08 surveys, then remaining sites (up to the original density of 1 survey site per 20 ha) in the patch were surveyed, consistent with the original method. This explains the variable number of sites sampled in 2016 shown in (Table 3-1), in comparison to previous surveys in the Mt Burr Range.

This sampling methodology still allowed all patches to be compared to previous survey periods, albeit with less power in cases where the number of survey sites was reduced. The Nangwarry and Caroline Forest patches were surveyed at 1 per 20 ha, as the two previous surveys had under-sampled at these patches.

In total, of the 372 and 343 sites surveyed previously (1998/99, 2007/08 respectively), 270 sites were re-surveyed in 2016.

Digging abundance was used to measure presence (occupancy), distribution and level of activity within a patch and can also be used, indirectly, as a surrogate for bandicoot abundance (Paull 2003). Diggings provide a clear indication that the site is or was being used (within a period of months) by the Southern Brown Bandicoot (Fairbridge *et al.* 2001) making it an efficient, non-intrusive alternative to trapping and handling. The diggings made by the Southern Brown Bandicoot are conical, near vertical diggings with one spoil mound (dug between their hind legs); see Figure 3-3. This usually makes them distinguishable from a range of other species including the echidna, swamp rat, bush rat, Australian raven, chough and European rabbit.

The Long-nosed Potoroo *Potorous tridactylus* also creates diggings that can be confused with the Southern Brown Bandicoot, but in the South East have only been recorded co-habiting with the Southern Brown Bandicoot in the Lower Glenelg River Conservation Park (adjacent to the Caroline Forest area, east of the Glenelg River – noting that at this location the river is a major geographical barrier to dispersal). The Long-nosed Potoroo is otherwise considered extinct in South Australia (west of the Glenelg River), and so was not a confounding factor for the survey results.

The number of survey sites allocated per patch, were stratified in relation to patch area. Site occupancy and abundance was estimated by actively walking through each site to record and count Southern Brown Bandicoot diggings. Each site was a 100 x 100 m (1 ha) quadrat; the approximate minimum home range size (9 ha being the upper recorded limit) for the species (Paull 2003).

Figure 3-3: A fresh, conical shaped Southern Brown Bandicoot digging. Inset shows the same image with impression of hind legs (red shading) and tail (blue shading) highlighted.
Photo: Mark Bachmann, 2002.

To ensure that the majority of each site was surveyed, the GPS "tracks" function was used. The level of activity at a site was determined by categorising diggings into age classes: fresh (<2 weeks), recent (2 weeks – 2 months), and/or old (>2 months), as shown in Figure 3-4.

Figure 3-4: Examples of fresh (left), recent (centre), and old (right) Southern Brown Bandicoot diggings.
Photos: Mark Bachmann.

The number of diggings was counted to generate an estimate per 100m walked within the quadrat (Paull 2003), but as we were especially interested in confirming the presence/absence of the Southern Brown Bandicoot we also estimated digging abundance for the entire 100 x 100 m. These counts were assigned into digging abundance score categories: 0 (0 diggings), 1 (1-5 diggings), 2 (6-20 diggings), 3 (21 -50 diggings) 4, (≥51 diggings).

Digging records were used to determine site occupancy and the proportion of a patch occupied, based on the number of sites per patch where the Southern Brown Bandicoot was present. The percentage of sites occupied within a patch was compared to an earlier survey period by calculating the difference in site occupancy (e.g. proportion of sites occupied in 2016 – proportion of sites occupied in 2007/08, per patch) (Table 2), to determine whether patch occupancy had decreased, remained stable or increased in 2016 (Figure 2 & 3). Thresholds of ≥30% increase or ≥30% decrease were applied (and were assumed sufficient to account for uncertainty).

3.3. Fire history analysis

Using comprehensive prescribed burning data (Forestry SA) available by compartment for most Native Forest Reserve patches for the past 60-80 years, the relationship between site 'occupancy' and 'activity' in respect to how both of these measures change with 'time since fire' could be examined. **Occupancy** is simply the presence or absence of diggings (and hence bandicoots); whereas **activity** is the more quantitative measure of digging abundance at those sites where the species was present (according the scale provided in Section 3.2).

For all fire history analysis, digging abundance data for each site survey was pooled across the 5 age class categories (0-4), to give a total activity estimate at the site. The hypothetical score range was from 0 to 12, but the potential maximum was actually only 9; as no sites within the data were found to have more than 50 diggings, there are no category 4 records.

Examples of different stages of post-fire recovering bandicoot (heathy woodland) habitat at Wandilo NFR, after a fire in February 2000, are shown in Figure 3-5.

Sept 2000 ***Sept 2003***

Figure 3-5: Post-fire habitat recovery after the February 2000 Wandilo bushfire

Photos: Mark Bachmann.

3.3.1 Patch and site based analysis

For the first round of fire history analysis, each compartment was assigned a 'time since fire' category, applicable at the **site and patch scale**.

Time since fire (by category) data was created for each of the three surveys, by firstly deducting the last fire age (for each compartment) from the year of survey (for each site in a given compartment), and then assigning the results according to the following scale categories: 1 – 6 years, 7 – 14, 15 – 20 and > 20 years since fire. This was done in order to align with those used by Paull (1999, 2003).

Due to a high degree of local variability in terms of digging abundance between sites at individual patches (Paull 2003), selected patches (identified as stable, decreasing or increasing in site occupancy from 2007 - 2016) were also examined individually, by comparing digging abundance per site across survey periods. This allowed the relationship between fire frequency (and/or year of fire) and digging abundance to be observed by compartment (per patch), also allowing visual determination of whether previously unoccupied and unburnt sites adjacent to burnt sites, became occupied post-fire.

3.3.2 Complete 'time since fire' analysis across all survey data

For the second round of fire history analysis, all 'time since fire' data (from all 3 surveys and all locations) was pooled, in order to create a much larger overall dataset for observing trends in bandicoot occupancy and activity, in its relationship to fire, at the **regional scale**.

The results were pooled and sorted according to time since fire (in years), which resulted in a list of 958 unique 'time since fire' digging abundance data records. Sites in a patch where fire history was not known resulted in the exclusion of 43 data records from the analysis. Thanks to the previous meticulous record keeping of ForestySA (and its predecessor, the Woods and Forests Department) over several decades, almost all (95.7% of) data were able to be assigned an accurate date of last fire.

Finally, when an average was generated for any given 'time since fire' year, years where the number of site records was less than 10 were excluded. This was done in order to prevent a skewed average in those years with limited records available. Because all records were given equal weighting as a data-point when charted, this prevented years that were data poor from distorting overall trends.

4. RESULTS

4.1. Occupancy across the region

Overall, Southern Brown Bandicoot patch occupancy has declined slightly from the 2007/08 survey, but is the same as the 1998/99 survey, with 23 of 29 patches visited across the South East region having confirmed populations in 2016 (Table 4-1). In comparison, 23 and 25 (of 29) patches were occupied in the 1998/99 and 2007/08 survey periods respectively.

Table 4-1: The percentage of survey sites occupied (where the Southern Brown Bandicoot was present) per native vegetation patch for the three survey periods: 1998/99, 2007/08 and 2016.

Patch	Locality	Size (ha)	% sites occupied 1998/99	% sites occupied 2007/08	% sites occupied 2016
Dry Creek	Caroline	419	27	64	24
Honeysuckle	Caroline	258	14	29	15
Brooksbys*	Mt Burr	15	0	0	0
Burr Slopes South*	Mt Burr	132	0	30	67
Glencoe Hill	Mt Burr	65	100	60	60
Gower Cons. Park*	Mt Burr	39	50	0	0
Grundy Lane	Mt Burr	261	73	60	82
Hackett Hill	Mt Burr	444	54	37	32
Honan	Mt Burr	1004	56	53	76
Kangaroo Flat	Mt Burr	214	89	100	89
Kay	Mt Burr	214	8	54	15
Lake Leake*	Mt Burr	30	0	0	0
Long	Mt Burr	120	67	44	0
McRosties*	Mt Burr	105	71	86	100
Mt Lyon*	Mt Burr	85	0	33	100
Mt McIntyre*	Mt Burr	57	50	100	100
Mt Watch	Mt Burr	47	80	80	0
Native Wells	Mt Burr	568	54	86	36
Overland Track*	Mt Burr	124	57	57	67
The Bluff	Mt Burr	71	0	0	0
The Marshes	Mt Burr	536	40	44	62
The Woolwash	Mt Burr	245	87	53	83
Wandilo	Mt Burr	397	83	83	95
Whennen	Mt Burr	234	77	69	67
Windy Hill North*	Mt Burr	15	50	50	50
Windy Hill South	Mt Burr	113	75	100	38
Byrnes	Nangwarry	373	67	33	11
Paltridges*	Nangwarry	67	0	50	33
The Heath	Nangwarry	211	60	60	20
			1998/99	**2007/08**	**2016**
TOTAL NUMBER OF SITES OCCUPIED (of 29)			23/29	25/29	23/29

**Indicates patches with low sample sizes of <5 sites surveyed in 2016, with all affected data, including earlier surveys, indicated in red. Hence figures for % of occupied sites at these patches are based on very limited sample sizes, and should be treated with caution.*

In 2016, based on site occupancy and patch size, the Mt Burr Range remains the South East stronghold for the Southern Brown Bandicoot, while the Nangwarry and Caroline Forests appear less viable on the basis of much lower recorded frequencies of confirmed bandicoot activity (Figure 4-1).

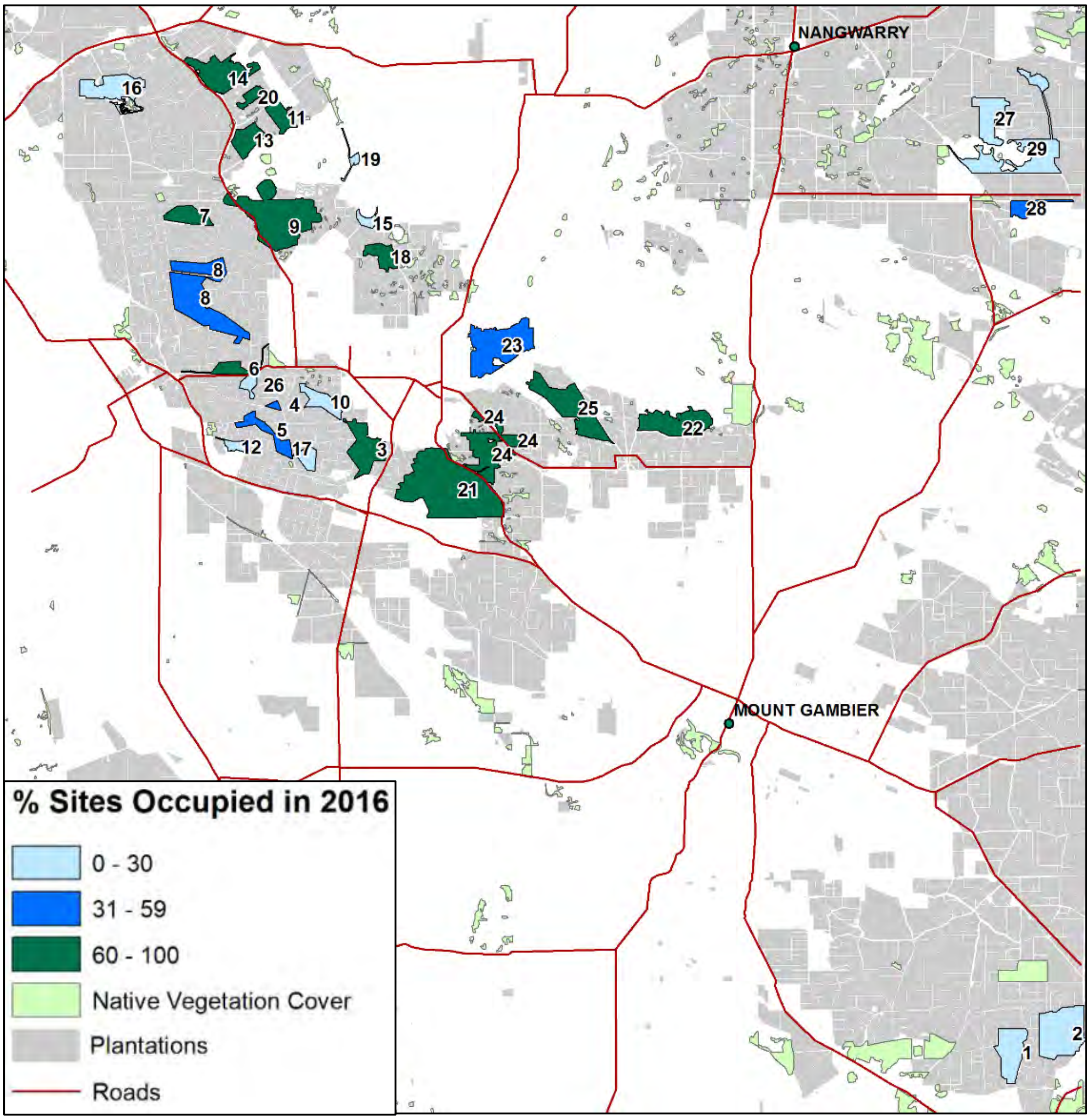

Figure 4-1: The percentage of sites occupied (where the Southern Brown Bandicoot was confirmed present) per native vegetation patch surveyed in 2016.

Consistent with this overall trend, the Mt Burr Range cluster of reserves contained the only patches with the highest site occupancy category; Grundy Lane, Kangaroo Flat, McRosties, Mt Lyon, Mt McIntyre, The Woolwash and Wandilo had site occupancy ≥80% (Figure 4-1).

Low site occupancy (<30%) was recorded in all three population areas, with the following reserves falling into that category: Kay, Brooksbys, Lake Leake, Gower Conservation Park, Long, Mt Watch and The Bluff (Mt Burr Range), The Heath and Byrnes (Nangwarry Forest) and Dry Creek and Honeysuckle (Caroline Forest) (Figure 4-1).

4.2. Occupancy rates per remnant patch

4.2.1 1998 to 2007: early trends in the Mt Burr Range patches

For the first inter-survey period (1998/99 – 2007/08), occupancy increased at four patches (Kay, Mt Lyon, Mt McIntyre, Native Wells) and decreased at three patches in the Mt Burr Range (Glencoe Hill, Gower Conservation Park and The Woolwash), as shown in Figure 4-2.

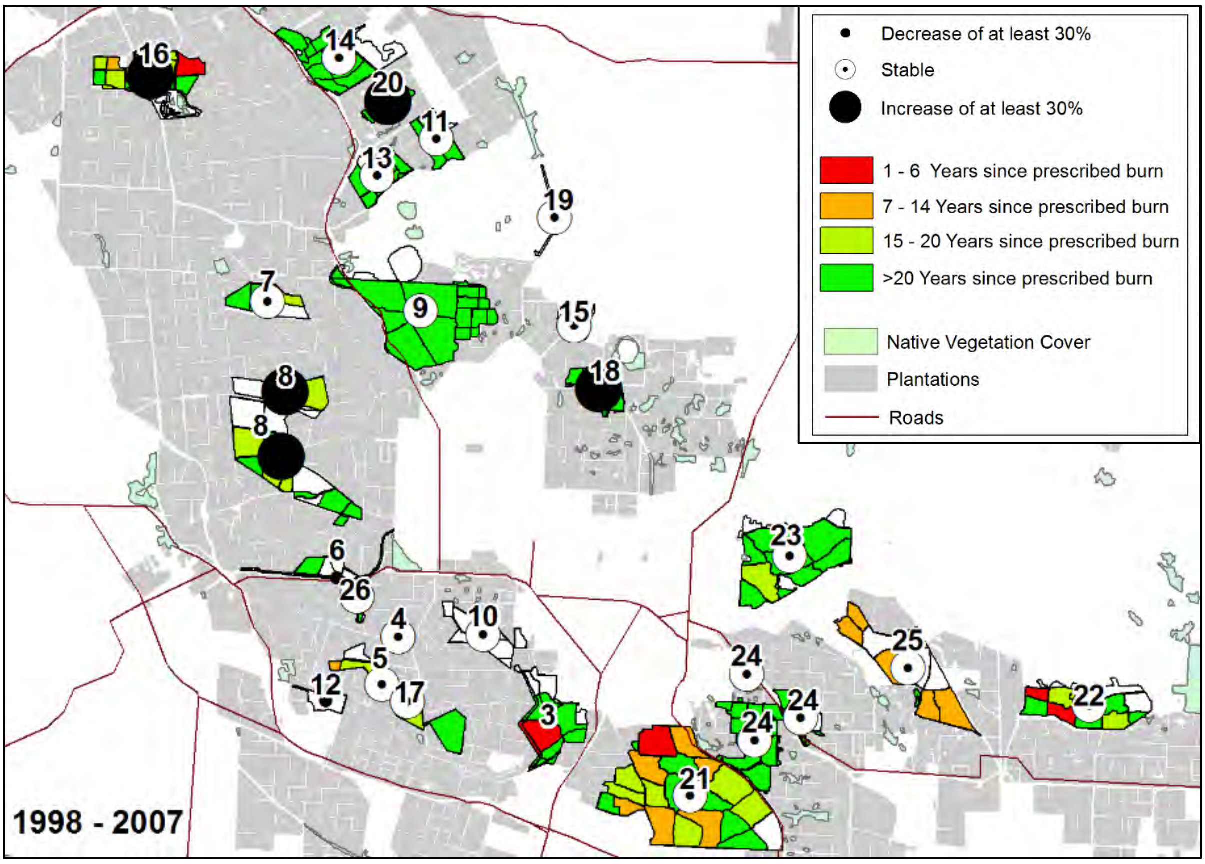

Figure 4-2: Change in Southern Brown Bandicoot occupancy and time since fire in the Mt Burr Range remnant patches: 1998 to 2007

4.2.2 1998 to 2016: longer-term trends in the Mt Burr Range patches

To reveal longer term trends (over a 17 or 18 year time frame), the percentage of sites occupied per patch were compared between the earliest and most recent survey periods (1998/99 and 2016).

Five patches in the Mt Burr Range had decreased occupancy (Glencoe Hill, Gower Conservation Park, Long, Mt Watch, Windy Hill South), and three patches (Burr Slopes South, Mt Lyon, Mt McIntyre) increased, as shown in Figure 4-3.

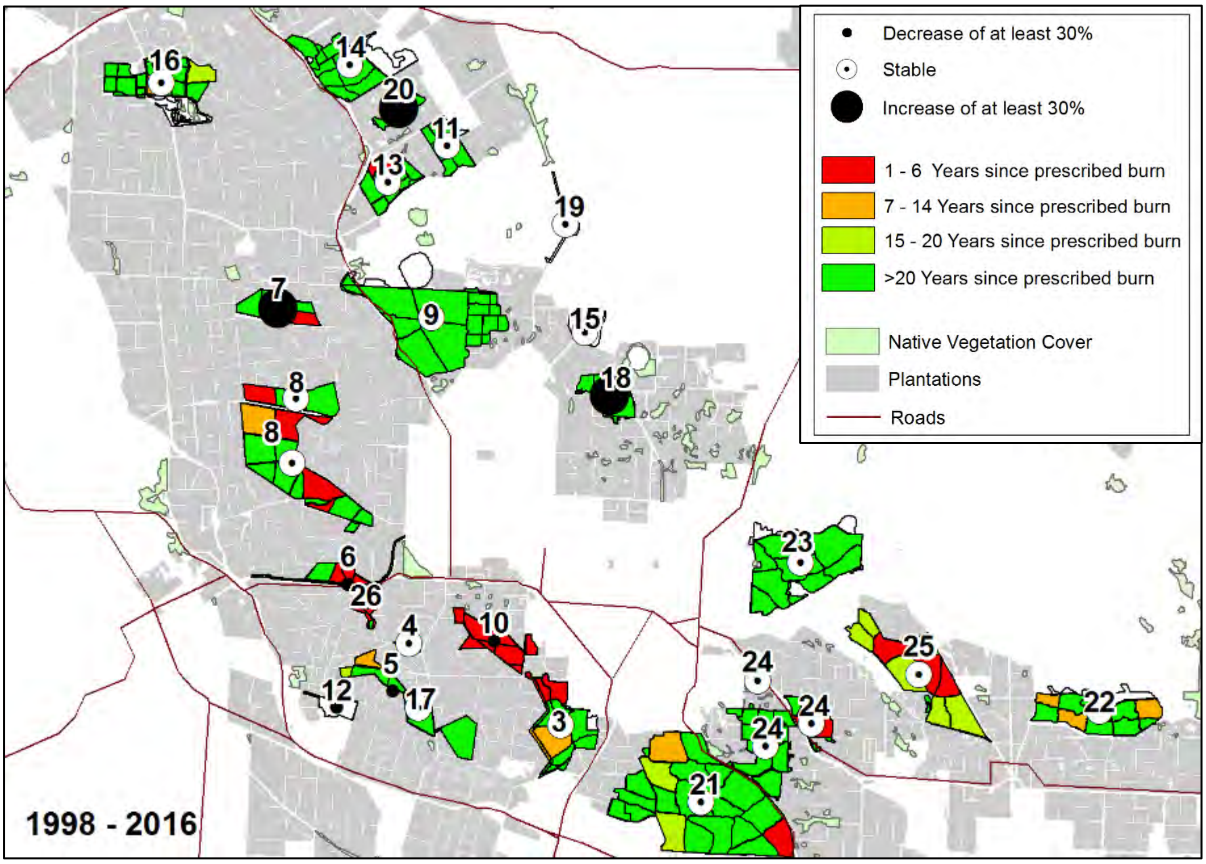

Figure 4-3: Change in evidence of Southern Brown Bandicoot occupation and time since fire in the Mt Burr Range remnant patches: 1998 to 2016

4.2.3 2007 to 2016: recent trends across all patches

A comparison between the percentage of survey sites occupied by the Southern Brown Bandicoot (i.e. diggings present) per patch across survey periods found that less than half of patches surveyed in 2016 (or 12 of 29) met or exceeded 2007/08 site occupancy (Table 4-1).

Patches experiencing an increase in site occupancy were Burr Slopes South, Mt Lyon and The Woolwash in the Mt Burr Range, as shown in Figure 4-4.

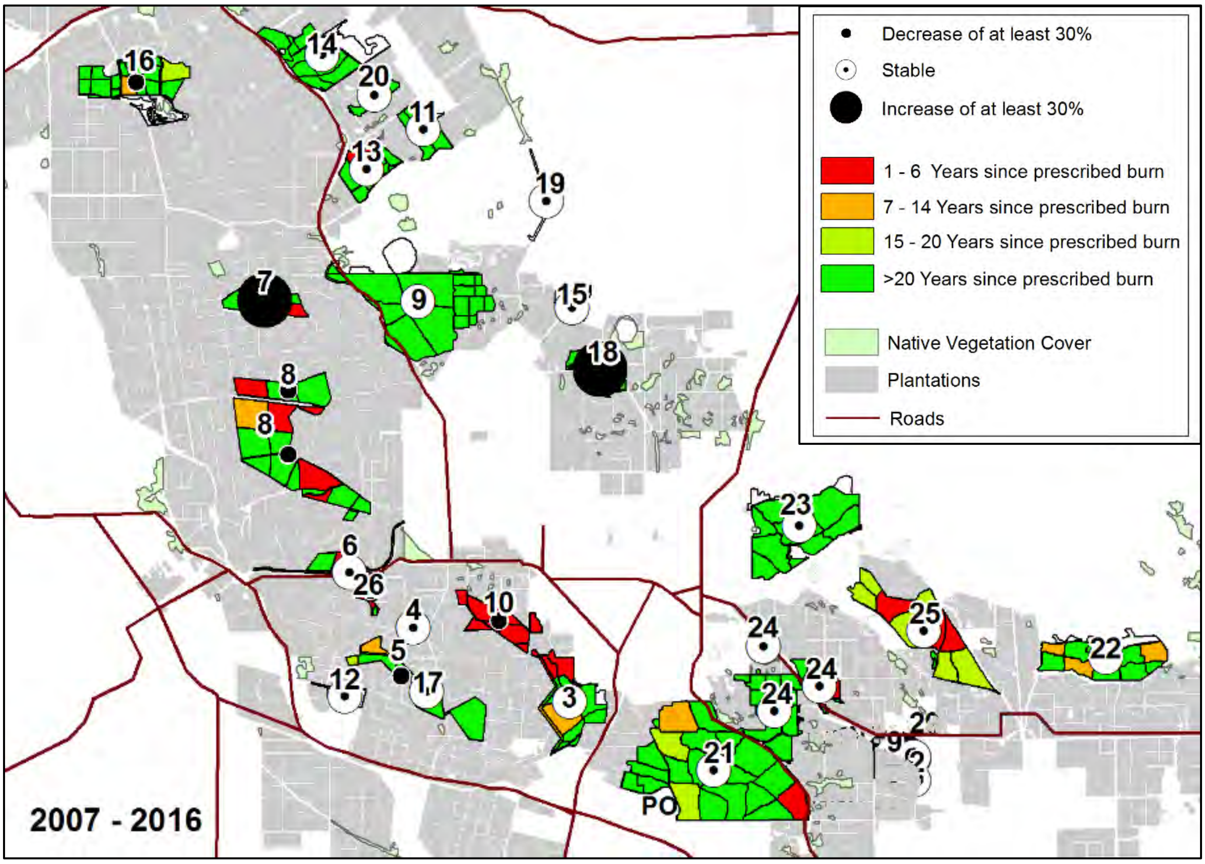

Figure 4-4: Change in evidence of Southern Brown Bandicoot occupation and time since fire in the Mt Burr Range remnant patches: 2007 to 2016

The time since prescribed burn for the majority of these patches was >20 years. Those patches where site occupancy decreased between these survey periods were Dry Creek (Caroline Forest), Kay, Long, Mt Watch, Native Wells, Windy Hill South and The Heath (Mt Burr Range). The majority of Long and Mt Watch and approximately one third of Native Wells were patches that had experienced recent prescribed burns (within 1-6 years).

In the Nangwarry Forest, The Heath decreased in 2016, while Byrnes and Paltridges remained stable, as shown in Figure 4-5. However, only one site within each of the three patches in 2016 had diggings, and they all consisted of a low abundance (score 1) of old diggings.

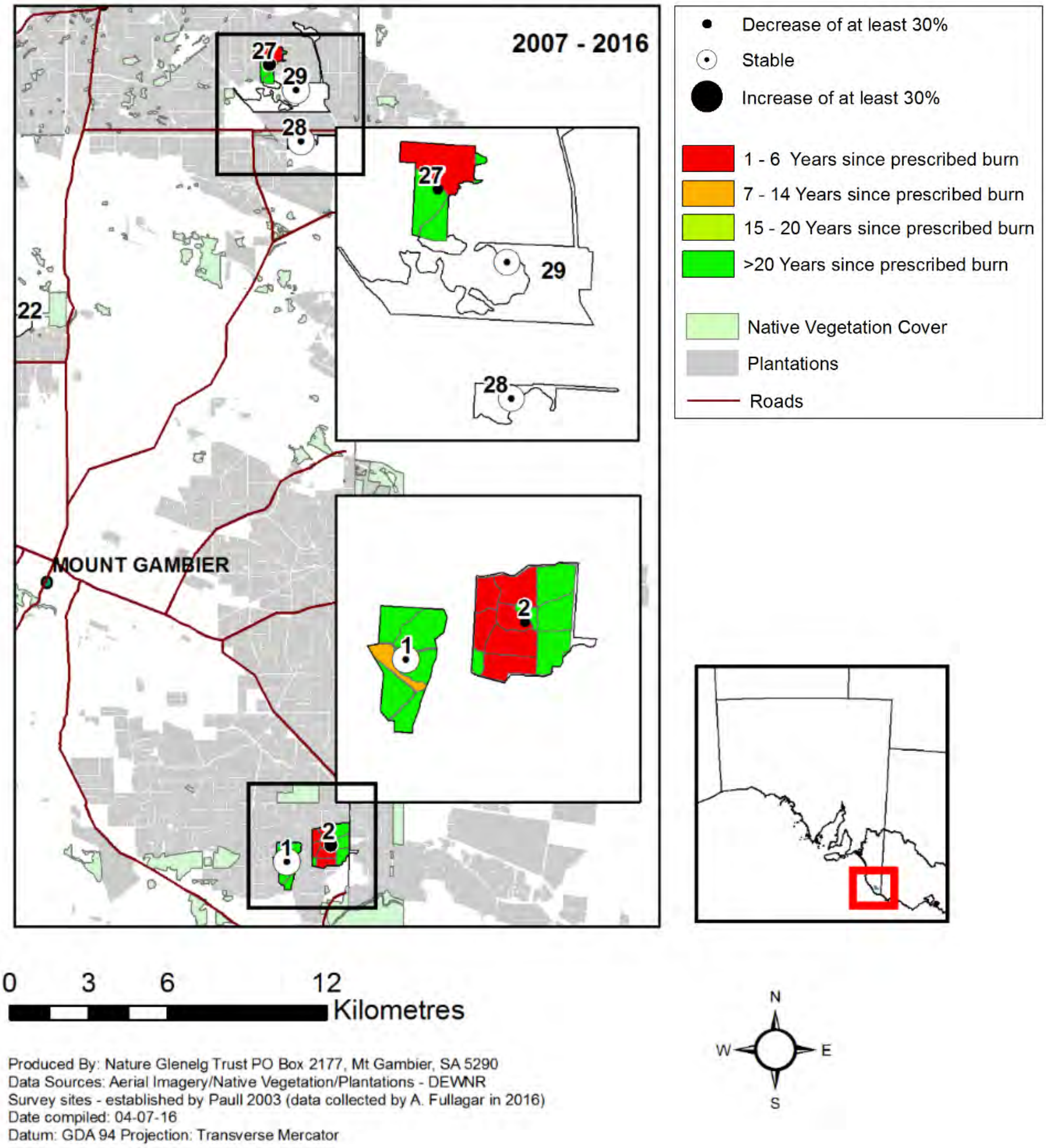

Figure 4-5: Change in evidence of Southern Brown Bandicoot occupation and time since fire in the Nangwarry and Caroline remnant patches – between the first (1998) and most recent (2016) surveys

The two patches in the Caroline Forest (Dry Creek and Honeysuckle) had low levels of occupancy that remained technically remained stable (Figure 4-5), but only on the basis of a few sites having signs of diggings. In 2016, no fresh or recent diggings were detected in Honeysuckle, while in Dry Creek, where approximately 2/3 of the patch was burnt in 2013, no fresh diggings were detected and only two sites had recent diggings.

What can be ascertained from the summary data for both of these forest areas is severely restricted by limited sample sizes; however, it is clear from the raw data that both the Caroline and Nangwarry Forest populations remain at critically low levels of both occupancy and activity.

4.3. Patch and compartment scale time since fire analysis

The relationship between the year of prescribed burns and the change in combined digging abundance was also investigated for each specific digging survey site within selected remnant patches. A number of example patches were selected on the basis of whether their rates of occupancy between surveys were stable, decreasing or increasing.

4.3.1 Sites with stable occupancy

Of the 19 patches that remained relatively stable in terms of site occupancy across the 2007/08 and 2016 surveys, Wandilo and The Marshes (Mt Burr Range) were selected for analysis, on the basis of having vastly different fire histories.

4.3.1.1 Wandilo Native Forest Reserve

At Wandilo, there was a general decline in combined digging abundance in 2016 compared to the two previous survey periods, where 13 of 20 (65%) in 1998/99 and 12 of 20 (60%) sites in 2007/08 had greater combined digging abundances (Figure 4-6).

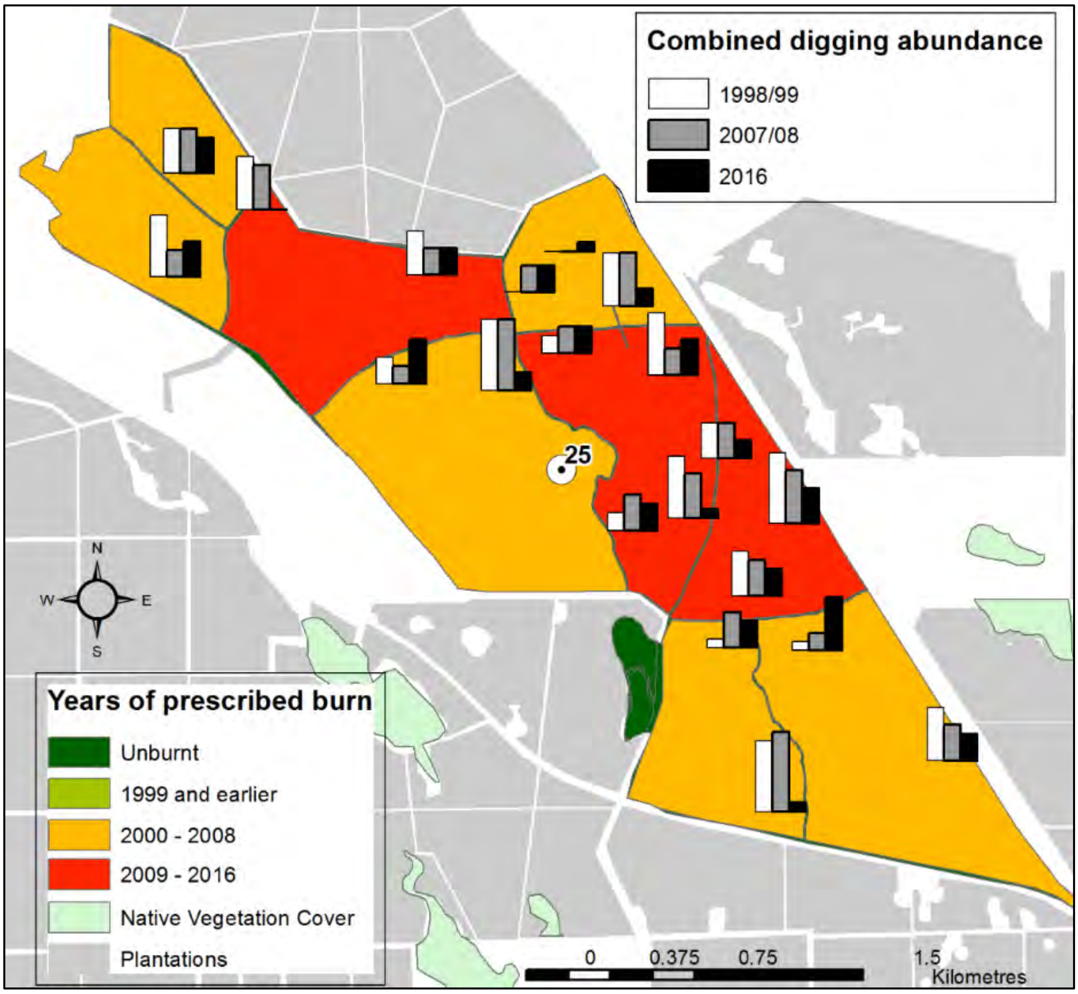

Figure 4-6: Wandilo (Mt Burr Range) with combined digging abundance per survey: 1998/99, 2007/08 and 2016. Overall site occupancy (or presence) for this patch was stable (2007-2016).
Note: Unburnt has no prescribed burning history recorded.

After almost all of the reserve burned in 2000, Southern Brown Bandicoot digging abundances have mostly declined in all areas when compared to their pre-burn activity status in 1998/99. It is interesting to note that a similar proportion of sites in both post-fire ages classes show equal or increased activity in 2016, compared to the 2007/08 survey. Hence in Wandilo, no clear 'time since fire' pattern of digging abundance activity can be easily discerned on the basis of the main two age classes of regenerating vegetation now found in this reserve.

However in summary, and crucially despite the recent intensive fire history, the Southern Brown Bandicoot not only persists, but is widespread in its use of habitat throughout this patch; noting that Wandilo has historically been considered a stronghold for the species.

4.3.1.2 Marshes Native Forest Reserve

In comparison, prescribed burns or bushfires haven't occurred in The Marshes since 1982 and 1983, with areas not burned in those event now extremely long unburned, as shown in Figure 4-7.

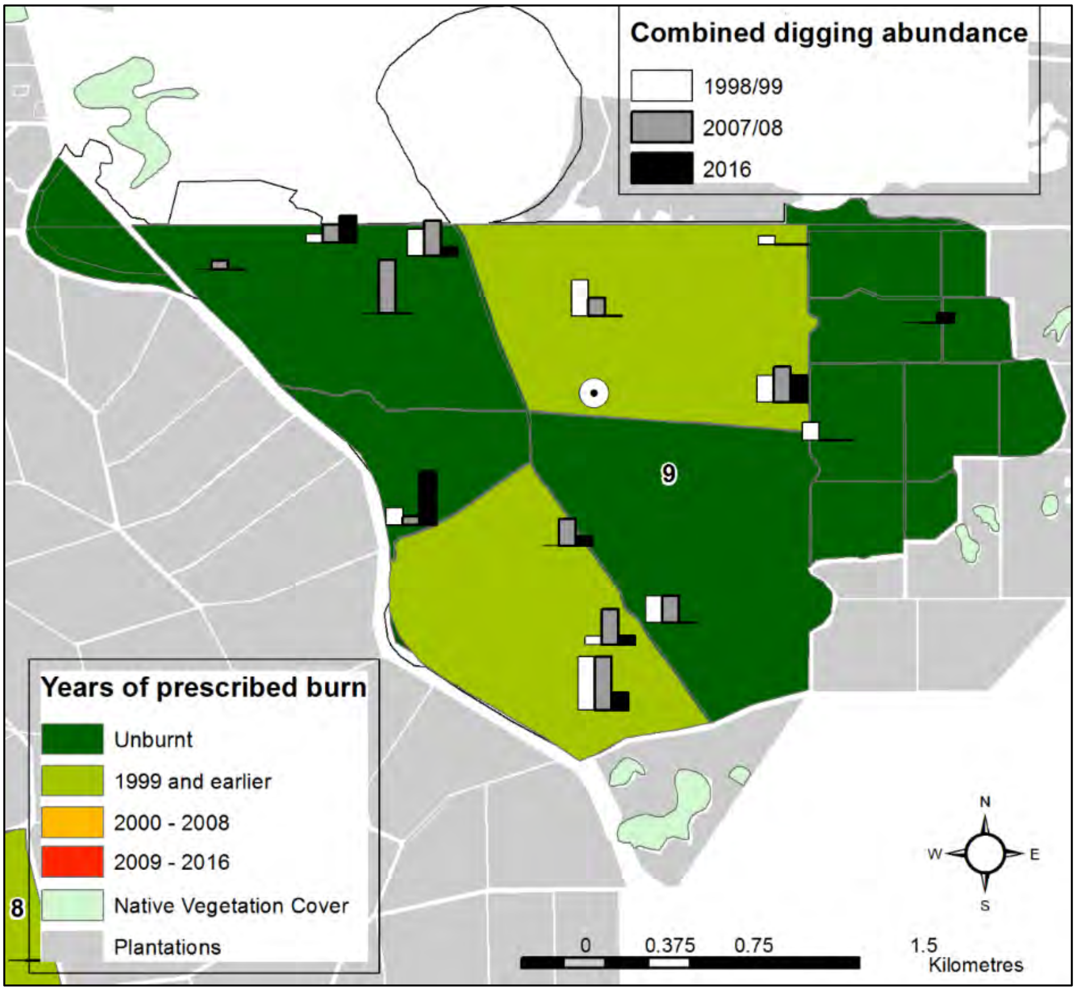

Figure 4-7: The Marshes (Mt Burr Range) with combined digging abundance per survey: 1998/99, 2007/08 and 2016. Overall site occupancy (or presence) for this patch was stable (2007-2016).
Note: Unburnt has no prescribed burning history recorded.

There was a general decline in combined digging abundance in the 2016 site surveys, with only 1 of 14 sites and 3 of 14 sites equal to or exceeding those of 1998/99 and 2007/08 surveys respectively. Of note, all of those three sites with increased combined digging abundance in 2016 (compared the two earlier survey periods), were located in long unburnt areas of the reserve (i.e. 3 of a total of 8 sites in those areas).

4.3.2 Sites with declining occupancy

Combined digging abundance and its relationship with prescribed burns was also assessed at sites with declining occupancy from 2007 to 2016: Dry Creek, Native Wells, Glencoe Hill, Mt Watch and Windy Hill.

4.3.2.1 Dry Creek Native Forest Reserve

At Dry Creek, detectability and combined digging abundances in 2016 were extremely low, with limited recent and old diggings (abundance scores = 1) seen at just 5 survey sites. These limited results were largely restricted to the eastern portion of the reserve which remained unburnt after the 2013 prescribed burn and subsequent bushfire (Figure 4-8).

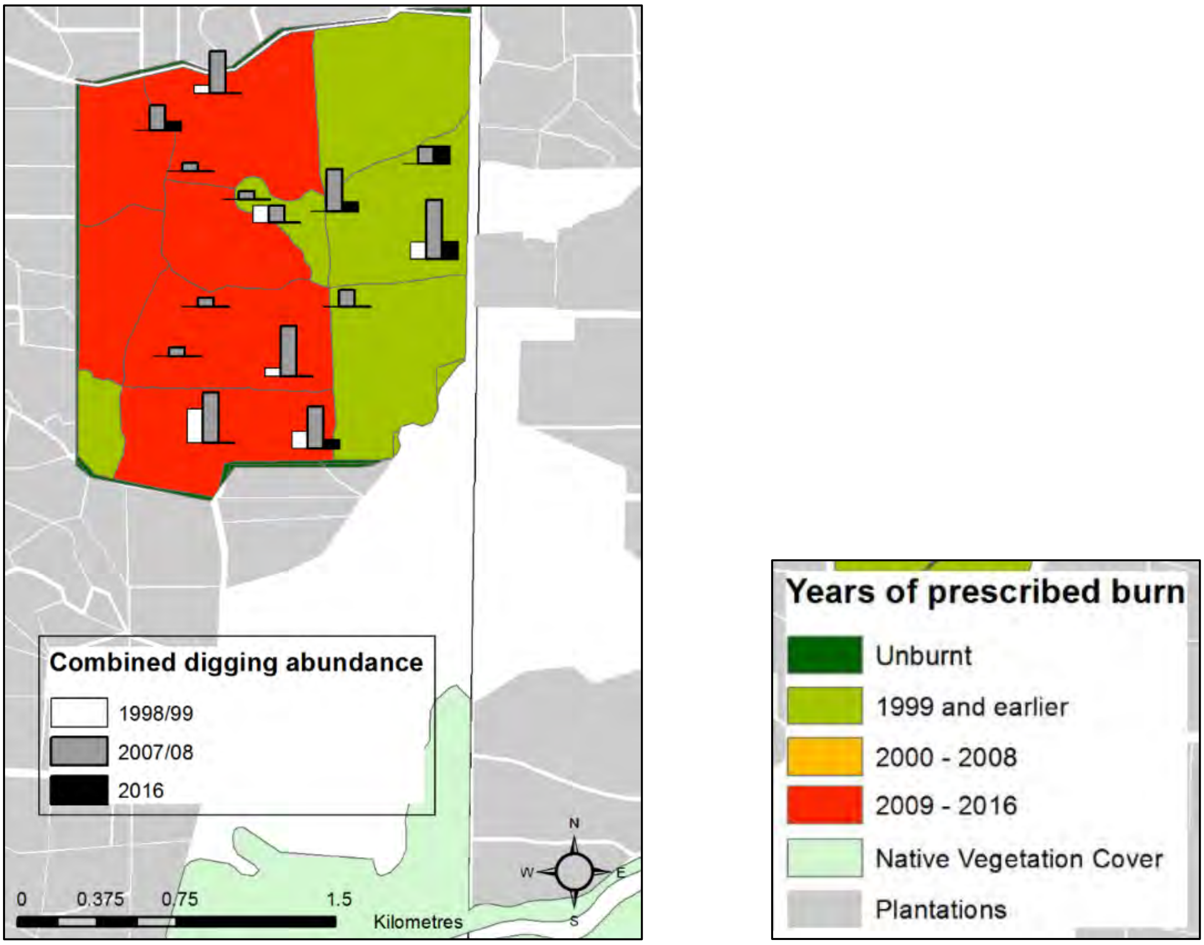

Figure 4-8: Combined digging abundance at Dry Creek (Caroline Forest sites), showing declining occupancy and activity. *Note: Unburnt has no prescribed burning history recorded.*

In 2016, diggings only occurred at 5 of 20 sites surveyed, four of which had declined in abundance since both the 1998/99 and 2007/08 survey periods. Hence, overall site occupancy in Dry Creek decreased by 40%, probably driven by the impact of that fire.

4.3.2.2 Native Wells Native Forest Reserve

At Native Wells, 12 of 28 sites recorded diggings in 2016 and 80% of these sites decreased in combined digging abundance from 2007/08 surveys (Figure 4-9).

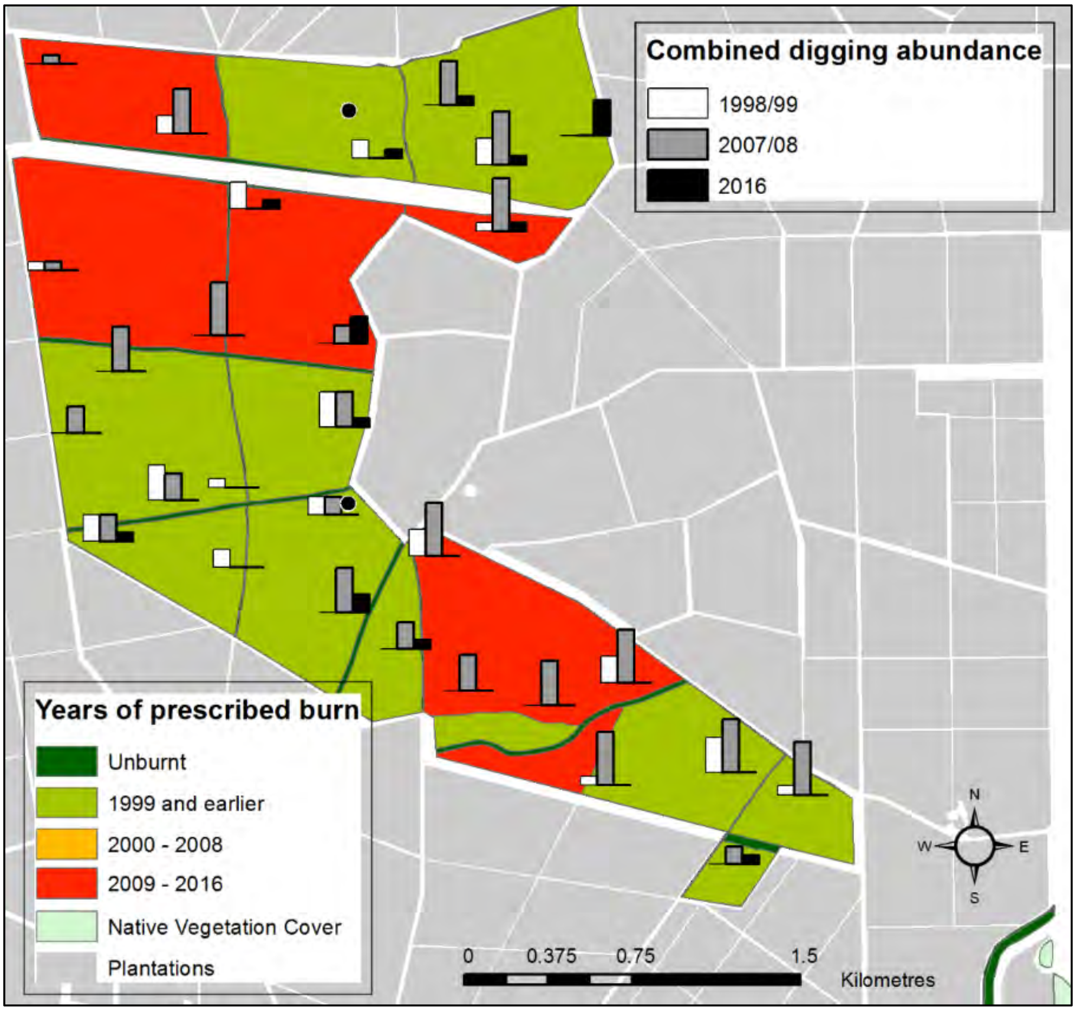

Figure 4-9: Combined digging abundance at Native Wells (Mt Burr Range), showing declining occupancy and activity. *Note: Unburnt has no prescribed burning history recorded.*

The majority (80%) of sites with diggings still recorded were situated in areas that had not been burnt since before 1999 (those compartments were burnt at various times from 1983-1990). The more recent burns in this reserve occurred in 2009, 2010 and 2014.

4.3.2.3 Glencoe Hill and Mount Watch Native Forest Reserves

Glencoe Hill and Mt Watch only recorded 3 of 9 sites with diggings and, of these, two sites declined in digging abundance since 2007/08 (Figure 4-10).

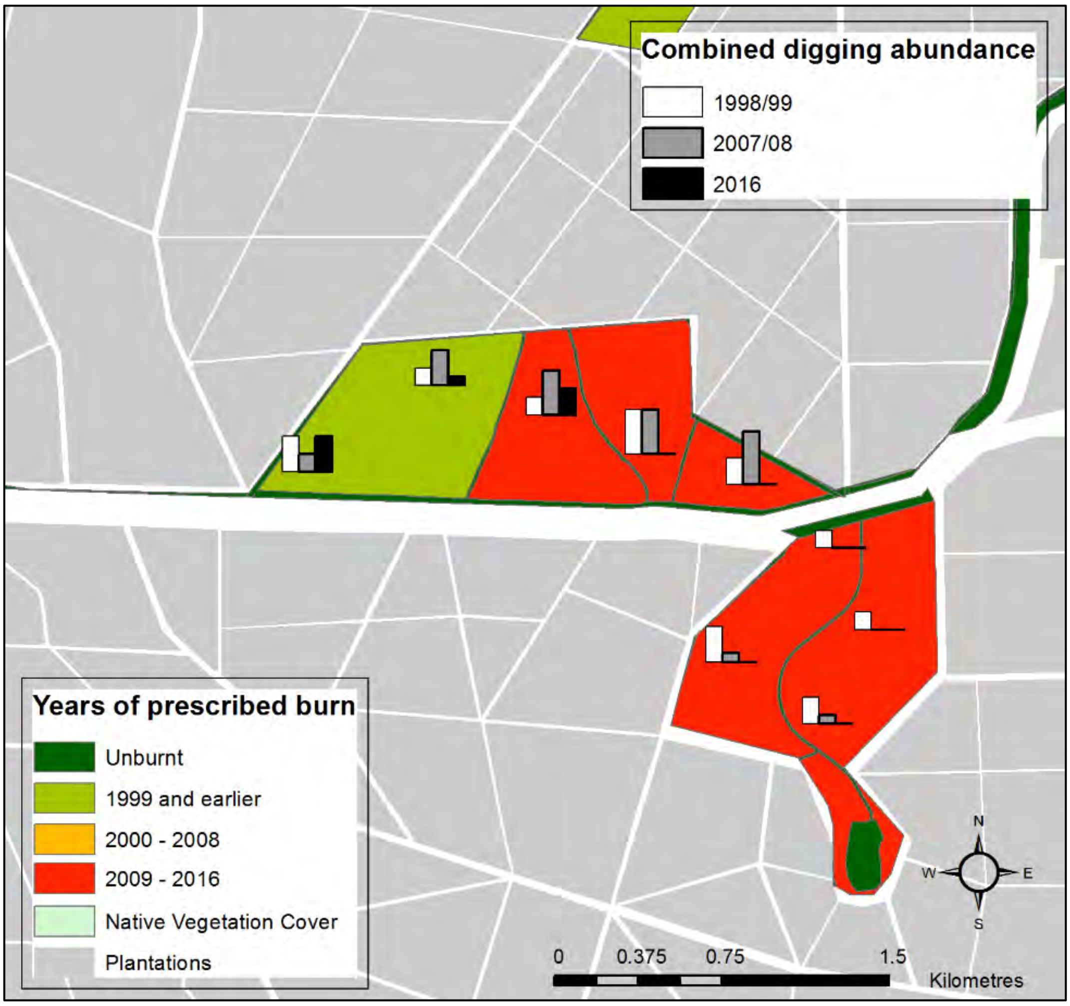

Figure 4-10: Glencoe Hill and Mt Watch site occupancy across both reserves (2007-2016).
Note: Unburnt has no prescribed burning history recorded.

Combined digging abundance in 2016 was greater in the western portion of Glencoe Hill, which consists of an older age of native vegetation (last burnt in 1957). This area had the only digging survey site which didn't experience a decline in activity since 2007, with the rest of the reserve recently burnt in 2015.

4.3.2.4 Windy Hill South Native Forest Reserve

Digging abundance surveyed results for Windy Hill South were variable, but mostly recorded declines, as shown in Figure 4-11.

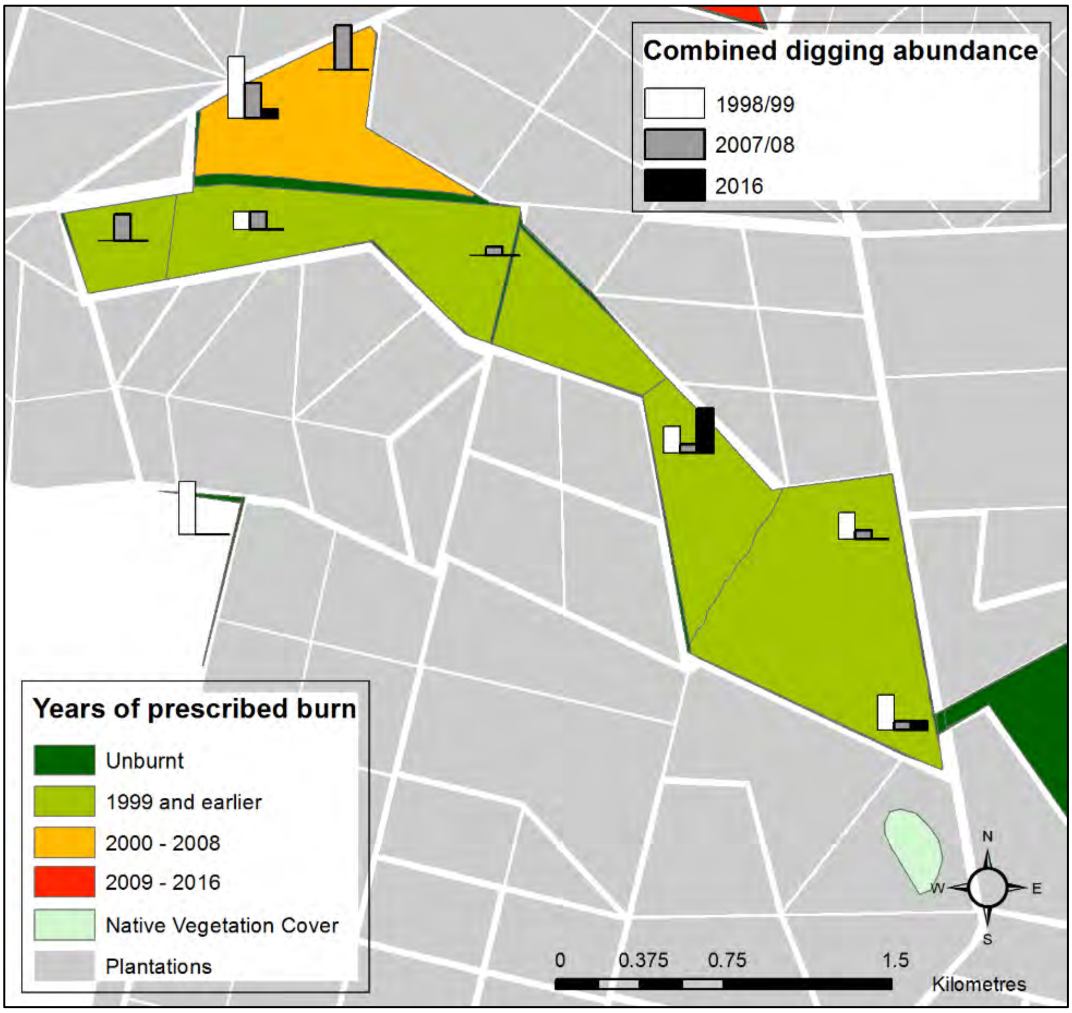

Figure 4-11: Windy Hill South site occupancy across the reserve (2007-2016).
Note: Unburnt has no prescribed burning history recorded.

The key exception was a single site in the centre of the reserve (not burned since the late 1980s), where digging abundance/activity spiked in the most recent survey to its highest recorded levels.

4.3.3 Sites with increasing occupancy

The Woolwash and Burr Slopes South, experienced a technical increase in site occupancy rates from 2007-2016. However, it should be noted that this result is based on limited sample sizes, with only 3 of 10 sites and 6 of 15 sites respectively revisited at each of these reserves. Hence it is difficult to draw any major conclusions for the results except to say that prior occupancy levels certainly appear to have been maintained in these reserves on the Mt Burr Range. To draw any major conclusions from the data in these reserves is not possible without an increase in sample size.

4.4. Regional time since fire analysis

Using the comprehensive fire history information available for the majority of patches or compartments where digging abundance site surveys have taken place, data were pooled and further analysed. Of 1001 individual site surveys completed in the three sampling periods, 95.7% (or 958) were from sites in compartments or patches with comprehensive fire history records and were used to generate the results found in this section.

To enable more meaningful analysis of such a large dataset, the bulk of additional analysis was conducted by generating averages for each year category along the 'time since fire' timeline. Figure 4-12 shows the distribution of available site survey data per year, classified according to time since fire.

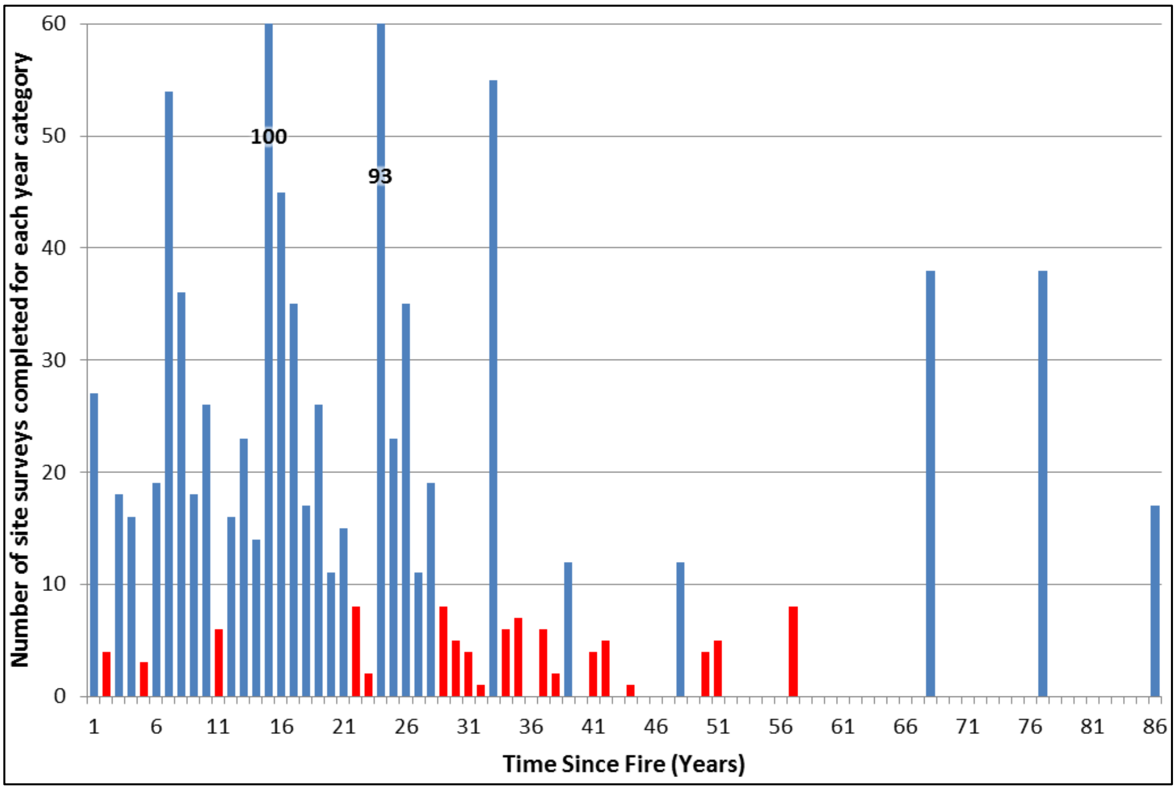

Figure 4-12: The spread of pooled data available for 'time since fire' analysis. Data poor years (with < 10 site surveys) that were excluded from most analyses are indicated in red.

Although this pooled data-set has the first 35 years represented by continuous time since fire data, 11 of these years consist of a limited number of site surveys (those with less than 10, as shown in red in Figure 4-12,) and were excluded from generating a subsequent yearly average digging abundance score from the raw data (see Table 4-2).

With over 90% (869 records) of the total 'time since fire' dataset available for the results presented in subsequent sections, the pooled data (despite its limitations) does present a fresh opportunity for undertaking time since fire analysis. Indeed, this is the most comprehensive regional dataset capable of exploring the relationship between bandicoot post-fire occupancy and activity yet assembled for the South East of South Australia.

Table 4-2: The amount of pooled data utilised for the time since fire analysis

	Number of site survey records		Number of *Time Since Fire* Years available for yearly data average analysis (of first X years)		
	Total usable data	% usable data	/10	/35	/86
All survey data with time since fire	958		10	35	48
Occupancy and Activity data (excluding years with < 10 site surveys)	869	90.7%	8	24	29

4.4.1 Regional bandicoot occupancy rates and time since fire

Using the complete regional dataset, the probability (as a percentage) of finding bandicoot occupied habitat can be generated, in any given year since the last fire. The results are charted in Figure 4-13.

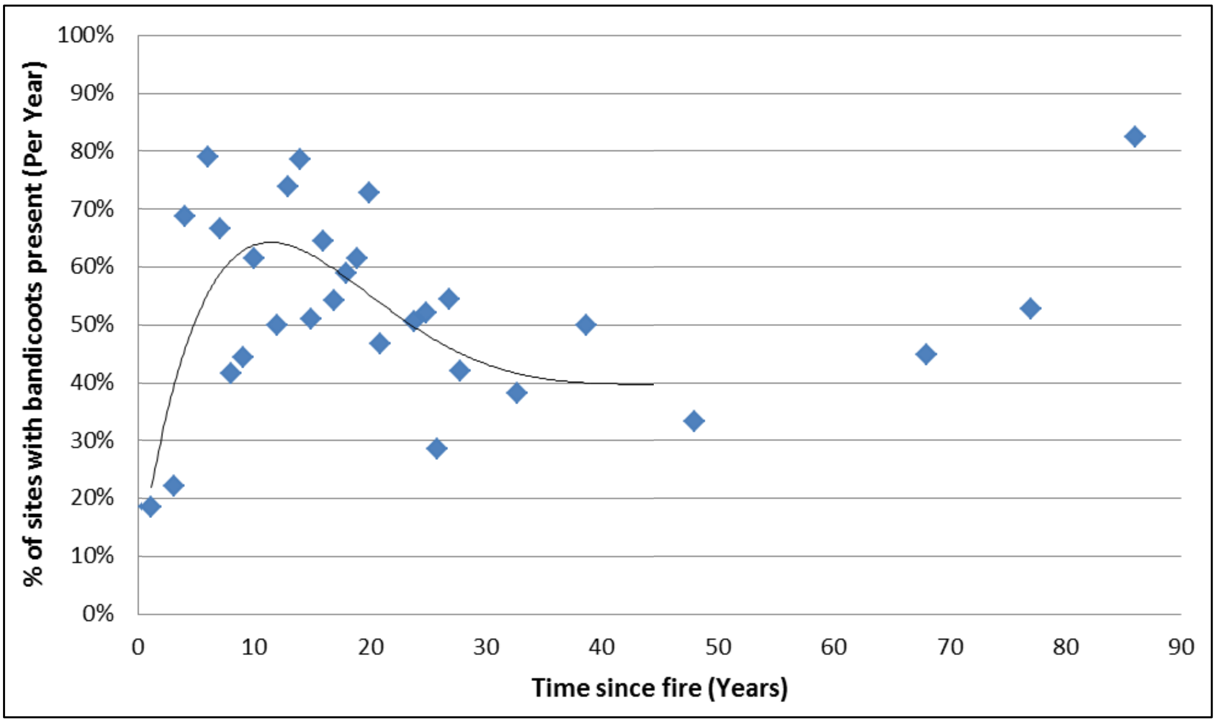

Figure 4-13: The likelihood of encountering bandicoot activity (presence of diggings) in any given 'time since fire' year, excluding years with < 10 site surveys completed. Polynomial trendline up to 45 years since fire (the most robust period of data available) was created in Excel.

Despite there only being a limited number of extremely long unburnt sites, they have produced some very interesting results, with probability of detection remaining comparable to earlier year classes. It is worth remembering that the long unburnt sites tend to occur in wetter, heavier soils (e.g. The Marshes) and may also be more naturally productive habitats. So it may be important to consider that they are not necessarily representative of the bulk of the drier, deeper sandy range country that comprises many of the remaining compartments represented in the data.

These older age classes are for all intents and purposes practical 'outliers', with the majority of compartments in remnant patches never likely to ever achieve this post-fire age classification due to current fire management practices. In order to have a closer look at defining the trend over the earlier post-fire period (noting that the first 35 years has very good data coverage and represents 84% of all site survey data), the oldest outliers were excluded from the polynomial trendline applied to the data and shown in Figure 4-13.

After low detectability of occupancy for the first few years (e.g. in Year 1, bandicoot diggings were present at less than 20% of survey sites), maximum occupancy levels appear to return within 4-5 years post fire (with detectable occupancy lifting to 70-80%). This change in the presence of bandicoot foraging evidence corresponds with the post-fire recovery of habitat – the regeneration and/or re-sprouting of native vegetation.

This early peak in occupancy rates is then sustained through to 15-20 years after fire, at which time there is an apparent average decline in the likelihood of detecting bandicoot presence. However, at no stage does detectability drop to the low levels associated with the immediate post-fire period, suggesting the habitat is least suitable for the Southern Brown Bandicoot to forage and (possibly more crucially) find cover during years 0-3 after burning.

4.4.2 Regional bandicoot activity rates and time since fire

Analysis of the relationship between bandicoot activity (based on the combined, averaged digging abundance scores for each year) and time since fire is also possible by pooling these data across all survey sites.

The results for the complete timeline are shown in Figure 4-14.

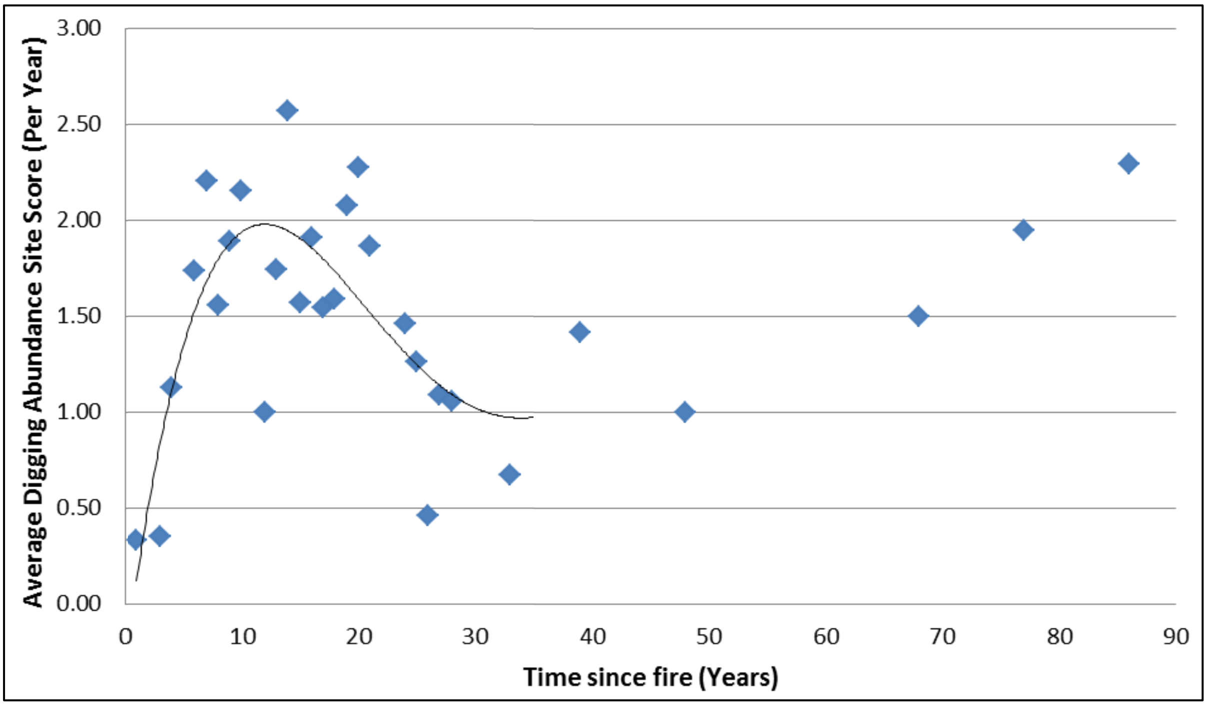

Figure 4-14: The level of bandicoot digging activity at any given 'time since fire'; excluding years with < 10 site surveys completed. Polynomial trendline up to 35 years since fire (the most robust period of data available) created in Excel.

At first glance, a similar trend to that observed in Figure 4-13 is also apparent in the digging abundance data – and that is not entirely surprising because the datasets are closely related, but it is important to understand that they represent two slightly different things about bandicoot behaviour.

Figure 4-13 simply indicates that bandicoots are present, without telling us specifically about habitat productivity for bandicoot foraging (except that the area meets a minimum productivity threshold required for presence). However, the data illustrated in Figure 4-14, is a more sensitive measure of habitat productivity as it incorporates the level of observed bandicoot activity at all sites.

Again, it is important to note the apparent sustained productivity of the long unburnt sites. But to illustrate the trend over the first 35 years after fire (noting the more complete data coverage of this period), the oldest outliers were excluded from the polynomial trendline applied to the data shown in Figure 4-14.

This trend is similar to that presented in Figure 4-13 – albeit with some subtle differences.

Clearly, the data adequately confirm the obvious change in the trend of bandicoot activity caused by the immediate negative impact of fire on habitat; both in terms of cover and foraging productivity. This change is reflected in low rates of digging abundance for the first four years post-fire, after which time an obvious increase in activity occurs (and is sustained) from around years 6-7, and lasting around for 10-15 years. It is interesting to note that this early rise in digging activity is delayed by a couple of years, occurring after the slightly earlier (year 4 or 5) rise in occupancy noted in Figure 4-13.

This delay in rising digging activity compared to occupancy is probably confirmation that it takes longer for food resources to recover as the habitat recovers, despite the level of cover clearly becoming conducive to bandicoot presence from a couple of years earlier. It may also represent the time it takes for local bandicoot numbers to increase after re-occupation, in response to the recovering habitat and resources. Understanding the average length of this 'lag effect' to achieve effective habitat recovery after fire, is a crucial consideration in the design (size, scale and regularity) of burning regimes that are applied to the fragmented patches of bandicoot habitat that remain in the South East.

Digging abundances appear to drop quite sharply between 20 to 30 years after fire (before plateauing); a more sharp decline than the corresponding drop in occupancy over the same post-fire period. This suggests that as habitat productivity declines, bandicoots will continue to utilise it, but at a reducing rate of foraging intensity. Presumably this simply reflects a reduction in the carrying capacity of the habitat as potential food resources become scarcer, or as the floristic attributes (i.e. levels of cover) change as some species senesce.

The data indicate that the sandy, drier, more regularly burned, stringybark heaths of the South East of South Australia may peak in productivity as bandicoot habitat approximately 7 years to 20 years after fire. However sustained, relatively higher levels of bandicoot activity were observed in many of the long unburned sites, also indicating that a simple, uniform relationship between bandicoots and fire regimes in their habitat in the South East region does not exist.

5. DISCUSSION

The Southern Brown Bandicoot is considered to be threatened with extinction as a result of the cumulative impacts of habitat clearing (both reduced extent and increased fragmentation), altered fire regimes and introduced predators, yet the South East of South Australia remains an apparent stronghold for the species, despite these influences acting on local populations.

At a cursory glance, the results of the latest round of digging abundance surveys indicate two key things:

1) **Occupancy** – the detected presence of the Southern Brown Bandicoot within the majority of patches containing the most suitable remnant vegetation for the species in the lower South East – **remains stable**.

This is a positive outcome for collating basic evidence of the persistence of the species in the region, but (as a simplistic measure) does potentially conceal finer level changes occurring at the site or sub-population level. In particular, while populations of the Mt Burr Range are sustained at higher levels across a large number of reserves, occupancy levels in the Nangwarry and Caroline Forest native vegetation remnants appear to remain critically low. The future persistence of bandicoots in these habitats should be of significant immediate concern to biodiversity managers in the South East.

2) **Digging activity** – physical evidence of the amount of feeding behaviour taking place within representative areas of native vegetation, as a surrogate measure of bandicoot abundance – **has declined**.

While potentially concerning, the coarseness of the relative digging abundance data means it is also very difficult to readily determine if this is a significant or meaningful change that is likely to impact on the future conservation prospects for the species in the region, especially in the habitat patches of the Mt Burr Range. For example, the spatial and seasonal utilisation of habitats within remnant areas can change through time with the (often variable) nature of bandicoot activity. Because digging activity is only a surrogate measure of presence (albeit a very good one based on the species' compulsive digging behaviour) and the potential for observer error, it is difficult to be entirely conclusive when analysing the data produced by a study of this type. However, given the large scale of replication in the survey and it being the best general measure available, it is not unreasonable to assume that this measured decline in activity may be revealing a real trend.

The main identified issues, in no particular order based on a range of ecological characteristics, that are most likely capable of influencing observed digging activity include:

- Climatic trends driving food resource availability;
- Habitat quality (especially understorey simplification as a result of woody weed invasion – e.g. *Acacia longifolia* and *Pinus radiata*);
- Predation pressure;
- Time since fire driving key habitat parameters (especially availability, productivity and cover); and

- Population dynamics of the species itself.

It is extremely difficult to tease apart the range of influences potentially impacting upon activity levels, but climatic trends (as described in an earlier section) and habitat quality (based on Forestry SA investment in woody weed management) are assumed to have been somewhat stable in their influence on survey results over the past 20 years. The further discussion here will seek to explore the final three of these factors in additional detail.

5.1. Predation pressure

In later discussion sections, it is also assumed that predation pressure has been relatively stable over the 20 year survey period, based on no significant changes in ForestrySA predator management programs (which have been seasonal and sporadic over that time) across Native Forest Reserves, the land tenure of most bandicoot habitat in the South East. However, because the issue of predation pressure and the role of predator control is an ongoing point of uncertainty in discussions regarding the future conservation of the species in the region, it is given additional consideration here.

5.1.1 The simple logic of fox control

Fox control has for many years been considered by many ecologists and conservation managers as a basic tenet of orthodox ‘best practice’ conservation land management in Australia. This is based on the simple logic that the fox is an introduced species, implicated in the rapid demise of many species of small-medium mammal fauna on the mainland after its release in Victoria (circa 1871) and subsequent spread across the mainland. Fox baiting has also naturally lent itself to forming part of ‘good neighbour’ management programs where conservation areas and sheep grazing enterprises sit alongside each other in the landscape (common in this region), and where fox suppression can directly and measurably benefit annual lambing success rates (and hence economic returns) for primary producers.

5.1.2 Defining the problem

However, unequivocal evidence of the benefits of sustained fox control in natural ecosystems are much harder to define and measure, and as a result are often simply assumed by conservation land managers. For an expensive activity that can be difficult to justify over the long term, and where assumed or demonstrated benefits can be quickly eroded (through fox re-invasion) if and when suppression ceases, this is problematic.

There also remains the ongoing problem that mainland Australia’s natural apex mammal predator(s) are no longer present across much of south-eastern Australia, including the South East NRM Region, after the deliberate eradication of the Dingo *Canis lupis dingo*, and gradual (and possibly associated) demise of the Tiger Quoll *Dasyurus maculatus*. In their absence, this apex predation role has been partially assumed by the fox, meaning that it is highly likely that eradication or suppression will have flow-on effects for the wider native ecosystem, in its modern composition and modified state. Indeed, there have been some high profile examples of unintended perverse outcomes that took many years to materialise, such as the secondary, post-recovery crash of the Woylie *Bettongia penicillata ogilbyi* population in the Western Shield project area of Western Australia (Yeatman 2012), associated with mesopredator release (i.e. increase in cats) after long-term fox suppression.

5.1.3 After more than 10 years, what do Glenelg Ark results tell us?

One locally relevant, long term fox control program that has placed additional emphasis on collecting basic response data on some of its expected target species, including the Southern Brown Bandicoot, is Glenelg Ark (Figure 5-1).

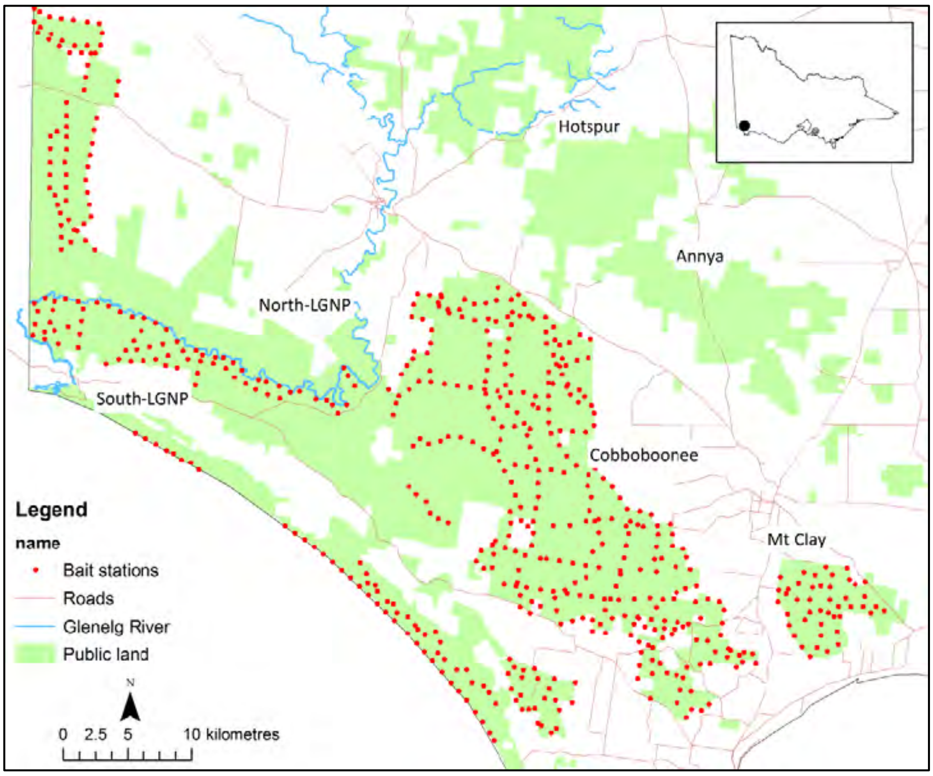

Figure 5-1: Glenelg Ark fox control operations area in Victoria, adjacent to the Caroline Forest area in the South East of SA (map from Robley et al. 2017).

This program has a direct, proximal influence on Lower Glenelg River Conservation Park: the fourth bandicoot population area in the South East of South Australia; the only population area not induced in the digging abundance survey method (hence not otherwise represented in the data in this report). Unlike most mainland fox control programs initiated with a goal of benefitting biodiversity, Glenelg Ark has:

(1) **Been able to take advantage of the location of the lower reach of the Glenelg River**, a substantial natural geographic barrier (Figure 5-2) that prevents rapid reinvasion of habitats by foxes in a large part of the western portion of the project baiting area, as shown in Figure 5-1. This is also the feature that separates the Lower Glenelg bandicoot population from the more fragmented populations in the near-border zone to the west (the Caroline Forest remnant vegetation patches in SA), and north (Rennick State Forest in Victoria). With the exception of fenced enclosures (e.g. Australian Wildlife Conservancy Reserves), peninsulas (e.g. Peron Peninsula in WA) or extremely large baited project areas (e.g. Western Shield in WA), most mainland fox baiting programs (including those in the South East NRM region) are usually subjected to continuous reinvasion by migrant foxes from adjacent non-baited land. Hence the western portion of the Glenelg Ark project area has a natural in-built advantage by integrating this natural landform 'barrier' into its design.

Figure 5-2: Looking in a northerly direction across the Glenelg River, from Lower Glenelg River CP in SA towards Dry Creek: a formidable barrier for the movement of ground dwelling fauna.

(2) **Collected monitoring data throughout the duration of the program on the response of three native species**: the Common Brushtail Possum *Trichosurus vulpecula*, Long-nosed Potoroo *Potorous tridactylus*, and Southern Brown Bandicoot *Isoodon obesulus*. In particular, the monitoring program has used hair tubes and camera traps to determine changes in occupancy rates (i.e. detection rates of presence) of these species at paired (i.e. baited and non-baited) sites through time.

The distribution of monitoring sites across the project area is shown in Figure 5-3.

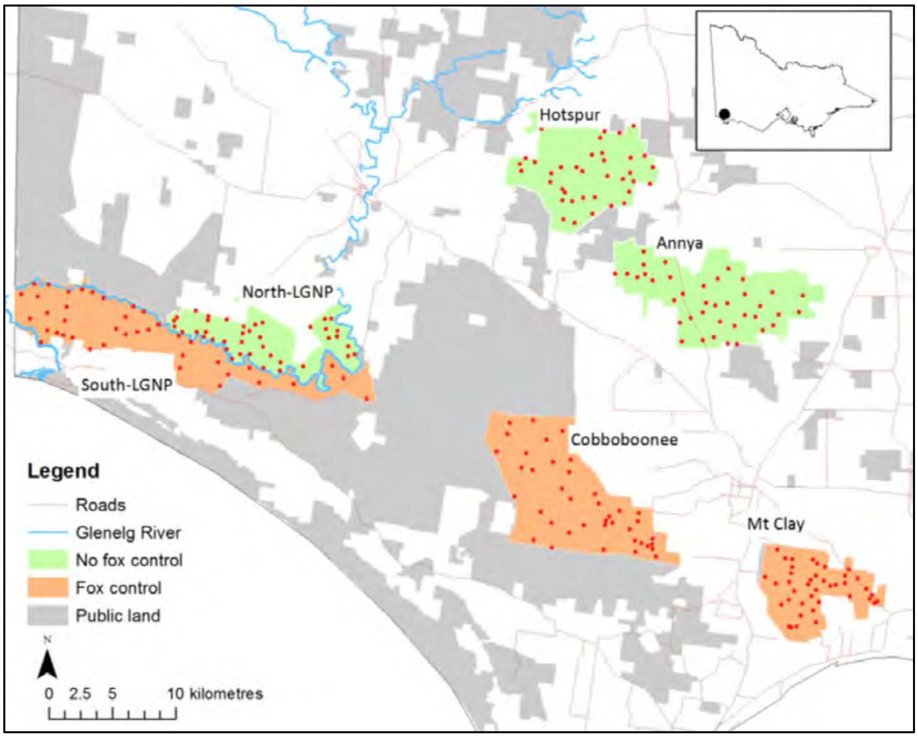

Figure 5-3: Monitoring sites in the treated (tan polygons) and non-treated (green polygons) monitoring locations of Glenelg Ark are indicated by red dots (map from Robley et al. 2017).

Glenelg Ark has been operating continuously ever since 2005, when 1080 baiting and fauna monitoring commenced, making it an extremely useful case study for helping to understand the long-terms effects of fox control in temperate mainland south-eastern Australian ecosystems. It is particularly relevant to this report of areas of bandicoot habitat nearby in SA. The changing rates of detection for the target species summarised across all monitoring sites throughout the life of the fox baiting program thus far are shown in Figure 5-4.

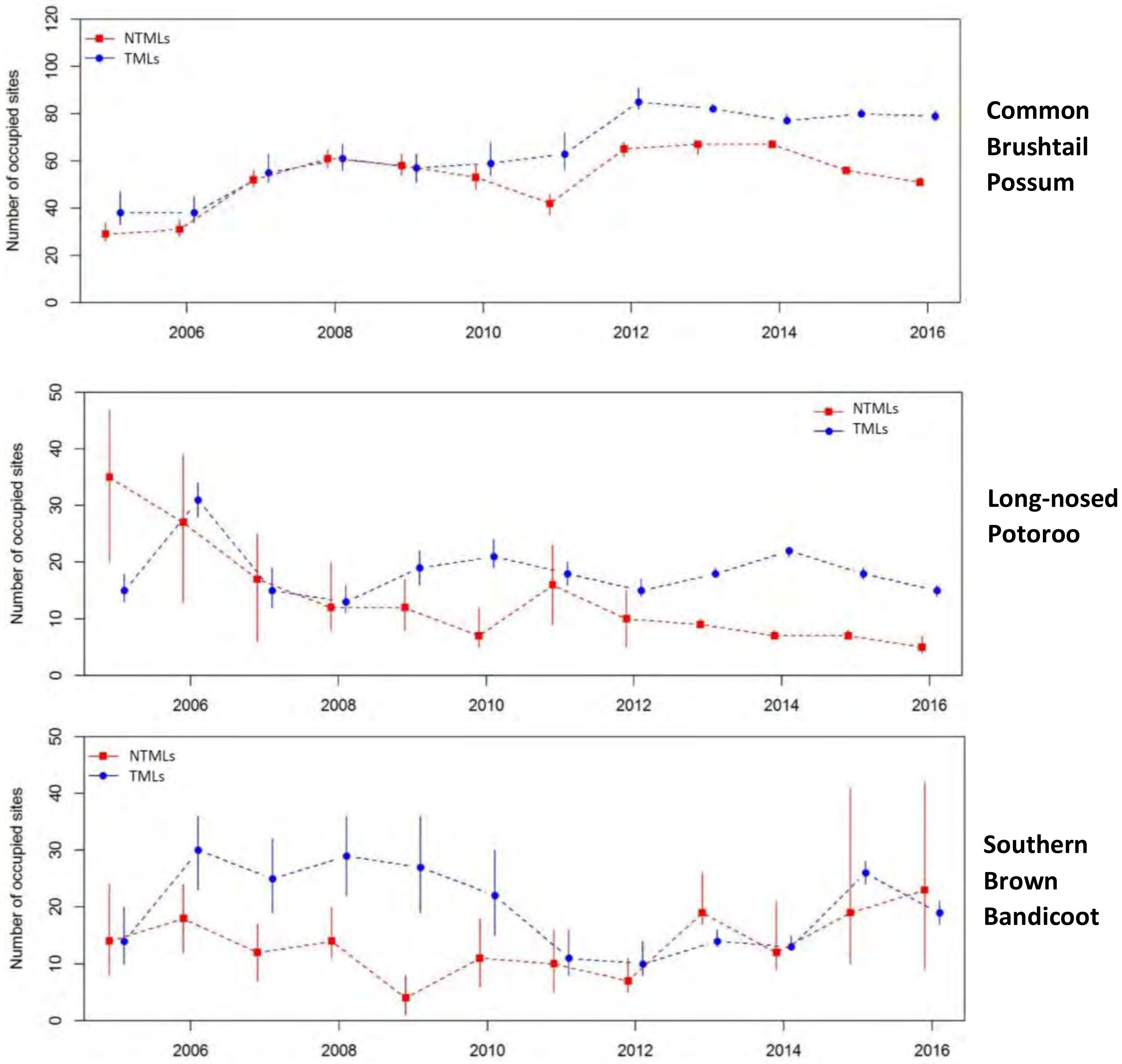

Figure 5-4: Estimated number of monitoring sites occupied over time by target species in baited (TMLs) and non-baited (NTMLs) areas of Glenelg Ark. Dots indicate the medians and the bars represent the 95% high-density intervals (from Robley et al. 2017).

As indicated by the charts from Robley et al. (2017) presented in Figure 5-4 (noting that they only represent rates of detected presence across sites, not changes in abundance), Glenelg Ark has resulted in a sustained, increased proportion of sites where both Brushtail Possums and Long-nosed Potoroos have been detected in comparison to control areas. However, after an early increase in detection rates after fox baiting commenced, confirmed bandicoot occupancy rates experienced a sharp decline in 2011, to levels similar to those being recorded in control (non-baited) areas, with no significant difference demonstrated since. This is despite the fact that the program has been effective throughout, with fox activity demonstrated to be significantly lower at baited locations than those with no fox control (Figure 5-5).

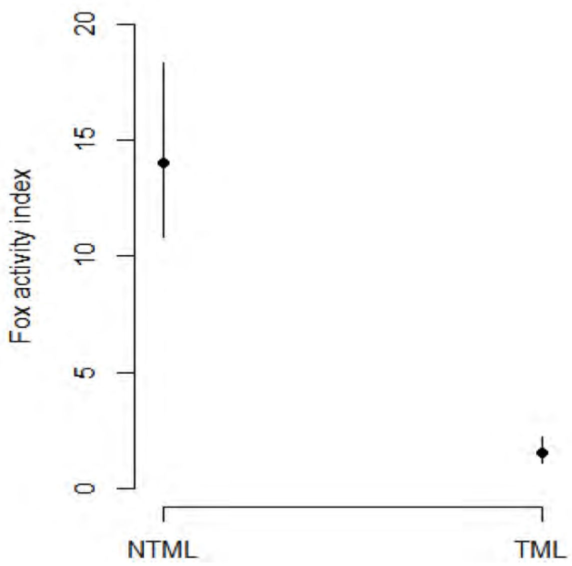

Figure 5-5: Fox activity (number of images per day at each camera site) at treatment monitoring locations (TMLs) and non-treatment monitoring locations (NTMLs). Bars are Bayesian 95% credible intervals. (from Robley et al. 2017).

So up until this point in time, after more than 10 years of best-practice, continuous large-scale fox baiting, there is no significant or clear positive relationship between long-term or sustained Southern Brown Bandicoot occupancy rates and the demonstrated level of ongoing fox suppression in the Glenelg Ark project area.

Exactly why the crash in bandicoot detection rates presented in Figure 5-4 happened in 2011 is open to speculation, but includes hypotheses such as:

- competition with a larger, more exploratory (i.e. less arboreal) Brushtail Possum population, due to reduced predation and behavioural change caused by lack of fear;
- a change in understorey habitat condition as a result of increased browsing by herbivores (possums, wallabies, etc.), driven by reduced predation rates; or,
- an increased cat *Felis catus* population whose behaviour may have also changed from reduced fox competition or suppression (i.e. mesopredator release).

Prior to the crash, over the first five years of the Glenelg Ark Program, the regularly assumed benefits of fox baiting for bandicoots (on the basis of them being a confirmed prey item for foxes), would appear to have been strongly demonstrated by the initial spike in the bandicoot site occupancy rate. However, it is now apparent on the basis of the subsequent decline in occupancy (much like the Woylie example in WA), that the ability to maintain this relationship over the longer-term is questionable, or at best for Glenelg Ark, inconclusive.

5.1.4 The concept of trophic cascades

It remains possible, and indeed the data suggests, that wider interactions (between predators, other prey, competitors and habitat) in these ecosystems where bandicoots still persist, are critically important when fox suppression is sustained over the longer-term. Hence it remains likely that, on the basis of the concept of *trophic cascades*[1], that simply attempting to eliminate the current established apex predator in the system (whether that species is native or not) is capable of having unforeseen knock-on effects throughout the ecosystem over time, as expressed in the three hypotheses outlined (see prior dot points).

> [1] ***Trophic cascade*** *describes the indirect control that a top predator exerts on species at lower, non-adjacent trophic levels. In a top-down trophic cascade, ecological processes and consequences initiated by a change at the top of the food chain work their way down to lower trophic levels and eventually rebalance the ecological relationships of numerous species. Hence, the removal of the top predator from a food chain can raise the population or alter the behaviour of its prey, leading in turn to reductions of species at other trophic levels.*
>
> *(AccessScience Editors, 2015)*

Crucially, and despite the loss of so many similar sized mammals on the mainland, bandicoots have continued to persist in heathy woodland and heathland habitats with sufficient cover, including many sites where no fox baiting occurs, for over 120 years.

From the time of their arrival in the 1890s, the fox quickly replaced the rapidly disappearing Tiger Quoll and Dingo (the latter species especially and more quickly lost through successful, coordinated efforts by humans to eradicate them) as the apex mammalian predator in local ecosystems. Today we have no way of fully understanding the cascading effects that played out as a result of the rebalancing of the ecosystem that took place from that time, except by observing the end result: i.e. the loss of a range of small-medium mammal species in the process; but crucially, the Southern Brown Bandicoot wasn’t one of them.

Of course, this is not to say that bandicoots may have not been more widespread and utilised other habitats on the mainland prior to the that ‘rebalancing’ taking place, as supported by regular observations of more eclectic habitat use by the species in Tasmania where predator-prey relationships are less interrupted (see Figure 5-6 and Figure 5-7).

Figure 5-6: Not an uncommon sight in Tasmania: a roadkill Southern Brown Bandicoot
Photo: Mark Bachmann

Figure 5-7: Roadkill Southern Brown Bandicoot in farmland of the Midlands, one of the Tasmania's most modified regions and with a bio-climate very similar to the south-eastern part of the continent; demonstrating that, before 120 years ago, the species was probably not as restricted to dense cover habitat (despite this now being typical) on the mainland. *Photo: Mark Bachmann*

However, for a short-lived, high turnover mammal species, the continued persistence of the species in South Australia – over 100 years later, in the presence of foxes, and despite a range of additional threats – is highly informative.

While Glenelg Ark results offer caution against simply assuming direct, positive benefits will continue to result from sustained, comprehensive fox suppression over the longer term for potential prey species, it does also demonstrate how fox control may have specific benefits in reducing short-term predation pressure on bandicoot populations. This is key information that should be taken into account (i.e. considering deployment of fox baiting) when planning future translocations or reintroductions of bandicoots in the South East region, to help ensure short-term survival of released animals and improve changes of persistence.

Obvious questions also remain about whether ongoing partial suppression of foxes to the point of gaining a benefit for bandicoots (and other target species) is possible, without reducing apex predator density to the point where mesopredator release or major changes in Brushtail Possum behaviour occur. This might be achieved through:

- a more subtle fox control program with variable baiting intensity (either spatially or temporally); or,

- trial releases or reintroductions of alternative apex marsupial predators, such as the Tiger Quoll or Devil (*Sarcophilus harrisii*) noting that the latter was widespread on the mainland prior to the arrival of the Dingo; also taking account of the fact that the Dingo is now locally extinct and unlikely to be politically or socially acceptable as a reintroduction option.

This discussion highlights the necessary role of predation (as an ecological process) in our mainland ecosystems, and that it is a complex issue that requires further trials and applied research in the field. New approaches are required to prevent land managers across the mainland simply repeating the same mistakes, as it becomes increasingly clear that fox suppression through baiting alone is not a long-term or sustainable solution.

5.2. Time since fire

5.2.1 Brief overview of literature

The information available on peak habitat suitability after fire, across the range of the Southern Brown Bandicoot is highly variable. Local research conducted by David Paull (1993; 1995), supported previous observations of Stoddart and Braithwaite (1979), with animals more likely to be found in areas with recent (5-7 year) evidence of fire. However, this seral stage of habitat was most commonly represented across sites in those studies, and bandicoots were also present in very recently burnt (1-2 year) and long unburnt (> 20 year) habitats. In other reported cases in south-eastern Australia, peak bandicoot abundance wasn't reached until 14-15 years post-fire, while large scale bushfires have also been known to cause local extinctions of the species from previously occupied habitat (DEC, 2006).

Hence the prevailing view among the research community would appear to:

1) suggest that habitat suitability is uniformly compromised in the short term after fire, through the removal of cover and food resources.
2) highlight a range of confounding factors that make general statements about longer-term, post-fire habitat suitability or peak productivity much more difficult to universally prescribe or define.

Those confounding factors which include the habitat type and fire characteristics (intensity, scale, coverage) – not to mention proximity to a source population (see next section of discussion) – would appear to dictate when (i.e. how quickly) a patch (or part of a patch) becomes suitable again as bandicoot habitat, when its productivity peaks and if its productivity is sustained.

It is also known from past studies that not all habitats are used equally and the difference in sites favoured by the Southern Brown Bandicoot indicate variation in habitat suitability between patches (Rees and Paull 2000). For some soil and vegetation type combinations, fire appears to be a key driver in a longer-term cycle of vegetation succession and habitat productivity, while for others (especially wetter habitats) it is probably much less important.

5.2.2 Contribution of this study to our understanding

With these background considerations in mind, the results of the digging abundance survey are revealing, particularly as the occupancy and activity record (using the combined data across all 3 surveys) provides such a long continuous run of 'time since fire' years. In agreement with the previous work on the ecology of the Southern Brown Bandicoot, this most recent study indicates that there is a clear early relationship between time since fire and both bandicoot occupancy and activity, especially in the immediate post-fire period.

The results presented in this study have shown that evidence of bandicoot occupancy (presence) after fire appears to peak around year 5, a year or two prior to digging activity levels then beginning to peak from around year 7. Both of these findings are broadly consistent with the earlier work in the region of Paull (1995). On the basis of the data in this study, this period of increased (albeit variable) activity is then sustained for the subsequent 10-15 years, before declining and then plateauing.

However, on the basis of survey results in some of the wetter, long unburned patches, it would appear that productivity, and hence suitability for bandicoots, is at least sometimes retained over the much longer term. In the cases highlighted in this study, such prolonged productivity can even be retained at levels comparable to much younger successional vegetation. These outlying records and the site characteristics of those patches are worthy of additional future investigation – particularly if those areas are subject to prescribed burning or bushfires at some point in the future.

With the reality being that most of the native vegetation patches will never reach such a long unburnt time since fire, and with so many stringybark woodlands situated on lower productivity, drier soils, the implications of fire management regimes for the younger age classes are probably of more interest for land managers to understand. In that regard, consistent with earlier studies on the species' post-fire recolonisation potential, it is important to note that bandicoots do remain widely present and highly active in patches with a regular, recent history of burning (such as Wandilo and other patches in the Mt Burr Range cluster).

The complexity of this area of work is greatly compounded (and also confounded) by lag effects and variable post-fire habitat response due to seasonal rainfall patterns, as well as the season and scale of burning, meaning that no two burns will deliver precisely the same result on the ground over time. The fact that ForestrySA's burning program at the compartment (sub-patch) scale has formed a fundamental component of the prevailing management regime within native vegetation remnants of the lower South East pine forest matrix for so long (as the results of this study clearly articulated in Section 4.4), clearly demonstrate that this management regime has not been detrimental to the persistence of the Southern Brown Bandicoot in these (mostly) heathy woodland remnants. In the majority of these areas, bandicoots are often associated with moderate to dense stands of stringybark woodland (*Eucalyptus baxteri, Pteridium esculentum*) and heathland (*Xanthorrhoea* sp., *Leptospermum* sp.) (Paull 2003).

5.2.3 Use of fire for vegetation management within the bandicoot's range

On the basis of this discussion alone, using fire as a vegetation management tool in bandicoot habitat would not appear to be a threatening process for the species in the South East region. Despite the species continuing to persist in long-unburned areas of habitat, the Southern Brown Bandicoot is also well adapted to take advantage of post-fire recovering habitats in the South East region; but only where prescribed burning occurs <u>at the right scale and frequency</u>. In fact, the compartment based configuration of Native Forest Reserve patches of native vegetation may have fortuitously lent itself to helping ensure the scale of past burns has not been detrimental to bandicoot persistence within those overall patches.

In the Mt Burr Range, Wandilo had one of the highest patch occupancies (>80%), yet the regular, recent effect of fire is apparent. Five of the eight sites burnt since 2009 recorded a decline in combined digging abundance between survey years. However, at appropriate frequencies, the species can benefit from deliberate patch burning to maintain a complex mosaic of native vegetation (Stoddart and Braithwaite 1983, Possingham and Gepp 1996). In support of this notion of rapid recovery, three of eleven sites that declined during the previous survey (2007/08) following the Wandilo fire in 2000, had an increase in digging abundance scores in 2016, indicating recovery 16 years after fire.

Importantly, while fire regimes do clearly influence Southern Brown Bandicoot occurrence, they may not be as important as vegetation, habitat structure and soil type (Rees and Paull 2000, Paull 2004, Brown and Main 2010), which may partially explain the persistence of the species in some very long unburnt patches in the South East. Understanding how different vegetation types respond to fire (or the lack of fire) is critical (e.g. regeneration time, provision of food and shelter), in order to recommend and establish more effective and sensitive fire regimes at the sub-patch (i.e. compartment) scale. While for many areas influencing proposed timing of planned prescribed burned will be crucial, there will also be additional compartments worth deliberately reserving from burning to maintain a suite of different attributes only likely to be found in older succession, higher productivity habitats.

5.2.4 Summary

It is clear from this study that fire management has played a key role in shaping much of the remaining habitat for the Southern Brown Bandicoot in the South East NRM Region, and that the species is tolerant of a wide range of fire histories.

However, on the basis of available evidence from this study, the assertion by some authors that the Southern Brown Bandicoot would be negatively impacted by a deliberate policy of medium-long term fire exclusion, also cannot be simply supported. In the results and consistent with the literature, bandicoot occupancy and activity does appear to decline after 20 years since fire, but it then plateaus and the species remains present and active in much older vegetation age classes. Indeed evidence of bandicoots occupying and intensively utilising older habitats over 30 years since fire (and much older) was repeatedly revealed in this study. As an example, Grundy Lane, Kangaroo Flat, McRosties, Mt Lyon, Mt McIntyre and The Woolwash all returned site occupancy levels of ≥80% and were associated with stringybark woodland, where the majority of each patch had not been burnt for well over 30 years (up to > 60-70 years).

However, it must also be remembered that fire exclusion carries the very real risk of making the complete burning of some remnant (especially drier) patches of now isolated habitat in a single bushfire event more likely, with the potential to cause local ‘patch’ extinction of bandicoots. If used judiciously at a scale and frequency capable of achieving a mixture of age classes and successional states, cognisant that habitat becomes increasingly available to the species from 5-7 years post burn, then fire clearly has a role in managing the isolated fragments of habitat that do remain, by making the landscape less prone to uncontrolled, hot and widespread bushfires. However, long unburned, productive habitats for bandicoots would also ideally continue to be reserved from burning, making it possible to maintain and evaluate different approaches to fire management for the Southern Brown Bandicoot in the future.

It is worth acknowledging that this is broadly the approach that has already proven itself, by successfully sustaining bandicoot populations across a large network of remnants surrounded by pine forests (especially on the Mt Burr Range) in the South East NRM Region over the past 50 years, despite the known detrimental effects of habitat fragmentation.

5.3. Population dynamics

The South East region presents a fascinating case study in the population dynamics and genetic structuring of the Southern Brown Bandicoot. The region retains four sub-populations groups that are now geographically isolated, with three of these assessed in this study (Figure 1-2):

1) **Mt Burr Forest** – consisting of a minimum of 24 patches of native vegetation, mostly in reasonable proximity to each other, and situated within a wider, continuous matrix of *Radiata pine* plantation. Fragmentation caused by clearance and plantation establishment up until the 1970s.

2) **Nangwarry Forest** – consisting of 3 patches of native vegetation in close proximity to each other, surrounded by *Radiata pine* plantations, but (on the basis of all available evidence) completely isolated from other populations. Fragmentation caused by clearance and plantation establishment up until the 1970s.

3) **Caroline Forest** – consisting of 2 patches of native vegetation that support the species in close proximity to each other, surrounded by *Radiata pine* plantations, but within reasonable proximity to potential habitat that also supports the species in Victoria (at Princes Margaret Rose Cave and in Rennick State Forest). Fragmentation caused by clearance and plantation establishment up until the 1970s.

4) **Lower Glenelg** (*not included in the digging abundance survey*) – despite its proximity to the Caroline Forest sites, the small South Australian Conservation Park and adjacent National Parks (Lower Glenelg and Cobboboonee) in Victoria form a single patch of over 50,000 hectares of continuous native vegetation. This site is geographically isolated from other populations in SA (see Figure 5-2), and is therefore subjected to the prevailing management regime of adjacent Victorian Reserves (see Section 5.1.3).

5.3.1 A regional meta-population

Prior to the clearance and development of the South East, the Mt Burr Range, Nangwarry and Caroline bandicoot populations are extremely likely to have effectively comprised a single regional *meta-population*[1].

> [1] *A **meta-population** is a spatially structured population that persists over time as a set of local populations with limited (but regular) dispersal between them. At equilibrium, the frequencies of local extinctions and colonisations are in balance.*
>
> *(van Nouhuys 2016)*

While there may have been some discrete areas of suitable outlying habitat supporting more isolated populations, dispersal events through less optimal habitats in the landscape would have ensured all of these populations retained their genetic integrity and viability. Crucially, it also meant that short term extinctions as a result of fire or some other stochastic event, would be reversed by the next migration or dispersal event, with founders or supplementary animals arriving from a nearby (but separate) population.

Additionally, based on the behaviour and distribution of the species in Tasmania, where predator-prey relationships in particular are less interrupted, it is clear that the species has become more of a restricted 'habitat specialist' on the mainland, in response to current predation threats. The cover afforded by the dense heathy woodland habitats of the stringybark woodlands favoured by the species, is clearly one key reason this species has resisted extirpation in the face of introduced predators when so many other (in fact almost all other) similar sized (critical weight range) small mammals have been lost from the south-eastern Australian mainland.

With this in mind, it is very likely that the original regional distribution in the South East region would have been much more continuous and widespread prior to broad-acre land clearance, eradication of native predators and the introduction of the Feral Cat *Felis catus* and European Red Fox *Vulpes vulpes*.

5.3.2 Fragmentation and modern genetic structuring

As the South East was developed, and with predator-prey relationships permanently altered or interrupted (eradication of dingoes and release of foxes in the 1890s), over the past 120 years we've witnessed both a crash in the abundance of small mammals and the long-term loss of landscape connectivity between the populations west of the Glenelg River: the Mt Burr Range, Nangwarry and Caroline bandicoot populations. These woodlands became the last strongholds of what would formerly have been a much more expansive and continuous regional distribution.

Then within each of these last remaining (originally much larger) heathy woodland remnant areas over deeper sandy soils, substantial areas of native vegetation were cleared to establish pine plantations up until and including the period of large-scale mechanised clearance that continued through to the 1950s-1970s. This led to a further internal fragmentation of those remaining habitat areas.

Recent studies have shown that genetic structuring now exists in the fragmented Southern Brown Bandicoot populations of the South East (Li *et al.* 2014, Li *et al.* 2015), and that the effect of genetic isolation increases with the distance between patches. Indeed, evidence for dispersal among habitat patches was found to now be limited and dispersal generally only occurred among some neighbouring patches (in the Mt Burr Range), but even then, only those within close enough proximity to each other. The study by Li *et al.* (2015) concluded that the genetic structuring observed was most likely to have resulted from fragmentation (clearance) of the landscape surrounding the remnant patches over the past 40-80 years.

That means that the regional, semi-continuous, Southern Brown Bandicoot meta-population originally present across the heathy woodlands of the South East and western Victoria, has now been replaced with a series of sub-populations isolated to varying degrees and with vastly different capacities for interacting with other bandicoot populations in similar nearby habitat 'islands'. In this way, a form of *extinction debt*[2] may still be unfolding across the region for bandicoots (and other species) in smaller, isolated habitat fragments.

[2] ***Extinction debt*** *refers to the process where, as habitats become increasingly fragmented, species that are reproductively isolated from other populations of their own species may take generations to die out. This gives rise to a higher number of species than would be otherwise expected for the size of the fragment, and the false impression that many species can persist in habitat patches that are too small to sustain minimum viable populations into the future.*

(Tilman et. al 1994)

5.3.2.1 Mt Burr Range

High level genetic analysis completed by Li *et al.* (2015) identified three population clusters, grouped on the basis of increased genetic similarity, within the Mt Burr Range bandicoot population area. These population clusters are shown on a modified map (Figure 5-8), adapted from Li *et al.* 2015, to illustrate this form of genetic partitioning that has resulted from landscape fragmentation.

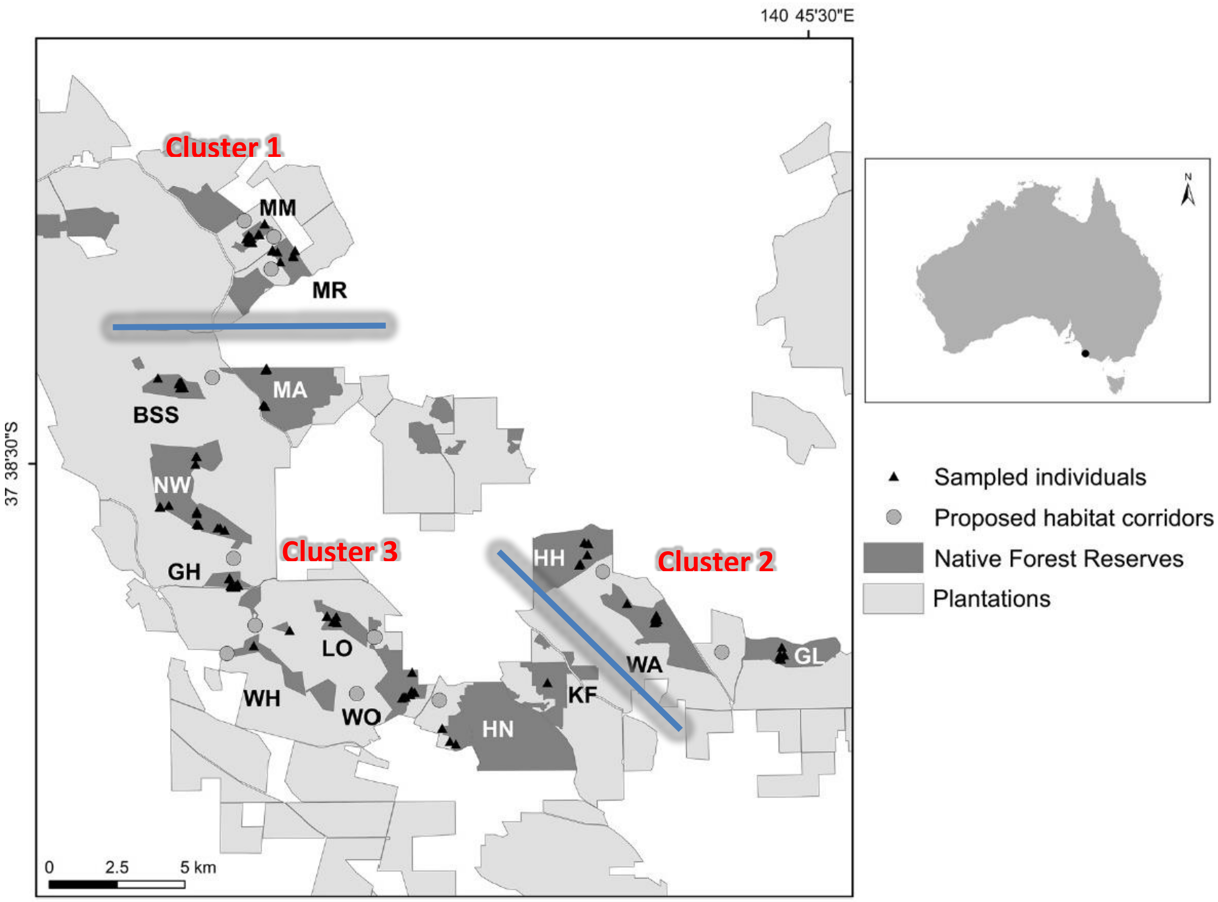

Figure 5-8: The genetic legacy of fragmentation on* the Southern Brown Bandicoot *within the Mt Burr Range population area. Map adapted from Li et al. 2015.

The genetic data demonstrates that the original meta-population effect, which is crucial for maintaining genetic exchange and recolonisation potential, hasn't entirely collapsed in the Mt Burr Range. Indeed this research outcome is supported by field observations made by ForestrySA staff, of an isolated uninhabited patch on the Mt Burr Range being recolonisation by bandicoots.

Further, the results of genetic differentiation analyses at a finer (patch) scale showed strong differentiation between patches. Those patches located closer together were less differentiated than those further apart (Li *et al.* 2015). This implies that occasional dispersal events are maintaining some genetic exchange between neighbouring patches within each cluster, but that this is not sufficient (or occurring regularly enough) to overcome the effect of wider landscape fragmentation.

For the most part over the past 50 years, chance dispersal events have had to take place through adjacent pine plantation with limited understorey for protection. This illustrates the importance of the biodiversity corridor strategy (Horn, 2003), which aims to increase the probability of successful bandicoot dispersal by providing more conducive native vegetation pathways for movement, in seeking to reconnect these habitat 'islands'. However, the corridor strategy, which mainly focusses on connectivity between patches situated closest to each other, doesn't address reinstating connectivity between clusters (or some larger distances within clusters) due to the increased distance (and hence cost) of restoring corridors between more distant patches. For example, no corridors are currently proposed or planned between patches in Cluster 2 and Cluster 3, nor between Burr Slopes South and Native Wells, near the northern edge of Cluster 3 (where it is closest to Cluster 1).

Overall, the sheer number of remnant areas that sustain bandicoots on the Mt Burr Range, their (for the most part) relatively close proximity to each other, and the fact that future dispersal will be assisted by a network of habitat corridors that are being established, gives increased hope for the future viability and sustainability of bandicoots in this part of the region. However, even with this strategy in place, assisted migration (through translocations) should still be seriously considered as a proactive management strategy to overcome the wider, and now entrenched, effects of fragmentation that are apparent in the genetic data across the Mt Burr Range bandicoot population area.

5.3.2.2 Caroline and Nangwarry Forests

However, while the genetic research so far is silent on the Caroline and Nangwarry population areas (which didn't have sufficient samples for analyses to be undertaken), it can clearly be inferred on the basis of the research outcomes so far that these outlying areas are likely to be most as risk from the detrimental effects associated with of genetic isolation and inbreeding depression.

The process of land conversion for plantation establishment was especially comprehensive in the Caroline and Nangwarry Forests, where the remnant proportion (and connectivity) of native vegetation is extremely low. Based on the distance to other potential habitat, these sites would now appear to be completely isolated (definite for Nangwarry, probable for Caroline) from other extant bandicoot populations in SA or Victoria.

The Nangwarry Forest remnants also face the challenge of being situated close to what appears to be the current edge of the northern climatic (rainfall) envelope now occupied by the species in the region. This may be especially significant on the basis of future projected bio-climatic shifts associated with climate change predictions for the region.

5.3.3 Summary in the context of digging abundance survey findings

On the basis of this information, it is perhaps not surprising that the populations in the Caroline and Nangwarry Forests appear to be less viable, as also represented in the digging abundance survey data – both in terms of rates of occupancy and activity.

These smaller, more isolated patches are prone to local extinction without recolonisation and consist of smaller populations at risk of reduced genetic fitness and inbreeding depression. The digging abundance survey results (both occupancy rates and activity levels) in these patches – despite clearly not being an absolute or wholly reliable measure – are certainly indicative of populations under considerable duress.

In contrast, the Mt Burr Range populations, while not showing uniform trends in activity levels over time, at least have stable trends in occupancy that are consistent with this area representing the most viable management unit for the species (along with Lower Glenelg) in the South East region. However despite this and on the basis of the genetic information discussed, this current stronghold for the species in the South East region cannot afford to be taken for granted, and future proactive management options should be considered to ensure this population area is not compromised over the longer-term.

5.4. Recommended improvements to the method

5.4.1 Employing supplementary methods for confirming presence

Despite its usefulness as a broad and rapid assessment technique, the current digging abundance survey method does have a number of inherent weaknesses. As a coarse measure of Southern Brown Bandicoot presence, the digging abundance method has proven to be an excellent tool for rapid detection. However, if activity patterns within a patch have shifted in response to habitat changes, then there is a chance that simply revisiting the previous survey sites (while satisfactory for ensuring repeatability of the method) may not conclusively determine if bandicoots are present within the patch.

In summary, while confidence that occupied sites (based on presence of diggings) contain bandicoots is high, how can we be sure that sites that record only '0' scores are indeed truly entire patches where bandicoots are absent? Given the importance being placed on these surveys for helping to determine regional status and broad patch occupation trends by the species, eliminating the possibility of 'false negatives' in the data is a crucial consideration for the design of future surveys. With this in mind, it is suggested that a supplementary method should be employed in the future within patches where all existing survey sites fail to register bandicoot activity, to help ascertain if this initial result is an accurate indicator of patch occupancy.

It just so happens that a regularly repeated trend of more intense digging activity has often been observed over the years in areas where bandicoots are present under Black Wattle

Acacia mearnsii, where that tree species forms small groves within forest remnants, as shown in Figure 5-9.

Figure 5-9: A grove of Black Wattle in Brown Stringybark woodland. *Photo: Mark Bachmann*

Based on those observations and the literature, it is clear that the root zone of the Black Wattle (see Figure 5-10) is capable of producing an increased abundance of foraging resources for bandicoots, including the hypogeal sporocarps (underground truffle-like fungal fruiting bodies) of mycorrhizal fungi directly associated with Black Wattle roots (Watson, 2000), and insect larvae, particularly of the Hepialidae family (B. Haywood, pers. comm.).

Figure 5-10: The root zone beneath mature Black Wattle is often more open than surrounding woodland vegetation and can usually be quickly searched to verify bandicoot presence
Photo: Mark Bachmann

Hence, targeted additional searches of Black Wattle groves are suggested, noting that these are not especially common in most of the remnant patches in the South East but are visually distinctive, based on foliage characteristics and general appearance (Figure 5-9). This may greatly assist in fine tuning a rapid supplementary method for seeking to confirm patch occupancy when the regular survey method has failed to detect bandicoot presence.

Suggested supplementary method, if the regular digging abundance method fails to detect the presence of bandicoots in a patch:

1. Drive around the perimeter and all internal tracks within the remnant patch, looking for large specimens or groves of Black Wattle (*Acacia mearnsii*).

2. If and when detected, GPS the location of the tree or grove, and note its characteristics (i.e. single large tree, patch of trees, etc.).
3. Walk around the tree(s) and search for evidence of bandicoot digging activity.
4. Classify digging abundance for the site, irrespective of its size, according to the same scoring categories used for the general survey method (i.e. 0, 1, 2, 3, 4).
5. Repeat method until a Black Wattle grove registers bandicoot activity, at which time that wider patch becomes 'occupied' and the supplementary survey can end.
6. If no Black Wattle Groves register bandicoot activity after all tracks have been driven, then the patch remains 'unoccupied' and can be more confidently considered vacant for the purposes of monitoring occupancy trends.

In the context of the results of the most recent survey, it is suggested that this method be employed to review the status of bandicoot occupancy in the following patches:

- Brooksbys, Lake Leake, The Bluff and Gower CP in the Mt Burr Range.
- All previously surveyed patches in the Nangwarry and Caroline Forest areas, due to the very low rates of detection using the standard digging abundance survey method, to help inform future management options for these areas (see Section 5.5). In these sites, the method may include modifying step 5 (above), by continuing to assess additional Black Wattle groves (after detection, if that occurs) for helping determine the pattern of occupancy throughout the patch.
- Additional patches in the Caroline Forest not included in the digging abundance survey (Warreanga NFR and Penambol CP), to determine occupancy in those patches. This also will help inform future management options for the Caroline population area (see Section 5.5).

5.4.2 Statistical analysis options

It is acknowledged that the data analysis presented in this report is limited in scope, presenting simple analysis of the raw data for bandicoot occupancy rates and coarse activity trends based on the digging abundance score categories. Hence, it is suggested that the data in its current form, from all three digging abundance surveys, should be provided to a biometrician to determine if any analyses with greater statistical power may be applied. This is also likely to result in suggested improvements to the method for future surveys.

5.4.3 Raw versus categorised data

Further, the data used in this report is naturally limited in its resolution, as a result of being rapidly collected and simply assigned to one of five broad digging abundance categories, or three age categories (as per the method). In future, it may be worth considering (or indeed trialling) the time burden associated with collecting finer resolution data (i.e. exact, numerical digging scores) to enable more sensitive data analyses of bandicoot activity to occur. That data could also be transformed into the current categories for comparison and/or combination with earlier survey results.

5.5. Recommendations for management

5.5.1 Mt Burr Range patches

The Mt Burr Range cluster of sites is currently faring the best of its own accord, and with the additional connectivity between patches (through ongoing implementation of the corridor strategy) and continued judicious use of fire, should has every reason to remain an important core area for ensuring the persistence of the Southern Brown Bandicoot in the South East into the future. However, even with this strategy in place, assisted migration (through translocations) should still be seriously considered as a proactive management strategy to overcome the wider, and now entrenched, effects of fragmentation that are apparent in the genetic data from recent studies of the Mt Burr Range bandicoot population.

A further digging abundance survey to check on the status of these populations is also recommended in 5 years, to ensure (a) continued widespread occupancy and (b) that the moderate trend in declining bandicoot activity reported in 2016 doesn't continue.

5.5.2 Nangwarry patches

The outlying, more isolated remnant the Southern Brown Bandicoot population in the Nangwarry Forest is clearly under significant duress, returning very limited records over recent digging abundance survey. Strategies for supplementing the genetic diversity and hence viability of this area should be considered.

The possibility of a trial reintroduction of the species into the nearby, but currently isolated, Nangwarry NFR should also be considered for attempting to bolster this general population area – especially given the lack of nearby habitat in adjacent Victoria.

In addition to the above proposals, further digging abundance (or other) surveys of this area are recommended to inform management, undertaken on and annual or biennial basis.

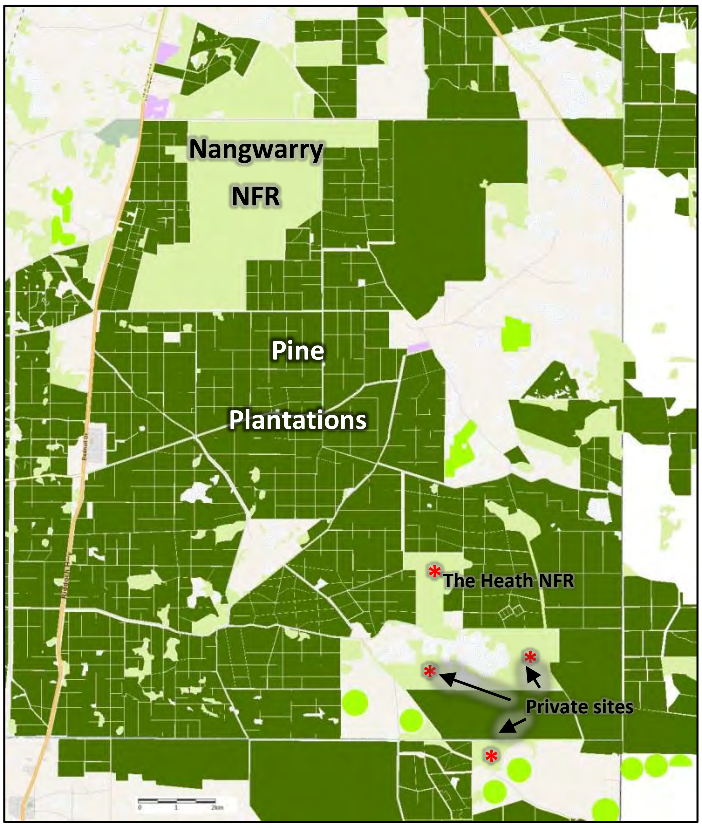

Figure 5-11: The Nangwarry Forest bandicoot population area. Red asterisks (*) indicate sites with confirmed Southern Brown Bandicoot records within the past 20 years. Nangwarry NFR is a substantial area of potential bandicoot habitat where a trial reintroduction could be attempted.

5.5.3 Caroline patches

Similar to Nangwarry, the remnant bandicoot population in the Caroline Forest is not faring well. However, unlike the Nangwarry patches, additional areas of habitat for the species are situated nearby – to the west of the Glenelg River (from Donovans (SA) beyond the Princess Margaret Rose Cave (Vic)) and in Rennick State Forest (Victoria), as shown in Figure 5-12.

Figure 5-12: The Caroline Forest and Lower Glenelg bandicoot population areas, with existing corridors marked red and planned corridor marked yellow. Red asterisks (*) indicate sites with confirmed Southern Brown Bandicoot records within the past 20 years.

While a treed corridor (one of the earliest established) along the state border between the northern and southern portions of Dry Creek NFR, links this area to habitat on the Glenelg River, supplementary efforts to alter tree density, and increase understorey diversity and cover, may make the corridor more conducive for facilitating dispersal of ground dwelling mammals. Further, options for establishing a cross-border biodiversity corridor between Dry Creek NFR and Rennick State Forest in Victoria should be investigated with the managers of the intervening pine plantations (Hancock Victorian Plantations). Population supplementation via translocation should also be considered to bolster the viability of this general population area, and digging abundance (or other) surveys of this area are also recommended to inform management, undertaken on and annual or biennial basis.

6. CONCLUSION

In terms of addressing the key objectives of this study, the results of the 2016 digging abundance surveys indicate two key findings relevant to the past 20 years:

1) **Occupancy** – the detected presence of the Southern Brown Bandicoot within the majority of patches containing the most suitable remnant vegetation for the species in the lower South East – **remains stable**.
2) **Digging activity** – physical evidence of the amount of feeding behaviour taking place within representative areas of native vegetation, as a surrogate measure of bandicoot abundance – **has declined**.

This means that while bandicoot distribution across the region remains unchanged, our surrogate measure of their abundance has declined.

Populations are under apparent duress in the outlying (and particularly isolated) Caroline and Nangwarry Forest sites, where all available evidence would point to these populations being under severe stress from smaller patch size, increased isolation and reduced genetic fitness (caused by isolation and inbreeding depression). Managing the future conservation of bandicoots across the vast network of fragmented reserves, within a matrix of plantations in the South East, presents some particular challenges. The key monitoring challenge is to keep an accurate account of (a) species distribution (b) changes in population abundance through time, and (c) population connectivity for maintaining genetic fitness.

It is clear that the digging abundance survey method – while certainly not perfect – does provide the opportunity to deliver a relatively consistent, rapid assessment technique over a large number of sites; capable of answering the first question (presence /absence) and providing a surrogate measure for beginning to tackle the second question, albeit a greater level of survey effort may be required in some patches. We are fortunate that such a rapid assessment technique is available because an equivalent option doesn't exist for most other threatened small mammal species. At present, the third question can only be answered through more intensive methods (e.g. trapping) and tissue sampling followed by genetic analysis to ascertain population genetic trends.

Key final recommendations from this work are:

- For digging abundance surveys to be repeated at Mt Burr Range sites in 5 years, and at Nangwarry and Caroline sites on an annual or biennial basis to help guide any future management strategies within the updated Regional Action Plan.
- For implementation of more active interventions (translocations / reintroductions) to ensure populations are not lost from the Nangwarry and Caroline sites.
- To protect and maintain the region's most viable Southern Brown Bandicoot population within the Mt Burr Range cluster of patches, through supporting the regional corridor strategy and giving serious consideration to a program of assisted migration (through translocations). This proactive strategy would help to overcome the long-term effects of fragmentation evident in the bandicoot genetic data.
- The judicious use of fire at the right spatial and temporal scale is recognised as a tool for managing the isolated habitat patches that do remain, given the species' demonstrated tolerance of a wide range of fire histories, but must be cognisant that habitat only becomes increasingly available to bandicoots from 5-7 years post burn.

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