Yandicoogina JSW & Oxbow Iron Ore Project

TSOP 2015 Compliance Report

EPBC 2011/5815 Condition 14: Threatened Species offset Plan

MS 914 Condition 10: Residual Impact and Risk Management Measures

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This report has been prepared by Rio Tinto Iron Ore (**Rio Tinto**), on behalf of Hamersley Iron-Yandi Pty Limited (the **Proponent**), specifically for the Yandicoogina JSW & Oxbow Project. Neither the report nor its contents may be referred to without the express approval of Rio Tinto, unless the report has been released for referral and assessment of proposals.

Document Status					
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1	T. Savage	T. Robertson	1 April 2016	OEPA/DoE	April 2016

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CONTEXT

The Yandicoogina Junction South West and Oxbow Project (the **Project**) is subject to both Western Australian State and Commonwealth environmental approval via Ministerial Statement 914 and EPBC Decision Notice 2011/5815, both of which include an offset condition:

- Condition 10-1 of MS 914 which requires the contribution of $3M AUD towards an offset.
- Condition 14 of EPBC 2011/5815 requires the submission of a Threatened Species Offset Plan (**TSOP**) which includes a contribution of no less than $3M over five years (Condition 14a).

Both agencies have agreed that the State offset requirement could be used to fund the development of the Commonwealth required TSOP.

Specifically, the TSOP is required to offset significant residual impacts to biodiversity and to two Matters of National Environmental Significance (**MNES**): the northern quoll and the Pilbara olive python; by managing threatening processes (identified in Condition 14b EPBC 2011/5815) as:

1. introduced predators;
2. introduced herbivores;
3. wildfire; and
4. weeds.

The TSOP (Rio Tinto 2015; RTIO-HSE-0274440) was approved by the Office of the Environmental Protection Authority (**OEPA**) on 19 January 2015 (RTIO-HSE-0248720) and by the Department of the Environment (**DoE**) on 5 March 2015 (RTIO-HSE-0275796).

Management actions have been prioritised following consultation with the Department of Parks and Wildlife and a Biodiversity Offsets Advisory Panel comprising independent experts. On their advice, the TSOP prioritises resources and expenditure towards the delivery of a landscape-scale Introduced Predator Control Program (Action #1) and associated monitoring. As a result, a relatively small proportion of the overall funds and resources are directed towards managing the remaining three actions on introduced herbivores; wildfire; and invasive weeds.

The Introduced Predator Control Program was designed collaboratively by the Department of Parks and Wildlife (**Parks and Wildlife**), Rio Tinto (on behalf of the **Proponent**, Hamersley Iron-Yandi Pty Limited) and the Biodiversity Offsets Advisory Panel and commenced in 2015 as the Northern Quoll Eradicat® Cat Bait Uptake and Survivorship Study. The aim of the Survivorship Study was to determine the impact of feral cat baiting on northern quolls and thus inform the scope of the operational Predator Control program for subsequent years. The Survivorship was approved by the Parks and Wildlife Animal Ethics Committee (Approval # 2014/11).

ANNUAL REPORTING

This is the first compliance report against Condition 14 of EPBC 2011/5815 and it details the works progressed in 2015, as highlighted in the table below.

Management program	Action	Details of work progressed	Status / Comments
Introduced Predator Control program	1	Northern Quoll Eradicat® Cat Bait Uptake and Survivorship Study	Completed **Appendix 1**
		Baseline monitoring of northern quoll population	Completed **Appendix 2**
		Trial baseline monitoring of Rothschild's Rock-wallaby	Completed **Appendix 2**
Introduced Herbivore Management	3	Mustering of Red Hill Station cattle and feral cattle across target areas of Yarraloola Station	Completed **Appendix 3**
Fire Management	5	Fire scar mapping and fire metric calculations using Landsat imagery	Completed **Appendix 4**
	5	Ground-monitoring of fire age, intensity and fuel loads	Completed **Appendix 5**
Weed Management	6	Ground-monitoring of weed presence and abundance across LMA	Completed **Appendix 5**
	6	Transects and photo reference points established within the LMA and Red Hill control site	Completed **Appendix 5**
Offset Funds		Condition 14a and 15 of EPBC 2011/5815 and Condition 10 of MS 914	Completed.

1 INTRODUCED PREDATOR CONTROL

GOAL: *To enhance northern quoll and Pilbara olive python populations (and populations of other native fauna) and their habitat through a reduction in introduced predators (principally feral cats but also foxes and wild dogs) within the LMA*.

1.1 ACTION 1: NORTHERN QUOLL SURVIVORSHIP STUDY

1.1.1 Management Objective

To assess the field uptake of feral cat baits Eradicat® by northern quoll and its impact on their survivorship and reproduction, and to subsequently develop an effective introduced predator control strategy that will benefit the northern quoll and other threatened fauna in the LMA.

1.1.2 Proposed Method

A detailed description of the Northern Quoll Eradicat® Cat Bait Uptake and Survivorship Study (**Survivorship Study**) was provided in the TSOP with the following high level commitments:

- The Survivorship Study will cover two sites: 20,000 ha of Yarraloola Station will be baited; and the Red Hill pastoral lease with be unbaited (the control site).
- The impact of feral cat baiting on northern quolls will be assessed by comparing survivorship before and after cat baiting at both sites (BACI design).
- Survivorship of northern quolls will be assessed by survival of radio-collared individuals at each site; and detection of northern quolls on a camera array.
- Ground and aerial radio-tracking will be undertaken in the 4-6 week period prior to cat baiting and during an 8 week period post baiting.
- If dead northern quolls are detected the carcasses will be retrieved where possible and autopsied to determine the cause of death.
- Parks and Wildlife will report on the outcomes of the Survivorship Study which will include a definitive recommendation of broad scale application of the baits across the LMA as part of ongoing introduced predator control.

1.1.3 2015 Program Output

The Survivorship Study was successfully completed in 2015 with details provided in Appendix 1 (RTIO-HSE- 0275786) and summarised below:

- 9,750 Eradicat® baits were dropped over the 20,000 ha bait area in July 2015 (cool, dry period) as depicted in Figure 1-1.
- Northern quoll response was monitored via radio-tracking (21 northern quolls at Yarraloola and 20 at Red Hill control site), remote camera grid and cage trapping (health and reproductive activity parameters).

- The litter size for northern quolls at Yarraloola, where 1080 cat baiting had occurred, was not significantly different to that recorded for northern quolls at Kakadu, Northern Territory (7.3 + 0.3 py/female; Oakwood 2000). It is therefore unlikely that sub-lethal ingestion of 1080 impacted on litter size during this study.

- No records of death, impacts to health or reproductive status of northern quolls, were attributed to the baiting.

- Cat predation was significant with mortality to 20% of study population over a 6 month period.

1.1.4 2015 Analysis and Outcomes

The Survivorship Study provides for the following outcomes:

- The study to examine the potential impact of using Eradicat® cat baits on the survivorship of northern quolls in the Pilbara region of Western Australia.

- Identified the level of impact that feral cat predation has on a northern quoll population and highlighted the importance of managing feral cats in the Pilbara to prevent further threatened fauna declines.

- Significant contribution to achieving some of the objectives of the national recovery plan for the northern quoll.

- The same numbers of confirmed northern quoll deaths were recorded at both Yarraloola and the control site at Red Hill, all due to predation by either feral cats or canids.

- Any reduction to the loss of predator adults and / or juveniles in the local population will improve northern quoll numbers over time and reduce the risk of local extinction.

- The use of Eradicat® baits in the cooler, drier months at a landscape scale does not pose a risk to northern quoll populations, and that this management action would likely benefit them and other threatened fauna in the Pilbara.

Based on this, the Introduced Predator Control Program (proposed as Action 2[1] in the TSOP) will be implemented over the next four years (2016 – 2019) across the majority of the LMA using Eradicat® cat baits.

[1] RTIO-HSE-0279071 Introduced Predator Control Program 2015-2019, Parks and Wildlife (Morris and Thomas 2014)

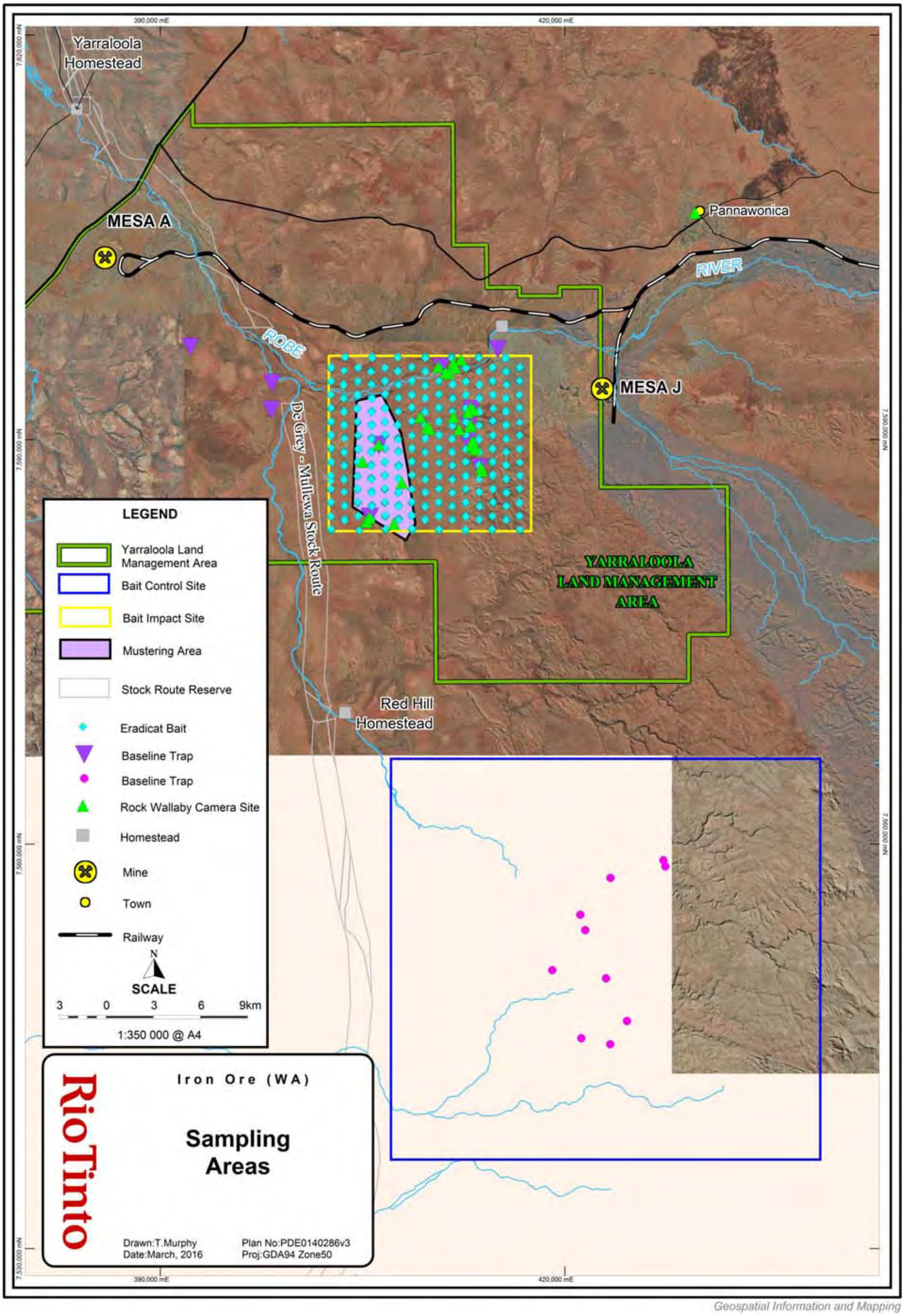

Figure 1-1: 2015 Survivorship Study Sampling Areas

1.2 FERAL CAT MONITORING

No monitoring of feral cat abundance within the LMA was conducted in 2015 due to the limited scope of cat baiting completed during the Survivorship Study (20,000 ha). However, during 2015, the design (location, shape and size) of the camera monitoring arrays from both operational and statistical power perspectives was discussed and reviewed via workshops with Department of Parks and Wildlife and the Advisory Panel. It was agreed that feral cat abundance will be inferred from occupancy models derived from cat detections on the camera arrays.

Operational cat baiting over approximately 147,000 ha will commence in 2016, and the monitoring of feral cats will be undertaken at both the Yarraloola baited site and the Red Hill control site. The methodology for monitoring the abundance of feral cats will broadly follow that shown in Morris and Thomas (2014) and will involve the establishment of camera trap arrays (ca. 60 Reconyx Hyperfire PC900 cameras, with 2-3 km spacing between cameras) at each site.

1.3 NORTHERN QUOLL MONITORING

1.3.1 Background

Baseline monitoring of the abundance of northern quoll, rock-wallabies (as Pilbara olive python surrogates), and feral cats within the LMA was undertaken in 2015 in order to provide a robust foundation from which to measure the benefit of the Introduced Predator Control Program.

1.3.2 Proposed Monitoring Program

The following measures were proposed in the TSOP:

- The monitoring program was designed on the basis of trapping and monitoring radio-collared northern quolls at both the baited and unbaited sites, before and after the cat baiting at Yarraloola (BACI experimental design).
- A baseline phase was scheduled for August – September 2015 (to provide abundance and breeding information) and then annually once operational baiting commenced in 2016.
- Up to 7 monitoring sites were to be established in suitable northern quoll habitat in the baited area (Yarraloola), and three monitoring sites in unbaited areas, either the Red Hill site and / or the UCL, depending on suitability of habitat and northern quoll numbers. Habitat data will be collected at all monitoring sites.
- The 9 Parks and Wildlife regional northern quoll monitoring sites to be used as reference sites to aid in the interpretation of trends observed at impact and control sites.
- Remote camera monitoring of quolls will be undertaken using a 1 km spacing grid (16 lured cameras, covering 900 ha) nested within the larger 3 km spacing camera grid established for introduced predator monitoring.

1.3.3 2015 Monitoring Outputs

The outputs from the 2015 monitoring program are detailed in Appendix 2 (RTIO-HSE-0276405) and summarised below:

- At Yarraloola, northern quolls were trapped at 43 sites in 2015, of which 11 were selected as baseline monitoring sites (Figure 1-2).
- At Red Hill, northern quolls were trapped at a total of 21 sites, and 10 of these were selected as baseline monitoring sites.
- Baseline monitoring of northern quolls at these sites was undertaken between August and October 2015. Trapping at this time was just prior to the annual male die off, and also provided information on reproductive success.
- At each site, northern quolls were trapped using linear transects of 20 small Sheffield cage traps baited with peanut butter, oats and sardines, and set at 25m intervals. This is a variation to the methodology proposed in the TSOP (and used by the northern quoll regional monitoring project {Dunlop *et al*. 2014}), where 50 traps are set at 50 m spacing. At Yarraloola, northern quolls were at low densities and this trapping configuration was shown to be as effective at capturing all the northern quolls in the immediate area, but with less effort.
- An average of 3 – 4 individual northern quolls were recorded at each of the Yarraloola and Red Hill monitoring sites, lower than the average 8 individuals recorded elsewhere (Dunlop *et al*. 2014), but within the range of 0 – 23 individuals recorded at regional monitoring sites. Similarly, trap success rates of 6 – 7% are lower than that recorded elsewhere in the Pilbara (9 – 10%).
- The lower numbers of individuals recorded at each monitoring site will mean that additional sites will be required at both Yarraloola and Red Hill to provide sufficient power to detect significant changes in the quoll populations.
- Timing is a key issue for monitoring quoll populations as the pronounced movement behaviour of males at certain times of the year may have a strong influence on capture rates.

1.3.4 2015 Analysis and Outcomes

- An additional 7 sites at Yarraloola and 8 sites at Red Hill will be selected and a total of 18 sites in each area will be used for northern quoll monitoring from 2016 – 2019 to allow the monitoring to detect a 67% change in quoll populations.
- The timing for monitoring will be consistent between years and that monitoring in any one year is concluded within the shortest possible timeframe.

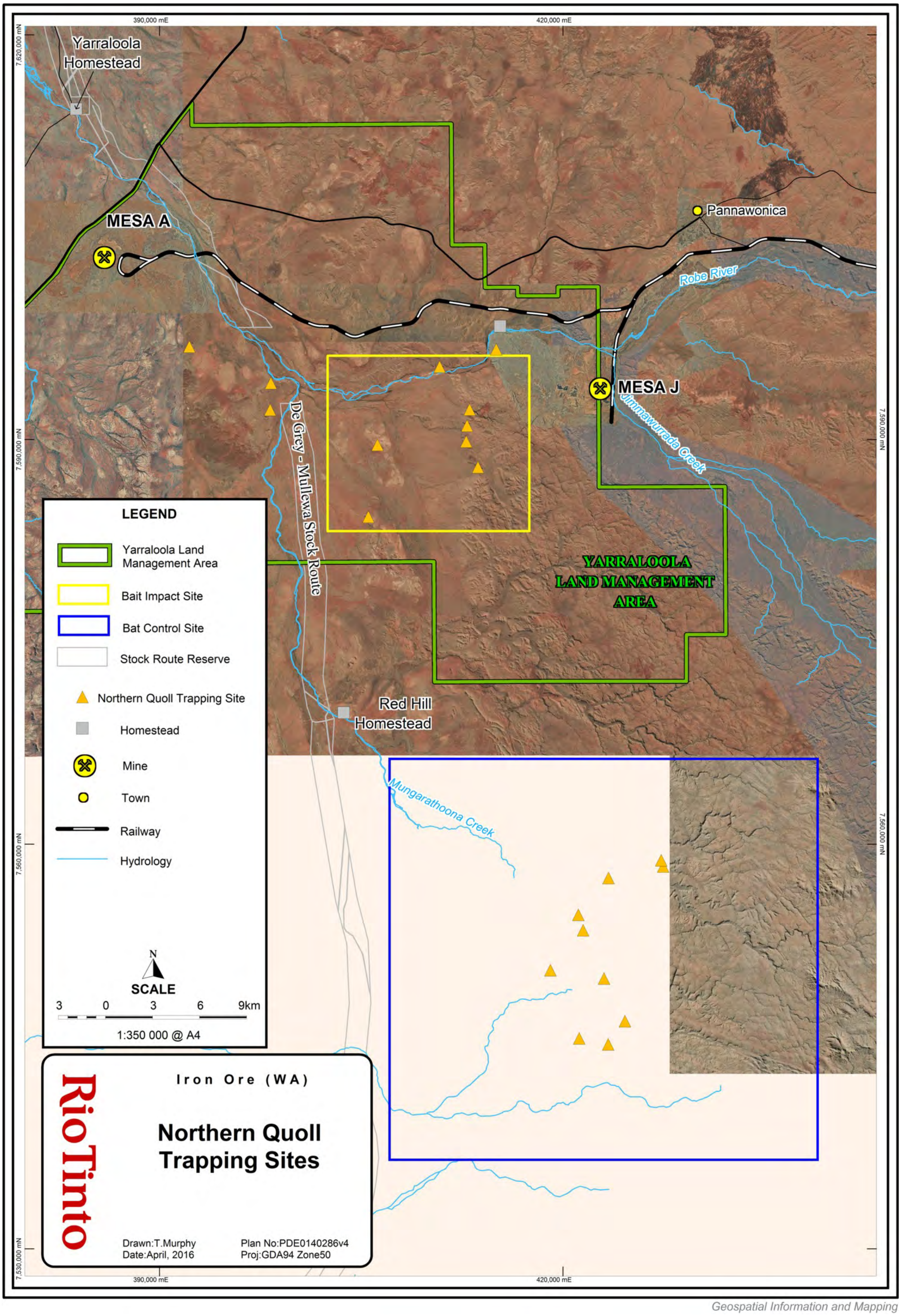

Figure 1-2: **Northern quoll trapping sites**

1.4 ROCK-WALLABY MONITORING

1.4.1 Background

Any benefit of feral cat baiting to Pilbara olive pythons will be difficult to demonstrate as they are cryptic, typically occur at low densities and require different monitoring techniques.

Monitoring surrogate prey species such as the Rothschild's rock-wallaby was therefore proposed in the TSOP (Morris and Thomas 2015) based on the assumption that female pythons need large prey items to lay down fat reserves for breeding. Monitoring rock-wallaby abundance through the use of camera traps was considered a viable option.

1.4.2 Proposed Monitoring Program

It was intended that rock-wallabies would be monitored by locating rock-wallaby refuges and camera traps used to identify individuals so that a minimum number of rock-wallabies known to be alive (MNKTBA) could be determined.

1.4.3 2015 Monitoring Outputs

The outputs from the 2015 monitoring program are detailed in Appendix 2 (RTIO-HSE-0276405) and summarised below:

- Between mid-July and the end of August 2015 individual camera traps were set at 28 locations within the trial cat baiting cell considered suitable for rock-wallabies.
- Cameras were set facing rocky caves and crevices, areas where rock-wallabies would access for shelter, grooming and basking. An apple lure was placed in front of each camera as a lure for rock-wallabies.
- Over six weeks, rock-wallabies were only detected at 8 of the 28 (28.6%) camera trap sites.
- Only single detections of rock-wallabies were made over this period.

1.4.4 2015 Analysis and Outcomes

The low detection rate suggests that using this methodology will not have sufficient power to detect any Pilbara olive python population changes. Other more direct measures of python abundance are therefore required to monitor changes.

Two options are currently being considered for inclusion in the overall monitoring program in subsequent years:

i. Direct monitoring of the survivorship of newly hatched Pilbara olive pythons by radio-telemetry, as this younger life stage is considered to be the most vulnerable to predation by feral cats.

   Reliable transmitters that can be surgically implanted into pythons will allow researchers to follow their movements through the landscape (Pearson *et al*. 2002, 2003). This technique will allow the collection of direct evidence of feral cat or fox predation, if any, as well as obtaining other ecological information critical for improving monitoring techniques for this species.

ii. Use an assessment of python DNA from scats or shed skin (environmental or eDNA) to detect the presence of pythons at waterholes along the Robe River. Changes in population status may be detectable from changes in the frequency of python DNA detection in the environment over time, but this technique is still in development.

The Proponent is considering the viability of these options and will, in consultation with Parks and Wildlife, DoE and the OEPA) update the Introduced Predator Control and Monitoring Program accordingly.

Based on these outputs and outcomes the Proponent considers that the objective of Action 1 has been met within budget and as per the TSOP schedule.

2 INTRODUCED HERBIVORE MANAGEMENT

GOAL: *To enhance northern quoll and Pilbara olive python habitat through a reduction in feral cattle within the LMA.*

2.1 ACTION 3: MUSTER TO REMOVE FERAL CATTLE ACROSS THE LMA

2.1.1 Management Objective

Reduce the number of feral cattle and their impacts within the LMA through periodic mustering.

2.1.2 Proposed Method

The following measures where proposed in the TSOP:

- Aerial mustering will be supported by a ground-based team using vehicles (buggy and motorcycle). Cattle will be mustered to existing paddocks and yards within Yarraloola Station or Red Hill Station.
- Areas of good or moderate pastoral potential will be targeted as well as areas proximal to surface water and/ or offering protection and shade.
- Yarraloola Station mustering activities will be expended to incorporate UCL in the southeast as well as parts of Yarraloola Station that are otherwise considered un-economical to muster.
- Musters will be planned in consultation with station management, mustering contractors and in collaboration with neighbouring stations as appropriate.

2.1.3 2015 Program Output

The outputs from the 2015 muster are detailed in Appendix 3 and highlighted below:

- The muster was completed over 3,490 ha during which 500 cattle were collected. Almost 300 of these belonged to neighbouring properties and were removed. Very few feral cattle were collected. 200 cattle belong to Yarraloola Station and therefore remain in the area.

2.1.4 2015 Analysis and Outcomes

Based on the 2015 outputs the 2016 mustering programme will cover a larger area within the LMA, including the adjoining UCL.

2.2 ACTION 4: CULL OF FERAL INTRODUCED HERBIVORES

No cull was required or initiated within the LMA during 2015 as the muster undertaken was successful in removing 300 cattle from Yarraloola Station.

Based on these outputs and outcomes the Proponent considers that the objective of Action 3 has been met

3 WILDFIRE MANAGEMENT

Goal: *To monitor and, where necessary, manage fire in the LMA in a manner that maintains or enhances its current relatively benign impacts on northern quolls, Pilbara olive pythons and their habitats.*

3.1 ACTION 5: FIRE REGIME MONITORING

3.1.1 Management Objective

To monitor the frequency and extent of fire within the LMA and, if necessary, to undertake measures which reduce the risk of fire disproportionally affecting northern quoll and Pilbara olive python habitat within the LMA

3.1.2 Proposed Method

The following measures were proposed in the TSOP:

- Fire monitoring across the LMA will utilise a combination of desktop-based GIS analysis of remotely sensed data and field monitoring methods.
- Monitoring of fire-related parameters planned as part of the TSOP will build a high resolution picture of key fire history parameters across the LMA and will seek to elucidate the relative contribution of natural, accidental and prescribed ignition to the fire regime within the LMA (of critical importance in determining the required patterns of any future prescribed burning).
- Monitoring will facilitate the development of targeted management actions if monitoring demonstrates such actions are required.
- If monitoring demonstrates actions are required, Rio Tinto will consult with relevant stakeholders to develop a Fire Management Plan (**FMP**) with an objective of reducing the risk of a single wildfire affecting a large proportion of the LMA.

3.1.3 2015 Program Output

Parks and Wildlife (Appendix 4) completed the desktop fire regime monitoring for 2015. The main outputs from this desktop assessment include:

- Fire frequency across the LMA from 1999 – 2015;
- Fuel age across the LMA from 1999 -2015;
- Seral states (time since last fire) across the LMA; and
- A series of fire metrics.

The Proponent completed the 2015 Land Condition Monitoring for the Yarraloola LMA and the Red Hill Control Site (Appendix 5) with the following outputs:

- Most sites showed very little evidence of fire scarring as expected; the survey was designed to avoid recently burnt areas for this first phase of data collection. The amount of fire scarring will be compared at each site year on year.
- Visual fuel loads were lower in rocky northern quoll monitoring habitats compared to riparian and plains habitats, as expected.

Based on these outputs the Proponent considers that the objective of Action 5 has been met.

4 WEED CONTROL

Goal: *To understand the diversity and distribution of weeds within the LMA and the potential implications for the management of northern quoll and Pilbara olive python habitat.*

4.1 ACTION 6: MONITORING OF WEEDS OF LAND MANAGEMENT AREA

4.1.1 Management Objective

To monitor the diversity and extent of weeds and, if necessary, undertake measures to minimise their impact on northern quoll and Pilbara olive python habitat within the LMA.

4.1.2 Proposed Method

The following weed monitoring measures were proposed in the TSOP:

- Weed monitoring will be undertaken across the LMA in order to track changes in the richness and extent of exotic plant species. Monitoring effort will be focused within habitats important for Pilbara olive python and northern quoll and known to be susceptible to weed establishment (e.g. riparian habitats).
- Weeds will be monitored as a component of the suite of land condition parameters.
- Photo reference points and point-intercept transects will be the primary methods used to monitor changes in weed diversity and cover/abundance over time.
- Weed Record Points (WRP) will be completed opportunistically as a means of recording new weeds or new occurrences of weed species across the LMA. WRPs will consist of a 5 x 5 m quadrat within which the cover of all weed species will be recorded.
- The results of monitoring will be evaluated to determine whether active control is warranted in priority areas of northern quoll and Pilbara olive python habitat.

4.1.3 2015 program output

The Proponent completed the Land Condition Monitoring survey in 2015 which identified the species richness, cover and relative cover of weeds across the LMA. This information is presented as Table 3-8 in Appendix 5.

Weeds were mostly recorded from riparian and plains habitats; very few weeds were recorded from the rocky northern quoll habitats regardless of treatment group.

The LCM Report provides baseline data with which to compare subsequent years results.

Based on these outputs the Proponent considers that the objective of Action 6 has been met.

5 TSOP EXPENDITURE

In accordance with Condition 15 of EPBC 2011/5815 and Condition 10 of MS 914, the Proponent provides the following breakdown of expenditure regarding the implementation of the TSOP over 2014 and 2015:

Itemised Expenses	2014 expenditure	2015 expenditure	Total
RTIO employee related costs	$258.50	$490.00	**$748.50**
Contractors	$1,109.09	$110.031.33	**$111,140.42**
External Services	$135,420.00	$332,410.00	**$467,830.00**
Travel and related expenses	$3,951.62	$48,922.64	**$52,874.26**
Other operating costs		$6,148.80	**$6,148.80**
Total	**$140,739.21**	**$498,002.77**	**$638,741.98**

6 REFERENCES

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7 APPENDICES

Appendix 1: RTIO-HSE-0275786 2015 TSOP Survivorship Study

Appendix 2: RTIO-HSE-0276405 2015 Baseline monitoring for northern quoll and Rothschild

Appendix 3: RTIO-HSE-0278945 2015 TSOP Mustering Report

Appendix 4: RTIO-HSE-0279894 2015 Yarraloola Desktop Fire Regime Monitoring

Appendix 5: RTIO-HSE-0279929 2015 TSOP Land Condition Monitoring Report

Yandicoogina JSW and Oxbow Project: Threatened Species Offset Plan.

The northern quoll cat bait uptake and survivorship study, Yarraloola Land Management Area, Pilbara Region, WA.

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This document is available in alternative formats on request.

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Cover photograph: Northern quoll *Dasyurus hallucatus*, J Hayward 2010.

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Acknowledgements

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Executive Summary

Predation by feral cats and other introduced predators has been shown to be a significant threatening process for many species of medium-sized mammals, in the Pilbara and elsewhere in Australia. As part of an environmental offset condition, Rio Tinto were required to prepare a Threatened Species Offset Plan (TSOP) that implements management actions to benefit the EPBC Act listed northern quoll and Pilbara olive python. Rio Tinto has defined an area (the Yarraloola Land Management Area, LMA) within which management actions described in the TSOP will be delivered. The LMA encompasses a part of the Yarraloola pastoral lease, as well as smaller parts of adjoining tenure, in the west Pilbara. A central component of the TSOP was the development and implementation of an introduced predator control program. A key aspect of the development of this program was an assessment of the impact of using *Eradicat®* feral cat baits in the presence of northern quolls, as the carnivorous quolls are potentially at risk from toxic bait consumption.

A study examining the survivorship of northern quolls and their uptake of toxic *Eradicat®* baits was undertaken from May – October 2015. The impact of toxic feral cat baiting was primarily assessed by monitoring survivorship of radio-collared northern quolls at the baited site within the LMA and comparing with survivorship at an unbaited site on the adjacent Red Hill pastoral lease. The uptake of *Eradicat®* baits was assessed through examination of the mouth and scats of live quolls for signs of Rhodamine B (RhB) biomarker. Where possible, dead quolls were also examined closely for signs of bait ingestion through evidence of RhB pigmentation. Five of the 21 radio-collared quolls at

Yarraloola died during this study, two of these deaths occurred before baiting. Four deaths were from cat predation and one was unknown. Five of the 20 quolls radio-collared at Red Hill are known to have died during the same period; two of these were from cat predation, and two from canid predation. Another was recovered but its cause of death could not be confirmed. The fate of a further two quolls was unknown as the animals/carcasses were not recovered. Potential sub-lethal impacts of the sodium fluoroacetate toxin (1080) on quoll reproduction were assessed through monitoring the number of pouch young produced as a measure of reproductive output. The average litter size was higher in the cat baited area at Yarraloola compared to the unbaited area at Red Hill, and was within the range reported elsewhere for northern quolls.

Data on movements were also obtained and these showed that males ranged over significantly larger areas than did females during the trial. A composite map of male and female quoll movement areas, and aerial bait drops, and the suspected spread of baits on the ground, indicates that quolls were exposed to feral cat baits during this trial. However, none of the 30 quolls captured at Yarraloola after baiting, or the four recovered quoll carcases showed signs of RhB ingestion.

The conclusion of this study was that *Eradicat®* baiting in the cooler and drier winter months is unlikely to detrimentally impact on the northern quoll population at Yarraloola, but that the current level of predation by feral cats is likely to contribute to the long term decline of this population. Introducing an operational landscape scale feral cat baiting program, with appropriate monitoring, at Yarraloola is most likely to benefit the northern quoll population and this is supported by Population Viability Analysis modelling of the population over time.

1 Background

The Yandicoogina Junction South West (JSW) and Oxbow Iron Ore Expansion Project was approved by the Western Australian Government and the Commonwealth Government (via MS 914 and EPBC Decision Notice 2011/5815 respectively) subject to a number of conditions, including the Commonwealth requirement for submission of a Threatened Species Offset Plan (TSOP) by Rio Tinto (Rio Tinto 2014) to benefit the threatened northern quoll (*Dasyurus hallucatus*) and Pilbara olive python (*Liasis olivaceus barroni*). This was completed in December 2014 and provided details of measures to control and/or manage introduced predators, feral herbivores, unmanaged fires and invasive weeds.

The introduced predator control program (Morris and Thomas 2014) focused on controlling feral cats, given their significant detrimental impact on native fauna, particularly mammals and ground dwelling birds. There are few records of foxes in the TSOP area. In Western Australia (WA), the most effective way of controlling feral cats at the landscape scale is through baiting with the *Eradicat®* cat bait. However this bait was only registered in December 2014 for operational use in WA in areas where potential non-target species, such as northern quolls, do not occur. This study was undertaken under an APVMA research permit to assess the survivorship of northern quolls and their uptake of toxic *Eradicat®* baits before, during and after a toxic cat baiting program. The results of this study will be used to plan an operational cat baiting program across the Yarraloola LMA for the period 2016 - 2019 and beyond.

2 Introduction

Since European settlement, 29 (9.2%) of Australia's terrestrial mammal species have become extinct, and another 57 species (18.3%) have declined significantly and are considered threatened (Woinarski *et al*. 2014). Predations by introduced predators (particularly the European red fox *Vulpes vulpes* and feral cat *Felis catus*) have been identified as significant factors in mammal declines in

Australia. In the 1980 - 90s, predation by foxes was shown to be a significant threatening process for native fauna in WA (Kinnear *et al*. 2002, Morris *et al*. 2003). More recently, feral cat predation has been identified as a major issue for native mammal conservation (Marlow *et al.* 2015, Fisher *et al*. 2014, Wayne *et al*. 2013) and Woinarski *et al*. (2014) regard this as the factor now affecting the largest number of threatened and near threatened mammal taxa. Predation by feral cats is a listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act* (EPBC 1999).

Twelve species of terrestrial mammal have become extinct in the Pilbara region of WA in the last 200 years, and another seven species have declined (McKenzie *et al*. 2006). A review of the conservation values, threats and management options for biodiversity conservation in the Pilbara (Carwardine *et al*. 2014) identified effective feral cat control was a key strategy for conserving terrestrial vertebrates of conservation significance. Without cat control it was likely that another five species of terrestrial vertebrate (including the spectacled hare-wallaby and bilby) will become regionally extinct in the Pilbara in the next 20 years, and another 18 species will continue to decline (including the northern quoll).

The northern quoll (*Dasyurus hallucatus*) is one of the seven Pilbara medium-sized mammal species that has persisted in the Pilbara bioregion (McKenzie *et al*. 2006). All of these species, except perhaps the echidna (*Tachyglossus aculeatus*), have declined to some extent in the Pilbara, and three, including the northern quoll, are listed as threatened species under State and Commonwealth legislation. The northern quoll was once distributed widely across northern Australia, from the Pilbara and Kimberley, across the Top End of the Northern Territory, to southern Queensland, but has now contracted to several disjunct populations (Braithwaite and Griffiths 1994, Oakwood 2008). An alarming decrease or complete collapse in once locally abundant populations of the northern quoll has occurred in recent years as a direct result of the invasion of the cane toad, *Rhinella marina* (Woinarski *et al*. 2008; Woinarski *et al*. 2010). Three other factors were also identified as contributing to the decline of northern quolls and other medium-sized mammals across northern Australia: changed habitats through widespread fires, predation by feral cats, and novel disease (Woinarski *et al*. 2011). Due to these declines and threatening processes, the northern quoll is listed as Endangered under both the Commonwealth's EPBC Act (1999) and the Western Australian *Wildlife Conservation Act 1950*.

Baiting using a type of sausage bait with the toxin sodium fluoroacetate (1080) is recognized as the most effective method for controlling feral cats over large areas on mainland WA and large islands (Algar and Burrows 2004; Algar *et al*. 2007; DEWHA 2008; Short *et al*. 1997), where there is limited risk posed to non-target species. The *Eradicat*® bait (Algar and Burrows 2004; Algar *et al*. 2007) has been used under APVMA approved 'research use permits' to demonstrate baiting efficacy at a number of sites across WA, including Dirk Hartog Island, Montebello Islands, Lorna Glen (Matuwa), Cape Arid National Park, Fitzgerald River National Park, Fortescue Marsh and Peron Peninsula. In December 2014, the *Eradicat*® feral cat bait was registered for operational use in areas of WA where there are no non-target risks to fauna. The bait could potentially be used in the Pilbara to reduce feral cat (and fox and dog) densities and improve conservation outcomes for northern quolls and other threatened fauna such as the bilby (*Macrotis lagotis*). However, prior to *Eradicat*® being used operationally in the Pilbara, potential non-target baiting impacts on northern quolls had to be identified and resolved. As a top order native predator, the northern quoll is at potential risk to poisoning after ingestion of the toxic sausage baits. Based on a 1080 LD_{50} of 7.5 mg/kg (King *et al*. 1989), an average size Pilbara northern quoll (380-580 g) would only need to ingest approximately one toxic cat bait containing 4.5mg of 1080 to be at risk. Calver *et al*. (1989) identified that in the laboratory, the northern quoll was at risk from accidental poisoning from crackle baits containing 6 mg of 1080 for dingo control. However, King (1989) showed that an aerial dingo baiting program did not pose a hazard to free ranging northern quolls.

The national recovery plan for the northern quoll (Hill and Ward 2010) contains objectives to reduce the impact of feral predators on northern quolls, and to implement efforts to protect key northern quoll populations from the impacts of feral predators. This study assessed the risk of toxic cat baiting to a free-ranging northern quoll population, and the results will contribute to the achievement of these recovery plan objectives in the Yarraloola LMA, and elsewhere in the Pilbara. Assessing the impact of toxic baiting to control feral cats on northern quolls is an important component in the development of landscape scale programs to control introduced predators and reduce the extinction risk for quolls and other medium-sized mammals in the Pilbara. This trial did not assess the efficacy of *Eradicat*® baiting in controlling feral cats as it was only undertaken on a relatively small area. However, elsewhere in the Pilbara, at Fortescue Marsh, cat baiting efficacy over areas >100,000 ha has been as high as 85% (D. Algar *pers com*).

3 Study sites

This study was undertaken at two sites in the western Pilbara region of WA. The trial cat baiting program was undertaken over a 20,000 ha area, within the 163,213 ha Yarraloola LMA (Figure 1). This site is approximately 120 km south west of Karratha and 60 km east of Onslow near the Pilbara coast (centroid: 21° 44’ 50”S, 116° 08’ 31”E). The small mining town of Pannawonica is located 10 km north east of the LMA. An unbaited area on the adjacent Red Hill pastoral lease, approximately 65 km south of the Yarraloola baited site, was used as a control for this study.

These sites experience a semi-arid climate typical of the Pilbara bioregion. Summers are hot and winters mild. Rainfall is characteristically extremely variable and follows a loose bi-modal rainfall pattern with the majority of rainfall occurring during January, February and March in association with tropical cyclone and heat trough events. Tropical cyclones typically deliver large falls of rain over extensive areas whereas thunderstorm events associated with heat troughs are much more localised. A second, smaller rainfall peak occurs in May and June as a result of southern frontal systems which are at their northern extent of influence over the area, interacting with moist tropical air from the north-west. The historic yearly average rainfall for Pannawonica, over 43 years, is 404 mm but yearly rainfall is highly variable (Bureau of Meteorology).

Since the 1980’s, the WA Department of Agriculture and Food (DAFWA) has been controlling wild dog/dingo hybrids (*Canis familiaris / lupus*) via 1080 baiting on the Yarraloola pastoral lease; aerially baiting along the length of the Robe River (incorporating part of the Mullewa – De Grey stock route), southern half of Warramboo Creek and numerous other ephemeral water points within the LMA. In addition, *ad hoc* hand-baiting for dingoes / dogs has been undertaken by the Yarraloola pastoral managers around artificial water points and other areas of high dog activity including areas within the LMA. This baiting continued during this program as part of the ongoing pastoral management of Yarraloola Station. There is some evidence that *Eradicat*® baiting programs reduces dingo/dog abundance by ca. 25% at Matuwa (Lorna Glen) in the northern Goldfields (M Wysong, unpublished data).

The European red fox does occur in the Pilbara region (King and Smith 1985), however most records are along the coast and few are in the rocky areas of the inland Pilbara. Foxes may penetrate the inland Pilbara along river systems such as the Robe River. Berry *et al*. (2012) have demonstrated that baiting with *Eradicat*® baits in the rangelands significantly reduced fox densities and it is likely that aerial cat baiting would also reduce fox abundances at Yarraloola if they were present.

4 Methods

4.1 Cat baiting

4.1.1 Feral cat baits

The *Eradicat®* feral cat baits used in the Yarraloola trial baiting program were manufactured at the Department of Parks and Wildlife's (Parks and Wildlife) Bait Manufacturing Facility at Harvey, WA. The bait is similar to a chipolata sausage in appearance, approximately 20 g wet-weight, dried to 15 g, blanched and then frozen. This bait is composed of 70% kangaroo meat mince, 20% chicken fat and 10% digest and flavour enhancers (Patent No. AU781829). Toxic feral cat baits are dosed at 4.5 mg of 1080 per bait. Prior to bait application, feral cat baits were thawed at the Auski Roadhouse airstrip, adjacent to the Great Northern Highway near Wittenoom, and placed in direct sunlight on-site. This 'sweating' process causes the oils and lipid-soluble digest material to exude from the surface of the bait. All feral cat baits were sprayed, during the sweating process, with an ant deterrent compound (Coopex®) at a concentration of 12.5 g/L as per the manufacturer's instructions. This process is aimed at preventing bait degradation by ant attack and enhancing acceptance of baits by cats by limiting the physical presence of ants on and around the bait medium. For this trial, the toxic baits were also impregnated with the non-toxic biomarker RhodamineB (RhB) to confirm if northern quolls had ingested cat baits.

4.1.2 Cat baiting risk assessment

A "1080 Baiting Application and Risk Assessment" as required by the *Code of Practice for Safe Use and Management of 1080 in Western Australia (August 2010)* was completed prior to undertaking the cat baiting program at Yarraloola. This is standard practice for any 1080 baiting undertaken by Parks and Wildlife and this process examines the potential risks of 1080 baiting to non-target native animals and human health. An assessment of species potentially at risk is shown in the draft operational introduced predator control program for the Yarraloola LMA (Morris and Thomas 2014), and this concluded that there was little potential risk to any other native species, apart from the northern quoll. Similarly, Algar *et al*. (2011) evaluated the risk of cat baiting to native mammal species at Fortescue Marsh, in the east Pilbara and concluded that the northern quoll was the species most at risk from a toxic cat baiting trial.

The risk to people operating in the baited area was also assessed as part of the risk assessment process. The 20,000 ha baited cell was located away from public use areas such as roads, railways, town sites and mine sites. Neighbours were notified by Pilbara Region Parks and Wildlife staff and 1080 baiting warning signs were erected at appropriate locations. Briefings were provided to the Kuruma and Marthudunera traditional owners on the potential risks of 1080 baiting to their use of the baited areas within the Yarraloola LMA. A site visit to the Yarraloola LMA by representatives of the Kuruma and Marthudunera Traditional Owners was also facilitated by Parks and Wildlife prior to finalising the area to be baited. The greatest risk for traditional owner groups was the potential for poisoning of domestic dogs if they were taken into the cat baited area. Domestic dogs, like cats and foxes have a low tolerance to 1080 (McIlroy 1981, McIlroy 1986), and would only need to consume 1-2 baits to receive a lethal dose. There were no reports of domestic dogs in the baited cell during this study or of any accidental deaths during the baiting trial.

4.1.3 Cat baiting operations

Cat baiting operations for this study were conducted under a research use permit issued by the APVMA in December 2014, and valid from the 9 December 2014 to 30 November 2016. Toxic cat baiting is also governed by the '*Code of Practice on the Use and Management of 1080' (Health Department, Western Australia)* and associated '*1080 Baiting Risk Assessment'* (see above).

Baiting at Yarraloola took place on 6 July 2015 and followed Parks and Wildlife cat baiting prescriptions. This was the coolest and driest period for the Yarraloola area when bait uptake by feral cats is maximised due to the low abundance and activity of prey items, in particular reptiles and small mammals (Algar and Burrows 2004). Bait degradation due to rainfall, ants, and hot weather is also significantly reduced at this time. No rainfall was recorded at Pannawonica or Red Hill station in June, August or September. At both sites, 1.2 mm of rain was recorded on 12 July, six days after baiting, and at Pannawonica another 14.2 mm was recorded on 22 July (14.8 mm at Red Hill), 16 days after baiting (Bureau of Meteorology). The *Eradicat®* cat bait remains palatable to feral cats, and most likely other non-target fauna with single rainfall events of up to 25mm.

After being loaded into the aircraft at the Auski Roadhouse airstrip near the Great Northern Highway, cat baits were aerially delivered over the 20,000ha trial cat baited area (Figures 2 and 3). The baiting program was conducted under the Parks and Wildlife Western Shield Aerial Baiting Contract with baits deployed in batches of 50 at one kilometre (50 baits / km^2) intervals along previously designated baiting flight lines. Flight lines were one kilometre apart and covered the entire baiting cell. The baiting aircraft flew at 150 knots and 500 feet above ground level. A GPS point was recorded on the flight plan each time baits left the aircraft (Figure 3). Previous trials have shown that under these flight conditions, the ground spread of the 50 baits will be approximately 250 x 50 m (Algar *et al*. 2011).

This cat baiting operation occurred at a time when northern quolls, particularly males, were very mobile as they looked for mates. Normally at this time also, first year quolls would be becoming reproductively active and females would be gaining weight in readiness for pregnancy and suckling pouch young (Dunlop *pers com*). The recorded times for breeding activity for female Pilbara northern quolls in the Pilbara varies slightly with those from the Northern Territory and Kimberley (Table 1).

4.2 Northern quoll survivorship

The impact of feral cat baiting on northern quolls was assessed, using a Before-After-Control-Impact (BACI) experimental design, by comparing quoll survivorship at the Yarraloola (cat baited) and Red Hill (unbaited) sites, before and after cat baiting at Yarraloola. Survivorship was primarily determined by monitoring radio-collared individuals at each site. A supplementary trial of quoll detections on a camera array at Yarraloola was also undertaken. The health of captured quolls and evidence of reproductive success in females was also assessed as measures of the impact of cat baiting.

The dates of field activities at Yarraloola and Red Hill are shown in Table 2. At each site, quolls were trapped using linear transects of up to 50 small Sheffield cage traps (Sheffield Wire Company, Welshpool, WA) baited with a mixture of peanut butter, oats and sardines. This is similar to the methodology used by the northern quoll regional monitoring project (Dunlop *et al.* 2014); however for the trapping undertaken to fit and retrieve radio-collars, the trapping intensity varied depending on the quoll trap success rates. During the course of this study, it was determined that trapping effort for the monitoring phase of this project (2015-2019) could be reduced to 20 traps at 25 m spacing at each site, instead of 50 traps at 50m spacing, as currently used in the regional quoll monitoring program. At Yarraloola quolls were at low densities and this reduced trapping effort was shown to be as effective at trapping all the quolls in the immediate area, but with less effort. Traps were placed in sheltered, shady locations and covered with a hessian bag for protection of any trapped animals from the heat. Trap lines ran along rocky breakaways and mesas, as well as in and around gorges where quolls were known (based on preliminary surveys), or thought likely to occur. All trapped quolls were weighed, measured and sexed, and a small tissue sample taken from each ear for DNA analysis. Each animal was individually marked with a passive implant transponder (PIT) tag inserted subcutaneously between the shoulder blades. Other species captured were also recorded and tissue samples taken. All trapping data were entered into an MS Excel spreadsheet and later an MS Access database.

Adult quolls weighing between 300 and 790 g were fitted with VHF neck-mounted radio-transmitters equipped with mortality mode (Sirtrack, Havelock North, NZ; 12-13 g) (Table 4). These radio-collars were initially tasked with operating only during daylight hours to prolong battery life to six months. Night time operation was later invoked by delaying radio-collar start times by up to three hours as radio-tracking at night when quolls were active was found to be more efficient. Ten females and 11 males at Yarraloola, and 10 females and 10 males at Red Hill were fitted with radio-collars and released at their site of capture at least 15 days prior to the baiting at Yarraloola (Table 3). Quolls were re-trapped between August and October to remove radio-collars. Trapping in September/October was also used to assess whether breeding was occurring (presence and persistence of pouch young), and was also undertaken as the initial baseline monitoring session for quolls. Additional trapping was periodically undertaken post-baiting to attempt to confirm the survival of individuals when radio-tracking had been unsuccessful.

Ground and aerial radio-tracking was undertaken in the four week period prior to cat baiting and during the twelve week period post-cat baiting to determine survivorship of the radio-collared quolls (Table 2). If dead quolls were detected through the mortality signal, carcasses were retrieved where possible and examined to determine cause of death. In particular, remains were examined closely for the presence of the RhB biomarker. If predation was thought to be the cause of death, the retrieved radio-collars were placed in plastic bags and kept in a freezer prior to DNA analysis (Helix Molecular Solutions, The University of Western Australia) to determine the most likely predator responsible for death (Berry *et al.* 2012). Radio-tracked quolls also provided information on habitat usage, home range and movement areas. Home range was estimated using the convex hull method (Worton 1995).

A 6 x 6 grid of digital infrared camera traps (Reconyx Hyperfire PC900) was set at 400m x 300m spacing to trial this non-invasive methodology for monitoring the impact of cat baiting on northern quolls. Each camera was attached to a peg and set approximately 40cm above the ground. A non-reward food lure (peanut butter, sardines and oats) was placed 2m in front of the camera. Lures were activated when the cameras were set up, and reinvigorated immediately after cat baiting on 6 July 2015. Cameras were operated for 13 days before baiting, and 15 days after baiting. Images were downloaded just prior to baiting occurring, and again when the cameras were collected at the end of the camera trial. Images were sorted by species, and the number of quoll detections recorded. A change in the camera detection rate of quolls before and after baiting may provide an immediate indication of quoll response to the baiting. The location of the camera grid in relation to the trial cat baiting cell is shown in Figure 4. The GPS locations of the camera grid corners were: NW 116.14175, -21.78305; SW 116.14167, -21.79660; SE 116.16101, -21.79670; and NE 116.16109, -21.78315.

4.3 Northern quoll bait uptake

All northern quolls trapped, and those recovered dead, at Yarraloola after the cat baiting on 6 July were examined for purple / pink signs of the biomarker RhB. In particular, the mouth and lips were closely inspected. Scats from trap captures were also examined for any purple / pink colouration.

The baiting coordinates recorded from the baiting aircraft were overlaid with movement areas of the radio-collared quolls to determine whether quolls would have had the opportunity to encounter cat baits (Figures 5, 6).

4.4 Northern quoll Population Viability Analysis (PVA)

Prior to the baiting program, Program VORTEX was used to predict the risk of northern quoll population decline and extinction and this allowed an understanding of what level of quoll mortality could be tolerated before the population declined. Empirical data such as demographic structure, mortality and survival rates and reproductive rates were obtained from the Pilbara regional quoll monitoring program (Dunlop *pers com.*) and from published northern quoll demographic studies across Australia (e.g. Braithwaite and Griffiths 1994, Oakwood 2000). The risk of the cat baiting to the survival of the northern quoll population was determined by examining quoll population trends provided by the PVA under certain mortality scenarios. Six scenarios were simulated:

1. No cat baiting (baseline or current scenario).
2. Increase initial population size of northern quoll – resident population sizes of 40, 60 and 80 were modelled.
3. Impact of cat bait-related mortality on adult northern quoll – adult mortality rates of 5%, 10%, 15% and 20% were modelled.
4. Impact of cat bait-related mortality on juvenile northern quoll – juvenile mortalities of 5%, 10%, 15% and 20% were modelled.
5. Increased adult survivorship as a result of reduced cat predation (due to baiting) – adult mortality rates decreased by 5%, 10%, 15% and 20% were modelled.
6. Increased juvenile survivorship as a result of reduced cat predation (due to baiting) – juvenile mortality rates decreased by 5%, 10%, 15% and 20% were modelled.

5 Results

5.1 Cat baiting

The feral cat baiting program occurred as scheduled on 6 July, 2015 and all baits were delivered as planned. A total of 9,750 *Eradicat*® baits were delivered at an application rate of 48.75 baits/km^2, slightly less than the prescribed 50 baits/km^2. A plan showing where baits were dropped from the aircraft is shown in Figure 3.

5.2 Northern quoll survivorship

At Yarraloola, trapping for northern quolls suitable to fit radio-collars was undertaken from 20 May to 25 June. A total of 1860 trap nights occurred across 21 sites with 166 quoll captures (8.9% trap success rate) of 39 (18 females, 21 males) individuals. Ten females and 11 males were selected and fitted with a radio-collar. A minimum bodyweight of 300g was selected so that the radio-collar weight was no more than 3-5% of the body weight (Table 3). Two of the radio-collared quolls (one male, one female) died prior to the baiting. Both deaths were believed to be from feral cat predations. At Red

Hill, there were 137 captures of 39 (17 females, 22 males) individuals in 1739 trap nights (7.9% trap success rate) across 12 sites. Ten females and 10 males were selected and fitted with radio-collars (Table 3).

Body weights of males were significantly higher than females at both sites (Table 5) and within the range of body weights recorded for other Pilbara northern quoll populations (for example, Dunlop *et al.* 2015). Male body weights were lower at both sites in October compared to May, most likely due to a loss of condition just prior to the annual male die off, a demographic characteristic of this species (Oakwood *et al.* 2000). This difference was significant only for the Yarraloola males ($t_{(7)} = 4.36$, $p = 0.003$).

Reproductive success was assessed through the production of pouch young in female quolls. Pouch young first appeared in late August at Yarraloola and early September at Red Hill. At Yarraloola, 18 female quolls were trapped from early August to October. Fourteen of these had pouch young and the average litter size was 6.8 $\pm$ 0.3 (s.e.) pouch young. In the same period, 13 female quolls were trapped at Red Hill and nine of these had pouch young. The average litter size at Red Hill was 5.3 $\pm$ 0.5 (s.e.) pouch young and this was significantly less than the average litter size at Yarraloola ($t_{19} = 2.44$, $p = 0.029$).

At the time of baiting, nine female and 10 male northern quolls with radio-collars were known to be alive at Yarraloola, and all 20 collared quolls were alive at Red Hill. After baiting at Yarraloola, in the period July - October another three collared (two females, one male) quolls died, two were confirmed to be due to cat predation from DNA analyses and one was believed to be a cat predation based on teeth marks on the collar (but no DNA evidence). At Red Hill, five of the 20 radio-collared quolls are known to have died; two of these due to cat predation and two were due to canid predation. The DNA on another of the retrieved collars, which was suspected to be a predation, was too weak to amplify to get any confirmed predator results. The radio-collars of another two quolls went into mortality mode and may have died, however the radio-collars and / or quolls (alive or dead) were not recovered (Tables 1, 2).

Northern quolls, including those fitted with radio-transmitters were regularly detected on the camera grid prior to cat baiting at Yarraloola (Figure 5). However, following baiting, no quolls were detected, despite the continued known persistence of the radio-collared quolls in this area. This anomaly is believed to be due to the use of a non-reward lure and that the quolls no longer came within range of the cameras once they learnt that a food reward was not available. The value of using remote camera arrays for monitoring quolls will be discussed in the report on the baseline monitoring currently in preparation.

5.3 Northern quoll bait uptake

There were 108 captures of 30 individual quolls (17 males, 13 females) at Yarraloola after the baiting, between July and October. These captures included radio-collared and new, un-collared quolls. All were inspected for evidence of cat bait ingestion by searching for purple / pink colouration (consistent with RhB exposure) around the mouth and lips, and in scats found in traps. No such evidence was observed, and none showed any sign of 1080 poisoning.

Male quolls at Yarraloola and Red Hill exhibited significantly larger mean home range areas and longer linear movements than females (Table 5). At Yarraloola, male home ranges overlapped with an average of 8.5 $\pm$ 1.8 (s.e.) baiting locations and male quolls would most likely have been exposed to many cat baits as they moved around their home ranges (Figure 6). Females had significantly smaller home ranges and shorter linear movements and on average only intersected 0.6 $\pm$ 0.2 (s.e.) baiting locations. However, the average linear movement for females at Yarraloola was 1031 m, greater than the one kilometer baiting interval and at least 50 % of the females where home ranges were calculated (YF02, YF03, YF09 and YF12) were most likely to have been exposed to some bait drop sites (Figure 7). Only one of these (YF12) died during this trial, and this was most likely due to cat predation, although this was not confirmed by DNA analysis. At Yarraloola, male home ranges were estimated from an average of 15 radio-fixes per quoll, and female home ranges were estimated from an average of 13 radio-fixes per quoll.

5.4 Northern Quoll Population Viability Analysis

The results of the PVA were prepared in a separate report (Moro 2015). In summary, in the absence of cat baiting (current situation), northern quolls persist but there is a small but steady decline in population over time (up to 10% population decline in 20 years). Improving adult or juvenile survivorship above current levels (i.e. reducing mortalities due to cat predation) improved numbers in the population over 20 years, reducing the risk of a local extinction event. Simulations were most sensitive to perturbations in adult mortality above 10% or juvenile mortality above 5% of current (baseline) levels, leading to dramatic declines in the numbers of quoll in an area. Importantly, improved juvenile survivorship above current levels (for example, due to reduced predation by feral cats) reduces the risks of decline in the quoll population by up to 54%.

6 Discussion

This study has been the first to examine the potential impact of using *Eradicat*® cat baits on the survivorship of northern quolls in the Pilbara region of Western Australia, or elsewhere. It has also identified the level of impact that feral cat predation has on a northern quoll population and highlighted the importance of managing feral cats in the Pilbara to prevent further threatened fauna declines. In doing so, it has contributed significantly to achieving some of the objectives of the national recovery plan for the northern quoll (Hill and Ward 2010).

Despite potential exposure to aerially distributed toxic *Eradicat*® cat baits deployed following the Parks and Wildlife cat baiting prescription, there was no evidence that quolls consumed baits, or died as a result of the trial baiting program. Previous studies have predicted that northern quolls would be at risk if they ingested 1080 baits (Calver *et al*. 1989, King *et al*. 1989), and the lack of deaths attributed to bait ingestion at Yarraloola suggests that quolls did not ingest any cat baits they may have encountered. The same numbers of confirmed quoll deaths were recorded at both Yarraloola and the un-baited site at Red Hill, all due to predation by either feral cats or canids. The closely related chuditch, or western quoll (*Dasyurus geoffroii*) was also considered to be at risk from 1080 baiting programs in the south-west of WA (King *et al.* 1989, Soderquist and Serena 1993). However, subsequent field trials using toxic fox baits were shown to benefit chuditch populations rather than pose a risk to them (Morris *et al.* 2003).

Sub-lethal doses of 1080 can still be harmful to populations. Toxins passed through milk can kill the pouch young of northern quolls, as well as other marsupials such as tammar wallabies and brushtail possums (McIlroy 1981). Sub-lethal doses of 1080 can also potentially cause sterility in males as has been demonstrated in rats (Sullivan *et al.* 1979). The litter size for quolls at Yarraloola where 1080 cat baiting had occurred was not significantly different to that recorded for quolls at Kakadu, Northern Territory (7.3 $\pm$ 0.3 py/female; Oakwood 2000) and it is unlikely that sub-lethal ingestion of 1080 impacted on litter size during this study.

We now have available empirical data from this study site on the cat / canid predation rate on northern quolls. At least 20% of the radio-collared quoll were predated by either feral cats or canids over a period of six months, and this was the most significant cause of mortality for the radio-collared adult quolls. While this mortality rate was slightly less than that modelled in the PVA (Scenario 1, annual adult mortality between 56% for females and 98% for males) the modelled data considered all types of mortality (including natural deaths and predation from native predators). Therefore, any reduction to the loss of adults and / or juveniles in the local population will improve numbers over time and reduce the risk of local extinction (Moro 2015). Feral cat predation was a significant part of this mortality, highlighting the value of implementing landscape scale feral cat control programs in the Pilbara. Ongoing canid control would probably also benefit quolls in this situation.

Many of the dead quolls were recovered from drainage lines suggesting that quolls face considerable predation risk when they use these corridors to traverse open landscapes between rocky areas. In the rangelands at Matuwa (Lorna Glen) preliminary observations from a GPS radio-collar trial show that dingoes do use drainage lines, and that there is some spatial separation of dingo and cat activity in this area (M. Wysong *pers com*).

It is possible that cane toads will penetrate into the Pilbara from the Kimberley using artificial water points and permanent water holes to access a largely waterless landscape (Tingley *et al.* 2012). Flooding due to cyclonic rainfall could exacerbate the spread of cane toads into the Pilbara. Additional mortality, over and above that currently occurring at Yarraloola primarily due to cat and canid predation, particularly to the juvenile age cohort, is possible in the future if cane toads become established in and near river systems such as the Robe River. This suggests that where the cause of mortality can be managed such as by effective feral cat control, this should be undertaken to ensure the longer term conservation of northern quolls in the Pilbara.

This study has identified some issues with the effectiveness of the aerial VHF radio-tracking operations in iron-rich, rocky environments such as at Yarraloola and Red Hill. This was due initially to the receiver equipment on the aircraft not operating at maximum efficiency and requiring further checking. There were also issues with receiving signals from quolls located in day-time refuges within rock piles and mesas. Signals were often weak, intermittent, highly directional and exceptionally short range, making it difficult to accurately locate quolls, particularly during the day. However, the aerial radio-tracking did allow several of the quolls, particularly males, to be located after they had travelled several kilometres from their last known locations, and outside the range of hand-held aerials. In the later stages of the program, ground radio-tracking was hampered by the loss of most of the whip aerials fitted to the neck-mounted transmitters. This was most likely due to quolls pushing between rocks when moving to and from day-time refuges, and continually flexing the base of the whip aerial. The effectiveness of radio-tracking from the ground improved once night time operations were undertaken.

With the demonstration that GPS telemetry can be used on northern quolls in the Pilbara (Henderson 2015), it is recommended that a research study using this technology, instead of VHF telemetry, would provide better information on the temporal and spatial use of habitat by both northern quolls and feral cats and allow an assessment of the extent to which they may overlap and encounter each other. If undertaken before and after a cat baiting program it would also provide additional evidence for the effectiveness of Eradicat® baiting to reduce cat abundance in the Pilbara, and impact, if any, on the northern quoll population.

The results of this study indicated that using *Eradicat*® baits in the cooler, drier months to reduce cat abundance at a landscape scale should not pose a risk to northern quoll populations, and that this management action would likely benefit them and other threatened fauna in the Pilbara. It is recommended that any further *Eradicat*® baiting at landscape scales in areas where northern quolls are known to exist adopt an adaptive management approach and monitor both northern quoll and feral cat abundances. This monitoring for quolls should include a regular trapping program with the power to detect significant changes in quoll abundances and the use of the RhB biomarker to assess any bait uptake. The use of a biomarker to detect bait ingestion would be particularly important if baiting was undertaken at any other time of the year when non-target species may be more active, or at a time when young northern quolls may be exposed to toxic baits.

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Tables

	Apr	May	Jun	Jul	Aug	Sep	Oct
PILBARA							
No development		■	■				
Pouch developed			■	■	■	■	
Pouch young present					■	■	■
Teats regressed	■	■					
NORTHERN TERRITORY							
No development	■	■					
Pouch developed			■				
Pouch young present				■	■		
Teats regressed	■	■				■	■

Table 1. Recorded times of breeding for female Pilbara and Northern Territory northern quolls. (Pilbara data sourced from Dunlop *pers com*, Northern Territory data sourced from Begg 1981)

Field Trip #	Date(s)	Field Activity
1	18 May – 5 June	Northern quoll trapping at Yarraloola and Red Hill to fit radio-collars.
	14 June	Fit and tested aircraft tracking aerials on C172
	22 June	Aerial radio-tracking at Red Hill and Yarraloola.
2	13 – 26 June	Ground radio-tracking at Yarraloola and Red Hill: pre-bait monitoring. Set up quoll monitoring camera grid at Yarraloola.
	6 July	Aerial cat baiting at Yarraloola.
	6 - 7 July	Aerial radio-tracking at Red Hill and Yarraloola.
	13 - 14 July	Aerial radio-tracking at Red Hill and Yarraloola.
3	6 - 19 July	Ground radio-tracking at Yarraloola and Red Hill; post-bait monitoring. Close down quoll monitoring camera grid at Yarraloola.
4	27 July – 7 August	Ground radio-tracking at Yarraloola and Red Hill; post-bait monitoring.
	28 – 29 July	Aerial radio-tracking at Yarraloola and Red Hill. Final aerial tracking.
5	17 – 28 August	Ground radio-tracking at Yarraloola and Red Hill; post-bait monitoring. Trapping to commence removal of male radio-collars. Quoll baseline monitoring.
6	7 – 18 September	Ground radio-tracking at Yarraloola and Red Hill; post-bait monitoring, trapping to remove male radio-collars.
7	5 – 16 October	Ground radio-tracking at Yarraloola and Red Hill; post-bait monitoring, trapping to remove female radio-collars. Final field trip, return field equipment to Perth.

Table 2. Dates of field activity at Yarraloola and Red Hill.

	Yarraloola (cat baited)		Red Hill (unbaited)	
	Males	**Females**	**Males**	**Females**
# quolls trapped	21	18	22	17
# fitted with radio-collar	11	10	10	10
# confirmed dead	2	3	2	3
Cat predation	2	2	1	1
Canid predation	0	0	1	1
Unconfirmed cause of death	0	1*	0	1*
Carcass not recovered	0	0	1	1
# collars removed	10	10	8	10

Table 3. Number of northern quolls trapped, fitted with radio-collars and their survivorship: June – October 2015. (* insufficient DNA, but believed to be a cat predation from teeth marks on collar)

Quoll ID (Y = Yarraloola, R = Red Hill, M = male, F = female)	**Body Weight (g)**	**Date fitted with radio-collar**	**Date recorded dead**	**Cause of death**	**# days post-bait**	**Date radio-collar removed**
YM04	790	27/05/15				23/08/2015
YM05	630	29/05/15				25/08/2015
YM06	510	29/05/15				22/08/2015
YM07	715	01/06/15				21/08/2015
YM08	690	02/06/15				23/08/2015
YM11	580	14/06/15	28/07/2015	Cat predation	22	
YM13	715	18/06/15				23/08/2015
YM14	685	18/06/15				16/10/2015
YM15	705	19/06/15	last alive date 03/08/15	Fate unknown, collar not retrieved	ca. 43	.
YM16	630	22/06/15	6/07/2015	Cat predation	0	
YM17	788	23/06/15				25/08/2015
YF01	310	20/05/15	18/06/2015	Cat predation	Died before baiting	
YF02	590	25/05/15				14/10/2015
YF03	270	27/05/15				8/10/2015
YF09	300	03/06/15				25/08/2015
YF10	350	04/06/15				10/10/2015
YF12	408	14/06/15	17/09/2015	Assumed cat predation, no DNA analysis	74	
YF18	310	23/06/15				7/10/2015
YF19	320	24/06/15				7/10/2015
YF20	395	24/06/15	8/07/2015	Cat predation	2	
YF21	340	25/06/15				11/10/2015
RM01	620	20/05/15	20/08/2015	Fate unknown, collar not retrieved		
RM02	640	20/05/15				9/09/2015
RM08	550	27/05/15				24/08/2015
RM09	440	29/05/15		Fate unknown, collar not retrieved		
RM11	925	29/05/15	10/09/2015	Canid predation		
RM12	685	29/05/15		Fate unknown, collar not		

				retrieved		
RM14	695	31/05/15				24/08/2015
RM16	595	31/05/15	5/08/2015	Assumed cat predation, no DNA analysis		
RM18	725	02/06/15				22/08/2015
RM20	540	04/06/15				20/08/2015
RF03	340	22/05/15				9/09/2015
RF04	490	19/05/15	9/09/2015	Cat predation		
RF05	310	25/05/15	2/06/2015	Fate unknown, collar not retrieved		
RF06	470	25/05/15				9/09/2015
RF07	350	27/05/15	3/06/2015	Cat predation		
RF10	300	29/05/15				17/09/2015
RF13	390	30/05/15				14/09/2015
RF15	320	31/05/15				14/09/2015
RF17	330	31/05/15				8/10/2015
RF19	576	03/06/15	8/07/2015	Canid predation		

Table 4. Timelines for the fitting of radio-collars on northern quolls at Yarraloola and Red Hill, and their fate.

	Yarraloola		**Red Hill**	
	Males (n = 8) (mean + SE)	**Females (n = 7) (mean + SE)**	**Males (n = 6) (mean + SE)**	**Females (n = 9) (mean + SE)**
Pre-bait: May 2015 (g)	690.4 + 31.9	342.8 + 44.5	628.3 + 27.8	365.0 + 21.0
Post-bait: October 2015 (g)	567.6 + 28.1	352.0 + 23.1	604.2 + 46.2	363.3 + 18.1

Table 5. Body weights of radio-collared northern quolls at Yarraloola and Red Hill.

	Yarraloola		**Red Hill**	
	Males (mean + SE)	**Females (mean + SE)**	**Males (mean + SE)**	**Females (mean + SE)**
Home range (ha)	931.1 + 259.9	32.5 + 10.7	301.4 + 108.9	13.8 + 6.6
Linear movements (m)	6689.3 + 1833.7	1031.4 + 136.1	3330.0 + 613.2	844.4 + 132.5

Table 6. Home range size (convex hull) and linear movement lengths for northern quolls at Yarraloola and Red Hill.

Figures

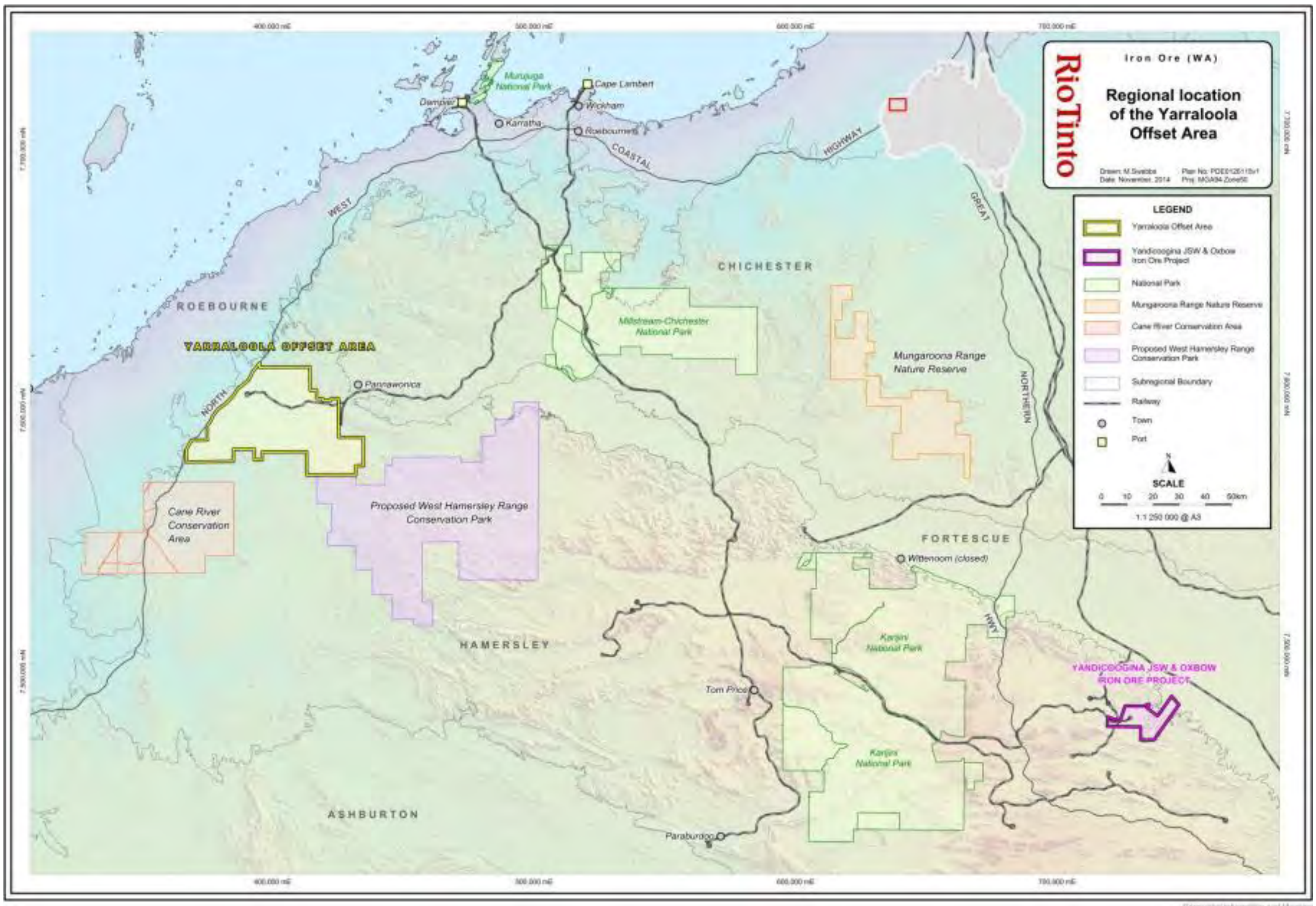

Figure 1. Regional location of the Yarraloola Land Management Area (LMA) in the west Pilbara region of Western Australia.

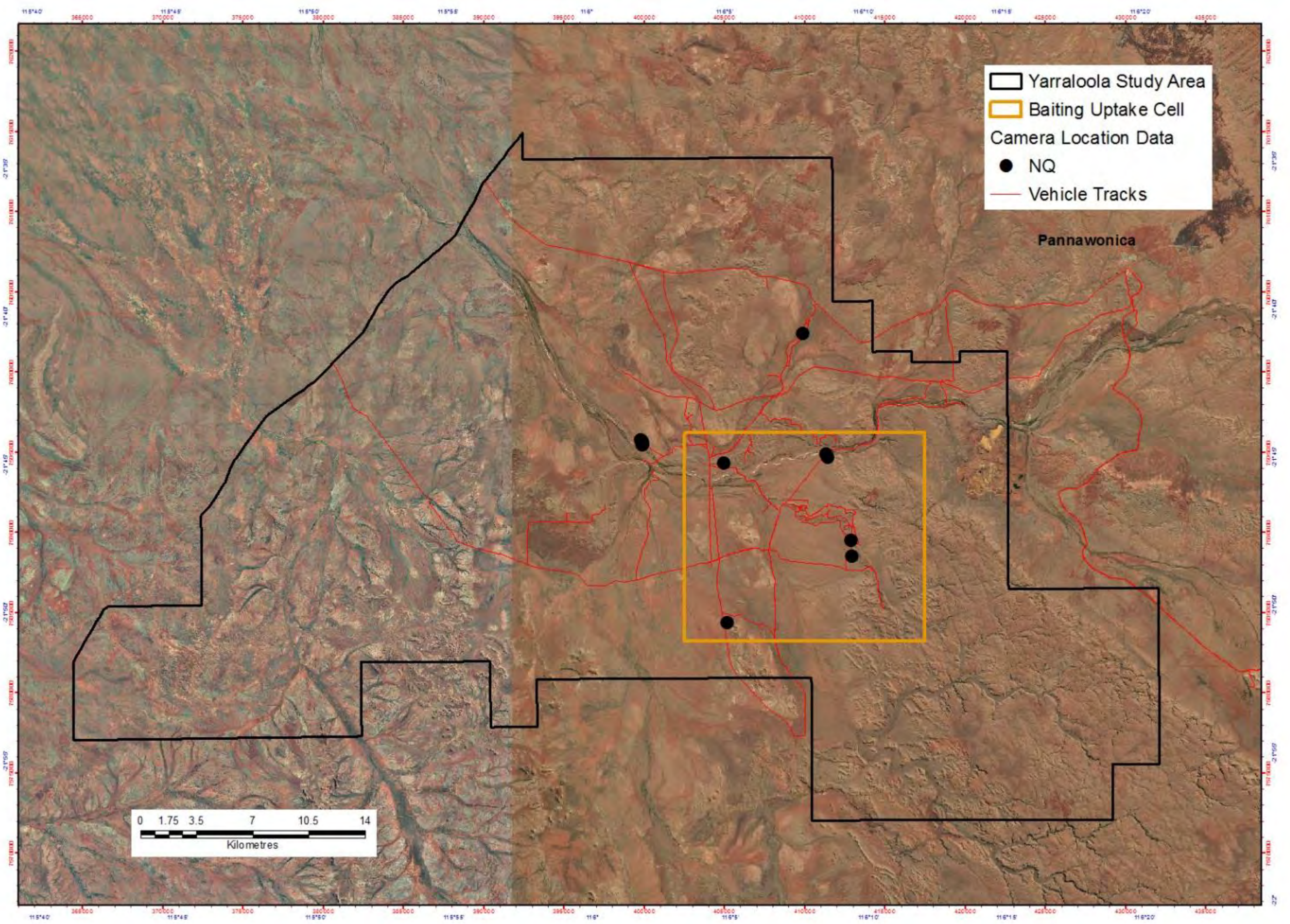

Figure 2. Location of the trial cat baiting cell (20,000 ha) within the Yarraloola LMA.

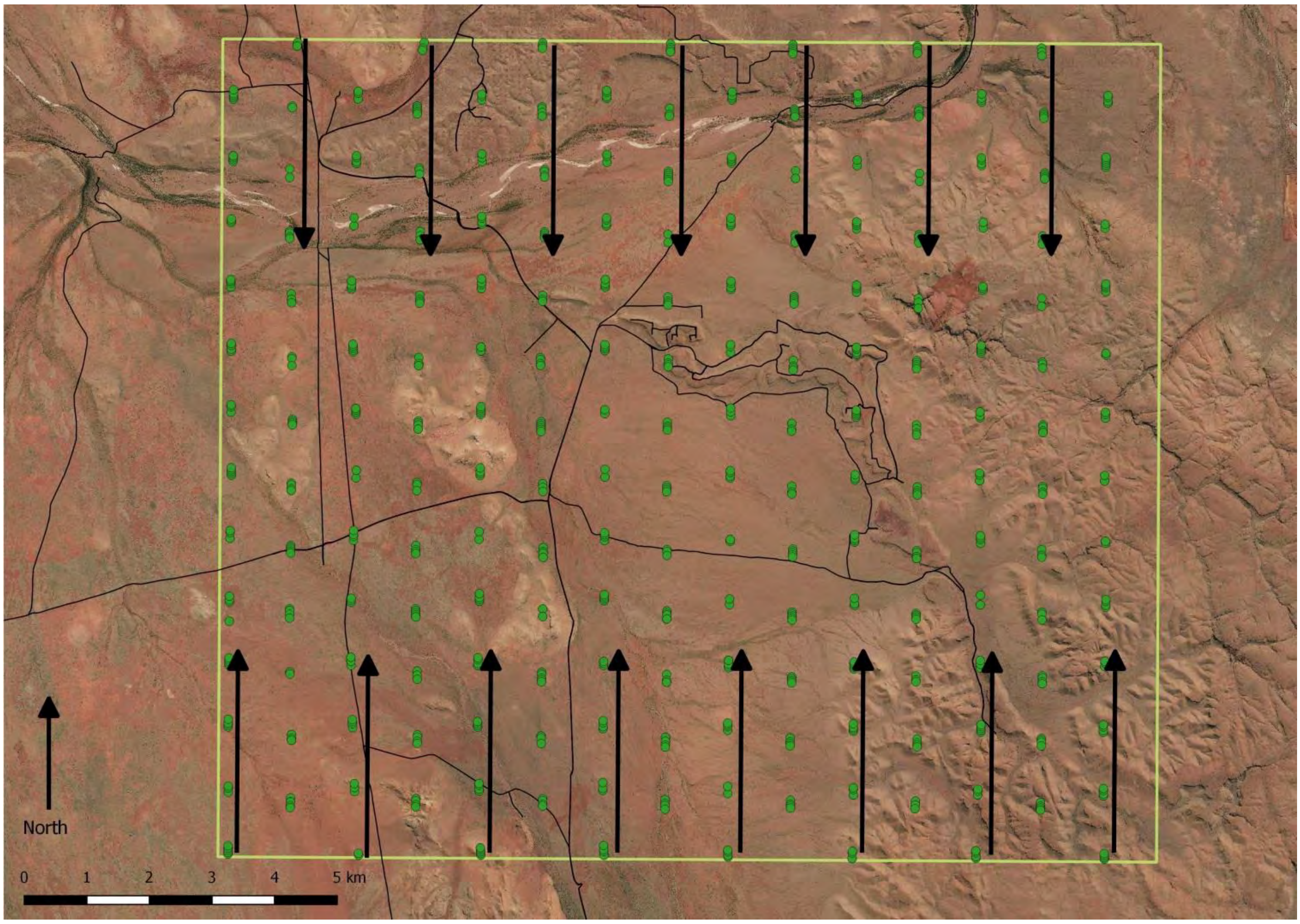

Figure 3. Locations of where *Eradicat*® baits were dropped from an aircraft over the trial cat bait site at the Yarraloola LMA, July 2015. Fifty baits were dropped from 500 feet a.g.l at each of the clumped green dots. Arrows indicate the flight direction of the baiting aircraft.

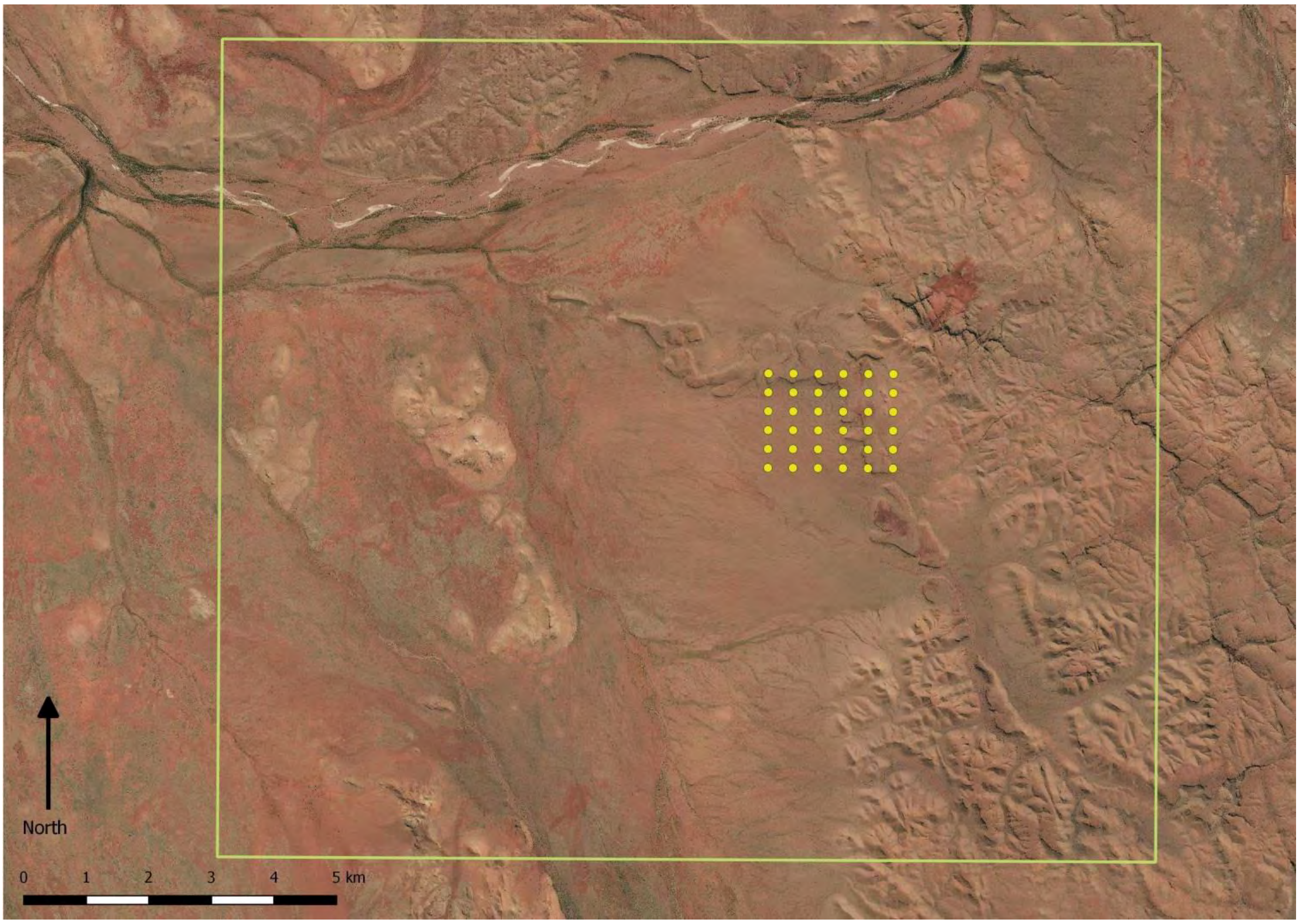

Figure 4. Location of 6 x 6 remote camera grid within the trial cat baited area in the Yarraloola LMA.

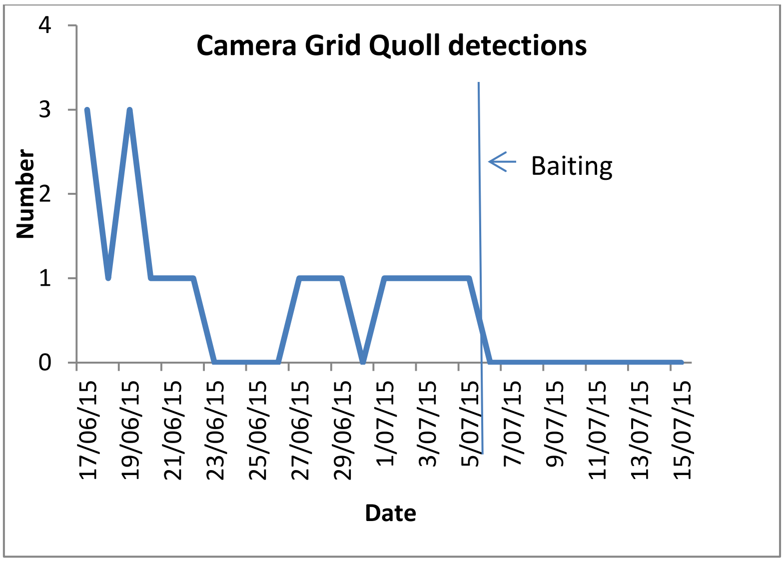

Figure 5. Number of northern quolls detected by remote cameras before and after cat baiting at Yarraloola.

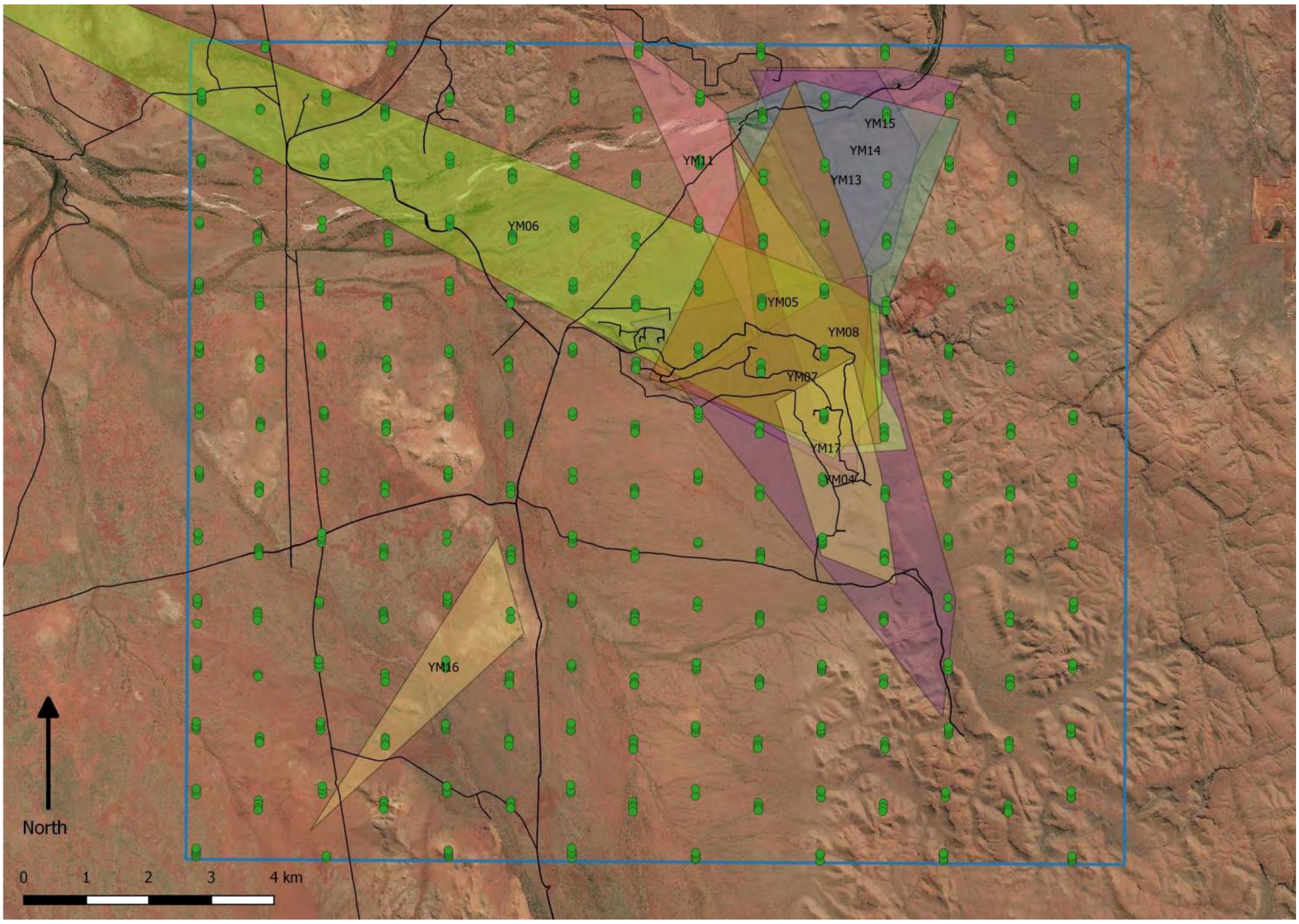

Figure 6. Home range movements of male northern quolls at Yarraloola in relation to the cat bait drop sites.

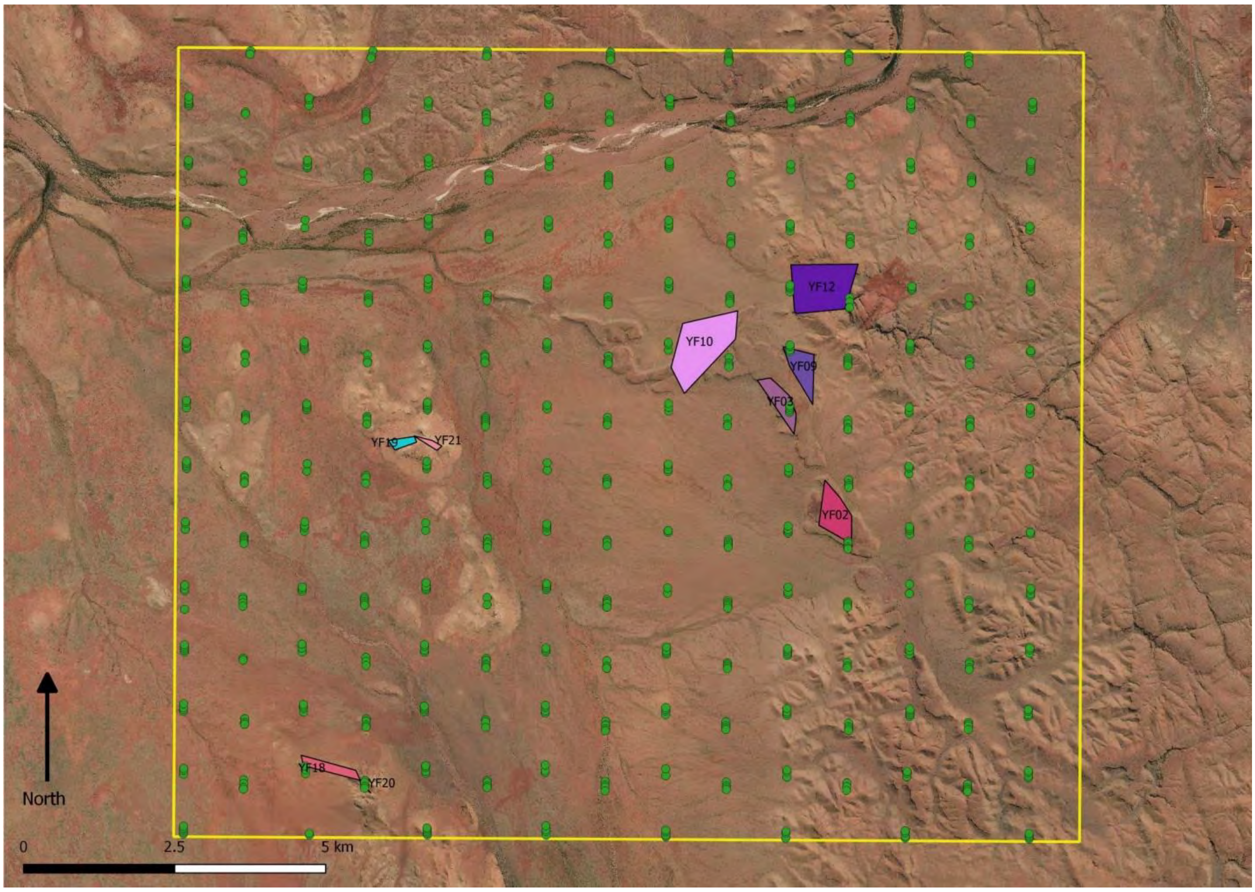

Figure 7. Home range movements of female northern quolls at Yarraloola in relation to cat bait drop sites.

Yandicoogina JSW and Oxbow Project: Threatened Species Offset Plan.

Baseline monitoring for northern quoll and Rothschild's rock-wallaby at *Eradicat®* baited and unbaited sites, Pilbara Region, WA.

2015

Keith Morris, Mark Cowan, John Angus, Hannah Anderson, Sean Garretson, Russell Palmer, Matt Williams and David Pearson.

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February 2016

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Cover photograph: Northern quoll *Dasyurus hallucatus*, J Hayward 2010.

Contents

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Executive Summary

Predation by feral cats and other introduced predators has been shown to be a significant threatening process for many species of medium-sized mammals, in the Pilbara and elsewhere in Australia. As part of an environmental offset condition, Rio Tinto was required to prepare a Threatened Species Offset Plan (TSOP) that implemented management actions to benefit the *EPBC* Act listed northern quoll and Pilbara olive python. Rio Tinto has defined an area (the Yarraloola Land Management Area, LMA) within which management actions described in the TSOP will be delivered on the Yarraloola pastoral lease, in the west Pilbara.

A central component of the TSOP was the development and implementation of an effective introduced predator control program (focussed on feral cats), and an effective monitoring program that detected changes in the abundance of feral cats, northern quolls and Pilbara olive pythons. A proposal for an operational introduced predator control program was developed by Parks and Wildlife in 2014 and this included monitoring feral cat abundance using camera trap arrays, northern quoll abundance through a targeted trapping program, and Pilbara olive python abundance using the abundance of a surrogate prey species, Rothschild's rock-wallaby. A key aspect in the development of this program was an assessment of the impact of using *Eradicat®* feral cat baits in the presence of northern quolls, as the carnivorous quolls are potentially at risk from toxic bait consumption. A study examining the survivorship of northern quolls and their uptake of toxic *Eradicat®* baits was undertaken at Yarraloola / Red Hill from May – October 2015 and this concluded that baiting for feral cats did not detrimentally impact on northern quolls at this site. This study also showed that predation by feral cats was a significant cause of northern quoll deaths.

In conjunction with this northern quoll survivorship study, planning for a longer-term monitoring program for feral cats, northern quolls and Pilbara olive pythons was undertaken, and baseline

monitoring of northern quolls and rock-wallabies was commenced. This study has shown that to significantly detect a 67% change in quoll abundance, 18 monitoring sites at each of Yarraloola and Red Hill would be required, and this power of detection will improve over time. It also showed that using the detection of Rothschild's rock-wallabies as a surrogate for monitoring Pilbara olive pythons was not feasible and more direct measures of python abundance were required.

1 Background

The Yandicoogina Junction South West (JSW) and Oxbow Iron Ore Expansion Project was approved by the Western Australian Government and the Commonwealth Government (via MS 914 and EPBC Decision Notice 2011/5815 respectively) subject to a number of conditions, including the Commonwealth requirement for submission of a Threatened Species Offset Plan (TSOP) by Rio Tinto (Rio Tinto 2015) to benefit the threatened northern quoll (*Dasyurus hallucatus*) and Pilbara olive python (*Liasis olivaceus barroni*). This provided details of measures to control and/or manage introduced predators, feral herbivores, unmanaged fires and invasive weeds, and monitoring programs to detect changes in abundances of northern quolls and Pilbara olive pythons. The focus of the TSOP was a best-practice introduced predator control program implemented within defined management zones across a proposed Land Management Area.

In order to provide a robust foundation from which to measure benefit of the introduced predator control program, planning and baseline monitoring of the abundance of northern quoll, rock-wallabies (as Pilbara olive python surrogates), and feral cats within the TSOP Land Management Area (LMA) and control (i.e. unbaited) areas were undertaken in 2015. Monitoring locations were tentatively identified at both the control and impact areas during reconnaissance surveys of the TSOP LMA in 2014 in readiness for commencement of the baseline monitoring program in 2015.

Monitoring programs for the northern quoll, Pilbara olive python (using the prey species Rothschild's rock-wallaby as a surrogate) and introduced predators were developed in 2014 and described in the Operational Introduced Predator Control Program – Yarraloola Offset Area, Pilbara Region, WA 2015-2019 (Morris and Thomas 2014). The monitoring of rock-wallaby abundance was suggested as a surrogate for Pilbara olive python abundance at a 2014 workshop given the difficulties and cost of establishing a monitoring program for Pilbara olive pythons. However, this decision was reviewed at another workshop held in October 2015, and other proposals to monitor Pilbara olive pythons more directly were discussed and will be pursued.

The baseline monitoring study reported here was undertaken in conjunction with a study to assess the survivorship of northern quolls and their uptake of toxic *Eradicat®* baits before, during and after a toxic cat baiting program (Morris *et al.* 2015). The results of these studies will be used to plan an operational, landscape scale cat baiting program, and fauna monitoring program for the Yarraloola LMA for the period 2016 – 2019, and beyond.

2 Introduction

Predation by introduced predators (particularly the European red fox *Vulpes vulpes* and feral cat *Felis catus*) has been identified as a significant factor in the loss of vertebrate fauna in Australia. In the 1980 - 90s, predation by foxes was shown to be a significant threatening process for native fauna in WA (Kinnear *et al*. 2002, Morris *et al*. 2003). More recently, feral cat predation has been identified as a major issue for native mammal conservation (Fisher *et al*. 2014, Marlow *et al.* 2015, Wayne *et al*. 2013) and Woinarski *et al*. (2014) regard this as the factor now affecting the largest number of threatened and near threatened mammal taxa. Predation by foxes and feral cats are both listed as

Key Threatening Processes under the Commonwealth's *Environment Protection and Biodiversity Conservation Act (EPBC* 1999).

A review of the conservation values, threats and management options for biodiversity conservation in the Pilbara (Carwardine *et al*. 2014) identified that for terrestrial vertebrates of conservation significance (including northern quolls and Pilbara olive pythons), effective feral cat control would provide most benefits. Without cat control it is likely that another five species of terrestrial vertebrate will become regionally extinct in the Pilbara in the next 20 years, and another 18 species will continue to decline.

The northern quoll is one of the seven medium-sized mammal species that has persisted in the Pilbara bioregion (McKenzie *et al*. 2006). All of these species, except perhaps the echidna (*Tachyglossus aculeatus*), have declined to some extent in the Pilbara, and three, including the northern quoll, are listed as threatened species under State and Commonwealth legislation. The northern quoll was once distributed widely across northern Australia, from the Pilbara and Kimberley, across the Top End of the Northern Territory, to southern Queensland, but has now contracted to several disjunct populations (Braithwaite and Griffiths 1994, Oakwood 2008). The Pilbara northern quoll population has been shown to be genetically distinct from the Kimberley population (How *et al*. 2009). An alarming decrease or complete collapse in once locally abundant populations of the northern quoll has occurred in recent years across northern Australia as a direct result of the invasion of the cane toad, *Rhinella marina* (Woinarski *et al*. 2008; Woinarski *et al*. 2010). The Pilbara population represents the last population that has not experienced major declines associated with the arrival of cane toad. Three other factors have also been identified as contributing to the decline of northern quolls and other medium-sized mammals across northern Australia: changed habitats through widespread fires, predation by feral cats, and novel disease (Woinarski *et al*. 2011). Due to these declines and threatening processes, the northern quoll is listed as Endangered under both the *EPBC Act* (1999) and the Western Australian *Wildlife Conservation Act* (WCA) 1950.

The Pilbara olive python is restricted to the Pilbara and north Ashburton regions of WA (Smith 1981, Pearson 1993). Recent genetic analysis of olive pythons from the Kimberley and Pilbara suggest the Pilbara olive python is a distinct species (Spencer and Pearson 2013). It is listed as Vulnerable under the *EPBC Act* (1999) and the *WCA* (1950). Some information on its distribution, ecology, population trends and conservation threats is available (Pearson 2003, 2007, Tutt *et al*. 2002, 2004), but detailed knowledge is lacking. Few specimens have been collected and lodged in the WA Museum. Its large size, habitat preferences, probable low densities and diet of large vertebrates (including a number of threatened species) makes it potentially vulnerable to anthropogenic changes to its habitat. No decline in the size of the overall population of Pilbara olive pythons or the distribution has been detected, but there are insufficient historical and recent data to establish any such trends.

Pilbara olive pythons persist at relatively low densities, are cryptic, nocturnal and generally inhabit rocky environments (Pearson 2003). They are not trappable and usually don't trigger camera traps as they move slowly and their body heat is typically not greatly dissimilar to ambient. Because of these factors, effective direct monitoring techniques have not been developed, and the monitoring of prey species (such as northern quolls and Rothschild's rock-wallaby) abundances instead was proposed as a surrogate for monitoring Pilbara olive pythons (Rio Tinto 2015, Morris and Thomas 2014). A number of potential threats could cause local or wider extinctions including: habitat destruction and alteration by infrastructure or mining projects; habitat degradation around water bodies due to cattle, direct predation of young pythons by foxes and feral cats, and the loss of important food species (such as bats, quolls and rock-wallabies) due to predation by foxes and feral cats, habitat change or inappropriate fire regimes. Cane toads are likely to spread from the Kimberley to the Pilbara (Tingley *et al.* 2012) and Pilbara olive pythons may be at risk through ingestion of these. While the occasional Northern olive python was found dead during the invasion of cane toads into the east Kimberley, a radio-telemetry study did not detect any deaths due to toads. Olive pythons remain abundant around Kununurra five years after the arrival of toads (Pearson in prep.).

A field trial examining the survivorship and uptake of toxic *Eradicat®* cat baits by northern quolls at Yarraloola was undertaken in 2015 (Morris *et al.* 2015). This demonstrated that quolls were unlikely to be at risk from toxic cat baiting operations during the cooler, drier months in the Pilbara. Planning is now underway to implement a landscape scale (ca. 147,000 ha) toxic cat baiting program in the Yarraloola LMA. The monitoring study reported here provides baseline information on northern quoll abundances before landscape scale cat baiting was implemented in the Yarraloola LMA area and reports on the effectiveness of using the rock-wallaby as a surrogate for Pilbara olive python monitoring. It also provides recommendations for ongoing feral cat, northern quoll, and Pilbara olive python monitoring programs once toxic cat baiting is implemented at a landscape scale at the Yarraloola offset area.

3 Study sites

This study was undertaken at the two sites in the western Pilbara region of WA used for the trial cat baiting program (Morris *et al.* 2015); the Yarraloola LMA (Figure 1) and the Red Hill pastoral lease, approximately 65 km south of the Yarraloola site. The Yarraloola site will be baited using *Eradicat®* baits to control feral cats over ca. 147,000 ha from 2016 to 2019. The Red Hill site will not be baited for feral cats and will be used as a control comparison site for Yarraloola.

These sites experience a semi-arid climate typical of the Pilbara bioregion. Summers are hot and winters mild. Rainfall is extremely variable and follows a loose bi-modal pattern with the majority of rainfall occurring during January, February and March in association with tropical cyclone and heat trough events. Tropical cyclones typically deliver large falls of rain over extensive areas whereas thunderstorm events associated with heat troughs are much more localised. A second, smaller rainfall peak occurs in May and June as a result of southern frontal systems which are at their northern extent of influence over the area. The historic yearly average rainfall for Pannawonica, over 43 years, is 404 mm (Bureau of Meteorology).

4 Methods

4.1 Feral cat monitoring

There was no monitoring of feral cat abundance at Yarraloola or Red Hill in 2015, as cat baiting was only undertaken over a small area (20,000ha). Operational cat baiting over ca. 147,000 ha will commence in 2016, and the monitoring of feral cats will be undertaken at both the Yarraloola baited site and the Red Hill unbaited site. The methodology to be used for monitoring the abundance of feral cats will broadly follow that shown in Morris and Thomas (2014) and will involve the establishment of camera trap arrays (ca. 60 Reconyx Hyperfire PC900 cameras, with 2-3 km spacing between cameras) at each site. During 2015 the design (location, shape and size) of the camera monitoring arrays was discussed from both operational and statistical power perspectives. Feral cat abundance will be inferred from occupancy models derived from cat detections on the camera arrays.

4.2 Northern quoll monitoring

At Yarraloola, northern quolls were trapped at 43 sites during the course of the cat bait survivorship and baseline monitoring study in 2015. Of these, 11 were selected as baseline monitoring sites (Figure 2). At Red Hill, northern quolls were trapped at a total of 21 sites, and 10 of these were selected as baseline monitoring sites (Figure 3). Baseline monitoring of northern quolls at these sites was undertaken between August and October 2015. Trapping at this time was just prior to the annual male die off, and also provided information on reproductive success. At each site, quolls were trapped using linear transects of 20 small Sheffield cage traps baited with peanut butter, oats and sardines, and set at 25m intervals. This is a variation to the methodology used by the northern quoll regional monitoring project (Dunlop *et al.* 2014), where 50 traps are set at 50 m spacing. At Yarraloola quolls were at low densities and this trapping configuration was shown to be as effective at capturing all the quolls in the immediate area, but with less effort. Traps were placed in sheltered, shady locations and covered with a hessian bag for protection of any trapped animals from the heat. Trap lines ran along rocky breakaways and mesas, as well as in and around gorges where quolls were known to be (from preliminary surveys). All trapped quolls were weighed, measured and sexed, and a small tissue sample taken from each ear for DNA analysis. For each new quoll captured, a unique passive implanted transponder (PIT) tag (Allflex® 12mm FD-X transponder, Allflex, Australia) was inserted under the skin between the shoulder blades to allow future identification of individuals. Other species captured were also recorded and tissue samples taken. All trapping data were recorded on data sheets prior to entry into an MS Excel spreadsheet and later, an MS Access database.

To ensure that the number of monitoring sites proposed would have sufficient power to detect significant ($p < 0.05$) changes in quoll abundances, a power analysis of the amount of change that could be detected for various numbers of monitoring sites at Yarraloola and Red Hill was undertaken (Appendix 1). The number of different individual animals trapped was used as an index of abundance for each site. Using a procedure known as ‘bootstrapping’, random samples were drawn from these data to simulate alternative monitoring protocols of various numbers of sampling sites in each area being re-trapped over several years. The data were analysed using Analysis of Variance (ANOVA) to estimate the relative size of the difference in average abundance between the baited and reference areas required to obtain a statistically significant difference for each protocol.

4.3 Rock-wallaby monitoring

Because of the difficulties in monitoring Pilbara olive pythons directly, the TSOP (Rio Tinto 2015) and Morris and Thomas (2014) proposed that python abundance should be monitored using the abundances of prey items such as northern quolls and Rothschild’s rock-wallaby as surrogates. Northern quolls were monitored as shown in 4.2 above. It was intended that rock-wallabies would be monitored by locating rock-wallaby refuges and camera traps used to identify individuals so that a minimum number of rock-wallabies known to be alive (MNKTBA) could be determined.

Between mid-July and the end of August 2015 individual camera traps were set at 28 locations within the trial cat baiting cell considered suitable for rock-wallabies. Cameras were set facing rocky caves and crevices, areas where rock-wallabies would access for shelter, grooming and basking. An apple lure was placed in front of each camera as a lure for rock-wallabies.

5 Results

5.1 Feral cat monitoring

There was no monitoring of feral cats during 2015, as no landscape scale cat control was undertaken. The limitations on being able to establish a roughly square or rectangular grid of camera traps as proposed in Morris and Thomas (2014) were discussed with Rio Tinto. During the 2016 – 2019 cat monitoring program, camera trap locations will need to be limited to a walking distance of 400 m either side of access tracks as the use of quad bikes on Yarraloola is not permitted.

To determine the impact of the cat baiting program on feral cat abundance, camera trap arrays will be established in both the baited (Yarraloola) and unbaited (Red Hill) sites to allow for the calculation of occupancy rates by feral cats before and after baiting (Before, After, Control, Impact design). A minimum of 50 camera traps will be used at each site, with additional cameras set at Yarraloola if time allows. Where foot access is possible, camera traps will be set by walking up to 400 m from existing tracks. ArcMap will be used to randomly generate 60-80 potential camera points adjacent to tracks at each site. Camera placement buffers of 50m to 400m will be generated either side of tracks that are accessible by vehicle. A script will be used in ArcMap to generate random points within this buffer so that each camera point is at least 3 km from its closest neighbour. This distance should ensure that each camera is independent (i.e. avoid individual feral cats appearing on multiple cameras during the recording period). For the baited site at Yarraloola, cameras will be placed at least 3 km inside the bait cell boundary. The exact location of the cameras at Yarraloola and Red Hill will be selected during an initial visit to sites in April 2016.

The camera surveys will be conducted for 21 days in late May to late June before the cat baiting (in early July) and for 21 days in mid-July to mid-August after the baiting. Lures for the camera trap surveys will be set approximately 3 m from the camera. A 100 ml glass jar with holed sifter lid containing approximately 15 ml of an oil-based scented lure (‘Catastrophic’, Outfoxed, Victoria) will be attached to a stake approximately 30 cm from the ground. A visual lure consisting of a 1.5 m long bamboo cane will be joined to the stake, with white turkey feathers connected to the cane 30 cm above the scented lure and a strip of wired silver tinsel taped to the top of the cane.

5.2 Northern quoll monitoring

There were 880 trap nights achieved for northern quoll monitoring at Yarraloola and 800 trap nights at Red Hill (Tables 1 and 2). There was no significant difference in the average number of individual quolls captured per 100 trap nights at Yarraloola (3.97 $\pm$ 0.98 individuals) and Red Hill (3.25 $\pm$ 1.23 individuals) ($t_{(18)}$ = 0.487, p = 0.632, NS). Similarly there was no significant difference in trap success rates (including recaptures) of northern quolls at Yarraloola (6.72 $\pm$ 2.62%) and Red Hill (7.25 $\pm$ 1.95%) ($t_{(18)}$ = -0.142, p = 0.889, NS) (Tables 1 and 2). More males than females were trapped at both Yarraloola and Red Hill sites (Table 3), however the sex ratio was not significantly different from parity at Yarraloola ($X^2_{(1)}$ = 0.345, p = 0.0.063, NS), but was significantly different at Red Hill ($X^2_{(1)}$ = 3.846, p = 0.049). Males continued to be captured into October.

There was no significant difference in body weights between male ($t_{(39)}$ = 0.931, p = 0.081, NS) or female northern quolls ($t_{(18)}$ = 0.887, p = 0.156, NS) at Yarraloola and Red Hill (Table 3). Body weights were within the range recorded for other Pilbara northern quoll populations (for example, Dunlop *et al.* 2014). As reported in Morris *et al.* (2015), male body weights were lower at both sites in October compared to May, most likely due to a loss of condition just prior to the annual male die off, a demographic characteristic of this species (Oakwood *et al.* 2001). This difference was significant only for the Yarraloola males ($t_{(7)}$ = 4.36, p = 0.003).

At Yarraloola, during the baseline monitoring, all the female quolls captured (n = 14) had pouch young and the average litter size was 6.8 $\pm$ 0.3 (s.e.) pouch young per female. Similarly at Red Hill, all of the females trapped during the baseline monitoring (n = 8) had pouch young, and the average litter size was 5.3 $\pm$ 0.5 (s.e.) pouch young per female. This was significantly less than the litter size for females at Yarraloola ($t_{(19)}$ = 2.441, p = 0.029).

The results of the bootstrapping simulation show that the current number of monitoring sites (11 at Yarraloola, 10 at Red Hill), used over a single year of sampling, would only detect a very large (94%) change in quoll abundance as statistically significant. If the number of monitoring sites was nearly doubled, to 18 at each site, a change in abundance of 67% would be sufficient to achieve statistical significance. Four years of repeated monitoring at 9 or 18 sites per area would be needed to detect changes in abundance of 46% or 33%, respectively.

5.3 Rock-wallaby monitoring

Over six weeks, rock-wallabies were only detected at 8 of the 28 (28.6%) camera trap sites (Table 4, Figure 3). Only single detections of rock-wallabies were made over this period, and this low detection rate suggest that using this methodology would not have sufficient power to detect any population changes. Other more direct measures of python abundance are required to monitor changes.

Two options are currently being considered for inclusion in the overall monitoring program in subsequent years. One option involves the direct monitoring of the survivorship of newly hatched Pilbara olive pythons by radio-telemetry, as this younger life stage is considered to be the most vulnerable to predation by feral cats. An alternative option being investigated is to use an assessment of python DNA from scats or shed skin (environmental, or eDNA) to detect the presence of pythons at waterholes along the Robe River. Changes in population status *may* be detectable from changes in the frequency of python DNA detection in the environment over time, but this technique is still in development.

6 Discussion

This study has provided the opportunity to trial and modify the proposed monitoring programs for feral cats, northern quolls and Pilbara olive pythons, so that the impact of landscape scale cat baiting in the Yarraloola LMA on northern quoll and Pilbara olive python abundances can be evaluated. Information on northern quoll abundance and demographics has also been obtained, and can be put into a Pilbara regional context (Dunlop *et al.* 2014).

Assessing the efficacy of feral cat baiting through the use of camera trap arrays to provide measures of occupancy and estimates of abundance of feral cats before and after cat baiting has been used at other Pilbara sites, and is capable of detecting significant reductions in cat abundance following cat baiting (Clausen *et al*. 2015). The design of the camera arrays at Yarraloola and Red Hill, including the number of camera trap (cat detection) sites, and pattern of their distribution can now be refined given knowledge of the extent of the operational cat baiting cell, access limitations and extent of the track network.

An average of 3 – 4 individual northern quolls were recorded at each of the Yarraloola and Red Hill monitoring sites, lower than the average 8 individuals recorded elsewhere (Dunlop *et al.* 2014), but within the range of 0 – 23 individuals recorded at regional monitoring sites. Similarly, trap success rates of 6 – 7% are lower than that recorded elsewhere in the Pilbara (9 – 10%). The lower numbers of individuals recorded at each monitoring site will mean that additional sites will be required at both Yarraloola and Red Hill to provide sufficient power to detect significant changes in the quoll populations. An additional 7 sites at Yarraloola and 8 sites at Red Hill will be selected and a total of 18 sites in each area used for northern quoll monitoring from 2016 – 2019 to allow the monitoring to detect a 67% change in quoll populations. Timing is a key issue for monitoring quoll populations as the prounounced movement behavior of males at certain times of the year may have a strong influence on capture rates. On this basis it is recommended that timing for monitoring is consistent between years and that monitoring in any one year is concluded within the shortest possible timeframe.

Any benefit of feral cat baiting to Pilbara olive pythons will be difficult to demonstrate as they are cryptic, typically occur at low densities and require different monitoring techniques. Monitoring surrogate prey species such as the Rothschild's rock-wallaby was proposed (Morris and Thomas 2015) based on the assumption that female pythons need large prey items to lay down fat reserves for breeding. Monitoring rock-wallaby abundance through the use of camera traps was considered a viable option. However this study has shown that rock-wallabies are probably not at sufficiently high densities at Yarraloola for any significant population changes to be detected following cat baiting. Although rock-wallabies are known prey for Pilbara olive pythons (Pearson 2003), the link between rock-wallaby abundance and python abundance has not been demonstrated. It would be preferable to develop a more direct measure of python abundance.

Environmental DNA (*e*DNA) methods detect DNA that has been shed into aquatic environments by cryptic or low density species (Hunter *et al.* 2015, Furlan *et al.* 2015). This technology could be trialed to detect presence / absence of olive pythons in the pools along the Robe River and other water holes in the study areas. Given this is a new and experimental technology, there are several areas of uncertainty including the sensitivity, residence time of the DNA, and the conversion process from presence/absence information to a narrative on the status of the python population in the study area. Thomsen *et al.* (2012) have demonstrated that the abundance of *e*DNA, as measured by qualitative polymerase chain reaction (qPCR) correlates positively with population abundance estimated with traditional tools in some aquatic and amphibious taxa. Further trialing of this technology could be undertaken to assess its usefulness in monitoring changes in python abundance.

An alternative technique is to monitor, at the cat baited and unbaited sites, the survivorship of newly hatched and juvenile python cohorts, by radio-tracking, as these are likely to be the life stages most at risk from feral cat or fox predation. Reliable transmitters that can be surgically implanted into pythons allow researchers to follow their movements through the landscape (Pearson *et al.* 2002, 2003). This technique allows the collection of direct evidence of feral cat or fox predation, if any, as well as obtaining other ecological information critical for improving monitoring techniques for this species. It enables assessment of the likely impacts of other threatening processes such as changes to habitat from wildfire or destruction of riparian vegetation by cattle by comparing life history parameters (such as activity patterns, reproductive rates, shelter use and diet) between impacted and control populations. Almost all our current knowledge on the biology of Pilbara olive pythons has been obtained through radio-telemetry (Pearson 2003, 2007; Tutt *et al*. 2002, 2004).

The development / modification and implementation of the northern quoll, Pilbara olive python, and feral cat monitoring programs as discussed above will allow, for the first time, an evaluation of the effectiveness and conservation benefit of a landscape scale cat baiting program in the Pilbara region. The results of this work will inform other similar cat management programs elsewhere in the Pilbara, and potentially provide significant benefits to threatened fauna in this region.

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Tables

Table 1. Baseline monitoring - northern quoll trapping effort and success in the Yarraloola Land Management Area (cat baited site).

Trap site ID	Number of traps set	Trapping dates	Number of trap nights	Number of individuals trapped (M:F)	Total captures	Trap success rate (%)	Individuals captured per 100 trap nights
30	20	20/08/15-24/08/15	80	3 (2:1)	3	3.75	3.75
31	10	20/08/15-28/08/15	80	6 (5:1)	16	20.00	7.50
32	20	22/08/15-26/08/15	80	7 (6:1)	10	14.00	8.75
33	20	24/08/15-28/08/15	80	8 (7:1)	18	22.50	10.00
36	20	08/09/15-12/09/15	80	1 (0:1)	1	1.25	1.25
37	20	08/09/15-12/09/15	80	1 (0:1)	1	1.25	1.25
39	20	13/09/15-17/09/15	80	1 (0:1)	1	1.25	1.25
40	20	06/10/15-10/10/15	80	1 (0.1)	1	1.25	1.25
41	20	13/09/15-17/09/15	80	2 (1:1)	2	2.50	2.50
42	20	06/10/15-10/10/15	80	3 (1:2)	3	3.75	3.75
43	20	06/10/15-10/10/15	80	2 (1:1)	2	2.50	2.50
Mean ± s.e.			**80**	**3.5**	**5.8**	**6.72 ± 2.62**	**3.97 ± 0.98**

Table 2. Baseline monitoring - northern quoll trapping effort and success at the Red Hill (unbaited site).

Trap site ID	Number of traps set	Trapping dates	Number of trap nights	Number of individuals trapped (M:F)	Total captures	Trap success rate (%)	Individuals captured per 100 trap nights
E	20	18/08/15-22/08/15	80	3 (2:1)	8	10.00	3.75
F	20	18/08/15-22/08/15	80	1 (1:0)	2	2.50	1.25
G	20	18/08/15-22/08/15	80	1 (1:0)	1	1.25	1.25
H	20	08/09/15-12/09/15	80	3 (1:2)	7	8.75	3.75
I	20	23/08/15-27/08/15	80	2 (2:0)	5	6.25	2.50
J	20	23/08/15-27/08/15	80	11 (9:2)	25	31.25	13.75
L	20	08/09/15-12/09/15	80	3 (1:2)	5	6.25	3.75
M	20	08/09/15-12/09/15	80	1 (0:1)	3	3.75	1.25
N	20	12/09/15-16/09/15	80	0	0	0	0
P	20	12/09/15-16/09/15	80	1 (1:0)	2	2.50	1.25
Mean ± s.e.			**80**	**2.6**	**5.8**	**7.25 ± 1.95**	**3.25 ± 1.23**

Table 3. Body weights (g, mean ± s.e.) of northern quolls captured at baseline monitoring sites between August and October at Yarraloola and Red Hill.

Yarraloola		Red Hill	
Males (n = 23)	Females (n = 12)	Males (n = 18)	Females (n = 8)
579.2 ± 12.5	355.2 ± 12.6	543.9 ± 12.8	389.4 ± 7.6

Table 4. Locations and success of remote camera traps set to detect rock-wallabies at Yarraloola from mid – July to end of August 2015. Detection rates for northern quolls (radio-collared and uncollared) are also shown.

Camera ID	latitude	longitude	Northing	Easting	# NQ with radio-collars detected	# NQ without radio-collars detected	# rock-wallabies detected
YP027	-21.7718	116.1608	7592192	413241.1	1	0	1
YP021	-21.8476	116.1033	7583776	407344.9	0	0	1
YP020	-21.8125	116.1667	7587697	413873.7	0	0	1
YP019	-21.7946	116.0925	7589634	406190.7	1	0	1
YP018	-21.8464	116.083	7583894	405241.5	0	0	0
YP017	-21.7733	116.1568	7592031	412829	0	0	0
YP016	-21.846	116.0836	7583937	405304.1	0	0	0
YP013	-21.7846	116.1504	7590773	412169.1	1	0	0
YP012	-21.8105	116.166	7587916	413792.8	1	1	0
YP004	-21.8434	116.0858	7584229	405529.6	1	1	1
YP002	-21.7955	116.1595	7589574	413120.5	1	1	0
YP052	-21.7402	116.1467	7595683	411757.2	0	1	1
YP055	-21.7379	116.152	7595942	412304.1	0	1	1
YP031	-21.7428	116.1356	7595394	410618.1	0	0	0
YP059	-21.7434	116.1479	7595336	411888.9	0	0	0
YP049	-21.7704	116.1587	7592353	413016.5	0	0	0
YP033	-21.7763	116.1463	7591691	411743.5	1	0	0
YP050	-21.806	116.0809	7588362	405002.6	0	0	0
YP028	-21.8204	116.1091	7586791	407922.5	0	0	0
YPO64	-21.7473	116.1431	7594898	411395.3	0	0	0
YP053	-21.7466	116.1407	7594973	411142.5	0	0	0
YP060	-21.7764	116.1225	7591668	409277.1	0	0	0
YP025	-21.7832	116.1272	7590915	409769.8	0	0	1
YP015	-21.7843	116.1291	7590794	409971.6	0	0	0
YP032	-21.7982	116.161	7589278	413272.6	0	1	0
YP045	-21.7966	116.1617	7589446	413346.9	0	0	0
YP054	-21.7926	116.16	7589897	413168.5	0	0	0
YP056	-21.783	116.1583	7590956	412988.3	0	0	0
YP046	-21.7817	116.1585	7591097	413008.4	1	0	0
YP047	-21.6402	116.3201	7606839	429644	0	0	1

Figures

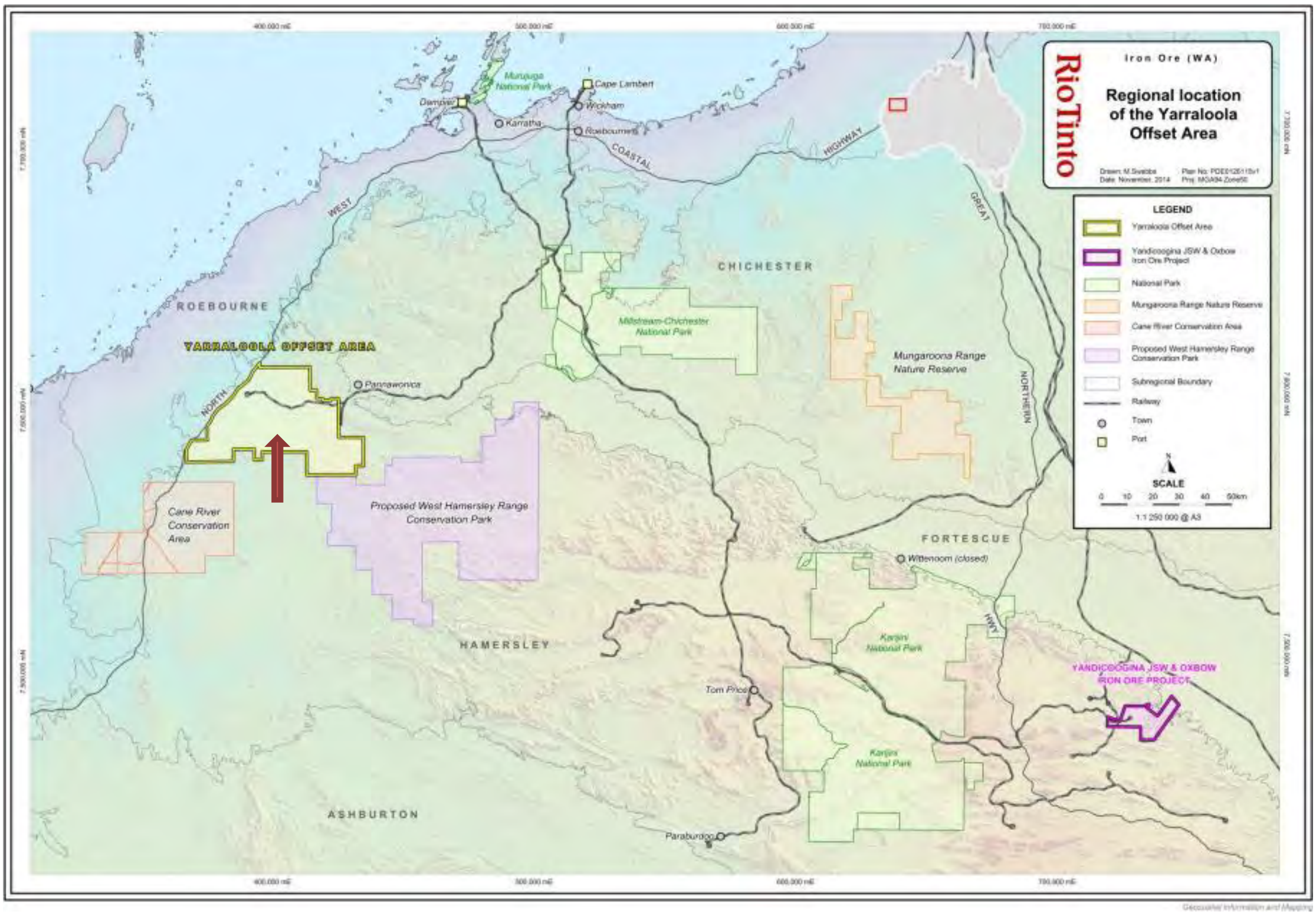


Figure 1. Regional location of the Yarraloola Land Management Area in the west Pilbara region of Western Australia.

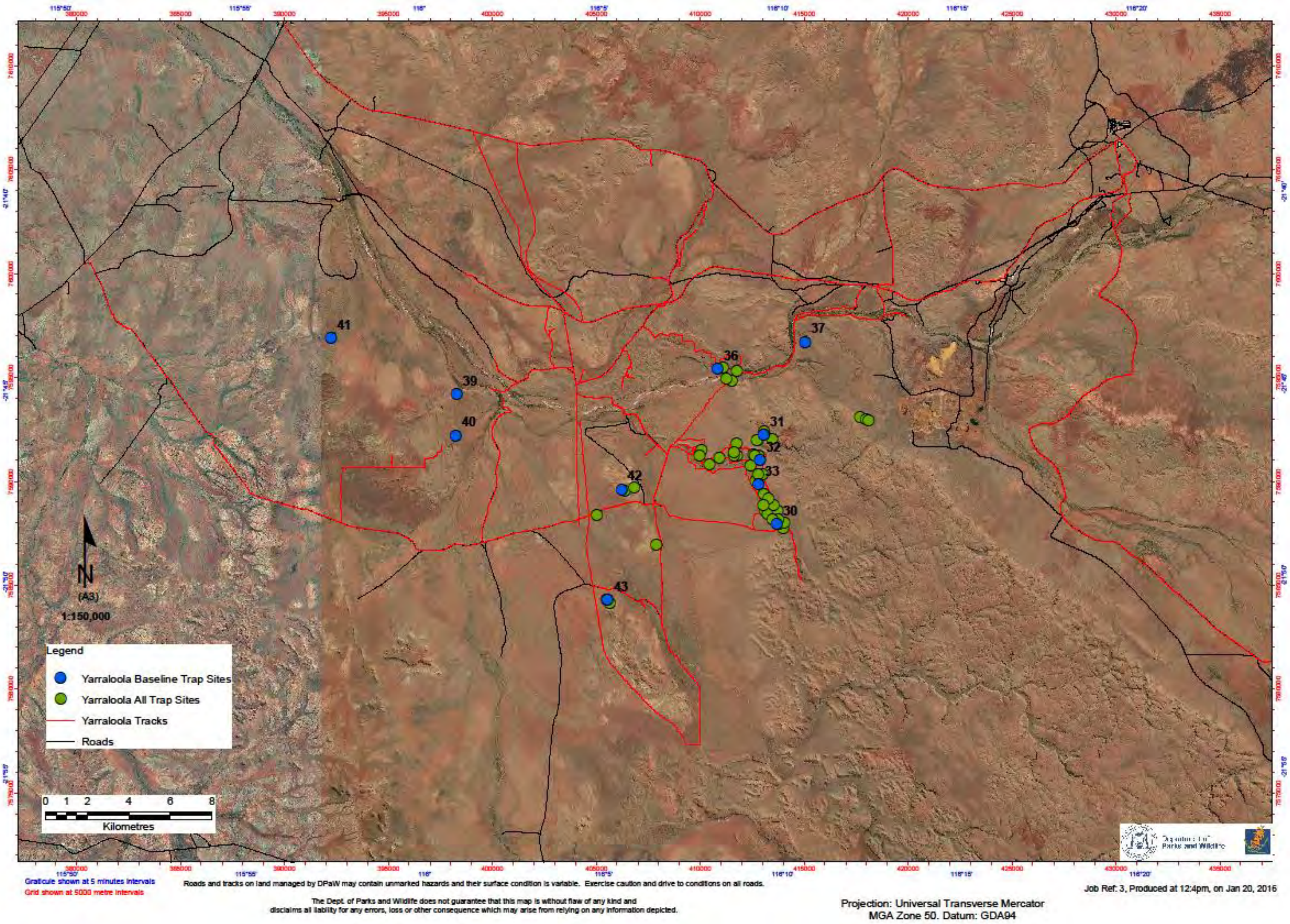


Figure 2. Locations of northern quoll trapping (●) and baseline monitoring (●) sites at Yarraloola (cat baited).

Figure 3. Location of northern quoll trapping (●) and baseline monitoring (●) sites at Red Hill (not cat baited).

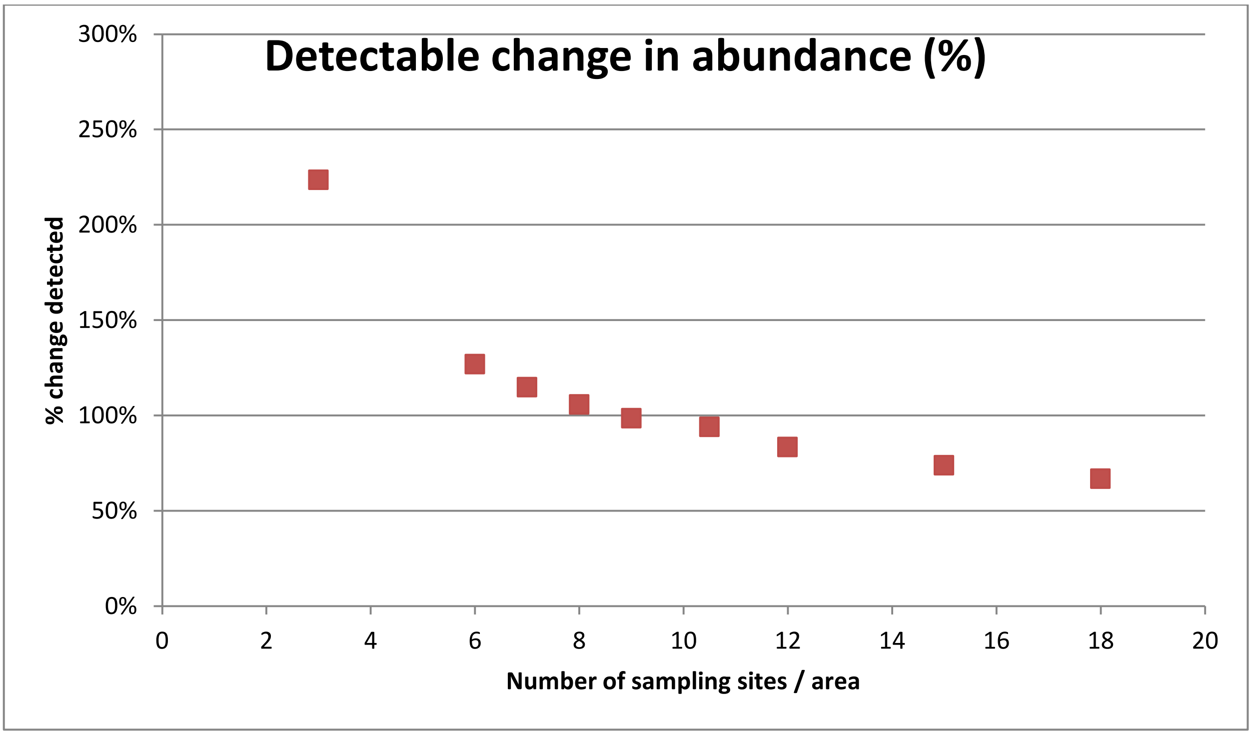


Figure 4. Power analysis of northern quoll sampling effort required at Yarraloola and Red Hill.

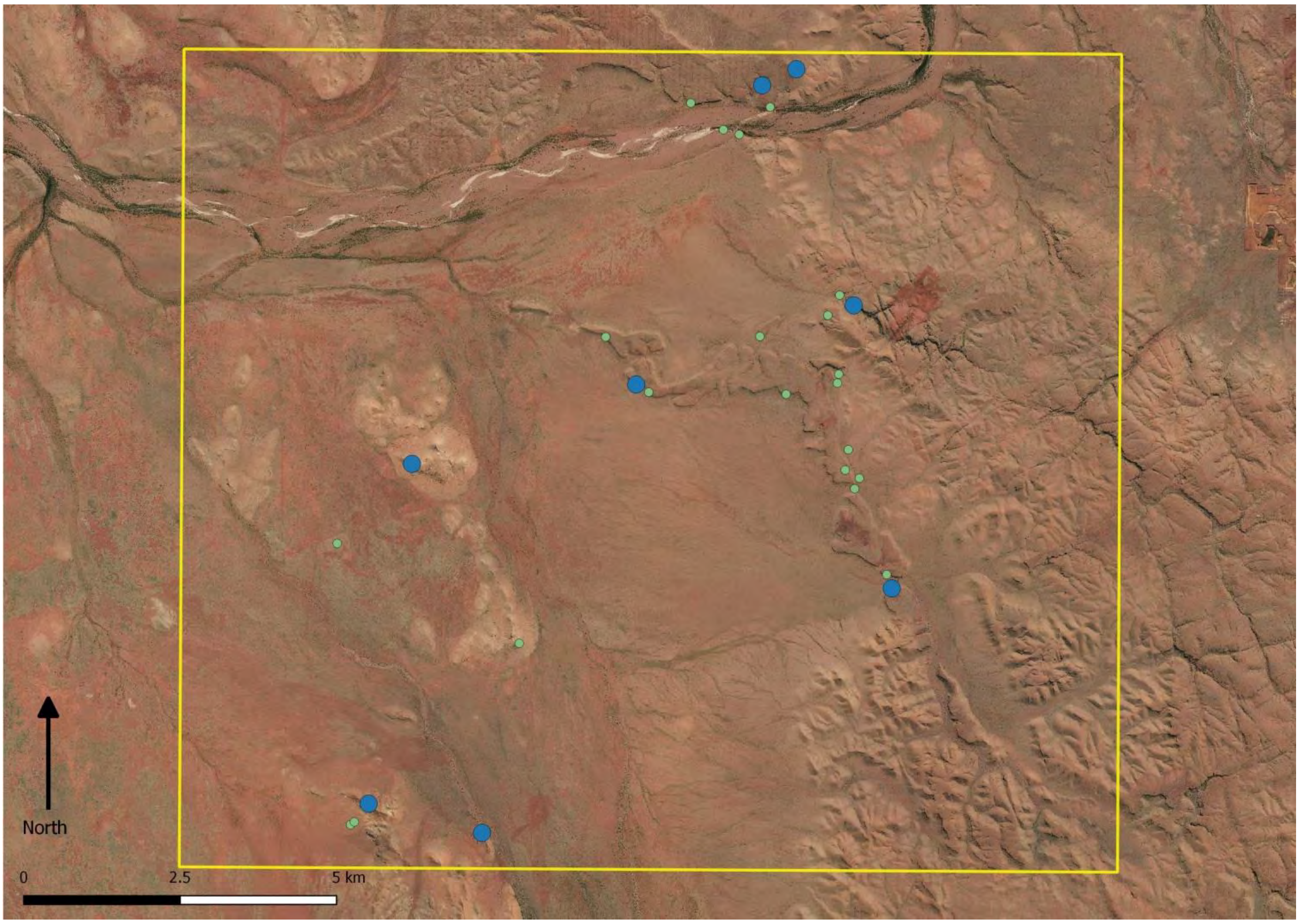


Figure 5. Location of camera traps set for detecting rock-wallabies at Yarraloola from mid-July to end of August 2015 within the trial cat baiting cell. Blue dots represent sites of rock-wallaby detections (one rock-wallaby at each site).

Appendix 1. Details of power analysis undertaken to determine the number of monitoring sites required to detect a significant change in northern quoll abundances.

I've looked at the trapping results from Yarraloola and Red Hill and estimated the amount of change in the <u>number of individuals</u> trapped/site that would be needed to get a statistically significant result (i.e. the 'detectable effect size').

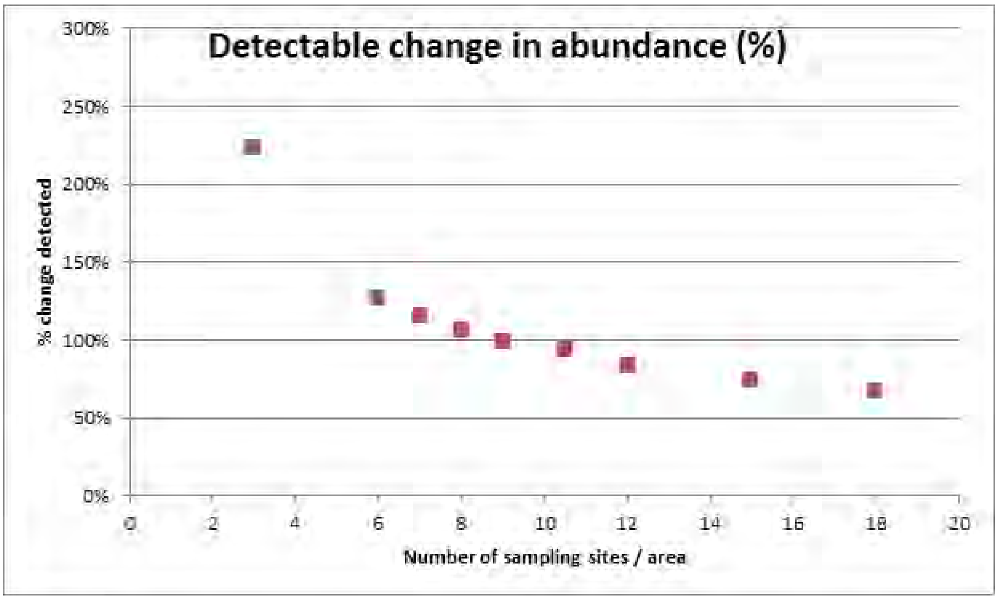
I've also looked at what change can be detected for various numbers of sample sites per sampling area. The current level of sampling is 10.5 sites/area (i.e. 11 at Yarraloola and 10 at Red Hill).

The current design could detect a change of 94% in one area (i.e. an increase in the average #individuals per site from 2.9 – the current overall average value – to 5.6).

Using 9 sites/area will likely detect a 99% change, whereas a doubling of that (18 sites/area) should detect a change of 67%.

At best, 4 years of sampling at 9 sites/area/year may detect a 46% change in abundance; 4 years of sampling at 18 sites/ area about 33%.

These large sample sizes arise because of the ~tenfold variability in the #NQs per site – from 0 to 11 at Red Hill, from 1 to 9 at Yarraloola



There are several important assumptions that must be noted for this analysis:

At each site there are 20 traps run for 4 nights, during a period when animals are reasonably active/trappable.

Trapping sites are located in areas where NQs are likely to be detected (only 1 site at Red Hill had 0 captures).

This is for 1 year of sampling (additional years will increase the effective sample size, by a factor of somewhere between 0 and 1). Variability in abundance between years is not yet known, and these calculations could be revisited when more data is available.

This analysis uses ANOVA of untransformed data. A more sophisticated log-linear model (over dispersed Poisson or negative binomial) gives mildly better precision, detecting an 80% (vs 94%) change, but may be difficult to apply to the repeated-measures data that will arise after several years of sampling.

Basic summary stats for the two areas are:

Individuals

site	sites	mean	se
Roy Hill	10	2.50	0.93
Yarraloola	11	3.18	0.89
Combined	21	2.86	
Difference		0.68	
Difference (%)		24%	

EMS	8.64
se.diff	1.28
p-value	0.60
alpha	0.05
D.E.Size	2.69
D.E. %	94%

Bootstrapped EMS for 9 sites/area is 7.9510, which was used in calculating the figures in the graph, other than for the actual sample of 10.5 sites/area

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Yandicoogina TSOP 2015 Mustering

Summary Report

Yarraloola Land Management Area

March 2016

V1

RTIO-HSE-0278945

Disclaimer and Limitation

This report has been prepared by Rio Tinto Iron Ore (**Rio Tinto**), on behalf of Hamersely Iron - Yandi (the **Proponent**), specifically for the Yandicoogina TSOP Program. Neither the report nor its contents may be referred to without the express approval of Rio Tinto, unless the report has been released for referral and assessment of proposals or made publically available for compliance reporting.

Document Status					
Rev	**Author**	**Reviewer/s**	**Date**	**Approved for Issue**	
				To Whom	**Date**
1	T Savage	M Brownlee, M Brand	08/03/16	OEPA / DoE	08/03/16

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FIGURES

1 BACKGROUND

In accordance with the Yandicoogina Threatened Species Offset Plan (**TSOP**) – Action 3, the Proponent (Hamersley Iron-Yandi Pty Limited (**HIY**)) is required to remove feral cattle from the Yarraloola Land Management Area (**LMA**) through an annual mustering program.

The aim of the 2015 muster was to reduce the number of unmanaged, introduced herbivores (namely stock from neighbouring pastoral stations and feral cattle) and thereby reduce their impacts within the LMA.

2 EXPECTED BENEFITS TO NORTHERN QUOLL AND PILBARA OLIVE PYTHON

Mustering will reduce the total number of cattle within the LMA by removing cattle belonging to neighbouring stations and feral cattle. This reduction is expected to benefit both the northern quoll and Pilbara olive python by reducing the impact of grazing within important foraging and dispersal habitat, in particular, riparian vegetation associated with the channel and permanent pools of the Robe River and other drainage lines.

3 SUMMARY OF 2015 PROGRAM

The 2015 mustering program included the following:

- Upon consultation and under agreement from HIY, the neighbouring Red Hill Station coordinated and completed the muster. Mustering took place in July 2015 and utilised a helicopter with buggies and motorbikes for the ground support team. Red Hill coordinated and completed the muster as the Yarraloola Station was in the process of securing a new leasee during the period of mustering.

- The area mustered covered approximately 3,490 hectares (**ha**). The attached Figure 4-1 represents the location of the muster area proximal to surface water and/or offering protection and shade.

- Approximately 500 cattle were collected during the muster. Almost 300 of these belonged to neighbouring pastoral properties and were removed. Very few feral cattle were collected.

- Therefore 200 cattle belonging to Yarraloola Station remain in the area.

4 PROPOSED 2016 PROGRAM

The muster program scheduled for 2016 will seek to address the following:

- The mustering will be implemented across the broader LMA, including the adjoining unallocated crown land (**UCL**).

- Mustering will continue to be coordinated with the lease holder of Red Hill Station and the new lease holder of Yarraloola Station.

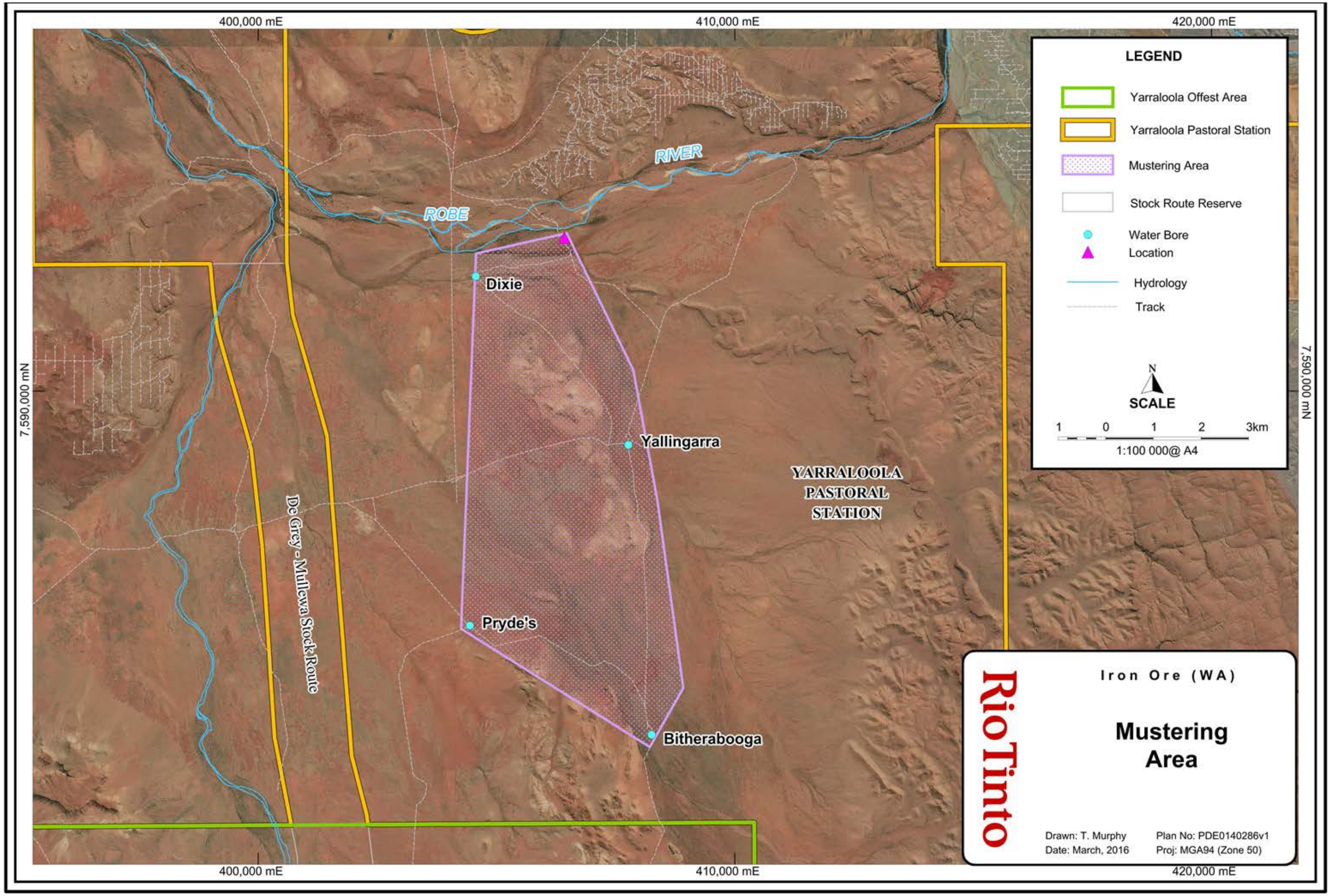

Figure 4-1: Muster Area

Yarraloola annual desktop fire regime monitoring: 2015

By Jane Chapman[1] and Katherine Zdunic[2]
[1]Research Officer (Remote Sensing)
[2]Senior Research Officer (Remote Sensing)
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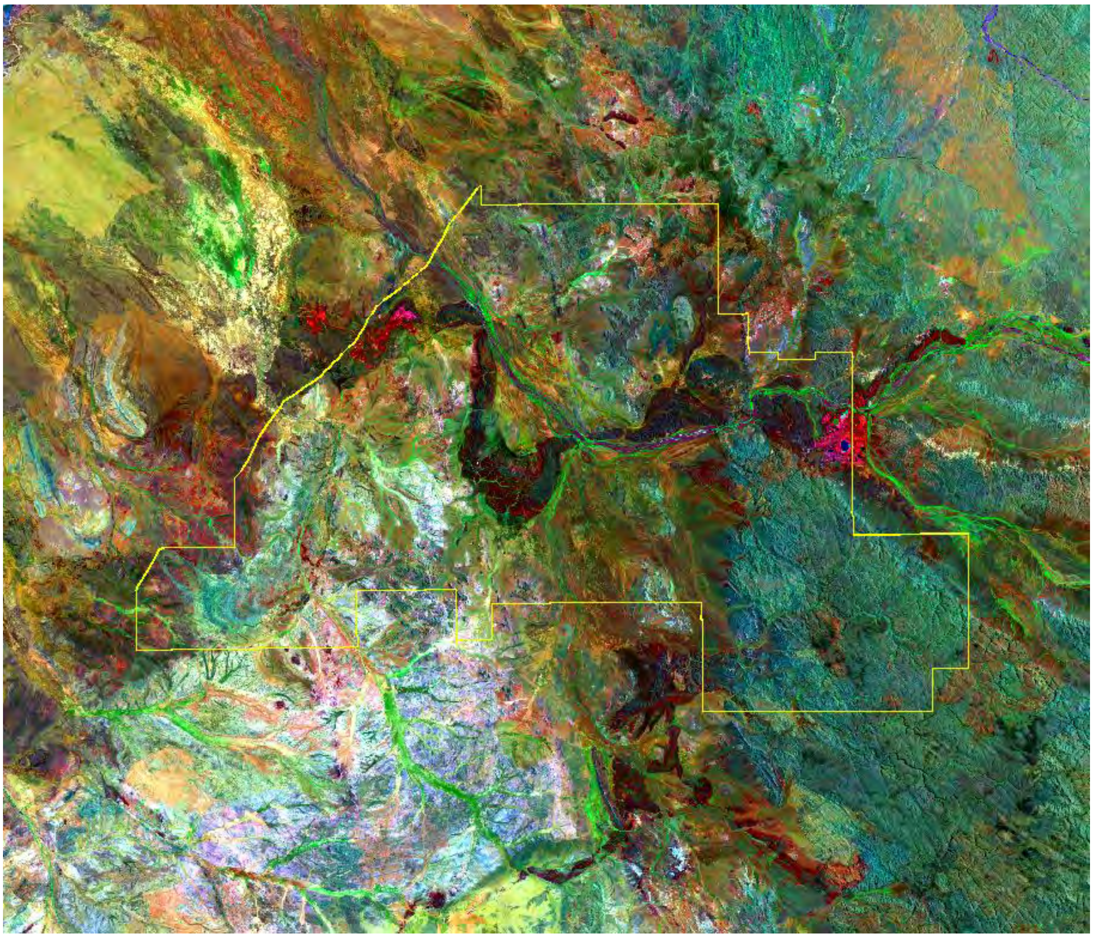
GIS Branch
Department of Parks and Wildlife

March 2016



Department of
Parks and Wildlife

Contents

1. Objective

This is the draft report which includes fire metrics over the Yarraloola pastoral lease and land management area for the time period 1999 – 2015. This draft report will require reviewing by Rio Tinto prior to the delivery of the finalised 2015 annual fire metric report. This report addresses the tasks outlined in the document Yandi TSOP - Annual desktop fire monitoring - SoW - DRAFT 21aug2014.doc.

The maps produced for this report are;

- Fire frequency across study area for all years of available data
- Fuel age across study area for all years of available data
- Seral states across study area

The fire metrics contained in this report are listed in Table 1.

Table 1: Fire metrics covered in the report for the period 1999 – 2015.

Metric	Status
Total area (ha) and proportion burned each year ▪ across entire study area ▪ within vegetation classes ▪ within mapped NQ & POP habitat	Achieved
Proportion of area within each fire frequency (No. times burnt over years for which data available) ▪ across study area ▪ within vegetation classes ▪ within NQ & POP habitat	Achieved
Proportion of area within each 'time since fire' (i.e. fuel age) class (0-3 yrs, 4-6 yrs, 7-9 yrs, 10-12 yrs, 13-15 yrs, >15 yrs) ▪ across study area ▪ within vegetation classes ▪ within NQ & POP habitat	Achieved
Proportion of area within each Spinifex seral state (after Burrows & Butler 2011) ▪ across study area ▪ within vegetation classes ▪ within NQ & POP habitat	Achieved, but limited to the 16 years of data currently available. BOM data is used for rainfall accumulation measures.
Proportion of area outside of the Fire regime groups; • 8 – 40 years • 20 – 40 years	Achieved
Size class distribution of burnt patches each year within study area (burn patch size classes to be determined following preliminary data analysis).	Discussed, agreed to be put on hold until improved data available.

2. Project area

The project area known as the Land Management Area (LMA) is indicated in blue on Figure 1, and indicates the area subject to analysis. In order to understand fires that occur close to, or overlap this boundary a 10km buffer area for map production only has been identified (Yarra_Fire_Monitoring_Project_Area_trans.shp). The composite vegetation mapping and fauna habitat areas used in the analysis have been supplied by Rio Tinto (YARRALOOLA_VEG_BROAD_RTIO_exported.shp; Yarraloola_potential NQ & POP habitat FINAL_trans.shp).

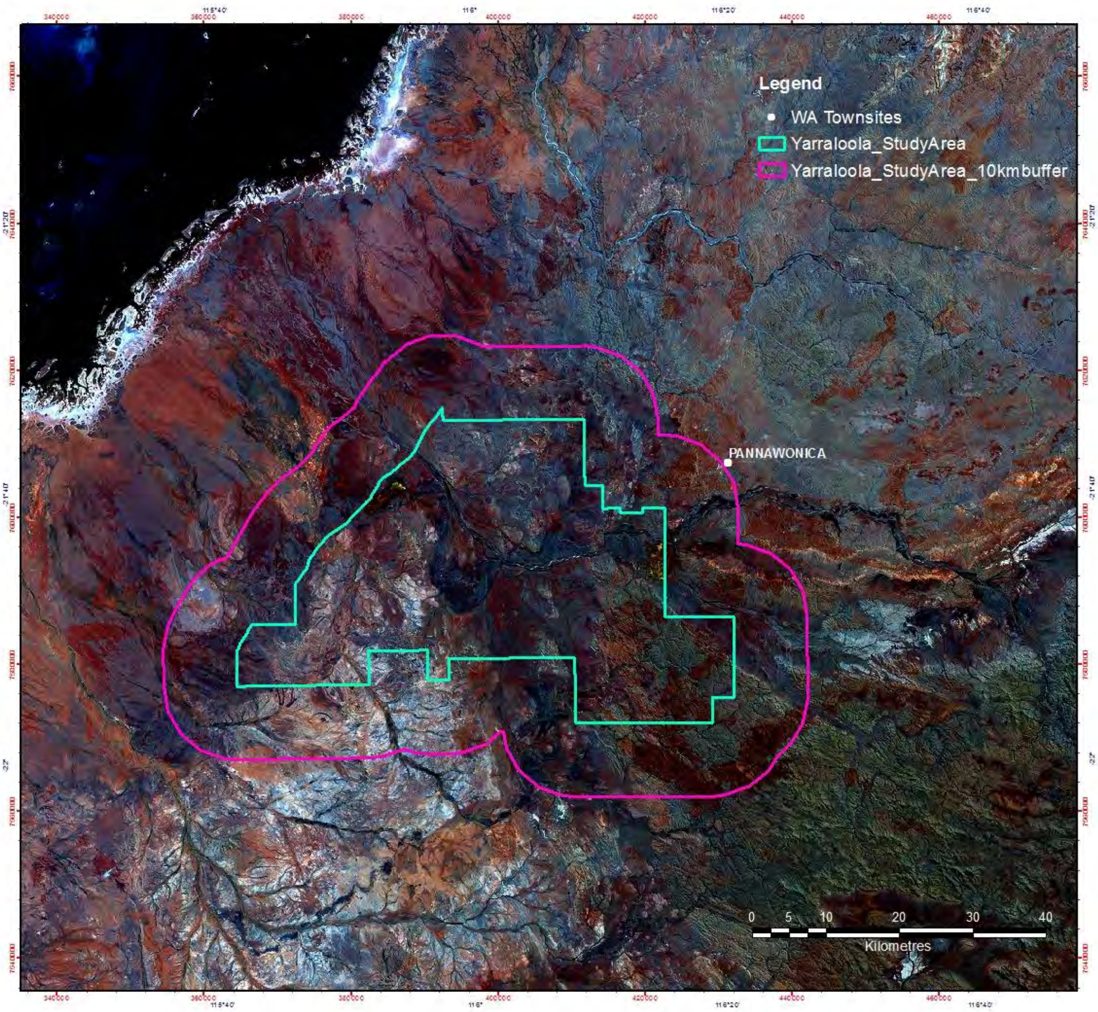


Figure 1: Yarraloola Land Management Area and 10km buffer area for map production

3. Data

Fire metrics were calculated using a combination of datasets provided by Rio Tinto, the Bureau of Meteorology (BoM) and the Department of Parks and Wildlife (DPaW). Table 2 displays the datasets utilised in the fire metrics analysis.

Table 2: Datasets used in the Yarraloola fire metric analysis.

Dataset	Source	Description
yarra_fire_interval_diss_20141003.shp	Rio Tinto	Fire regime boundaries
Yarraloola_potential NQ & POP habitat FINAL_trans.shp	Rio Tinto	Northern Quoll and Pilbara Olive Python habitat extent
Yarra_Fire_Monitoring_Study_Area_exported.shp	Rio Tinto	Yarraloola LMA boundary
Yarra_Fire_Monitoring_Project_Area_trans.shp	Rio Tinto	Yarraloola LMA boundary
YARRALOOLA_VEG_BROAD_RTIO_exported.shp	Rio Tinto	Yarraloola vegetation mapping
IDCJAC0009_005069_1800_Data.csv	BoM	Rainfall data for station

		number 5069
Pilbara_fires_Z50_1999.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2001.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2003.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2004.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2006.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2007Oct.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2008.shp	DPaW	Fire scar boundaries
Pilbara_fires_Z50_2009.shp	DPaW	Fire scar boundaries
114075_2010-2011_FireScars.shp	DPaW	Fire scar boundaries
114075_2011-2012_FireScars.shp	DPaW	Fire scar boundaries
11475_2012-2013_FireScars.shp	DPaW	Fire scar boundaries
Fortescue_and_Offshore_Fires_2013_2014.shp	DPaW	Fire scar boundaries
Fortescue_River_Catchment_fire_mapping_2015.shp	DPaW	Fire scar boundaries
201516_Pilbara_Fire_Mapping_mga50.shp	DPaW	Fire scar boundaries

3.1 Landsat satellite imagery

Since 1972, NASA and the US Geological Survey have been launching and managing Landsat satellites, which have provided continuous image coverage of the Earth's surface to date (http://landsat.usgs.gov/about_mission_history.php). Access to this historic archive of images for viewing and analysis, is fundamental in constructing a fire history. Landsat 5, 7and 8 satellite imagery has a 30 metre pixel resolution and slightly different band specifications. For Landsat 7 and 8 these differences are shown in Figure 2.

Fire scars for 1999 -2015 were mapped across path row 114/075 using Landsat Satellite imagery. The Landsat index system of path row uses first number of the scene e.g. "114" to refer the path and second number e.g. "075" to refer the row, which identify specific locations of the satellite imagery covering the entire earth.

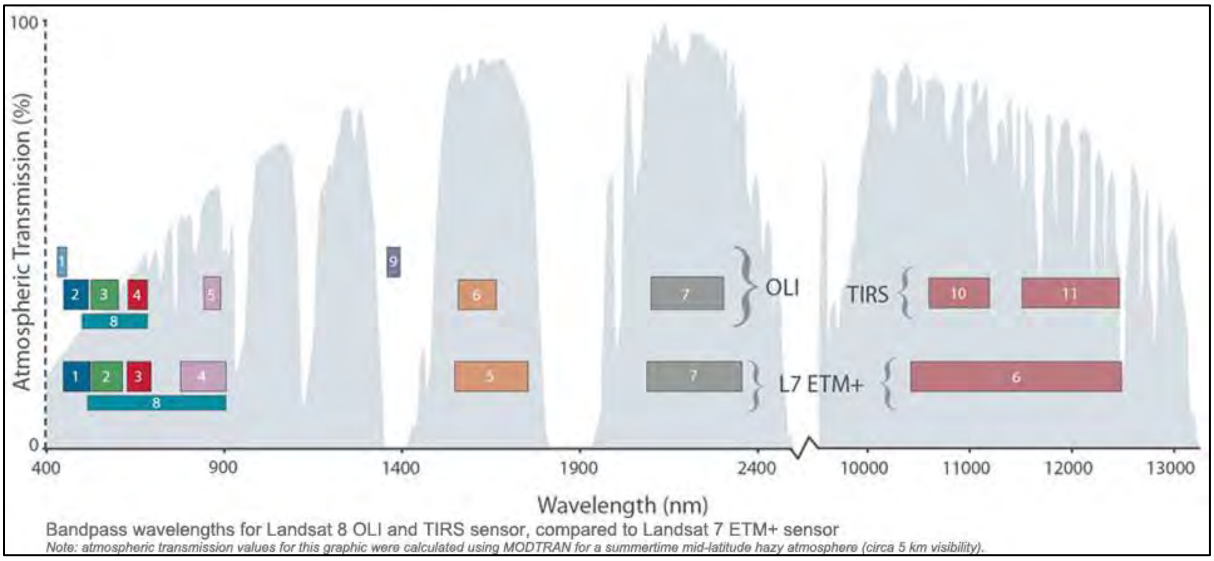


Figure 2: Landsat satellite bands comparison (USGS website accessed 30/10/2015 http://landsat.usgs.gov/L8_band_combos.php).

3.2 Historical fire mapping

In the past fire mapping was carried out from continental Landsat mosaics produced for the National Carbon Accounting System (NCAS); (http://www.ga.gov.au/scientific-topics/earth-obs/accessing-satellite-imagery/ordering/product-information/landsat-continental-mosaic). Fire mapping was produced for the dates below and are only attributed with the image date, not the fire ignition date (Table 3). Historically the cost of Landsat imagery was prohibitively high and so historical fire scar mapping was only completed using the NCAS Landsat mosaics. The NCAS data is not annual in the time period 1999 to 2006, and the historical fire mapping reflects this with annual data missing from 2000, 2002 and 2005. In more recent years Landsat data has become freely available from the USGS archive (http://landsat.usgs.gov/), and this data has been used to generate annual difference images. Again the fire scar is only attributed with the image date and not the fire ignition date.

Pre-processing of imagery is required to make it appropriate for use in time series analysis. This requires the position of the imagery to be co registered and differences due to sun angle and atmosphere resolved. Imagery sourced from NCAS has been processed for time series analysis with rectification and calibration to a common reference (Caccetta et al., 2007). Imagery sourced from USGS has systematic processing applied to ensure rectification is appropriate for time series analysis http://landsat.usgs.gov/Landsat_Processing_Details.php). Variations due to differing illumination angles in USGS data are resolved using software provided by CSIRO using methods developed by Wu et al. (2001).

Table 3: Historical fire mapping image sources and dates over the Yarraloola pastoral lease.

Source data	Image date	Mapping Year
NCAS	23/11/1999	1999
NCAS	16/02/2002	2001
NCAS	21/06/2004	2003
NCAS	16/02/2005	2004
NCAS	06/02/2007	2006
NCAS	04/10/2007	2007
NCAS	10/01/2009	2008
NCAS	14/02/2010	2009
USGS	23/12/2010	2010
USGS	12/02/2012	2011
USGS	02/03/2013	2012
USGS	25/02/2014	2013
USGS	16/03/2015	2014
USGS	29/12/2015	2015

3.3 Vegetation complex mapping

The vegetation mapping dataset was provided by Rio Tinto. This dataset was used to calculate area based statistics for each vegetation complex within the Yarraloola LMA. The total areas and the description for each vegetation class are listed in Table 4. Figure 3 displays a map of Yarraloola LMA and the supplied vegetation mapping.

Table 4: Vegetation classes and area statements over Yarraloola Land Management Area.

Vegetation class ID	Description	Area (ha)
1	Acacia sparse shrubs over Chenopod isolated low shrubs over mosaic of mid-dense to sparse tussock grasses and Triodia hummock grasses on stony plains	35384
2	Acacia sparse to very sparse shrubs over mid-dense to sparse Triodia hummock grasses on plains	37419
3	Eucalyptus and Melaleuca tall open forest or tall woodland over Acacia & Melaleuca tall open shrubland over mixed open tussock and hummock grassland in major drainage lines	6674
4	Isolated medium Eucalyptus and Corymbia trees over sparse to isolated Acacia shrubs over mid-dense Triodia hummock grasses on low hills and plains	19113
5	Isolated or emergent medium Eucalyptus trees over isolated to very sparse Acacia shrubs over mid-dense Triodia hummock grass on hills, ridges and mesas.	64118
6	Mid-dense to very sparse Eucalyptus trees over mid-dense Acacia shrubs over mid-dense Triodia hummock grasses on minor drainages	224
7	Sparse medium Eucalyptus trees over mid-dense to sparse Acacia and Eremophila shrubs over sparse to very sparse hummock and tussock grasses on minor incised drainage lines	281

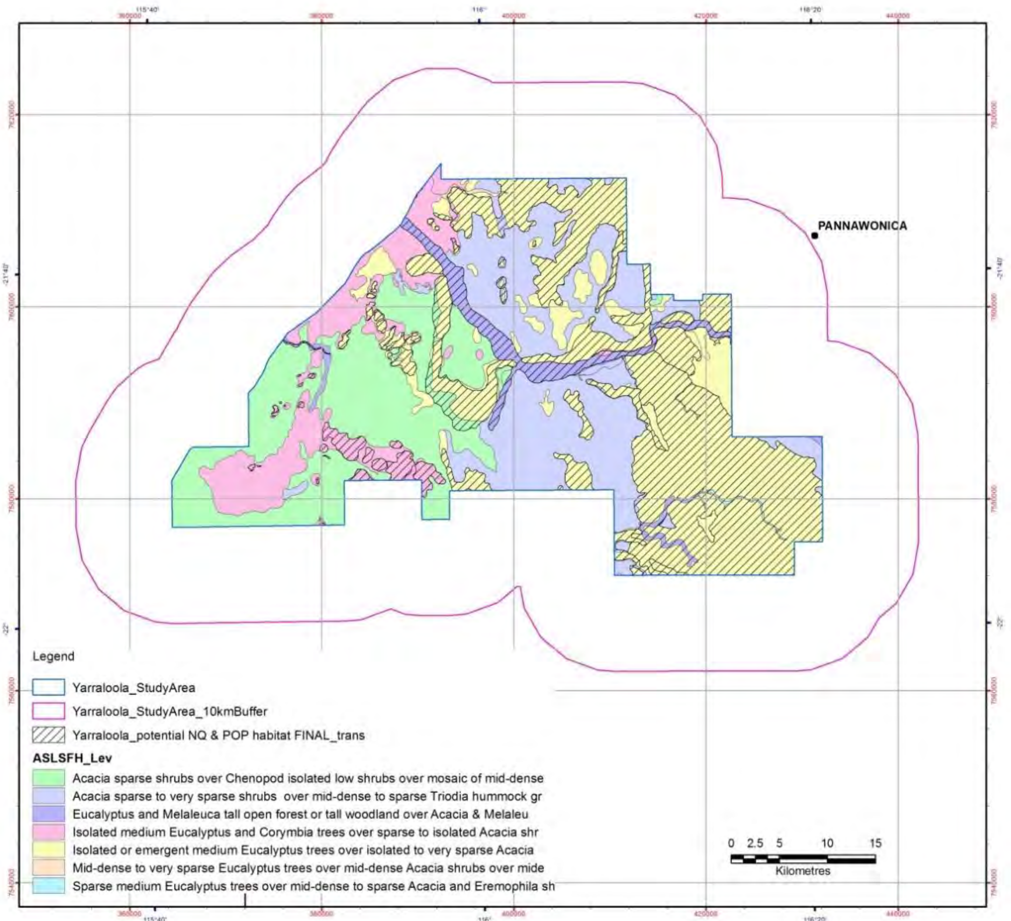


Figure 3: Yarraloola Land Management Area, vegetation mapping and fauna habitat.

3.4 Northern Quoll and Pilbara Olive Python boundary

An ESRI shapefile with the habitat extent of the Northern Quoll (NQ) and Pilbara Olive Python (POP) was provided by Rio Tinto. Mapped habitat for both NQ and POP is based on land system mapping (van Vreeswyk *et al.*, 2004) and represents a coarse estimate of available habitat within the LMA. The total area of the fauna habitat covers 65,665 hectares of Yarraloola LMA. Figure 3 displays a map of the fauna habitat within Yarraloola LMA. Throughout this document the habitat area for the fauna will be referred to as the NQ and POP habitat.

3.5 Seral state

Determination of the seral state is based on time since fire or accumulated rainfall, which determines how much growth there has been post-fire (Burrows and Butler, 2011). Table 5 displays the seral states for spinifex dominated ecosystems.

Table 5: Seral states of vegetation based on time since last fire and accumulated rainfall (Burrows and Butler, 2011).

Seral state	Time since fire and accumulated rainfall
Very early	fuel age <=6 yrs or 1500mm accumulated rain
Early	6 yrs < fuel age<=12 yrs or 1500mm < accumulated rain <=3000mm
Intermediate	12 yrs< fuel age <=24 yrs or 6000mm<accumulated rain<=6000mm
Late	24 yrs < fuel age <= 36 yrs or 6000mm<accumulated rain<=9000mm
Very late	fuel age > 36 yrs or >9000mm accumulated rain

To determine the number of years in each seral state category rainfall data was acquired from the BoM for station number 5069 (Pannawonica). Based on Burrows and Butler (2011) research the accumulated rainfall was the determining factor rather than fuel age for the breakdown of the landscape into seral states. The fuel age dataset was classified using the dates from the rainfall accumulation to establish the seral state of the vegetation (Table 6).

Table 6: Classification of Yarraloola fire mapping years into seral states based on accumulated rainfall.

Year	Rainfall (mm)	Cumulative Sum rainfall (mm)	Seral state
2015	417.2	417.2	
2014	326.0	743.2	
2013	389.0	1132.2	
2012	300.4	1432.6	Very early
2011	574.8	2007.4	
2010	261.2	2268.6	
2009	584.8	2853.4	Early
2008	552.0	3405.4	
2007	130.2	3535.6	
2006	700.2	4235.8	
2005	331.5	4567.3	
2004	618.2	5185.5	Intermediate
2003	199.9	5385.4	
2002	112.8	5498.2	
2001	346.2	5844.4	
2000	698.9	6543.3	
1999	562.4	7105.7	Late

3.6 Fire regime areas

The fire regime dataset was provided by Rio Tinto. There are two fire regimes investigated in this report; fire regime 8-40 years which covers 120,649 hectares and fire regime 20-40 years which covers 42,563 hectares of the Yarraloola LMA.

4. Methodology

The methodology describes both the capture of the fire scar extents and the calculation of the fire metric statistics.

4.1 Fire scar mapping

Fire scar data from 1999 – 2015 was used to generate the fire metrics. For each Landsat scene, an annual image was analysed, with annual images missing for the years 2000, 2002 and 2005. In the period 2000-2009 previous fire mapping derived from NCAS Landsat images has been used and there was no control over image date selection. In the 1999 and 2010-2015 fire mapping, to minimise the effect of seasonal variation, January Landsat images were selected, however due to image availability, quality and cloud cover this was not always possible. Therefore imagery dates vary between December and March.

To identify fire scars from annual Landsat imagery three techniques were utilised. This involved visualisation using false colour displays and identification of fire scar extents from differenced normalised burn ratio (dNBR) images and differenced near infrared band (dNIR) images. These techniques are discussed in the following sections and were performed using ER Mapper v14 image processing software.

4.1.1 False colour image displays

The use of mid-Infrared and near-Infrared in the false colour band combination of Landsat bands 7, 4 and 2 displayed in bands red, green and blue, is suitable for detecting the loss of moisture and vegetation in arid environments and due to fire. Recent fire scars appear as dark red in this type of display and older fire scars as lighter reds. The use of Landsat bands 7 and 4 is strategic as these bands are used in the dNBR and dNIR images used to determine the fire extent. When examining multiple years of imagery real changes due to fire become more obvious.

4.1.2 Differenced normalised burn ratio (dNBR)

The normalised burn ratio (NBR) has been in use since the late 1990's to identify fires in Landsat imagery (Carl and Benson, 1999). If the vegetation has recovered to the same state between the ignition date and the Landsat annual image date then there will not be enough of a "difference" between the images and the fire scar will not be detected. The equation for the NBR (equation 1), results in a single image band with values from -1 to +1, where the fire scars have negative image values.

$$NBR = (band4 - band7) / (band4 + band7) \qquad EQ.1$$

The fire scar extents for a Landsat image date can be isolated using the negative values of the equation that represent the fire scar. However, this may extract other locations in the landscape, which are not a result of fire. Using the differenced NBR (dNBR), which compares the NBR of the current year with the NBR of the previous year (equation 2), can provide a clear image of the fire scar only occurring in the current year.

dNBR = NBR previous year – NBR current year *EQ.2*

4.1.3 Differenced near infrared band (dNIR)

When using false colour image displays and dNBR images to detect fire scars alone it was evident that detecting fires that had burnt several months prior to the date of image acquisition was not always possible. This was due to the apparent post-burn 'greening-up' of the burnt area. In this spinifex dominated environment when there is regrowth following fire the new growth has significantly more chlorophyll or greenness than the pre burn vegetation. Consequently, a simple difference between the Near Infrared (NIR) reflectance values of the current and previous year images was used to highlight the difference between the increases in chlorophyll occurring in the new vegetative growth (Lowenthal, 2014; equation 3). With reference to the false colour display image, this ratio detected burns that were not identified by the dNBR image.

dNIR = NIR (previous year) – NIR (current year) *EQ.3*

4.1.4 Fire extent mapping

In order to map the extent of fire scars image value thresholds are applied to the dNBR and dNIR images to separate the fire scars from fluctuations the rest of the image. Due to the variation between image dates and ignition dates of fires, different dNBR and dNIR image thresholds are required for each fire scar identified in an annual image. The result of this is a raster mask of each fire scar which accurately represents the extent of the burn including the gaps and patchiness of the burn as identified by the imagery, not a generalised outer boundary.

4.2 Fire metric statistics

Metrics were derived from the fire scar datasets using ArcGIS 10.3. This software is geographical information systems software that allows the viewing, analysis and storage of spatial data.

4.2.1 Vector data cleaning

Fire scar shapefiles were examined for errors in the data which might cause errors in the area statistics. Duplicate polygons were found and removed. Duplicate polygons can occur when the same fire is mapped more than once, this is more common around the edges of Landsat scene boundaries. In order to find duplicate polygons within each year of fire scar mapping the "Count Overlapping Polygons" toolbox in ArcGIS was used (http://blogs.esri.com/esri/arcgis/2012/11/13/spaghetti_and_meatballs/). Duplicate polygons were then deleted. Part of the cleaning process was to ensure all data were in the same coordinate system and that all datasets had been repaired using the "Repair Geometry" tool in ArcGIS.

Once all the individual years of fire scar datasets were cleaned they were merged into one shapefile and clipped to the Yarraloola LMA 10km buffer shapefile using the "Clip" tool in ArcGIS. This dataset was further clipped to the Yarraloola LMA area of interest.

4.2.2 Fire frequency

The fire frequency dataset was created by running the "Count Overlapping Polygons" toolbox on the shapefile of combined fire scar datasets. This tool gives every polygon in the dataset a "Join_count" value. This value represents how many times that area has burnt over the time period. The Fire frequency for habitat shapefile was created by clipping the original Fire frequency shapefile to the habitat boundary provided by Rio Tinto. The original Fire frequency shapefile was intersected with the vegetation and fire regime shapefile provided by Rio Tinto to extract those fire metrics. From the final fire frequency shapefiles area totals in hectares were calculated for the various classes and categories and the metrics were derived from these.

4.2.3 Fuel age and seral state

The fuel age dataset was created by using the "Union" tool. The tool uses each cleaned individual shapefile of fire scar mapping and creates a dataset where the attributes of each polygon are merged together. For example an area which burned in 2005 and 2009 will contain both year attributes. A new field "YEAR" was added to the fuel age shapefile. By using a selection query this field was attributed with the most recent "Map_YR" attribute. For example, a polygon which burnt 3 times in 2001, 2006 and 2009 will have the "YEAR" attribute of 2009 as that represents the last time it burnt and the fuel age is calculated from that value. In the display for the fuel age shapefile fire scars were grouped into fuel ages by the categories 0 – 3 years (2015, 2014, 2013), 4 – 6 years (2012, 2011, 2010), 7 – 9 years (2009, 2008, 2007), 10 - 12 years (2006, 2004), 13 – 15 years (2003, 2001) and > 15 years (1999). The fuel age for habitat shapefile was created by clipping the original fuel age shapefile to the habitat boundary provided by Rio Tinto. The original fuel age shapefile was intersected with the vegetation and fire regime shapefile provided by Rio Tinto to extract those fire metrics. From the final fuel age shapefiles area totals in hectares were calculated for the various classes and categories and the metrics were derived from these.

The seral state shapefiles were created from the fuel age dataset. The seral states were based on different groupings of years. Seral states were broken down into Very early (2015, 2014, 2013, 2012), Early (2011, 2010, 2009), Intermediate (2008, 2007, 2006, 2004, 2003, 2001) and Late (1999).

4.2.4 Graphing fire metrics

Graphs were produced using the statistical package R (https://www.r-project.org/). This enables repeatability in the graphing as a script has been produced for each graph set up and annual updates require the latest data to be entered.

5. Results

The results address the fire metrics requested and listed in Table 1. As there are many tables and figures relating to each fire metric for ease of navigation the structure of this section is outlined in Table 7.

Table 7: Structure of the fire metrics results.

Metric	Category	Graphs/ tables
5.1 Total area (ha) and proportion burned each year.	5.1.1 Across entire study area	Table 9 Figures 4, 5, 6
	5.1.1 Within mapped NQ & POP habitat	Table 9 Figures 5, 6
	5.1.2 Within vegetation classes	Tables 10, 11 Figures 7, 8 Alternative style graphs: Figure 9 and Figure 10
5.2 Proportion of area within each fire frequency (No. times burnt over years for which data available).	5.2.1 Across entire study area	Fire frequency map Figure 11 Table 12 Figures 12, 13, 14
	5.2.1 Within mapped NQ & POP habitat	Table 12 Figures 12, 13, 14
	5.2.2 Within vegetation classes	Tables 13, 14 Figures 15, 16, 17 Alternative style graphs: Figure 18 and Figure 19
5.3 Proportion of area within each 'time since fire' (i.e. fuel age) class (0-3 yrs, 4-6 yrs, 7-9 yrs, 10-12 yrs, 13-15 yrs, >15 yrs).	5.3.1 Across entire study area	Fuel Age map Figure 20 Table 16 Figures 21, 22, 23
	5.3.1 Within mapped NQ & POP habitat	Table 16 Figures 21, 22, 23
	5.3.2 Within vegetation classes	Tables 17, 18 Figures 24, 25, 26 Alternative style graphs: Figure 27 and Figure 28
5.4 Proportion of area within each Seral state.	5.4.1 Across entire study area	Fuel Age map Figure 29 Table 19 Figures 30, 31, 32
	5.4.1 Within mapped NQ & POP habitat	Table 19 Figures 30, 31, 32
	5.4.2 Within vegetation classes	Tables 21, 22 Figures 33, 34, 35 Alternative style graphs: Figure 36 and Figure 37
5.5 Proportion of area outside of the Fire regime groups;	8 – 40 years and 20 – 40 years	Fire regime map Figure 38 Table 23

In order to provide context of each variable across the Yarraloola LMA the area of each variable that fire metrics were calculated for is displayed in Table 8.

Table 8: Area statistics for each zone; area statements were used to calculate metrics based on these zones.

Zone	Total area (ha)	% of study area
Yarraloola LMA	163,214	100
POP NQ Habitat	65,665	40
Fire Regime 8 – 40 yrs	120,649	74
Fire Regime 20 – 40 yrs	42,563	26
Vegetation class 1	35,384	22
Vegetation class 2	37,419	23
Vegetation class 3	6,674	4
Vegetation class 4	19,113	12
Vegetation class 5	64,118	39
Vegetation class 6	224	< 1
Vegetation class 7	281	< 1

5.1 Total area and proportion burned in each fire mapping year

The following statistics show total area burnt in hectares for each year of available fire mapping. A variety of graphs and tables are presented for each fire metric to allow for different options to be explored. Metrics calculated are provided as;

Total area (ha) and proportion burned each year:

- across the entire study area
- within mapped NQ & POP habitat
- within vegetation classes

The rainfall data for Pannawonica station was obtained via the Bureau of Meteorology website and is displayed in Figure 4 along with the total area (ha) burnt for each year of available fire mapping.

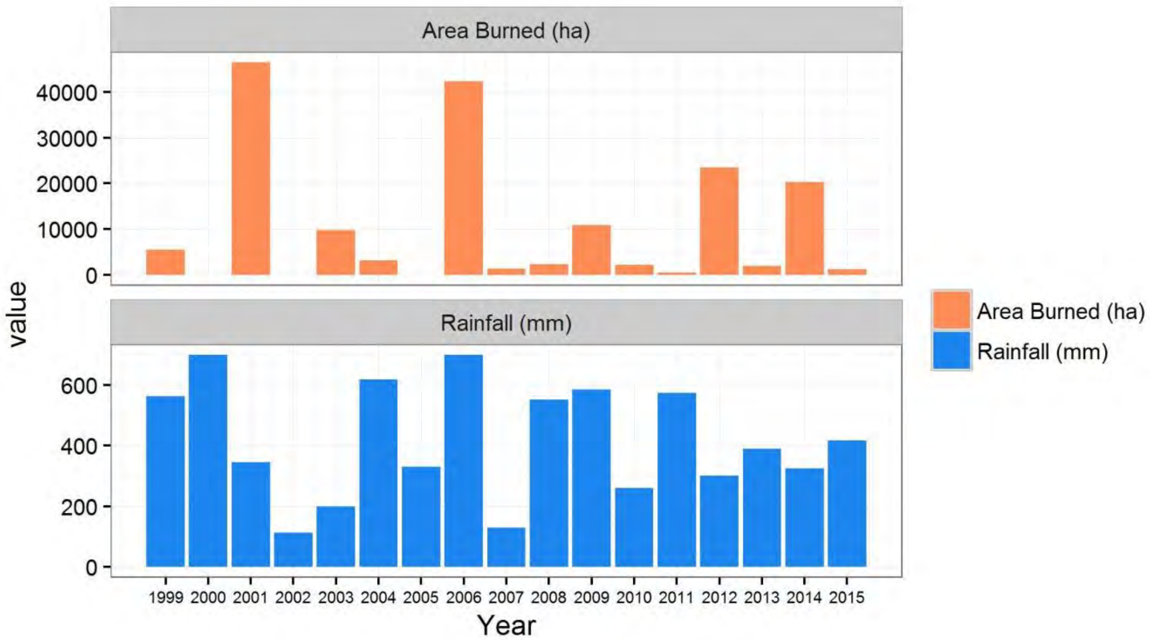


Figure 4: Annual rainfall (mm) from Pannawonica station and area burned (ha) for each year of available mapping, note no fire mapping available for the years 2000, 2002 and 2005.

5.1.1 Across Yarraloola LMA and mapped NQ & POP habitat

The NQ and POP habitat and total Yarraloola area metrics have been combined in both the tables and figures as the NQ and POP habitat is a subset of the total area and this reduces the number of tables, graphs and figures. Table 9 displays the total area of land mapped as burnt over Yarraloola and the NQ and POP habitat. The percentages based on these area figures are also displayed in Table 9. Figures of the area statements are displayed in Figure 5 and percentages values are displayed in Figure 6.

Table 9: Total area and percentage of land burnt (ha) over Yarraloola LMA and NQ & POP habitat for each year of available fire mapping.

Total area (ha) Percentage	Year													
	1999	2001	2003	2004	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Yarraloola	5488	46470	9824	3182	42330	1293	2268	10843	2188	522	23531	1986	20362	1205
%	3	28	6	2	26	1	1	7	1	<1	14	1	12	1
NQ/POP Habitat	477	13717	5490	105	21888	187	211	2009	203	1	8460	402	15871	28
%	1	21	8	<1	33	<1	<1	3	<1	<1	13	1	24	<1

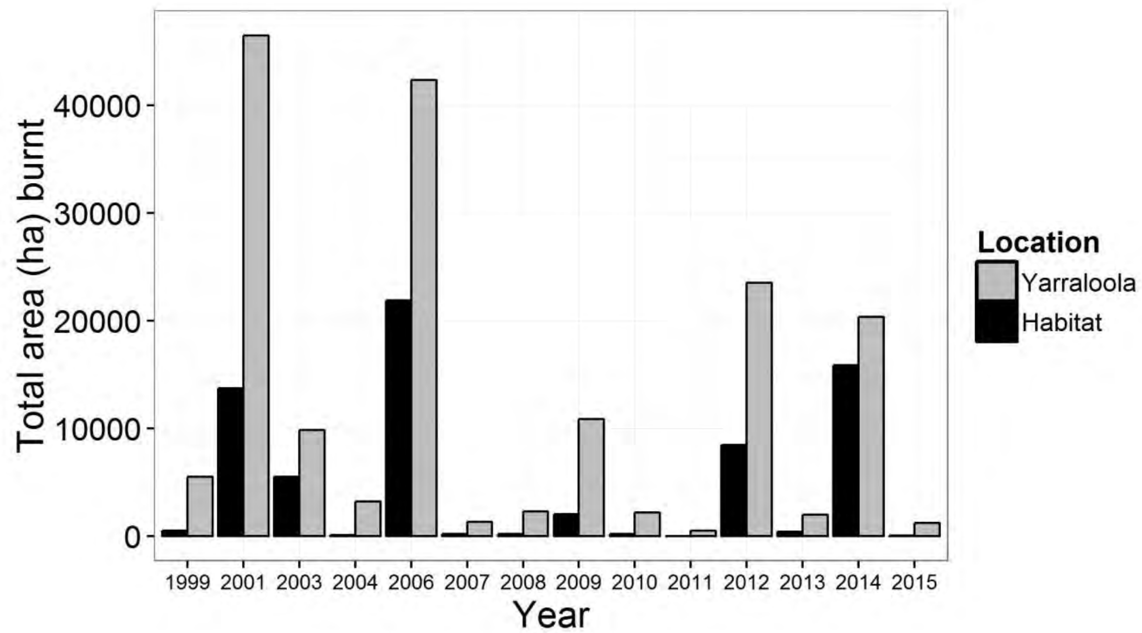


Figure 5: Total area (ha) burnt per year across Yarraloola LMA and NQ & POP habitat.

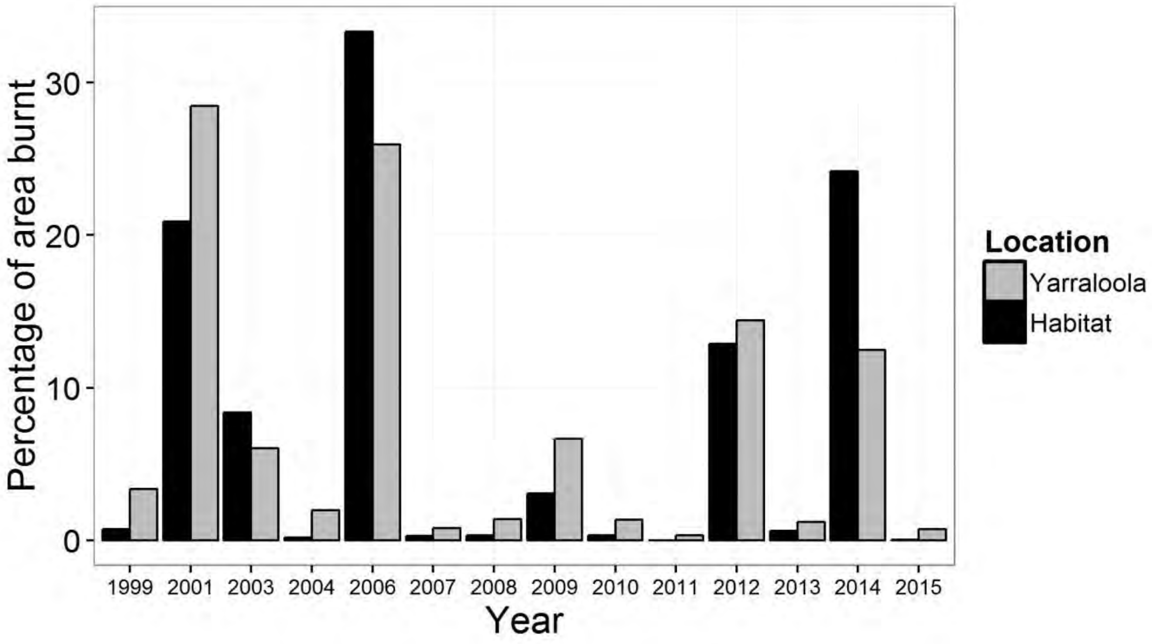


Figure 6: Total percentage burnt per year across Yarraloola LMA and NQ & POP habitat range.

5.1.2 Vegetation classes

Table 10 displays the total area of land mapped as burnt across the different vegetation classes. The percentages based on these area figures are displayed in Table 11. Figures of the area statements are displayed in Figure 7 and percentages of those figures are displayed in Figure 8. Alternative graphs for displaying the metrics for vegetation classes across Yarraloola LMA are displayed in Figure 9 and Figure 10. These display the same data but give an alternative visual representation.

Table 10: Total area in hectares of area burnt over Yarraloola LMA within the vegetation classes for each year of available fire mapping.

Total area (ha) per Veg class	Year 1999	2001	2003	2004	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	451	18124	784	992	932	0	1688	6938	0	519	6019	1270	342	928
2	2883	6255	2962	0	13042	906	385	1330	1985	0	4502	0	3378	0
3	174	1162	592	390	246	45	13	32	0	0	382	0	487	29
4	1109	8484	63	1756	4122	0	56	1259	0	2	3962	320	578	28
5	871	12765	5406	44	23680	343	126	1283	203	0	8661	395	15540	0
6	0	52	0	0	205	0	0	0	0	0	0	0	0	0
7	0	43	17	0	102	0	0	0	0	0	4	0	36	0

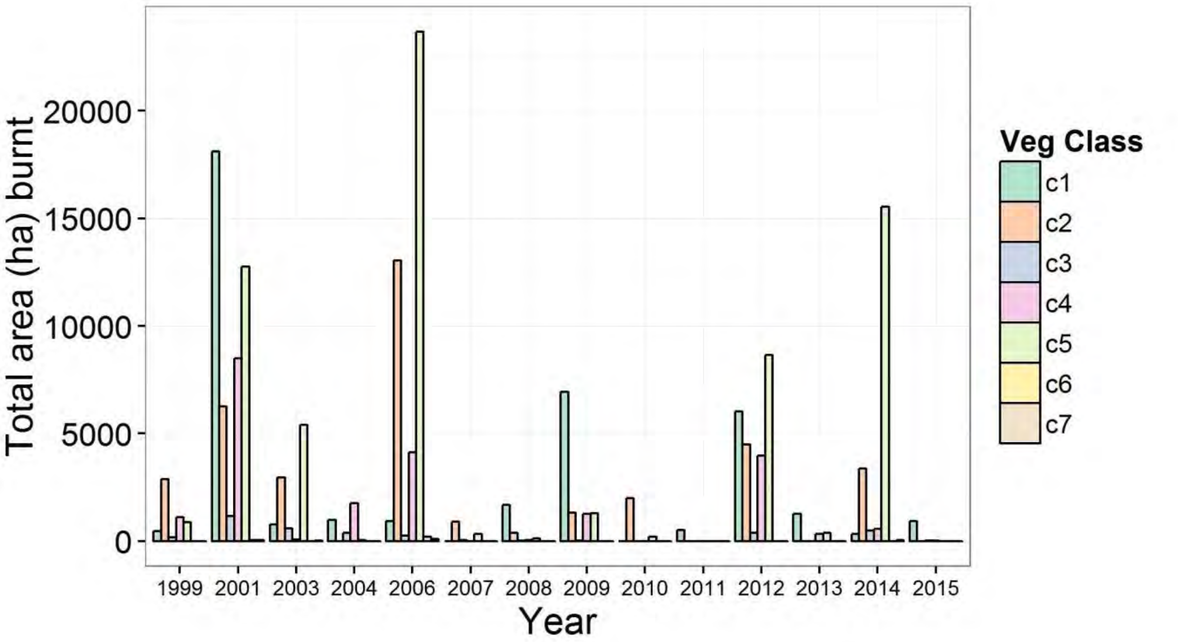


Figure 7: Total area (ha) burnt per year across Yarraloola LMA Vegetation classes for each year of available fire mapping.

Table 11: Total percentage of area burnt over Yarraloola LMA within the vegetation classes for each year of available fire mapping.

% area Veg class	1999	2001	2003	2004	2006	Year 2007	2008	2009	2010	2011	2012	2013	2014	2015
1	1	51	2	3	3	0	5	20	0	1	17	4	1	3
2	8	17	8	<1	35	2	1	4	5	0	12	<1	9	0
3	3	17	9	6	4	1	<1	<1	0	0	6	0	7	<1
4	6	44	<1	9	22	0	<1	7	0	<1	21	2	3	<1
5	1	20	8	<1	37	1	<1	2	<1	0	14	1	24	0
6	0	23	0	0	92	0	0	0	0	0	0	0	0	0
7	0	15	6	0	36	0	0	0	0	0	1	<1	13	0

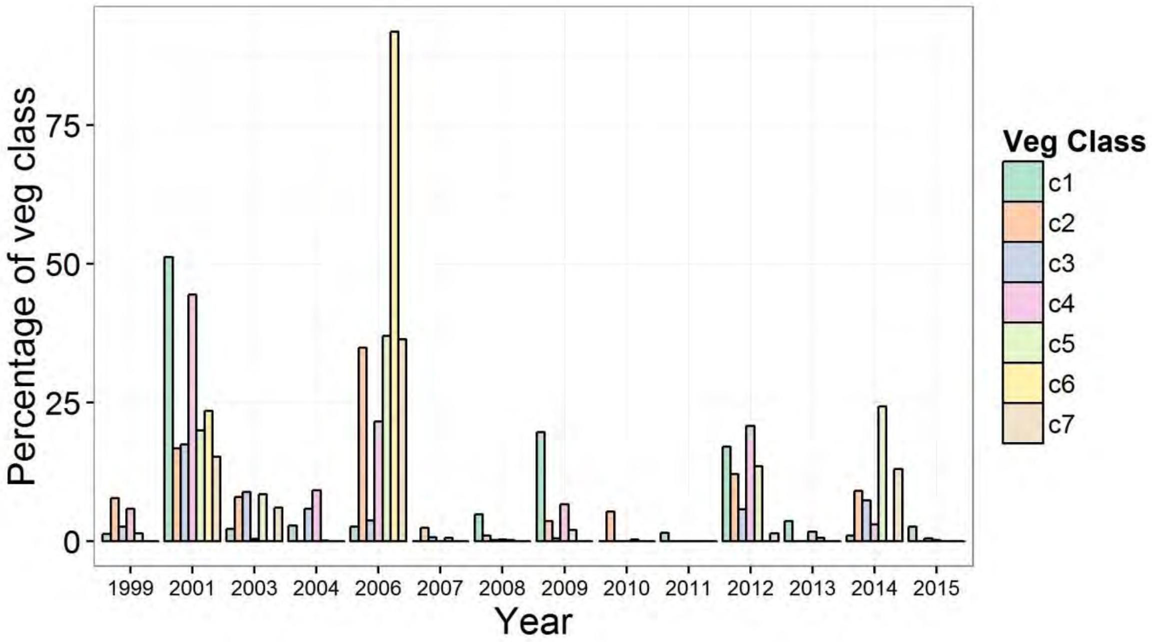


Figure 8: Total percentage burnt per year across Yarraloola LMA Vegetation classes for each year of available fire mapping.

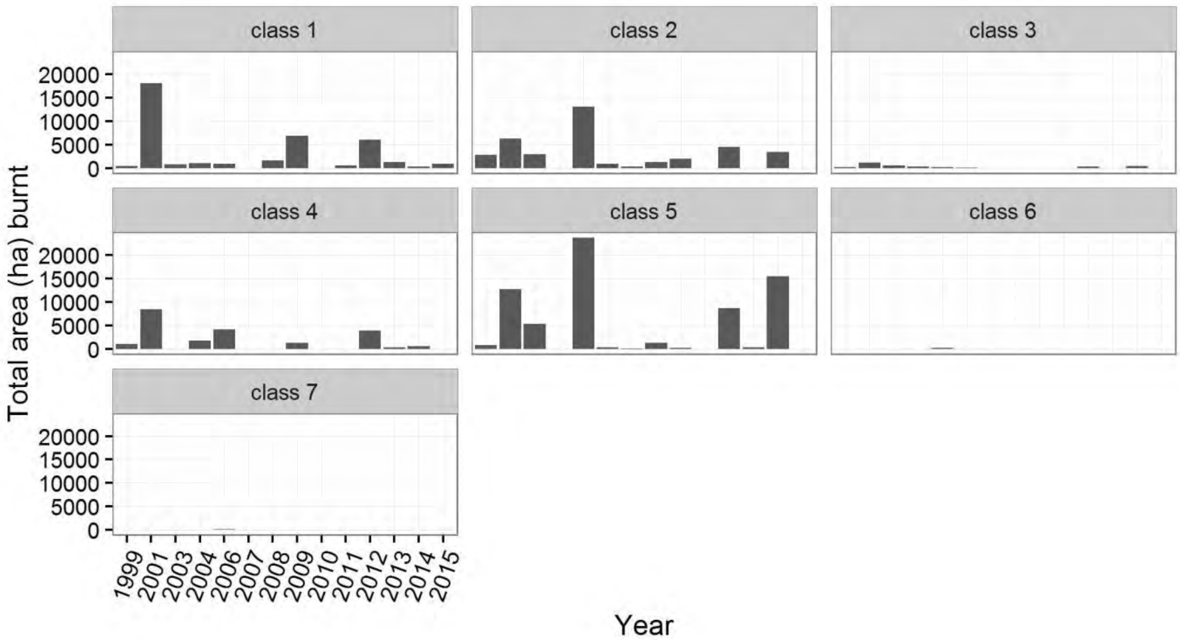


Figure 9: Alternative graph for total area (ha) burnt per year across Yarraloola LMA Vegetation classes for each year of available fire mapping.

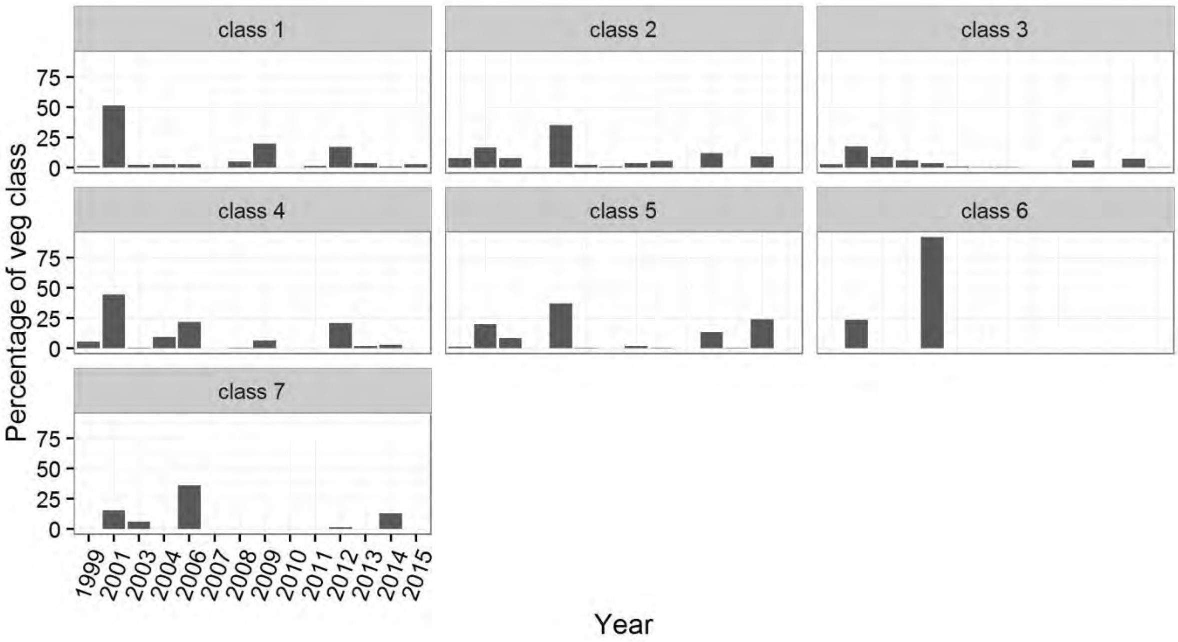


Figure 10: Alternative graph for total percentage burnt per year across Yarraloola LMA Vegetation classes for each year of available fire mapping.

5.2 Fire frequency

The following statistics show the total area and proportion of the study area mapped as burnt within each fire frequency category for the time period 1999 – 2015. Within the Yarraloola LMA the highest burn frequency between 1999 and 2015 was 4. Note that the fire frequency map, Figure 11 shows some areas burnt up to 5 times. This is within the 10km buffer zone displayed on the maps but not within the Yarraloola LMA and as such these area statistics have not been included in the tables and graphs. Metrics calculated are provided as:

Proportion of study area within each fire frequency (number times burnt over years for which data available)

- across study area
- within NQ & POP habitat
- within vegetation classes

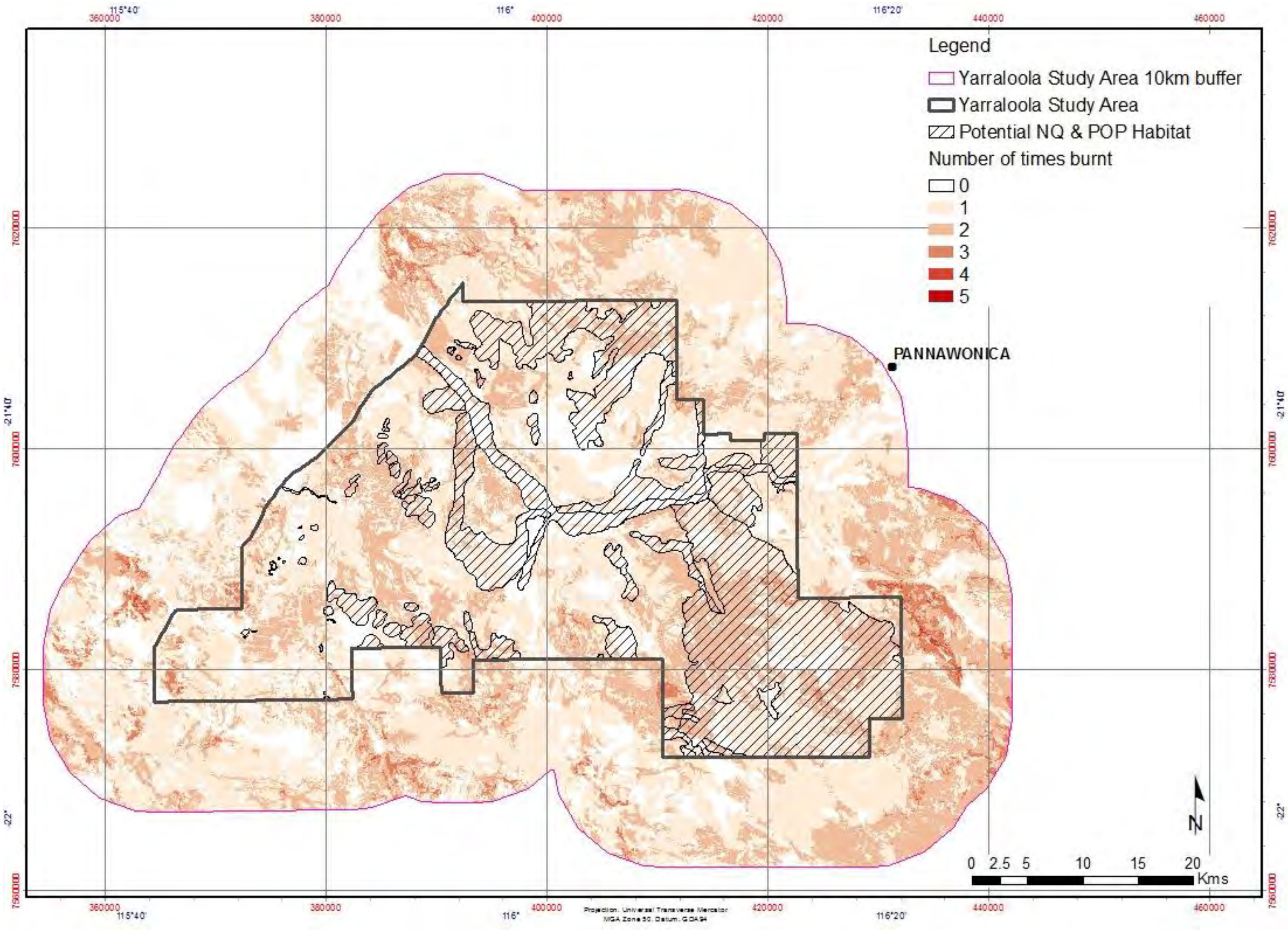


Figure 11: Fire frequency map of Yarraloola LMA and surrounding area, locations with number of times burnt of 5 are outside the Yarraloola LMA. Map also shows boundary for the NQ & POP habitat.

5.2.1 Fire frequency across Yarraloola LMA and mapped NQ & POP habitat

The NQ and POP habitat and Yarraloola LMA area metrics have been combined in both the tables and figures. Table 12 displays the total area of land mapped as burnt per fire frequency across Yarraloola LMA and NQ and POP Habitat for the time period 1999 – 2015. The percentages based on these area figures are also displayed in Table 12. Figures of the area statements are displayed in Figure 12 and percentages of those figures are displayed in Figure 13 and Figure 14.

Table 12: Total area (ha) and percentage per fire frequency across Yarraloola LMA and NQ & POP habitat.

	Fire	Frequency	Class		
Total area (ha)	0	1	2	3	4
Yarraloola	34942	86479	40376	1406	11
%	21	53	25	1	0
Habitat	14330	34032	16893	410	1
%	22	52	26	1	0

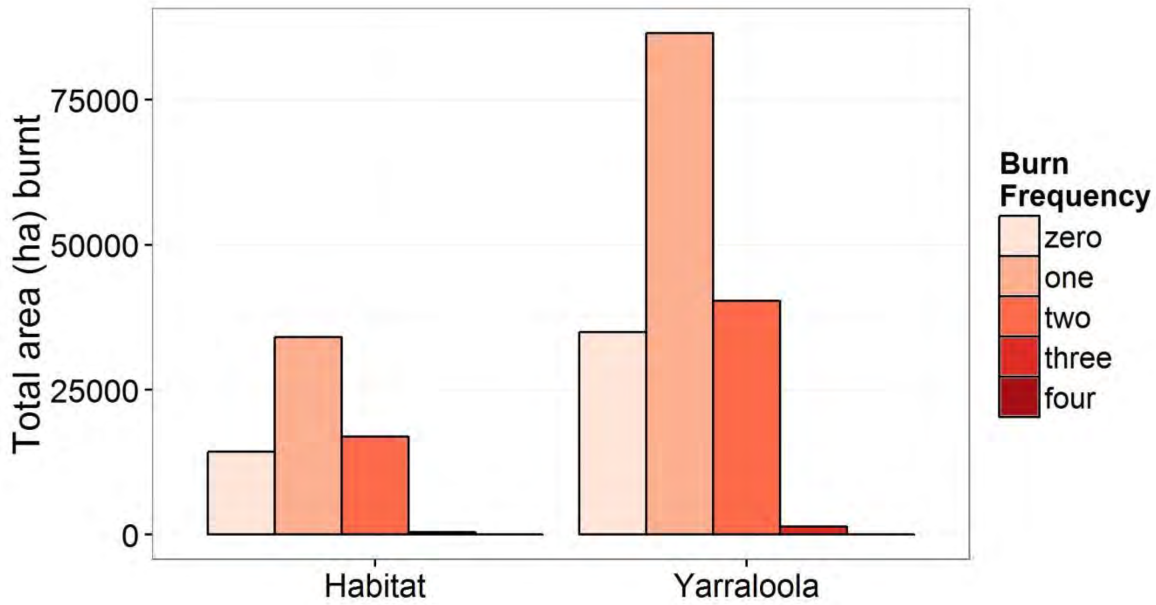


Figure 12: Area of the Yarraloola LMA within each of 5 fire frequency classes over the 1999 - 2015 study period.

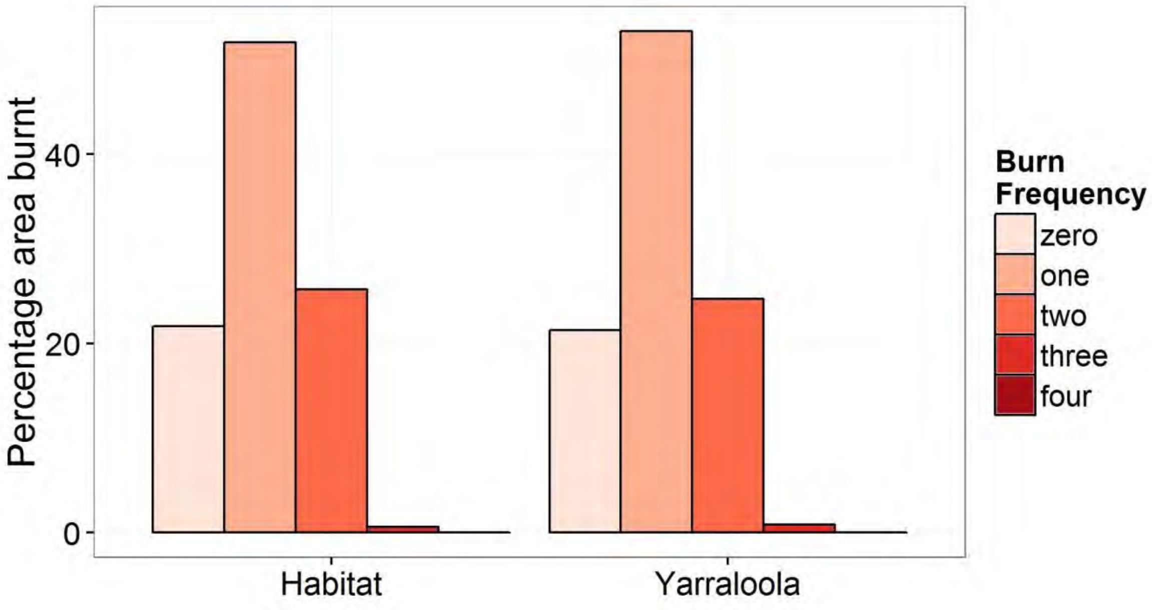


Figure 13: Percentage of the Yarraloola LMA within each of 5 fire frequency classes over the 1999 - 2015 study period.

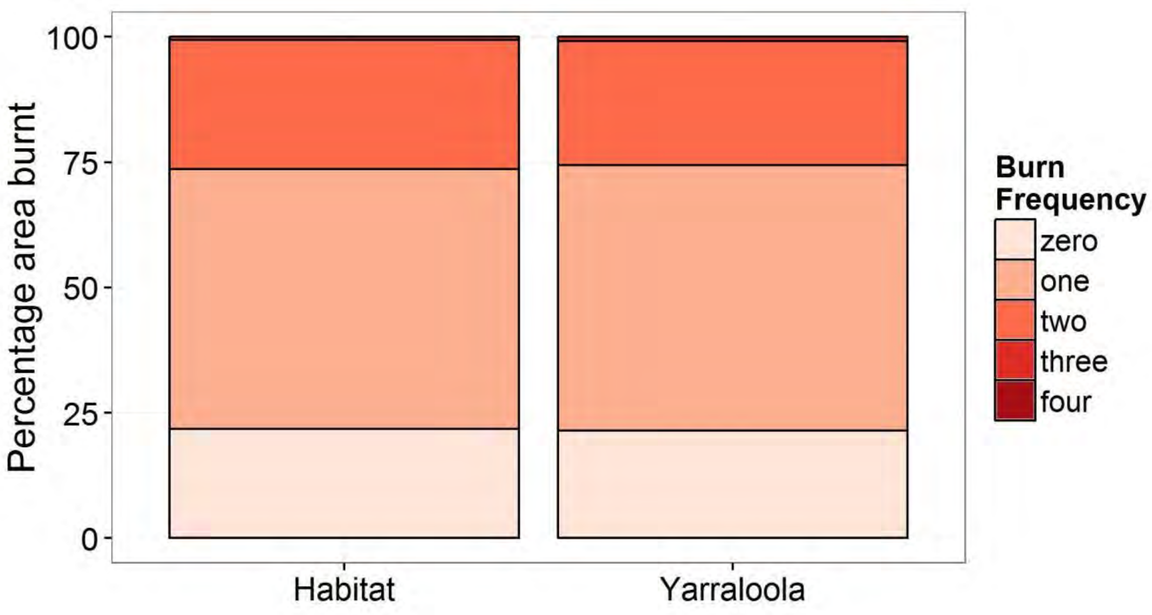


Figure 14: Percentage of the Yarraloola LMA within each of 5 fire frequency classes over the 1999 - 2015 study period.

5.2.2 Fire frequency across vegetation classes

Table 13 displays the total area of land mapped as burnt within each fire frequency class for the different vegetation classes over the time period 1999 – 2015. The same data, expressed as percentages, are displayed in

Table 14. Graphs of the area statements are displayed in Figure 15 and percentages of those figures are displayed in Figure 16 and Figure 17. Alternative graphs displaying the metrics for vegetation classes across Yarraloola LMA are displayed in Figure 18 and Figure 19. These display the same data but are arranged separately for each vegetation class to aid more detailed visual interpretation.

Table 13: Total area for each fire frequency class within the vegetation classes across Yarraloola LMA from 1999 – 2015.

Total area per		Fire	Frequency	Class	
Vegetation class	0	1	2	3	4
1	7119	18719	9081	462	3
2	8561	19964	8472	417	5
3	3698	2485	459	30	2
4	3306	9959	5762	85	0
5	12135	35051	16521	411	1
6	3	183	38	0	0
7	121	119	42	0	0

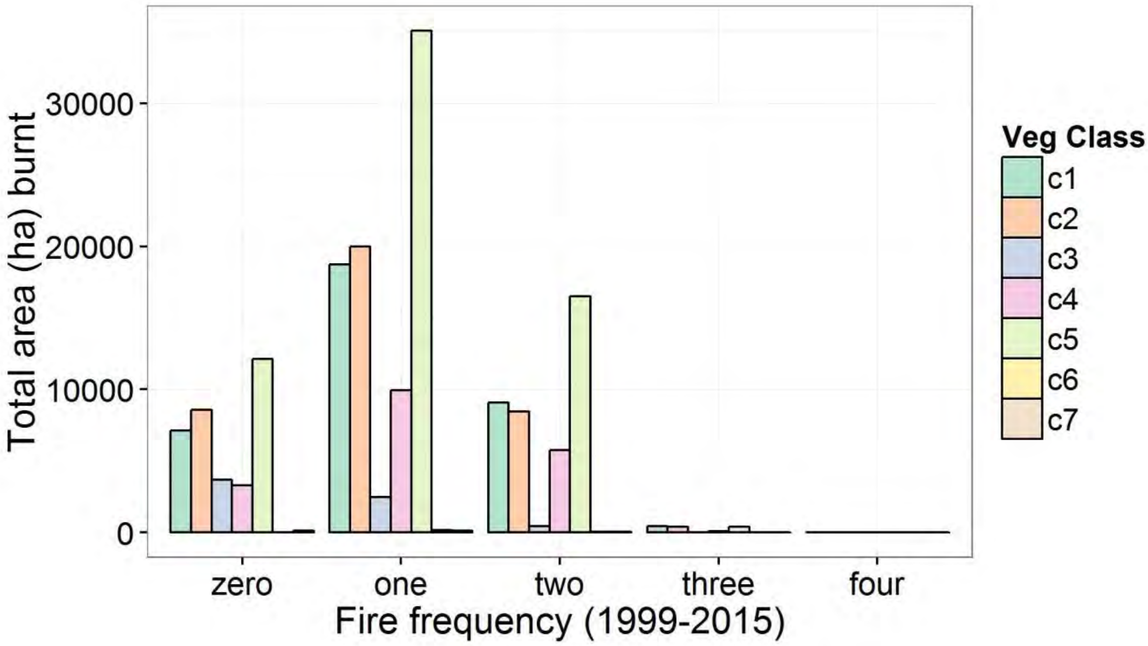


Figure 15: Total area (ha) for each fire frequency class within the vegetation classes across Yarraloola LMA from 1999 – 2015.

Table 14: Percentage area for each fire frequency class within the vegetation classes across Yarraloola LMA from 1999 – 2015.

Total %		Fire	Frequency	Class	
	0	1	2	3	4
1	20	53	26	1	0
2	23	53	23	1	0
3	55	37	7	0	0
4	17	52	30	0	0
5	19	55	26	1	0
6	2	82	17	0	0
7	43	42	15	0	0

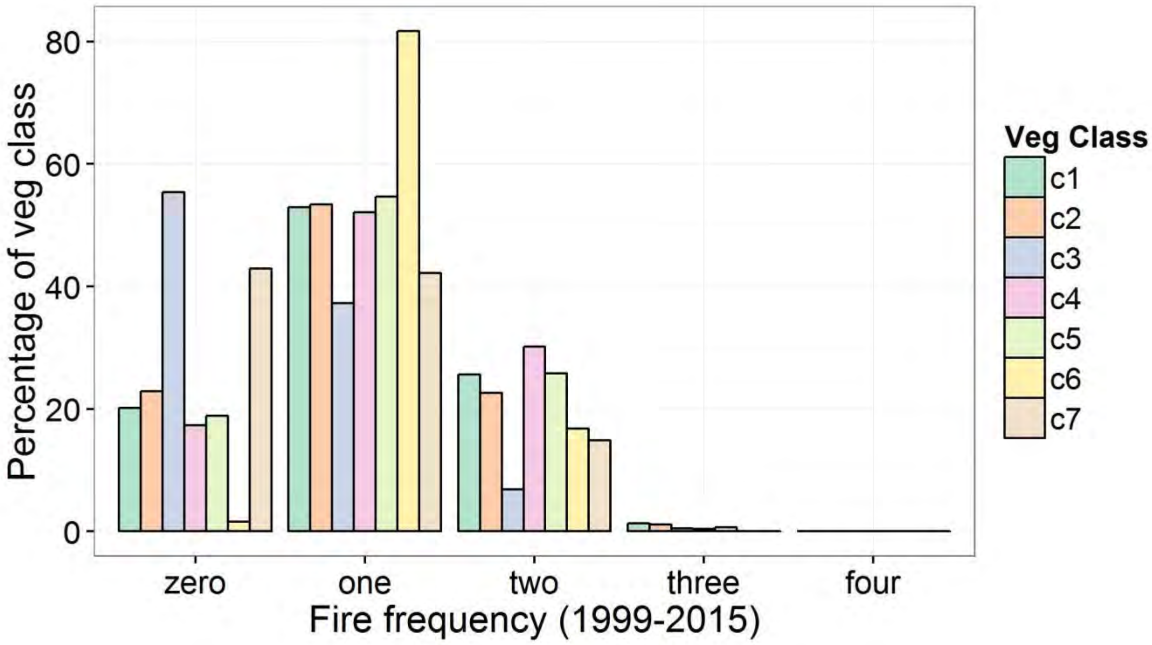


Figure 16: Percentage burnt per fire frequency within the different vegetation classes across Yarraloola LMA from 1999 – 2015.

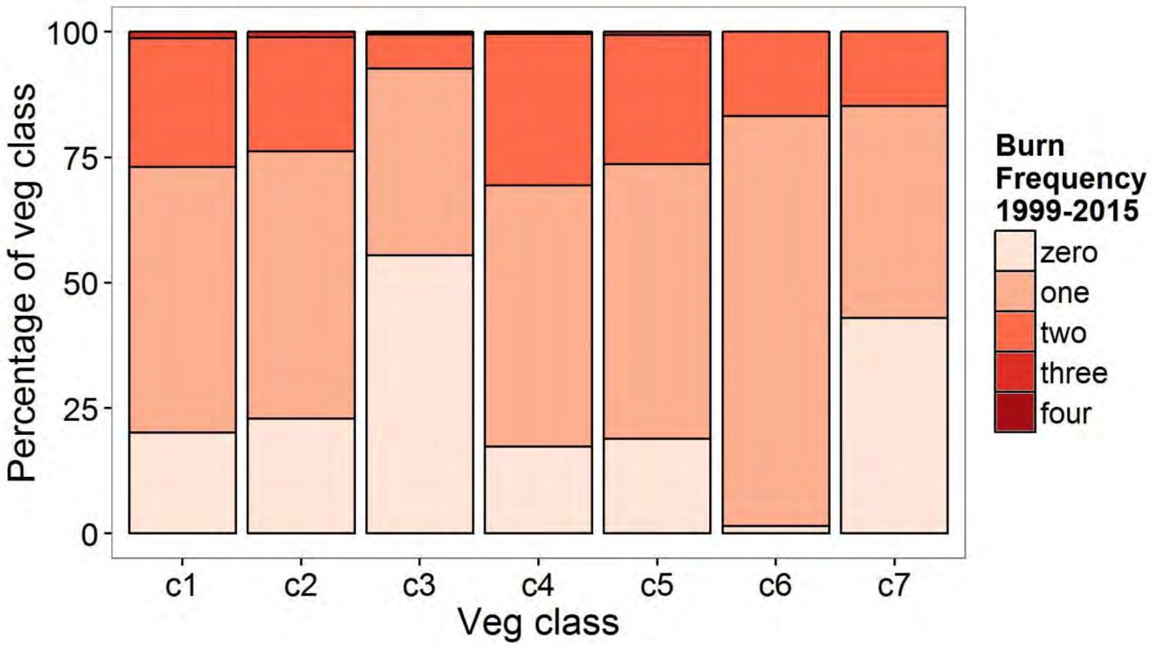


Figure 17: Percentage burnt per fire frequency within the different vegetation classes across Yarraloola LMA from 1999 – 2015.

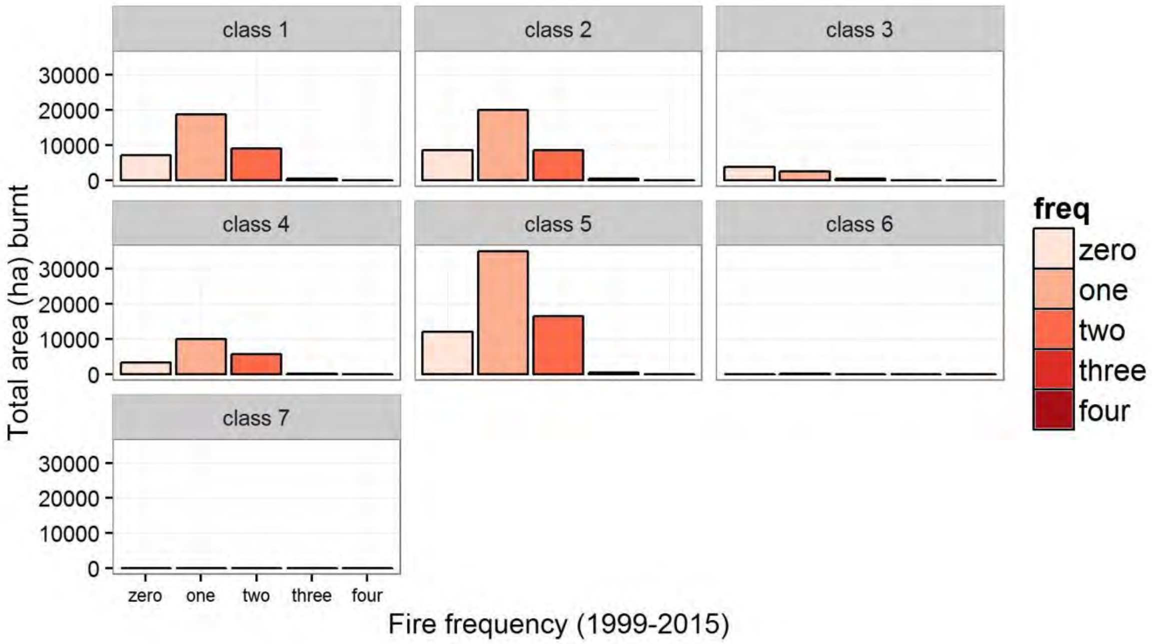


Figure 18: Total area (ha) burnt per fire frequency within the different vegetation classes across Yarraloola LMA from 1999 – 2015.

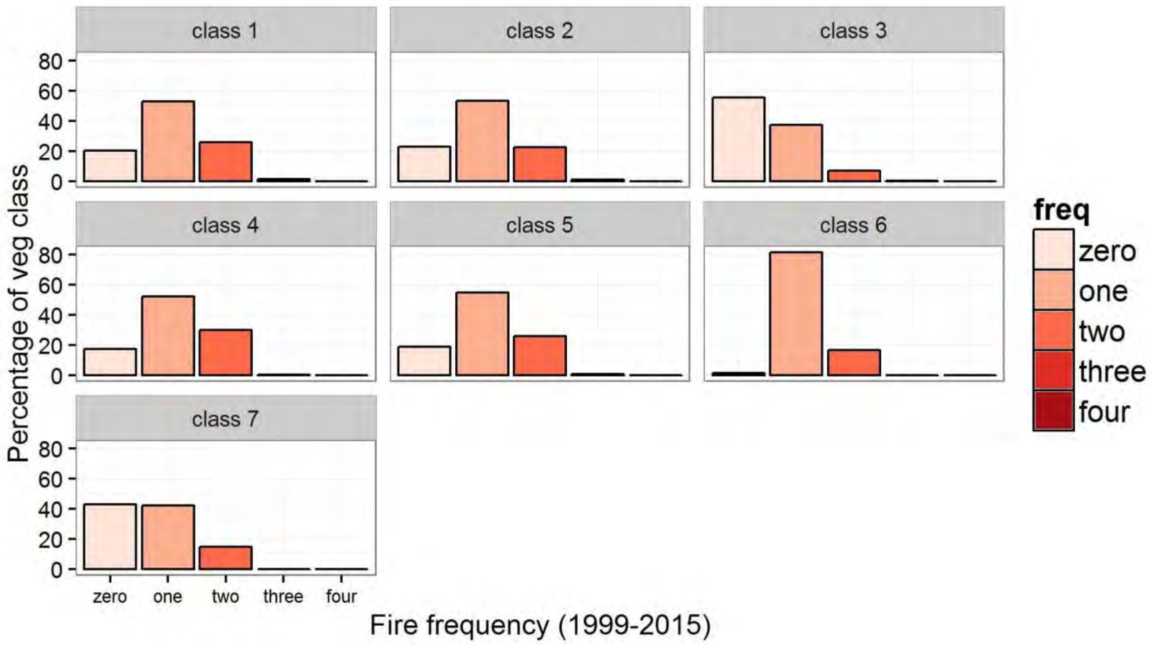


Figure 19: Percentage burnt per fire frequency within the different vegetation classes across Yarraloola LMA from 1999 – 2015.

5.3 Fuel Age

The following statistics show the total area and proportion mapped within each 'time since fire' (fuel age) class for the time period 1999 – 2015. A Fuel Age map for Yarraloola LMA is shown in Figure 20 with the NQ and POP habitat boundary overlayed. Metrics calculated are provided as:

Total area and proportion within each 'time since fire' (i.e. fuel age) class (0-3 yrs, 4-6 yrs, 7-9 yrs, 10-12 yrs, 13-15 yrs, >15 yrs)

- across the study area
- within NQ & POP habitat
- within vegetation classes

Table 15 shows the breakdown of the available years of fire mapping into Fuel age classes;

Table 15: Fire mapping years broken down into Fuel age classes

Fuel age class (years)	Years
0-3	2015, 2014, 2013
4-6	2012,2011, 2010,
7-9	2009, 2008, 2007
10-12	2006, 2005 (no data), 2004
13-15	2003, 2002 (no data), 2001
>15	2000 (no data), 1999

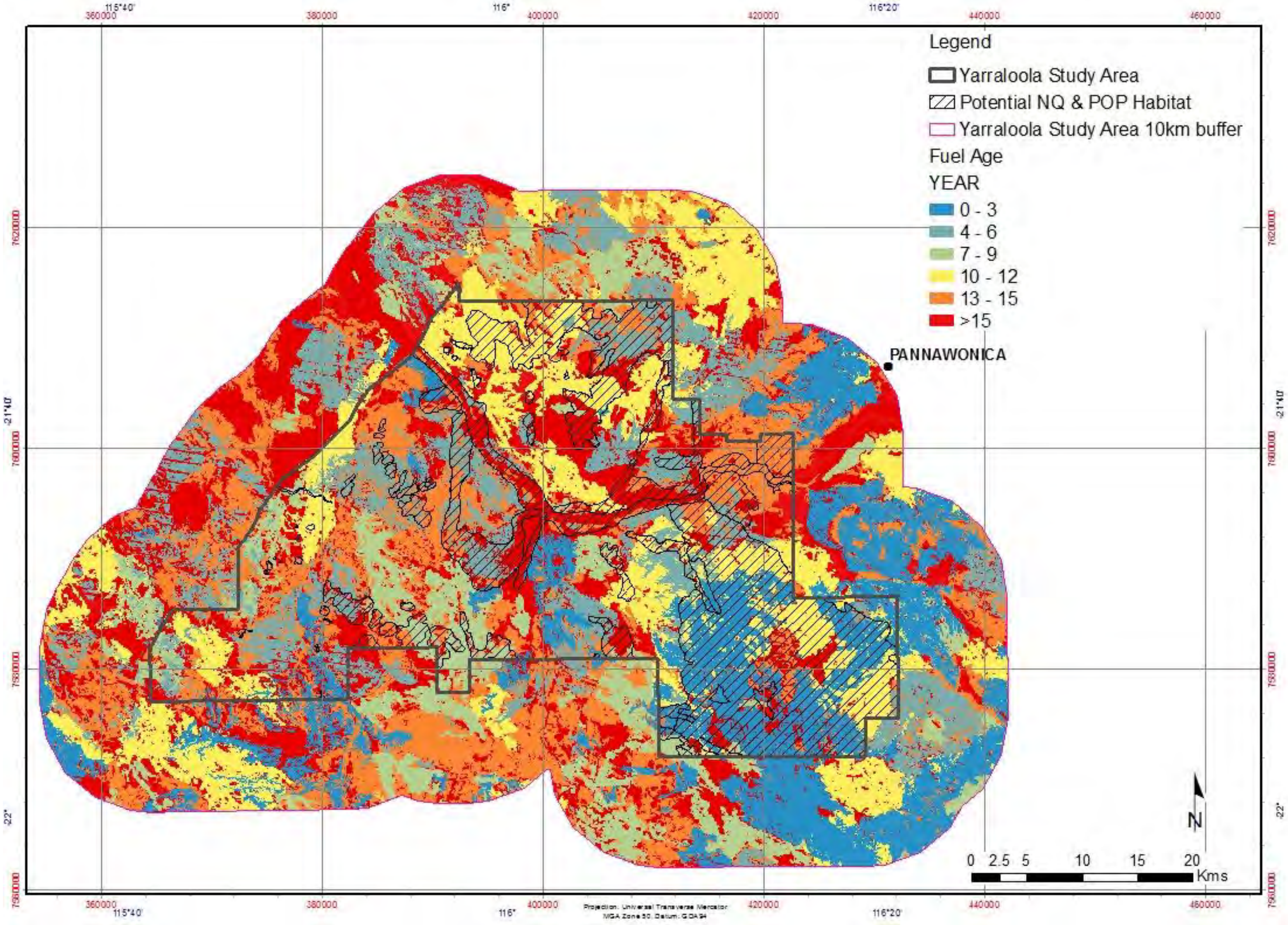


Figure 20: Fuel age map for Yarraloola LMA and surrounding area for the time period 1999 – 2015.

5.3.1 Fuel age across Yarraloola LMA and mapped NQ & POP habitat

The NQ and POP Habitat and Yarraloola LMA area metrics have been combined in both the tables and figures. Table 16 displays the total area of land mapped as burnt per fuel age across Yarraloola LMA and NQ and POP Habitat for the time period 1999 – 2015. The percentages based on these area figures are also displayed in Table 16. Graphs of the area statements are displayed in Figure 21 and percentages of those figures are displayed in Figure 22 and Figure 23 in two different display formats.

Table 16: Total area (ha) within each fuel age (years) across the Yarraloola LMA and NQ & POP habitat within the LMA.

		Fuel age class	(years)			
Total area (ha)	0 -3	4-6	7-9	10-12	13-15	> 15
Yarraloola	23550	25763	13381	32170	31278	2130
%	14	16	8	20	19	1
NQ & POP Habitat	16298	8631	2390	13147	10620	249
%	25	13	4	20	16	0

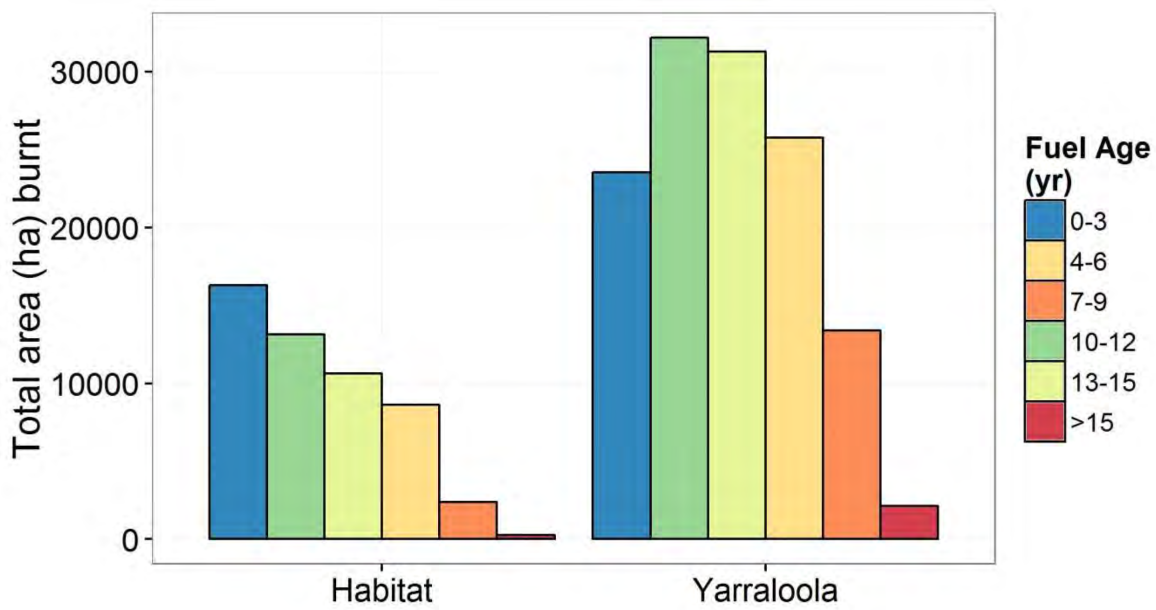


Figure 21: Total area (ha) within each fuel age class (years) across the Yarraloola LMA and NQ & POP habitat within the Yarraloola LMA.

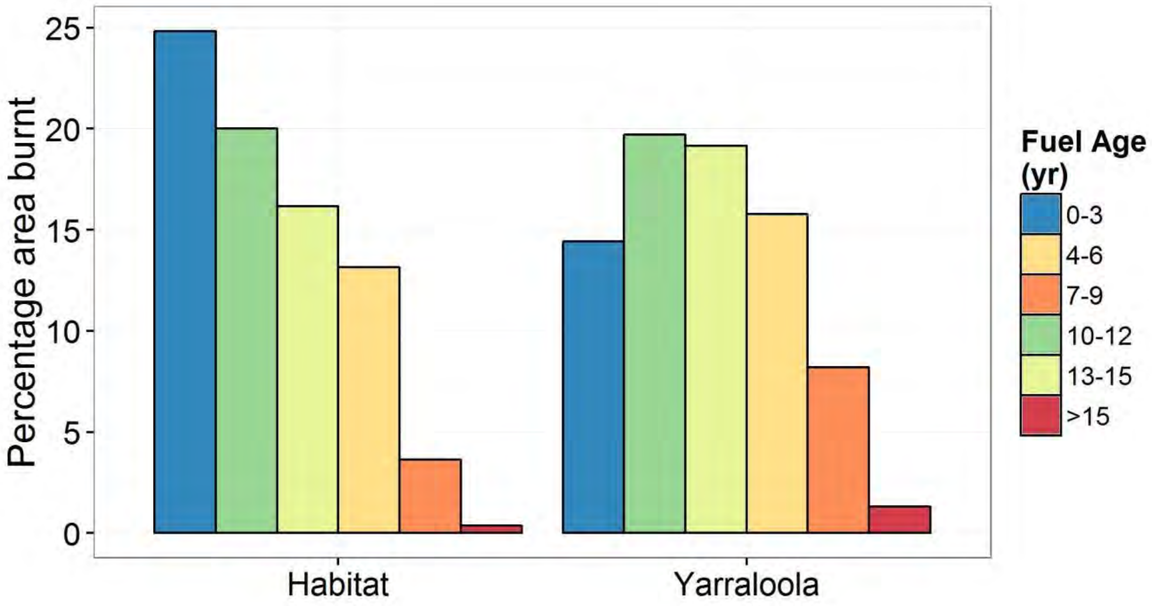


Figure 22: Percentage of Yarraloola LMA and the NQ & POP habitat within each fuel age class.

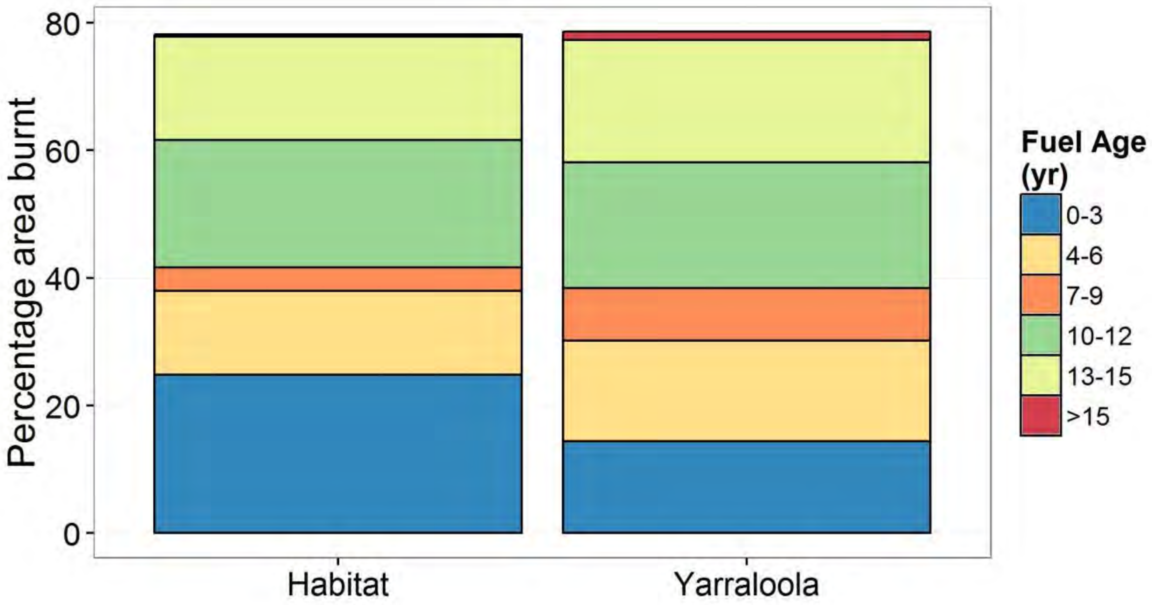


Figure 23: Percentage of Yarraloola LMA and the NQ/POP habitat within each fuel age class.

5.3.2 Fuel age across vegetation classes

Table 17 displays the total area of land mapped within each fuel age class within different vegetation classes of the Yarraloola LMA over the time period 1999 – 2015. The percentages based on these area calculations are displayed in Table 18 and presented graphically in Figure 24 and percentages of those figures are displayed in Figure 25 and Figure 26. Alternative graphs for displaying the metrics for vegetation classes across Yarraloola LMA are displayed in Figure 27 and Figure 28. These display the same data but give an alternative visual representation.

Table 17: Area (ha) within each fuel age class (years) across the vegetation classes within the Yarraloola LMA.

		Fuel age class	(years)			
Vegetation class	0 -3	4-6	7-9	10-12	13-15	> 15
1	1832	6420	7746	1623	10491	153
2	4307	6171	2538	10047	4691	1106
3	487	382	60	507	1443	97
4	927	3955	1299	4977	4414	235
5	15960	8831	1738	14744	10171	539
6	0	0	0	205	15	0
7	36	4	0	67	53	0

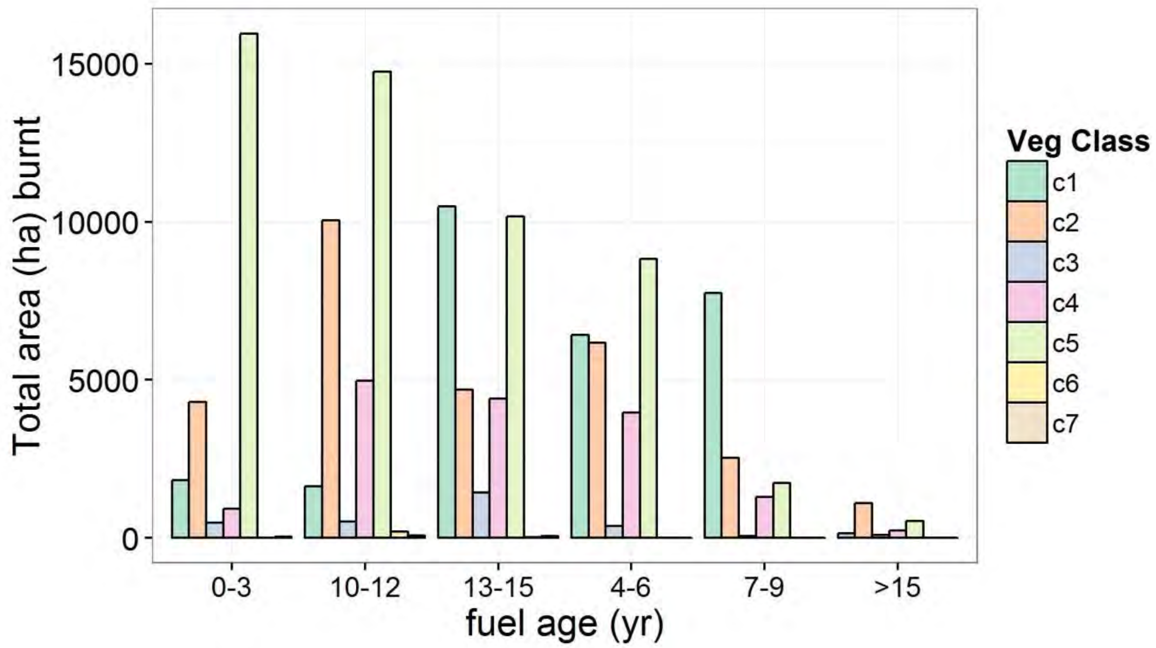


Figure 24: Total area (ha) within each fuel age class (years) across vegetation classes within the Yarraloola LMA.

Table 18: Percentage area within each fuel age class (years) across vegetation classes within the Yarraloola LMA.

		Fuel age class	(years)			
Vegetation class	0 -3	4-6	7-9	10-12	13-15	> 15
1	5	18	22	5	30	0
2	12	16	7	27	13	3
3	7	6	1	8	22	1
4	5	21	7	26	23	1
5	25	14	3	23	16	1
6	0	0	0	92	7	0
7	13	1	0	24	19	0

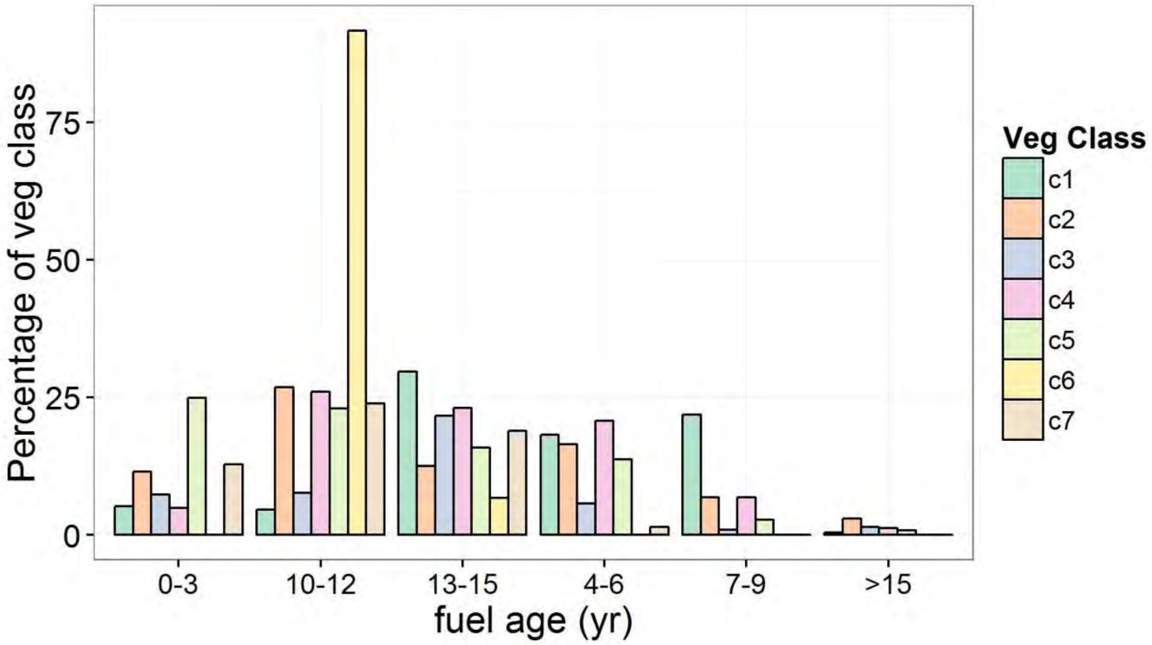


Figure 25: Percentage area within each fuel age class (years) across different vegetation classes within the Yarraloola LMA.

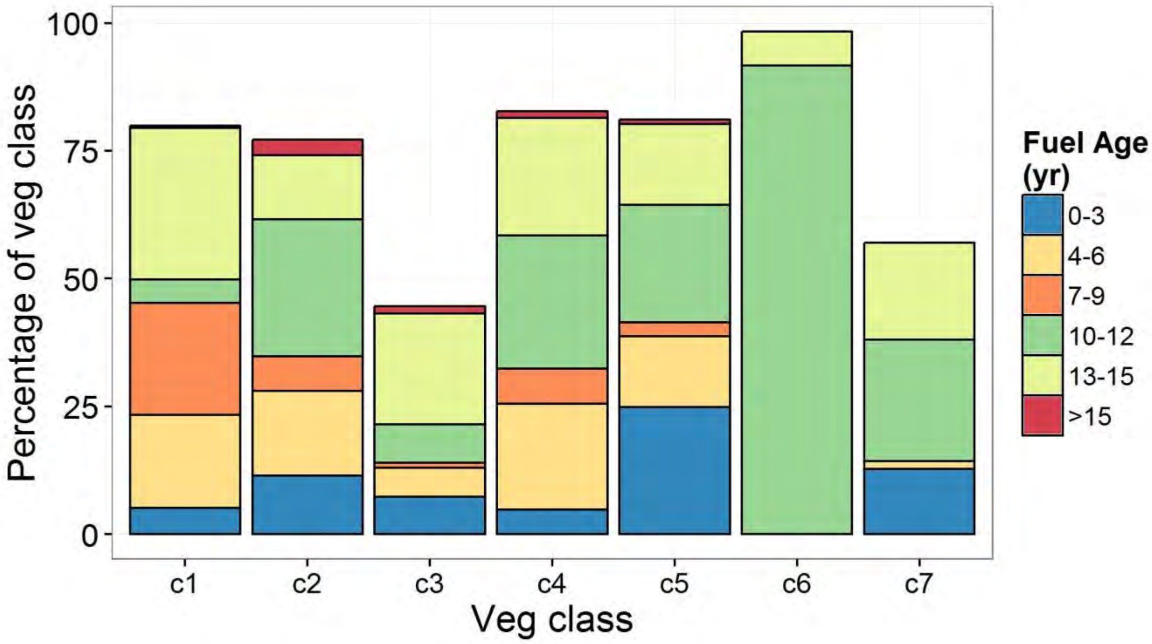


Figure 26: Percentage area within each fuel age class (years) across different vegetation classes within the Yarraloola LMA.

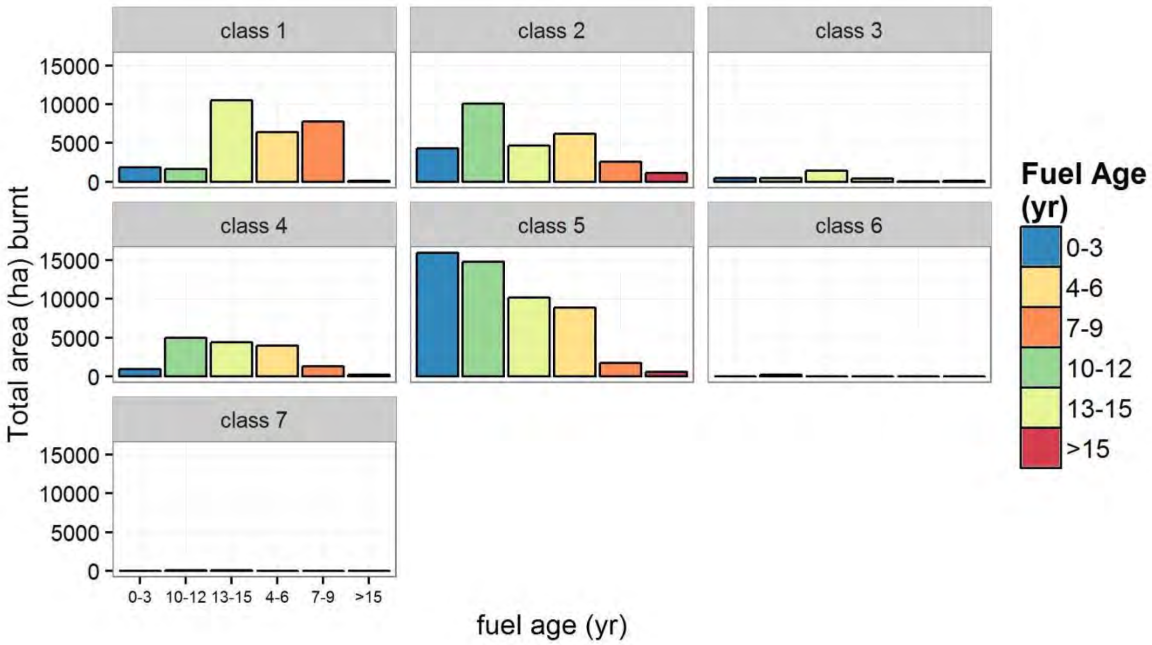


Figure 27: Total area (ha) within each fuel age class (years) across vegetation classes within the Yarraloola LMA.

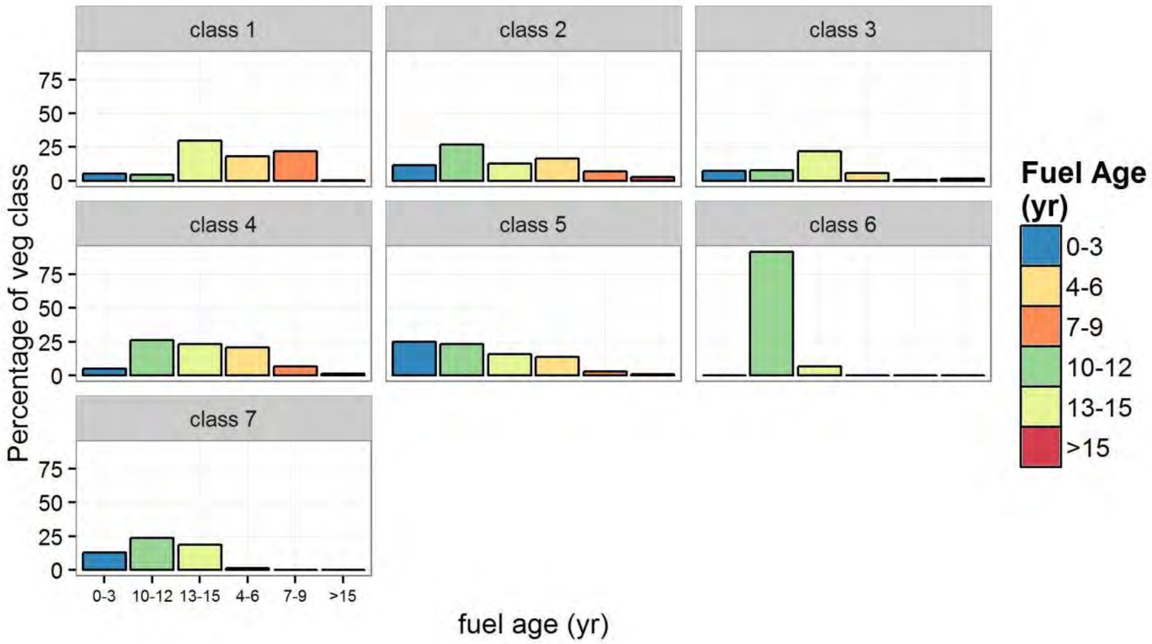


Figure 28: Percentage area within each fuel age class (years) across different vegetation classes within the Yarraloola LMA.

5.4 Seral state

The following statistics show the total area and proportion mapped within each seral state category for the time period 1999 – 2015. The seral state map for Yarraloola LMA is shown in Figure 29 with the NQ and POP habitat boundary overlayed. Metrics calculated are provided as:

Total area (ha) and proportion of area within each Spinifex seral state (after Burrows & Butler 2011):

- across study area
- within NQ & POP habitat
- within vegetation classes

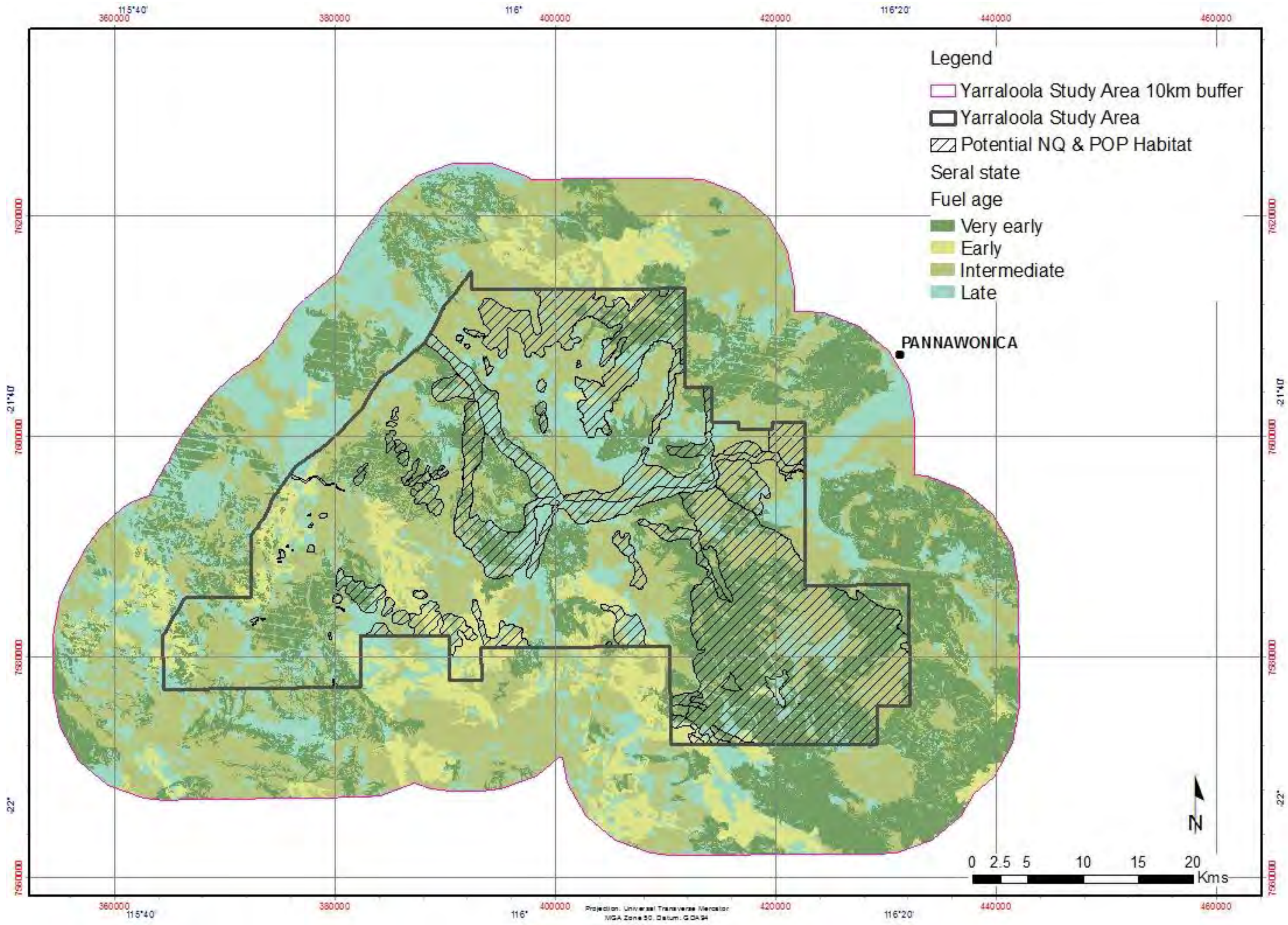


Figure 29: Map showing seral states of vegetation across Yarraloola LMA and surrounding area for the time period 1999 – 2015.

5.4.1 Seral states across Yarraloola LMA and within mapped NQ & POP habitat

The NQ and POP Habitat and Yarraloola LMA area metrics have been combined in both the tables and figures. Table 19 displays the total area of land mapped within each seral state across Yarraloola LMA and NQ and POP Habitat for the time period 1999 – 2015. The percentages based on these area calculations are also displayed in Table 19. Figures of the area statements are displayed in Figure 30 and percentages of those figures are displayed in Figure 31 and Figure 32.

Table 19: Area (ha) of the Yarraloola LMA and NQ & POP habitat that falls within each of four seral states (defined in terms of time in years since fire and following Burrows & Butler 2011).

		Seral state		
Total area (ha)	Very early	Early	Intermediate	Late
Yarraloola LMA	47004	12277	66860	2130
	29	8	41	1
NQ & POP Habitat	24731	2195	24161	249
	38	3	37	<1

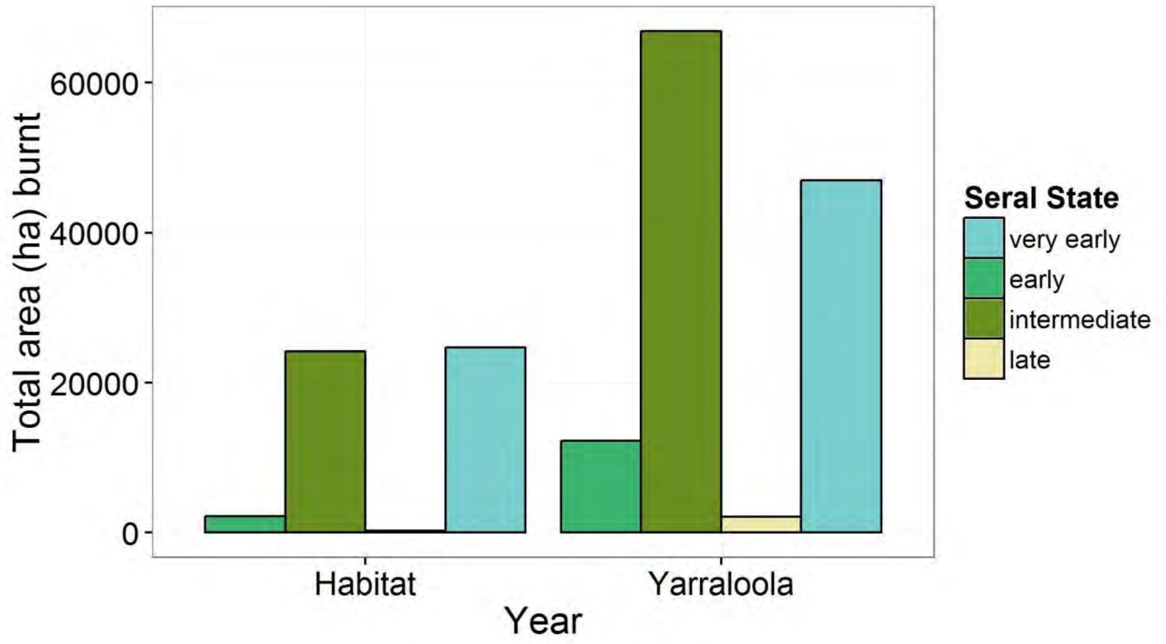


Figure 30: Area (ha) of the Yarraloola LMA and NQ/POP habitat that falls within each of four seral states (defined in terms of time in years since fire and following Burrows & Butler 2011).

Burrows and Butler (2011) research produced a table of optimal percentages of the landscape to be occupied by the range of seral states in the Bullimore and Sandplain landsystems (Table 1). Figure 31**Error! Reference source not found.** displays the optimal percentage for the seral states mapped as a dashed red line. As the very late seral state is not mapped it is not shown on the graph.

Table 20: Theoretical idealised proportion of function habitats (seral states) for Bullimore and Sandplain Landsystems based on vital attributes of keystone species (Triodia spp.). Reproduced from Burrows and Butler (2011).

Seral state	Very Early (<=6 yrs)	Early (6-12 yrs)	Intermediate (12-24 yrs)	Late (24-36 yrs)	Very Late 36+ yrs
% Landscape	19.4%	17.4%	26.3%	20.5%	16.4%

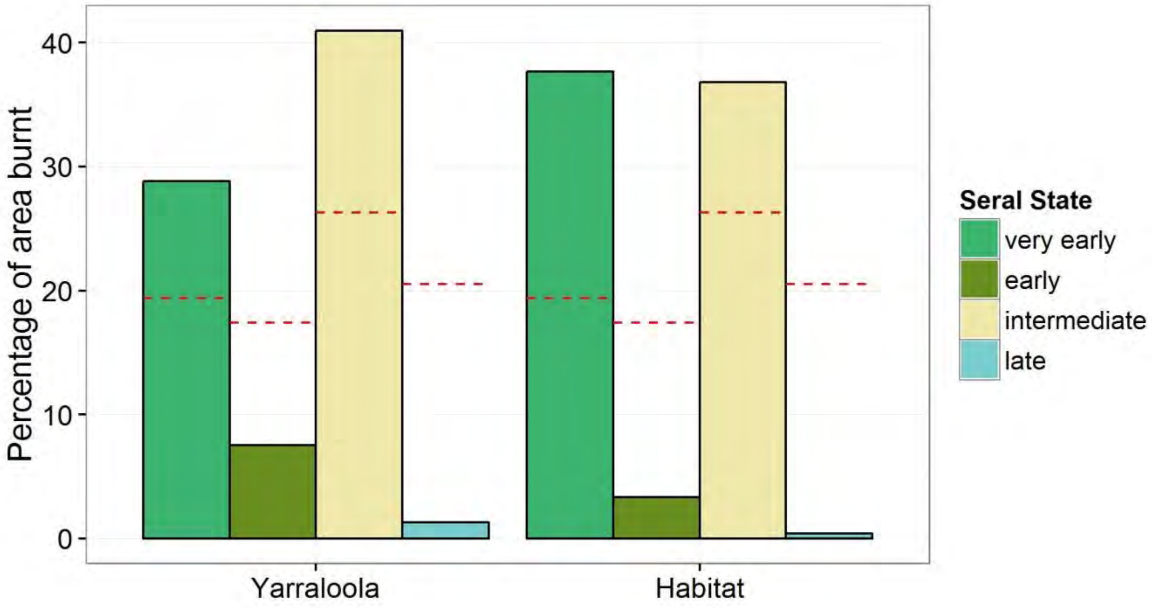


Figure 31: Percentage area within each seral state across Yarraloola LMA and the NQ/POP habitat with optimal percentage per seral state displayed as a dashed red line as per Burrows and Butler (2011).

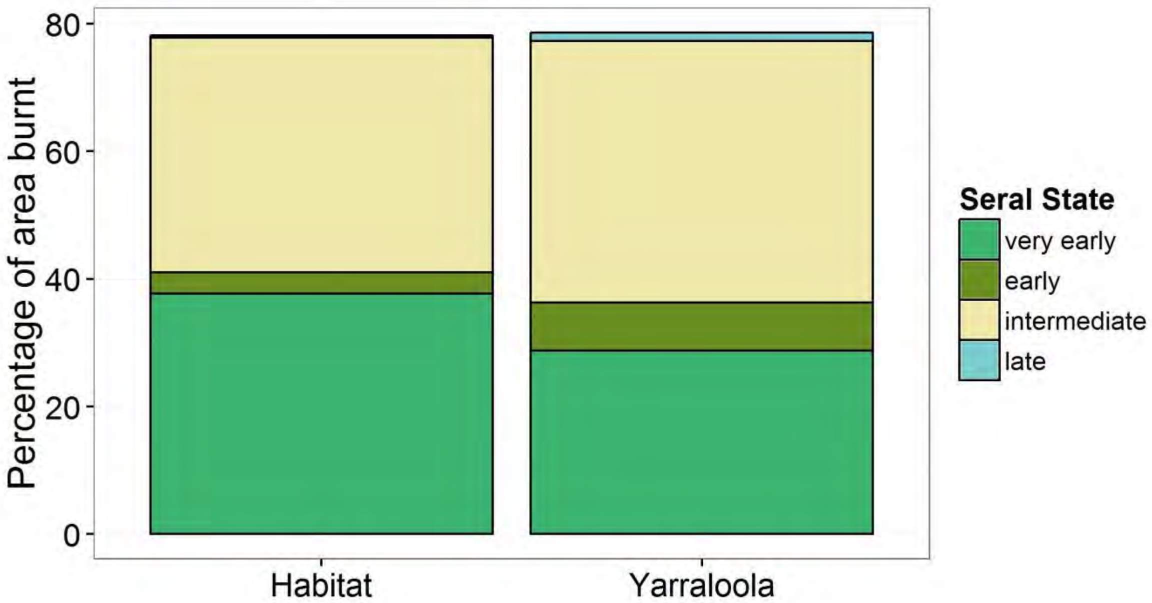


Figure 32: Percentage area within each seral state across Yarraloola LMA and the NQ/POP habitat.

5.4.2 Seral states across vegetation classes

The percentages based on these area figures are displayed in Table 22. Graphs of the area statements are displayed in Figure 33 and percentages of those figures are displayed in Figure 34 and Figure 35. Alternative graphs for displaying the metrics for vegetation classes across Yarraloola LMA are displayed in Figure 36 and Figure 37. These display the same data but give an alternative visual representation.

Table 21 displays the total area of land mapped as burnt per seral state within the different vegetation classes for the time period 1999 – 2015. The percentages based on these area figures are displayed in Table 22. Graphs of the area statements are displayed in Figure 33 and percentages of those figures are displayed in Figure 34 and Figure 35. Alternative graphs for displaying the metrics for vegetation classes across Yarraloola LMA are displayed in Figure 36 and Figure 37. These display the same data but give an alternative visual representation.

Table 21: Total area (ha) within each seral state across vegetation classes within the Yarraloola LMA.

		Seral state		
Vegetation class	Very early	Early	Intermediate	Late
1	7827	6520	13766	153
2	8795	3011	15947	1106
3	869	32	1978	97
4	4880	1245	9446	235
5	24592	1469	25383	539
6	0	0	220	0
7	40	0	120	0

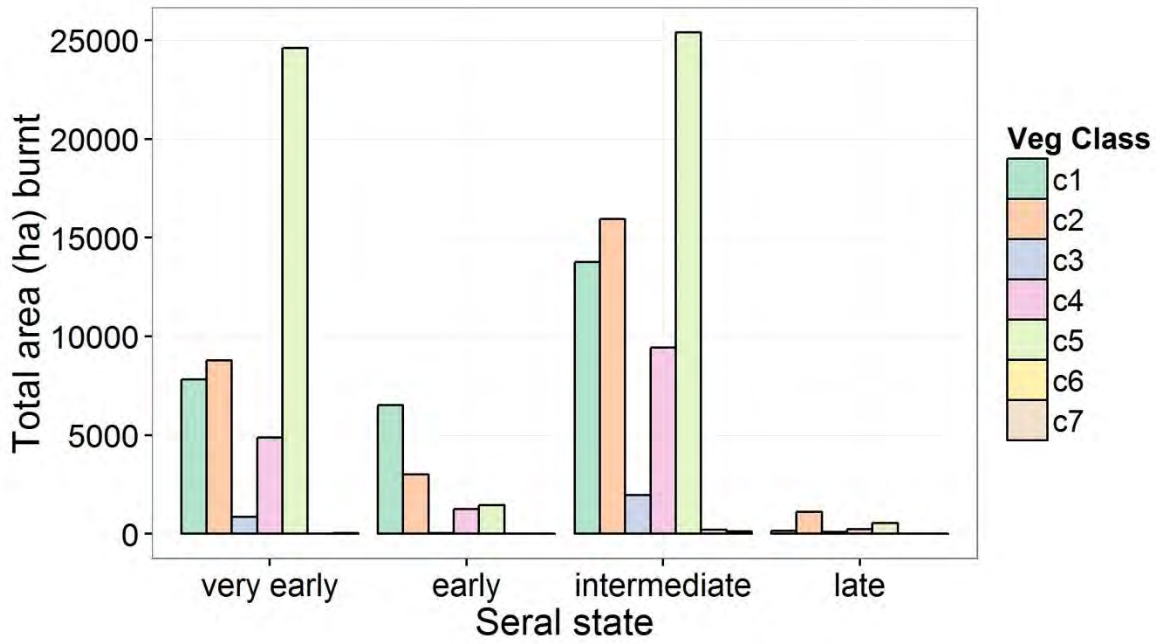


Figure 33: Total area (ha) within each seral state across vegetation classes within the Yarraloola LMA.

Table 22: Percentage area within each seral state across vegetation classes within the Yarraloola LMA.

		Seral state		
Vegetation class	Very early	Early	Intermediate	Late

1	22	18	39	0
2	25	9	45	3
3	2	0	6	0
4	14	4	27	1
5	69	4	72	2
6	0	0	1	0
7	0	0	0	0

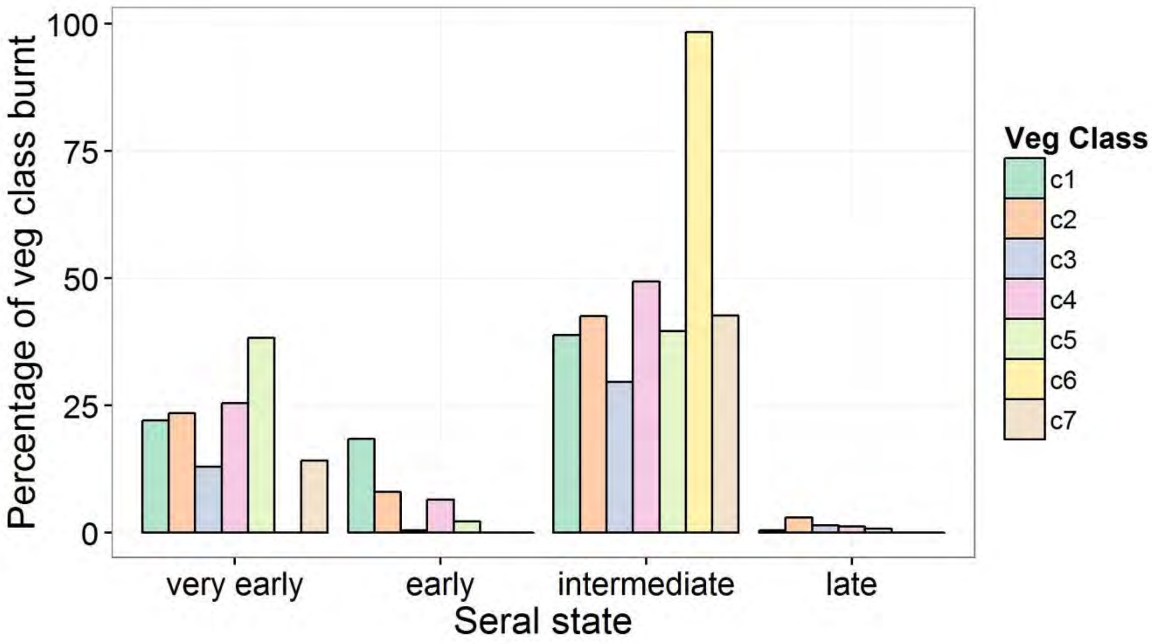


Figure 34: Percentage area within each seral state across vegetation classes within the Yarraloola LMA.

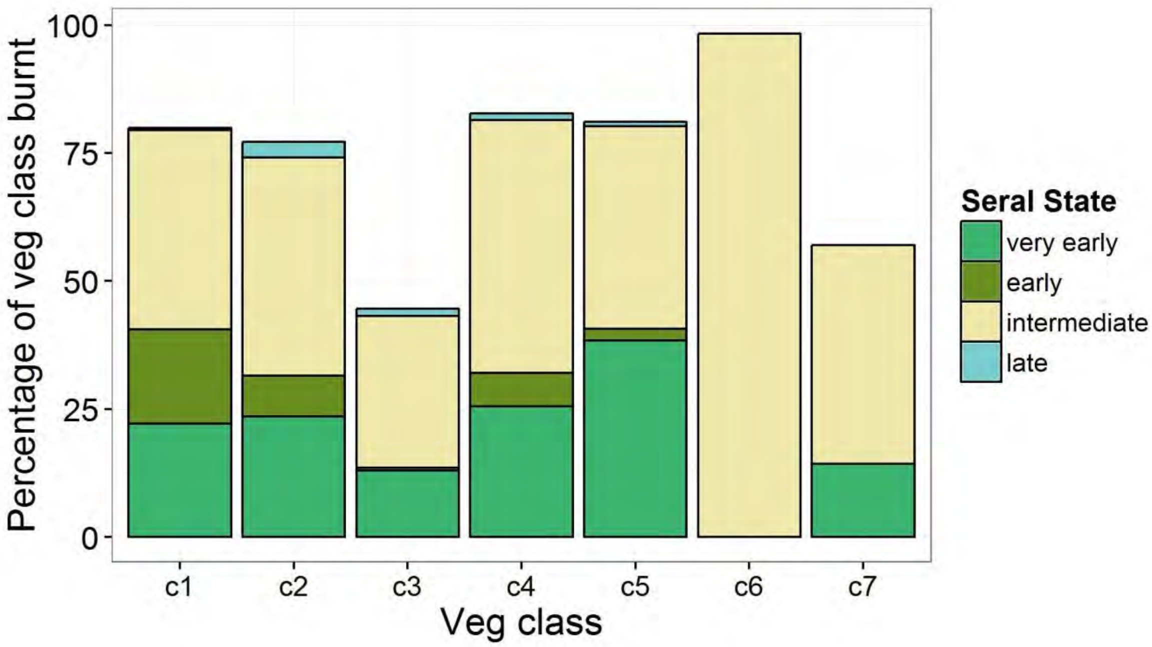


Figure 35: Percentage area within each seral state across vegetation classes within the Yarraloola LMA .

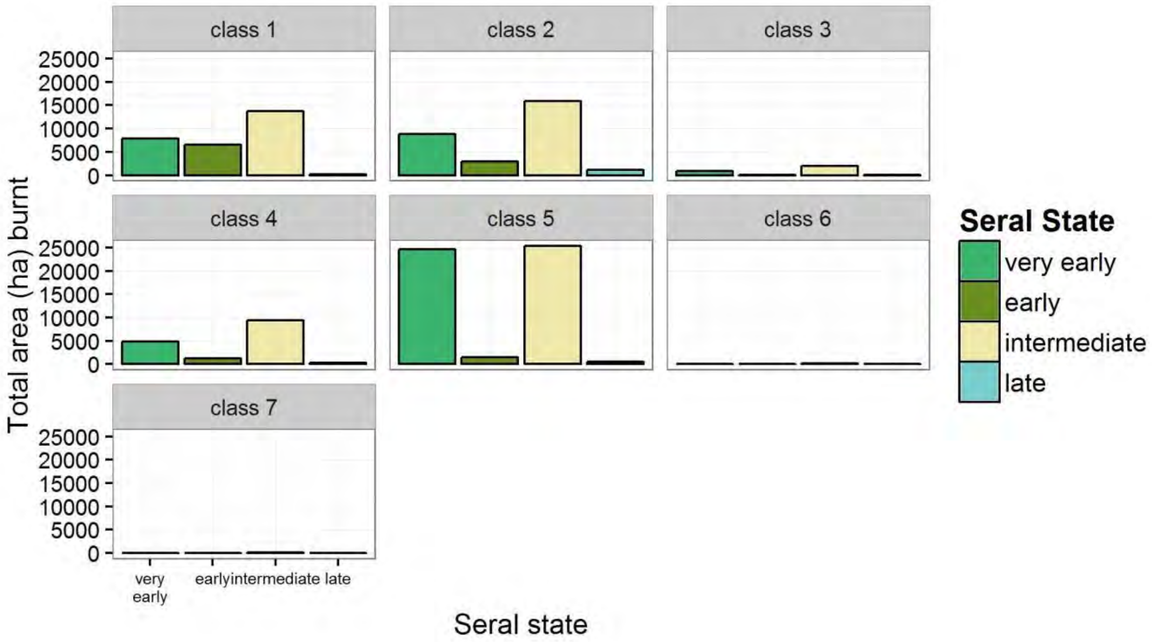


Figure 36: Total area (ha) within each seral state across vegetation classes within the Yarraloola LMA.

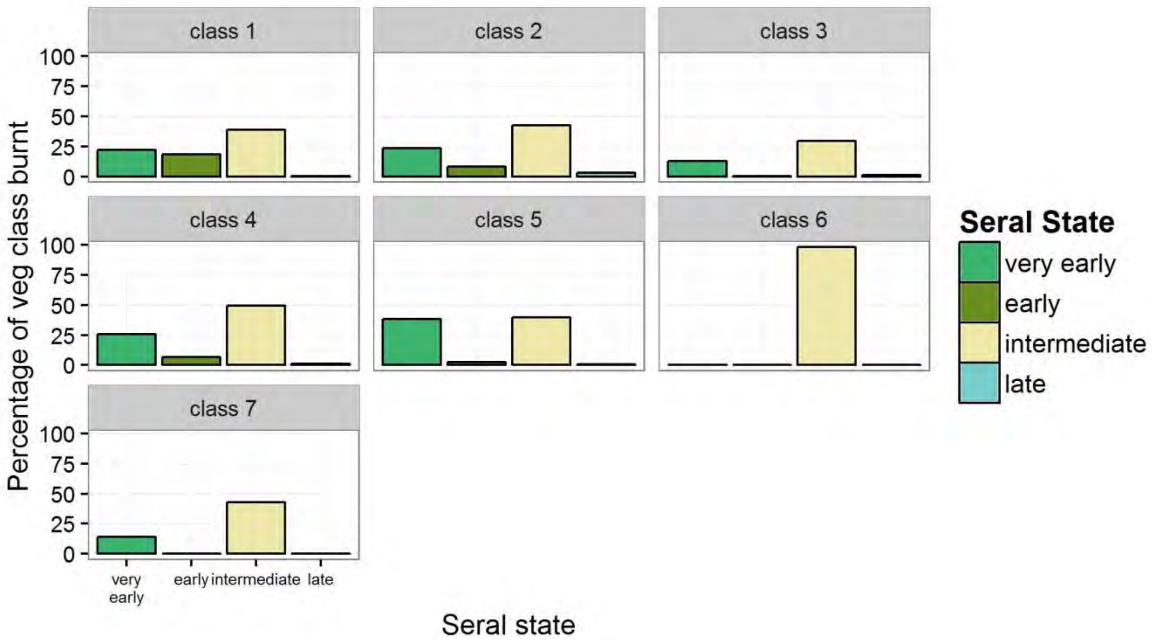


Figure 37: Percentage area within each seral state across vegetation classes within the Yarraloola LMA.

5.5 Fire regime groups

The Fire regime dataset was provided by Rio Tinto. The Yarraloola LMA was divided into two fire interval groups; “8 – 40 years” and “20 – 40 years”. Given that the available fire mapping only covers 15 years of data from 1999 – 2015 it is possible to determine what proportion of the 8 - 40 year interval falls outside of that time period by determining the proportion of the fire regime which has a fuel age less than 8 years. Similarly given the constraints of the data, for the Fire regime 20 – 40 years it is only possible to show the proportion of the fire regime which has a fuel age of < 15 years. Fire regime statistics are displayed in Table 23.

Table 23: Area (ha) of Yarraloola LMA Fire regime “8 – 40 years” which has a fuel age less than 8 years, and Fire regime “20 – 40 years” which has a fuel age < 15 years.

	Area (ha)	
	Inside regime	Outside regime
8 - 40 years	52131	44517
%	43	37
20 - 40	NA	31622
%	NA	74

See Figure 38 for a map showing the extents of the Fire regimes and the fire mapping with a fuel age < 8 years.

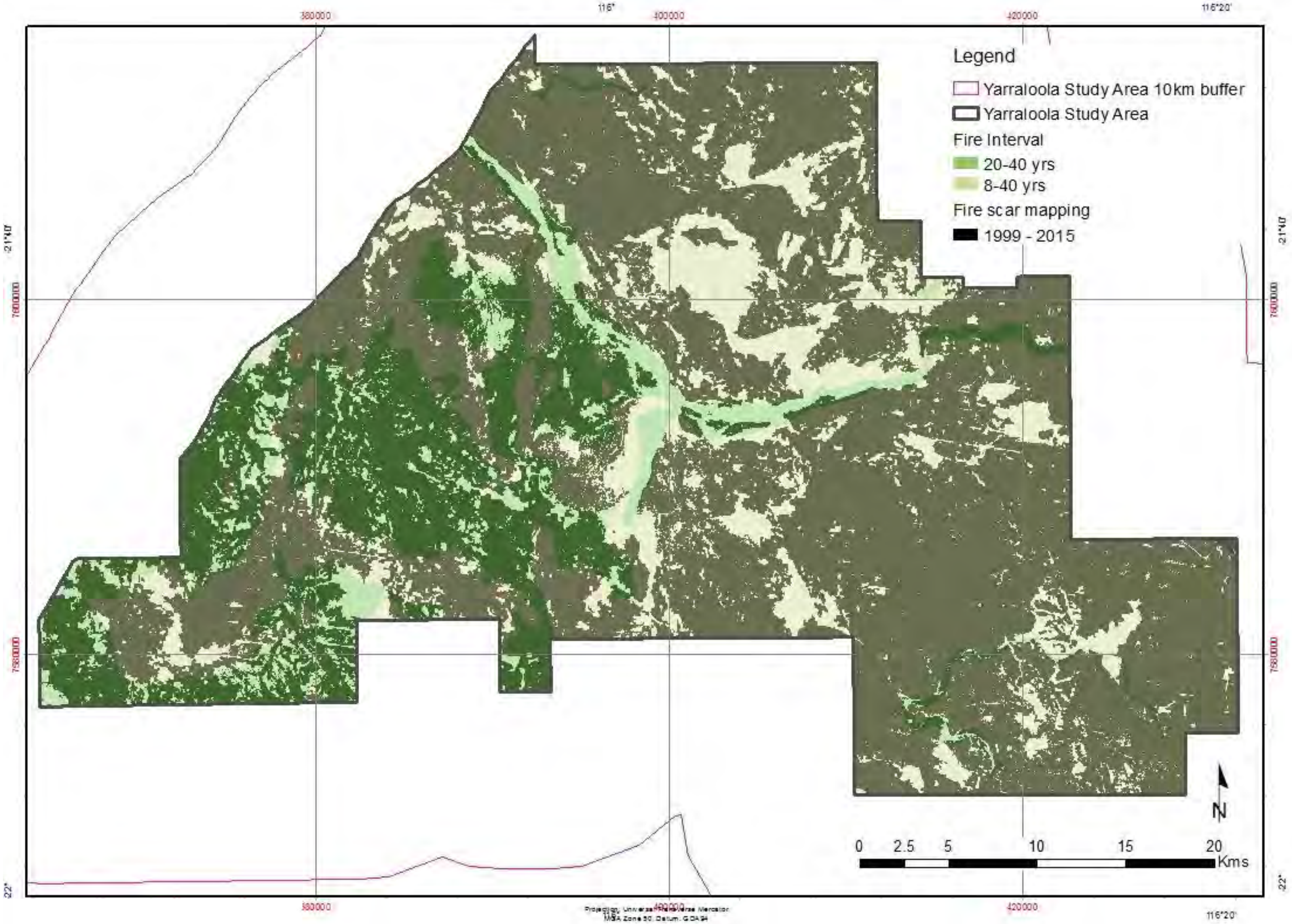


Figure 38: Fire regimes of the Yarraloola LMA and fire mapping. Note, the green layers of this map are transparent over the black fire mapping layer. Darker tones of green indicate where these layers are overlapping.

6. Data limitations

6.1 Spatial resolution

Landsat satellite imagery has a 30m pixel resolution for the reflectance bands which are used for extracting fire scars. Small fires less than 30m X 30m and detailed edging around larger fires are not able to be extracted at this resolution. Due to the uncertainty around the smaller fires any isolated area of mapped 'fire' less than 1 hectare is deleted from the final dataset.

6.2 Fire date attribution

At this current time it is not possible to attribute the fire scar data with monthly date attribution. Fire scars are currently mapped using a difference image between two dates which are generally one year apart. Using this method we are only capable of showing the change in the vegetation between those two dates and as such can only determine that the fire occurred at some point in that year interval.

6.3 Size class distribution of fire scars

In order to calculate metrics based on the size class distribution of fire scars it must first be possible to attribute the fire scars with a more accurate date. The fire scars represent an annual change in vegetation cover over an area. For example; if a fire starts in March and burns 50 ha before extinguishing then another fire starts in June and burns another 50 hectares right up to the boundary of the March fire an annual snapshot of that area would show 1 large fire of 100 ha rather than two 50 ha fires a few months apart in age. Calculating metrics based on size class distribution using the current fire scar data would yield results which indicated a higher percentage of larger fires than in reality.

6.4 Missing annual fire scar data

Historical fire scar data for years 2000, 2002 and 2005 is not available; therefore comparisons of annual changes in fire scar area cannot be made for the period 1999 – 2006. Where there are greater than annual gaps the fire scars identified could have occurred at any time within the two year period between image dates. This impacts the fire metric analysis in that statistics such as average burnt area per year cannot be calculated across the entire time period.

6.5 Landsat 7 SLC-Off missing data stripes

During the period November 2011 to April 2013 the only available Landsat imagery was from Landsat 7 ETM+ and this imagery had missing data lines ('stripes') which affects the detection and attribution of fires scars. This results in some fires having 'stripes' of missing mapping which then affects the calculation of areas, fuel age and fire frequency.

Landsat images affected by the Scan Line Corrector (SLC) failure are missing approximately 22% of data. Generally the most area lost is towards the edges of the scene with the middle of a scene unaffected. Figure 39 shows an example of the area of the Yarraloola LMA affected by the SLC failure in 2012. The white stripes in the image represent missing data.

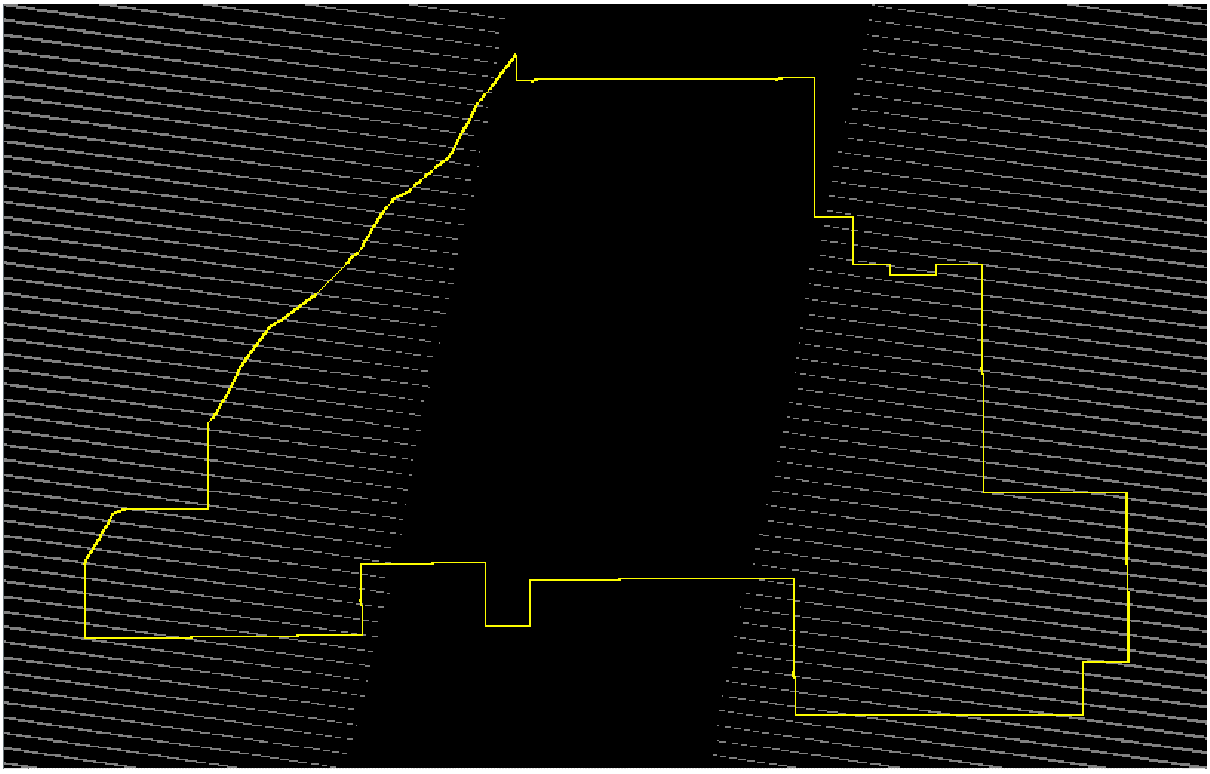


Figure 39: Location of missing data across the Yarraloola LMA for Landsat image date 02/03/2012.

Landsat 7 images affected by the SLC failure were used for the fire mapping in years 2012 and 2013. Within the Yarraloola LMA approximately 5.7% of the Landsat 7 image data was missing for the 2012 mapping and approximately 5.8% of the Landsat 7 image was missing for the 2013 mapping.

Table 24: Percentage of area within the Yarraloola LMA which is missing data for affected image dates.

Landsat 7 image date	Percentage of area no data
12/02/2012	5.7
02/03/2013	5.8

7. References

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Data Delivery

Datum and projection: GDA 94 MGA50

Date delivered: 26/02/2016

Contact: Katherine Zdunic/Jane Chapman, Remote Sensing and Spatial Analysis Section, GIS Branch, Department of Parks and Wildlife Western Australia, 17 Dick Perry Avenue, Kensington. Katherine.Zdunic@dpaw.wa.gov.au, Jane.Chapman@dpaw.wa.gov.au

Dataset Delivered	**Format**	**Description**
Yarraloola_Fuel_Age_1998_2015_HAB.shp	ESRI shapefile	Fuel age dataset clipped to NQ/POP Habitat boundary
Yarraloola_Fuel_Age_1998_2015_VEG.shp	ESRI shapefile	Fuel age dataset intersected with vegetation complex dataset
Yarraloola_Fuel_Age_1998_2015_10km_buff.shp	ESRI shapefile	Fuel age dataset for the Yarraloola LMA and surrounding area within 10km buffer for the time period 1999 – 2015
Yarraloola_Count_Overlap_2015_VEG.shp	ESRI shapefile	Fire frequency dataset intersected with vegetation complex dataset
Yarraloola_Count_Overlap_2015_HAB.shp	ESRI shapefile	Fire frequency dataset clipped to NQ/POP Habitat boundary
Yarraloola_Count_Overlap_2015_10km_buff.shp	ESRI shapefile	Fire frequency dataset for the Yarraloola LMA and surrounding area within 10km buffer
Yarraloola_Fire_1998_2015_10km_buff.shp	ESRI shapefile	Fire scar mapping for Yarraloola LMA and surrounding area within a 10 km buffer for the time period 1999 – 2015 for all available years
Draft_Yarraloola_Fire_stats_report_24022016.docx	PDF	This report document
Yarraloola_LMA_Maps (folder)	JPEG	Fuel age, Fire frequency and Seral state maps
Yarraloola LMA fire metrics metadata.docx	Word doc	

Rio Tinto

Yandicoogina TSOP 2015

Land Condition Monitoring Report

Yarraloola and Red Hill study sites

March 2016

Final RTIO-HSE-0279929

Disclaimer and Limitation

This report has been prepared by Rio Tinto Iron Ore (**Rio Tinto**), on behalf of Hamersley Iron-Yandi Pty Limited (the **Proponent**), specifically for the Yandicoogina Threatened Species Offset Plan (**TSOP**). Neither the report nor its contents may be referred to without the express approval of Rio Tinto, unless the report has been released for referral and assessment of proposals.

Document Status					
Rev	Author	Reviewer/s	Date	Approved for Issue	
				To Whom	Date
1	C. O'Neill	E. Carroll T. Souster M. Brand	31/03/2016	DoE / OEPA	April 2016

EXECUTIVE SUMMARY

The approved Yandicoogina Threatened Species Offset Plan details the management and monitoring actions that Hamersley Iron-Yandi Pty Limited is committed to undertake in order to provide benefits to the northern quoll and the Pilbara olive python. These management actions are to manage the threatening processes of: introduced predators; feral introduced herbivores; weeds; and inappropriate fire regimes over a five year period from 2015 to 2019.

This report summarises the results of the 2015 Land Condition Monitoring (in relation to the effects of grazing, fire and weeds) which was completed at Yarraloola Land Management Area and at the Red Hill Control Site.

Data collected from quadrat sites at both the Yarraloola LMA and Red Hill Control Site using floristic quadrat and Line Point Intercept transect methods provide a baseline with which to compare to data from subsequent years.

Although the experimental design did not allow statistical tests of significance, it is considered that the northern quoll monitoring habitats from the Yarraloola LMA and RHCS appear to have similar attributes for the measured parameters.

Disturbance at all sites was moderate to low. Evidence of grazing, albeit negligible at northern quoll monitoring sites, is noticeable on plains and riparian habitats, as anticipated. Most sites showed very little evidence of fire scarring as expected; the survey was designed to avoid recently burnt areas for this first phase of data collection. The amount of fire scarring will be compared at each site year on year. Visual fuel loads were lower in rocky northern quoll monitoring habitats compared to riparian and plains habitats, as expected. Weeds were mostly recorded from riparian and plains habitats; very few weeds were recorded from the rocky northern quoll habitats regardless of treatment group.

Based on the outputs from the 2015 land condition monitoring program, the Proponent acknowledges various limitations and has identified opportunities for improvement in the 2016 program.

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FIGURES

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APPENDICES

1 INTRODUCTION

Hamersley Iron-Yandi Pty Limited (the **Proponent**) operates the Yandicoogina Junction South West and Oxbow Project (the **Project**) which is located in the central Pilbara region of Western Australia, approximately 90 km north-west of Newman and 300 km south-east of Dampier.

The Project was subject to both Western Australian (**WA**) State and Commonwealth environmental assessment processes and was approved by the WA Minister for the Environment; Water on 18 October 2012 via Ministerial Statement 914 (**MS 914**) and the Commonwealth Minister for the Environment on 20 November 2012 via EPBC Decision Notice 2011/5815 (**EPBC 2011/5815**).

Both approvals were subject to a number of conditions, including offsets. In particular, Condition 14 of EPBC 2011/5815 required the Proponent to develop a Threatened Species Offset Plan (**TSOP**) detailing planned management and monitoring actions to provide benefits to the two Matters of National Environmental Significance (**MNES**) species that the Project may impact: northern quoll and the Pilbara olive python. Condition 14 further specifies that the Proponent is required to manage the threatening processes of: introduced predators; feral introduced herbivores; weeds; and fire.

The TSOP was approved by both government agencies in 2015 and it prioritises resources and expenditure towards the delivery of a landscape scale Introduced Predator Control program and associated monitoring across the Yarraloola Land Management Area (**Yarraloola LMA**) over a five year period (2015 – 2019).

The TSOP also includes periodic mustering and culling of unmanaged introduced herbivores. In addition, should the annual monitoring identify the need, the Proponent will also implement weed control and fire management programs. As part of the TSOP, the Proponent is required to monitor the progress and outcomes that result from implementation of the prescribed management actions.

1.1 SCOPE AND LIMITATIONS

The scope of this report is to summarise the results of the 2015 program of on-ground monitoring of management actions relating to the threatening processes of grazing, fire and weeds.

- Status monitoring – species diversity, richness, cover, condition etc.
- Threat monitoring – field based measurements of grazing intensity, fire regimes and weeds.

Note that this report only accounts for field based measures of fire regime; desktop based assessments are dealt with in a separate report (Parks and Wildlife 2016b).

Monitoring of all of these variables was conducted as a single program termed 'Land Condition Monitoring' which was completed at Yarraloola LMA and also at the Red Hill Control Site (**RHCS**). This report includes and compares results from the both sites.

The monitoring of the introduced predator program is considered separately (Parks and Wildlife 2015, 2016a).

2 METHODOLOGY

2.1 STUDY TEAM AND SURVEY TIMING

The survey team and timing were as follows:

- Yarraloola LMA: 5 – 18 October 2015; Samuel Luccitti, Senior Ecologist and Caitlin O'Neill, Ecologist, both of Rio Tinto.
- RHCS: 16 – 22 November; Samuel Luccitti and Carly Nixon, Specialist Environmental Approvals, both of Rio Tinto.

2.2 WEATHER

The closest Meteorological station providing climate data for both rainfall and temperature is Pannawonica, located approximately 20.5 km north-west of the Yarraloola LMA area and 47km north-west of the RHCS. Weather data from the Bureau of Meteorology (**BoM**) for Pannawonica is presented in

Figure 2-1 (BoM 2016).

The regional climate is semi-arid to semi-tropical with a summer rainfall season and relatively dry winter season, which varies in frequency and volume from year to year. The summer wet months extend from November to April with temperatures above 38°C. The remainder of the year is moderate to warm with temperatures in the mid 20°Cs in June and July. The closest data for Pan evaporation rates is in Port Hedland, which averages 3,500 mm per annum (BoM 2016), exceeding annual rainfall averages.

Annual rainfall is variable with tropical lows producing large regional rainfall events (between 100 mm and 200 mm in a few days) to isolated thunderstorm events in the dry (winter) season. For Pannawonica; the mean annual rainfall for the period 1971 to 2013 is 401.8 mm, with most precipitation occurring between December and April (coinciding with the cyclone season).

Unseasonal rain from a tropical low during May 2015 delivered significantly higher than average rainfall to the Pilbara region. Pannawonica received 65 mm in one day, the 2 May (BoM 2016). Slightly higher than average rainfall was also recorded during October and November. This rain is unlikely to have affected the results of the survey enough to deem it suboptimal.

Maximum temperatures reflected a moderately warm summer to winter period (BoM 2016). Temperatures preceding the survey were within expected ranges and close to mean maximum temperatures (Figure 2-1).

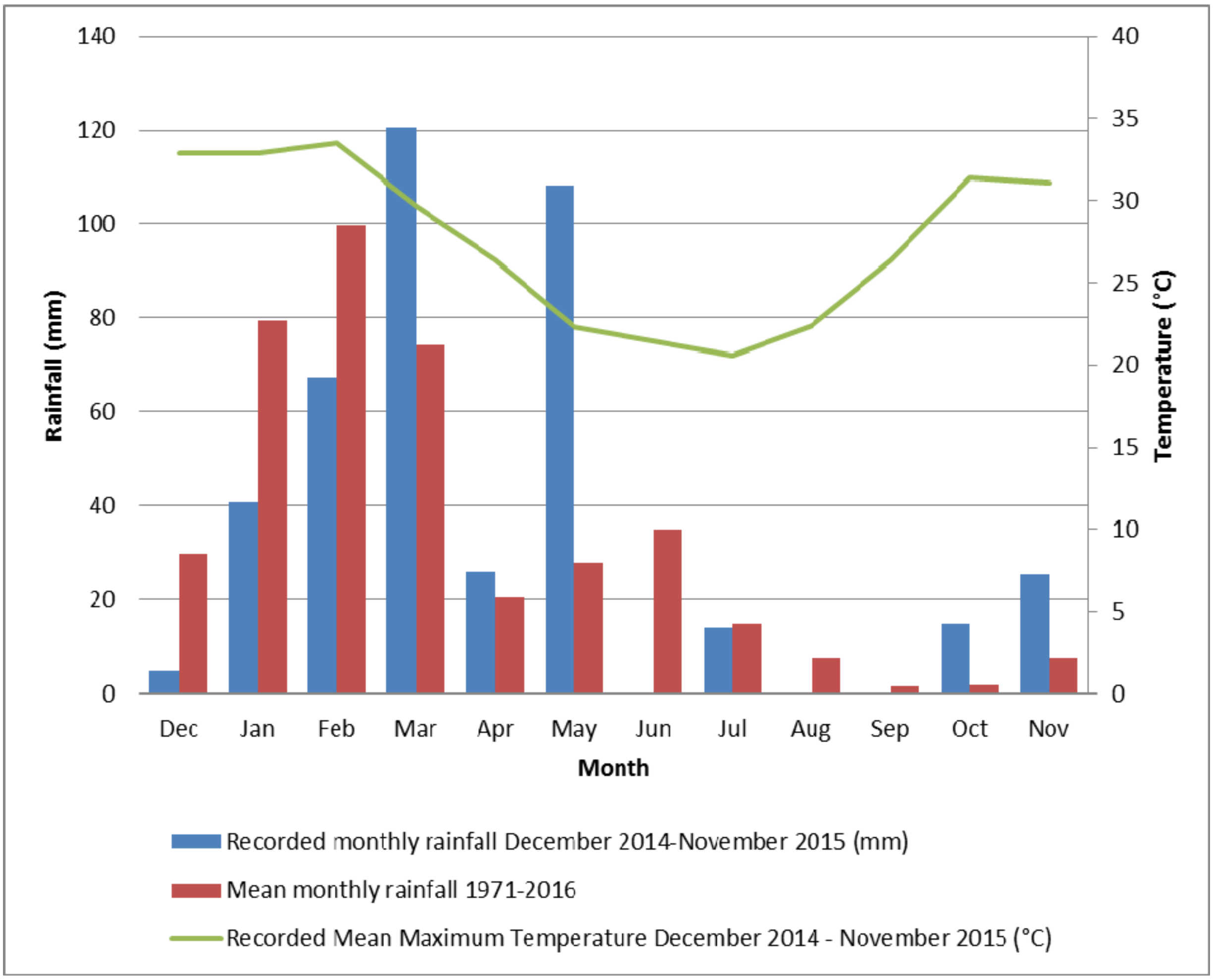

Figure 2-1: Comparison of actual and mean monthly rainfall and temperatures for Pannawonica

2.3 SURVEY DESIGN AND SITE LOCATIONS

Three types of survey site (flora quadrat, weed record point {**WRP**} and photo reference points {**PRP**}) were spread across the Yarraloola LMA and RHCS. Figure 2-2 shows their locations and GPS locations are provided in Appendix 1.

Floristic quadrats were completed at each northern quoll monitoring site in the Yarraloola LMA and RHCS (see Parks and Wildlife 2015 for more information). Within the Yarraloola LMA a floristic quadrat was also completed within each vegetation type. Thus, significantly more sites were recorded from the Yarraloola LMA as sites from riparian and plains habitat types were included. No sites from analogous habitats within the RHCS were included. Quadrats were completed as per EPA Guidance Statement 51 (Environmental Protection Authority 2004). A PRP was also completed at the south east corner of the quadrat. A line-point intercept transect (**LPI**) was completed along the east-west quadrat boundaries. Additional PRPs were placed in riparian zones of the Robe River in the Yarraloola LMA.

Weed Record Points (**WRPs**) were placed opportunistically in areas with noticeably large numbers of weeds on the Yarraloola LMA.

Additional site context information was collected from all three types of field site. Appendix 1 lists the methods used at each site. This contextual information was used to describe and understand disturbance (fire, weeds, grazing pressure) occurring at the site.

Table 2-1: Summary of the number and type of field sites included in 2015 land condition monitoring

Type	Yarraloola LMA	Red Hill Control Site	TOTAL
Floristic quadrats	19	10	29
Weed Record Points	6	0	6
Additional Photo Reference Points	8	0	8

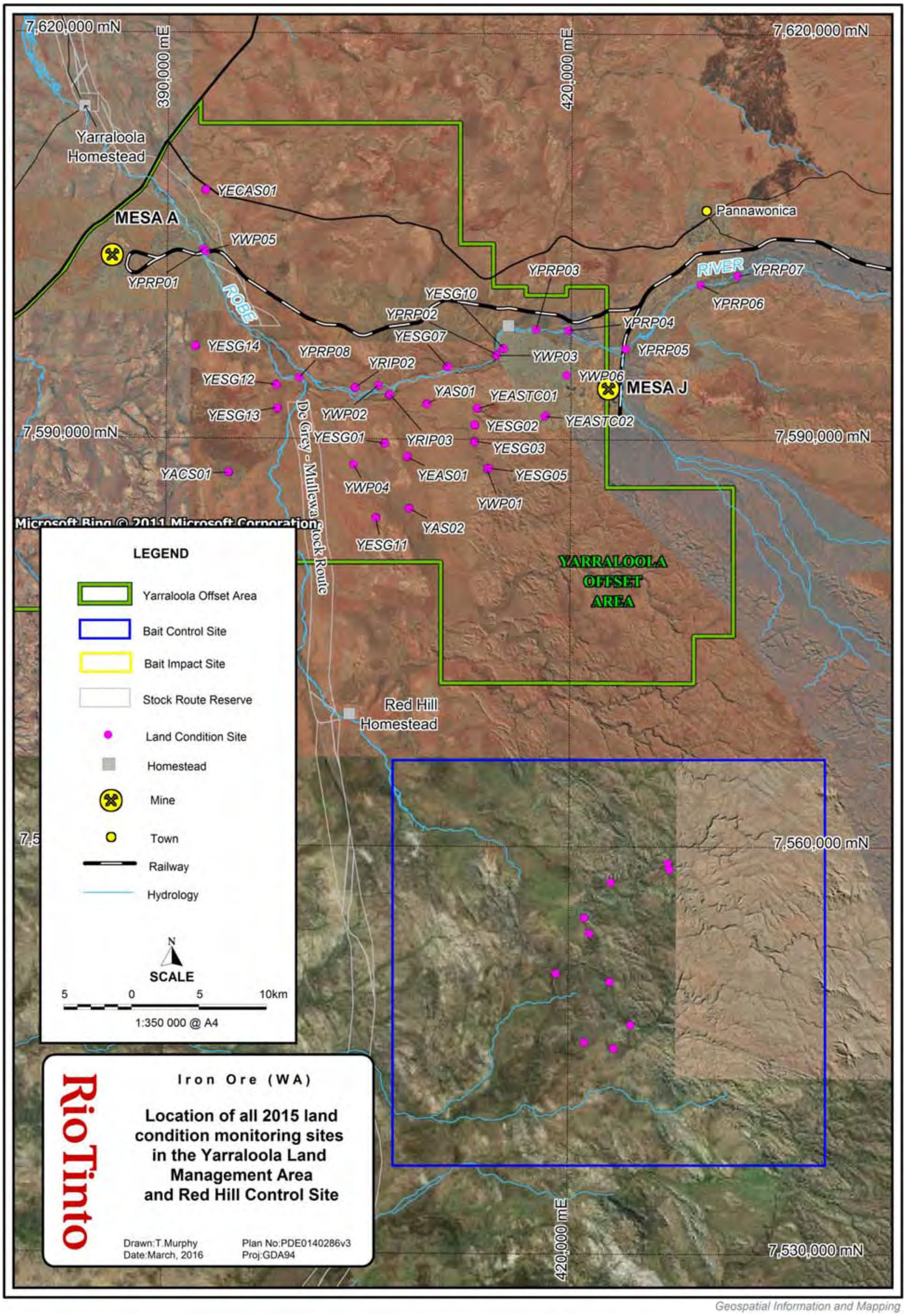

Figure 2-2: Location of all land condition sites

2.4 SURVEY SITE DESIGN

2.4.1 Floristic quadrat

Floristic quadrat data was collected as per the methods detailed in section 2 of Rio Tinto (2016). Key points include:

- Quadrats were 50 x 50m. Where these dimensions would overlap more than one vegetation type, the quadrat was re-arranged to cover the same area. Thus, quadrats located at northern quoll monitoring sites were mostly configured as 100 x 25m quadrats.
- Structural characteristics, including vegetation strata, vegetation structural formation, growth form and vegetation height classes were described as per NVIS vegetation classification code (Department of Environment 2015).
- Statistical analysis was completed using Microsoft Excel.
- All species cover estimates of '+' or 'present' were changed to 0.5%.
- Species growth for was identified as the potential form even if the species is quite small.
    - Shrubs denoted as perennial, usually above 1 m height.
    - Forbs denoted as annual, mostly shorter than 1m.
    - Nil to negligible amounts of chenopod shrub, mallee shrub and samphire shrub were recorded and thus these growth form categories were omitted from statistical analysis.

2.4.2 Line-point intercept (LPI) transects

A LPI transect was completed for each quadrat. This was located along the northern and southern boundaries of the quadrat unless stipulated in Appendix 6. An LPI transect was only completed along one of the East-West running boundaries for rectangular quadrats.

2.4.3 Photo Reference Points (PRP)

Approximately 20 images were taken at each PRP and stitched together to form a 360 degree panoramic view in Adobe Photoshop CS6. The panorama stitching settings were: using the 'Automate>Photomerge' function, select the 'Cylindrical' layout as well as the options for 'Blend images together', 'Vignette removal' and 'Geometric distortion correction'. Due to the large file size, images were reduced to a maximum of 20,000 pixels in length and saved as a jpg file with a resolution conversion of 10% (low resolution).

Photos were taken using a Canon 60D digital SLR camera using automatic settings for a lens set to 24mm unless otherwise stated in Appendix 6.

PRPs were marked with a steel fence dropper. Additional PRPs in riverine areas have also been surveyed using highly accurate dGPS to ensure repeatability of the survey in the event that fence droppers are washed away in flooding rain.

For 'additional PRP' sites that were used to monitor riparian vegetation additional scores were calculated. The relative surface area of water was ranked from 0-10 with 0 equalling no water and 10 equalling water to the horizon in at least one direction. The vegetation vigour, or greenness, was also scored from 0-10 with 0 equalling no green vegetation and 10 equalling nothing but green vegetation. This specifically pertained to vegetation in and immediately adjacent surface water bodies. Thus, the relative change in the amount of surface water and vegetation vigour can be compared between years.

2.4.4 Weed Record Points (WRP)

A WRP is a data point capturing either the absence of weeds or the occurrence of a specific weed species over a discrete 5 x 5 m area. For each occurrence the spatial location, species, abundance (stem count), foliar cover (%cover), life stage, life form and control method are recorded. More details are contained in Rio Tinto (2016).

2.4.5 Site context information

Site context information was collected for each site. This information can be used as explanatory variables with which to correlate trends in the qualitative data collected. Site context information included (details in Rio Tinto 2016):

- Site description information: GPS coordinates, time date and observers, site names and type, photo numbers, location relative to landmarks, landform pattern and element, slope, aspect, outcrop lithology, soil colour and texture, micro relief, distance to the nearest water, mud map.
- Vegetation Condition ranking as per the subjective categories in Trudgen (1988).
- Drainage.
- Disturbance ranking.
- Grazing intensity ranking, categories of evidence and percentage utilisation.
- Erosion ranking.
- Climatic conditions.
- Fire age, intensity and fuel load following FESA Visual Fuel Load Guide for the Pilbara Region (FESA 2009).

More detailed methods can be found in Rio Tinto (2016) including the datasheet for initial data collection.

2.5 FLORA IDENTIFICATION

Common species that were known to the botanist, Samuel Luccitti, were identified and recorded in the field. Voucher samples of unknown or conservation significant flora were collected, pressed and then dried in the field to allow further examination. Each specimen was assigned a unique reference identification number to facilitate tracking of data.

The specimens were identified by using taxonomic keys from relevant publications, in addition to comparing them to the collections held at the Western Australian Herbarium (**WAH**), by Brian

Morgan. Where necessary, WAH botanist Andrew Perkins and other specialist taxonomists were consulted for identification of difficult taxa. The identifications were then recorded on the sample registers. Voucher quality specimens will be lodged with the WAH. Nomenclature was checked for currency using DPaW's FloraBase database, and updated where required. All flora records were entered into Max V3, and a final species list was developed.

2.6 DATA ANALYSIS

Data was analysed using Microsoft Excel software package. Table 2-2 lists the metrics that were computed for each site and references where appropriate. All metrics use methods described in Rio Tinto (2016). External references are also included where applicable. All scoring categories are described in detail in Rio Tinto (2016).

Due to the unpaired nature of the sampling sites between the two treatment groups (Yarraloola LMA and RHCS), quantitative statistical differences between treatment groups could not be calculated. Instead, qualitative differences are described.

Table 2-2: Metrics calculated from the 2015 land condition data

Type	Metric	Information source	Unit of measurement	Reference source
Community composition and structure	Species richness	Quadrat	Count	n/a
	Evenness (J)	Quadrat	Index (0-1)	Pielou (1975)
	Species diversity (Shannon-Weiner Index)	Quadrat	Index (0-5)	Shannon and Weaver (1949)
	Total cover (no overlaps)	LPI	%	n/a
	Total cover (including overlaps)	Quadrat	%	n/a
		LPI	%	n/a
	Native/exotic canopy, mid-storey and ground stratum cover (incl. overlaps)	Quadrat	%	Walker and Hopkins (1990)
	Native/exotic ground stratum cover by growth form (T, S, G, H, V, F)	Quadrat	%	n/a
		LPI		
	Presence/absence of vegetation strata	Additional PRPs		Walker and Hopkins (1990)
	Presence/absence and relative cover of growth forms	Additional PRPs		n/a
Habitat and ecosystem function parameters	Leaf litter cover	LPI	%	The University of Adelaide (2012)
	Bare ground cover	LPI	%	The University of Adelaide (2012)
	Coarse woody debris cover	LPI	%	The University of Adelaide (2012)
	Rock cover	LPI	%	The University of Adelaide (2012)
Disturbance parameters	Frequency (no. of point intercepts) of cattle dung	LPI	%	The University of Adelaide (2012)
	Frequency (no. of point intercepts) of cattle tracks	LPI	%	The University of Adelaide (2012)
	No. plant point-intercepts grazed	LPI	%	The University of Adelaide (2012)
	Average percentage utilisation of palatable species	LPI	%	n/a
	Overall percentage utilisation of palatable species	Site context data from all sites	%	n/a
	Grazing intensity (3 metrics) • cattle • native • total grazing pressure	Site context data from all sites	Subjective categories	n/a

Type	Metric	Information source	Unit of measurement	Reference source
	Number of evidence sources for grazing	Site context data from all sites	Count	n/a
	Total active erosion pressure	Site context data from all sites	Subjective categories	n/a
	Percentage of site affected by erosion	Site context data from all sites	Subjective categories	n/a
	Total disturbance pressure (clearing, mining, weeds)	Site context data from all sites	Subjective categories	n/a
	Fire age	Site context data from all sites	Subjective categories	n/a
	Fire intensity	Site context data from all sites	Subjective categories	n/a
	Visual fuel load (biomass)	Site context data from all sites	Subjective categories	FESA (2009)
	Trudgen's vegetation condition	Site context data from all sites	Subjective categories	Trudgen (1988)
	Weed total cover	WRP	%	n/a
		Quadrat	%	n/a
		Additional PRPs	%	n/a
	Weed relative cover	WRP	%	n/a
		Quadrat	%	n/a
		Additional PRPs	%	n/a
	Weed species richness	WRP	Count	n/a
		Quadrat	Count	n/a
		Additional PRPs		n/a
Moisture conditions	Presence/absence and relative extent of surface water of permanent or ephemeral pools	Additional PRPs	Subjective categories	n/a
	Vegetation greenness/vigour	Additional PRPs	Subjective categories	n/a
	Climatic conditions	Site context data from all sites	Subjective categories	n/a

3 RESULTS

The following section describes general differences between habitat and treatment groups for each metric. Appendix 2 to Appendix 5 lists the values for each metric for each site. Appendix 1 lists the sites and the assigned habitat groupings, while Appendix 6 includes a full site description and PRP photo for each.

3.1 COMMUNITY COMPOSITION AND STRUCTURE

QUADRAT DATA: Sites from the Yarraloola LMA have slightly higher average species richness (Table 3-1). However, this value is skewed due to a high number of species at a few sites from riparian and plains habitats. No sites from analogous habitats were recorded from the RHCS. Also, when the abundance of each species is included in the comparison the RHCS appears more diverse and less dominated by a small subset of species present in high abundance[1].

The Yarraloola LMA has slightly more cover when overlaps[2] between different stratums are included. The ground stratum makes up the majority of cover for both sites. While the Yarraloola LMA has more cover in the ground stratum than the RHCS, the RHCS has more cover in the upper and mid stratum. Hummock grasses are the dominant growth form cover type for both sites. There is a similar amount of cover between sites in all growth form categories except hummock grasses (Yarraloola LMA almost double) and trees (RHCS slightly higher).

LPI DATA: Total cover estimates including areas of overlap[2] between vegetation strata are similar between both the Yarraloola LMA and RHCS while the Yarraloola LMA has slightly higher cover when overlap are excluded (Table 3-2). Interestingly the cover estimate for RHCS is slightly higher when overlaps are included indicating the RHCS has an increased amount of vegetation strata complexity when compared to the Yarraloola LMA.

Similar to the quadrat data, cover estimates divided by growth form indicate that hummock grasses dominate both sites. Again, there is a similar amount of cover between sites in all growth form categories except hummock grasses (Yarraloola LMA approximately 50% more) and trees (RHCS slightly higher).

Cover estimates including overlaps from LPI are generally much lower than those calculated from quadrat data. The more objective nature of the LPI data collection method is the most obvious explanation.

There are also very few differences in cover, with or without including overlaps, between northern quoll monitoring sites at the Yarraloola LMA and those from plains and riparian habitats. Appendix 3 details the cover values for each site.

[1] Species abundance was measured as the percentage cover, 'diversity' by the Shannon-Weiner Index (XX) and 'domination/evenness' by the J statistic (XX).

[2] 'overlaps' are points where vegetation may be present simultaneously at multiple height stratum e.g. a grass overshadowed by a shrub overshadowed by a tree. When included, overlaps mean the percentage cover could theoretically be greater than 100%. Thus overlaps help to characterise the complexity of a habitat as well as the cover. Calculations without overlaps instead give a true estimate of cover as seen from space.

PRP DATA: Species richness and vegetation cover (including overlaps) at PRP sites in the Yarraloola LMA vary greatly from 3-10 species and 13-72% cover (Table 3-3). All sites have an upper, mid and ground story with the exception of YPRP07 which is missing a mid-story. All sites have tree and sedge growth forms and do not have hummock grass. The presence and abundance of forbs, tussock grass and shrubs vary between sites. The presence and abundance of large Eucalyptus trees and *Typha domingensis* at all sites is indicative of low lying and routinely wetted riparian habitats of the Pilbara, which were the intended target habitats.

Table 3-1: Community composition and structure values for both the Yarraloola LMA and RHCS calculated from quadrat data

Site name (No. sites)		Richness (No. species)	Diversity (Shannon Weiner Index)	Evenness (J)	Total cover including overlaps (%)	Cover by vegetation stratum (%)			Cover by growth form (%)					
						Upper	Mid	Ground	Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb
YLMA (19)	Median	21.0	1.4	0.5	88.0	5.0	21.0	60.0	2.0	19.5	1.0	55.0	0.0	4.0
	Average	24.5	1.6	0.5	84.2	6.2	21.9	56.7	4.1	21.7	5.5	47.9	0.2	4.8
RHCS (10)	Median	23.5	2.2	0.7	74.0	7.5	22.5	35.3	7.5	24.8	6.0	32.5	0.3	1.5
	Average	23.3	2.1	0.7	76.5	10.7	25.0	42.4	10.3	23.6	5.3	33.1	0.5	3.8

Table 3-2: Community composition and structure values for both the Yarraloola LMA and RHCS calculated from line-point intercept data

Site name (No. sites)		Total cover without overlaps (%)	Total cover with overlaps (%)	Cover by growth form including overlaps (%)					
				Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb
YLMA (19)	Median	49.5	48.0	0.00	5.94	0.00	34.31	0.00	0.00
	Average	50.2	51.7	2.04	7.41	2.09	39.59	0.00	0.54
RHCS (10)	Median	41.1	48.0	4.12	6.44	1.98	25.74	0.00	0.00
	Average	46.5	53.0	11.81	10.84	3.57	25.83	0.10	0.81

Table 3-3: Community composition and structure from photo reference points in the Yarraloola LMA

Site name	Richness (No. species)	Total vegetation cover including overlaps (%)	Presence/absence of vegetation strata			Cover by growth form including overlaps (%)					
			Upper	Mid	Ground	Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb
YPRP01	7	13	1	1	1	5	1	0	0	4	3
YPRP02	5	43	1	1	1	30	0	0	0	12.5	0.5
YPRP03	5	61	1	1	1	15	20.5	0	0	25	0
YPRP04	3	22	1	1	1	10	0	0	0	12	0
YPRP05	7	57	1	1	1	45	0	0	0	10.5	1.5
YPRP06	9	46	1	1	1	30	7.5	3.5	0	4.5	0.5
YPRP07	8	65	1	0	1	40	15	0	0	5.5	4
YPRP08	10	72	1	1	1	40.8	20	6	0	2	3

3.2 HABITAT AND ECOSYSTEM FUNCTION PARAMETERS

LPI DATA: Both treatment groups have similar amounts of litter cover (approx. 40%). However while the Yarraloola LMA has markedly less rock substrate than litter, the RHCS has a similar amount of rock and litter substrate (Table 3-4).

The Yarraloola LMA has slightly more gravel and bare substrate while the RHCS has more coarse woody debris.

The increased prevalence of cryptogrammic cover at Yarraloola is recorded from plains habitats that were not sampled at the RHCS. Thus differences between treatment groups are likely an artefact of sampling.

Table 3-4: Cover by substrate type as calculated from LPI transect data

Site name (No. sites)		Cover by substrate (%)					
		Bare	Cryptogram (any lichen, moss, algae, etc.)	CWD - course woody debris (>10cm)	Gravel (particles 2mm - 2cm)	Litter (dead vegetation not attached <10cm)	Rock (particles < 20cm)
YLMA (19)	Median	9.80	0.00	0.00	15.69	43.14	25.49
	Average	15.63	0.36	0.08	21.59	39.54	22.80
RHCS (10)	Median	0.50	0.00	1.49	10.40	36.14	42.44
	Average	2.29	0.00	1.39	15.47	42.17	38.69

3.3 DISTURBANCE PARAMETERS

LPI DATA: Both the metrics 'frequency (no. of point intercepts) of cattle dung' and 'Frequency (no. of point intercepts) of cattle tracks' could not be calculated from the LPI transect data. Too few intercepts were encountered to create a metric capable of detecting change over time. Thus, these metrics will not be calculated for future surveys.

Only three sites had line-point intercepts with plants that had been grazed. These three sites were from the Yarraloola LMA and all were in plains and riparian habitats as opposed to the typically rocky habitats of northern quoll monitoring sites. Sites and the percentage of plant intercept grazed were YEAS05 (8.7%), YRIP02 (37%) and YRIP03 (12.5%).

Given the low numbers of intercepts with grazed vegetation, the metric 'Average percentage utilisation of palatable species' was deemed to have insufficient data and was not calculated in 2015.

SITE CONTEXT DATA: The average total utilisation of palatable species is negligible in habitats at northern quoll monitoring sites regardless of treatment group (Table 3-5). However utilisation in plains and riparian habitats is significantly higher (approximately 30-50%) regardless of the method used to estimate the scoring; scores estimated from quadrat, WRP or PRP data are similar.

Total disturbance intensity scores from the combined impacts of clearing, mining and grazing are very low for all sites. There is relatively little disturbance at all sites with grazing the biggest contributor.

Scores for the intensity and percentage cover of erosion action at each site vary widely and thus no interpretations are made. Nevertheless, data are included (Table 3-5).

Most sites have existed a long time without fire. Of those that show evidence of fire most show minor impact scars on some trees and shrubs (Table 3-6). This is similar across habitats, with the exception of the quoll monitoring habitats from RHCS which show evidence of tree and shrub death from fire. Thus the RHCS was possibly exposed to more intense fires when they did occur. As expected, biomass at quoll monitoring habitats is usually low compared to riparian and plains habitats.

All sites in quoll monitoring habitats are in Good or Very Good condition as measured by Trudgen's (1988) Vegetation Condition scores (Table 3-7). While a significant amount of riparian and plains habitat sites are also in Good to Very Good condition, there is also a large portion that is in Poor to Very Poor condition.

Table 3-9 lists the weeds present in both treatment groups. Figure 3-1 shows the location of all Yarraloola LMA land condition monitoring sites over the prospective weed areas. More species of weed were collected from the Yarraloola LMA most likely because a) 'Weed Record Points' specifically sought to sample areas with weeds and b) unlike at the RHCS, sites from the Yarraloola LMA included riparian and plains habitats which are more prospective for weed species due to the increased availability of water.

There was a negligible number of weed species, percentage cover or relative percentage cover of weeds recorded from northern quoll monitoring habitats in either treatment group (Table 3-8). Most weeds species were collected from riparian and plains habitats as expected. Sites with the highest weed cover were the Yarraloola LMA WRPs which is as expected since these sites were specifically chosen to represent areas of high weed cover. Cover in the WRPs was significant (30-40%).

Table 3-5: Intensity of grazing and erosion disturbance factors calculated from subjective site context scoring

Site name	Habitat type	Sites (n)		Overall utilisation of palatable species (%)	Average grazing intensity score (categorical)			Number of evidence sources for grazing	Total active erosion pressure (0=low, 4=high)	Percentage of site affected by erosion**	Total disturbance intensity from clearing mining and grazing (0=low, 4=high)
					Cattle (0=low, 4=high)	Native (0=low, 4=high)	Total (0=low, 4=high)				
YLMA	Quoll monitoring	11	Median	0.0	0.0	1.0	1.0	2.0	1.0	40.0	0.0
			Average	1.9	0.3	1.4	1.6	1.7	1.8	40.5	0.0
	Plains/riparian*	7	Median	50.0	1.0	1.0	2.0	2.5	1.0	15.0	0.1
			Average	31.4	1.4	0.9	2.0	2.0	0.9	21.9	0.1
RHCS	Quoll monitoring	10	Median	0.0	0.5	1.0	1.5	1.0	0.0	0.0	0.1
			Average	3.0	0.6	1.0	1.6	1.4	0.0	0.0	0.2
YLMA WRPs	Plains/riparian	6	Median	40.0	2.0	0.0	2.0	3.0	0.0	0.0	0.6
			Average	38.3	1.8	0.3	2.2	2.3	0.7	35.0	0.5
YLMA PRPs	Riparian	8	Median	50.0	2.0	0.0	2.5	3.0	0.0	0.0	0.3
			Average	32.5	2.0	0.4	2.4	3.3	0.0	0.0	0.3

* site YAS01 omitted from these calculations

** values can exceed 100% where two types of erosion overlap

Table 3-6: Fire age, intensity and fuel load at all sites as measured by subjective categorical site context data.

Site name	Habitat type	Sites (n)	Fire Age (% of sites)					Fire intensity (% of sites)					Visual fuel load - biomass (% of sites)			
			nil	<1 yr	1 - 2 yrs	2 - 5 yrs	>5 yrs	No damage	Minor impact scars on some trees/shrubs	Minor impact scars on most trees/shrubs	Some trees/shrubs killed	Most trees/shrubs killed	0-5 t/ha	5-10 t/ha	10-15 t/ha	15+ t/ha
YLMA	Quoll monitoring	11	0	0	0	0	100	64	18	0	18	0	45	36	18	0
	Plains/ Riparian	8	0	13	0	0	88	50	38	13	0	0	38	25	25	13
RHCS	Quoll monitoring	10	10	0	0	10	80	10	30	0	60	0	50	40	10	0
YLMA WRPs	Plains/ Riparian	6	0	0	0	0	100	100	0	0	0	0	n/a	n/a	n/a	n/a
YLMA PRPs	Riparian	8	75	0	0	0	25	100	0	0	0	0	0	0	25	75

Table 3-7: Percentage of sites in each Trudgen (1988) vegetation condition category from site context data

Site name (No. sites)	Habitat type	Sites (n)	Trudgen (1988) vegetation condition (% of sites)					
			Excellent	Very Good	Good	Poor	Very Poor	Completely Degraded
YLMA	Quoll monitoring	11	0	91	9	0	0	0
	Plains/riparian*	7	0	43	14	29	14	0
RHCS	Quoll monitoring	10	0	60	40	0	0	0
YLMA WRPs	Plains/riparian	6	0	33	0	67	0	0
YLMA PRPs	Riparian	8	0	50	38	13	0	0

Table 3-8: Species richness, cover and relative cover of weeds at all sites

Site name	Habitat type	Sites (n)		Weed richness (No. of species)	Total weed cover including overlaps (%)	Relative weed cover (weeds/total cover)
YLMA	Quoll monitoring	11	Median	0.0	0.0	0.0
			Average	0.6	0.4	0.3
	Plains/riparian	8	Median	2.0	1.0	1.0
			Average	1.9	5.8	10.1
RHCS	Quoll monitoring	10	Median	0.0	0.0	0.0
			Average	0.6	1.4	1.8
YLMA WRPs	Plains/riparian	6	Median	2.0	37.8	100.0*
			Average	2.3	34.6	100.0*
YLMA PRPs	Riparian	8	Median	1.5	1.0	1.9
			Average	1.8	2.4	3.9

*100% of cover recorded at WRPs was weeds because that was the only type of species information collected; other species were present but not recorded.

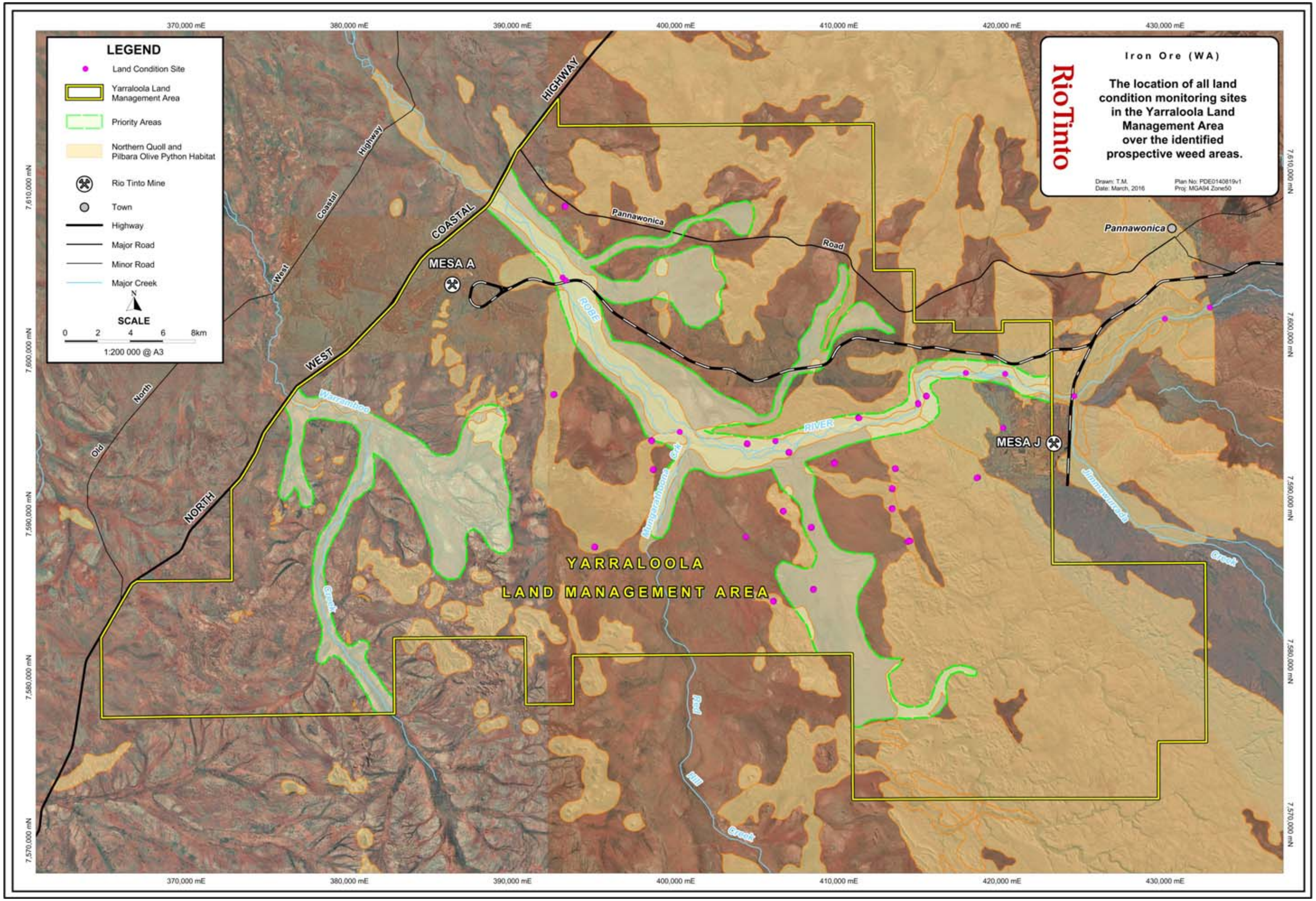

Figure 3-1: **The location of all Yarraloola LMA land condition monitoring sites over the prospective weed areas**

Table 3-9: Weed species present at sites within the Yarraloola LMA and RHCS

Weed species	YLMA	RHCS
Acetosa vesicaria	Y	
Aerva javanica	Y	
Argemone ochroleuca	Y	Y
Cenchrus ciliaris	Y	
Cenchrus setiger	Y	
Cucumis melo	Y	
Cynodon dactylon	Y	
Flaveria trinervia	Y	
Lactuca serriola	Y	
Malvastrum americanum	Y	Y
Passiflora foetida	Y	
Setaria ?verticillata	Y	Y
Sonchus oleraceus	Y	
Vachellia farnesiana	Y	Y

3.4 MOISTURE CONDITIONS

Climatic conditions were 'Dry, no stress' at all sites except RH-N and RH-P. Both of these had recorded recent rain with no impact to vegetation.

Climatic conditions at all additional PRP sites were 'Dry, no stress' reflecting the paucity of recent rain prior to survey. However, sizeable groundwater fed pools were present at most sites. Table 3-10 lists the scorings for the relative amounts of surface water. Sizeable pools are present at sites YPRP08, YPRP05 and YPRP06 corresponding with the previously known permanent pools Robe Pool, Medawandy Pool and Matangkuna Pool respectively. These sites also had the highest vegetation vigour, or greenness, scores. Vegetation vigour at other sites with less surface water was also reasonable, probably reflecting large amounts of subsurface water availability.

Table 3-10: Moisture conditions recorded from additional PRP sites.

Site	Relative amount of surface water (score 0-10)	Vegetation vigour (score 0-10)
YPRP01	5	6
YPRP02	1	4
YPRP03	1	5
YPRP04	5	7
YPRP05	7	7
YPRP06	7	6.5
YPRP07	2	4
YPRP08	7.5	7

4 DISCUSSION

4.1 SUMMARY OF LAND CONDITION STATUS

4.1.1 Community composition, structure, habitat and ecosystem function

Data collected from quadrat sites at both the Yarraloola LMA and RHCS using floristic quadrat and LPI transect methods provide a solid baseline with which to compare to data from subsequent years. Thus far, northern quoll monitoring habitats from the Yarraloola LMA and RHCS appear to have similar attributes for the measured parameters.

Data from the PRP sites suggest their locations are indicative of the intended target habitats. Riparian vegetation species, structure and surface water expression were as expected. Therefore monitoring of these will be continued.

While tests for statistical significance were not possible due to the unpaired sampling design, generally the Yarraloola LMA recorded a higher species richness, diversity and cover. However this is likely due to the inclusion of sites from plains and riparian habitats at Yarraloola LMA and not at the RHCS.

Despite the sampling in-equivalence, the RHCS provides more complex habitat in terms of growth form and strata and substrate cover, possibly indicating it is further along the natural succession pathway than the Yarraloola LMA. In addition, RHCS has more substrate typical of habitats that are burnt less frequently and thus further along in the process of vegetation community succession than sites from the Yarraloola LMA. Course woody debris can only accumulate when vegetation has had significant amounts of time since last fire. Conversely, bare soil and gravel cover is typical of habitat early in the successional process.

4.1.2 Disturbance factors

Disturbance at all sites was relatively low, with evidence of grazing at a measurable intensity.

Unfortunately grazing intensity could only be measured using subjective methods. All metrics indicate that grazing intensity is negligible at northern quoll monitoring sites but is noticeable on plains and riparian habitats, as expected.

Most sites showed very little evidence of fire scarring. Visual fuel loads were lower in rocky northern quoll monitoring habitats compared to riparian and plains habitats, as expected.

Weeds were mostly recorded from riparian and plains habitats; very few weeds were recorded from the rocky northern quoll habitats regardless of treatment group. The cover and extent of weeds was minimal except from Yarraloola LMA's WRP sites, which were intended as indicative measurements of areas of high weed infestation. Thus these WRPs were well selected. It is likely that there are similar infested sites in the RHCS but these were not measured as a part of this report.

4.1.3 Moisture conditions

Weather prior to the survey was typical for the area and season. Since there is no existing monitoring for moisture condition occurring on the sites, the 2015 data constitutes a baseline with which to compare changes between years. No further analysis is possible on the current data.

4.2 LIMITATIONS

4.2.1 Unpaired sampling design

It was not valid to statistically compare numerical values from the RHCS and Yarraloola LMA sites as 'Control' and 'Impact' sites using only data from the 2015 sampling. This is because the set of sites were chosen from a range of habitats and differences in values between habitats are likely bigger than differences between treatment groups. To overcome this limitation, paired sites in similar habitats between treatment groups would need to be established. Instead, comparison of the trend in values at each site can be made between treatment groups over time.

4.2.2 LPI transects

LPI as calculated in this study may underestimate the cover of rare species due to the reduction in number of transects from that recommended in publicly endorsed protocols such as AusPlots (University of Adelaide 2012). Per site transect numbers were originally minimised to two to improve the efficiency and practicality of data collection. However very low encounter rates for rare species (e.g. one intercept of sedge species in all data collected in 2015) indicate that an increase in the number of transects per site should be considered before collecting the next round of data. In summary, while a useful and objective method to calculate overall vegetative cover, LPI as it was measured in 2015 should not be considered as an effective method for estimating the cover of rare species going forward.

The measurement of grazing intensity using LPI was not successful during this study. There were too few intercepts of tracks, dung, or grazed plants to calculate a metric capable of detecting changes in grazing intensity over time. The majority of sites did not record any intercepts with tracks, dung or grazed plants. Reasons for this could be:

- **Not enough transects**: 2 x 50m LPI transects per site is not enough to detect change over time. More transect will undoubtedly record more intercepts with tracks, dung or grazed plants. The AusPlots (University of Adelaide 2012) methodology utilised 10 x 100m transects per site however this number is likely to be impractical with the resources available in the current study. A mid-way compromise could be sought.

- **Innate quality of the landscape**: Grazing effects are diffuse in the Pilbara rangelands to the point where any attempt to use LPI transects to detect change is unlikely to be successful. The potential for this effect was first theorised during a similar study of land condition at Juna Downs Station (EcoLogical 2014). This effect is likely due to the naturally low productivity habitats present in the Pilbara rangelands. Herbivores must cover large amounts of area to find the required amount of food.

The three sites with grazed vegetation intercepts were in riparian and plains habitats; no sites at northern quoll monitoring sites had intercepts with grazed vegetation. This is as expected, since herbivores of all types usually prefer to graze on riparian and plains habitats due to the increased productivity and thus abundance of palatable species. Furthermore, without (or even with) methodological changes, it is unlikely that LPI transects will be able to detect changes in grazing intensity in the habitats of northern quoll monitoring sites because very little grazing is naturally occurring.

4.2.3 Benchmarking

The data collected thus far is useful only in determining the intensity of disturbance parameters relative to other sites in the study. To determine and understand the significance of the actual intensity would require the collection of data from 'benchmark' sites throughout the Pilbara region similar to those created by the Queensland BioCondition scheme (Queensland Government 2015).

None of these benchmark sites are likely to be pristine, thus only 'best on offer' can be selected. While this exercise requires allocation of limited resources it could help the Proponent more accurately understand the effect of altered land management practices on the Yarraloola LMA and thus aid more effective adaptive management.

5 2016 LAND CONDITION MONITORING

Whilst sampling during 2015 was considered adequate, based on adaptive management, the following changes are proposed to further improve the 2016 land conditioning monitoring program:

- Include sites from riparian and plains habitats at RHCS so that an analogous set of sites from both the Yarraloola LMA and RHCS will exist and can be compared. This will improve the ability to detect changes to those habitats most likely to respond to changes in grazing, weed and fire regimes. Habitats at northern quoll monitoring sites can already be compared between treatment groups with the current set of sites. However these are not the habitats likely to change most due to altered grazing, weed and fire regimes.

- WRPs: In order to create a system that is reliable and sensitive enough to detect meaningful change in weed abundance and diversity, extra WRPs will be installed within the Yarraloola LMA in 2016 in areas with little current surveillance but high likelihood of weed invasion i.e. in the south-west and west. The small size combined with the magnified effects of imprecise re-location of quadrats indicates an increased number is needed for reliable statistical analysis.

- LPI transects: this study indicates that cover measures collected with more objective methods (LPI) are significantly different to more subjective measurements (quadrat). Given the discrepancy and the low encounter rate of rare species and evidence of grazing, the number of LPI's per site will be rationalised during subsequent sampling rounds. To ensure ongoing confidence in and compatibility of data, the 2016 sampling round will continue to collect quadrat and site context data along with an increased number of LPI transects.

- Data sheet: Several items were redundant methods of collecting information and will therefore be omitted from data collection in 2016:

  - Remove % substrate cover as estimated by eye.

  - Introduce a new fire age class of '5-10 years post fire' in the place of the '>5years' age class.

  - Erosion intensity and percentage cover scores should be substituted for descriptive notes. These scores where highly subjective and not easily applied to the Pilbara environment due to the general lack of soils of any depth. Sometimes the lack of soil makes it appear as thus active erosion is occurring across the whole site. These methods of estimating erosion are not informative.

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7 APPENDICES

Appendix 1: Methods used at each field site included in the 2015 land condition monitoring for the Yandicoogina TSOP

Site name	Area	Habitat	GPS coordinates (GDA94)		Floristic quadrat			WRP	Additional PRP	Site context information
			Easting	Northing	Quadrat	LPI	PRP			
YACS01	YLMA	Plains/ riparian	115.981	-21.814	Y	Y	Y			Y
YAS01	YLMA	Plains/ riparian	116.123	-21.768	Y	Y	Y			Y
YAS02	YLMA	Plains/ riparian	116.110	-21.837	Y	Y	Y			Y
YEAS01	YLMA	Plains/ riparian	116.109	-21.803	Y	Y	Y			Y
YEASTC01	YLMA	Quoll monitoring	116.159	-21.771	Y	Y	Y			Y
YEASTC02	YLMA	Plains/ riparian	116.208	-21.776	Y	Y	Y			Y
YECAS01	YLMA	Plains/ riparian	115.964	-21.625	Y	Y	Y			Y
YESG01	YLMA	Quoll monitoring	116.092	-21.794	Y	Y	Y			Y
YESG02	YLMA	Quoll monitoring	116.157	-21.782	Y	Y	Y			Y
YESG03	YLMA	Quoll monitoring	116.157	-21.793	Y	Y	Y			Y
YESG05	YLMA	Quoll monitoring	116.168	-21.811	Y	Y	Y			Y
YESG07	YLMA	Quoll monitoring	116.137	-21.743	Y	Y	Y			Y
YESG10	YLMA	Quoll monitoring	116.178	-21.731	Y	Y	Y			Y
YESG11	YLMA	Quoll monitoring	116.087	-21.844	Y	Y	Y			Y
YESG12	YLMA	Quoll monitoring	116.014	-21.755	Y	Y	Y			Y
YESG13	YLMA	Quoll monitoring	116.016	-21.770	Y	Y	Y			Y
YESG14	YLMA	Quoll monitoring	115.957	-21.729	Y	Y	Y			Y
YPRP01	YLMA	Plains/ riparian	115.963	-21.664					Y	Y
YPRP02	YLMA	Plains/ riparian	116.173	-21.735					Y	Y
YPRP03	YLMA	Plains/ riparian	116.201	-21.718					Y	Y
YPRP04	YLMA	Plains/ riparian	116.225	-21.719					Y	Y
YPRP05	YLMA	Plains/ riparian	116.265	-21.731					Y	Y
YPRP06	YLMA	Plains/ riparian	116.319	-21.689					Y	Y
YPRP07	YLMA	Plains/ riparian	116.346	-21.683					Y	Y
YPRP08	YLMA	Plains/ riparian	116.031	-21.750					Y	Y
YRIP02	YLMA	Plains/ riparian	116.072	-21.757	Y	Y	Y			Y
YRIP03	YLMA	Plains/ riparian	116.096	-21.761	Y	Y	Y			Y
YWP01	YLMA	Plains/ riparian	116.166	-21.811				Y		Y
YWP02	YLMA	Plains/ riparian	116.088	-21.755				Y		Y
YWP03	YLMA	Plains/ riparian	116.173	-21.736				Y		Y
YWP04	YLMA	Plains/ riparian	116.070	-21.808				Y		Y
YWP05	YLMA	Plains/ riparian	115.964	-21.666				Y		Y
YWP06	YLMA	Plains/ riparian	116.223	-21.749				Y		Y
RH-E	RHCS	Quoll monitoring	116.255	-22.087	Y	Y	Y			Y
RH-F	RHCS	Quoll monitoring	116.236	-22.110	Y	Y	Y			Y
RH-H	RHCS	Quoll monitoring	116.269	-22.182	Y	Y	Y			Y
RH-J	RHCS	Quoll monitoring	116.215	-22.147	Y	Y	Y			Y
RH-L	RHCS	Quoll monitoring	116.236	-22.193	Y	Y	Y			Y
RH-M	RHCS	Quoll monitoring	116.257	-22.197	Y	Y	Y			Y
RH-N	RHCS	Quoll monitoring	116.297	-22.078	Y	Y	Y			Y
RH-P	RHCS	Quoll monitoring	116.295	-22.074	Y	Y	Y			Y
RH-X	RHCS	Quoll monitoring	116.254	-22.153	Y	Y	Y			Y
RH-Z	RHCS	Quoll monitoring	116.239	-22.121	Y	Y	Y			Y

Appendix 2: Raw community composition values for each site from quadrat data

Site name	Total cover including overlaps (%)	Diversity (Shannon Weiner Index)	Richness (No. species)	Evenness (J)	Cover by vegetation strata (%)			Cover by growth form (%)					
					Upper	Mid	Ground	Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb
RH-E	116.5	2.68	35	0.75	30	57.5	29	30	53.5	12	10.5	2	8.5
RH-F	45.5	2.52	24	0.79	17	10.5	17.5	17	10.5	8.5	7.5	0.5	1.5
RH-H	70	2.27	23	0.72	0	36.5	34	0	35	1.5	30	0.5	3
RH-J	60	1.25	9	0.57	5	19	35	0	25	0	35	0	0
RH-L	37.5	0.99	7	0.51	0	3.5	35.5	0	1.5	0.5	35	0	0.5
RH-M	91.5	2.52	24	0.79	10	48	34	10	47.5	7.5	25	0	1.5
RH-N	112.5	2.19	29	0.65	25	20.5	64	25.5	24.5	7.5	50	0.5	4.5
RH-P	71	3.01	47	0.78	5	26.5	41.5	5	25.5	3.5	20	0	17
RH-X	77	1.69	20	0.56	5	6	65.5	5	7.5	5	57.5	1	1
RH-Z	83	1.52	15	0.56	10	5	67.5	10	5.5	7	60	0	0.5
YACS01	118	1.33	20	0.44	0	58	62	0	53.5	0.5	60	0	4
YAS01	80.5	1.89	25	0.59	20	17	43.5	0	33.5	1	40	0.5	5.5
YAS02	90	1.22	23	0.39	16	2.5	68.5	0	19.5	1.5	65	0	4
YEAS05	99.5	1.90	36	0.53	5	26	72	5	22	6	60	0.5	6
YEAST02	87	3.00	52	0.76	20	17	49.5	22	14.5	24.5	15.5	0.5	10
YEASTC01	88	2.35	43	0.63	7.5	20	60	8	12	10.5	40.5	0.5	16
YECAS01	107.5	1.84	25	0.57	5	35	67	5	35.5	2	60	0.5	4.5
YESG01	66	0.70	7	0.36	5	1	55.5	5	5.5	0.5	55	0	0
YESG02	41	1.31	9	0.60	1	4.5	31	1	9	0.5	30	0	0.5
YESG03	96.5	0.71	5	0.44	0.5	2	66	0	30.5	0	65.5	0	0.5
YESG05	127.5	2.70	60	0.66	15	67.5	84.5	15	25	14	62	0.5	11
YESG07	90	1.26	32	0.36	2	12.5	74.5	2	6.5	1	70	0.5	10
YESG10	106.5	1.09	16	0.39	1	3	74	1	33	0.5	70	0	2
YESG11	52.5	1.48	20	0.50	5	33.5	38.5	5	9	0.5	35	0.5	2.5
YESG12	77	1.09	12	0.44	1	30	46.5	1	29.5	1	45.5	0	0
YESG13	58.5	1.44	11	0.60	5	6.5	25.5	5	27	0.5	25	0	1
YESG14	88	0.87	15	0.32	2	4	73.5	2	12	1	70	0	3
YPRP01	13		7		5	25	7	5	1	0	0	4	3
YPRP02	43		5		30	6	13	30	0	0	0	12.5	0.5
YPRP03	60.5		5		15	0	25.5	15	20.5	0	0	25	0
YPRP04	22		3		10	10	12	10	0	0	0	12	0
YPRP05	57		7		45	10.5	11.5	45	0	0	0	10.5	1.5
YPRP06	46		9		30	1	8.5	30	7.5	3.5	0	4.5	0.5
YPRP07	64.5		8		40	1	9.5	40	15	0	0	5.5	4
YPRP08	71.8		10		40	20	11.3	40.8	20	6	0	2	3

Site name	Total cover including overlaps (%)	Diversity (Shannon Weiner Index)	Richness (No. species)	Evenness (J)	Cover by vegetation strata (%)			Cover by growth form (%)				
					Upper	Mid	Ground	Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb
YRIP02	45	1.83	21	0.60	0	27	30	0	15	25.5	2	0	2.5
YRIP03	81	2.14	33	0.61	7.5	32	54.5	0	19	13.5	40	0	8.5
YWP01	2		1		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
YWP02	80		2		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
YWP03	2.5		2		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
YWP04	30		2		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
YWP05	47.5		4		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
YWP06	45.5		3		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Appendix 3: Raw community composition and habitat and ecosystem from LPI data

Site name	Total number of intercepts	Total cover (%)	Total cover including overlaps (%)	Cover by growth form including overlaps (%)						Cover by substrate (Proportion)					
				Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb	bare	Cryptogram (any lichen, moss, algae, etc.)	CWD - course woody debris (>10cm)	gravel (particles 2mm - 2cm)	litter (dead vegetation not attached <10cm)	rock (particles < 20cm)
RH-E	101	72.3	87.1	36.6	40.6	5.9	0.0	0.0	4.0	0.01	0.00	0.02	0.01	0.86	0.10
RH-F	101	38.6	45.5	25.7	1.0	2.0	16.8	0.0	0.0	0.00	0.00	0.03	0.09	0.34	0.54
RH-H	101	65.3	68.3	0.0	19.8	0.0	48.5	0.0	0.0	0.15	0.00	0.01	0.06	0.55	0.23
RH-J	101	38.6	39.6	0.0	5.9	0.0	33.7	0.0	0.0	0.00	0.00	0.00	0.33	0.31	0.37
RH-L	101	26.7	26.7	0.0	0.0	0.0	26.7	0.0	0.0	0.00	0.00	0.00	0.48	0.15	0.38
RH-M	101	38.6	48.5	5.0	18.8	0.0	24.8	0.0	0.0	0.01	0.00	0.03	0.10	0.37	0.50
RH-N	91	32.7	39.6	3.3	4.4	11.0	18.7	0.0	2.2	0.01	0.00	0.00	0.12	0.40	0.47
RH-P	101	43.6	47.5	3.0	7.9	2.0	33.7	0.0	1.0	0.05	0.00	0.01	0.08	0.56	0.30
RH-X	101	50.5	59.4	8.9	3.0	12.9	32.7	1.0	1.0	0.00	0.00	0.02	0.11	0.36	0.51
RH-Z	101	58.4	67.3	35.6	6.9	2.0	22.8	0.0	0.0	0.00	0.00	0.02	0.18	0.33	0.48
YACS01	102	75.2	102.9	0.0	38.2	0.0	64.7	0.0	0.0	0.16	0.00	0.01	0.12	0.72	0.00
YAS01	102	39.6	42.2	0.0	7.8	0.0	34.3	0.0	0.0	0.21	0.02	0.00	0.45	0.32	0.00
YAS02	102	49.5	52.0	0.0	6.9	0.0	45.1	0.0	0.0	0.26	0.00	0.00	0.23	0.51	0.00
YEAS05	102	63.4	67.6	3.9	9.8	5.9	48.0	0.0	0.0	0.43	0.00	0.00	0.05	0.51	0.01
YEAST02	102	44.6	48.0	4.9	2.9	4.9	34.3	0.0	1.0	0.10	0.00	0.00	0.19	0.44	0.27
YEASTC01	101	43.6	46.5	4.0	5.9	5.0	27.7	0.0	4.0	0.04	0.00	0.00	0.01	0.66	0.29
YECAS01	102	58.4	60.8	0.0	3.9	2.0	54.9	0.0	0.0	0.34	0.00	0.00	0.16	0.50	0.00
YESG01	102	56.4	55.9	0.0	0.0	0.0	55.9	0.0	0.0	0.00	0.00	0.00	0.26	0.05	0.69

Site name	Total number of intercepts	Total cover (%)	Total cover including overlaps (%)	Cover by growth form including overlaps (%)						Cover by substrate (Proportion)					
				Tree	Shrub	Tussock grass	Hummock grass	Sedge	Forb	bare	Cryptogram (any lichen, moss, algae, etc.)	CWD - course woody debris (>10cm)	gravel (particles 2mm - 2cm)	litter (dead vegetation not attached <10cm)	rock (particles < 20cm)
YESG02	102	38.6	41.2	0.0	8.8	0.0	32.4	0.0	0.0	0.12	0.00	0.00	0.11	0.23	0.55
YESG03	102	60.4	59.8	0.0	0.0	0.0	59.8	0.0	0.0	0.03	0.00	0.00	0.54	0.27	0.16
YESG05	204	66.3	34.3	15.2	1.5	6.4	10.8	0.0	0.5	0.24	0.00	0.00	0.14	0.26	0.35
YESG07	102	65.3	70.6	0.0	2.0	1.0	62.7	0.0	4.9	0.04	0.00	0.00	0.09	0.69	0.19
YESG10	102	62.4	66.7	0.0	6.9	0.0	59.8	0.0	0.0	0.00	0.00	0.00	0.48	0.24	0.28
YESG11	102	36.6	37.3	2.0	1.0	0.0	34.3	0.0	0.0	0.01	0.00	0.00	0.21	0.14	0.65
YESG12	102	35.6	35.3	0.0	11.8	0.0	23.5	0.0	0.0	0.09	0.00	0.00	0.29	0.30	0.31
YESG13	102	44.6	47.1	8.8	15.7	0.0	22.5	0.0	0.0	0.09	0.00	0.00	0.15	0.43	0.33
YESG14	102	55.4	55.9	0.0	1.0	1.0	53.9	0.0	0.0	0.00	0.00	0.00	0.64	0.11	0.25
YRIP02	102	26.7	26.5	0.0	16.7	9.8	0.0	0.0	0.0	0.45	0.00	0.00	0.00	0.55	0.00
YRIP03	102	31.7	31.4	0.0	0.0	3.9	27.5	0.0	0.0	0.37	0.05	0.00	0.00	0.58	0.00

Appendix 4: Raw disturbance factor values from site context data

Site ID	Habitat	Vegetation condition (Trudgen 1988)	Total disturbance intensity from clearing mining and grazing (0=low, 4=high)	Average grazing intensity score (categorical, 0-4)				Overall utilisation of palatable species (%)	Climatic condition	Total active erosion pressure (0=low, 4=high)	Percentage of site affected by erosion	Fire Age	Fire Intensity	Visual fuel load - biomass
				Cattle	Native	Total	Number of evidence sources for grazing							
RH-E	Quoll monitoring	Good	0.5	2	1	3	2	10	Dry, no stress	0	0	>5 yrs	Some trees/shrubs killed	5-10 t/ha
RH-F	Quoll monitoring	Very Good	0	0	1	1	1	0	Recent rain, no impact on veg	0	0	nil	No damage	0-5 t/ha
RH-H	Quoll monitoring	Very Good	0.25	1	1	2	1	0	Dry, no stress	0	0	>5 yrs	Some trees/shrubs killed	5-10 t/ha
RH-J	Quoll monitoring	Good	0	0	1	1	1	0	Dry, no stress	0	0	>5 yrs	Some trees/shrubs killed	0-5 t/ha
RH-L	Quoll monitoring	Very Good	0	0	1	1	2	0	Dry, no stress	0	0	2 - 5 yrs	Minor impact scars on some trees/shrubs	5-10 t/ha
RH-M	Quoll monitoring	Very Good	0	0	1	1	1	0	Dry, no stress	0	0	>5 yrs	Some trees/shrubs killed	0-5 t/ha
RH-N	Quoll monitoring	Very Good	0.25	1	1	2	2	10	Recent rain, no impact on veg	0	0	>5 yrs	Minor impact scars on some trees/shrubs	0-5 t/ha
RH-P	Quoll monitoring	Good	0.75	1	1	2	2	10	Recent rain, no impact on veg	0	0	>5 yrs	Some trees/shrubs killed	10-15 t/ha
RH-X	Quoll monitoring	Very Good	0	1	1	2	1	0	Dry, no stress	0	0	>5 yrs	Some trees/shrubs killed	5-10 t/ha
RH-Z	Quoll monitoring	Good	0.25	0	1	1	1	0	Dry, no stress	0	0	>5 yrs	Minor impact scars on some trees/shrubs	0-5 t/ha
YACS01	Plains/ riparian	Very Good	0	1	1	2	2	0	Dry, no stress	1	25	>5 yrs	No damage	10-15 t/ha
YAS01	Plains/ riparian		0			0	0			0	0	>5 yrs	Minor impact scars on most trees/shrubs	0-5 t/ha
YAS02	Plains/ riparian	Good	0.25	1	1	2	3	50	Dry, no stress	0	0	>5 yrs	Minor impact scars on some trees/shrubs	5-10 t/ha
YEAS05	Plains/ riparian	Poor	0.25	2	1	3	3	50	Dry, no stress	1	20	>5 yrs	No damage	5-10 t/ha

Site ID	Habitat	Vegetation condition (Trudgen 1988)	Total disturbance intensity from clearing mining and grazing (0=low, 4=high)	Average grazing intensity score (categorical, 0-4)				Overall utilisation of palatable species (%)	Climatic condition	Total active erosion pressure (0=low, 4=high)	Percentage of site affected by erosion	Fire Age	Fire Intensity	Visual fuel load - biomass
				Cattle	Native	Total	Number of evidence sources for grazing							
YEAST02	Plains/ riparian	Very Good	0	1	1	2	2	20	Dry, no stress	3	100	>5 yrs	Minor impact scars on some trees/shrubs	10-15 t/ha
YEASTC01	Quoll monitoring	Very Good	0	0	2	2	2	0	Dry, no stress	5	50	>5 yrs	No damage	5-10 t/ha
YECAS01	Plains/ riparian	Very Good	0	0	0	0	0	0	Dry, no stress	1	10	>5 yrs	Minor impact scars on some trees/shrubs	15+ t/ha
YESG01	Quoll monitoring	Very Good	0	0	2	2	2	0	Dry, no stress	1	80	>5 yrs	Minor impact scars on some trees/shrubs	0-5 t/ha
YESG02	Quoll monitoring	Very Good	0.25	0	1	1	1	0	Dry, no stress	0	0	>5 yrs	No damage	0-5 t/ha
YESG03	Quoll monitoring	Very Good	0	0	1	1	1	0	Dry, no stress	1	40	>5 yrs	No damage	10-15 t/ha
YESG05	Quoll monitoring	Good	0	1	2	3	3	20	Dry, no stress	1	20	>5 yrs	No damage	10-15 t/ha
YESG07	Quoll monitoring	Very Good	0	1	1	2	1	0	Dry, no stress	5	110	>5 yrs	No damage	0-5 t/ha
YESG10	Quoll monitoring	Very Good	0	1	2	3	2	0	Dry, no stress	2	50	>5 yrs	No damage	5-10 t/ha
YESG11	Quoll monitoring	Very Good	0	0	1	1	3	1	Dry, no stress	1	15	>5 yrs	No damage	0-5 t/ha
YESG12	Quoll monitoring	Very Good	0	0	1	1	1	0	Dry, no stress	1	20	>5 yrs	Some trees/shrubs killed	5-10 t/ha
YESG13	Quoll monitoring	Very Good	0	0	1	1	1	0	Dry, no stress	2	40	>5 yrs	Some trees/shrubs killed	5-10 t/ha
YESG14	Quoll monitoring	Very Good	0	0	1	1	2	0	Dry, no stress	1	20	>5 yrs	Minor impact scars on some trees/shrubs	0-5 t/ha
YPRP01	Plains/ riparian	Good	0.25	3	1	4	4	50	Dry, no stress	0	0	nil	No damage	10-15 t/ha
YPRP02	Plains/ riparian	Very Good	0.25	1	0	1	2	0	Dry, no stress	0	0	>5 yrs	No damage	15+ t/ha
YPRP03	Plains/ riparian	Very Good	0	1	0	1	3	10	Dry, no stress	0	0	nil	No damage	15+ t/ha
YPRP04	Plains/ riparian	Very Good	0	1	0	1	3	0	Dry, no stress	0	0	nil	No damage	10-15 t/ha
YPRP05	Plains/ riparian	Very Good	0.75	2	0	2	4	50	Dry, no stress	0	0	nil	No damage	15+ t/ha
YPRP06	Plains/ riparian	Good	0.5	2	1	3	4	50	Dry, no stress	0	0	nil	No damage	15+ t/ha
YPRP07	Plains/ riparian	Good	0.25	3	1	4	3	50	Dry, no stress	0	0	nil	No damage	15+ t/ha
YPRP08	Plains/ riparian	Poor	0.25	3	0	3	3	50	Dry, no stress	0	0	>5 yrs	No damage	15+ t/ha

Site ID	Habitat	Vegetation condition (Trudgen 1988)	Total disturbance intensity from clearing mining and grazing (0=low, 4=high)	Average grazing intensity score (categorical, 0-4)				Overall utilisation of palatable species (%)	Climatic condition	Total active erosion pressure (0=low, 4=high)	Percentage of site affected by erosion	Fire Age	Fire Intensity	Visual fuel load - biomass
				Cattle	Native	Total	Number of evidence sources for grazing							
YRIP02	Plains/ riparian	Very Poor	0.75	3	1	4	3	50	Dry, no stress	1	20	>5 yrs	No damage	0-5 t/ha
YRIP03	Plains/ riparian	Poor	0.75	2	1	3	3	50	Dry, no stress	0	0	nil	No damage	0-5 t/ha
YWP01	Plains/ riparian	Very Good	0	1	0	1	1	30	Dry, no stress	3	200	>5 yrs	No damage	n/a
YWP02	Plains/ riparian	Poor	0.75	3	0	3	3	50	Dry, no stress	1	10	>5 yrs	No damage	n/a
YWP03	Plains/ riparian	Very Good	0.25	1	1	2	1	0	Dry, no stress	0	0	>5 yrs	No damage	n/a
YWP04	Plains/ riparian	Poor	0.75	2	0	2	3	80	Dry, no stress	0	0	>5 yrs	No damage	n/a
YWP05	Plains/ riparian	Poor	0.75	2	0	2	3	50	Dry, no stress	0	0	>5 yrs	No damage	n/a
YWP06	Plains/ riparian	Poor	0.5	2	1	3	3	20	Dry, no stress	0	0	>5 yrs	No damage	n/a

Appendix 5: Species per site matrix

	Sites																																										
Species	RH-E	RH-F	RH-H	RH-J	RH-L	RH-M	RH-N	RH-P	RH-X	RH-Z	YACS01	YAS01	YAS02	YEAS05	YEAST02	YEASTC01	YECAS01	YESG01	YESG02	YESG03	YESG05	YESG07	YESG10	YESG11	YESG12	YESG13	YESG14	YPRP01	YPRP02	YPRP03	YPRP04	YPRP05	YPRP06	YPRP07	YPRP08	YRIP02	YRIP03	YWP01	YWP02	YWP03	YWP04	YWP05	YWP06
?Amaranthus sp.											0.5	0.5		0.5	0.5	0.5	0.5					0.5	0.5	0.5			0.5																
?Aristida burbidgeae										2																																	
?Chenopod shrub																0.5																											
?Terminalia canescens																2																											
?Terminalia canescens																0.5																											
Abutilon ?otocarpum								0.5																												0.5	0.5						
Abutilon lepidum												0.5	0.5																														
Abutilon otocarpum														0.5																													
Abutilon sp.																0.5																											
Abutilon sp. 1																																					0.5						
Abutilon sp. Dioicum (A.A. Mitchell PRP 1618)	5	2					0.5	0.5	2.5	0.5					0.5	0.5					0.5	0.5					0.5									0.5							
Acacia ?eriopoda x														0.5																													
Acacia ?hamersley																										5																	
Acacia acradenia																						2																					
Acacia ampliceps																												0.5															
Acacia ancistrocarpa				0.5									5	4			5	2									0.5										0.5						
Acacia aptaneura						5				0.5																																	
Acacia arida																									25	20	10																
Acacia bivenosa	0.5		10	0.5		0.5		0.5	1	0.5	8		0.5	0.5			25	2	0.5	30	0.5		25	2		0.5	0.5																
Acacia citrinoviridis	15		0.5			10		5																																			
Acacia inequilatera											2		10	2																							2						
Acacia pruinocarpa				20		0.5									5	0.5			5		0.5																						
Acacia pyrifolia	2		2.5				0.5	0.5							0.5	0.5																											
Acacia sp. 1											40																																
Acacia synchronicia											0.5	10		4									5	0.5												2.5	0.5						
Acacia trachycarpa														2								0.5	0.5					0.5		20			2.5	5	5	2.5	5						
Acacia tumida	5	2								2.5															2																		
Acacia xiphophylla												20												0.5																			
Acacia orthocarpa																0.5																											
Acacia sclerosperma subsp. scler osperma														0.5																						5							
Acacia tenuissima																								0.5																			
Acetosa vesicaria																0.5																											
Aerva javanica																																				0.5	0.5				10	2	0.5
Alternanthera nana														0.5																													
Alternanthera nodiflora																					0.5															0.5							
Argemone ochroleuca	2							10														0.5										0.5	0.5	2	2								
Aristida burbidgeae	0.5	2.5																																									
Astrotricha hamptonii		0.5																																									
Boerhavia sp.2								0.5						0.5																													
Bonamia ?pilbarensis																	0.5																										
Bonamia media			0.5																																								
Bulbostylis barbata												0.5																															
Capparis spinosa var. nummulari a							0.5	0.5							0.5																												
Cassytha sp.										0.5																																	
Cenchrus ciliaris													0.5	5	0.5		0.5				0.5	0.5											2.5			25	10	2	70	0.5	20	35	30
Cenchrus setiger																					0.5																					10	15
Cheilanthes sieberi						0.5	0.5					0.5															0.5																
Cheilanthes sieberi subsp. sieberi								0.5																																			
Chrysopogan fallax														0.5			0.5																										
Cleome viscosa	0.5	0.5	0.5		0.5		0.5	0.5	0.5		0.5		0.5	0.5	0.5	0.5	0.5				0.5	0.5		0.5				0.5									2						
Clerodendrum floribundum	0.5																				5																						
Codonocarpus cotinifolius																	0.5																										
Corchorus crozophorifolius	10	0.5	10			0.5	5	5	0.5		0.5					0.5					0.5	0.5				0.5											0.5						
Corchorus sp. 1								0.5																																			
Corchorus sp. 2																																					0.5						
Corymbia candida																	5																										
Corymbia ferriticola		2																																									
Corymbia hamersleyana							20		2.5					5		5							0.5																				
Cucumis melo											0.5																									0.5						0.5	
Cymbopogon ambiguus	10	2.5	0.5			2.5	2.5	2	2.5	2.5					0.5	0.5					0.5				0.5		0.5																
Cynodon dactylon																																	1		6								
Cyperus sp.													0.5	0.5																													
Cyperus vaginatus	2														0.5													1	0.5	15	5	10	2.5	5	2								

Cyperus cunninghamii subsp. cunninghamii		0.5					0.5		0.5																																		
Cyperus hesperius																					0.5																						
Digitaria ctenantha																					0.5																						
Dodonaea coriacea																								0.5																			
Dodonaea pachyneura		2				15																																					
Dodonaea petiolaris						2.5																																					
Duperreya commixta						0.5		0.5							0.5																												
Duperreya commixta	2																																										
Eleocharis sp.																													2														
Enneapogon caerulescens								0.5																																			
Eragrostis eriopoda													0.5																								3						
Eragrostis sp. 1															0.5																												
Eremophila fraseri				2.5															3					2																			
Eremophila sp. 1						5																																					
Eriachne ?tenuiculmis															10						0.5																						
Eriachne mucronata	0.5	2.5	0.5		0.5	5	2.5	0.5	2.5						2	10			0.5		0.5		0.5	0.5		0.5	0.5																
Eriachne pulchella																		0.5																									
Eucalyptus camaldulensis	30																															5											
Eucalyptus leucophloia						10	5		2.5	5								5			10		0.5	5	1	5	2																
Eucalyptus leucophloia																						2																					
Eucalyptus leucophloia (outside quadrat)																			1																								
Eucalyptus victrix								5							20	0.5					5													25	0.5								
Eulalia aurea															5																												
Euphorbia australis	0.5		0.5					0.5							0.5						0.5																						
Euphorbia biconvexa												0.5																															
Euphorbia boopthena	0.5										0.5		0.5		0.5						0.5															0.5							
Euphorbia sp.																					0.5																0.5						
Euphorbia australis var. subtomentosa														0.5																													
Euphorbia boophthona																																					0.5						
Evolvulus alsinoides																						0.5															0.5						
Evolvulus alsinoides var. decumbens															0.5		0.5																										
Ficus brachypoda							0.5								2																												
Fimbristylis dichotoma			0.5						0.5							0.5	0.5					0.5		0.5																			
Flaveria trinervia																					0.5	0.5																					
Flueggea virosa subsp. melanthesoides															0.5																												
Glinus lotoides															0.5																												
Gomphrena canescens								0.5									0.5																										
Gomphrena cunninghamii															0.5																												
Gomphrena sp.																			0.5																								
Goodenia microptera											0.5	0.5									0.5	0.5																					
Gossypium australe	2.5		0.5					0.5			0.5		0.5	0.5							0.5															0.5	0.5						
Gossypium robinsonii	2.5	0.5						0.5							0.5						5												2.5										
Grevillea pyrifolia																					0.5																						
Grevillea wickhamii								0.5								0.5						0.5																					
Grevillea berryana						5																																					
Grevillea pyramidalis subsp. leucadendron			2.5				0.5								2																												
Hakea lorea													0.5	2																													
Hakea ?chordophylla																	0.5																										
Hakea chordophylla																				0.5																							
Hakea lorea subsp. lorea																											0.5									0.5	0.5						
Heliotropium sp.												0.5																															
Heliotropium ovalifolium											0.5																																
Hibiscus sp.		0.5					0.5		0.5																																		
Hibiscus coatesii						0.5															0.5																						
Hibiscus goldsworthii								0.5							0.5																												
Hibiscus sturtii var. campylochlamys		0.5																							0.5																		
Hybanthus aurantiacus								0.5							0.5						0.5																						
Indigofera colutea													0.5																														
Indigofera monophylla	0.5						0.5														0.5																						
Indigofera ?boviperda subsp. boviperda																	3																				0.5						
Indigofera sp. Bungaroo Creek (S. van Leeuwen 4301)			0.5																																								
Ipomoea muelleri		0.5																																			0.5						

Jasminum didymum		0.5				0.5	0.5	0.5		0.5					0.5	0.5			0.5		0.5		0.5																				
Jasminum didymum subsp. linear e														0.5																													
Keraudrenia velutina subsp. elliptica				0.5																																							
Lactuca serriola															0.5																												
Lepidium platypetalum														0.5																													
Lobelia heterophylla subsp. pilba rensis															0.5							0.5																					
Malvaceae sp.								0.5																		0.5																	
Malvastrum americanum								0.5						0.5																						0.5	0.5						
Melaleuca argentea																												5		15	10	40	30	15	40.3								
Melaleuca argentea																													30														
Melaleuca glomerata															0.5	0.5																											
Melhania oblongifolia								0.5																																			
Mollugo molluginea															0.5																												
Mollugo molluginea																0.5																											
Mukia maderaspatana (L.) M.Roem.								0.5				0.5	0.5	0.5	0.5	0.5					0.5	0.5																					
Nicotiana occidentalis																0.5					0.5	0.5	0.5																				
Notoleptopus decaisnei var. decaisnei																					0.5																						
Paraneurachne muelleri															0.5										0.5																		
Paspalidium clementii											0.5	0.5					0.5																										
Passiflora foetida																													0.5			0.5		2	1					2			
Pentalepis trichodesmoides	0.5							0.5													0.5															0.5							
Petalostylis labicheoides				0.5																													2.5	10	15								
Petalostylis labichiodes																					0.5																						
Phyllanthus maderaspatensis																0.5					0.5						0.5																
Pluchea dentex																0.5																											
Pluchea ferdinandi-muelleri															0.5															0.5													
Pluchea rubelliflora																					0.5																						
Poaceae sp.																						0.5																					
Polycarpaea longiflora							0.5	0.5	0.5						0.5	0.5					0.5																						
Polycarpaea corymbosa (L.) Lam. var. corymbosa														0.5																													
Pterocaulon sphacelatum	0.5		0.5				0.5	0.5				0.5	0.5		0.5	0.5					0.5	0.5		0.5													2						
Ptilotus astrolasius											0.5	0.5		0.5		0.5					0.5																3						
Ptilotus axillaris																						0.5																					
Ptilotus calostachyus			0.5								0.5															0.5																	
Ptilotus clementii																0.5					0.5	0.5		0.5																			
Ptilotus exaltatus												0.5				0.5						0.5	0.5	0.5													0.5						
Ptilotus fusiformis																				0.5			0.5																				
Ptilotus obovatus	0.5	0.5					10	0.5						0.5	0.5	0.5					0.5	0.5	0.5			0.5																	
Ptilotus astrolasius					0.5																																						
Ptilotus axillaris												0.5	0.5	0.5		0.5	0.5				0.5																0.5						
Ptilotus incanus								0.5																																			
Rhodanthe margarethae						0.5	2								0.5						0.5	2					0.5																
Rhynchosia bungarensis		0.5													0.5	3					0.5																						
Rhynchosia minima							0.5						0.5	0.5			0.5																				0.5						
Salsola australis R.Br.												0.5				0.5	0.5																										
Sauropus sp.															0.5																												
Senna ?venusta									0.5																																		
Senna artemisioides subsp. helmsii												0.5																															
Senna artemisioides subsp. oligophylla						0.5	0.5										0.5																										
Senna glutinosa subsp. glutinosa	0.5		2.5		0.5	0.5	2.5	2.5	1	0.5	0.5						0.5	1			0.5	0.5	0.5	0.5	0.5	0.5																	
Senna glutinosa subsp. pruinosa									0.5																																		
Senna notabilis												0.5																								0.5	2						
Senna artemisioides subsp. oligo phylla														2																													
Sesbania cannabina																					0.5																						
Setaria ?verticillata	0.5							0.5													0.5																		10				
Shrub A	2																																										
Sida ?fibulifera																																					0.5						
Sida cardiophylla																						0.5			0.5																		
Sida fibulifera								0.5						0.5																						0.5							
Sida rohlenae	0.5																						0.5																				

Sida sp.														0.5																													
Sida ?arsiniata						0.5																																					
Sida ?sp. Pilbara (A.A. Mitchell PRP 1543)									0.5	0.5																																	
Sida ?sp. Shovelanna Hill		0.5																																									
Sida ?sp. spiciform panicles (E. Leyland s.n. 14/8/90)		0.5																																									
Sida ?sp. verrucose glands (F.H. Mollemans 2423)														0.5																													
Sida arsiniata												0.5	0.5																								0.5						
Sida rohlenae subsp. Rohlenae							0.5	0.5														0.5																					
Solanum cleistogamum/horridum													0.5																														
Solanum diversiflorum											0.5	0.5	0.5	0.5							0.5			0.5												0.5	0.5						
Solanum gabrielae					0.5																																						
Solanum lasiophyllum						0.5	0.5	0.5	0.5			0.5			0.5	0.5					0.5	0.5	0.5	0.5	0.5											0.5							
Sonchus oleraceus																																0.5											
Sporobolus australasicus													0.5	0.5	0.5		0.5																			0.5							
Sporobolus virginicus												0.5									0.5																0.5						
Stemodia grossa												0.5	0.5		0.5						0.5							2.5															
Streptaglossa decurrens								0.5			0.5			0.5		5						0.5														0.5							
Streptoglossa bubakii																																					0.5						
Stylobasium spathulatum	5		5				2	0.5								5					5				0.5																		
Swainsona formosa																0.5																											
Tephrosia rosea	2		0.5					0.5													0.5																						
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)								2.5																																			
Tephrosia sp. Fortescue (A.A. Mitchell 606)													0.5																														
Terminalia canescens		15								5																																	
Themeda triandra	0.5	1	0.5				2.5			2.5					5						10																						
Trachymene oleracea															0.5	0.5					0.5	0.5					0.5																
Trachymene sp.																																					0.5						
Trianthema triquetrum																	0.5																										
Tribulus suberosus				0.5		0.5												0.5						1																			
Trichodesma zelyanicum	0.5		0.5					0.5							0.5	0.5					0.5	0.5					0.5																
Triodia epactia	10		20				5	5	45		60	10	65	60	10		45				15															2	40						
Triodia wiseana	0.5	5	10	5	20	10	45	15	10	50		30			0.5	40	15	55	25	65	45	70	70	35	45	25	70																
Triodia sp. Robe River (M.E. Trudgen et al. MET 12367)		2.5		30	15	15			2.5	10					5	0.5			5	0.5	2				0.5																		
Triumfetta appendiculata															0.5	0.5																											
Triumfetta chaetocarpa											0.5										0.5			0.5																			
Triumfetta maconochieana	0.5		0.5					0.5							0.5																												
Typha domingensis Pers.																												3	10	10	7	0.5	2	0.5									
Vachellia farnesiana	0.5																0.5																										
Wahlenbergia caryophylloides															0.5																												
Waltheria indica																					0.5																						

Appendix 6: Site data sheet with panoramic photographs

Site ID: RH-E	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Side slope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 5° E
Area: RHCS	**Latitude:** 116.254625	**Soil colour**: Red Brown
Date and time: 20/11/2015 10:10:00 AM	**Longitude:** -22.086677	**Soil texture**: Sand, fine to medium grain with interspersed rocks, becoming rocky with gravel on midslope.
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5619-5639	**Drainage:** Well to imperfect	

NVIS description: Woodland of *Eucalyptus camaldulensis* over a high open shrubland of *Acacia citrinoviridis*, *Acacia tumida* and *Gossypium spp.* over a very open hummock grassland of *Cymbopogon ambiguus* and *Triodia epactia.*

Comments: Foot to midslope beneath sheer rocky crest, extends into creek tributary. Native and cattle scats observed (cattle confined to lower creek). Grazing observed. Evidence of historic fire, some dead trees observed, some scarring.

Site ID: RH-F	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Gully
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 15° W
Area: RHCS	**Latitude:** 116.235537	**Soil colour**: Red Brown
Date and time: 20/11/2015 7:30:00 AM	**Longitude:** -22.110357	**Soil texture**: Large rocks to gravel, few areas of course sand with gravel.
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5575-5593	**Drainage:** Imperfect	

NVIS description: Low open woodland of *Terminalia canescnes* over an open shrubland of *Abutilon sp. Dioicum* (A.A. Mitchell PRP 1618), *Acacia tumida* and *Dodonaea pachyneura* over a very open hummock grassland of *Triodia wiseana, Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367), and *Eriachne mucronata*.

Comments: 100m transect in gully of gorge, north and south sides bounded by steep midslope to sheer crest. Marker pegs not possible due to rocky substrate. Infilled with large boulders. Native animal scats. No evidence of fire observed. Some very small shallow pools of water observed (<30cm in diameter).

Site ID: RH-H	**Plot dimensions:** 25mx100m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Footslope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 2° W
Area: RHCS	**Latitude:** 116.268752	**Soil colour**: Red Brown
Date and time: 18/11/2015 11:25:00 AM	**Longitude:** -22.181696	**Soil texture**: Gravel and patches of fine sand
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5440-5459	**Drainage:** Well to imperfect	

NVIS description: Open shrubland of *Acacia bivenosa* and *Stylobasium spathulatum* over low open shrubland of *Acacia pyrifolia*, *Grevillea pyramidalis subsp. Leucadendron* and *Corchorus crozophorifolius* over open hummock grassland of *Triodia wiseana* and *Triodia epactia* over very open tussock grassland of *Eriachne mucronata.*

Comments: Footslope to plain between rocky hills (gorge) and creekline. Base of rocky hills with gentle midslope and steep rocky top. Native and cattle scats observed - cattle in creekline only, none observed on lower slope. Minor evidence of historic fire, a few long burnt branches.

Site ID: RH-J	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 7° W
Area: RHCS	**Latitude:** 116.215157	**Soil colour**: Red Brown
Date and time: 19/11/2015 2:10:00 PM	**Longitude:** -22.147353	**Soil texture**: Gravel
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5552-5573	**Drainage:** Well to imperfect	

NVIS description: Scattered trees of *Acacia pruinocarpa* over open shrubland of *Eremophila fraseri* and shrubland of *Acacia pruinocarpa* over very open hummock grassland of *Triodia wiseana* and open hummock grassland of *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367).

Comments: Crest of mesa. Runs parallel to and back from steep rocky crest/breakaway. Few native scats, no cattle scats observed. Some evidence of historic fire - dead shrubs.

Site ID: RH-L	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 12° W
Area: RHCS	**Latitude:** 116.235769	**Soil colour**: Red Brown
Date and time: 18/11/2015 2:34:00 PM	**Longitude:** -22.193144	**Soil texture**: Gravelly
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5464-5482	**Drainage:** Imperfect	

NVIS description: Open hummock grassland of *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367) and *Triodia wiseana*.

Comments: Top of mesa breakaway. Two kangaroos observed. Quadrat parallel to and located on edge of mesa breakaway. 20m north of track. Native scats observed. Large spinifex tussocks burnt internally regrown. Small tussocks (estimated 3-5 years old) undamaged. No larger spinifex to show damage, unable to gauge fire intensity. No erosion observed.

Site ID: RH-M	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 7° ESE
Area: RHCS	**Latitude:** 116.256633	**Soil colour**: Red Brown
Date and time: 18/11/2015 7:40:00 AM	**Longitude:** -22.197215	**Soil texture**: Rocks and gravel
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5416-5434	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* over high open shrubland of *Acacia citrinoviridis*, *Grevillea berryana* and *Acacia aptaneura* over shrubland of *Dodonaea pachyneura* and *Eremophila sp. 1* over open hummock grassland of *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367) and *Triodia wiseana* over tussock grass of *Eriachne mucronata* and *Cymbopogon ambiguus*.

Comments: Upper slope of mesa. Mesa moderately disturbed by drill lines and tracks. Top and upper slope of mesa. Native animal scats observed. Evidence of historic fire, long dead burnt tree trunk/branches. Northwest to northeast (length of quadrat). 5m from top of mesa and 15 m from end of access track. No evidence of erosion.

Site ID: RH-N	**Plot dimensions:** 90mx30m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 5° W
Area: RHCS	**Latitude:** 116.296813	**Soil colour**: Red Brown
Date and time: 17/11/15 1:20:00 PM	**Longitude:** -22.078263	**Soil texture**: Loose shale and rock
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5644-5664	**Drainage:** Well to imperfect	

NVIS description: Low woodland of *Corymbia hamersleyana* and low open woodland of *Eucalyptus leucophloia* over open shrubland of Corchorus crozophorifolius, *Senna glutinosa subsp. Glutinosa* and *Ptilotus obovatus* over hummock grassland of *Triodia wiseana* and very open hummock grassland of *Triodia epactia* over very open tussock grassland of *Eriachne mucronata*, *Themeda triandra* and *Cymbopogon ambiguus*.

Comments: Midslope below sheer rocky crest. Native animal scats observed on extremely steep rocky terrain. Sparse vegetation at based of low rocky hills (estimated 30m sheer rock). Historical evidence of fire- burnt tree limbs. Cattle track observed on lower slope.

Site ID: RH-P	**Plot dimensions:** 25mx100m	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Stream channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 5° NW
Area: RHCS	**Latitude:** 116.295486	**Soil colour**: Red Brown
Date and time: 17/11/15 8:55:00 AM	**Longitude:** -22.074156	**Soil texture**: Alluvium coarse to very fine sand in patches
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5390-5409	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus victrix* over scattered tall shrubs of *Acacia citrinoviridis* over open shrubland of *Corchorus crozophorifolius*, *Senna glutinosa subsp. glutinosa* and *Tephrosia sp. B Kimberley Flora* (C.A. Gardner 7300) over open hummock grassland of Triodia wiseana and very open hummock grassland of Triodia epactia over very open herb of *Argemone ochroleuca*.

Comments: Red Hill creek (track in low flow channel, base of steep rocky hills, westerly side of creek). Base of low rocky hills. Cattle and native animal scats observed. Native animal tracks observed. Evidence of historic fire in burnt tree trunks (long dead). No erosion observed.

Site ID: RH-X	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 7° S
Area: RHCS	**Latitude:** 116.253771	**Soil colour**: Red Brown
Date and time: 19/11/2015 7:45:00 AM	**Longitude:** -22.153054	**Soil texture**: Rock and course gravel over patchy fine sand
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5487-5505	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* and *Corymbia hamersleyana* over scattered shrubs of *Abutilon sp. Dioicum* (A.A. Mitchell PRP 1618), *Senna glutinosa subsp. glutinosa* and Acacia bivenosa over hummock grassland of *Triodia epactia* and very open hummock grassland of *Triodia wiseana* and *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367) over very open tussock grassland of *Cymbopogon ambiguus* and *Eriachne mucronata*.

Comments: Midslope beneath sheer rock crest, northwest of permanent pool in gorge. No pegs used. Southeast to northeast corner at bearing of 340°. 100x25m quadrat from Eucalyptus at base of rocky cliff (no marker). Native and cattle scats observed (cattle scats on plain only, none in quadrat). Evidence of historic fire - burnt, long dead tree branches, some scarring to living trees. Starting point is larger single trunk Eucalyptus. First tree north of point on midslope.

Site ID: RH-Z	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Footslope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 15° N
Area: RHCS	**Latitude:** 116.238962	**Soil colour**: Red Brown
Date and time: 19/11/2015 10:30:00 AM	**Longitude:** -22.120744	**Soil texture**: Large rock and large gravel
Observers: CN & SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 5509-5527	**Drainage:** Imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* over scattered low trees of *Terminalia canescens* over open shrubland of *Acacia tumida* over hummock grassland of *Triodia wiseana* and very open hummock grassland of *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367) over very open tussock grassland of *Themeda triandra*, Cymbopogon ambiguus, and *Aristida burbidgeae*.

Comments: Narrow gorge, rocky creek bed to rocky midslope to the west, bounded by steep rocky cliff to the east. Many trees are dead or have dead limbs. Long unburnt. Few native scats observed. No peg on southwest corner location estimated due to steep rocky cliff. No photo on southwest corner due to unstable rocky terrain.

Site ID: YACS01	**Plot dimensions:** 50mx50m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 0-5°
Area: YLMA	**Latitude:** 115.980844	**Soil colour**: Red Brown
Date and time: 07/10/2015	**Longitude:** -21.813501	**Soil texture**: Sandy clay loam
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 4800-4825	**Drainage:** Well to imperfect	

NVIS description: Open scrub of *Acacia sp. 1* and high open shrubland of *Acacia bivenosa* and *Acacia inequilateral* over hummock grassland of *Triodia epactia*.

Comments: Central southern plain south of Robe River. Plain that has had some moderate inundation at some point. 100m south of main track. Calculate fuel load from photos and distance to water from map, there may be a more nearby creek. No evidence of grazed plants. Ephemeral creek to the east.

Site ID: YAS01	**Plot dimensions:** 50mx50m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: 0°
Area: YLMA	**Latitude:** 116.123204	**Soil colour**: Red Brown
Date and time: 22/9/15	**Longitude:** -21.767526	**Soil texture**:
Observers: SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 4719-4744	**Drainage:**	

NVIS description: High shrubland of *Acacia xiphophylla* over open shrubland of *Acacia synchronicia* over open hummock grassland of *Triodia epactia* and *Triodia wiseana*.

Comments: Valley flat between mesas and Robe River in south of Robe River in central eastern part of land management area. Closest water hole is large permanent pools of Robe River.

Site ID: YAS02	**Plot dimensions:** 50mx50m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 0°
Area: YLMA	**Latitude:** 116.11041	**Soil colour**: Red Brown
Date and time: 22/9/15	**Longitude:** -21.837268	**Soil texture**: Sandy loam
Observers: SL	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 4748-4766	**Drainage:** Imperfect	

NVIS description: High open shrubland of *Acacia inequilateral* and *Acacia ancistrocarpa* over hummock grassland of *Triodia epactia*.

Comments: Open plain (gravelly). Acacia and tall shrubs of spinifex in the southeast of the land management area. 50-80% utilisation of palatable species e.g. *Cenchrus ciliaris* and *Eragrostis eriopoda.*

Site ID: YEAS05	**Plot dimensions:** 50mx50m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 0°
Area: YLMA	**Latitude:** 116.108776	**Soil colour**: Red Brown
Date and time: 22/09/15	**Longitude:** -21.803382	**Soil texture**: Sandy loam
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 4767-4789	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Corymbia hamersleyana* over scattered tall shrubs of *Acacia inequilateral* and *Hakea lorea* over open shrubland of *Acacia synchronicia*, *Acacia ancistrocarpa* and *Acacia trachycarpa* over hummock grassland of *Triodia epactia*.

Comments: Southeast in land management area, south of bore on sandy plain. Scattered Eucalypts over Acacia over Spinifex. 4-5 cattle at nearby water point. Complete fuel load from photos. Front page completed on 22/9/15 by SL alone, but the rest completed by SL & CO on 7/10/15.

Site ID: YEAST02	**Plot dimensions:** 25mx100m	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 2° N
Area: YLMA	**Latitude:** 116.159345	**Soil colour**: Red Brown
Date and time: 18/10/15 7:30:00 AM	**Longitude:** -21.771101	**Soil texture**: Alluvium
Observers: SL & CO	**Coords accuracy:** ±5m	**Micro-relief**: Large boulders in alluvial matrix. Mounds of alluvium.
PRP Photo #s: 5361-5383	**Drainage:** Well to imperfect	

NVIS description: Woodland of *Eucalyptus victrix* over high open shrubland of *Acacia pruinocarpa* and *Grevillea pyramidalis subsp. leucadendron* over tussock grass of *Eulalia aurea*, *Eriachne tenuiculmis* and *Themeda triandra* over very open hummock grassland of *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367) and *Triodia epactia*.

Comments: Southwest of Mesa J in gorge at edge of ranges. Southwest of Mesa H. Confined north-south running gorge. Northern Quoll camera surveillance point. Transect runs along eastern creek bank. Some minor evidence of cattle use and native herbivores. Long unburnt. In gorge/creek. Active creekline.

Site ID: YEASTC01	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Footslope + stream channel
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 2° NNW
Area: YLMA	**Latitude:** 116.208069	**Soil colour**: Red Brown
Date and time: 10/08/2015 9:00:00 AM	**Longitude:** -21.775921	**Soil texture**: Rock and gravel (alluvium) in sandy loam matrix.
Observers: SL & CO	**Coords accuracy:** ±6m	**Micro-relief**: zero
PRP Photo #s: 4835-4862	**Drainage:** Well to imperfect	

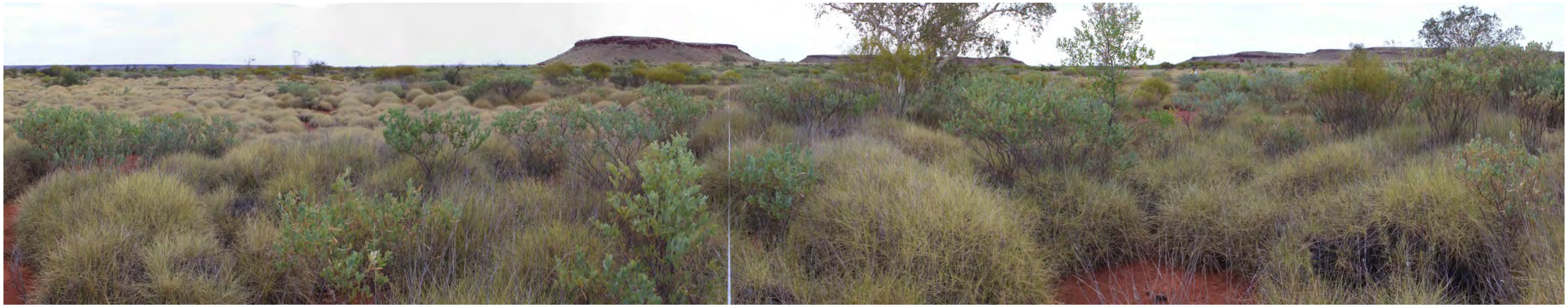
NVIS description:

Comments: At baseline Quoll monitoring site ('the gorge'/ Area 6). Crosses river bed and spinifex plain between gorge walls. Gorge is on edge of the Hamersleys, southeast of Robe River. Calculate fuel load from photos. Eastern and western sides of quadrat slope 2-3 degrees into creek bed there for minor local drainage/seepage into creek.

Site ID: YECAS01	**Plot dimensions:** 50mx50m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 0°
Area: YLMA	**Latitude:** 115.964058	**Soil colour**: Red Brown
Date and time: 10/12/2015 1:00:00 PM	**Longitude:** -21.624925	**Soil texture**: Sandy clay loam
Observers: SL & CO	**Coords accuracy:** ±5m	**Micro-relief**: zero
PRP Photo #s: 4910-4933	**Drainage:** Imperfect	

NVIS description:

Comments: Southeast of Pannawonica turn off from main road. North of Robe River and Mesa A. Flat plain with mesas surrounding. Get fuel load from photos. Large Spinifex hummocks indicate long unburnt. Some shrub senescens evident. Also some minor Triodia senescens.



Site ID: YESG01	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 25° E
Area: YLMA	**Latitude:** 116.092188	**Soil colour**: Red Brown
Date and time: 14/10/15 3:30:00 PM	**Longitude:** -21.79397	**Soil texture**: Skeletal, gravel and rock
Observers: SL & CO	**Coords accuracy:** ±7m	**Micro-relief**: Car sized rocks over smaller rocks and gravel
PRP Photo #s: 5093-5107	**Drainage:** Well to imperfect	

NVIS description:

Comments: Large white metamorphic outcrop in plain to the south of Robe river east face of outcrop. From base of breakaway down Spinifex slope. Slope has lots of loose rocks, big and small. Unconsolidated. Investigate geological origins further - looks metamorphic/conglomerate. Old fire scars on larger Eucalypts and some course woody debris showing charring.

Site ID: YESG02	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 10° W
Area: YLMA	**Latitude:** 116.156919	**Soil colour**: Red Brown
Date and time: 13/10/15 11:30:00 AM	**Longitude:** -21.782194	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 4967-4985	**Drainage:** Well to imperfect	

NVIS description:

Comments: On mesa top near mesa edge. Mesas south of Robe River. East side of Red Hill mesas. Flat/small slope. Some small amount of clearing for nearby track and drill pads. Get fuel load from photos.

Yandicoogina TSOP 2015

Land Condition Monitoring Report

Yarraloola and Red Hill study sites

March 2016

Final RTIO-HSE-0279929

Appendix 6: Site data sheet with panoramic photographs

Site ID: YESG03	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 4° W
Area: YLMA	**Latitude:** 116.157263	**Soil colour**: Red Brown
Date and time: 14/10/15 7:30:00 AM	**Longitude:** -21.792782	**Soil texture**: Skeletal with gravel and rocks
Observers: SL & CO	**Coords accuracy:** ±4m	**Micro-relief**: Stony gravel
PRP Photo #s: 5030-5047	**Drainage:** Well to imperfect	

NVIS description:

Comments: On top of west side of Red Hill mesas south of Robe river. Flat rocky Acacia over Spinifex. Next to Quoll baseline site, midway down mesa chain. Eucalyptus *leucophloia* line immediately to the west on mesa edge. Eucalyptus *leucophloia* of Triodia *wiseana* and Triodia *sp. Robe River* with occurrences of Ficus *brachypoda* on mesa edge/cliff breakaway slope.

Site ID: YESG05	**Plot dimensions:** 25mx100m	**Landform pattern**: Low Hills (30-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: Slope 25° S, River 2° S
Area: YLMA	**Latitude:** 116.167764	**Soil colour**: Red Brown
Date and time: 14/10/15 10:00:00 AM	**Longitude:** -21.810865	**Soil texture**: Slope- Skeletal. River - Silty alluvium.
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Loose mounds of alluvium in creek bed
PRP Photo #s: 5051-5069	**Drainage:** Well to imperfect	

NVIS description:

Comments: South of Robe, southern end of Red Hill mesas. On mesa slope between mesa breakaway and riverbed. Next to baseline site. Half on river as slope not wide enough. 2 x 100m point intercept transects to encounter both vegetation types (northeast - northwest, southeast – southwest).

Site ID: YEASTC01	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Footslope and stream channel
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 2° NNW
Area: YLMA	**Latitude:** 116.208069	**Soil colour**: Red Brown
Date and time: 08/10/2015 9:00:00 AM	**Longitude:** -21.775921	**Soil texture**: Rock and gravel (alluvium) in sandy loam matrix
Observers: SL & CO	**Coords accuracy:** ±6m	**Micro-relief**: zero
PRP Photo #s: 4835-4862	**Drainage:** Well to imperfect	

NVIS description:

Comments: At baseline Northern Quoll monitoring site ('the gorge'/ Area 6). Crosses river bed and spinifex plain between gorge walls. Gorge is on edge of the Hamersleys, southeast of Robe River. Calculate fuel load from photos. Eastern and western sides of quadrat slope 2-3 degrees into creek bed therefore minor local drainage/seepage into creek.

Site ID: YECAS01	**Plot dimensions:** 50mx50m	**Landform pattern**: Plain (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 0°
Area: YLMA	**Latitude:** 115.964058	**Soil colour**: Red Brown
Date and time: 12/10/2015 1:00:00 PM	**Longitude:** -21.624925	**Soil texture**: Sandy clay loam
Observers: SL & CO	**Coords accuracy:** ±5m	**Micro-relief**: zero
PRP Photo #s: 4910-4933	**Drainage:** Imperfect	

NVIS description: Low open woodland of *Corymbia candida* over high shrubland of *Acacia bivenosa* and high open shrubland of *Acacia ancistrocarpa* over low open shrubland of *Indigofera boviperda subsp. boviperda* over hummock grassland of *Triodia epactia* and open hummock grassland of *Triodia wiseana*.

Comments: Southeast of Pannawonica turn off from main road. North of Robe River and Mesa A. Flat plain with mesas surrounding. Get fuel load from photos. Large Spinifex hummocks indicate long period since fire. Some shrub senescens evident. Also some minor Triodia senescens.

Site ID: YESG01	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 25° E
Area: YLMA	**Latitude:** 116.092188	**Soil colour**: Red Brown
Date and time: 14/10/15 3:30:00 PM	**Longitude:** -21.79397	**Soil texture**: Skeletal, gravel and rock
Observers: SL & CO	**Coords accuracy:** ±7m	**Micro-relief**: Car sized rocks over smaller rocks and gravel
PRP Photo #s: 5093-5107	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* over scattered shrubs of *Acacia ancistrocarpa*, *Acacia bivenosa* and *Senna glutinosa subsp. glutinosa* over hummock grassland of *Triodia wiseana*.

Comments: Large white metamorphic outcrop in plain to the south of Robe River east face of outcrop from base of breakaway down Spinifex slope. Slope has lots of loose rocks, big and small. Unconsolidated. Investigate geological origins further - looks metamorphic/conglomerate. Old fire scars on larger Eucalypts and some course woody debris showing charring.

Site ID: YESG02	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 10° W
Area: YLMA	**Latitude:** 116.156919	**Soil colour**: Red Brown
Date and time: 13/10/15 11:30:00 AM	**Longitude:** -21.782194	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: zero
PRP Photo #s: 4967-4985	**Drainage:** Well to imperfect	

NVIS description: High open shrubland of *Acacia pruinocarpa* over low open shrubland of *Eremophila fraseri* over open hummock grassland of *Triodia wiseana* and very open hummock grassland of *Triodia sp. Robe River* (M.E. Trudgen et al. MET 12367).

Comments: On mesa top near mesa edge. Mesas south of Robe River. East side of Red Hill mesas. Flat/small slope. Some small amount of clearing for nearby track and drill pads. Get fuel load from photos.

Site ID: YESG03	**Plot dimensions:** 50mx50m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:**	**Slope & aspect**: 4° W
Area: YLMA	**Latitude:** 116.157263	**Soil colour**: Red Brown
Date and time: 14/10/15 7:30:00 AM	**Longitude:** -21.792782	**Soil texture**: Skeletal with gravel and rocks
Observers: SL & CO	**Coords accuracy:** ±4m	**Micro-relief**: Stony gravel
PRP Photo #s: 5030-5047	**Drainage:** Well to imperfect	

NVIS description: Scattered tall shrubs of *Hakea chordophylla* over shrubland of *Acacia bivenosa* over hummock grassland of *Triodia wiseana.*

Comments: On top of west side of Red Hill mesas south of Robe river. Flat rocky Acacia over Spinifex. Next to Northern Quoll baseline site, midway down mesa chain. *Eucalyptus leucophloia* line immediately to the west on mesa edge. *Eucalyptus leucophloia* of *Triodia wiseana* and *Triodia sp. Robe River* with occurrences of *Ficus brachypoda* on mesa edge/cliff breakaway slope.

Site ID: YESG05	**Plot dimensions:** 35mx71m	**Landform pattern**: Low Hills (30m-90m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm	**Slope & aspect**: Slope - 25° S and River - 2° S
Area: YLMA	**Latitude:** 116.167764	**Soil colour**: Red Brown
Date and time: 14/10/15 10:00:00 AM	**Longitude:** -21.810865	**Soil texture**: Slope- Skeletal and River - Silty alluvium
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Loose mounds of alluvium in creek bed
PRP Photo #s: 5051-5069	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* and *Eucalyptus victrix* over high open shrubland of *Clerodendrum floribundum*, *Stylobasium spathulatum* and *Gossypium robinsonii* over hummock grassland of *Triodia wiseana* and very open hummock grassland of *Triodia epactia* over very open tussock grassland of *Themeda triandra*.

Comments: South of Robe, southern end of Red Hill mesas. On mesa slope between mesa breakaway and riverbed. Next to Northern Quoll baseline site. Half on riverbed as slope not wide enough. 2 x 100m point intercept transects to encounter both vegetation types (northeast - northwest, southeast – southwest).

Site ID: YESG11	**Plot dimensions:** 50x50	**Landform pattern**: Low Hills (30-90 m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 10° N
Area: YLMA	**Latitude:** 116.086586	**Soil colour**: Red Brown
Date and time: 16/10/15 8:00:00 AM	**Longitude:** -21.843669	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Loose gravel/rocks. Some outcropping bedrock
PRP Photo #s: 5189-5215	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* over scattered tall shrubs of *Acacia bivenosa* over open shrubland of *Eremophila fraseri* and Tribulus ?sub over a hummock grassland of *Triodia wiseana*.

Comments: Rocky metamorphic rock outcrop in Southern edge of Yarraloola station, south of Robe River. Adjacent to northern quoll baseline site. On saddle/crest between minor drainage lines. Area burnt 3-8y ago; much evidence of burn. Some *Acacia/Eremophila* re-sprouting and *Triodia* new growth.

Site ID: YESG07	**Plot dimensions:** 35x70	**Landform pattern**: Low Hills (30-90 m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** N/A	**Slope & aspect**: 30° S
Area: YLMA	**Latitude:** 116.137297	**Soil colour**: Red Brown
Date and time: 13/10/15 8:00:00 AM	**Longitude:** -21.742577	**Soil texture**: Skeletal on rocky steep slope
Observers: SL & CO	**Coords accuracy:** 6	**Micro-relief**: Zero
PRP Photo #s: 4949-4962	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* over open shrubland of *Acacia acradenia* over hummock grassland of *Triodia wiseana*.

Comments: Baseline quoll site on south face of Mesa G. Robe River to the south border on side of mesa from footslope to edge of breakaway. Grazing on southern edge of quadrat near river margin. Some track activity too. Large fallen tree in the quadrat. Steep mesa hill slope with dense *Triodia wiseana*. Abundant annuals/ephemerals amongst perennial *Triodia* ground cover. Old, senescent eucalypts with small to medium hollows.

Site ID: YESG10	**Plot dimensions:** 50x50	**Landform pattern**: Low Hills (30-90 m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** N/A	**Slope & aspect**: 25° SW
Area: YLMA	**Latitude:** 116.177691	**Soil colour**: Red Brown
Date and time: 15/10/15 13:30 PM	**Longitude:** -21.73074	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Round pebbly gravel, loose, covering surface.
PRP Photo #s: 5137-5156	**Drainage:** Well to imperfect	

NVIS description: Shrubland of *Acacia bivenosa* over open shrubland of *Acacia synchronicia* over hummock grassland of *Triodia wiseana.*

Comments: Edge of Mesa H (west). On Mesa face between Mesa and Robe River. Directly across from Yeera bluff. Very old two tiered spinifex and acacia slope. Abuts northern quoll baseline site. Very loose friable rock. Very old *Triodia*. Lots of kangaroo scats. Large *Triodia* hummocks meaning the area has beenlong unburnt. *Eucalyptus leucophloia* present as young regeneration ~ 1-2m but mature trees present outside plot as scattered low tree canopy.

Site ID: YESG12	**Plot dimensions:** 50x50	**Landform pattern**: Low Hills (30-90 m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:** N/A	**Slope & aspect**: 5° W
Area: YLMA	**Latitude:** 116.014307	**Soil colour**: Red Brown
Date and time: 16/10/15 11:30:00 AM	**Longitude:** -21.754677	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Large rocky boulders and gravel
PRP Photo #s: 5220-5241	**Drainage:** Well to imperfect	

NVIS description: Open woodland of *Eucalyptus leucophloia* over open shrubland of *Acacia tumida* over shrubland of *Acacia arida* over hummock grassland of *Triodia wiseana.*

Comments: Top of Mesa F near NW edge. Robe River directly to the Nth. Near baseline NQ site. Adjacent to large breakaway off Mesa face. Fire damage on surrounding trees. Trees in middle are dead due to fire. Lots of leaf litter under *Acacias* (2-3cm). Fallen burnt log present. Very large old *Triodia*. Dog scats nearby. Tracks and exploration drill pads ~ 20m south of plot. Course woody debris occasionally throughout plot. Occasional dead *Acacia* shrub indicating some senescence possibly due to water stress. Mature *Triodia* hummocks. *Eucalyptus leucophloia* senescent with two large dead *Eucalyptus leucophloia* skirting trees in plot. *Eucalyptus leucophloia* likely killed by fire >5y ago.

Site ID: YESG13	**Plot dimensions:** 50x50	**Landform pattern**: Low Hills (30-90 m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Crest
Survey Year: 2015	**Camera settings:** N/A	**Slope & aspect**: 10° E
Area: YLMA	**Latitude:** 116.015926	**Soil colour**: Red Brown
Date and time: 16/10/15 15:00:00 PM	**Longitude:** - -21.770469	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Large loose rocks and gravel
PRP Photo #s: 5244-5262	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Eucalyptus leucophloia* over shrubland of *Acacia arida* and open shrubland of *Acacia ?hamersley* over open hummock grassland of *Triodia wiseana.*

Comments: East face of Mesa F, midway down. Plot located on top of mesa at edge of breakaway. Eastern third of plot captures vegetation on break of slope which isdifferent to mesa top. Large dead tree from fire. Litter below *Acacia* shrubs to ~ 5-10mm deep. Obvious transport of litter and other material downslope after heavy rainfall. Semi-permanent rock pool 100m away in ephemeral creek. Dog scat in quadrat. Course woody debris common across plot as is litter from *Acacia arida*. *Triodia wiseana* sparse in comparison to previous plot (YESG12). Large pisolite outcropping on eastern edge of plot as captures top of mesa breakaway break of slope.

Site ID: YESG14	**Plot dimensions:** 50x50	**Landform pattern**: Low Hills (30-90 m)
Survey Name: TSOP Land Condition	**Habitat:** Quoll monitoring	**Landform element**: Sideslope
Survey Year: 2015	**Camera settings:** N/A	**Slope & aspect**: 25° S
Area: YLMA	**Latitude:** 115.957176	**Soil colour**: Red Brown
Date and time: 17/10/15 9:30:00 AM	**Longitude:** -21.728713	**Soil texture**: Skeletal
Observers: SL & CO	**Coords accuracy:** unknown	**Micro-relief**: Large loose rocks and gravel. Very friable.
PRP Photo #s: 5267-5285	**Drainage:** Well to imperfect	

NVIS description: Scatter low trees of *Eucalyptus leucophloia* over open shrubland of *Acacia arida* over hummock grassland of *Triodia wiseana*

Comments: South edge of Mesa D on bottom of slope. Next to northern quoll baseline monitoring site. West of Robe River. Large cave in cliff face nearby. Dead tree from fire nearby. Steep rocky slope with gravel over outcropping regolith. Occasional *Eucalyptus leucophloia* juveniles 1-1.5m. Large *Triodia* hummocks indicate long unburnt though *Eucalypts* and course woody debris indicate past fire.

Site ID: YPRP01	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 2° W
Area: YLMA	**Latitude:** 115.9626	**Soil colour**: N/A
Date and time: 12/07/15	**Longitude:** -21.6642	**Soil texture**: Stream cobbles
Observers: SL & BB	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 5665-5693	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Melaleuca argentea* over scattered sedges of *Cyperus vaginatus* over very open herbs of *Stemodia grossa*.

Comments: Edge of large pool on Robe River downstream of rail bridge. *Typha domingensis*and other emergent macrophytes heavily utilised. Other emergent macrophyte species are present but are not identifiable because they are heavily grazed. No evidence of recent fire. Active erosion of stream bed during periods of flooding.

Site ID: YPRP02	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° W
Area: YLMA	**Latitude:** 116.1727	**Soil colour**: Red Brown
Date and time: 12/08/15	**Longitude:** -21.7348	**Soil texture**: Coarse gravelly alluvium with some silt
Observers: SL	**Coords accuracy:** 4	**Micro-relief**: Large mounds of gravel and silt
PRP Photo #s: 5918-5950	**Drainage:** Well to imperfect	

NVIS description: *Melaleuca argentea* woodland over *Melaleuca argentea* low open forrest (juveniles) over *Cyperus vaginatus* open sedgeland.

Comments: Eastern edge of Yeera Bluff, south of the main access point on the Robe River. *Passiflora foetida* on edge of unstable alluvium bank. Old cow pats. *Typha domingensis*not grazed. *Eleocharis* sp., *Typha domingensis* and *Cyperus vaginatusas* emergent macrophytes in creek and on bank.

Site ID: YPRP03	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 2° S
Area: YLMA	**Latitude:** 116.2012	**Soil colour**: N/A
Date and time: 12/08/15	**Longitude:** -21.7183	**Soil texture**: Stream cobbles
Observers: SL	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: -5883-5915	**Drainage:** Well to imperfect	

NVIS description: Woodland of *Melaleuca argentea* over shrubland of *Acacia trachycarpa* over open sedges of *Cyperus vaginatus*.

Comments: Robe River channel up stream of Yeera Bluff. Only erosion during high flow/flood. Small and permanent pools in stream channel. No reeds observed. Cattle use creek but not much evidence in immediate vicinity.

Site ID: YPRP04	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° N
Area: YLMA	**Latitude:** 116.2245	**Soil colour**: N/A
Date and time: 12/08/15	**Longitude:** -21.719	**Soil texture**: Stream cobbles
Observers: SL	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 5840-5878	**Drainage:** Well to imperfect	

NVIS description: Low open woodland of *Melaleuca argentea* over very open sedges of *Cyperus vaginatus*.

Comments: Robe River stream channel. 1-2km upstream from Mesa J dirt access road. Open Robe channel with *Melaleuca argentea* regrowth. Emergent macrophytes in permanent waterhole. Stream channel appears highly mobile. Site has low erodability due to stream cobbles. Erosion only during high low/floods.

Site ID: YPRP05	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 4° S
Area: YLMA	**Latitude:** 116.2654	**Soil colour**: Red Brown
Date and time: 12/08/15	**Longitude:** -21.7314	**Soil texture**: Sandy loam
Observers: SL	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 5805-5836	**Drainage:** Well to imperfect	

NVIS description: Low open forest of *Melaleuca argente*a over open woodland of *Eucalyptus camaldulensis* over very open sedges of *Cyperus vaginatus*.

Comments: Medawandy pool below Mesa J rail bridge NE of Mesa J mine. Disturbance (clearing and mining) is historic and reflects rail infrastructure presence. *Passiflora foetida* occasional in understory. *Argemone ochroleuca* rare/occasional. Emergent macrophytes up to 50% utilisation. No observed utilisation of terrestrial groundcover. Young *Melaleuca argentea* regrowth extensive and forms canopy. No active erosion observed. Only erosion due flooding.

Site ID: YPRP06	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 3° S
Area: YLMA	**Latitude:** 116.3193	**Soil colour**: N/A
Date and time: 12/08/15	**Longitude:** -21.6888	**Soil texture**: Stream cobbles
Observers: SL	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 5766-5797	**Drainage:** Well to imperfect	

NVIS description: Woodland of *Melaleuca argente*a over open shrubland of *Gossypium robinsonii, Petalostylis labicheoides* and *Acacia trachycarpa* over very open sedges of *Cyperus vaginatus* over very open tussock grassland of *Cenchrus ciliaris*.

Comments: Matangkuna Permanent Pool. South of Pannawonica on Robe River downstream of Pannawonica Hill. Stable but with massive erosion during floods. *Cenchrus cilliaris*, *Argemone ochroleuca*,and *Elymus repens* are common in understory. Heavily grazed groundcover and disturbance by cattle accessing waterhole. Exclusive grazing of emergent *Typha* and other macrophyte in waterhole.

Site ID: YPRP07	**Plot dimensions:** PRP	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 5° S
Area: YLMA	**Latitude:** 116.3459	**Soil colour**: N/A
Date and time: 12/08/15	**Longitude:** -21.6827	**Soil texture**: Stream cobbles
Observers: SL	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 5721-5754	**Drainage:** Well to imperfect	

NVIS description: Woodland of *Eucalyptus victrix* and *Melaleuca argentea* over open shrubland of *Petalostylis labicheoides* and *Acacia trachycarpa* over very open sedges of *Cyperus vaginatus.*

Comments: Base of Pannawonica Hill on Robe River downstream of main camping area. Heavy grazing of *Typha domingensis* and some terrestrial ground cover. *Typha domingensis* 50-80% utilisation. Many tracks and scats as evidence of cattle. Weeds occasionally in upstream. Massive erosion during floods but otherwise river cobble is stable.

Site ID: YPRP08	**Plot dimensions:** PRP	**Landform pattern**: Plains (<10m)
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 15° S
Area: YLMA	**Latitude:** 116.031387	**Soil colour**: Red brown
Date and time: 13/10/15	**Longitude:** -21.750087	**Soil texture**: Silty alluvium and gravel
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 4990-5016	**Drainage:** Well to imperfect	

NVIS description: open forest of *Melaleuca argentea* over shrubland of *Petalostylis labicheoidesover* open shrubland of *Acacia trachycarpa* over scattered sedges of *Cyperus vaginatus* over scattered tussock grass of *Cynodon dactylon*.

Comments: North bank of Robe Pool on Robe River in *Melaleuca argentea*/*Petalostylis labicheoides* woodland on bank where cattle have been coming to drink. Fringing macrophyte. *Elymus repens and Passiflora foetida* observed. Active flooding processes occurring causing erosion..

Site ID: YRIP02	**Plot dimensions:** 50x50	**Landform pattern**: Alluvial Plains
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° S
Area: YLMA	**Latitude:** 116.071581	**Soil colour**: Red brown
Date and time: 17/10/15	**Longitude:** -21.757108	**Soil texture**: Silty loam
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Small mounds of tussock and smaller hoof print depressions
PRP Photo #s: 5331-5353	**Drainage:** Imperfect	

NVIS description: Scattered tall shrubs of *Acacia trachycarpa* over high open shrubland of *Acacia sclerosperma subsp. Sclerosperma* and scattered shrubs of *Acacia synchronicia* over an open tussock grassland of *Cenchrus ciliaris* and a scattered hummock grass of *Triodia epactia*.

Comments: *Acacia* shrubland over *Triodia* and tussock grasses on elevated riparian plain/terrace of Robe River. Immediately west of gas pipeline track. Heavily grazed terrace above Robe River. Coarse woody debris common throughout plot. Highly disturbed due to grazing. Ground cover would be substantially higher after good rains when *Cenchrus ciliaris* is at its best. Acacias likely represent woody weeds as a result of over grazing.

Site ID: YRIP03	**Plot dimensions:** 50x50	**Landform pattern**: Alluvial Plains
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 2° W
Area: YLMA	**Latitude:** 116.095823	**Soil colour**: Red brown
Date and time: 9/05/15	**Longitude:** -21.761498	**Soil texture**: Loamy sand
Observers: SL	**Coords accuracy:** N/A	**Micro-relief**: Zero
PRP Photo #s: 4701-4717	**Drainage:** Imperfect	

NVIS description: Scattered shrubs of *Acacia inequilatera* over open shrubland of *Acacia trachycarpa* over hummock grassland of *Triodia epactia* over very open tussock grassland of *Cenchrus ciliaris* and *Eragrostis eriopoda*.

Comments: Terrace of Robe River valley between two channels. Central part of TSOP Land Management Area. Extensive soil surface disturbance by cattle.. Mixed annual and perennial scattered shrubs amongst ground layer.

Site ID: YWP01	**Plot dimensions:** 5x5	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 0
Area: YLMA	**Latitude:** 116.166068	**Soil colour**: Red brown
Date and time: 13/10/15 14:00 PM	**Longitude:** -21.811418	**Soil texture**: Stream cobbles in patchy silty loam matrix
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Zero
PRP Photo #s: 4988	**Drainage:** Well to imperfect	

Comments: South end of Red Hill mesa, South of Robe. In creekline next to mesa where baseline northern quoll site is. In floodplain. Unconsolidated river alluvium. *Triodia epactia* open grassland with mixed ephemeral shrubs on major creekline.

Site ID: YWP02	**Plot dimensions:** 5x5	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° N
Area: YLMA	**Latitude:** 116.088169	**Soil colour**: Red brown
Date and time: 13/10/15 15:30 PM	**Longitude:** -21.755488	**Soil texture**: Silty loam
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Soil lumps formed under hummocks and converted to tussocks
PRP Photo #s: 4989	**Drainage:** Well to imperfect	

Comments: On alluvial terrace to north of Robe River. Near crossing by track. SW of Mesa G. In lumpy scraggly shrubs covering grazed tussock and hummock grassland. *Acacia trachycarpa* shrubland over *Cenchrus ciliaris* closed grassland.

Site ID: YWP03	**Plot dimensions:** 5x5	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° E
Area: YLMA	**Latitude:** 116.172916	**Soil colour**: Red brown
Date and time: 15/10/15 12:30 PM	**Longitude:** -21.735563	**Soil texture**: Alluvium with some silt
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Head sized boulders; some unstable alluvium mounds
PRP Photo #s: 5136	**Drainage:** Well to imperfect	

Comments: Near PRP02. On east side of Yeera Bluff pool approx. 50m from pool in alluvium. Large unstable alluvium covered by dense leaf litter and *Melaleuca*. Massive unstable alluvium during flood. *Passiflora foetida* is present. *Melaleucas* approx 20m Sth have some moderate fire scarring. Leaf litter deep 5-10cm. Robe River major creek line vegetation on mobile course alluvium.

Site ID: YWP04	**Plot dimensions:** 5x5	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Stream Channel
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° E
Area: YLMA	**Latitude:** 116.070247	**Soil colour**: Red brown
Date and time: 16/10/15 10:30 AM	**Longitude:** -21.808245	**Soil texture**: Silty alluvium
Observers: SL & CO	**Coords accuracy:**	**Micro-relief**: Large mounds of partially unconsolidated alluvium
PRP Photo #s: 5218	**Drainage:** Well to imperfect	

Comments: On terrace next to moderate drainage (tributary of Robe R.). South of Robe R., SE of Mesa F. *Cucumis melo* outside quadrat

Site ID: YWP05	**Plot dimensions:** 5x5	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 3° E
Area: YLMA	**Latitude:** 115.964477	**Soil colour**: Red brown
Date and time: 17/10/15 14:30 PM	**Longitude:** -21.665825	**Soil texture**: Silty loam
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Small mounds and depressions from hoofprints
PRP Photo #s: 5330	**Drainage:** Well to imperfect	

Comments: In river terrace back from pool on east side Mesa B. N of rail access road and rail line. Large trees nearby with old fire scars. Larger fractal of mounds reflects old depositional history from previous floods. Cattle have eaten weeds and in doing so created hoofprint microrelief andhave disturbed vegetation. *Eucalyptus camaldulensis* open woodland of *Acacia trachycarpa* and *Petalostylus labichiodes* open tall shrubland over *Aerva javanica* scattered shrubs of *Cenchrus* spp. tussock grassland. Heavily grazed but with some persistent native shrubs and native overstory. *Cenchrus* dominates groundcover on much of creek line terrace where loamy soils occur (ie above gravel alluvium of active stream bed).

Site ID: YWP06	**Plot dimensions:** 5x5	**Landform pattern**: Alluvial Plain
Survey Name: TSOP Land Condition	**Habitat:** Plains/ riparian	**Landform element**: Plain (flat)
Survey Year: 2015	**Camera settings:** Canon 60D Auto settings. 24mm 200	**Slope & aspect**: 1° N
Area: YLMA	**Latitude:** 116.223095	**Soil colour**: Red brown
Date and time: 18/10/15 11:00 AM	**Longitude:** -21.748921	**Soil texture**: Silty loam in alluvium
Observers: SL & CO	**Coords accuracy:** 4	**Micro-relief**: Small mounds and depressions from hoofprints
PRP Photo #s: 5385	**Drainage:** Imperfect	

Comments: On South terrace of Robe River adjacent to heavy vehicles access to Mesa J. Natives persist amongst the *Cenchrus ciliaris* groundcover. Some browsing of shrubs e.g. *Grevillea, Hybanthis, Stylobasium*. *Cenchrus ciliaris* 20% utilisation. Grazing has altered floristics and structure. *Grevillea pyrafolia* scattered tall shrubs of *Stylobasium spathulatum* shrubland of *Cenchrus* spp. tussock grassland with mixed Malvaceae and other low shrubs. Heavily cattle grazed flood plain area of Robe River. Cenchrus spp. have 20-30% utilisation. Other native species (*Grevillea, Hybanthis*) also show evidence of browsing.