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

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February 2016

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The recommended reference for this publication is:

Morris K, Cowan M, Angus J, Anderson H, Garretson S, Palmer R, Williams M, Pearson D (2016). Baseline monitoring for northern quoll and Rothschild's rock-wallaby at *Eradicat®* baited and unbaited sites, Pilbara Region WA. Department of Parks and Wildlife, 2016, Perth.

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

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Acknowledgements

This study was undertaken as part of a Threatened Species Offset Plan (TSOP) and largely funded by Rio Tinto. Australian Premium Iron (API) also provided significant in-kind support for operations at Red Hill. The TSOP was developed in liaison with Mr Sam Luccitti (Rio Tinto) and the Biodiversity Offsets Advisory Panel (Dr Andrew Burbidge, Dr John Woinarski and Dr Hal Cogger) established by Rio Tinto. Mr Phil Davidson (Manager – Environment API) and Mr Ryan Francis, Mr Andrew Lohan and Mr Fran Hoppe (API Cardo Camp) facilitated visits to the Red Hill site. We thank Digby and Leanne Corker for permission to access the Red Hill pastoral lease, and the Kuruma and Marthudunera Traditional Owners for access to their traditional lands on Yarraloola and Red Hill pastoral leases. Mr Neil Thomas supervised the initial stages of this project. Ms Caitlin O'Neill and Mr Brent Johnson provided field assistance. Drafts of this report were reviewed by Parks and Wildlife Science and Conservation Division staff, *Western Shield* staff, Pilbara Region staff, members of the Biodiversity Offsets Advisory Panel and Ms Caitlin O'Neill. A workshop to determine the Scope of Works for the baseline monitoring study was held in October 2014 and attended by relevant Parks and Wildlife scientists and experts, Rio Tinto ecological and environmental advisors, and the Biodiversity Offsets Advisory Panel. The results of the 2015 baseline monitoring program were presented at another workshop with similar attendees held in October 2015. The baseline monitoring program was undertaken as part of the trial northern quoll cat bait uptake study which was approved by the Parks and Wildlife Animal Ethics Committee (Approval # 2014/11).

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 ± 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 ± 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

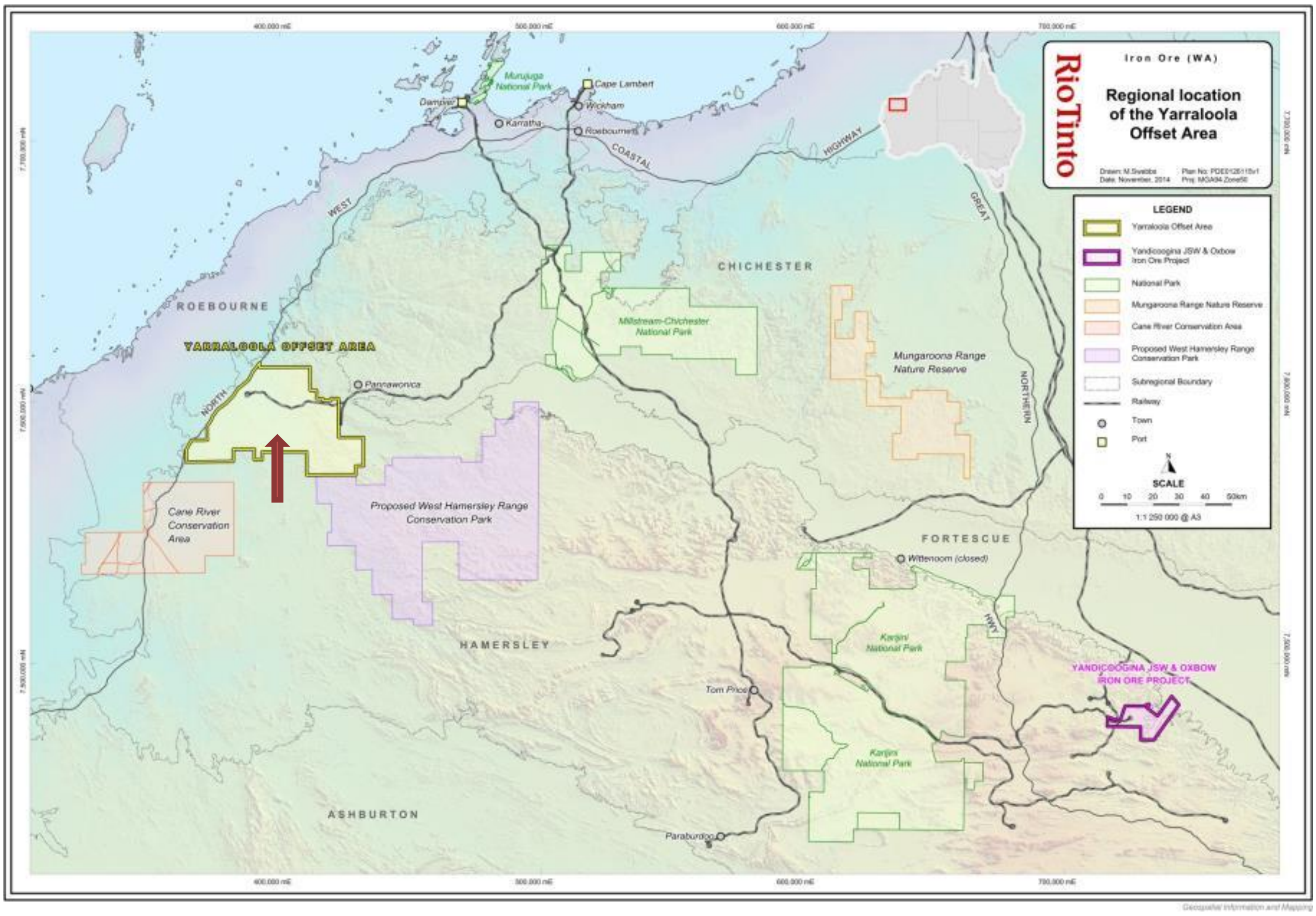


Figure 1. Regional location of the Yarraloola Land Management Area in the west Pilbara region of Western Australia.

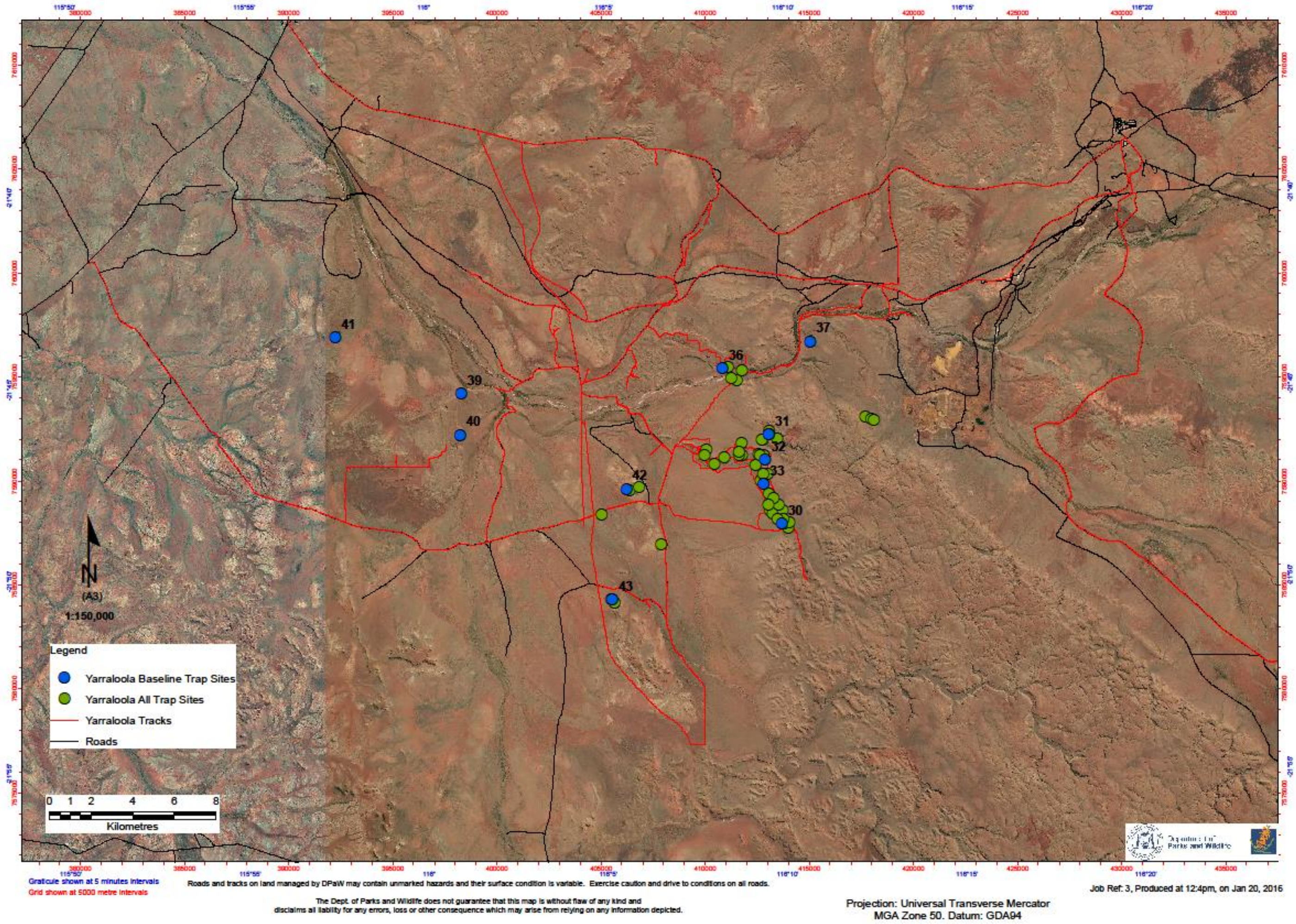


Figure 2. Locations of northern quoll trapping (●) and baseline monitoring (●) sites at Yarraloola (cat baited).

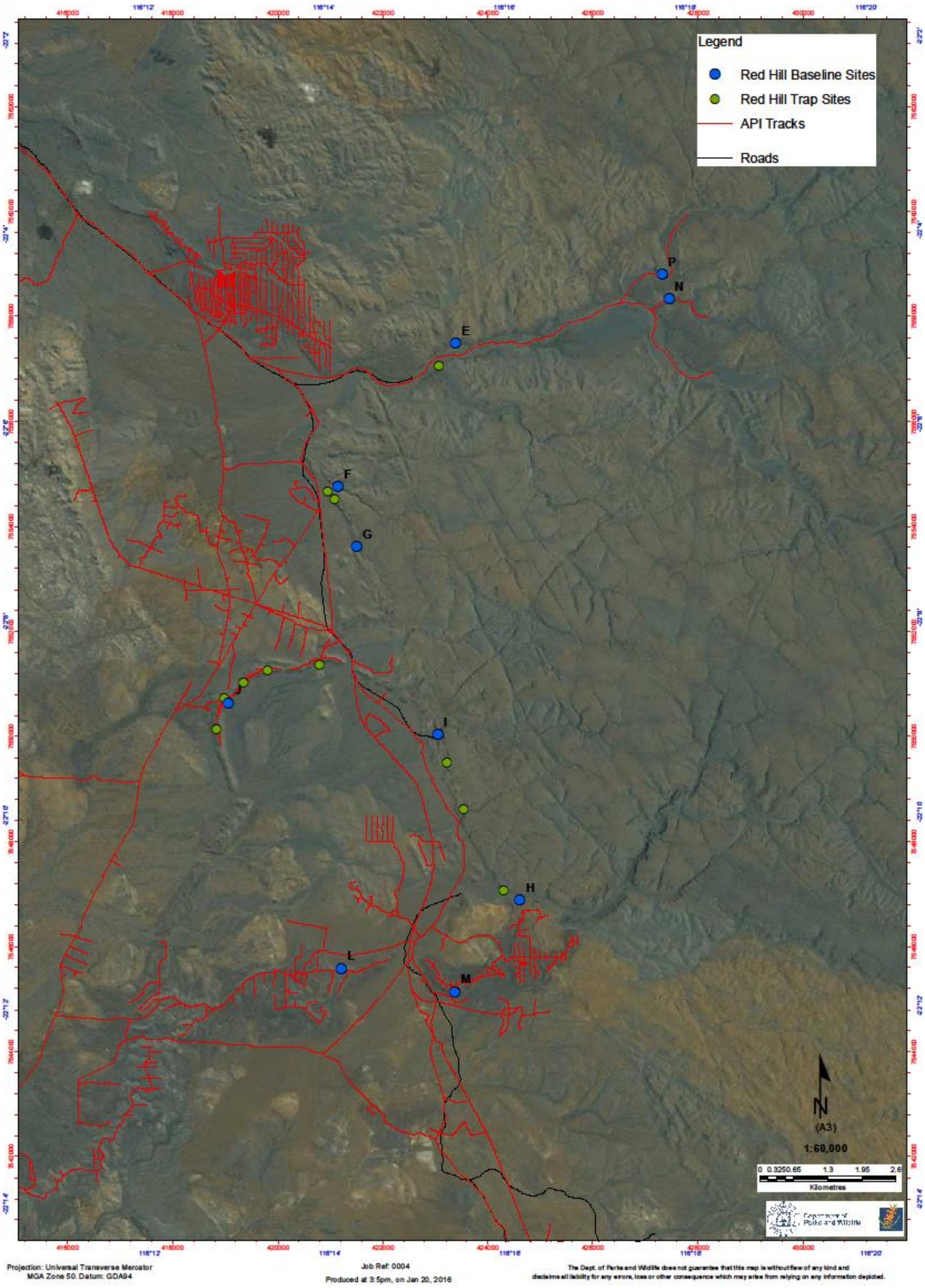


Figure 3. Location of northern quoll trapping (●) and baseline monitoring (●) sites at Red Hill (not cat baited).

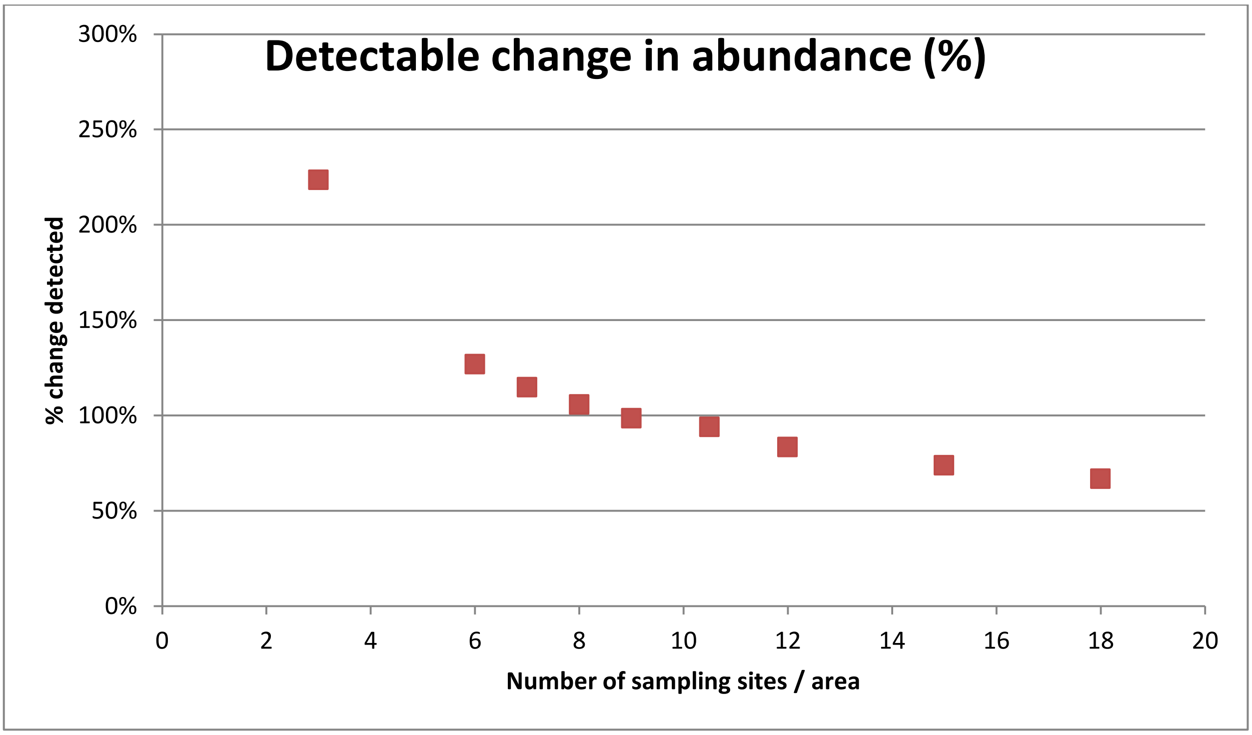


Figure 4. Power analysis of northern quoll sampling effort required at Yarraloola and Red Hill.

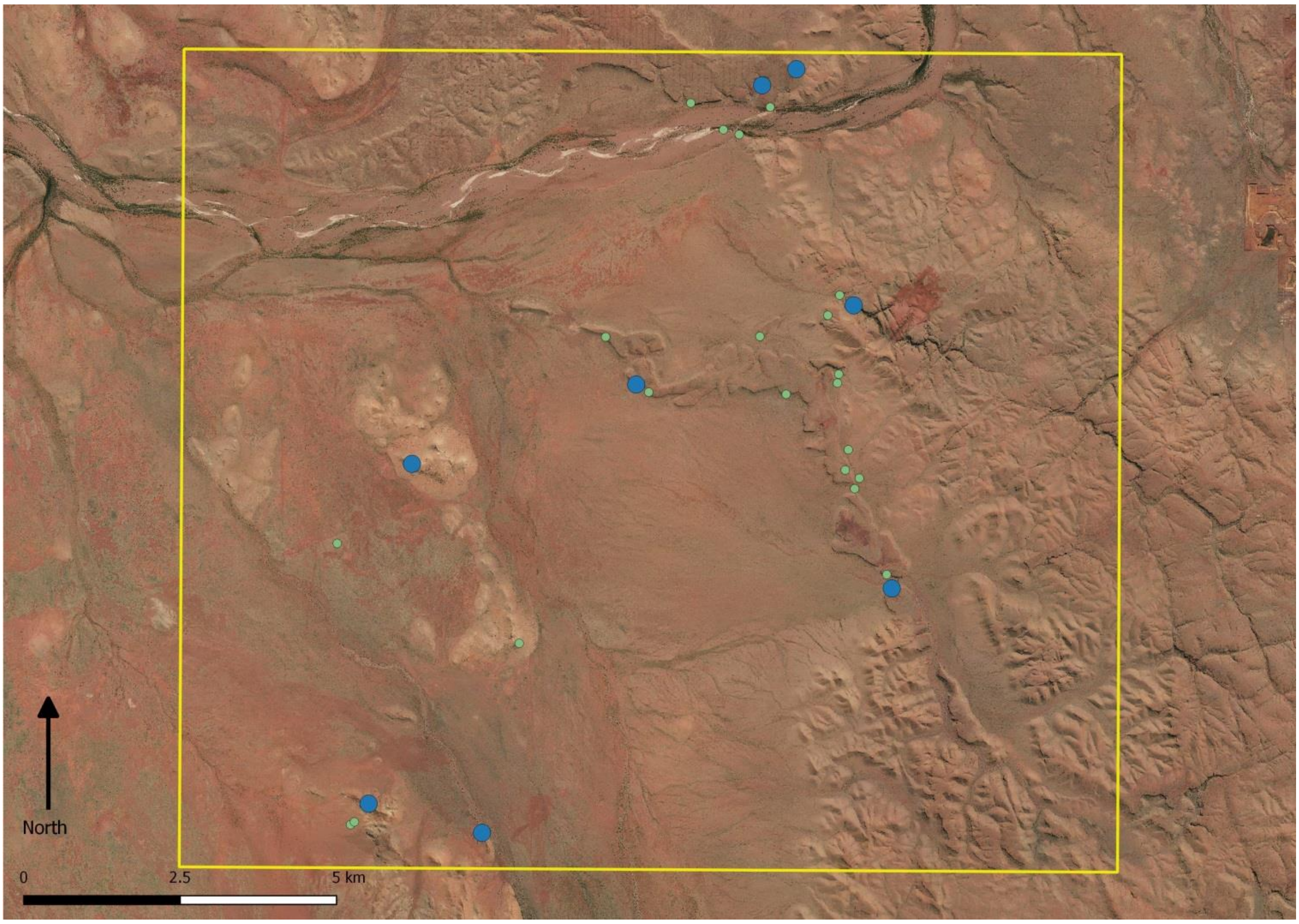


Figure 5. Location of camera traps set for detecting rock-wallabies at Yarraloola from mid-July to end of August 2015 within the trial cat baiting cell. Blue dots represent sites of rock-wallaby detections (one rock-wallaby at each site).

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').

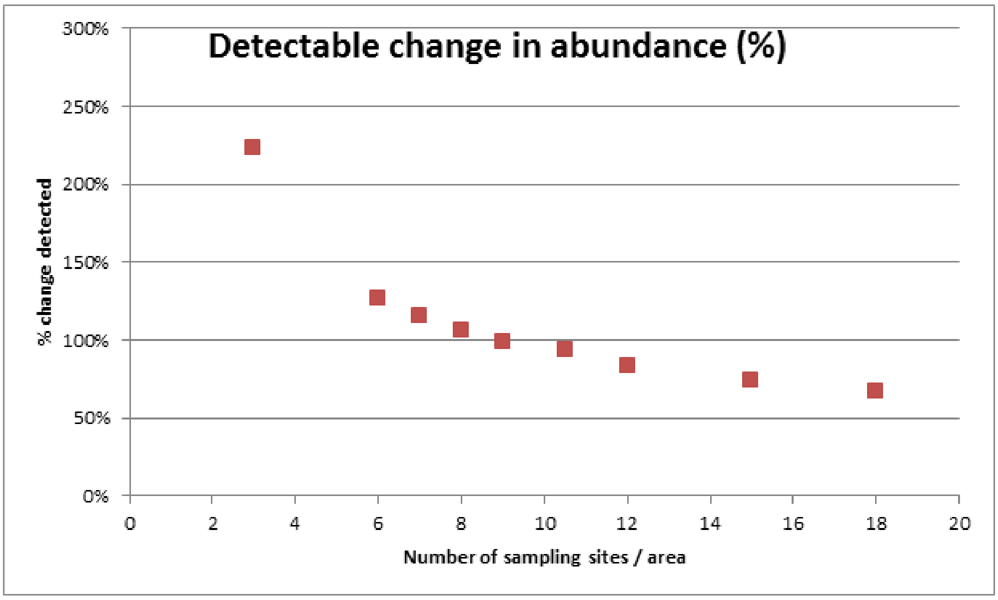
I've also looked at what change can be detected for various numbers of sample sites per sampling area. The current level of sampling is 10.5 sites/area (i.e. 11 at Yarraloola and 10 at Red Hill).

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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