Woolgoolga to Ballina Pacific Highway upgrade

Threatened Mammal Monitoring Annual Report 2017

Version 3.0

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1.0 INTRODUCTION

1.1 Project Overview and Background to this Monitoring

The Woolgoolga to Ballina Pacific Highway Upgrade comprises approximately 155 km of highway to achieve a four-lane divided road extending north of Woolgoolga at the northern extent of Sapphire to Woolgoolga Upgrade to south of Ballina where it ties into the southern extent of the Ballina bypass. The project includes grade separated interchanges, service roads and upgrades to local road connections.

The Threatened Mammal Management Plan (RMS 2015) addresses the impacts of the upgrade and proposed mitigation on a number of threatened mammal species including the Long-nosed Potoroo (Potorous tridactylus tridactylus), Rufous Bettong (Aepyprymnus rufescens) and Brush-tailed Phascogale (Phascogale tapoatafa). The management plan identifies both areas of known and potential habitat throughout the Project corridor and proposes a number of management actions to ensure the long-term survival of these species in the area of the project. In order to gauge the performance of these management actions, a pre-construction baseline monitoring survey was undertaken (Lewis 2015). The objective of these studies were to identify known threatened mammal sites and to collect baseline data on the population and habitat condition. In summary, these studies along with some earlier construction monitoring have identified the following:

- The constructed carriageway bisects:
    - Areas of known Long nosed Potoroo habitat with seven locations selected along with a further seven paired reference sites for monitoring;
    - Areas of known Rufous Bettong with five locations selected along with a further five paired reference sites for monitoring; and
    - Areas of known Brush-tailed Phascogale habitat with seven locations and a further seven reference sites for monitoring.

With construction nearing completion in Section 1 (southern end – October 2017 and northern end December 2017) and 2 (October 2017) combined with the commencement of construction in Sections 3-11, Pacific Complete (PC) engaged Jacobs to implement the BACI population monitoring surveys. The following reports on these findings.

2.0 STATUS OF THE MONITORING PROGRAMS

The current report refers to surveys in the following sections:

- Section 2 with Year 3 sampling for Rufous Bettong and Year 2 sampling for Brush-tailed Phascogale
- Section 3-10 for Year 1 monitoring of Long-nosed Potoroo (S6,7 and 10), Rufous Bettong (S3) and Brush-tailed Phascogale (S3,6 and 7).

They follow on from construction phase surveys conducted during 2015 and 2016 in section 2 (Lewis 2017; 2018) and pre-construction surveys conducted in sections 3, 6, 7 and 10 (Lewis 2014; Lewis 2015).

3.0 LONG-NOSED POTOROO (POTOROUS TRIDACTYLUS TRIDACTYLUS)

3.1 Species Profile

3.1.1 Description of the Subject Species

In northern NSW, Potoroo may weigh up to 1.9 kg (740–1850 grams) and have a head and body length of about 360 mm and a tail length between 200–260 mm (Bali et al. 2003; Plate 3-1). Their fur tends to be greyish-brown above and light grey below. It is distinguished from the slightly larger, but very similar Long-footed Potoroo (Potorous longipes) in a number of subtle ways including its shorter tail (less than 260 mm long) and smaller hind-foot (shorter than its head). The Long-nosed Potoroo also lacks a leathery pad on the sole of its foot, just behind the inner toe (a hallucal pad; Van Dyck and Strahan 2008; OEH 2015).

Plate 3-1. Long-nosed Potoroo.

3.1.2 Distribution

The Long-nosed Potoroo is found along the south-east coast of Australia, from Queensland to eastern Victoria and Tasmania, including some of the Bass Strait islands (OEH 2015). There are geographically isolated populations in western Victoria and NSW. In NSW, it is generally restricted to coastal heaths and forests east of the Great Dividing Range, with an annual rainfall exceeding 760 mm (Mason 1997; OEH 2015).

3.1.3 Habitat and Ecology

The Long nosed Potoroo inhabits coastal heaths, rainforests, dry and wet sclerophyll forests (Seebeck 1995; Mason 1997; Bali et al. 2003). A dense understorey with occasional open areas is an essential part of its habitat, and may consist of grass-trees, sedges, ferns or heath, or of low shrubs of tea-trees, Melaleuca or Banksia. A sandy loam soil or sandy soil with a developed humus layer is also a common feature. The fruit-bodies of hypogeous (underground-fruiting) fungi are a large component of the diet of the Long-nosed Potoroo, however, they also regularly forage on roots, tubers, insects and their larvae along with other soft-bodied animals in the soil (Bennett and Baxter 1989).

Potoroo diggings are similar to those of the Northern Brown Bandicoot (Isoodon macrourus) and it can be very difficult to distinguish between the two species. Potoroo tend to be nocturnal in their habits, hiding by day in dense vegetation often referred to as squat sites. In the southern part of its range, Potoroo have been observed foraging during the winter daylight hours in Victoria and Tasmania (Long 2001). Individuals are mainly solitary, non-territorial and have home range sizes of 2–5 ha in north eastern NSW (Bali et al. 2003). Breeding typically occurs in late winter to early summer and a single young is born per litter although adults are capable of two reproductive bouts per annum (OEH 2015).

3.2 Survey Methods

Field surveys were performed in accordance with the Threatened Mammal Management Plan (RMS 2015). The following details the areas surveyed along with the timing of field surveys and how the data were treated or analysed. A summary of this round of monitoring and how each survey ties into the construction monitoring period is summarised in Table 3-1.

Table 3-1. Summary of the Potoroo monitoring covered in this round of monitoring.

Technique/Timing	Technique	Survey 1	Survey 2	Monitoring period (phase)
Camera Traps	36 cameras for 14 nights	Section 6, 10 – Late autumn - winter 2017	Section 6 – Late Spring and Summer 2017/2018	Year 1 (construction)
		Section 7 – Spring 2016	Section 7 – Late autumn winter 2017	Year 1 (construction)
Spotlighting	1 person hour deployed twice per survey	Section 6, 10 – Late autumn - winter 2017	Section 6 – Late Spring and Summer 2017/2018	Year 1 (construction)
		Section 7 – Spring 2016	Section 7 – Late autumn winter 2017	Year 1 (construction)
Nocturnal Drive Transect	2-3 km driving twice per survey	Section 6, 10 – Late autumn - winter 2017	Section 6 – Late Spring and Summer 2017/2018	Year 1 (construction)
		Section 7 – Spring 2016	Section 7 – Late autumn winter 2017	Year 1 (construction)
Road Kill Survey	Throughout the survey period	Section 6, 10 – Late autumn - winter 2017	Section 6 – Late Spring and Summer 2017/2018	Year 1 (construction)
		Section 7 – Spring 2016	Section 7 – Late autumn winter 2017	Year 1 (construction)

3.2.1 Site Selection and Treatment Design

Seven paired BACI (Before-After-Control-Impact) sites were monitored and numbered from 2-8 (Lewis and Smith 2014; Table 3-2). Sites for the purpose of reporting have been classified as impact sites which are the site numbers followed by the letter A whilst control or reference sites are denoted by the letter B.

Table 3-2. Summary of the paired treatment sites for Potoroo.

W2B Section	BACI Site Name	Mitigation Treatment	BACI Site Name
6	Site 2A -Impact	Ch.100640 combined culvert 1.8 x 2.4, 71m long; Ch.101100 dedicated culvert 2.4 x 3, 38m long; and Ch.101541 bridge, 132 long x 10.5m wide	Site 2B - Control (Bundjalung National Park)
7	Site 3A-Impact	~Ch.115000 combined culvert	Site 3B- Control (Tabbimobile Swamp Nature Reserve)
7	Site 4A -Impact	Ch.118464 Bridge 20m	Site 4B – Control (Doubleduke State Forest)
10	Site 5A -Impact	Ch. 147600 RCBC x 38 x 2400 x 2400	Site 5B – Control (JALI Aboriginal Lands)
10	Site 6A -Impact	Ch. 148600 culvert 3 x 3 x 60m	Site 6B – Control (JALI Aboriginal Lands)
10	Site 7A -Impact	Ch. 150520 culvert 2.4 x 1.5 x 42 m; Ch. 150600 culvert 3.6 x 1.62 x 42 m	Site 7B – Control (JALI Aboriginal Lands)
10	Site 8A -Impact	Ch. 155920 RCBC 33 x 2400 x 2400	Site 8B – Control (JALI Aboriginal Lands)

3.2.2 Monitoring Technique (Camera Trapping)

Monitoring was performed in the manner ascribed in the threatened mammal management plan (RMS 2015). That being, at each site, 12 camera traps (Scoutguard™ 560 k zero glow) were installed 100 m apart to establish of grid of 300 X 400 m grid (12 ha). Each camera trap site was baited using one large handful of peanut butter, honey and oats with added natural vanilla extract (Queen Brand™). The bait was scattered over an area of 4–9 m^2 and the earth was partly disturbed to increase the likelihood of the area being visited by Potoroo. Cameras were generally fixed to a tree or stump in a horizontal facing position around 1–1.5 m off the ground with the primary objective of maximising the field of view. The positioning of cameras was guided by recent field survey evaluations of camera trap orientation whilst surveying for other small macropods and potoroids (see Taylor et al. 2013). The following recording parameters were standardised for all camera traps:

- Timer mode set from dusk till dawn whilst adjusting for differing daylight hours and changes in daylight saving;
- Sensitivity mode was set to 'high' and where required, vegetation such as long grass was trimmed to reduce false trigger events (i.e. grass being blown in the wind);
- Each triggering event recorded a 10 second video 8 megabyte (mb) in file size; and
- Reset time interval for retriggering was set at 30 seconds.

3.2.3 Timing of the Field Surveys

Sampling was divided into two survey periods with spring and early summer followed by a second survey in autumn to early winter. To accommodate the early staging works in Section 7, Year 1 survey 1 was implemented between the 5th November and 20th November 2016 for Sites 3 and 4, and this was considered the spring-summer census. Year 1 survey 2 was then undertaken between the 27th March and the 11th April 2017 as autumn sampling at Sites 3 and 4 in Section 7. The autumn census at sites 2, 5, 6, 7 and 8 was performed between the 28th March and the 28th May 2017whilst the

second survey (i.e. late spring into summer) was performed between the 23rd December 2017 and the 8th January 2018. Plans to implement the surveys 6 weeks earlier (i.e. November 2017) were delayed following a wildfire at Site 5, 6 and 7 which resulted in most of the monitoring site being recently burnt.

On each occasion, cameras were left operating over a continuous 14 night period which culminated in 168 nights of camera effort for each survey and a combined sampling effort of 336 camera nights per site (Table 3-3). Three stolen cameras were recorded at Site 7A, 7B and 8B (1 from each site) and as such only the retrieved cameras can be reported here.

The above approach ensured the temporal independence of the two baseline surveys was achieved with the repeated sampling being undertaken at intervals exceeding 90 days, a requirement outlined in the Threatened Mammal Management Plan (RMS 2015).

Table 3-3. Summary of the installation and retrieval time periods for camera trap monitoring.

Survey Period	Site Name	W2B Section	Installation Date	Retrieval Date	Ascribed Sampling Period	No. Nights	No. Cameras Retrieved	Effort (Camera Trap Nights)
1	Site 2A - Impact	6	28.03.2017	13.04.2017	Autumn	14	12	168
1	Site 2B - Control	6	28.03.2017	13.04.2017	Autumn	14	12	168
1	Site 3A - Impact	7	05.11.2016	20.11.2016	Spring-Summer	14	12	168
1	Site 3B - Control	7	05.11.2016	20.11.2016	Spring-Summer	14	12	168
1	Site 4A - Impact	7	05.11.2016	20.11.2016	Spring-Summer	14	12	168
1	Site 4B - Control	7	05.11.2016	20.11.2016	Spring-Summer	14	12	168
1	Site 5A - Impact	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 5B -Control	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 6A - Impact	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 6B -Control	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 7A - Impact	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 7B - Control	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 8A - Impact	10	13.05.2017	28.05.2017	Autumn	14	12	168
1	Site 8B - Control	10	13.05.2017	28.05.2017	Autumn	14	12	168
2	Site 2A - Impact	6	23.12.2017	08.12.2017	Spring-Summer	14	12	168
2	Site 2B - Control	6	23.11.2017	08.12.2017	Spring-Summer	14	12	168
2	Site 3A - Impact	7	27.03.2017	11.04.2017	Autumn	14	12	168
2	Site 3B - Control	7	27.03.2017	11.04.2017	Autumn	14	12	168
2	Site 4A - Impact	7	27.03.2017	11.04.2017	Autumn	14	12	168
2	Site 4B - Control	7	27.03.2017	11.04.2017	Autumn	14	12	168
2	Site 5A - Impact	10	24.12.2017	08.01.2018	Spring-Summer	14	12	168
2	Site 5B -Control	10	24.12.2017	08.01.2018	Spring-Summer	14	12	168
2	Site 6A - Impact	10	24.12.2017	08.01.2018	Spring-Summer	14	12	168
2	Site 6B -Control	10	24.12.2017	08.01.2018	Spring-Summer	14	12	168
2	Site 7A - Impact	10	24.12.2017	08.01.2018	Spring-Summer	14	11	154
2	Site 7B - Control	10	24.12.2017	08.01.2018	Spring-Summer	14	11	154
2	Site 8A - Impact	10	24.12.2017	08.01.2018	Spring-Summer	14	12	168
2	Site 8B - Control	10	24.12.2017	08.01.2018	Spring-Summer	14	11	154
					Total			Trap nights 4662

3.3 Statistical Analysis

The camera trap data is reported as the mean activity level or rate derived from the number of cameras that detected Potoroo and reported for each of the two survey periods (i.e. Survey 1 and Survey 2). For example, videos that recorded Potoroo from four of the 12 cameras for Baseline Survey 1 was expressed as 33.33% (4/12) and two of the 12 cameras during Baseline Survey 2 was expressed as 16.67% (2/12). The mean was derived from the percentage activity values for the two survey periods. So using the above example again, the two survey results of 33.33% + 16.67% were used to derive a mean of 25%. The activity rate was performed for all exotic predator species recorded so that additional affects could also be explored. Together, these values provide the Year 1 dataset which can be directly compared with the preconstruction baseline dataset.

The acceptable tolerance level for camera activity was calculated by finding the difference between the baseline activity and that of Year 1 for each treatment. The difference between the two treatments was then used to determine if the acceptable tolerance level of 25% had been exceeded as per Table 8.5 in the TMMP (RMS 2015). For example, at Site 8, the impact site declined from 58.3% in the baseline survey to 18.18% in Year 1 leaving a difference of 40.12%. This 40.12% was then used to calculate the decline (40.12/58.3 x 100) of 68.8%. At the control site, the baseline survey recorded 87.5% and this declined in Year 1 to 61.37%, leaving a difference of 26.13%. This 26.13% was then used to calculate the decline (26.13/87.5 x 100) of 29.9%. Although both sites declined, the difference between the two treatments was 38.9% (i.e. 68.8 at impact) and 29.9 at the control). In this example, it exceeded the >25% threshold where corrective actions would then need to be considered in Table 8-5 of the TMMP (RMS 2015).

3.4 Year 1 Potoroo Activity Levels

Potoroo monitoring during Year 1 recorded 15138 ten second videos (i.e. 42 hrs footage). The mean activity of Potoroo ranged from 17% at Site 8A up to 83.3% at Site 7B after 14 nights (Figures 3-1; Figure 3-2; Table 3-4; Plate 3-2). At the remaining sites, mean activity levels ranged from 20.84% at Site 2A (Mororo-Jacky Bulbin area) through to 70.83% at Site 6B (Bagotville/Wardell South) with relatively high mean values across most of the Wardell sand plain. Sites adjacent to Wardell Road (Site 8B) and Lumleys Lane (Site 8A) recorded lower than expected activity levels with 17% and 61.37% respectively.

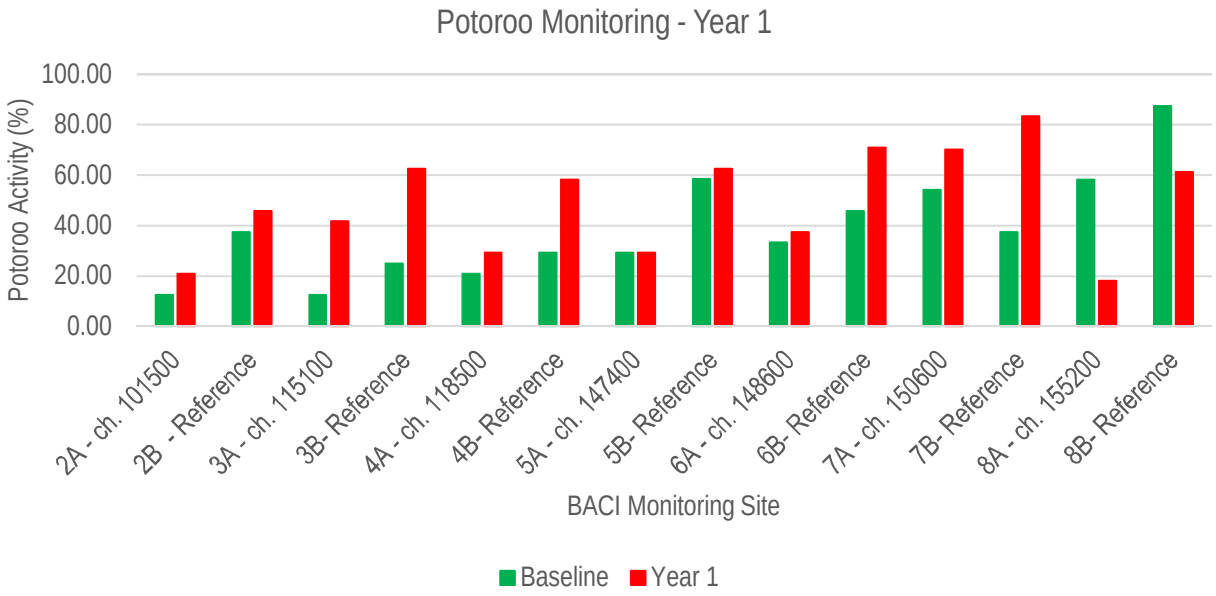

Figure 3-1. Potoroo activity levels at paired impact and control sites.

Plate 3-2. Example of a video image with a Long-nosed Potoroo (Site 6A - Impact: 26th December 2017 0137hrs). Note time/data not available as screenshot from streaming video

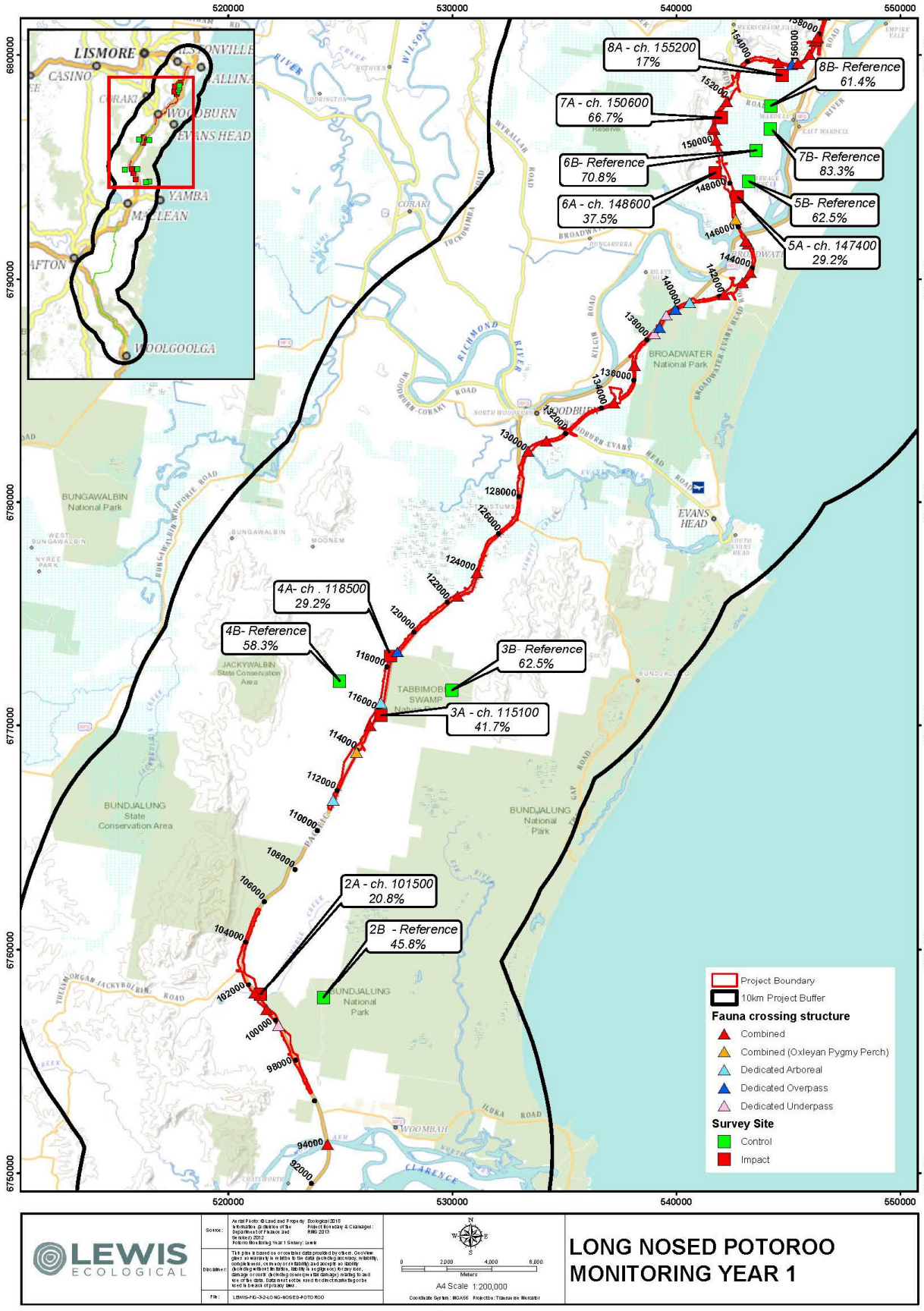

Figure 3-2. Location of impact and control monitoring sites with mean Potoroo activity rates for Year 1.

Table 3-4. Summary of the mean activity rates (%) for Year 1 Potoroo monitoring.

Site	Baseline	Year 1	Comments/Notes
2A - ch. 101500	12.5	20.8	Clearing had partially commenced on the opposite site of the carriageway
2B - Reference	37.5	45.8	
3A - ch. 115100	12.5	41.7	Clearing had occurred on the opposite side of the highway
3B- Reference	25.0	62.5	
4A - ch. 118500	20.8	29.2	No clearing had commenced
4B- Reference	29.2	58.3	
5A - ch. 147400	29.2	29.2	Clearing had occurred for the second survey conducted in summer 2017
5B- Reference	58.4	62.5	
6A - ch. 148600	33.4	37.5	Clearing had occurred for the second survey conducted in summer 2017
6B- Reference	45.9	70.8	
7A - ch. 150600	54.2	66.7	Clearing had occurred for the second survey conducted in summer 2017
7B- Reference	37.5	83.3	
8A - ch. 155200	58.3	17.0	Clearing had occurred for the second survey conducted in summer 2017
8B- Reference	87.5	61.4	

3.5 Time Area Spotlighting for Potoroo

Potoroo were spotlighted at three sites with:

- One adult at Site 5B during the summer survey;
- One adult at Site 6A and 6B each during the summer survey.

Site 5B and 6B had been recently burnt as part of a 300 ha wild fire across the Wardell sandplain, and with this, there was improved visibility for the surveyor.

3.6 Nocturnal Drive Transects for Potoroo

No Potoroo were detected during the nocturnal drive transects.

3.7 Road Kill Transects for Potoroo

No Potoroo were detected during the road kill transects.

3.8 Measuring the Influence of Exotic Predators

Year 1 monitoring recorded two species of exotic predator (Wild Dog and Fox) at 13 of the 20 monitoring grids. No Cat was recorded during Year 1 monitoring. Fox was recorded at Site 3A, 5A, 5B, 7A and 8A with only Site 3A a new occurrence (Figure 3-3). There was increased Fox activity at Site 5B where activity increased from 4.17% during the baseline survey to 8.33% in Year 1. More marked increases were recorded at Site 7A and 8A in Year 1 with activity levels increasing from 4.17% in the baseline survey to 26.14% and 27.27% respectively. At Site 8A, the deployed cameras captured footage of a Fox that had predated on a Potoroo (Plate 3-3).

Wild Dog was recorded at two of the monitoring sites, Site 2A where activity levels had increased from 4.17% in the baseline survey to 20.84% in Year 1 (Figure 3-3; Plate 3-4). At Site 4A, Dog activity levels had also increased from 4.17% in the baseline survey to 8.33% in Year 1. Interestingly, no Dog activity was recorded at Site 3A and 6B where activity levels of 4.17% and 8.33% were recorded in the baseline survey.

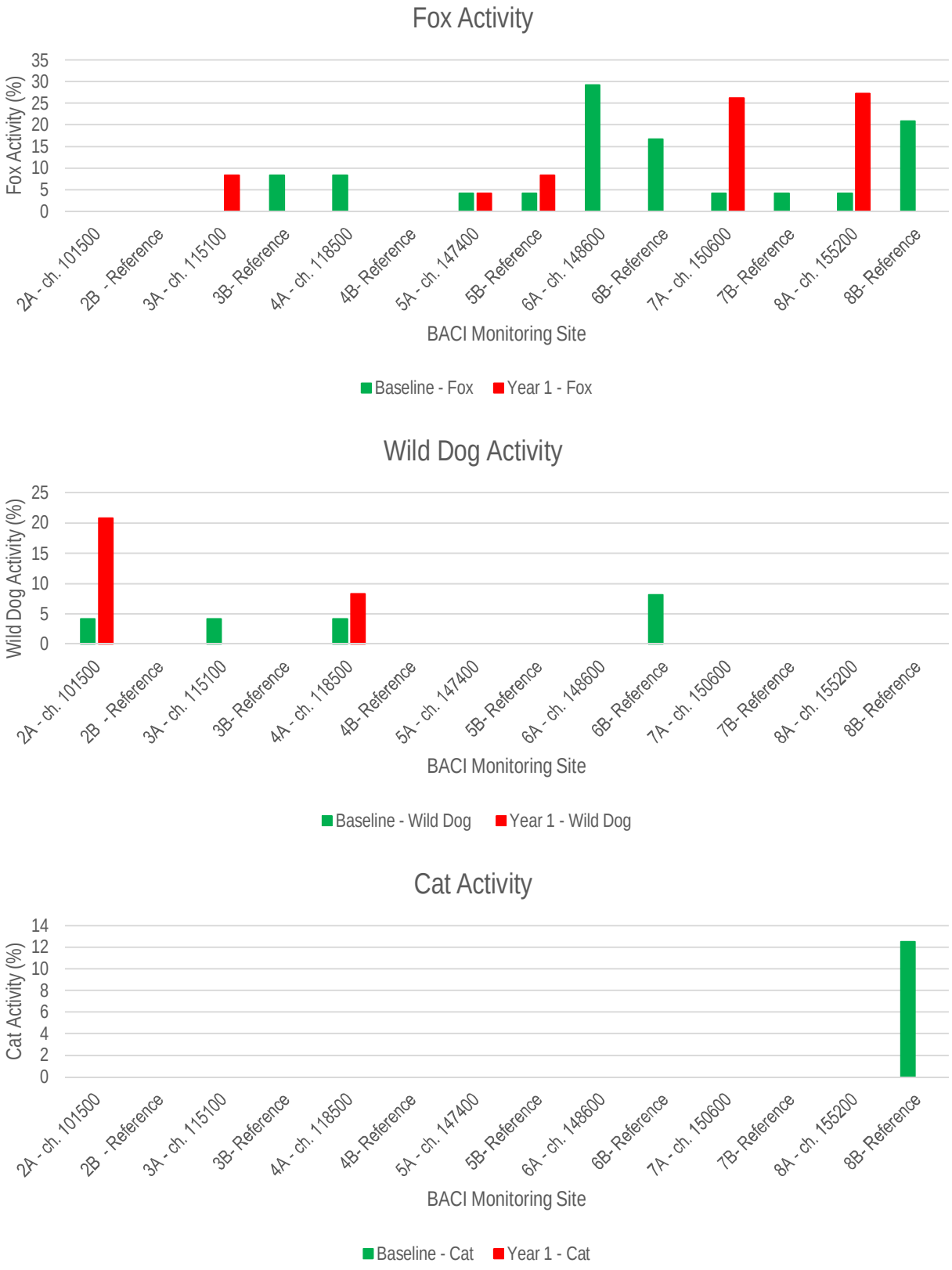

Figure 3-3. Year 1 activity levels of exotic predators (cat, fox, wild dog) at each of the monitoring sites.

Plate 3-3. Image of a Red Fox with Potoroo prey recorded from Site 8A (ch.155200) at 0426am – 4th January 2018.

Plate 3-4. Image of a Wild Dog/Dingo recorded from Site 2A (CH101500) at 0505am - 13th April 2017.

3.9 Discussion of Year 1 Monitoring Data (Construction Phase)

Year 1 monitoring confirmed Potoroo continue to inhabit all of the 14 monitoring grids with individuals recorded during both of the seasonal surveys. On most occasions, Potoroo activity levels were found to increase and there were a number of sites where levels had more than doubled from the baseline survey. For example, Site 3A where activity had increased from 12.50% in the baseline survey to 41.67% in Year 1 and this was almost mirrored in the paired reference Site 3B which increased from 25.00% in the baseline survey to 62.50% in Year 1. Some construction works had commenced at this site albeit on the opposite side of the road and this is thought to have had little overall effect. With this in mind, the recorded variation is considered natural.

A wild fire event in spring of 2017 had burnt through monitoring Sites 5 and 6 which meant that habitat had changed markedly from the first survey in May to the second survey in December and January. Interestingly, the activity levels remained at or slightly above those recorded in the baseline survey. At Site 6B there was a notable increase in activity which had increased by 50%. At least some of this would have been attributed to individuals foraging over a greater area and potentially being more attracted to the trapping baits deployed. Nonetheless, the population appears comparable to the baseline surveys in and around these Jali lands

Site 8A was the only monitoring grid where Potoroo activity decreased with the impact site declining from 58.30% in the baseline survey to 18.2% in Year 1, yet this same decline was recorded at the adjacent reference site which declined from 87.50% in the baseline survey to 61.37% in Year 1. Fox activity had increased at the impact site where Potoroo are now a confirmed prey item (see Plate 3-3), yet interestingly two kilometres to the south, no exotic predators were recorded yet Potoroo activity declined. A predator control program focusing on the broader area had removed six wild dogs and 15 foxes around this time and is likely to have reduced exotic predatory pressures at these northern sites (AFPMS 2018). Some targeted works closer to Lumleys Lane may benefit the Potoroo population at Site 8.

Potoroo were spotlighted at three sites during Year 1 monitoring which is an improvement on past use of this technique when no Potoroo could be spotlighted during the baseline survey. The observations of Potoroo at Site 5B and 6B can be explained by the wildfire event of September/October 2017 that left the site with reduced vegetative cover and increased observer visibility. In time, this observer visibility will reduce and the ability to effectively spotlight these two monitoring grids will diminish as vegetation regenerates and reduces observer visibility. At Site 6A, one adult Potoroo was briefly spotlighted during the summer survey, a site that is relatively open with its sparse shrub cover and tall eucalypt overstorey. This site is currently isolated from the Potoroo population on the Wardell sandplain and is of particular monitoring interest to the overall program.

No Potoroo were recorded during drive transects in or adjacent to the monitoring grids. Similarly, no Potoroo were recorded as part of the road kill transects. This is comparable to the baseline survey and both techniques continue to

contribute very little to the monitoring program. Consequently, it is recommended that they be removed from the monitoring program.

3.10 Performance Indicators and Corrective Actions

A series of performance indicators and corrective actions have been outlined in Section 8.2.4 of the Threatened Mammal Management Plan (RMS 2015). This plan states that should it become clear that sites that were occupied prior to road construction (i.e. established impact monitoring sites) have become unoccupied, or abundance (estimated using the transect counts) has declined beyond the identified thresholds (i.e. 25%) relative to control/reference sites, corrective actions must be implemented in accordance with those provided in Table 8-5.

Monitoring is to be conducted until such time as the mitigation measures have proven to be effective over three consecutive monitoring periods (TMMP; s.8.1). The plan identifies acceptable thresholds that if exceeded, would trigger corrective actions.

This may include any of the following:

a. >25% decline in Long-nosed Potoroo activity levels from paired control site through the use of camera trap grids
b. >50% decline from paired control site from spotlighting surveys

The following corrective actions are discussed in the plan

- Review monitoring methods and implement a more intensive monitoring and assessment schedule to confirm a decline in population density.
- Consider potential for natural variation to be responsible for decline in population numbers/density by comparison with control sites.
- Review results in conjunction with the road kill monitoring to check correlation with fence absence or breaches of the fence.
- Investigate habitat adjoining the highway and consider improving habitat condition and connectivity.

A summary of Potoroo activity levels is provided in Table 3-5. Potoroo activity in Year 1 increased or remained static from the baseline surveys at Sites 2, 3, 4, 5, 6 and 7. At Site 8 however, Potoroo activity declined by 68.8% following a drop in activity from 58.3% in the baseline survey to 18.2% in Year 1. The paired control or reference Site 8B also recorded a decline of 29.9% when Potoroo activity was measured at 87.5% in the baseline survey and 61.37% in Year 1. The difference between the two treatments is calculated at 38.9% and exceeds the 25% acceptable tolerance levels and thus requires a corrective action in accordance with Table 8.5 of the TMMP.

Spotlighting during Year 1 recorded incremental increases at Site 5B, 6A and 6B. Given that no Potoroo were recorded during the baseline survey, there is no decline >50% from the paired control site.

Nocturnal drive transects during Year 1 recorded no Potoroo and this mirrored the baseline survey. This represents a continuing absence of Potoroo using this technique and doesn't trigger any correction actions based on an absence of records for more than 2 years of nocturnal surveys.

Table 3-5. Mitigation measure, performance measures, corrective actions and timing during construction and operation.

Technique	Description	Acceptable Tolerance Level From the Control Site	Potoroo Site Reference Name	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B
Camera Traps	12 cameras installed on a 300 x 400 m grid	>25% decline in Potoroo activity levels from paired control site	Baseline (%)	12.5	37.5	12.5	25	20.8	29.2	29.2	58.4	33.4	45.9	54.2	37.5	58.3	87.5
			Year 1 (%)	20.84	45.84	41.67	62.5	29.17	58.34	29.17	62.5	37.5	70.83	70.08	83.34	18.18	61.37
			Comment Performance	Increase activity	Increase activity	Increase activity	Increase activity	Increase activity	Increase activity	Same as baseline	Small increase in activity	Small increase in activity	Increase activity	Increase activity	Large increase in activity	Large decline in activity	Decline in activity
Spotlight Surveys	4 units x 1 person hour (30 min per person) non-consecutive nights	50% decline	Baseline (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Year 1 (%)	0	0	0	0	0	0	0	0.25	0.25	0.25	0	0	0	0
			Comment Performance								Increase	Increase	Increase				
Nocturnal Drive Transect	4 units of 2-3 km transect employed on nights of spotlight surveys	Absence after 2 years of monitoring	Baseline (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Year 1 (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Comment Performance	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change
Road Kill Surveys	Surveys on multiple days and season in areas adjacent to monitoring grids	>200% increase in road kill records during surveys.	Baseline (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Year 1 (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Comment performance	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change	No change
			Performance above threshold (triggers corrective action)	No		No		No		No		No		No		Yes	

3.11 Conclusions and Recommendations

Population monitoring during Year 1 has demonstrated the continuing presence and viability of Potoroo populations bisected to accommodate the Woolgoolga to Ballina Upgrade. In Section 6, the Potoroo population associated with Tabbimoble Creek (Site 2) recorded a small increase in activity and this was mirrored at the adjacent control site further to the east in Bundjalung National Park. Only some small scale clearing along the existing carriageway and bridge works over Tabbimoble Creek had occurred. Further north in Section 7, both Sites 3 and 4 and their treatment classes recorded increases in activity. Around this time, some small scale clearing had occurred adjacent to Site 3A (Tabbimoble Overflow) and small mosaic clearing associated with geo technical investigation and service relocations around Site 4A (Tabbimoble Swamp Nature Reserve).

Further north in Section 10, the Potoroo populations associated with Site 5 and 6 (Southern Wardell Sandplain) remained static or at slightly higher activity levels than the baseline survey. Clearing operations had commenced during this survey period and just ahead of the spring survey, a wild fire burnt through most of these sites totalling around 300 ha. This reduction in ground cover made spotlighting a more productive technique than previous surveys with Potoroo spotlighted at a number of these sites. Around this time, a coordinated predator control program destroyed 15 Foxes and six Wild Dogs (Australian Feral Pest Management Service 2018) and is thought to have reduced predatory pressures on Potoroo in this area.

Further north on the Wardell sandplain, Potoroo activity levels had increased markedly at Site 7 (central Wardell Sandplain) which hadn't been burnt in the wild fire. This site had remained largely static with only some clearing adjacent to the impact site along Thurgates Lane in the late spring/summer survey. Meanwhile at Site 8 (Lumleys Lane, northern Wardell Sandplain), something different had occurred with Potoroo activity levels declining at both the impact (68%) and control site (29.9%), with this difference (38.1%) exceeding the acceptable threshold of 25% outlined in the TMMP (RMS 2015). As a decline has also occurred at the paired control site this may suggest natural variation or pressure from predators. Corrective actions should be visited and are discussed in Table 3-6.

Spotlighting resulted in the detection of Potoroo at a few sites with these observations occurring after the wildfire event when the habitat was regenerating, making detection easier. Even after this, no Potoroo were detected during the nocturnal drive transects. Overall, they continue to contribute very little data to the monitoring program and supports the earlier Potoroo monitoring of Section 7 that these techniques be discontinued (Lewis 2017).

Based on the Year 1 findings, the following recommendations are outlined in Table 3-6.

Table 3-6. Recommendations following Year 1 Potoroo population monitoring and Roads and Maritime response.

Recommendation No	Recommendation	Roads and Maritime Response
1.	Site 8A above performance threshold. Review correction actions for Site 8 in accordance with TMMP Table 8.5. As per point 2 decline also at control site and may be associated with predator activity. As per point 4 investigate habitat adjoining the highway and consider improving habitat condition and connectivity.	Adopted: RMS agree that predator activity noted near site 8 control and impact triggers performance level. Also agree this is a broader landscape issue as occurring at control as well as impact sites and not necessarily related to the project. Action will be to liaise with and inform regional stakeholders who currently perform feral animal control in Wardell and Jali lands and provide the data being collected. This is considered to suitable to address corrective action 4.
2.	Remove spotlighting and nocturnal drive transects from the monitoring program.	Adopted. RMS agrees that spotlighting and nocturnal drive transects are providing little value and as recommended in previous annual reports and on page 25 of the Threatened Mammal Management Plan.
3	Prioritise connectivity structures near CH148600 so as to restore habitat connectivity for Potoroo	Connectivity structures near CH148600 were installed in early 2019 and are in the final stages of landscape establishment and fencing.

3.12 References

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3.13 Appendix 1 – Camera Trap Data

Table A1. Camera trap survey results for Site 2 (CH101100) located adjacent to Section 6 (Tabbimoble Creek).

Site 2A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog
2A	0									
2B	78		1	1	1	1				
2C	37			1	1	1	1			
2D	32			1			1			
2E	30	1		1		1				
2F	45		1		1	1	1	1	1	
2G	6		1						1	
2H	31		1	1	1		1		1	1
2I	6		1		1					
2J	86	1			1	1		1		1
2K	59			1	1	1		1		
2L	28				1		1	1		
Total	438	2	5	6	8	6	5	4	3	2
Mean	36.5	16.67	41.67	50.00	66.67	50.00	41.67	33.33	25.00	16.67
Site 2 A - Late Spring-Summer 2017	**No. Videos**	**Potoroo**	**LN Bandicoot**	**Swamp Wallaby**	**Rodent**	**Common Brush-tail Possum**	**Antechinus**	**Northern Brown Bandicoot**	**Echidna**	**Wild Dog**
2A	26		1		1	1				
2B	44		1	1	1					1
2C	23	1			1	1	1			
2D	9			1			1			
2E	26	1		1						
2F	27		1		1	1		1	1	
2G	35									1
2H	78			1	1		1			

Site 2A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog
2I	34		1	1	1					
2J	87	1		1	1	1		1		
2K	58			1	1	1				1
2L	43				1		1	1		
Total	490	3	4	7	9	5	4	3	1	3
Mean	40.83	25.00	33.33	58.33	75.00	41.67	33.33	25.00	8.33	25.00

Site 2B - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog
2A	82	1	1	1	1		1			
2B	37	1	1	1	1		1		1	
2C	53	1		1	1		1			
2D										
2E	111	1		1			1	1		
2F	14			1	1			1		
2G	21	1	1	1	1		1			
2H	4			1						
2I	19				1					
2J	59	1	1	1			1			
2K	84		1				1	1		
2L	29			1				1	1	
Total	513	6	5	9	6	0	7	4	2	0
Mean	46.63	50.00	41.67	75.00	50.00	0.00	58.33	33.33	16.67	0.00

Site 2B - Late Spring-Early Summer 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brushtail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog
2A	66			1	1		1			
2B	99	1	1	1	1	1				

Site 2A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog
2C	99				1		1			
2D	17			1		1				
2E	111	1		1	1		1			
2F	22	1		1	1			1		
2G	27	1	1	1	1		1			
2H	66			1						
2I	14			1						
2J	44	1	1	1						
2K	36		1					1		
2L	86			1				1	1	
Total	687	5	4	10	6	2	4	3	1	0
Mean	57.25	41.67	33.33	83.33	50.00	16.67	33.33	25.00	8.33	0.00

Table A2. Camera trap survey results for Site 3 (CH115100) located adjacent to Section 7 (Tabbimoble Overflow 1).

Site 3A - Late Spring 2016	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
3A	37	1	1	1	1	1	1		1		
3B	49			1	1		1		1		
3C	11			1	1		1				
3D	34			1	1		1				
3E	32	1		1	1		1				
3F	33	1		1	1						
3G	26				1	1	1	1			
3H	102		1		1	1	1				
3I	3	1	1				1				
3J	10			1	1						1

Site 3A - Late Spring 2016	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
3K	40	1		1	1		1				
3L	49	1		1	1		1				
Total	426	6	3	9	11	3	10	1	2	0	1
Mean/Percentage	35.5	50.00	25.00	75.00	91.67	25.00	83.33	8.33	16.67	0.00	8.33

Site 3A – Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
3A	22		1	1	1	1	1		1		
3B	26			1			1		1		
3C	18				1			1			
3D	39			1		1	1				1
3E	3	1		1	1		1	1			
3F	22			1	1						
3G	34				1	1	1	1			
3H	43			2	1	1	1				
3I	23	1	1				1		1		
3J	9			1	1						
3K	9	1		1	1						
3L	25	1		1	1		1				
Total	273	4	2	10	9	4	8	3	3	0	1
Mean/Percentage	22.75	33.33	16.67	83.33	75.00	33.33	66.67	25.00	25.00	0.00	8.33

Site 3B - Late Spring 2016	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
3A	12				1		1				
3B	2										
3C	11				1						
3D	16							1			

Site 3A - Late Spring 2016	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
3E	45	1	1	1				1			
3F	18	1						1			
3G	14	1						1			
3H	74	1			1						
3I	84	1			1			1	1		
3J	61	1	1	1	1		1	1			
3K	34	1		1	1		1				
3L	10	1		1							
Total	381	8	2	4	6	0	3	6	1	0	0
Mean/Percentage	31.75	66.67	16.67	33.33	50.00	0.00	25.00	50.00	8.33	0.00	0.00

Site 3B - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
3A	2				1		1				
3B	17	1		1				1			
3C	22		1		1				1		
3D	20					1	1	1			
3E	17	1	1	1				1			
3F	34	1						1			
3G	75	1			1	1	1	1			
3H	33				1						
3I	57	1			1			1	1		
3J	55		1	1	1		1	1			
3K	37	1		1	1		1				
3L	16	1		1							
Total	385	7	3	5	7	2	5	7	2	0	0
Mean/Percentage	32.08333	58.33	25.00	41.67	58.33	16.67	41.67	58.33	16.67	0.00	0.00

Table A3. Camera trap survey results for Site 4 (CH118500) located adjacent to Section 7 (Tabbimoble Swamp Nature Reserve).

Site 4A - Late Spring 2016	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
4A	13										
4B	9		1	1	1	1					
4C	17	1					1			1	
4D	24	1		1	1	1			1		
4E	27				1		1				0
4F	8							1			
4G	17		1		1					1	
4H	33	1		1			1				
4I	3		1					1			
4J	22										
4K	19			1							
4L	7		1		1						
Total	199	3	4	4	5	2	3	2	1	2	0
Mean/Percentage	16.58333	25.00	33.33	33.33	41.67	16.67	25.00	16.67	8.33	16.67	0.00
Site 4A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox
4A	11						1				
4B	6		1	1	1	1	1		1		
4C	27	1					1				
4D	17	1		1		1			1		
4E	44				1		1				0
4F	11	1		1				1			
4G	26				1						
4H	15	1		1			1				
4I	6		1			1		1			
4J	3										

4K	22			1							
4L	34		1		1						
Total	222	4	3	5	4	3	5	2	2	0	0
Mean/Percentage	18.5	33.33	25.00	41.67	33.33	25.00	41.67	16.67	16.67	0.00	0.00

Site 4B - Spring 2016	No. videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Wild dog	Antechinus
a	149	1			1		1	1		1
b	17	1			1		1	1		
c	81	1		1	1		1	1		1
d	28	1			1			1		
e	68	1			1		1	1		
f	9	1			1					
g	66				1	1				
h	18							1		
i	186		1		1			1		
j	92	1	1		1		1			
k	68		1			1	1			
l	53	1	1		1			1		
Total	835	8	4	1	10	2	6	8	0	2
Mean/Percentage	69.58	66.67	33.33	8.33	83.33	16.67	50.00	66.67	0.00	16.67

Site 4B Autumn 2017	No. videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Antechinus
a	79	1			1		1	1		1
b	29		1				1	1		
c	73	1		1	1	1	1	1		1
d	29	1	1		1			1		
e	37				1		1	1		
f	19				1		1			
g	68					1	1			1

h	45	1						1		
i	28		1	1				1		
j	33	1			1		1			1
k	77		1			1	1			
l	43	1	1		1			1		
Total	560	6	5	2	7	3	8	8	0	4
Mean/Percentage	46.67	50	41.67	16.67	58.33	25.00	66.67	66.67	0.00	33.33

Table A5. Camera trap survey results for Site 5 (CH147400) located adjacent to Section 10 (Southern edge of Wardell Sand Plain).

Site 5A - Autumn 2017	Number Videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Eastern Grey Kangaroo	Mountain Possum	Brush Turkey	Fox	Koala
a	1													
b	19		1	1			1				1			
c	3						1							
d	9		1				1							
e	10	1	1											
f	22		1											
g	330													
h	44	1										1		
i	4				1		1							
j	295	1		1	1		1					1		
k	33		1									1		
l	217													
Totals	987	3	5	2	2	0	5	0	0	0	1	3	0	0
Mean/Percentage	82.25	25.00	41.67	16.67	16.67	0.00	41.67	0.00	0.00	0.00	8.33	25.00	0.00	0.00
Site 5A - Summer 2017/18	Number Videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Eastern Grey Kangaroo	Mountain Possum	Brush Turkey	Fox	Koala
a	77		1	1										
b	100	1	1	1	1	1	1	1						

Site 5A - Autumn 2017	Number Videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Eastern Grey Kangaroo	Mountain Possum	Brush Turkey	Fox	Koala
c	25					1								
d	33		1	1		1						1		
e	26			1	1			1						
f	44	1			1		1							
g	55		1	1				1				1		
h	28	1	1		1		1							
i	88	1			1			1						
j	5		1	1	1		1							
k	145		1	1	1	1		1						
l	17		1	1				1					1	
Totals	643	4	8	8	7	4	4	6	0	0	0	2	1	0
Mean/Percentage	53.58	33.33	66.67	66.67	58.33	33.33	33.33	50.00	0.00	0.00	0.00	16.67	8.33	0.00

Site 5B - Autumn 2017	Number videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Eastern Grey Kangaroo	Mountain Possum	Brush Turkey	Fox	Koala
a	98													
b	67	1	1		1		1	1						
c	166	1					1	1					1	
d	111		1		1									
e	98	1			1		1	1						
f	29	1	1					1				1		
g	97	1	1		1									
h	234				1		1	1					1	
i	232	1				1								
j	245													
k	17													
l	0													
Total	1394	6	4	0	5	1	4	5	0	0	0	1	2	0

Site 5A - Autumn 2017	Number Videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Eastern Grey Kangaroo	Mountain Possum	Brush Turkey	Fox	Koala
Mean/Percentage	116.17	50.00	33.33	0.00	41.67	8.33	33.33	41.67	0.00	0.00	0.00	8.33	16.67	0.00
Site 5B - Summer 2017/2018	Number videos	Potoroo	Swamp Wallaby	Brush-tailed Possum	Rodent	Echidna	Long-nosed Bandicoot	Northern Brown Bandicoot	Dingo/wild dog	Eastern Grey Kangaroo	Mountain Possum	Brush Turkey	Fox	Koala
a	123	1			1		1							
b	29	1	1		1		1							
c	201		1		1		1					1		
d	36		1											
e	49	1	1			1	1							
f	49	1			1		1							
g	116	1					1					1		
h	39	1	1				1							
i	178	1			1		1							
j	27	1			1		1							
k	9	1	1	1			1	1						
l	59	1						1						
Total	915	9	6	1	6	1	10	1	0	0	0	2	0	0
Mean/Percentage	76.25	75.00	50.00	8.33	50.00	8.33	83.33	8.33	0.00	0.00	0.00	16.67	0.00	0.00

Table A6. Camera trap survey results for Site 6 (CH148600) located adjacent to Section 10 (Old Bagotville Road).

Site 6A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala
6A	33			1	1							
6B	28	1	1	1	1		1					
6C	19		1		1				1			
6D	22	1	1	1	1		1					
6E	66		1		1				1			
6F	75				1				1			
6G	25	1	1		1		1					
6H	26	1	1	1	1				1			
6I	67			1								
6J	88		1		1							
6K	91		1	1	1							
6L	57	1		1	1				1			
Totals	597	5	8	7	11	0	3	0	5	0	0	0
Mean/Percentage	49.75	41.67	61.54	53.85	84.62	0.00	23.08	0.00	38.46	0.00	0.00	0.00
Spring Summer 2017/18	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala
6A	52	1										
6B	25	1	1		1		1					
6C	13		1		1				1			1
6D	39		1	1	1		1					
6E	23				1				1			
6F	15				1				1			
6G	44	1	1		1		1					
6H	56			1	1				1			

Site 6A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala
6I	7			1								
6J	15		1		1							
6K	28		1	1	1							
6L	71	1	1	1	1				1			
Totals	388	4	7	5	10	0	3	0	5	0	0	1
Mean/Percentage	32.33	33.33	53.85	38.46	76.92	0.00	23.08	0.00	38.46	0.00	0.00	7.69

Site 6B - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala
6A	60	1	1	1					1			
6B	50			1	1	1						
6C	34		1	1	1				1			
6D	17	1		1		1	1		1			
6E	38	1	1	1	1							
6F	23	1										
6G	45		1	1		1						
6H	107	1	1		1				1			
6I	31			1	1							
6J	31	1				1			1			
6K	44		1	1	1				1			
6L	474	1	1	1			1					
Totals	954	7	7	9	6	4	2	0	6	0	0	0
Mean/Percentage	79.5	58.33	53.85	69.23	46.15	30.77	15.38	0.00	46.15	0.00	0.00	0.00

Site 6B - Summer 2017/2018	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brushtail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala
6A	27	1	1	1					1			

Site 6A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Yellow-footed Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala
6B	103	1		1	1							
6C	105	1	1	1	1				1			1
6D	36			1					1			
6E	47	1	1	1	1							
6F	9	1										
6G	57		1	1	1	1						
6H	75	1	1	1	1							
6I	80	1	1	1	1							
6J	45	1	1	1		1			1			
6K	30	1	1	1	1		1		1			
6L	94	1	1	1								
Totals	708	10	9	11	7	2	1	0	5	0	0	1
Mean/Percentage	59	83.33	69.23	84.62	53.85	15.38	7.69	0.00	38.46	0.00	0.00	7.69

Table A7. Camera trap survey results for Site 7 (CH150600) located adjacent to Section 10 (Thurgates Lane).

Site 7A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
7A	40	1	1	1	1		1				1		
7B	44	1		1	1		1						
7C	66	1		1			1		1				
7D	40	1	1	1	1	1		1			1		
7E	27	1	1	1	1				1				
7F	66		1	1	1		1		1				
7G	18					1							
7H	26	1	1		1		1		1		1		1
7I	28			1					1				

Site 7A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
7J	18		1										
7K	19			1	1		1						
7L	18	1											
Totals	410	7	6	8	7	2	6	1	5	0	3	0	1
Mean/Percentage	34.17	58.33	50.00	66.67	58.33	16.67	50.00	8.33	41.67	0.00	25.00	0.00	8.33
Site 7A - Summer 2017/2018	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
7A	Stolen												
7B	35	1		1	1		1				1		
7C	16	1		1			1		1				
7D	68	1	1	1	1						1		
7E	73	1	1	1	1				1				
7F	75		1	1	1		1		1				
7G	0												
7H	42	1			1		1		1		1		1
7I	12	1		1					1				
7J	1	1											
7K	12	1			1		1						
7L	4	1											
Totals	338	9	3	6	6	0	5	0	5	0	3	0	1
Mean/Percentage	30.73	81.82	27.27	54.55	54.55	0.00	45.45	0.00	45.45	0.00	27.27	0.00	9.09
Site 7B - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
7A	67	1	1	1	1		1						
7B	29	1	1	1	1				1				
7C	19				1	1	1						

Site 7A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
7D	98	1	1	1	1								
7E	18	1	1			1			1				
7F	29	1	1	1	1		1						
7G	20				1	1	1		1				
7H	79	1	1	1	1				1				
7I	59	1	1	1		1							
7J	49	1	1		1		1						
7K	75		1	1	1								
7L	39	1		1	1								
Totals	581	9	9	8	10	4	5	0	4	0	0	0	0
Mean/Percentage	48.42	75.00	69.23	61.54	76.92	30.77	38.46	0.00	30.77	0.00	0.00	0.00	0.00

Site 7B - Summer 2017/18	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
7A	91	1	1	1	1		1						
7B	21	1		1	1				1				
7C	11				1	1	1						
7D	48	1	1	1	1								
7E	48	1	1	1		1			1				
7F	47	1	1	1	1		1						
7G	30	1		1	1				1				
7H	79	1	1	1	1				1				
7I	86	1	1	1	1								
7J	64	1	1		1								
7K	85	1	1	1	1				1				
7L	35	1		1	1				1				
Totals	645	11	8	10	11	2	3	0	6	0	0	0	0
Mean/Percentage	53.75	91.67	61.54	76.92	84.62	15.38	23.08	0.00	46.15	0.00	0.00	0.00	0.00

Table A8. Camera trap survey results for Site 8 (CH155200) located adjacent to Section 10 (Lumleys Lane and Wardell Road).

Site 8A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad	Comments
8A	77			1		1			1					
8B	46	1			1	1								
8C	29	1	1											
8D	46			1			1				1			
8E	89				1				1					
8F	Stolen													
8G	4		1		1									
8H	38						1		1					
8I	29	1		1										
8J	72		1		1		1				1			
8K	28			1	1			1						
8L	9				1						1			
Totals	467	3	6	6	9	2	3	1	3	0	3	0	0	
Mean/Percentage	42.45	27.27	27.27	33.33	54.55	18.18	27.27	9.09	27.27	0.00	27.27	0.00	0.00	
Summer 2017/18	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad	
8A	34		1	1		1			1		1			fox with potoroo - 2 foxes in same file
8B	19		1		1	1								
8C	91		1		1									
8D	86			1			1				1			
8E	62				1				1					
8F	Stolen													
8G	20		1	1	1		1							
8H	54			1	1		1		1					
8I	11	1	1	1	1									

Site 8A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad	Comments
8J	40		1		1		1				1			
8K	20			1	1			1						
8L	103				1									
Totals	540	1	6	6	9	2	4	1	3	0	3	0	0	
Mean/Percentage	49.09	9.09	54.55	54.55	81.82	18.18	36.36	9.09	27.27	0.00	27.27	0.00	0.00	

Site 8B - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
8A	24	1	1	1	1			1					
8B	78	1	1	1	1			1					
8C	36		1	1		1		1					
8D	45	1	1	1	1				1				
8E	19			1		1		1					
8F	35	1	1	1	1		1	1					
8G	28		1	1	1	1	1						
8H	88	1	1	1	1	1		1					
8I	45			1	1		1	1	1				
8J	67		1	1			1						
8K	25			1	1								
8L	9	1		1	1								
Totals	499	6	8	12	9	4	4	7	2	0	0	0	0
Mean/Percentage	41.58	50.00	66.67	100.00	75.00	33.33	33.33	58.33	16.67	0.00	0.00	0.00	0.00

Site 8B - Summer 2017/2018	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad
8A	47	1		1	1			1					
8B	52	1		1	1			1					
8C	68	1	1	1		1		1					

Site 8A - Autumn 2017	No. Videos	Potoroo	Long-nosed Bandicoot	Swamp Wallaby	Rodent	Common Brush-tail Possum	Antechinus	Northern Brown Bandicoot	Echidna	Wild Dog	Red Fox	Koala	Toad	Comments
8D	67	1	1	1	1				1					
8E	14			1		1		1						
8F	62	1	1	1	1		1	1						
8G	63		1		1	1	1							
8H	59	1	1	1	1			1						
8I	55	1		1	1			1	1					
8J	25		1	1					1					
8K	Stolen			1	1									
8L	20	1		1	1									
Totals	532	8	6	11	9	3	2	7	3	0	0	0	0	
Mean/Percentage	48.36	72.73	50.00	91.67	75.00	25.00	16.67	58.33	25.00	0.00	0.00	0.00	0.00	

4.0 BRUSH-TAILED PHASCOGALE (PHASCOGALE TAPOATAFA)

4.1 Species Profile

4.1.1 Description of the Subject Species

The Brush-tailed Phascogale (Phascogale tapoatafa) is a tree-dwelling marsupial carnivore. It has a characteristic, black, bushy 'bottlebrush' tail, with hairs up to 4 cm long. Its fur is grey above and pale cream below and it has conspicuous black eyes and large naked ears (Plate 4-1). Adults have a head and body length of about 20 cm, a tail length of about 20 cm and weigh between 110–235 grams (Soderquist and Rhind 2008).

Plate 4-1. Brush-tailed Phascogale from Site 6A (photo courtesy of Henry Cook).

4.1.2 Distribution

The Brush-tailed Phascogale has a patchy distribution around the coast of Australia. In NSW, it is mainly found east of the Great Dividing Range although there are occasional records west of the divide. Locally the Brush-tailed Phascogale is known to inhabit broad areas across the lower Clarence Catchment with records extending from Halfway Creek north to the Tabbimobile and New Italy areas and west through Nymbodia, Cangi, Coaldale and Drake (Bionet Wildlife Atlas 2014).

4.1.3 Habitat and Ecology

Brush-tailed Phascogale generally prefer dry sclerophyll open forest with sparse groundcover of herbs, grasses, shrubs or leaf litter (Soderquist and Rhind 2008). It is also known to inhabit heath, swamps, rainforest and wet sclerophyll forest. It is an agile climber and forages on arthropods and other invertebrates, nectar and sometimes small vertebrates. Females have exclusive territories of approximately 20–60 ha, while males have overlapping territories of up to 100 ha (Soderquist and Rhind 2008). Tree hollows with entrances typically 25-40 mm wide are used as nest/shelter sites, and many may be used over a short period of time. Mating occurs between May-July with the males dying soon after the mating season whereas females can live for up to three years but generally only produce one litter (Soderquist and Rhind 2008).

4.2 Monitoring Sites

Seven monitoring sites are distributed across Section 2, 3, 6 and 7 of the Woolgoolga to Ballina Upgrade with Site 1 and 6 located in Section 2 as part of Year 2 monitoring, Site 2, 3 and 7 located in Section 3 as part of Year 1 monitoring, Site 4 located in Section 6 and Site 5 in Section 7, both as Year 1 monitoring (Table 4-1). Sampling as part of Year 2 in Section 2 and for Year 1 in Section 3, 6 and 7 is summarised in Table 4-1.

Table 4-1. Summary of the Phascogale monitoring covered in this round of monitoring.

Technique/Timing	Technique	Survey 1	Survey 2	Monitoring period (Phase)
Arboreal Tree Trapping	25 arboreal traps for 4 consecutive nights	Section 2 – Early winter 2017	Section 2 – Winter 2017	Year 2 for Section 1&2 (construction)
		Section 3, 6, 7 – Autumn 2017	Section 3, 6, 7 – Winter 2017	Year 1 for Section 3,6 and 7 (construction)
Camera Traps	36 cameras for 14 nights	Section 2 – Winter 2017	Section 2 - Summer 2018	Year 2 for Section 1&2 (construction)
		Section 3 – Late summer/autumn 2017	Section 3 – Late autumn winter 2017	Year 1 for Section 3,6 and 7 (construction)
Spotlighting	1 person hour deployed twice per survey	Section 2 - Autumn 2017	Section 2 – Winter 2017	Year 2 for Section 1&2 (construction)
		Section 3, 6, 7 – Autumn 2017	Section 3, 6, 7 – Winter 2017	Year 1 for Section 3,6 and 7 (construction)
Nocturnal Drive Transect	2-3 km driving twice per survey	Section 2 - Autumn 2017	Section 2 – Winter 2017	Year 2 for Section 1&2 (construction)
		Section 3, 6, 7 – Autumn 2017	Section 3, 6, 7 – Winter 2017	Year 1 for Section 3,6 and 7 (construction)
Road Kill Survey	Throughout the survey period	Autumn –Winter 2017	Winter-Summer 2018	Year 2 for Section 1&2 Year 1 for Section 3,6 and 7 (construction)

4.2.1 Sampling Design

This sampling design known as a BACI (Before-After-Control-Impact) consists of the following:

- Impact sites which are identified in this instance with an ‘A” and may be potentially impacted by construction works or once the newly constructed carriageway is completed. Potential impacts may include but are not necessarily limited to habitat removal, a reduction in habitat connectivity, facilitating the distribution and increasing densities of exotic predators and creating hazards such as increased road strike;
- Reference or control sites which are identified in this instance with an ‘B” and possess similar geographic landscape and habitat traits as the impact sites but are located a sufficient distance from the Upgrade. In the case of the Phascogale, this is thought to be around 1 km as individuals occupy home range of 20-60 ha and males themselves are reportedly capable of overlapping territories of up to 100 ha (Soderquist and Rhind 2008).

Table 4-2. Summary of Phascogale monitoring sites and techniques deployed.

Section	Treatment Class		Techniques
	Impact	Control/Reference	
2	Site 1A - CH24580 arboreal rope crossing	Site 1B - 3 km to the east and south of Bald Knob Tick Gate Road	• 36 cameras for 14 nights on two separate survey periods • 25 arboreal traps for 4 nights on two separate survey periods • Spotlighting for 60 min on four separate occasions • Nocturnal drive transects for ~2-3 km on four separate occasions • Road kill surveys on opportunistic basis throughout survey period.
2	Site 6A - CH27420 combined culvert 3.6 x 2.4, 104m long	Site 6B – 3.6 km to the north west towards Braunstone in Glenugie State Forest	• 36 cameras for 14 nights on two separate survey periods • 25 arboreal traps for 4 nights on two separate survey periods • Spotlighting for 60 min on four separate occasions • Nocturnal drive transects for ~2-3 km on four separate occasions • Road kill surveys on opportunistic basis throughout survey period.
3	Site 2A – CH35230 combined culvert 2.4 x 2.4, 65 m long	Site 2B – 5.5 km north west in Bom State Forest	• Sampling could not be undertaken due to ongoing access constraints.
3	Site 3A – CH64505 combined RCBC 3600 x 3600	Site 3B – 8 km to the south east off Somervale Road in Pine Brush State Forest	• 36 cameras for 14 nights on two separate survey periods • 25 arboreal traps for 4 nights on two separate survey periods • Spotlighting for 60 min on four separate occasions • Nocturnal drive transects for ~2-3 km on four separate occasions • Road kill surveys on opportunistic basis throughout survey period.
3	Site 7A – CH37320 combined culvert 2.4 x 2.4, 69m long	Site 7B – 5.5 km south east in Glenugie State Forest	• Sampling could not be undertaken due to ongoing access constraints.
6	Site 4A – CH101100 dedicated culvert 2.4 x 3, 38m long	Site 4B – 3 km east in Bundjalung National Park	• 25 arboreal traps for 4 nights on two separate survey periods • Spotlighting for 60 min on four separate occasions • Nocturnal drive transects for ~2-3 km on four separate occasions • Road kill surveys on opportunistic basis throughout survey period. Note – Potoroo monitoring nearby provides some camera surveys with 12 units used over a 14 night period on two separate occasions.
7	Site 5A – CH116400 arboreal crossing	Site 5B – 7 km west in Jackywalbin Conservation Park	• 36 cameras for 14 nights on two separate survey periods • 25 arboreal traps for 4 nights on two separate survey periods • Spotlighting for 60 min on four separate occasions • Nocturnal drive transects for ~2-3 km on four separate occasions • Road kill surveys on opportunistic basis throughout survey period.

4.2.2 Sampling Regime

i. Camera Trapping

At Sites 2, 3, 6 and 7, 36 camera traps (Scoutguard 560 k zero glow) were installed across a 600 m grid (36 ha) with a 100 m trap spacing and left operating over a continuous 14 night period (504 nights effort; Table 4-2). Cameras were deployed in mid summer (8th January 2017) through to winter and used the following parameters:

- Timer mode set from dusk (1900 hrs) till dawn (0700 hrs) during warmer months and from 1700 hrs until 0600 hrs in the cooler late autumn and winter months;
- Sensitivity mode was set to 'high' and where required, vegetation such as long grass was trimmed to reduce false trigger events (i.e. grass being blown in the wind);
- Each triggering event recorded two still images set in 8 mb file size;
- Reset time interval for retriggering was set at 30 seconds.

Each camera trap was baited using one large handful of peanut butter, honey and oats bait with added natural vanilla extract (Queen Brand). The bait was scattered over an area of 4-9 m^2 and the earth was partly disturbed to increase the likelihood of the area being visited by the target species. Cameras were generally fixed to a tree or stump in a horizontal facing position around 1 m off the ground with the primary objective of obtaining the largest field of view possible.

All camera images were downloaded onto a desktop computer for viewing on a 20 inch screen with each image viewed and the animal identified by BL (Ben Lewis). All images were identified to species level apart from Antechinus and Rodents that were retained in these two groups.

Table 4-2. Summary of the installation and retrieval time periods for camera trap monitoring at Phascogale sites[1].

Site	Survey Number	Installation Date	Retrieval Date	No. Nights	No. Cameras Retrieved	Effort (Camera Trap Nights)
Site 1A Impact	1	No survey	No survey	No survey	No survey	No survey
Site 1A Impact	2	No survey	No survey	No survey	No survey	No survey
Site 1B Reference	1	08.01.2017	22.01.2017	14	36	504
Site 1B Reference	2	18.06.2017	02.07.2017	14	36	504
Site 2A Impact	1	No access	No access			
Site 2A Impact	2	No access	No access			
Site 2B Reference	1	17.06.2017	01.07.2017	14	36	504
Site 2B Reference	2	20.01.2018	05.02.2018	14	36	504
Site 3A Impact	1	28.04.2017	13.05.2017	14	36	504
Site 3A Impact	2	01.06.2017	15.06.2017	14	36	504
Site 3B Reference	1	28.04.2017	13.05.2017	14	36	504
Site 3B Reference	2	01.06.2017	15.06.2017	14	36	504
Site 6A Impact	1	09.01.2017	23.01.2017	14	36	504
Site 6A Impact	2	17.06.2017	01.07.2017	14	36	504
Site 6B Reference	1	09.01.2017	23.01.2017	14	36	504
Site 6B Reference	2	17.06.2017	01.07.2017	14	36	504
Site 7A Impact	1	No access	No access	14	36	504
Site 7A Impact	2	No access	No access	14	36	504
Site 7B Reference	1	07.04.2017	21.04.2017	14	36	504
Site 7B Reference	2	17.06.2017	01.07.2017	14	36	504
					Total	8064 trap nights

[1] Cameras were not used to target Brush-tailed Phascogale at Site 4 and 5 because live trapping was still the approved technique for population monitoring in 2017.

i. Spotlighting

Spotlighting was undertaken at all sites over two non-consecutive nights in each season (Table 4-3). Each spotlight transect lasted 1 person hour and involved walking systematically through camera or Elliott grid using a 800 lumen head torch. The number of positively identified Phascogale were recorded.

Table 4-3. Summary of the spotlight surveys at each site.

W2B Sect.	Site	Survey Period	Spotlight 1	Spotlight 2	Effort (Person Hours)	Nocturnal Drive Transect
2	Site 1A Impact	1	08.01.2017	21.01.2017	2	2 km north and south of the site on the Pacific Highway on each spotlight night
2	Site 1B Reference	1	08.01.2017	21.01.2017	2	2 km either side but on adjacent Bald Knob Tick Gate Road on each spotlight night
2	Site 1A Impact	2	06.07.2017	08.07.2017	2	2 km north and south of the site on the Pacific Highway on each spotlight night
2	Site 1B Reference	2	06.07.2017	08.07.2017	2	2 km either side but on adjacent Bald Knob Tick Gate Road on each spotlight night
3	Site 2A Impact	1	No access	No access	0	Use Old Pacific Highway as alternative
3	Site 2A Impact	2	No access	No access	0	Use Old Pacific Highway as alternative
3	Site 2B Reference	1	17.03.2017	27.04.2017	2	Stokers Road
3	Site 2B Reference	2	13.05.2017	30.05.2017	2	Stokers Road
3	Site 3A Impact	1	29.04.2017	04.05.2017	2	Drive along Coldstream Road for 1.5 km either side of Tyndale Crown turnoff
3	Site 3B Reference	1	29.04.2017	04.05.2017	2	Somervale Road either side and through middle of the grid
3	Site 3A Impact	2	14.06.2017	29.06.2017	2	Drive along Coldstream Road for 1.5 km either side of Tyndale Crown turnoff
3	Site 3B Reference	2	14.06.2017	29.06.2017	2	Somervale Road either side and through middle of the grid
6	Site 4A Impact	1	13.03.2017	28.03.2017	2	Access Number 2 trail and drive back towards Site 4A on Highway
6	Site 4B Reference	1	13.03.2017	28.03.2017	2	Mororo Fire Trail after Number 2 trail intersection
6	Site 4A Impact	2	21.04.2017	01.05.2017	2	Access Number 2 trail and drive back towards Site 4A on Highway
6	Site 4B Reference	2	21.04.2017	01.05.2017	2	Mororo Fire Trail after Number 2 trail intersection
7	Site 5A Impact	1	26.02.2017	08.03.2017	2	South Pacific Trail through trapping grid runs parallel to highway
7	Site 5B Reference	1	26.02.2017	08.03.2017	2	Glencoe Road adjacent to the trapping grid
7	Site 5A Impact	2	01.06.2017	26.06.2017	2	South Pacific Trail through trapping grid runs parallel to highway
7	Site 5B Reference	2	01.06.2017	26.06.2017	2	Glencoe Road adjacent to the trapping grid
2	Site 6A Impact	1	09.01.2017	23.01.2017	2	2 km either side using access track running parallel to existing Pacific Highway. Northern extent turns east onto Franklins Road on each spotlight night
2	Site 6B Reference	1	09.01.2017	23.01.2017	2	Track that accesses the site and continues through the camera grid
2	Site 6A Impact	2	07.07.2017	09.07.2017	2	2 km either side using access track running parallel to existing Pacific Highway. Northern extent turns east onto Franklins Road on each spotlight night
2	Site 6B Reference	2	09.01.2017	23.01.2017	2	Track that accesses the site and continues through the camera grid
3	Site 7A Impact	1	No access	No access	0	
3	Site 7B Reference	1	17.03.2017	27.04.2017	2	No. 2 Road and south along Morilla Road turn east along unnamed fire trail through grid
3	Site 7A Impact	2	No access	No Access	0	
3	Site 7B Reference	2	13.05.2017	30.05.2017	2	No. 2 Road and south along Morilla Road turn east along unnamed fire trail through grid
					32 hours	Approx. 100 km

iii. Nocturnal Drive Transects

Nocturnal drive transects were performed whilst commuting between the survey sites for distances of usually 2-3 km either side of the grid (Table 4-3). During this time, the vehicle was driven at speeds commensurate to the road or area being traversed. For example, narrow single lane tracks (e.g. Site 4B) were traversed at speeds of up to 20 kmph whilst an unsealed road was sampled at between 20-40 kmph (e.g. Site 1B). Sealed roads were driven at speeds of between 60-80 kmph (Site 3A Coldstream Road). The objective of this was to sample Phascogale in a way that was commensurate to other road users and vehicle/Phascogale interactions. All Phascogale observed during these surveys were recorded and their behaviour was documented.

iv. Road Kill Surveys

Road kill surveys were conducted over 29 days from mid summer 2017 into winter with 18 surveys in survey period 1 and 11 surveys in survey period 2 covering 534 km (Table 4-4). During each survey, the roadway was scanned for any road killed Phascogale along with the survey effort (distance travelled) within a few kilometres of the monitoring site. Typically, the vehicle was driven at speeds of 60-90 kmph (i.e. depending on traffic) to inspect for all dead wildlife (road kill) on the carriageway or within 3 m of the road verge. Once road kill Phascogale had been observed, a closer inspection of the carcass was undertaken to identify the age, sex and whether any pouch young were present.

Table 4-4. Summary of road kill surveys perform during the preconstruction baseline survey.

Date	Survey Period	Road Kill Surveys -Distance Travelled (KM)	W2B Section
06.01.2017	1	7	2
08.01.2017	1	5	2
09.01.2017	1	7	2
21.01.2017	1	7	2
22.01.2017	1	5	2
05.02.2017	1	7	2
10.02.2017	1	7	2
26.02.2017	1	47	3, 6 & 7
08.03.2017	1	16	6&7
13.03.2017	1	22	6&7
17.03.2017	1	25	3
28.03.2017	1	22	6&7
07.04.2017	1	16	3
08.04.2017	1	22	3
21.04.2017	1	45	3, 6 & 7
22.04.2017	1	22	3
27.04.2017	1	22	3
28.04.2017	1	24	3
	Total	18 days + 328 km	
12.05.2017	2	47	3,6&7
13.05.2017	2	24	3
01.06.2017	2	23	6&7
17.06.2017	2	7	2
18.06.2017	2	47	2,6&7
26.06.2017	2	23	6&7
01.07.2017	2	7	2
02.07.2017	2	7	2
06.07.2017	2	7	2

Date	Survey Period	Road Kill Surveys -Distance Travelled (KM)	W2B Section
08.07.2017	2	7	2
10.07.2017	2	7	2
	Total	11 days + 206 km	

v. Arboreal Tree Trapping

Arboreal tree trapping was performed at six of the monitoring sites (Table 4-2). Tree trapping comprised 25 Elliott (B Type or similar) positioned 2 m above the ground and baited with peanut butter, honey and oat mixture. The base of the tree trunk and for a few metres above was sprayed with a diluted honey and water solution (25% ratio) and this was applied daily.

Table 4-5. Summary of the arboreal tree trapping program.

Site	Survey Number	Installation Date	Retrieval Date	No. Nights	Effort (Trap Nights)
Site 1A Impact	1	30.05.2017	03.06.2017	4	100*
Site 1A Impact	2	06.07.2017	10.07.2017	4	100*
Site 1B Reference	1	30.05.2017	03.06.2017	4	100*
Site 1B Reference	2	06.07.2017	10.07.2017	4	100*
Site 2A Impact	1	No access	No access	0	0
Site 2A Impact	2	No access	No access	0	0
Site 2B Reference	1	02.06.2017	06.06.2017	4	100*
Site 2B Reference	2	30.06.2017	03.07.2018	4	100*
Site 3A Impact	1	03.04.2017	07.04.2017	4	100*
Site 3A Impact	2	28.05.2017	01.06.2017	4	100*
Site 3B Reference	1	03.04.2017	07.04.2017	4	100*
Site 3B Reference	2	28.05.2017	01.06.2017	4	100*
Site 4A Impact	1	17.04.2017	21.04.2017	4	100*
Site 4A Impact	2	26.06.2017	30.06.2017	4	100*
Site 4B Reference	1	17.04.2017	21.04.2017	4	100*
Site 4B Reference	2	26.06.2017	30.06.2017	4	100*
Site 5A Impact	1	17.04.2017	21.04.2017	4	100**
Site 5A Impact	2	26.06.2017	30.06.2017	4	100**
Site 5B Reference	1	17.04.2017	21.04.2017	4	100**
Site 5B Reference	2	26.06.2017	30.06.2017	4	100**
Site 6A Impact	1	09.01.2017	23.01.2017	4	100***
Site 6A Impact	2	17.06.2017	01.07.2017	4	100***
Site 6B Reference	1	09.01.2017	23.01.2017	4	100***
Site 6B Reference	2	17.06.2017	01.07.2017	4	100***
Site 7A Impact	1	No access	No access	0	0
Site 7A Impact	2	No access	No access	0	0
Site 7B Reference	1	02.06.2017	06.06.2017	4	100*
Site 7B Reference	2	30.06.2017	03.07.2018	4	100*
					2400 trap nights

* denotes more survey effort completed then the baseline surveys which equates to unbalanced data set

** Adopted recommendation from the pre construction baseline surveys

*** Sampling was not undertaken at this site during the baseline survey.

4.3 Data Summaries and Statistical Analysis

4.3.1 Camera Traps

The camera trap data is reported as the mean activity level or rate derived from the number of cameras that detected Phascogale and was reported for each of the two survey periods (i.e. Survey 1 and Survey 2). For example, images of

Phascogale recorded from 5 of the 36 cameras for survey period one was expressed as 13.89% (5/36) and 15 of the 36 cameras during survey period two was expressed as 41.67% (15/36). The mean and standard errors were derived from percentage activity values for the two survey periods. So using the above example, this involved summing 13.89% + 41.67% to derive a mean of 20.90%. The activity rate was calculated for all exotic predator species recorded so that additional affects could be considered.

4.3.2 Spotlight Surveys

The spotlight monitoring data is derived from a mean of the four spotlighting surveys and expressed as the number of Phascogale recorded on a per hour of effort. For example, one Phascogale observed during the first spotlight survey followed by no Phascogale recorded on the remaining three surveys was expressed as 0.25 Phascogale per hour of spotlight effort. Two Phascogale recorded on one survey and another one on another survey was expressed as 0.75 per hour of spotlighting effort.

4.3.3 Nocturnal Drive Transects

The nocturnal drive transects data is derived from a mean of the two 2-3 km transect surveys and expressed as the number of Phascogale recorded per 2-3 km of effort.

4.3.4 Road Kill Surveys

The road kill monitoring data is derived from a tally of the total number of kilometers driven through areas of suitable Phascogale habitat under construction and simply expressed as the number of individuals recorded. This was then compared with the baseline data using the number of Phascogale recorded per 750 km.

4.3.5 Arboreal Tree Trapping

The arboreal tree trapping data is derived from the mean number of male and female Phascogale trapped at each site. For example, two males captured during survey one at Site 3B and one female captured during survey two would be calculate as one male and 0.5 females for that year of monitoring.

4.4 Presence of Phascogale at Monitoring Sites

4.4.1 Arboreal Trapping Surveys

Phascogale were trapped at four of the six monitoring sites summarised as follows:

- Site 1 (Wells Crossing) recorded no captures from either Site 1A or Site 1B;
- Site 2 (Bom Bom & Glenugie North) recorded one capture from Site 2B with a female (125 g) trapped on night 3 during Survey 1. No surveys were performed at Site 2A (CH35230) due to access constraints;
- Site 3 recorded no captures from Site 3A (Tyndale Crown Land) whilst Site 3B (Pine Brush State Forest) recorded a male Phascogale (100 g) during survey 1 and a female Phascogale (110 g) during survey 2 (Plate 4-2);
- Site 4 (Tabbimoble) recorded no captures;
- Site 5 recorded a female Phascogale (135 g) during survey 2 from Site 5A (Tabbimoble Swamp Nature Reserve) and no captures from Site 5B (Jackywalbin State Conservation Area);
- Site 6 (Glenugie) recorded a female Phascogale (130 g) that was captured on each night whilst there were no captures from Site 6B.

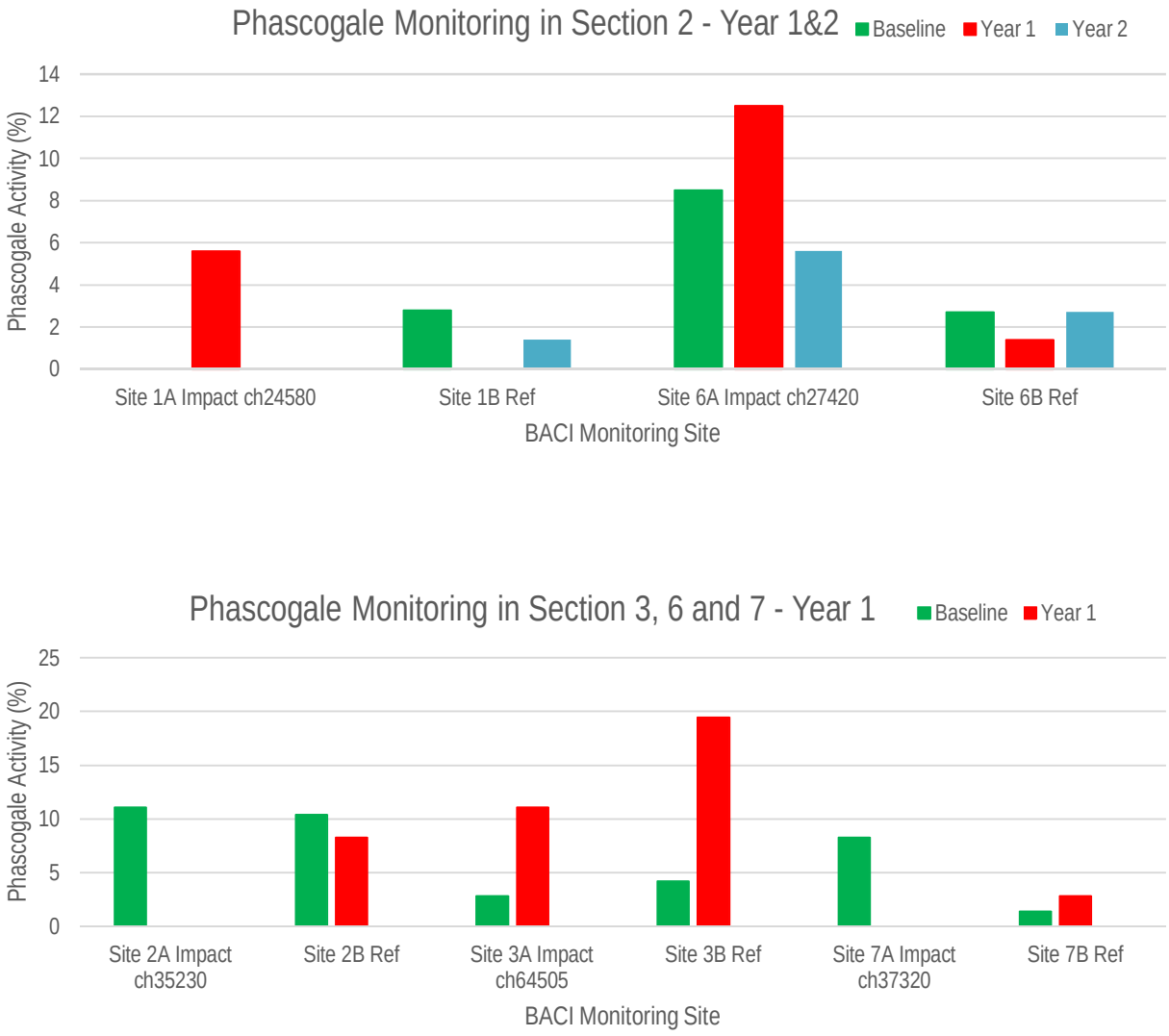
Plate 4-2. Phascogale captured in arboreal tree trap during Survey 1 at Site 3B (Pine Brush State Forest).

4.4.2 Camera Surveys

Year 1 and 2 Phascogale activity levels ranged from 1.4% at Site 1B (Yuraygir State Conservation Area) through to 19.5% at Site 3B (Pine Brush State Forest; Figure 4-1; Plate 4-3). These activity levels translate to approximately one in every 36 cameras being visited by Phascogale at Site 1B to one in every seven cameras at Site 3B. Each site is summarised as follows:

- Site 1 where the camera monitoring was discontinued at the impact site (CH24580) given it was not done during the baseline surveys to enable data comparison and it did not form part of the Threatened Mammal Management Plan (RMS 2015; RMS meeting notes 2 June 2017). The paired treatment of Site 1B recorded a small increase, up from 0% in Year 1 to 1.4% in Year 2, but down 50% from the 2.8% recorded in the baseline survey.
- Site 2 where the impact site (CH35230) could not be sampled due to access constraints. The reference site in Bom Bom State Forest (2B) recorded 8.3% in Year 1, down 20.2% from the 10.4% recorded in the baseline survey.

- Site 3 where the impact site (CH64505) recorded 11.1% in Year 1, a fourfold increase from the 2.8% recorded in the baseline survey. The reference site located in Pine Brush State Forest recorded a similar increase in activity from 4.4% in the baseline survey to 19.5% in Year 1.
- Site 4 (CH101100) and Site 5 (CH116400) were not subject to camera monitoring surveys at this time.
- Site 6 where the impact site (CH27420) recorded 5.6%, a 34% decline from the baseline survey with 8.5%. The reference site located further to the west towards Braunstone recorded 2.7%, the same as the baseline survey and a small incremental increase from 1.4% recorded in Year 1.
- Site 7 where the impact site (CH37320) could not be sampled due to access constraints. The reference site in Glenugie State Forest recorded 2.8% activity, twice the activity (i.e. 1.4%) recorded during the baseline survey.



Note – Camera monitoring wasn't undertaken at Site 1A during baseline survey and has been discontinued.

Figure 3-2. Phascogale activity levels between the preconstruction baseline survey (Green), Year 1 (red) (Section 2,3/6/7) and Year 2 (blue) (Section 2) monitoring.

Plate 4-3. Example of a Phascogale images recorded on the grid from Site 3A (left) and Site 3B (right) during autumn sampling.

Table 3-1. Summary of the paired treatment sites and Phascogale tenure for Year 2 at Site 1 and Site 6 and Year 1 at Site 2, 3, 4 and 7.

W2B Section	BACI Site Name	Mitigation Treatment	Phascogale Recorded	Camera	Elliott	Spotlight	Nocturnal Drive	Roadkill	BACI Site Name	Phascogale Recorded	Camera	Elliott	Spotlight	Nocturnal Drive	Roadkill
2	Impact 1A (24580)	arboreal rope crossing	No	nd	X	X	X	X	Control 1B (Yuraygir State Conservation Area)	Yes	√	X	X	X	X
3	Impact 2A (35230)	combined culvert 2.4 x 2.4, 65 m long	nd	nd	nd	nd	X	X	Control 2B (Bom State Forest)	Yes	√	√	X	√	X
3	Impact 3A (64505)	combined RCBC 3600 x 3600	Yes	√	X	X	X	X	Control 3B (Pine Brush State Forest)	Yes	√	√	√	X	X
6	Impact 4A (101100)	dedicated culvert 2.4 x 3, 38m long	No	nd	X	X	X	X	Control 4B (Bundjalung National Park)	No	X	X	X	X	X
7	Impact 5A (116400)	arboreal crossing	Yes	nd	√	X	X	X	Control 5B (Jackywalbin Conservation Area)	No	nd	X	X	X	X
2	Impact 6A (27420)	combined culvert 3.6 x 2.4, 104m long	Yes	√	√	√	X	X	Control 6B (Glenugie State Forest west)	Yes	√	X	X	X	X
3	Impact 7A (37320)	combined culvert 2.4 x 2.4, 69m long	nd	nd	nd	nd	X	X	Control 7B (Glenugie State Forest east)	Yes	√	X	X	√	X

nd = no data

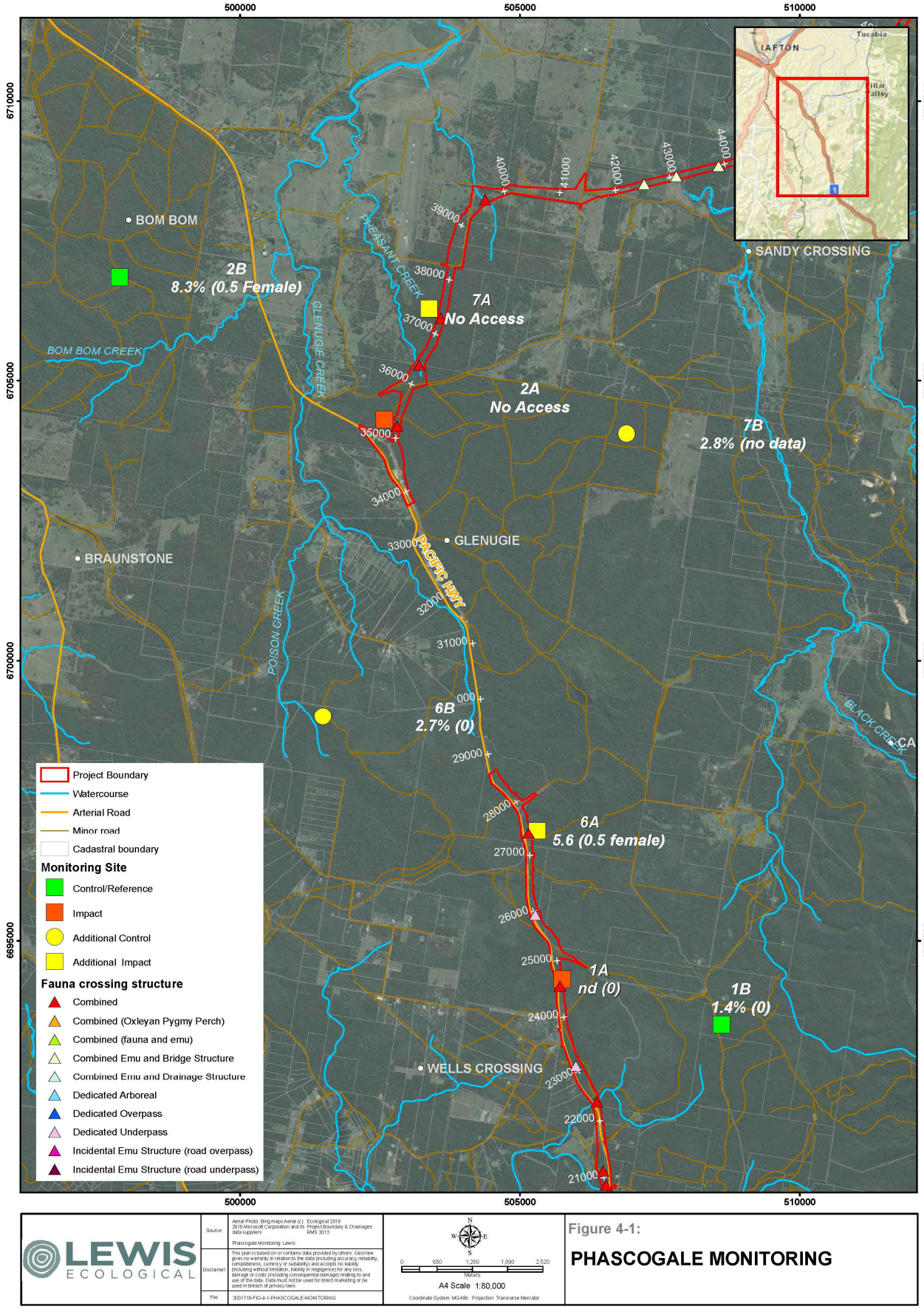


Figure 4-1. Phascogale activity levels at BACI Sites 1, 2, 6 and 7 in Sections 2 and 3 of the W2B Upgrade.

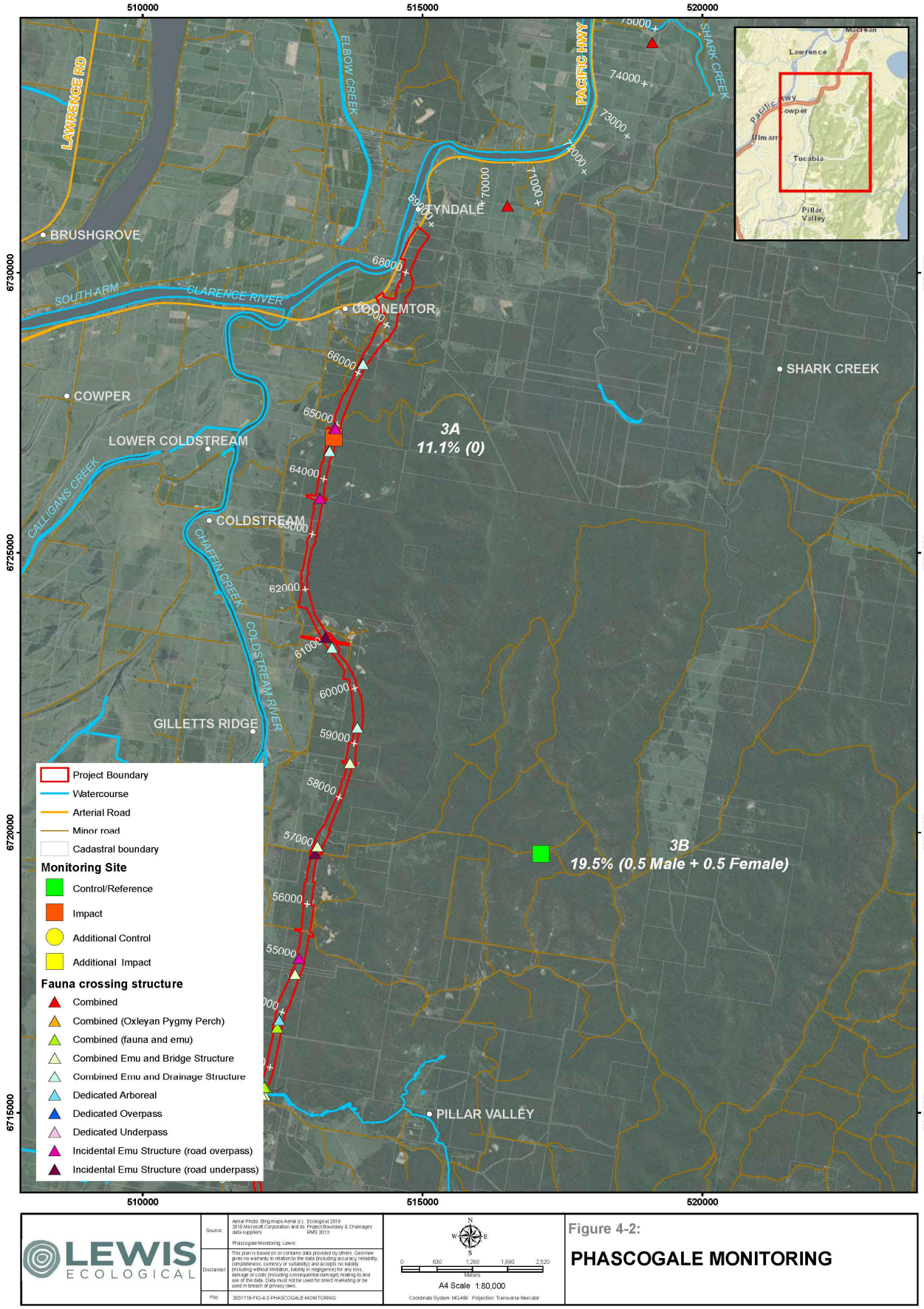


Figure 4-2. Phascogale activity levels at BACI Site 3 in Section 3 of the W2B Upgrade.

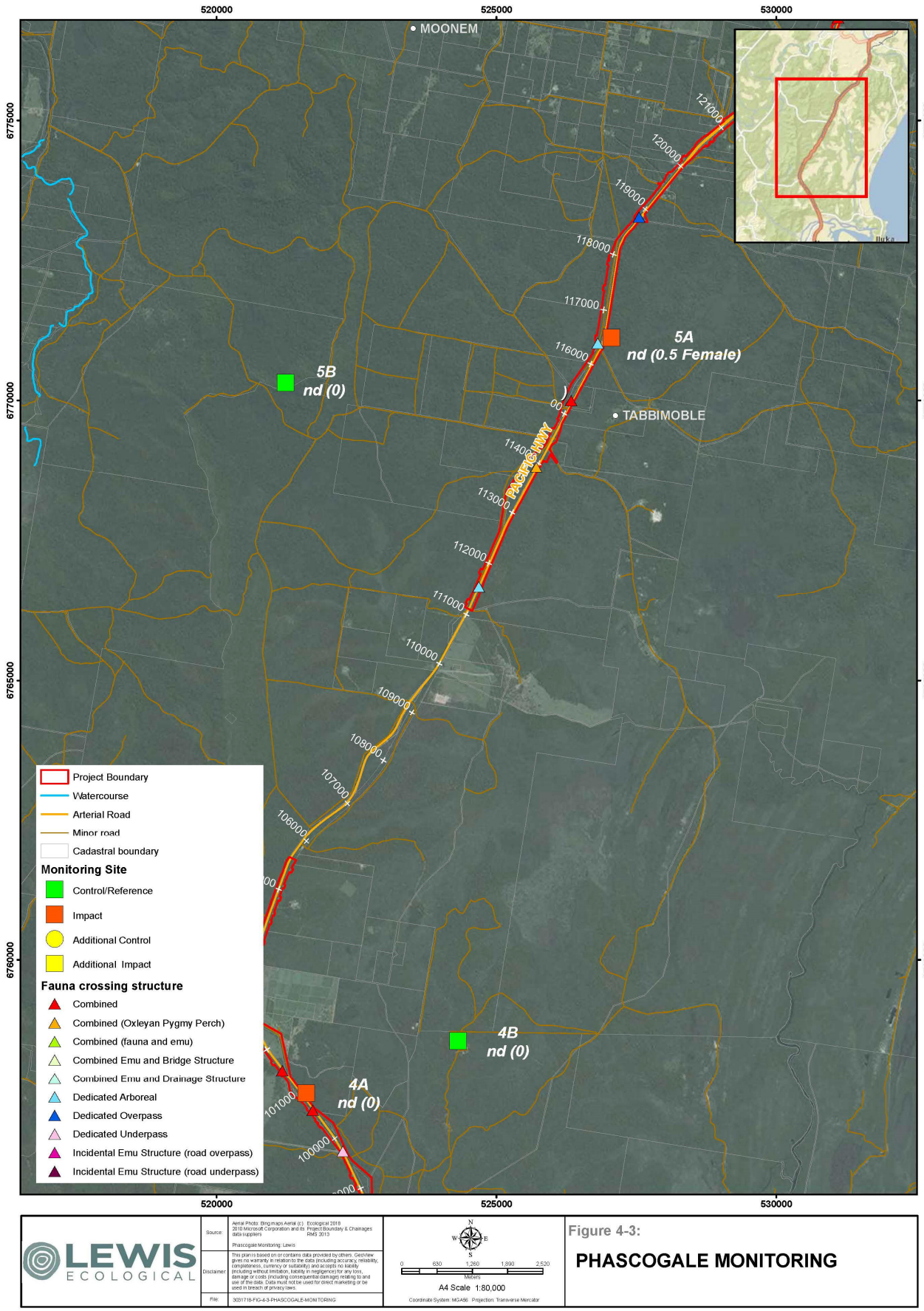


Figure 4-3. Phascogale activity levels at BACI Site 4 and 5 in Section 6 and 7 of the W2B Upgrade.

4.4.3 Spotlight Surveys and Nocturnal Driving Transects for Phascogale

Spotlight surveys recorded one Phascogale at Site 6A and Site 3B during the late summer early autumn survey. Both individuals appeared to be adults and were moving across the ground before taking shelter at the base of the tree, a Forest Oak (Allocasuarina torulosa) at Site 6A (see Plate 4-1) and an Ironbark at Site 3B. No Phascogale were spotlighted at the remaining sites (Table 4-4; Figure 4-1).

Phascogale were recorded on two occasions during the structured nocturnal drive transects. At Site 2B (Bom State Forest) one individual was observed moving erratically across the ground before disappearing out of sight whilst a single individual was recorded at Site 7B (Glenugie State Forest East) when it was briefly observed moving towards a pile of fallen timber near the western edge of the camera trap grid (Table 4-4).

Table 4-4. Results of the spotlight surveys and nocturnal drive transects for Phascogale.

W2B Section	Site	Survey Technique	Survey 1		Late Autumn/Winter		Baseline Mean No. Phascogale per Sampling Hour (Spotlighting) and per 2-3 km of nocturnal drive transect
			Spot. 1	Spot. 2	Spot. 3	Spot. 4	
2	Site 1a Impact	Spotlight	0	0	0	0	0.25 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
2	Site 1b Reference	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
2	Site 2a Impact	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
2	Site 2b Reference	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	1	0	0	0-0.25
3	Site 3a Impact	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
3	Site 3b Reference	Spotlight	0	0	1	0	0.25 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
6	Site 4a Impact	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
6	Site 4b Reference	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
7	Site 5a Impact	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
7	Site 5b Reference	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
2	Site 6a Impact	Spotlight	0	1	0	0	0.25 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
2	Site 6b Reference	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
3	Site 7a Impact	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	0	0	0 - 0
3	Site 7b Reference	Spotlight	0	0	0	0	0 - 0
		Nocturnal Drive Transect	0	0	1	0	0-0.25

4.4.4 Road Kill Transects for Phascogale

Road kill surveys performed over 29 days and 534 km of driving recorded the following:

- Survey 1 recorded no Phascogale from 328 km of driving over 18 days.
- Survey 2 recorded no Phascogale from 206 km of driving over 11 days.

4.4.5 Exotic Predator Activity Levels

Using the cameras to calculate presence and activity levels for exotic predators, the following Year 1 (Sites 2,3,4,5, 7) and Year 2 (Sites 1 and 6) activity levels were recorded at each site:

- Site 1 (no sampling at Site 1A) with the reference site (1B) recording the following Year 2 results:
    - 5.5% Wild Dog activity, an increase from both the Year 1 and the baseline survey;
    - 0% Red Fox activity and reflects no change from the baseline survey;
    - 1.4% Feral Cat activity, no change from the baseline survey yet a small decrease from Year 1 monitoring; and
    - 2.7% Feral Pig activity, a decline from Year 1 sampling but still an increase from the baseline survey when it had only been detected via diggings (Table 4-5).
- Site 2 where the impact site was not accessible whilst the reference site recorded the following Year 1 results:
    - 1.4% Wild Dog activity, an increase from the baseline survey when it was absent;
    - 1.4% Red Fox activity, an increase from the baseline survey when it was absent;
    - 2.8% Feral Cat activity, no change from the baseline survey; and
    - 0% Feral Pig activity, also no change from the baseline survey (Table 4-5).
- Site 3 with the impact site recording the following Year 1 results:
    - 8.33% Wild Dog activity, a decrease from the 11.1% recorded during the baseline survey;
    - 6.95% Red Fox activity, a marked decrease from the 19.45% recorded during the baseline survey;
    - 0% Feral Cat activity, a decrease from 4.15% recorded in the baseline survey; and
    - 0% Feral Pig activity, also no change from the baseline survey (Table 4-5).

  The reference site recorded the following Year 1 results:
    - 2.8% Wild Dog activity, a small increase from the 1.4% recorded in the baseline survey;
    - 2.8% Red Fox activity, a decrease from the 4.15% recorded during the baseline survey;
    - 2.8% Feral Cat activity, an increase from the baseline survey when it was absent; and
    - 0% Feral Pig activity, no change from the baseline survey (Table 4-5).
- Site 6 where the impact site (6A) recording the following Year 2 results:
    - 9.78% Wild Dog activity, a decrease from Year 1 monitoring but still a threefold increase from the baseline survey (Table 4-5);
    - 6.95% Red Fox activity, a substantial increase from earlier monitoring when it was absent during Year 1 and 2.8% during the baseline survey;
    - 0% Feral Cat activity; no change from the baseline survey; and

- 0% Feral Pig activity, no change from the baseline survey.

Meanwhile the reference site (6B) recorded:

- 5.56% Wild Dog activity, an increase from the baseline survey and Year 1 monitoring when it was absent (Table 4-5);
- 1.4% Red Fox activity, an increase from the baseline survey and Year 1 monitoring when it was absent;
- 0% Feral Cat activity, a decline from the baseline survey of 2.8%; and
- 0% Feral Pig activity, no change from the baseline survey.

- Site 7 where the impact site was not accessible whilst the reference site recording the following Year 1 results:
  - 4.15% Wild Dog activity, an increase from the baseline survey when it was absent (Table 4-5);
  - 2.1% Red Fox activity, an increase from the baseline survey when it was absent;
  - 2.8% Feral Cat activity, a decline from the baseline survey of 6.95%; and
  - 0% Feral Pig activity, no change from the baseline survey.

Table 4-5. Exotic animal activity for each monitoring site.

W2B Section	Site	Predator species	Survey 1 (%)	Survey 2 (%)	Year 2 Mean Activity (%)	Year 1 Mean Activity (%)	Pre-construction Baseline Mean (%)	Increase or Decrease in Activity between Baseline and Year 1/2 Survey
2	Site 1a Impact	Red Fox	nd	nd	nd	0	nd	Insufficient data
		Wild Dog	nd	nd	nd	5.6	nd	Insufficient data
		Feral Cat	nd	nd	nd	0	nd	Insufficient data
		Feral Pig	nd	nd	nd	0	nd	Insufficient data
2	Site 1b Reference	Red Fox	0	0	0	0	0	No change
		Wild Dog	8.3	2.7	5.5	4.15	2.8	Increase
		Feral Cat	2.7	0	1.4	2.3	1.4	No change
		Feral Pig	2.7	2.7	2.7	4.15	0	Increase
3	Site 2a Impact	Red Fox	nd	nd	next survey	nd	2.8	Insufficient data
		Wild Dog	nd	nd	next survey	nd	2.8	Insufficient data
		Feral Cat	nd	nd	next survey	nd	0	Insufficient data
		Feral Pig	nd	nd	next survey	nd	0	Insufficient data
3	Site 2b Reference	Red Fox	2.8	0	next survey	1.4	0	Increase
		Wild Dog	0	2.8	next survey	1.4	0	Increase
		Feral Cat	5.6	0	next survey	2.8	2.8	No change
		Feral Pig	0	0	next survey	0	0	No change
3	Site 3a Impact	Red Fox	8.33	5.56	next survey	6.95	19.45	Decrease
		Wild Dog	8.33	8.33	next survey	8.33	11.1	Decrease
		Feral Cat	0	0	next survey	0	4.15	Decrease
		Feral Pig	0	0	next survey	0	0	No change

W2B Section	Site	Predator species	Survey 1 (%)	Survey 2 (%)	Year 2 Mean Activity (%)	Year 1 Mean Activity (%)	Pre-construction Baseline Mean (%)	Increase or Decrease in Activity between Baseline and Year 1/2 Survey
3	Site 3b Reference	Red Fox	2.8	2.8	next survey	2.8	4.15	Decrease
		Wild Dog	2.8	2.8	next survey	2.8	1.4	Increase
		Feral Cat	2.8	2.8	next survey	2.8	0	Increase
		Feral Pig	0	0	next survey	0	0	No change
2	Site 6a Impact	Red Fox	11.11	2.78	6.95	0	2.8	Increase
		Wild Dog	13.89	5.66	9.78	13.9	2.8	Decrease from Year 1 but still increase from baseline
		Feral Cat	0	0	0	0	0	No change
		Feral Pig	0	0	0	0	0	No Change
2	Site 6b Reference	Red Fox	2.7	0	1.35	0	0	Increase
		Wild Dog	5.56	5.56	5.56	0	0	Increase
		Feral Cat	0	0	0	0	2.8	Decrease
		Feral Pig	0	0	0	0	0	No Change
3	Site 7a Impact	Red Fox	nd	nd	next survey	nd	22.3	Insufficient data
		Wild Dog	nd	nd	next survey	nd	1.4	Insufficient data
		Feral Cat	nd	nd	next survey	nd	0	Insufficient data
		Feral Pig	nd	nd	next survey	nd	1.4	Insufficient data
3	Site 7b Reference	Red Fox	1.4	2.8	next survey	2.1	0	Increase
		Wild Dog	2.8	5.56	next survey	4.15	0	Increase
		Feral Cat	0	5.56	next survey	2.8	6.95	Decrease
		Feral Pig	0	0	next survey	0	0	No change

Plate 4-4. Example of Feral Cat recorded from Site 3B (Pine Brush State Forest).

4.5 Discussion of Results

4.5.1 Phascogale Distribution and Activity

Sampling during the construction phase in 2017 as part of Year 2 sampling in Section 2 (Sites 1 and 6) and Year 1 sampling in Section 3, 6 and 7 has confirmed the continued presence of Phascogale from nine of the 14 monitoring sites. The absence of Phascogale from Site 1A (ch. 24580) suggests individuals may only occasionally inhabit this area as this species has only ever been recorded adjacent to the trapping grid using cameras and spotlighting. Phascogale were similarly recorded on the adjacent reference site (1B) during this round of camera monitoring yet there were no live captures as had been recorded during the baseline survey (see Lewis 2015). The adoption of a camera grid at the impact site would be useful as this currently appears a more reliable sampling technique than live trapping. Such information will be useful in determining the effectiveness of the nearby arboreal rope crossing at CH24580.

Sites 2 (CH35230) and 7 (CH37320) remain constrained with access only granted for the reference sites at present. Phascogale were recorded at both of these sites including a live capture at Site 2. Without monitoring the impact sites, they provide only limited information to the overall program in terms of regional population monitoring.

Phascogale were recorded at both of the Site 3 (64505) treatments where there was a fourfold increase in activity levels using the camera data. Live trapping at this location revealed a different story with no captures at the impact site and only a single capture on each of the surveys at the reference site in Pine Brush State Forest.

No Phascogale were recorded at either of the Site 4 treatments despite records of this species through the local area (Lewis 2014). Phascogale probably occur in the general vicinity of the trapping grid, however, the combination of high trap success of non-target species (i.e. Melomys, Rattus, Antechinus and Petaurids) diminishes trap success combined with the fact that Phascogale occupy a home range of 20-40 ha for females and up to 100 ha for males (Soderquist and Rhind 2008). With this in mind, year to year variability may simply represent individuals occupying other parts of their maternal home range which may or may not be subject to sampling. For example, the trapping grid of <5 ha may barely overlap with the home range of an individual Phascogale. Site 4A is located directly adjacent to a dedicated underpass at CH101100, so continued monitoring may be required in order to assess the overall effectiveness of this structure for Phascogale.

Phascogale were recorded from the impact treatment at Site 5 which is located adjacent to an arboreal rope crossing (CH116400). The trapping of a single adult female during the second survey (i.e. early winter 2017) is the first confirmed occurrence at this location as the baseline surveys were unable to capture any Phascogale despite there being historic records in the area (Lewis 2014; Lewis 2015). The absence of Phascogale from the adjacent reference site in Jackywalbin Conservation Area demonstrates the year to year variability in tenure. Previously, the baseline survey captured several individuals from this location over a number of days yet Phascogale have not been recorded since a fire burnt through this area approximately 12 months ago.

Phascogale were recorded at both of the Site 6 treatments and this included one individual that was repeatedly live trapped on four occasions at the impact site (CH27420). Phascogale have been consistently live trapped at this site since trapping began in Year 1. In contrast, Phascogale are yet to be trapped at the reference site (6B) although their presence is almost always detected using cameras.

Given the above, confirming declines in local Phascogale populations may require monitoring over longer time frames than simple year to year comparisons currently used to inform the monitoring program. Again, the fundamental values surrounding population viability may be answered simply via the presence of live individuals, detections at the connectivity structures and an absence of deceased individuals during road kill transects.

4.5.2 Exotic Predatory Species

There has been some variability in the recorded levels of exotic predator activity with increases at some sites and treatments but declines elsewhere. The most notable of these is the incremental decrease of Red Fox activity at Site 3A (CH64505) which has declined by 64% and Wild Dog which has declined by 25% at this site. A similar decline was recorded at the reference site in Pine Brush State Forest for Red Fox but not Wild Dog which had doubled since the baseline survey. The reported decline is encouraging given the construction of a combined culvert at this location.

Wild Dog activity at Site 6A has declined from the Year 1 survey but still remains markedly higher than the baseline. Red Fox activity has now increased at this site to two and half times that of the baseline survey. Together, it is likely to have an overall effect on how native wildlife including Phascogale may use the 3.6 m x 2.4 m underpass culvert seeking to restore habitat connectivity. The increase of both Wild Dog and Red Fox at the adjacent reference site located 2.5 km to the north west suggest exotic predators have increased throughout the general area, not just those areas adjacent to the road corridor.

4.6 Performance Measures and Corrective Actions

A series of performance indicators and corrective actions have been outlined in Section 8.2.4 of the Threatened Mammal Management Plan (RMS 2015). These have been summarised in Table 4-6 and discussed in further detail below.
Monitoring is to be conducted until such time as the mitigation measures have proven to be effective over three consecutive monitoring periods (TMMP; s.8.1). The plan identifies acceptable thresholds that if exceeded, would trigger corrective actions.

This may include any of the following:

c. >25% decline in Bettong, Phascogale or Long-nosed Potoroo activity levels from paired control site through the use of camera trap grids
d. >50% decline from paired control site from spotlighting surveys
e. >200% increase in road kill records during surveys. Baseline is 1 Bettong per 1500km of road transect and 1 Phascogale per 750km of road transect
f. Absence of records for >2 years during nocturnal driving surveys.

The following corrective actions are discussed in the plan

- Review monitoring methods and implement a more intensive monitoring and assessment schedule to confirm a decline in population density.
- Consider potential for natural variation to be responsible for decline in population numbers/density by comparison with control sites.
- Review results in conjunction with the road kill monitoring to check correlation with fence absence or breaches of the fence.
- Investigate habitat adjoining the highway and consider improving habitat condition and connectivity.

4.6.1 Phascogale Camera Activity Levels

Corrective actions are required when there has been a >25% decline in Phascogale activity levels from the paired control site at the camera trap grids. This occurred at Site 6 (CH27420) where Phascogale activity levels have declined 34% since the baseline survey with a greater decline of 55% from Year 1 (Table 4-6). This variability between years with

activity levels rising then falling does suggest it is natural variation. The paired reference site during this same time has maintained the same low activity level of 2.7% but had declined by 50% in Year 1. Further continued monitoring is required to assess this variability over time.

4.6.2 Spotlighting for Phascogale

Spotlighting during this round of monitoring was able to record Phascogale at two sites. Corrective actions are required when there is >50% decline from the paired control site from the spotlighting surveys. This will not occur when the baseline data failed to record Phascogale during the spotlighting survey, and as a consequence, this technique had been previously recommended for omission from the monitoring program (see Lewis 2015).

4.6.3 Phascogale Nocturnal Drive Transects

Nocturnal drive transects during this round of monitoring was able to record Phascogale at two sites. Corrective actions are required when Phascogale are absent for more than 2 years during nocturnal drive transects. As a consequence, the performance of this technique cannot be assessed until Year 3 of the program. To date, there are very few records and this technique appears more complementary and should only be used to casually inform the monitoring program.

4.6.4 Road Kill Monitoring

Corrective actions are required when there is a >200% increase in road kill records during surveys. There were no Phascogale recorded as road kill during this round of monitoring, a decline from the baseline monitoring of 1 per 750 km of transect (Table 4-6). Consequently, no road kill related corrective actions are currently warranted.

Table 5-1. Summary of survey techniques, baseline data and Year 1 survey results in relation to acceptable tolerance levels for Phascogale.

Technique	Acceptable Tolerance Level From the Control Site	Phascogale Site Reference Name	Site 1A	Site 1B	Site 2A	Site 2B	Site 3A	Site 3B	Site 4A	Site 4B	Site 5A	Site 5B	Site 6A	Site 6B	Site 7A	Site 7B
Camera Traps - 36 cameras installed on a 600 x 600 m grid 14 nights	25% decline of Phascogale	Baseline - Phascogale Mean	no data	2.8	11.1	10.4	2.8	4.2	no data	no data	no data	no data	8.50	2.70	8.3	1.4
		Phascogale Year 1	5.6	0.0	no data	8.3	11.11	19.45	no data	no data	no data	no data	12.50	1.39	no data	2.8
		Phascogale Year 2	no data	1.4					no data	no data	no data	no data	5.60	2.70		
		Comment	No data comparison possible	No data comparison possible	No data comparison possible	No data comparison possible	Fourfold increase	Fourfold increase					34% decline from baseline survey exceeds acceptable tolerance level	Same as baseline survey (static 0%) and recovered from Year 1 (49% increase)	No data comparison possible	Increase from baseline survey
Spotlight Surveys 4 units x 1 person hour (30 min per person) non-consecutive nights	50% decline	Baseline Mean	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Year 1	0.25	0	No data	0	0	0.25	0	0	0	0	0	0	No data	0
		Year 2	0	0									0.25	0		
		Comment Performance	Increase	No change	No data comparison possible	No comparison with impact site possible							Increase		No data comparison possible	No comparison with impact site possible
Nocturnal Drive Transect 4 units of 2-3 km transect employed on nights of spotlight surveys	Absence after 2 years of monitoring	Baseline Mean	0	0	0	0.25	0	0	0	0	0.25	0.25	0	0	0	0.25
		Year 1	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0.25
		Year 2	0	0									0	0		
		Comment Performance	No change	No change	No change	No change	No change	No change	No change	No change	Decline	Decline	No change	No change	No change	No change
Arboreal Tree Trapping Two 4 night surveys using 25 arboreal tree traps	> 25% decline from paired control site for arboreal tree trapping Brush-tailed Phascogale surveys	Baseline Mean	0	1 Fem.	1.5 Males	0	0	0	0	0	0	0.5 Fem. 1.5 Males	No data	No data	No data	No data
		Year 1	0	0	No data	0.5 fem	0	0.5 fem 0.5 male	0	0	0.5 fem	0	1.5 fem 0.5 male	0	No data	No data
		Year 2	0	0									0.5 fem	0		
		Comment Performance	No change	Decline to absent	No access	Increase	No change	Increase	No change	No change	Increase	Decline	No data comparison possible but a decline from Year 1	No change	No part of arboreal trapping program	No part of arboreal trapping program
Road Kill Surveys - surveys on multiple days and season in areas of suitable habitat and distance recorded	>200% increase	Preconstruction Base	1 Phascogale per 750 km of road transect													
		Year 1	Nil Phascogale													
		Year 2	Nil Phascogale													
		Comment Performance	No road kill Phascogale.													
		Corrective Action required	no	no	no	no	no	no	no	no	no	no	no	no	no	no

4.7 Conclusions and Recommendations

Monitoring as part of Year 2 in Section 2 and Year 1 in Sections 3, 6 and 7 has confirmed the continued presence of Phascogale at three of the seven impact sites and five of the seven reference sites. Importantly, two of the impact sites (2A CH35230 and 7A CH37320) cannot have the full extent of monitoring performed at this time due to ongoing access constraints. Although road kill surveys and nocturnal transects were performed in the vicinity of these areas, neither were able to detect Phascogale. The continued absence of Phascogale from Site 1A (Wells Crossing) and Site 4A (Tabbimoble) is probably more an artefact of relying on arboreal live trapping to determine their presence as opposed to adopting camera traps at these two locations.

The data collected during this round of monitoring points to a decline of Phascogale from Site 6A (27420) where activity levels have declined by 34% since the baseline survey and are currently down 55% from Year 1. The paired reference site shows some year to year variation too, however, it has currently recovered to the same pre construction baseline level. Exotic predators have increased at Site 6A with marked increases in both Fox and Wild Dog activity since the baseline survey but sampling during Year 2 has also revealed both species are now present at Site 6B where they were previously absent.

There was some improvement in the spotlighting and nocturnal drive transects during this round of monitoring with Phascogale recorded at Site 2B (Bom Bom State Forest), 3B (Pine Brush State Forest), 6A (Glenugie State Forest) and 7B (Glenugie State Forest). As a sampling technique used to assess population stability, both spotlighting and vehicle drive transects continue to provide little information to the overall monitoring program. This is simply because Phascogale are notoriously difficult to spotlight and this leaves the monitoring program with very little data.

The arboreal live trapping program produced mixed results during this round of monitoring but none of these exceeded thresholds necessarily requiring corrective actions. At Site 1, the data suggests Phascogale have disappeared from the trapping grid whilst the results of camera trapping show a different story with continuing low numbers. At Site 2, no comparison is possible given the impact site cannot be accessed. At Site 3, Phascogale appeared for the first time in the trapping grid at the reference site (Pine Brush State Forest) whilst they remain absent at the impact site (CH64505) to the contrary of the camera trap data. At Site 4 (Tabbimoble), Phascogale continue to remain absent from both the impact and reference site despite there being historic records in this locality. At Site 5 (Tabbimoble Swamp), Phascogale were recorded from the impact site yet remain absent from the reference site in Jackywalbin Conservation area which had previously recorded the highest Phascogale density in the baseline survey (Lewis 2015). At Site 6 (Glenugie), Phascogale remain on the trapping grid with a female repeatedly caught over all four nights yet no Phascogale were recorded from the reference site. The application of live trapping warrants review.

The road kill monitoring has confirmed no actual increase in the number of Phascogale being struck between the baseline survey and Year 1 or for Sites 1 and 6 now in Year 2. In light of the findings, some recommendations have been proposed in Table 4-7 to assist the monitoring program.

Table 4-7. Recommendations following Year 1/2 Phascogale population monitoring and Roads and Maritime response.

Recommendation No	Recommendation	Roads and Maritime Response
1.	Live trapping be replaced with camera trapping at all seven sites.	Adopted – RMS agrees that camera trapping is an improvement to the survey methodology.
2	Spotlighting be removed from the program.	Adopted. RMS agrees that spotlighting are providing little value following three years of monitoring in Section 2 and as recommended in previous annual reports.
3	Nocturnal drive transects be removed from the program.	Adopted. RMS agrees that nocturnal drive transects are providing little value following three years of monitoring in Section 2 and as recommended in previous annual reports..

4.8 References

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5.0 RUFOUS BETTONG (*AEPYPRYMNUS RUFESCENS*)

5.1 Species Profile

5.1.1 Description

The Rufous Bettong (Aepyprymnus rufescens) is a small marsupial measuring 70 to 80 cm in length from nose to tail. They have reddish-brown fur which extends onto the muzzle (Plate 5-1). They normally move quite slowly by placing the forelegs on the ground and bringing their hind legs forward together, but can also hop like a kangaroo (OEH 2014).

Plate 5-1. Rufous Bettong.

5.1.2 Distribution

Historically known from Coen in north Queensland to central Victoria with this range now contracted from Cooktown in Queensland to north-eastern NSW as far south as Mt Royal National Park. In NSW, the Rufous Bettong has largely vanished from inland areas apart from some sporadic and unconfirmed records in the Pilliga and Torrington districts (OEH 2014). In coastal NSW, the species is reasonably common inhabitant of the coastal forests and woodlands in the lower Clarence Catchment north from Kungala to about Tyndale and extends west to the Nymboida, Jackadgery and Drake areas (Bionet Wildlife Atlas 2016).

5.1.3 Habitat and Ecology

Bettong inhabit a variety of forests from tall, moist eucalypt forest to open woodland, with a tussock grass understorey (OEH 2014). A dense cover of tall native grasses is the preferred shelter. They sleep during the day in cone-shaped nests constructed of grass in a shallow depression at the base of a tussock or fallen log. At night they feed on grasses, herbs, seeds, flowers, roots, tubers, fungi and occasionally insects (OEH 2014).

5.2 Monitoring Methods

5.2.1 Monitoring Program

Five monitoring sites are distributed across Section 2 and 3 of the Woolgoolga to Ballina Upgrade with Site 1 and Site 2 located in Section 2, Site 3, 4 and 5 located in Section 3. Sampling as part of Year 1 (construction phase) monitoring is summarised in Table 5-1.

Table 5-1. Summary of the Bettong monitoring between January 2017 and January 2018.

Technique/Timing	Technique	Survey 1	Survey 2	Monitoring period (phase)
Camera Traps	36 cameras for 14 nights	Section 2 – Winter 2017	Section 2 - Summer 2018	Year 3 for Section 1&2 (construction)
		Section 3 – Autumn 2017	Section 3 – Late autumn winter 2017	Year 1 for Section 3 (construction)
Spotlighting	1 person hour deployed twice per survey	Section 2 - Winter 2017	Section 2 – Summer 2018	Year 3 for Section 1&2 (construction)
		Section 3 – Late summer/autumn 2017	Section 3 – Late autumn winter 2017	Year 1 for Section 3 (construction)
Nocturnal Drive Transect	2-3 km driving twice per survey	Section 2 – Winter 2017	Section 2 - Summer 2018	Year 3 for Section 1&2 (construction)
		Section 3 – Late summer/autumn 2017	Section 3 – Late autumn winter 2017	Year 1 for Section 3 (construction)
Road Kill Survey	Throughout the survey period	Autumn –Winter 2017	Winter-Summer 2018	Year 3 for Section 1&2 Year 1 for Section 3 (construction)

5.2.2 Monitoring Sites

The five paired monitoring sites referred to as Site 1A, 1B, 2A and 2B occur in Section 2 whilst Site 3A, 3B, 4A, 4B, 5A, and 5B occur in Section 3 with summary descriptions provided in Table 5-2. This sampling design known as a BACI (Before-After-Control-Impact) consists of the following:

- Impact sites which are identified in this instance with an ‘A” and may be potentially impacted by construction works or once the newly constructed carriageway is completed. Potential impacts may include but are not necessarily limited to habitat removal, a reduction in habitat connectivity, facilitating the distribution and increasing densities of exotic predators and creating hazards such as increased road strike;
- Reference or control sites which are identified in this instance with an ‘B” and possess similar geographic landscape and habitat traits as the impact sites but are located a sufficient distance from the Upgrade. In the case of the Bettong, this is thought to be around 2 km as individuals may occupy home ranges of approximately 20 ha and nightly movement of up to 625 m (Claridge et al. 2007).

Table 5-2. Preconstruction baseline monitoring sites for Bettong.

Paired Monitoring Site	Impact	Control/Reference	Comment & Status of Construction Activities
1 (Section 2)	Site 1A - CH23125 dedicated culvert 2.4 x 3, 22m long.	Site 1B - 3 km to the east and south of Bald Knob Tick Gate Road	• Bettong observed as road kill at Site 1A in circa 2010 and winter 2015. • The control site contains similar habitat types and Bettong have previously been observed adjacent to the grid. • Site now in operational phase. • Northbound carriageway adopted reuse strategy. • Connectivity structure under southbound only.
2 (Section 2)	Site 2A - CH27420 combined culvert 3.6 x 2.4, 104m long.	Site 2B - 3.6 km to the north west towards Braunstone in Glenugie State Forest	• Some variation in habitat type and suitability between the eastern and western side. Eastern side is a higher use area than the western side. • Reported as a road kill hotspot (Lewis 2014). • Site now in operational phase. • Northbound carriageway adopted reuse strategy. • Connectivity structure under southbound only.
3 (Section 3)	Site 3A – CH35230 combined culvert 2.4 x 2.4, 65m long	Site 3B – North eastern section of Glenugie State Forest to the east of 8 Mile Lane	• Access restriction placed on impact site. • Considered high quality habitat for Bettong. • No clearing commenced yet site designated construction.
4 (Section 3)	Site 4A – CH37320 combined culvert 2.4 x 2.4, 69m long.	Site 4B – 5.5 km north west in Bom Bom State Forest	• Access restriction placed on impact site. • Considered high quality habitat for Bettong. • No clearing commenced yet site designated construction. • Drive transect on Six Mile Lane
5 (Section 3)	Site 5A – CH64505 combined RCBC 3600 x 3600, 71m long.	Site 5B – 8 km south east in Pine Brush State Forest	• Marginal site for Bettong with past historic records but no activity during baseline survey. • Monitoring during and after clearing operations.

5.2.3 Sampling Regime

i. Camera Trapping

At each site, 36 camera traps (Scoutguard 560 k zero glow) were installed across a 600 m grid (36 ha) with 100 m trap spacing and left operating over a continuous 14 night period (504 nights effort) for each of the two surveys. The specific dates are summarised in Table 5-3.

At each site, cameras were installed using the following recording parameters:

- Timer mode set from dusk (1700 hrs) till dawn (0700 hrs) during the winter sampling and generally from 1900 hrs to 0700 hrs during the late summer/autumn sampling, the variation to adjust for daylight hours;
- Sensitivity mode was set to 'high' and where required, vegetation such as long grass was trimmed to reduce false trigger events (i.e. grass being blown in the wind);
- Each triggering event recorded two still images set in 8 mb file size;
- Reset time interval for retriggering was set at 30 seconds.

Each camera trap was baited using one large handful of peanut butter, honey and oats bait with added natural vanilla extract (Queen Brand). The bait was scattered over an area of 4-9 m^2 and the earth was partly disturbed to increase the likelihood of the area being visited by the target species. Cameras were generally fixed to a tree or stump in a horizontal facing position around 1 m off the ground with the primary objective of obtaining the largest field of view possible. The positioning of cameras was guided by recent field survey evaluations of camera trap orientation whilst surveying for other small macropods and potoroids (see Taylor et al. 2013).

All camera images were downloaded onto a desktop computer for viewing on a 20 inch screen with each image viewed and the animal identified by BL (Ben Lewis). All images were identified to species level apart from Antechinus and Rodents that were retained in these two groups.

Table 5-3. Summary of the installation and retrieval time periods for camera trap monitoring at Bettong sites.

Site	Survey Number	Installation Date	Retrieval Date	No. Nights	No. Cameras Retrieved	Effort (Camera Trap Nights)
Site 1A Impact	1	18.06.2017	02.07.2017	14	36	504
Site 1A Impact	2	13.01.2018	29.01.2018*	14	36	504
Site 1B Reference	1	18.06.2017	02.07.2017	14	36	504
Site 1B Reference	2	13.01.2018	29.01.2018*	14	36	504
Site 2A Impact	1	17.06.2017	01.07.2017	14	36	504
Site 2A Impact	2	20.01.2018	05.02.2018	14	36	504
Site 2B Reference	1	17.06.2017	01.07.2017	14	36	504
Site 2B Reference	2	20.01.2018	05.02.2018	14	36	504
Site 3A Impact	1	No access	No access			
Site 3A Impact	2	No access	No access			
Site 3B Reference	1	08.04.2017	22.04.2017	14	36	504
Site 3B Reference	2	27.05.2017	12.06.2017	14	36	504
Site 4A Impact	1	No access	No access			
Site 4A Impact	2	No access	No access			
Site 4B Reference	1	07.04.2017	21.04.2017	14	36	504
Site 4B Reference	2	17.06.2017	01.07.2017	14	36	504
Site 5A Impact	1	28.04.2017	13.05.2017	14	36	504
Site 5A Impact	2	01.06.2017	15.06.2017	14	36	504
Site 5B Reference	1	28.04.2017	13.05.2017	14	36	504
Site 5B Reference	2	01.06.2017	15.06.2017	14	36	504
					Total	8064 trap nights

*additional days sampling were ignored in total image set

ii. Spotlighting

Spotlighting was undertaken at all sites over two non-consecutive nights in each season (Table 5-4). Each spotlight transect lasted 1 person hour and involved walking systematically through the 600 m grid using a 800 lumen head torch. Only positively identified Bettong were recorded.

Table 5-4. Summary of the spotlight surveys at each site.

W2B Section	Site	Survey Period	Spotlight 1	Spotlight 2	Effort (Person Hours)	Nocturnal Drive Transect
2	Site 1A Impact	1	06.07.2017	08.07.2017	2	2 km north and south of the site on the Pacific Highway on each spotlight night
2	Site 1B Reference	1	06.07.2017	08.07.2017	2	2 km either side but on adjacent Bald Knob Tick Gate Road on each spotlight night
2	Site 1A Impact	2	18.01.2018	12.02.2018	2	2 km north and south of the site on the Pacific Highway on each spotlight night
2	Site 1B Reference	2	18.01.2018	13.02.2018	2	2 km either side but on adjacent Bald Knob Tick Gate Road on each spotlight night
2	Site 2A Impact	1	07.07.2017	09.07.2017	2	2 km either side using access track running parallel to existing Pacific Highway. Northern extent turns east onto Franklins Road on each spotlight night
2	Site 2B Reference	1	07.07.2017	09.07.2017	2	3 km south east of site terminating at the northern extent of the grid on each spotlight night
2	Site 2A Impact	2	14.01.2018	10.02.2018	2	2 km either side using access track running parallel to existing Pacific Highway. Northern extent turns east onto Franklins Road on each spotlight night
2	Site 2B Reference	2	14.01.2018	10.02.2018	2	3 km south east of site terminating at the northern extent of the grid on each spotlight night
3	Site 3A Impact	1	No access	No access	0	Use Old Pacific Highway as alternative
3	Site 3B Reference	1	17.03.2017	27.04.2017	2	No. 2 Road and south along Morilla Road turn east along unnamed fire trail through grid
3	Site 3A Impact	2	No access	No access	0	Use Old Pacific Highway as alternative
3	Site 3B Reference	2	13.05.2017	30.05.2017	2	No. 2 Road and south along Morilla Road turn east along unnamed fire trail through grid
3	Site 4A Impact	1	No access	No access	0	Six Mile Lane just to north of monitoring grid
3	Site 4B Reference	1	17.03.2017	27.04.2017	2	Stokers Road
3	Site 4A Impact	2	No access	No access	0	Six Mile Lane just to north of monitoring grid
3	Site 4B Reference	2	13.05.2017	30.05.2017	2	Stokers Road
3	Site 5A Impact	1	29.04.2017	04.05.2017	2	Drive along Coldstream Road for 1.5 km either side of Tyndale Crown turnoff
3	Site 5B Reference	1	29.04.2017	04.05.2017	2	Somervale Road either side and through middle of the grid
3	Site 5A Impact	2	14.06.2017	29.06.2017	2	Drive along Coldstream Road for 1.5 km either side of Tyndale Crown turnoff
3	Site 5B Reference	2	14.06.2017	29.06.2017	2	Somervale Road either side and through middle of the grid
					32 hours	Approx. 100 km

iii. Nocturnal Drive Transects

Nocturnal drive transects were performed whilst commuting between the survey sites for distances of usually 2-3 km either side of the grid (Table 5-5). During this time, the vehicle was driven at speeds commensurate to the road or area being traversed. For example, narrow single lane tracks (e.g. Site 2B) were traversed at speeds of up to 20 kmph whilst an unsealed road was sampled at between 20-40 kmph (e.g. Site 1B). Sealed roads were driven at speeds of between 60-80 kmph (Site 1A Pacific Highway). The objective of this was to sample Bettong in a way that was commensurate to

other road users and vehicle/Bettong interactions. All Bettong observed during these surveys were recorded and their behaviour was documented.

iv. Road Kill Surveys

Road kill surveys were undertaken opportunistically during the field survey program (Table 5-5). During each survey, the roadway was scanned for any road killed Bettong along with survey effort (distance travelled). Typically, the vehicle was driven at speeds of 60-90 kmph (i.e. depending on traffic) to inspect for all dead wildlife (road kill) on the carriageway or within 3 m of the road verge. Once road kill Bettong had been observed, a closer inspection of the carcass was undertaken to identify the age, sex and whether any pouch young were present. Surveys were conducted over 30 days with 17 surveys in survey period one and 13 surveys in survey period two (Table 5-5).

Table 5-5. Summary of road kill surveys during the monitoring period.

Date	Survey Period	Road Kill Surveys -Distance Travelled (KM)	W2B Section
26.02.2017	1	25	3
17.03.2017	1	25	3
07.04.2017	1	16	3
08.04.2017	1	22	3
21.04.2017	1	20	3
22.04.2017	1	22	3
27.04.2017	1	22	3
28.04.2017	1	24	3
12.05.2017	1	22	3
13.05.2017	1	24	3
17.06.2017	1	7	2
18.06.2017	1	7	2
01.07.2017	1	7	2
02.07.2017	1	7	2
06.07.2017	1	7	2
08.07.2017	1	7	2
10.07.2017	1	7	2
	Total	17 days + 271 km	
27.05.2017	2	18	3
01.06.2017	2	24	3
12.06.2017	2	18	3
15.06.2017	2	24	3
08.01.2018	2	7	2
13.01.2018	2	7	2
16.01.2018	2	7	2+3
20.01.2018	2	7	2
29.01.2018	2	7	2
05.02.2018	2	7	2
06.02.2018	2	39	2 + 3
08.02.2018	2	35	2 + 3
10.02.2018	2	44	2 + 3
	Total	13 days + 244 km	

5.2.4 Data Summaries and Statistical Analysis

i. Camera Traps

The camera trap data is reported as the mean activity level or rate derived from the number of cameras that detected Bettong and was reported for each of the two survey periods (i.e. Survey 1 and Survey 2). For example, images of Bettong recorded from 10 of the 36 cameras for survey period one was expressed as 27.78 % (10/36) and 15 of the 36 cameras during survey period two was expressed as 41.67% (15/36). The mean and standard errors were derived from percentage activity values for the two survey periods. So using the above example, this involved summing 27.78% + 41.67% to derive a mean of 34.73% with a standard error of 6.94. The activity rate was calculated for all exotic predator species recorded so that additional affects could be considered.

The acceptable tolerance level for camera activity was calculated by finding the difference between the baseline activity and the monitoring year for each treatment. The difference between the two treatments was then used to determine if the acceptable tolerance level of 25% had been exceeded as per Table 8.5 in the TMMP (RMS 2015). For example, if the impact site declined from 58.3% in the baseline survey to 18.18% in Year 3 would leave a difference of 40.12%. This 40.12% was then used to calculate the decline (40.12/58.3 x 100), in this case 68.8%. At the control site, if the baseline survey recorded 48% and this declined in Year 3 to 30%, leaving a difference of 18%. This 18% was then used to calculate the decline (18/48 x 100) of 37.5%. Although both sites declined, the difference between the two treatments was 31.3% (i.e. 68.8 at impact) and 37.5 at the control). In this example, it exceeded the >25% threshold where corrective actions would then need to be considered in Table 8-5 of the TMMP (RMS 2015).

ii. Spotlight Surveys

The spotlight monitoring data is derived from a mean of the four spotlighting surveys and expressed as the number of Bettong recorded on a per hour of effort. For example, one Bettong observed during the first spotlight survey followed by no Bettong recorded on the remaining three surveys was expressed as 0.25 Bettong per hour of spotlight effort. Two Bettong recorded on one survey and another one on another survey was expressed as 0.75 per hour of spotlighting effort.

iii. Nocturnal Drive Transects

The nocturnal drive transects data is derived from a mean of the two 2-3 km transect surveys and expressed as the number of Bettong recorded per 2-3 km of effort.

iv. Road Kill Surveys

The road kill monitoring data is derived from a tally of the total number of kilometers driven through areas of suitable Bettong habitat under construction and simply expressed as the number of individuals recorded. This was then compared with the baseline data using the number of Bettong recorded per 750 and 1500 km.

5.3 Monitoring Results

5.3.1 Presence of Bettong Using Cameras at Monitoring Sites

Cameras captured 18848 images at a mean of 2356 images per treatment site during this round of monitoring. Bettong were recorded at Site 2A (CH27420), Site 2B (Glenugie State Forest), Site 3B (Glenugie State Forest), Site 4A (Six Mile Lane), Site 4B (Bom Bom State Forest) and Site 5B (Pine Brush State Forest; Table 5-6; Figure 3-1; Plate 5-2). Bettong remain absent from Site 1A (CH23125), Site 1B (Yuraygir State Conservation Area) and Site 5A (64505) whilst access constraints prevented the full suite of surveys from Site 3A (CH35230) and Site 4A (CH37320).

Table 5-6. Summary of the paired treatment sites and Bettong tenure during Year 1 monitoring in Section 3 and Year 3 in Section 2.

W2B Section	BACI Site Name	Mitigation Treatment	Bettong Recorded	BACI Site Name	Bettong Recorded
2	Site 1A - CH23125	dedicated culvert 2.4 x 3, 22m long	No	Site 1B - (Yuraygir State Conservation Area)	No
2	Site 2A - CH27420	combined culvert 3.6 x 2.4, 104m long	Yes	Site 2B - (Glenugie State Forest west)	Yes
3	Site 3A – CH35230	combined culvert 2.4 x 2.4, 65m long	No data	Site 3B – North eastern section of Glenugie State Forest to the east of 8 Mile Lane	Yes
3	Site 4A – CH37320	combined culvert 2.4 x 2.4, 69m long.	Yes	Site 4B – 5.5 km north west in Bom Bom State Forest	Yes
3	Site 5A – CH64505	combined RCBC 3600 x 3600, 71m long.	No	Site 5B – 8 km south east in Pine Brush State Forest	Yes

5.3.2 Bettong Activity Levels

Bettong activity levels ranged from zero at Site 1A and 1B through to 42.17 at Site 3B (Figure 5-1 and 5-2; Table 5-7). The following is a site summary:

- At Site 1, the impact treatment (1A) continues to record zero with a general absence across this grid, down from the 1.4% recorded in the baseline survey. The paired control site (1B) similarly recorded zero Bettong activity, the same result as the baseline survey.
- At Site 2, the impact (2A) recorded 3.8%, a small increase from the 2.7% recorded in Year 2 but still markedly lower than the 8.5% recorded in the baseline survey (Figure 5-2). In contrast, activity levels declined at Site 2B, down from 52.7% in Year 2 to 38.2% in Year 3, however, this still remains markedly higher (45%) than the baseline of 26.4%. These increased activity levels translate to between one and two in every 36 cameras being visited by Bettong at Site 2A and 15 in every 36 cameras visited by Bettong at Site 2B.
- At Site 3, the impact (CH35230) could not be accessed during this round of monitoring. The reference site recorded a decline during Year 1 with activity of 27.8%, down from 32.1% recorded in the baseline survey (i.e. 13.4% decline).
- At Site 4, the impact (4A) could not be accessed during this round of monitoring. Bettong activity at the reference site was calculated at 42.2%, a 26.3% decline from the 57.2% activity recorded in the baseline survey.
- At Site 5, the impact (5A) site continues to record zero Bettong activity across the grid whilst the reference site (5B) was calculated at 12.5% for Year 1, a fourfold increase from the 2.7% recorded in the baseline survey.

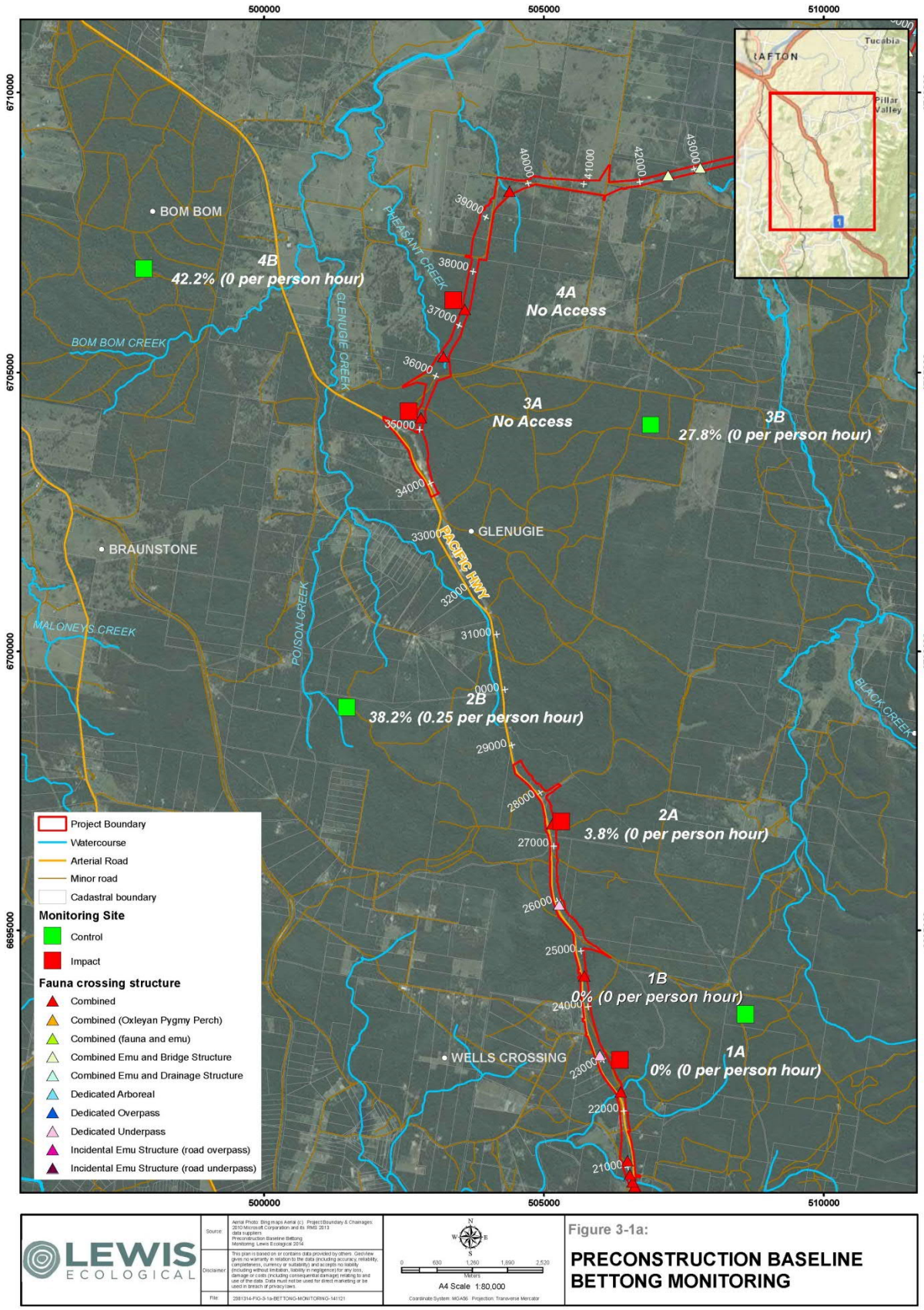


Figure 5-1. Bettong activity at monitoring sites 1-4 in Section 2 and 3 of the W2B Upgrade.

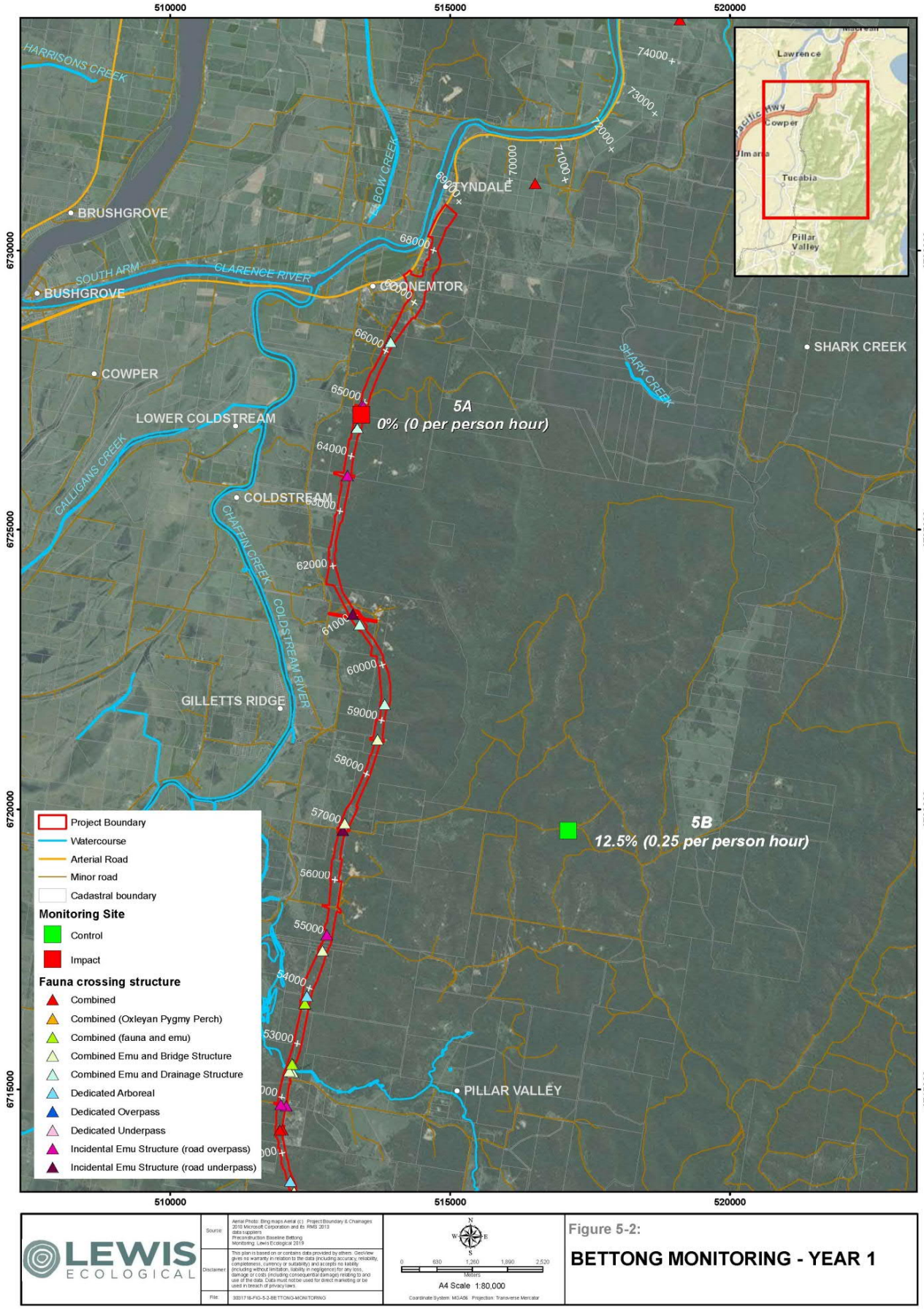
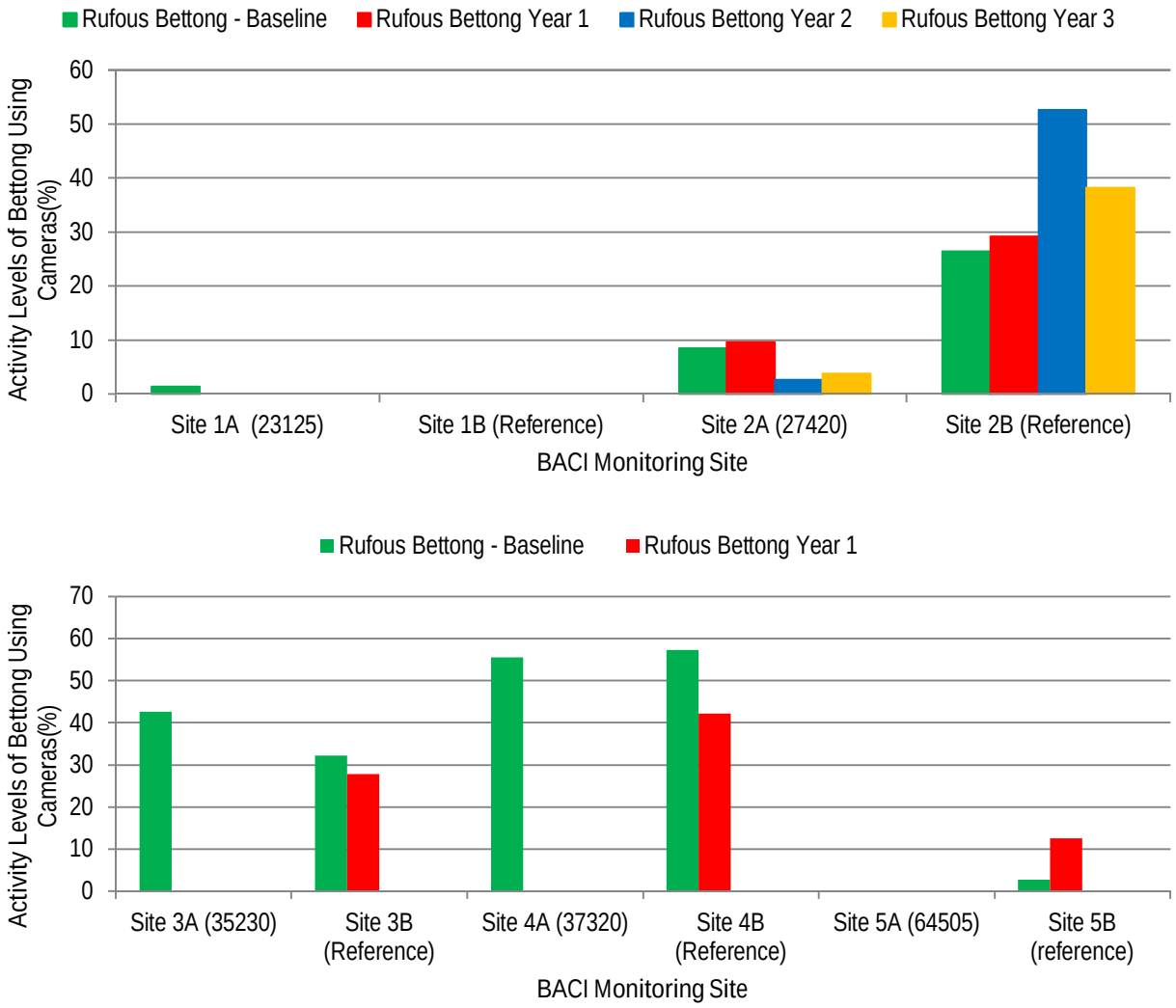


Figure 5-2. Bettong activity at monitoring Site 5 in Section 3 of the W2B Upgrade.



Note – No access to survey at Site 3A (35230) and 4A (37320)

Figure 5-2. Bettong activity levels between the preconstruction baseline survey (green) and Years 1 (red), 2 (blue) and 3 (orange).

Plate 5-2. Example of a Rufous Bettong image recorded on the Site 5B grid during Survey 1 sampling (Pine Brush State Forest).

Table 5-7. Summary of the activity rates including mean values of Bettong between the baseline survey, Year 1, Year 2 and Year 3 sampling.

Bettong Site Reference Name	Site 1A- Impact	Site 1B - Ref	Site 2A - Impact	Site 2B - Ref	Site 3A - Impact	Site 3B - Ref	Site 4A - Impact	Site 4B - Ref	Site 5A - Impact	Site 5B - Ref
Preconstruction Baseline Monitoring										
Bettong Survey 1	2.7	0.0	2.7	25.0	47.2	22.2	36.0	56.0	0.0	2.7
Bettong Survey 2	0.0	0.0	14.3	27.8	38.0	41.9	75.0	58.2	0.0	2.7
Preconstruction Baseline Mean	1.4	0.0	8.5	26.4	42.6	32.1	55.5	57.2	0.0	2.7
Year 1 Monitoring										
Survey 1	0	0	2.7	27.8	No data	25.0	No data	27.8	0.0	11.1
Survey 2	0	0	16.7	30.6	No data	30.6	No data	56.6	0.0	13.9
Year 1 Mean	0	0	9.7	29.2	No data	27.8	No data	42.2	0.0	12.5
Increase/Decrease Between Baseline and Year 1	Decrease	No Change	Increase	Increase	No data	Decrease	No data	Decrease	No change	Increase
Year 2 Monitoring										
Survey 1	0	0	2.7	47.0						
Survey 2	0	0	2.7	58.3						
Year 2 Mean	0	0	2.7	52.7						
Increase/Decrease Between Baseline and Year 2	Decrease	No Change	Decrease	Increase						
Year 3 Monitoring										
Survey 1	0	0	2.7	25.7						
Survey 2	0	0	4.9	50.7						
Year 3 Mean	0	0	3.8	38.2						
Increase/Decrease Between Baseline and Year 3	Decrease	No change	Decrease	Increase						

5.3.3 Spotlight Surveys and Nocturnal Driving Transects for Bettong

Bettong were recorded during spotlight surveys at Site 2B and Site 5B, each with a confirmed observation of one adult (Table 5-8). At Site 2B, the animal had been disturbed but paused momentarily before moving downslope into a dense patch of Acacia. At Site 5B, an adult was observed moving around foraging on the northern side of the camera trap grid in open Spotted Gum and Ironbark forest. The detection rate was calculated at 0.25 Bettong per survey for Site 2B and Site 5B but zero for the other sites (Table 5-8; Figure 5-1 and 5-2).

Bettong were recorded at two sites during nocturnal road transects with one recorded during an autumn census on Six Mile Lane close to Site 4A whilst another observation was made along the road that bisects Site 5B. At Site 4A, the animal had paused briefly on the southern side of the road verge whilst at Site 5B the animal was moving across the road in a northerly direction. At both of these sites, the mean recording rate for Year 1 is 0.25 whilst it remains at zero for the other sites (Table 5-8).

Table 5-8. Results of the spotlight surveys and nocturnal drive transects for Bettong.

W2B Section	Site	Survey Technique	Survey 1		Survey 2		
			Spot. 1	Spot. 2	Spot. 3	Spot. 4	Mean No. Bettong Per Sampling Hour (Spotlighting) and per 2-3 km of nocturnal drive transect
2	Site 1a Impact	Spotlight	0	0	0	0	0
		Nocturnal Drive Transect	0	0	0	0	0
2	Site 1b Reference	Spotlight	0	0	0	0	0
		Nocturnal Drive Transect	0	0	0	0	0
2	Site 2a Impact	Spotlight	0	0	0	0	0
		Nocturnal Drive Transect	0	0	0	0	0
2	Site 2b Reference	Spotlight	0	0	1	0	0.25
		Nocturnal Drive Transect	0	0	0	0	0
3	Site 3a Impact	Spotlight	No data	No data	No data	No data	No data
		Nocturnal Drive Transect	0	0	0	0	0
3	Site 3b Reference	Spotlight	0	0	0	0	0
		Nocturnal Drive Transect	0	0	0	0	0
3	Site 4a Impact	Spotlight	No data	No data	No data	No data	No data
		Nocturnal Drive Transect	1	0	0	0	0.25
3	Site 4b Reference	Spotlight	0	0	0	0	0
		Nocturnal Drive Transect	0	0	0	0	0
3	Site 5a Impact	Spotlight	0	0	0	0	0
		Nocturnal Drive Transect	0	0	0	0	0
3	Site 5b Reference	Spotlight	0	0	0	1	0.25
		Nocturnal Drive Transect	0	1	0	0	0.25

Pos. denotes a possible Bettong but could not be confirmed.

5.3.4 Road Kill Transects for Bettong

Road kill surveys performed over 30 days and 515 km of driving recorded no Bettong.

5.3.5 Exotic Predator Activity Levels

Using the cameras to calculate presence and activity levels for exotic predators, the following is summarised for each site:

- Site 1 (Wells Crossing) with the following Year 3 results:
    - Impact site with:
        - 4.2% Wild Dog activity, the same as the baseline survey and a small decrease from Year 1 and 2 (Table 5-9);
        - 1.4% Red Fox activity, an increase from when it has been previously absent in the baseline survey and during Year 1 and 2;
        - No Feral Cat activity which is the same as the baseline survey and a decline from Year 2; and
        - No Feral Pig activity, which is the same as the baseline survey and a decline from Year 1.
    - Reference site with:
        - 5.5% Wild Dog activity, an increase from both the Year 1 and the baseline survey (Table 5-9);
        - 0% Red Fox activity and reflects no change from the baseline survey;
        - 1.4% Feral Cat activity, no change from the baseline survey yet a small decrease from Year 1 monitoring; and
        - 2.7% Feral Pig activity, a decline from Year 1 sampling but still an increase from the baseline survey when it had only been detected via diggings.
- Site 2 (Glenugie State Forest) with the following Year 3 results:
    - Impact site with:
        - 7.0% Wild Dog activity, a decrease from Year 1 monitoring but still a threefold increase from the baseline survey (Table 5-9);
        - 2.8% Red Fox activity, the same as the baseline survey;
        - 0% Feral Cat activity; no change from the baseline survey; and
        - 0% Feral Pig activity, no change from the baseline survey.
    - Reference site with:
        - 2.8% Wild Dog activity, an increase from the baseline survey when it was absent and half the activity recorded in Year 2 (Table 5-9);
        - 1.4% Red Fox activity, an increase from the baseline survey and Year 1 monitoring when it was absent;
        - 0% Feral Cat activity, a decline from the 2.8% recorded in the baseline survey; and
        - 0% Feral Pig activity, no change from the baseline survey.
- Site 3 (Glenugie State Forest) with the following Year 1 results:

- Impact site (CH35230) could not be accessed.
- Reference site with:
  - 1.4% Wild Dog activity, an increase from the baseline survey when it was absent (Table 5-9);
  - 1.4% Red Fox activity, an increase from the baseline survey when it was absent;
  - 2.8% Feral Cat activity, no change from the baseline survey; and
  - 0% Feral Pig activity, also no change from the baseline survey (Table 5-9).

- Site 4 (Pheasant Creek and Bom Bom State Forest) with the following Year 1 results:
  - Impact site (CH37320) could not be accessed.
  - Reference site with:
    - 4.2% Wild Dog activity, an increase from the baseline survey when it was absent (Table 5-9);
    - 2.1% Red Fox activity, an increase from the baseline survey when it was absent;
    - 2.8% Feral Cat activity, a decline from the baseline survey of 7.0%; and
    - 0% Feral Pig activity, no change from the baseline survey.
- Site 5 (Tyndale & Pine Brush State Forest) with the following Year 1 results:
  - Impact site with:
    - 8.3% Wild Dog activity, a decrease of 25% from the 11.1% recorded during the baseline survey (Table 5-9);
    - 7.0% Red Fox activity, a decrease of 64% from the 19.45% recorded during the baseline survey;
    - 0% Feral Cat activity, a decrease from 4.2% recorded in the baseline survey; and
    - 0% Feral Pig activity, also no change from the baseline survey.
  - Reference site with:
    - 2.8% Wild Dog activity, double that of the baseline survey at 1.4% (Table 5-9);
    - 2.8% Red Fox activity, half that of the 4.2% recorded during the baseline survey;
    - 2.8% Feral Cat activity, an increase from the baseline survey when it was absent; and
    - 0% Feral Pig activity, no change from the baseline survey.

Plate 5-3. Image of Feral Cat from Site 5B.

Table 5-9. Exotic animal activity for each of the Bettong monitoring sites.

W2B Section	Site	Exotic Species	Pre-construction Baseline Mean (%)	Year 1 Mean Activity (%)	Year 2 Mean Activity (%)	Year 3 Mean Activity (%)	Increase or Decrease in Activity compared to the Baseline Survey
2	Site 1a Impact	Red Fox	0	0	0	1.4	Increase. Also the first time recorded on the grid
		Wild Dog	4.2	5.5	7.0	4.2	No change
		Feral Cat	0	0	1.4	0	No change
		Feral Pig	0	1.4	1.4	0	No change
2	Site 1b Reference	Red Fox	0	0	0	0	No change
		Wild Dog	2.8	4.2	5.5	7.0	Increase. 2.5 times higher
		Feral Cat	1.4	2.3	1.4	0	Decrease
		Feral Pig	0.0	4.2	2.7	0	No change
2	Site 2a Impact	Red Fox	2.8	0	7.0	2.8	No change
		Wild Dog	2.8	13.9	9.8	7.0	Increase. 2.5 times higher
		Feral Cat	0	0	0	0	No change
		Feral Pig	0	0	0	0	No change
2	Site 2b Reference	Red Fox	0	0	1.4	1.4	Increase. Also the first time recorded on the grid
		Wild Dog	0	0	5.6	2.8	Increase
		Feral Cat	2.8	0	0	1.4	Decrease
		Feral Pig	0	0	0	0	No change
3	Site 3a Impact	Red Fox	2.8	No data			Insufficient data for comparison
		Wild Dog	2.8	No data			Insufficient data for comparison
		Feral Cat	0	No data			Insufficient data for comparison
		Feral Pig	0	No data			Insufficient data for comparison
3	Site 3b Reference	Red Fox	0	1.4			Increase. First time recorded on the grid
		Wild Dog	0	1.4			Increase. First time recorded on the grid

W2B Section	Site	Exotic Species	Pre-construction Baseline Mean (%)	Year 1 Mean Activity (%)	Year 2 Mean Activity (%)	Year 3 Mean Activity (%)	Increase or Decrease in Activity compared to the Baseline Survey
		Feral Cat	2.8	2.8			No change
		Feral Pig	0	0			No change
3	Site 4a Impact	Red Fox	22.3	nd			Insufficient data for comparison
		Wild Dog	1.4	nd			Insufficient data for comparison
		Feral Cat	0	nd			Insufficient data for comparison
		Feral Pig	1.4	nd			Insufficient data for comparison
3	Site 4b Reference	Red Fox	0	2.1			Increase. First time recorded on the grid
		Wild Dog	0	4.2			Increase. First time recorded on the grid
		Feral Cat	7.0	2.8			Decrease by 2.5 times
		Feral Pig	0	0			No change
3	Site 5a Impact	Red Fox	19.5	7.0			Decrease by 2.75 times
		Wild Dog	11.1	8.3			Decrease by one third
		Feral Cat	4.15	0			Decrease to absent
		Feral Pig	0	0			No change
3	Site 5b Reference	Red Fox	4.2	2.8			Decrease
		Wild Dog	1.4	2.8			Increase
		Feral Cat	0	2.8			Increase
		Feral Pig	0	0			No change

5.4 Discussion of Monitoring Results

5.4.1 Bettong Activity

Bettong activity at both Site 1 treatments remains absent and given the long term trend of low numbers and the fact that this pattern is likely to continue there is merit in investigating the first corrective action to confirm if this is a real decline, or whether Bettong are still present outside the grid. Sampling an adjacent area such as to the west of the highway where previous road kill Bettong have been recorded would help to understand if there is in fact a decline or some small change in habitat use. From this, the overall value of this as a monitoring site could be discussed and provide useful information on the dedicated underpass structure constructed at ch.23125.

Further north at Site 2, the impact treatment continues to record Bettong with Year 3 recording a small increase to 3.8%, up from the 2.7% in Year 2 but still lower than the 8.5% in the baseline survey. Traditionally, Bettong are recorded in the south western part of this monitoring grid and don't tend to utilise most of the eastern part of this grid which tends to support dense Melalucea shrubs. The reference site recorded a decline during this round of monitoring where it has now declined from almost 53% to 38% which still equates to around a third of all cameras recording Bettong. Similar to past spotlighting surveys, a Bettong was spotlighted at this location and suggests this technique may only be a reliable indicator of presence where Bettong densities are high. This has been the case in the past at monitoring sites in Bom Bom State Forest and to the south of Six Mile Lane (Lewis 2015).

This round of monitoring involves the commencement of surveys at three sites located in Section 3 of the Upgrade. Access constraints prevented the full suite of surveys from being undertaken at Site 3A and 4A (i.e. the adjacent road kill and nocturnal drive transects were still undertaken), however, their reference or control sites were sampled in the same manner as the baseline survey. Both of the reference sites recorded small declines in activity and despite this, Bettong still visited a quarter to almost half of camera traps deployed in these areas. Access to the impact sites in the vicinity of Eight Mile Lane would greatly assist the current Bettong monitoring program given this area was regarded as a hotspot in the Threatened Mammal Management Plan and the results from the adjacent reference sites continue to support this statement.

Further north, Bettong still remain absent from the Site 5 impact treatment located on Tyndale Crown Reserve. There are historic records of Bettong from the area and the habitat appears suitable in some but not all parts of the monitoring grid. The baseline survey had recorded high numbers of Red Fox, Wild Dog and Feral Cat and these predatory effects may have resulted in some decline to the local Bettong population. Further to the south east, the reference site in Pine Brush State Forest recorded a notable increase in Bettong activity, up from 2.7% in the baseline survey to 12.5% in Year 1. This site was also where Bettong were both spotlighted and observed during a nocturnal drive transect yet they hadn't been in the past. Interestingly, Red Fox activity declined at this site over the same period.

5.4.2 Exotic Predatory Species

Exotic predators responded in multiple ways across the five monitoring sites. At Site 1, Red Fox appeared for the first time at the impact treatment and is a newly recorded species for this site. It remains absent from the adjacent reference site around 2.5 km to the east. In contrast, Feral Cat and Wild Pig were not recorded at either treatment site yet both species have been previously recorded at both treatment sites. Wild Dog remains at or above the baseline activity levels and has continued to increase throughout the monitoring program at the reference site but remains relatively static at the impact site at 4.2%.

Exotic predators have moved into the reference treatment at Site 2 where they were largely absent in the baseline survey and Year 1. At present, Red Fox, Wild Dog and Feral Cat are present on the reference grid whilst Red Fox and Wild Dog remain at or above baseline activity levels at the impact site to the south of Franklins Road (CH27420). Some strategic predator control would assist at improving habitat condition and the potential effectiveness of the underpass structure constructed at CH27420.

Camera monitoring was restricted to the reference treatments at Site 3 (Glenugie east) and Site 4 (Bom Bom State Forest). Both sites recorded an increase in the types of exotic predators with Red Fox and Wild Dog being recorded for the first time at both grids. This combined with the increased activity of Fox and Wild Dog at other reference sites does indicate there is possibly a more widespread increase in the numbers of exotic predators across the Wells Crossing and Glenugie areas and that similar rises in activity levels at impact treatments are a consistent regional trend.

Site 5 located further north near Tyndale and east of Tucabia recorded a different trend from the southern monitoring sites. At both treatments, exotic predators declined, particularly the Red Fox where its activity declined to almost a third of what it was during the baseline survey at the impact site (Tyndale Crown) whilst it almost halved at the reference site in Pine Brush State Forest. Interestingly, Bettong numbers at the reference site increased almost five fold indicating predators probably do influence the camera trap data.

5.6 Performance Measures and Corrective Actions

A series of performance indicators and corrective actions have been outlined in Section 8.2.4 of the Threatened Mammal Management Plan (RMS 2015). These have been summarised in Table 5-10 and discussed in further detail below. Monitoring is to be conducted until such time as the mitigation measures have proven to be effective over three consecutive monitoring periods (TMMP; s.8.1). The plan identifies acceptable thresholds that if exceeded, would trigger corrective actions.

This may include any of the following:

g. >25% decline in Bettong, Phascogale or Long-nosed Potoroo activity levels from paired control site through the use of camera trap grids
h. >50% decline from paired control site from spotlighting surveys
i. >200% increase in road kill records during surveys. Baseline is 1 Bettong per 1500km of road transect and 1 Phascogale per 750km of road transect
j. > 25% decline from paired control site for arboreal tree trapping Brush-tailed Phascogale surveys
k. Absence of records for >2 years during nocturnal driving surveys.

The following corrective actions are discussed in the plan

- Review monitoring methods and implement a more intensive monitoring and assessment schedule to confirm a decline in population density.
- Consider potential for natural variation to be responsible for decline in population numbers/density by comparison with control sites.
- Review results in conjunction with the road kill monitoring to check correlation with fence absence or breaches of the fence.
- Investigate habitat adjoining the highway and consider improving habitat condition and connectivity.

5.6.1 Bettong Activity Levels

Bettong activity has declined at Site 1A from 1.4% in the baseline survey to being absent (i.e. 100% decline) in Years 1, 2 and 3 triggering a corrective action in accordance with Table 8-5 of the TMMP (RMS 2015). Given that activity levels were very low during the pre-construction baseline survey there is merit in reviewing the existing monitoring methods and implement a more intensive monitoring and assessment schedule to confirm a decline in population density. The adjacent reference site remains at zero activity.

Further to the north at Site 2, the impact site has declined by 45% (8.5% versus 3.8%) whilst the reference site (2B) remains at 31% above the baseline survey. This equates to a 76% variation between the impact and the reference site at this location. Consequently, the activity levels recorded are now well beyond the 25% decline threshold and corrective

actions are warranted. In reality, these changes are probably a result of both natural variation and the increase of exotic predators. At Site 2A, there are usually small numbers of Bettong on the south west or western edge of the grid (i.e. closer to the road) and this remains so in Year 3, it's just the activity has reduced a little. Site 2B has always been a static site, the recorded increases may reflect a better year of reproduction or the presence of Fox and Dog for the first time has Bettong moving around a bit more to avoid predators. Importantly, predators have increased at both sites.

Site 3 and 4 could not be sampled as part of Year 1 monitoring due to access constraints. The grids at the reference sites recorded some notable declines of 13% at Site 3B in Glenugie State Forest and 26% at Site 4B in Bom Bom State Forest. Interestingly, Fox and Dog were recorded for the first time at each of these grids and start to present a picture with other sites in the area that suggest more broad scale increases of Fox and Dog, not just along the Upgrade corridor.

At Site 5, Bettong remain absent as they had done so in the baseline survey yet interestingly there are historic records in the general vicinity. The reference site (5B) located in Pine Brush State Forest recorded a 450% increase in activity with most of these records from the north west precinct of the grid.

In summary, corrective actions are currently required at Site 2A and due consideration should be given to adopting some corrective actions at Site 1A to substantiate the reported decline here.

5.6.2 Exotic Predator Activity Levels

There have been both notable increases and some declines in exotic predator levels (Table 5-10). Both treatments at Site 1 (Wells Crossing) recorded increases with Red Fox for the first time yet Wild Dog and Feral Cat remained at baseline levels of 4.2% and absent. At the adjacent reference site (1B), Wild Dog numbers increased by 250%.

Increased exotic predator activity remains high at Site 2 with both treatments recording increases since the baseline survey. At the impact site, Red Fox activity has remained static at 2.8%, a decline of 250% from Year 2 when it was 7%. Wild Dog remains at 7% which is 250% higher than the baseline survey, but importantly, it has declined from 9.8% in Year 2 and 13.9% in Year 1 when there was footage of a dog with pups on the grid. Feral Cat remains absent from the grid. Meanwhile, Wild Dog and Red Fox have moved into the reference site over the past two monitoring years with Year 3 activity levels of 2.8% and 1.4% respectively. Feral Cat activity is half that of the baseline survey at 1.4%.

Site 3 and 4 could not be monitored with cameras, however, their reference sites recorded Red Fox and Wild Dog for the first time with a 13% decline in Bettong activity at Site 3B in Glenugie State Forest and a 26% decline in Bettong activity at Site 4B in Bom Bom State Forest.

At Site 5, exotic predators declined or disappeared from the impact monitoring site with Red Fox activity declining by 64% from the baseline survey and Wild Dog declined by 25%. Feral Cat is now absent from the grid where it has previously been reported at 4.2% in the baseline survey. Red Fox similarly declined at the reference site where its activity had declined by 50% yet Wild Dog had doubled and Feral Cat was recorded for the first time.

5.6.3 Spotlighting and Nocturnal Drive Transects for Bettong

Both spotlighting and nocturnal drive transects continue to record low numbers of Bettong (Table 5-10). During this round of monitoring, no Bettong were spotlighted nor recorded during the nocturnal drive transects at Site 1, the same result as the baseline survey. At Site 2, no Bettong were spotlighted nor detected during the nocturnal drive transect at the impact site where they had been previously detected in the baseline survey. At the adjacent reference site, Bettong were spotlighted on one occasion which is a 50% decline from the baseline survey. At present, there is a 50% decline between the paired sites which is at, but does not exceed the tolerance level. No Bettong were detected during the nocturnal drive transect at the impact site and this has been the case for the past three years which exceeds the acceptable threshold. Corrective actions in the form of improving habitat quality and connectivity are considered the most appropriate of the corrective actions outlined in Table 8-5 of the Threatened Mammal Management Plan (RMS 2015).

At Site 3 and 4, no spotlighting was undertaken due to access constraints. Adjacent roads were traversed as part of the nocturnal drive transects with these surveys unable to record Bettong at either of the Site 3 treatments. Consequently, this is a decline from the baseline survey, however, another round of monitoring is required before any corrective actions are considered. At Site 4, a Bettong was recorded during one of the drive transects at the impact site and this equates to

the same number of Bettong recorded during the baseline survey. No Bettong were recorded at the adjacent reference site though. Another round of monitoring will be required before corrective actions can be considered.

Both spotlighting and nocturnal transects were performed at both of the Site 5 treatments. No Bettong were recorded at the impact site which is consistent with the baseline survey. Bettong were recorded during the spotlight survey at the reference site and another individual was recorded during a nocturnal drive transect that bisects the camera monitoring grid. These observations reflect a downturn in the detection rate of 50%.

5.6.4 Road Kill Monitoring

No Bettong were recorded during this round of monitoring. Therefore, no thresholds were exceeded.

Table 5-10. Summary of surveys results and acceptable tolerance levels for Bettong.

Technique	Acceptable Tolerance Level From the Control Site	Bettong Site Reference Name	Site 1A - Impact	Site 1B - Control	Site 2A - Impact	Site 2B - control	Site 3A - Impact	Site 3B - control	Site 4A - Impact	Site 4B - control	Site 5A - Impact	Site 5B - control
Camera Traps 36 cameras installed on a 600 x 600 m grid	25% decline of Bettong and	Baseline - Bettong Mean	1.4	0	8.5	26.4	42.6	32.1	55.5	57.2	0	2.7
		Bettong Year 1	0	0	9.7	29.2		27.8		42.17	0	12.5
		Bettong Year 2	0.0	0.0	2.7	52.7						
		Bettong Year 3	0	0	3.8	38.2						
		Comment – performance	Recorded decline to absent also very low activity in the baseline. Exceeds performance threshold	No change	A 45% decline from the baseline survey	31% increase from baseline survey	No access	13.4% decline	No access	26.3% decline	No change	463% increase
Spotlight Surveys 4 units x 1 person hour (30 min per person) non-consecutive nights	50% decline	Baseline Mean	0	0	1	0.5	0.25	0.25	1	0.75	0	0.5
		Year 1	0	0	0	0	No data	0	No data	0	0	0.25
		Year 2	0	0	0	0.5						
		Year 3	0	0	0	0.25						
		Comment performance	No change	No change	Absent for past 3 years.	50% decline		Decline		Decline	No change	50% decline
Nocturnal Drive Transect 4 units of 2-3 km transect employed on nights of spotlight surveys	Absence after 2 years of monitoring	Baseline Mean	0	0	0.25	0	0.25	0.25	0.25	0.25	0	0.5
		Year 1	0	0	0	0	0	0	0.25	0	0	0.25
		Year 2	0	0	0	0						
		Year 3	0	0	0	0						
		Comment performance	No change	No change	No change	No change	Decline but used an adjacent road	Decline	No change	Decline	No change	50% decline
Road Kill Surveys on multiple days and season in areas of suitable habitat and distance recorded	>200% increase	Preconstruction Base	1 Bettong per 1500 km of road transect									
		Year 1	2 Bettong from 197 km road transect				0	0	0	0	0	0
		Year 2	0 Bettong from 180 km road transect									
		Year 3	0 Bettong from 105 km road transect				Year 1 – 0 Bettong from 410 km road transect					
		Comment performance	Last road kill was Site 1A in Year 1				Nil road kill on or adjacent to monitoring sites					

Technique	Acceptable Tolerance Level From the Control Site	Bettong Site Reference Name	Site 1A - Impact	Site 1B - Control	Site 2A - Impact	Site 2B - control	Site 3A - Impact	Site 3B - control	Site 4A - Impact	Site 4B - control	Site 5A - Impact	Site 5B - control
		Corrective action required	Review monitoring methods and implement a more intensive monitoring and assessment schedule to confirm a decline in population density	Continue monitoring	Consider early intervention action given decline over 2 consecutive monitoring periods	Continue monitoring	-	-	-	-	-	-

5.7 Conclusion and Recommendations

Monitoring as part of Year 3 in Section 2 and Year 1 in Section 3 has found the following:

- Site 1 where Bettong numbers remain too low for any meaningful analysis and as this pattern is likely to continue there is merit in investigating the first corrective action to confirm if this is a real decline, or whether Bettong are still present outside the grid. The most suitable location is to the west of the north bound carriageway where the habitat appears more suitable and Bettong have been informally recorded there in the past. If Bettong are recorded at this adjacent location, the merits of retaining this site in the program can be considered at a later stage.
- Site 2 where Bettong activity remains 45% lower than the baseline survey yet Bettong activity at the reference site is 31% higher which equates to 76% variation between the two treatments. The change in activity at the impact site could be influenced by a combination of natural variation and an increase of exotic predators. Typically, most of the Bettong activity at this impact site occurs in the south west or western edge of the camera grid (i.e. closer to the road) and this remains so in Year 3, just a little less activity than had been recorded in the past monitoring events. In contrast, the control site has always remained a good static site, the recorded increases may reflect a batter year of reproduction or the presence of Fox and Wild Dog for the first time has Bettong moving around a bit more to avoid predation. Importantly, predators have increased at both sites.
- Site 3 where access restrictions to the impact site (CH35230) have prevented most of the surveys from being undertaken. The nocturnal drive transect of adjacent accessible roads that were used during the baseline survey were unable to detect Bettong. At the adjacent reference site, Bettong activity declined by 13% and this coincides with the first records of Red Fox and Wild Dog on the grid. No data comparisons between the two treatments are possible at this point in time.
- Site 4 where access restrictions to the impact site (CH37320) have prevented most of the surveys from being undertaken. The nocturnal drive transect was able to detect Bettong along Six Mile Lane, a road used as part of the baseline survey. At the adjacent reference site, Bettong activity declined by 26% and similar to Site 1A, 2A and 3B, Red Fox was recorded for the first time as was Wild Dog. No data comparisons between the two treatments are possible at this point in time.
- Site 5 where Bettong remain absent from the impact site (CH64505) where no Bettong have been recorded since the monitoring program commenced yet there are a number of historic records set in areas of seemingly suitable habitat. Exotic predator activity has declined with Red Fox down 64% and Wild Dog 25% from the baseline survey whilst Feral Cat has disappeared from the grid. Meanwhile, Bettong activity has increased almost fivefold at the reference site in Pine Brush State Forest and with this there has been a 50% decline in Red Fox activity but Wild Dog activity has doubled and Feral Cat has appeared for the first time on this grid. Consequently, no thresholds have been exceeded at this site.

In light of the findings, four recommendations have been proposed in Table 5-11.

Table 5-11. Recommendations based on the results of Year 1 and Year 3 Bettong monitoring and Roads and Maritime responses.

ID No	Recommendation	Roads and Maritime Response
1	Implement a one off Bettong camera trap survey to the west of the existing highway to confirm. This reflects adoption of corrective action "review monitoring methods……to confirm decline of population"	Adopted – RMS agree the numbers at site 1A and 1B are too low for any meaningful data and support a one-off sample on the opposite, west side of the highway to confirm presence. The merits of retaining site 1 in the program should be considered following the results from this one-off survey.
2	Implement corrective action at Site 2A (CH27420) that considers potential for natural variation to be responsible for decline in population numbers/density by comparison with control sites.	Noted: RMS agrees with conclusion that natural variation should be considered and may be responsible for declines at this site and is a broader regional issue, data on predator numbers and location to be reported to regional stakeholders.
3	Remove spotlighting and nocturnal drive transects from the monitoring program as per Lewis 2017 and 2018. They contribute very little data to the monitoring program.	Adopted. RMS agrees that spotlighting and nocturnal drive transects are providing little value following three years of monitoring in Section 2 and as recommended in previous annual reports.

5.8 References

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