# COMPLIANCE REPORT

## EPBC 2011/6228

# Mount Emerald Wind Farm

May 2020

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## DOCUMENT STATUS

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## APPROVAL FOR ISSUE

| Name | Signature | Date |
|---|---|---|
| Rene Kuypers | Rene Kuypers | 27-4-2019 |
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# ATTACHMENTS

## 1. DECLARATION OF ACCURACY

In making this declaration, I am aware that sections 490 and 491 of the Environmental Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) make it an offence in certain circumstances to knowingly provide false or misleading information or documents. The offence is punishable on conviction by imprisonment or a fine, or both. I declare that all the information and documentation supporting this compliance report is true and correct in every particular. I am authorised to bind the approval holder to this declaration and that I have no knowledge of that authorisation being revoked at the time of making this declaration.

| | |
|---|---|
| Signed: | |
| Full name (please print): | Anthony Yeates |
| Position (please print): | Director |
| Organisation (please print including ABN/ACN if applicable): | Mount Emerald Wind Farm Pty Ltd<br>ACN – 149 050 322<br>ABN – 19 149 050 322 |
| Date: | 29 April 2019 |

## 2. PROJECT DESCRIPTION

The Mount Emerald wind farm site is a large rural allotment (Lot 7 SP235224) comprising some 2,422ha. It is located approximately 3.5km south-west of Walkamin, off Springmount Road at Arriga on the Atherton Tablelands. Topographically, the site is situated at the northern most end of the Herberton Range (part of the Great Dividing Range) with the north-western section of the site being dominated by Walsh's Bluff.

The site is characterised by rugged terrain with elevations of between 540m up to 1089m ASL (above sea level). The town centre of Mareeba is situated approximately 18km to the north of the site, with the town of Atherton approximately 12km south-east of the site.

Other features of the site include a series of ephemeral drainage lines, including the headwaters of Granite Creek. An established 275kV transmission line (Powerlink: Chalumbin-Woree) and its associated easement traverses the site in an east-west direction, broadly bisecting it.

## 3. PROJECT ACTIVITY STATUS

The project commenced construction on the 7th February 2017.

On the 22nd February 2019, a notice of Commencement of Operation was issued under the terms of the construction contract, as such the wind farm is now considered to be currently in the "Operation" phase.

On the order of AEMO the wind farm is currently experiencing significant periods where the wind farm generation output is constrained to support network system strength. Work and upgrades are underway in conjunction with network operator (Powerlink) to remove this restriction with an outcome not expected until August 2020.

## 4. COMPLIANCE TABLE

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| **General** | | | | |
| 1 | The action is limited to the construction of a maximum of 63 wind turbines and associated infrastructure on the wind farm site | Max. 63 WTG | COMPLIANT | For Construction layout comprises 53 WTG.<br>As verified by TLDFP. (Attachment A) |
| 2 | To minimise impacts to EPBC Act listed threatened species, the approval holder must not disturb more than 78 ha of habitat for EPBC Act listed threatened species on the wind farm site | Max. 78ha of disturbed area | COMPLIANT | Ground Disturbance Tracking. (Attachment B) |
| 3 | Prior to commencement of the action, the approval holder must submit a Turbine Location and Development Footprint Plan identifying the final position of all proposed turbines, access roads and associated operational and maintenance infrastructure, for the written approval of the Minister | Turbine Location and Development Footprint Plan (TLDFP) | COMPLIANT | Approval received 18/1/17. (Previously supplied in 2018 Year 1 Compliance Report)<br>TLDFP sent to DOEE 13/01/2017<br>TLDFP (Previously suppled in 2019 Year 2 Compliance Report) |
| 4 | The Turbine Location and Development Footprint Plan must demonstrate how the approval holder has avoided and minimised disturbance to denning habitat for the Northern Quoll (Dasyurus hallucatus) and to *Grevillea glossadenia* and *Homoranthus porteri*. | Turbine Location and Development Footprint Plan (TLDFP) | COMPLIANT | Approval received 18/1/2017 (Previously supplied in 2018 Year 1 Compliance Report)<br>Documents sent to DOEE 13/01/2017<br>TLDFP shows locations of plant species (Previously suppled in 2019 Year 2 Compliance Report)<br>Refer to Design Justification Report (Previously supplied in 2018 Year 1 Compliance Report) |
| 5 | The approval holder must not commence the action until the Turbine Location and Development Footprint Plan has been approved by the Minister in writing. | Minister Sign-off | COMPLIANT | Approval of TLDFP received 18/1/2017. (Previously supplied in 2018 Year 1 Compliance Report)<br>Date of Commencement 7/2/2017. |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 6 | The Turbine Location and Development Footprint Plan must be implemented | Turbine Location and Development Footprint Plan (TLDFP) | COMPLIANT | Construction is occurring in-line with TLDFP |
| **Northern Quoll Management** | | | | |
| 7 | For the protection of the Northern Quoll, the approval holder must maintain a viable population of Northern Quoll on the wind farm site. | Northern Quoll population ~50 | | Current estimate of population remains as per previous study. |
| 8 | The approval holder must prepare and submit an Outcomes Strategy for the Minister's written approval which describes a monitoring program to inform adaptive management and determine whether the outcome required under condition 7 is being or has been met. The Outcomes Strategy must:<br>(a) be prepared by a suitably qualified expert;<br>(b) identify and justify performance measures, which are capable of accurate and reliable measurement, and will be used to measure the outcome required under condition 7;<br>(c) include a monitoring program, to detect changes in the performance measures. The monitoring must include baseline surveys, control sites and experimental design (to test the effectiveness of different management measures); and<br>(d) describe how the baseline and monitoring data will be adequate to: inform adaptive management; enable an objective decision to be made on whether the outcome described in condition 7 has been met. | Northern Quoll Outcomes Strategy (NQOS) | COMPLIANT | Approval received 23/12/16. (Previously supplied in 2018 Year 1 Compliance Report)<br>NQOS submitted 7/12/2016. (Previously supplied in 2018 Year 1 Compliance Report) |
| 9 | The approval holder must not commence construction until the Minister has approved the Outcomes Strategy in writing. | Minister Sign-off | COMPLIANT | Approval received 23/12/2016 (Previously supplied in 2018 Year 1 Compliance Report) |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 10 | The approved Outcomes Strategy must be implemented. | | COMPLIANT | All Survey Results have been posted to Project WEBSITE.<br>***www.mtemeraldwindfarm.com.au/compliance/***<br>USC Survey Work complete; Mt Emerald Wind Farm – Quoll Monitoring Final Report (Attachment A) |
| 11 | If the Minister is not satisfied that either the outcomes required under condition 7 are likely to be achieved, or there is insufficient evidence that the outcomes required under condition 7 are being achieved, the Minister may (in writing) require the approval holder to submit a plan for the Minister's approval to reduce, mitigate, remediate, or offset impacts to matters protected under the controlling provisions of this approval within a designated timeframe. The Minister may require the plan be prepared or reviewed by a suitably qualified person or another person specified or agreed to by the Minister. If the Minister approves the plan then the approved plan must be implemented. | Northern Quoll Mitigation Plan | NOT APPLICABLE | Not required at this time. |
| **Bare-rumped Sheathtail Bat and Spectacled Flying-fox Management** | | | | |
| 12 | Prior to commissioning, the approval holder must evaluate the effectiveness of suitable measures, including changed cut-in speed, avian radar system and SCADA system, to avoid and mitigate the impacts of turbine collision to Spectacled Flying-fox (*Pteropus conspicillatus*) and Bare-rumped Sheathtail Bat (*Saccolaimus saccolaimus nudicluniatus*) on the wind farm site. | Evaluation of Potential Measures to Reduce Turbine Collision | COMPLIANT | Email from DoEE confirming requirements met - 2/6/2017 (Previously supplied in 2018 Year 1 Compliance Report)<br>Report provided to DoEE 5/5/2017. (Previously supplied in 2018 Year 1 Compliance Report) |
| 13 | Prior to commissioning, the approval holder must submit to the Minister for written approval, a Wind Farm Implementation Plan that is informed by the results of the evaluation required by condition 12. The Wind Farm Implementation Plan must include: | Wind Farm Implementation Plan (WFIP) | COMPLIANT | WFIP approved 4/05/2018 (Previously supplied in 2019 Year 2 Compliance Report)<br>Final WFIP submitted to DoEE 24/4/2018. (Previously supplied in 2019 Year 2 Compliance Report) |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| | (a) details of intended outcomes and measurable performance criteria for the Spectacled Flying-fox and Bare-rumped Sheathtail Bat which are based on information contained in relevant guidance material including;<br>- *Matters of National Environmental Significance: Significant Impact Guidelines 1.1 Environmental Protection and Biodiversity Conservation Act 1999 (2013);*<br>- *EPBC Act Policy Statement 2.3 Wind Farm Industry (2009); and*<br>- *Draft Referral Guideline for 14 birds listed as migratory species under the EPBC Act (2015).*<br>(aa) a program to implement a *Low Windspeed Curtailment Study*;<br>(b) a program to monitor the effectiveness of progress against performance criteria; and<br>(c) contingency measures and corrective actions that will be implemented if performance criteria are not being or are not likely to be met. | | | |
| 14 | The Wind Farm Implementation Plan must be reviewed by a suitably qualified expert prior to submission to the Minister for approval. The Wind Farm Implementation Plan must include the findings of the review undertaken by the suitably qualified expert and details of how any recommendations made by the suitably qualified expert have been addressed. | Wind Farm Implementation Plan Review (WFIP) | COMPLIANT | WFIP approved 4/5/2018 (Previously supplied in 2019 Year 2 Compliance Report) |
| 15 | The approval holder must not commission the wind farm until the Wind Farm Implementation Plan has been approved by the Minister in writing. | Minister Sign-off | COMPLIANT | WFIP approved 4/5/2018 (Previously supplied in 2019 Year 2 Compliance Report) |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 16 | The approved Wind Farm Implementation Plan must be implemented. | | IN PROGRESS | Environmental consultant engaged to undertake the activities as per WFIP.<br>Bird and Bat Collision Mortality Studies Progress Report R2019-016 (Attachment B) |
| 17 | Upon the direction of the Minister, the approval holder must cease to operate any specified wind turbine generator/s if the Minister considers that, based on compliance reporting required by condition 26, they are having an impact on Bare-rumped Sheathtail Bat and Spectacled Flying-fox greater than the performance criteria required by condition 13(a) that cannot be mitigated or compensated. | Operational Strategy | | |
| **Offsets** | | | | |
| 18 | To compensate for residual significant impacts to EPBC Act listed threatened species, the approval holder must provide environmental offsets that comply with the principles of the EPBC Act Environmental Offsets Policy. | Offset Area Management Plan (OAMP) | COMPLIANT | Approval of OAMP provided 20/12/2016 (Previously supplied in 2018 Year 1 Compliance Report)<br>Response and final OAMP submitted 16/12/2016. (Previously supplied in 2018 Year 1 Compliance Report) |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 19 | The approval holder must prepare and submit an Offset Management Plan to the Minister for approval in writing . The Offset Management Plan must include:<br>(a) details of the minimum offset areas proposed to compensate for the loss of habitat for EPBC Act listed threatened species from the wind farm site,<br>(b) information about how the offset area/s provide connectivity with other relevant habitats and biodiversity corridors, including a map depicting the offset areas in relation to other habitats and biodiversity corridors;<br>(c) a description of the management measures that will be implemented on the offset site for the protection and management of habitat for EPBC Act listed threatened species, including a discussion of how measures proposed are consistent with the measures in conservation advice, recovery plans and relevant threat abatement plans;<br>(d) performance and completion criteria for evaluating the management of the offset area/s, and criteria for triggering remedial action (if necessary);<br>(e) a program, including timelines to monitor and report on the effectiveness of these measures, and progress against the performance and completion criteria;<br>(f) a description of potential risks to the successful implementation of the plan, and a description of the contingency measures that would be implemented to mitigate against these risks;<br>(g) the proposed legal mechanism and timelines for securing the offset/s; and<br>(h) a textual description and map to clearly define the location and boundaries of the offset area. This must be accompanied with the offset attributes and a shapefile. | Offset Area Management Plan (OAMP) | COMPLIANT | Approval of OAMP provided 20/12/2016 (Previously supplied in 2018 Year 1 Compliance Report)<br>Response and final OAMP submitted 16/12/2016. (Previously supplied in 2018 Year 1 Compliance Report) |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 20 | The approval holder must not commence construction until the Offset Management Plan has been approved by the Minister in writing. | Minister Sign-off | COMPLIANT | Approval of OAMP provided 20/12/2016 (Previously supplied in 2018 Year 1 Compliance Report) |
| 21 | The approved Offset Management Plan must be implemented | | COMPLIANT | 2017 Monitoring Report submitted 17/04/2018<br>2018 Monitoring Report submitted 6/12/2018<br>2019 Monitoring Report submitted 17/7/2019 (Attachment C) |
| **Administrative Conditions** | | | | |
| 22 | To avoid duplication, the approval holder may provide the Minister with plans and strategies prepared for the State and/or an Authority provided the plans, and/or strategies meets the conditions specified in this approval. The plans and/or strategies must include a cross reference table that clearly identifies:<br>(a) the condition specified in the approval for which the plan or strategy is being provided; and<br>(b) the relevant folder, chapter, section number and page number in the plan or strategy where the condition has been addressed. | | NOT APPLICABLE | Plans and Strategies have been provided to directly address conditions of this approval. |
| 23 | Within 10 business days after the commencement of the action, the approval holder must advise the Department in writing of the actual date of commencement. | Notification of Commencement of Construction | COMPLIANT | Date of Commencement 7 February 2017.<br>Notice provided 13/2/2017 (Previously supplied in 2018 Year 1 Compliance Report) and acknowledged. (Previously supplied in 2018 Year 1 Compliance Report) |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
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| 24 | The approval holder must maintain a dedicated webpage on compliance with these conditions that is publically available on the approval holder's website for the life of the approval. The webpage must include:<br>• a copy of the approval conditions (and any subsequent variations or other formal changes to the approval);<br>• all monitoring results and<br>• documentation required under these conditions and any other relevant information as directed by the Minister in writing.<br>Unless otherwise agreed to in writing by the Minister, the approval holder must provide a copy of documents required to be published on the dedicated webpage to members of the public upon request, within a reasonable time of the request. | Website | COMPLIANT | EPBC Decision Notice and Conditions placed on website.<br>**www.mtemeraldwindfarm.com.au/compliance/** |
| 25 | The approval holder must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval, including measures taken to implement any plans and strategies required by this approval and measures taken to achieve the outcomes specified in conditions 7 and 13 and make them available upon request to the Department.<br>Such records may be subject to audit by the Department or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the Department's website. The results of audits may also be publicised through the general media. | File management | | |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 26 | Within three months of every 12 month anniversary of the commencement of the action, the approval holder must publish a report on the webpage required in condition 24 addressing compliance with each of the conditions of this approval, including implementation of any plans and strategies as specified in these conditions and whether the outcome required by conditions 7 and 13 have been or are track to being met. The compliance report must consider the Department's Annual Compliance Report Guidelines.<br><br>Documentary evidence providing proof of the date of publication and non-compliance with any of the conditions of this approval must be provided to the Department at the same time as the compliance report is published. | EIS Compliance Report | COMPLIANT | Date of Commencement 7 February 2017.<br><br>2018 Year 1 Compliance Report – issued.<br><br>2019 Year 2 Compliance Report – issued. |
| 27 | The approval holder must report any contravention of the conditions of this approval to the Department within 2 business days of the approval holder becoming aware of the contravention. | Notification of Contravention | COMPLIANT | No contravention identified. |
| 28 | Upon the direction of the Minister, the approval holder must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the Minister. The audit must not commence until the Minister has approved the independent auditor and audit criteria. The audit report must address the criteria to the satisfaction of the Minister. | Independent Audit | NOT APPLICABLE | No direction from Minister at this time. |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
|---|---|---|---|---|
| 29 | The approval holder may choose to revise a plan or strategy approved by the Minister under conditions 3, 8, 13 and 19 without submitting it for approval under section 143A of the EPBC Act, if the taking of the action in accordance with the revised plan or strategy would not be likely to have a new or increased impact. If the approval holder makes this choice they must:<br>(a) notify the Department in writing that the approved plan or strategy has been revised and provide the Department with an electronic copy of the revised plan or strategy;<br>(b) implement the revised plan or strategy from the date that the plan or strategy is submitted to the Department; and<br>(c) for the life of this approval, maintain a record of the reasons the approval holder considers that taking the action in accordance with the revised plan or strategy would not be likely to have a new or increased impact. | Revised Plans:<br>#3 - Turbine Location and Development Footprint Plan<br>#8 - Northern Quoll Outcomes Strategy<br>#13 - Wind Farm Implementation Plan<br>#19 - Offset Area Management Plan | NOT APPLICABLE | TLDFP submitted 13/1/2017; approved 18/1/2017<br>TLDFP as-built (Previously supplied in 2019 Year 2 Compliance Report)<br>NQOS submitted 7/12/2016; approved 23/12/2016<br>WFIP submitted 24/4/2018; approved 4/5/2018<br>OAMP submitted 16/12/2016; approved 20/12/2016 |
| 30 | The approval holder may revoke its choice under condition 29 at any time by notice to the Department. If the approval holder revokes the choice to implement a revised plan without approval under section 143A of the Act, the approval holder must implement the version of the plan most recently approved by the Minister. | Revised Plans | NOT APPLICABLE | No revisions made at this time. |
| 31 | Condition 29 does not apply if the revisions to the approved plan or strategy include changes to environmental offsets provided under the plan or strategy in relation to a matter protected by a controlling provision for the action, unless otherwise agreed in writing by the Minister. This does not otherwise limit the circumstances in which the taking of the action in accordance with a revised plan or strategy would, or would not, be likely to have new or increased impacts. | Revised Plans | NOT APPLICABLE | No revisions made at this time. |

| No. | CONDITION | DELIVERABLE | DESIGNATION | CURRENT STATUS |
| --- | --- | --- | --- | --- |
| 32 | If the Minister gives a notice to the approval holder that the Minister is satisfied that the taking of the action in accordance with the revised plan would be likely to have a new or increased impact, then:<br>(a) condition 29 does not apply, or ceases to apply, in relation to the revised plan; and<br>(b) the approval holder must implement the version of the plan most recently approved by the Minister.<br>To avoid any doubt, this condition does not affect any operation of conditions 29 and 30 in the period before the day after the notice is given. | Revised Plans | NOT APPLICABLE | No revisions made at this time. |
| 33 | At the time of giving a notice under condition 32, the Minister may also notify that for a specified period of time condition 29 does not apply for one or more specified plans required under the approval. | Revised Plans | NOT APPLICABLE | No revisions made at this time. |
| 34 | Conditions 29, 30, 31 and 32 are not intended to limit the operation of section 143A of the EPBC Act which allows the approval holder to submit a revised plan to the Minister for approval. | Revised Plans | NOT APPLICABLE | No revisions made at this time. |
| 35 | If, at any time after five years from the date of this approval, the approval holder has not substantially commenced the action, then the approval holder must not commence the action without the written agreement of the Minister. | Drop Dead Date - 26 November 2020 | COMPLIANT | Refer to Condition 23. |

# A. NORTHERN QUOLL OUTCOMES STRATEGY – FINAL REPORT

# Mt Emerald Wind Farm
# Fauna Monitoring

# Final Report


28 June 2019

Dr Scott Burnett, Dr Carmen Piza-Roca and Daniel Nugent

University of the Sunshine Coast, 90 Sippy Downs Drive, Sippy Downs 4552

# Final Report Mt Emerald quoll, other target fauna and habitat monitoring July 2017 – Feb 2019

## Executive Summary


- Six, 306.25-ha camera trap monitoring plots, each consisting of 36 camera stations, were established on the northern Atherton Tablelands.
- We lost access to one of these sites and were unable to locate a replacement site, leaving five sites in operation during our six sampling sessions between July 2017 and March 2019.

- Camera traps recorded 712 independent detections of northern quolls over the two years at the five sites and 216 camera stations. Between 33 and 74 total individual quolls were detected during each of the six sampling sessions, and the numbers of individuals at any site ranged from 0 to 29 individuals in any single session.
- Quoll occupancy of the sites (i.e. proportion of camera stations detecting a quoll during any session) ranged from 0 (where no quolls were detected) to 0.818, with a mean 0.328 (SD=0.217). Modelled occupancy at each site ranged from 0 to 0.81201, with a mean 0.51037 (SD=0.192)
- Very low numbers of feral cats were recorded on three of the five sites (including the two Mt Emerald sites), very low numbers of dingoes were recorded on all sites and low numbers of pigs were recorded on 4 of the five sites (including the two Mt Emerald sites). Cane toads were recorded on all sites.
- **There is no statistical evidence that estimated population size of quolls changed in response to the construction works at Mt Emerald over the two-years of this project. However, the raw population counts hint that there may have been a decrease in breeding success leading to fewer juvenile quolls on the MEWF sites in Feb 2019. A similar pattern was observed at one of the control sites (Davies Creek), but wasn't observed at the other two control sites.**
- **There is strong statistical evidence that the distribution of quolls decreased on the MEWF site with each subsequent seasonal visit, particularly during the February 2019 juvenile pre-breeding season at ME1 indicating a decline in new recruits into the population following the July 2018 breeding season.**
- There is no evidence that populations of any of the non-quoll target species changed in response to the construction works at Mt Emerald over the two-years of this project.
- Given that the construction phase of MEWF works are now finalised, we would not expect to observe any ongoing direct effects on quoll or other fauna populations. However, our findings here cannot be used to imply that there will be no ongoing impact on quoll populations resulting from altered habitats, population dynamics or medium to long-term effects on habitat quality resulting from landscape changes arising from the MEWF project.

- Quoll habitat was assessed at 108 camera stations. This monitoring program was designed to detect pervasive landscape-level habitat changes arising from the MEWF project, in the event that a change in quoll populations was detected and putative drivers of that change needed to be identified.

- Although we detected some changes in the quoll habitat directly surrounding the camera trap stations, these changes did not significantly differ from control sites.
- **There is no qualitative or statistical evidence that there has been a change in quoll habitat at the camera trap stations as a result of the MEWF project over the two years of this project. However, it is noted that this monitoring is spatially very localised, as are the impacts of the MEWF construction works, and, therefore, we haven't directly monitored those impacts.**

- We make several recommendations designed to assist the continued presence and health of the northern quoll population at the MEWF site;
    - A 3-season 2020 monitoring session is recommended to assess whether there has been a continued decline in breeding success of quoll on the Mt Emerald sites and to establish whether quoll occupancy has stabilised. This should follow the protocols used here in order to render data comparable with that collected here.
    - Conduct early wet season acoustic surveys for artificial cane toad breeding sites and decommission where possible. The spike in toad numbers at the ME1 site in February 2019 may indicate the inadvertent creation of artificial toad breeding ponds. A survey of these sites to identify any such locations and allow their decommissioning would be a technically simple operation with potentially important positive ecological outcomes for quolls and the entire ecosystem at the MEWF site.
    - Maintain a healthy dingo population at MEWF. The two MEWF sites had the highest incidence of cats of any of the five sites monitored (though still low). Cats are a known predator of northern quolls and the best option for keeping them in low numbers is helping to maintain a healthy Dingo population at these sites by not undertaking poisoning or shooting campaigns against the species there.
    - Full BioCondition should be repeated whenever quoll monitoring is repeated in order to detect pervasive vegetative habitat changes (such as intrusion of weeds or deleterious changes in fire frequency and intensity).

## Introduction

The northern quoll is a small carnivorous marsupial which occurs patchily across northern Australia (Woinarski *et al*. 2012). Within this range, it inhabits dry sclerophyll forest on rocky landscapes ranging from sea-level to 1300-m altitude. Northern quoll populations have suffered a catastrophic range decline, which has been attributed to cane toads *Rhinella marina* (Burnett *et al*. 1996), altered fire regimes (Woinarski *et al.* 2012) and predation by feral cats *Felis catus* and dingoes/wild dogs *Canis familiaris/dingo*. The decline in northern quolls appears to have started in eastern Australia in the early-mid 1900's, and has spread to the north and west (Woinarski *et al.* 2012). Dry forests on the hills and slopes associated with the northern Atherton Tablelands have been identified as a key refuge for the species in north-eastern Australia (Burnett *et al.* 2013). The Mt Emerald Windfarm (MEWF) site has been identified as a potentially important part of that refuge, both in terms of the numbers of northern quolls which occur there, and the role of the mountain ranges on which the MEWF is located, as a corridor for gene flow between the Lamb Range population and the Herberton Range population of the species (Conroy *et al.* 2013).

The construction of the MEWF at Mt Emerald, far north Queensland, received approval from the Australian Commonwealth Government in 2015 conditional upon implementation of an ongoing monitoring program of the population of northern quolls, *Dasyurus hallucatus*, within the project area and at a number of "control" sites in the immediate vicinity of the MEWF. Given the possibility of a quoll decline being detected at MEWF, we also collected quantitative data on key habitat attributes and the presence of feral carnivores and cane toads at our camera trapping stations in order to be able to better disentangle the drivers of any such decline.

The monitoring program, conducted over 6 sessions, has been reported as each session was completed (http://mtemeraldwindfarm.com.au/compliance/), and provides a qualitative assessment of the trends in individuals detected, modelled population size and site occupancy of northern quolls at the MEWF sites compared to a set of regional control sites. The timing of this monitoring coincides with three stages in the life of northern quoll populations in far north Queensland (S. Burnett unpubl. data). These stages cover the period immediately prior to and during the breeding season (July-August each year), the post breeding period (October-November each year), and the juvenile pre-breeding phase (February-March each year). This allows us to explore at which stage any observed population changes are occurring. The seasonal progress reports produced to date indicated no obvious change in the quoll population (measured by any of the three metrics listed above), nor in the habitat parameters measured (including vegetative and predators or cane toads).

This final report consolidates the data from each survey into a single data set, presents detailed methods and a new analysis using quantitative models and plots aimed at detecting statistically significant changes in the abundance and occupancy of the quoll populations at the five monitoring sites. We similarly explore whether the MEWF project has resulted in increases in feral animals at those sites, and whether there is any impact on habitat attributes at our monitoring sites. Our key finding is that, with the data collected during the two-year period, there is inconclusive evidence on whether the MEWF has had an impact on quolls. While there is no discernible impact on population size, there is some indication of a decline in juveniles which may hint at lowered breeding success in the 2018 breeding season. We have also identify a statistically significant decrease in quoll occupancy in MEWF sites relative to the control sites.

## Methods

This project utilised repeated plot-based camera trapping of target fauna and transect-based habitat monitoring on two impact sites within the MEWF footprint, and four control sites in the surrounding region (Fig. 1). Each of the six sites consisted of a 6 x 6 station grid with each station spaced 350m apart. This gave 36 survey points encompassing 306.25 ha at each survey site.

### Northern quoll and other fauna species monitoring

Baited trail cameras were used to collect capture-recapture and site occupancy data on northern quoll *Dasyurus hallucatus.* Wild dogs/dingo*, Canis familiaris/dingo,* feral cat *Felis catus,* feral domestic pig, *Sus scrofa* and cane toads *Rhinella marina* relative abundance (number of detections) was also monitored using this method.

At each site (with the exception of site Tinaroo – see Table 1), fauna monitoring occurred during six, 14-day deployments between July 2017 and March 2019 (Fig. 1, Table 1). We lost access to site Tinaroo after two rounds of monitoring (i.e. from February 2018 onwards) due to veto of our Scientific Purposes Permit renewal application by the Native Title holders of that area. We therefore only surveyed five of the original six sites for the full duration of the proposed monitoring term (Table 1).

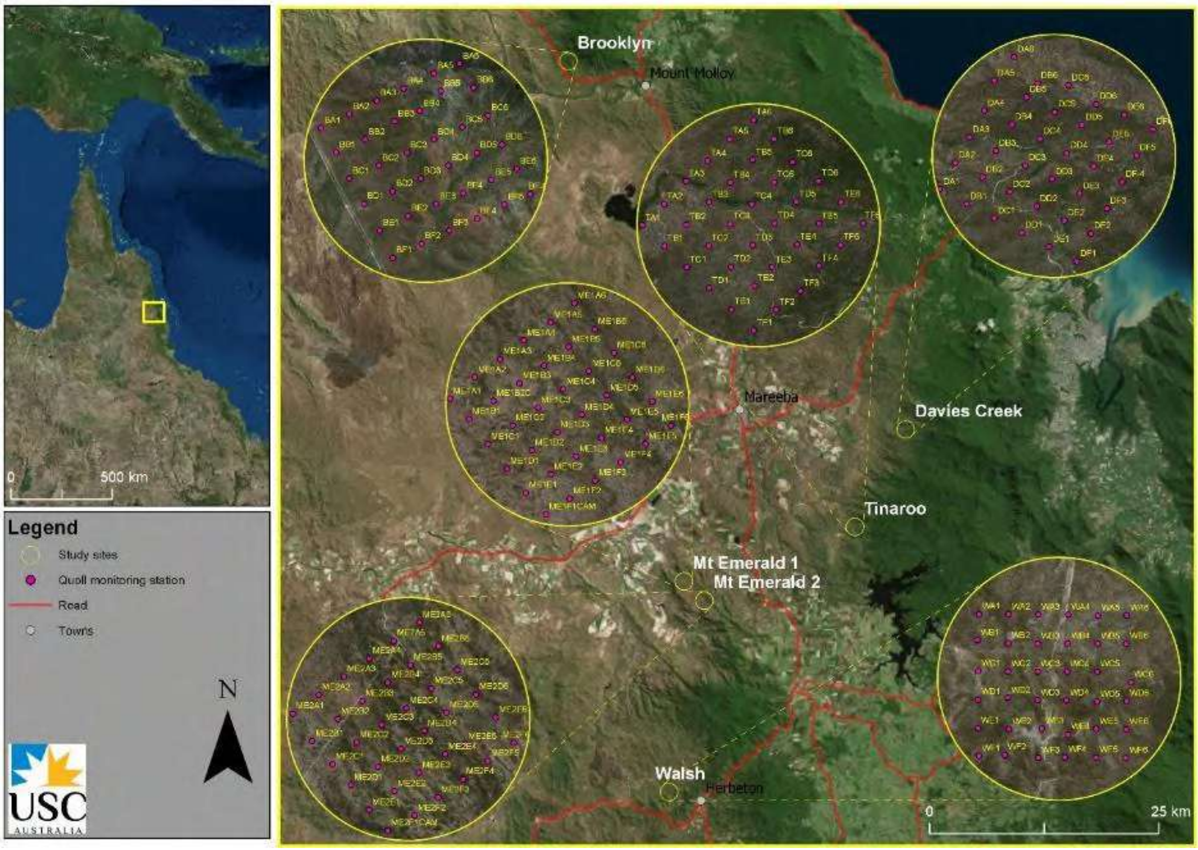


**Fig. 1. Indicative locations of the camera trapping stations (purple circles) at the six monitoring sites used to monitor northern quoll populations in the northern Atherton Tablelands from July 2017 onwards. Monitoring site names are displayed in white text. Local place names are in black text. The exploded views (large yellow circles) show the orientation and placement of the camera trap stations within each site. Note that site "Tinaroo" was not utilised from February 2018 due to permits being denied for this area from that point onwards. Basemap: GoogleEarth Pro 9 December 2017.**

Camera trapping entailed the use of a single Bestguarder Trail Camera Model SG990v (www.faunatech.com.au) at each station, mounted horizontally onto a tree trunk, 150 cm above and aimed perpendicularly to the ground (Fig. 2). In the centre of the target area, a PVC bait cannister loaded with five chicken necks was pegged to the ground. The bait cannister consisted of a 10-cm-long, 50-mm-diameter PVC pipe capped at both ends. At one end the cap was a vented cowling, which would allow the scent of the lure to disperse, but which prevented animals from consuming the bait. Trail cameras were deployed for a minimum 14 nights and programmed for 24-hour operation, to take three photographs per detection event, and to continue to capture photo bursts for as long as an animal remained within the detection area. The flash setting was set to incandescent flash for all night time image capture. Bait cannisters and cameras were not reloaded during the 14 days when they were deployed.

**Table 1. Site location, survey timing and effort at each of the survey sites. "Type" refers to whether the site was a control or an impact site. "Coords" refers to the central coordinate (Station C3– refer Fig. 1) of each site (in decimal degrees), "Monitoring Session." refers to each of the six repeat surveys at each site.**

| | | | Monitoring Session | | | | | |
|---|---|---|---|---|---|---|---|---|
| Site | Type | Coords | 1 | 2 | 3 | 4 | 5 | 6 |
| **Brooklyn Sanctuary** | **Control** | -16.65, 145.2538 | **10/07/17 – 25/07/17** | **4/10/17 – 18/10/17** | **23/2/18 – 11/03/18** | **18/2/19 – 02/08/18** | **2/10/18 – 17/10/18** | **19/2/19 – 11/03/19** |
| **Davies Creek (Danbulla NP)** | **Control** | -17.01, 145.5818 | **04/07/17 – 19/07/17** | **6/10/17 - 20/10/17** | **20/2/18 – 06/03/18** | **17/7/18 – 31/07/18** | **1/10/18 – 15/10/18** | **18/2/19 – 04/03/19** |
| **Mt Emerald 1** | **Impact** | -17.1603, 145.3671 | **31/07/17 – 15/08/17** | **23/10/17 – 6/11/17** | **13/3/18 - 19/04/18** | **02/8/18 – 16/08/18** | **18/10/18 – 1/11/18** | **12/3/19 – 27/03/19** |
| **Mt Emerald 2** | **Impact** | -17.1793, 145.3872 | **01/08/17 – 16/08/17** | **24/10/17 – 7/11/17** | **12/3/18 – 10/4/18** | **03/8/18 – 17/08/18** | **18/10/18 – 2/11/18** | **13/3/19 - 28/03/19** |
| **Tinaroo (Dinden NP)** | **Control** | -17.1046, 145.5324 | **20/07/17 – 04/08/17** | **5/10/17 - 20/10/17** | **NA** | **NA** | **NA** | **NA** |
| **Walsh** | **Control** | -17.3637, 145.3524 | **12/07/17 – 27/07/17** | **25/10/17 – 11/10/17** | **24/2/18 – 10/03/18** | **19/7/18 – 08/08/18** | **10/10/18 – 24/11/18** | **25/2/19 – 22/03/19** |

**Fig. 2. Trail camera deployment (left) and bait presentation (right). The camera on the left is facing directly down at the bait cannister (Source: N. Foster). The bait cannister method used in this project has the upwards end of the cannister capped with a vented cowling to allow scent to disperse (right).**

## Habitat Monitoring

Habitat monitoring utilised a modified BioCondition monitoring method (Eyre *et al.* 2015). The standard BioCondition Monitoring protocol was modified by increasing the course woody debris plot from 50 x 20m to 100 x 20m. Habitat monitoring was undertaken at half of the camera trapping stations, and repeated during each quoll monitoring session (Fig. 3). In keeping with standard BioCondition monitoring protocols (Eyre *et al.* 2015), if there were no obvious signs of disturbance such as storm, fire or construction damage observed at a site, then measures of tree and course woody debris abundance were not recorded again between sessions. All measures were however recorded on the last survey (February 2019) regardless of whether a disturbance was detected. The BioCondition plots were typically situated so that the camera station was the centre point of the BioCondition transect but in some instances, the landscape dictated that the camera station was at one end of the transect.

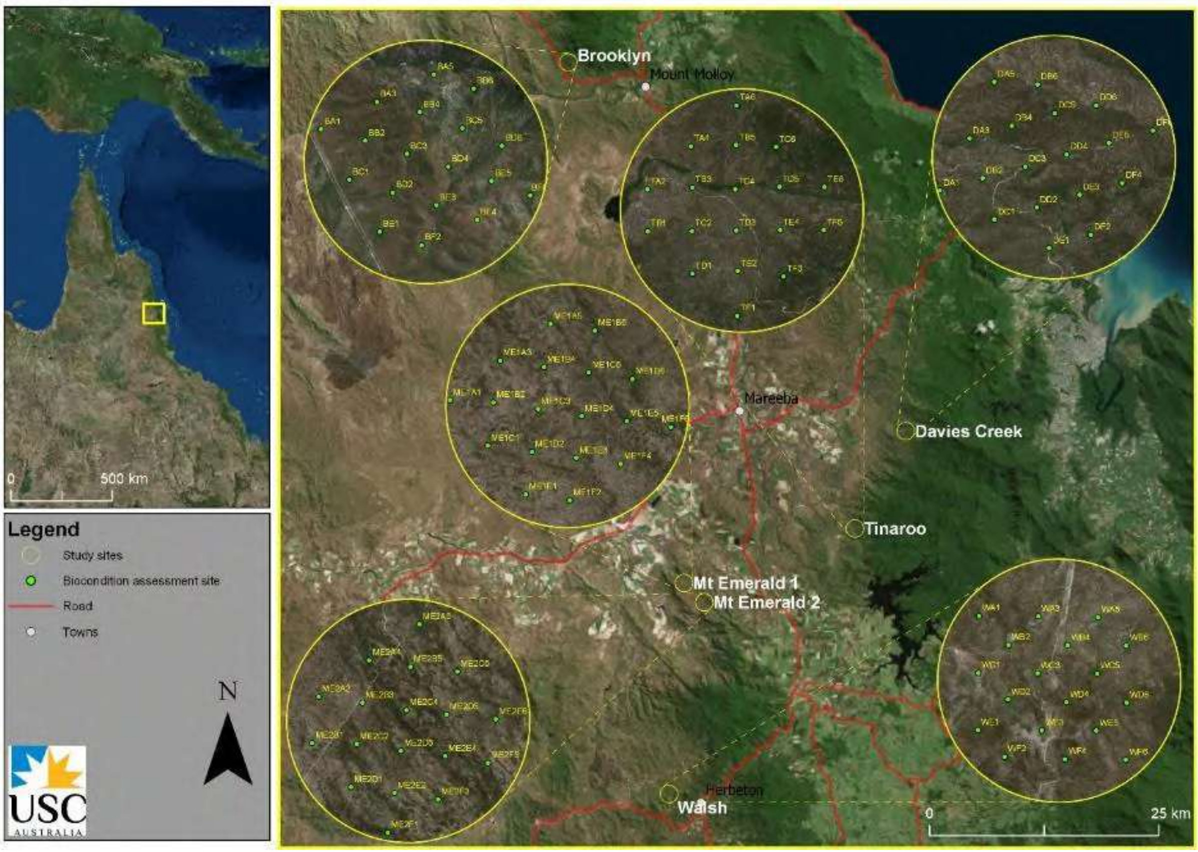


**Fig. 3. Locations of the 108 BioCondition monitoring plots (green dots) which were used to monitor quoll habitat on our camera trapping sites in the northern Atherton Tablelands from July 2017 onwards. Monitoring site names appear in white text. Local place names appear in black text. The exploded views ( large yellow circles) show the orientation and placement of the BioCondition monitoring plots within each site. Note that site Tinaroo was not utilised from February 2018 onwards due to permits being denied for this area. Basemap: GoogleEarth Pro 9 December 2017.**

## Data analyses

### *Fauna data*

The species captured by each trail-camera image were tagged with species and individual (in the case of quoll) tags using the software program *digiKam* (digikam.org). These tagged pictures were summarised and prepared for further analyses using the package *camtrapR* (Niedballa *et al.* 2016) within the R statistical environment (R Core Team, 2016). Prior to compiling species and individual summary data, we checked that the photo creation date and time of each picture were accurate. This was achieved by comparing the *dateTimeOriginal* metadata of the photos captured at camera set-up against our field notes. Where discrepancies were identified, these were corrected using the *timeshift()* function in *camtrapR*. We then compiled species record tables for each site and session using a 15-minute rule to distinguish independent detections of any species/individual (i.e. if images of a single species or individual were detected within 15 minutes of one another, they were not counted as separate detections). Quolls and cats were able to be identified to individual level by their unique coat markings. All other target and non-target fauna were identified to species only.

Northern quoll populations at each site and session were quantified using a number of population metrics including, (i) minimum number known to be alive (KTBA) (i.e., minimum number of individuals which were photographed and identified during each monitoring session), (ii) a population size estimate generated by the R-package *RMark* (Laake 2013), and (iii) a naïve occupancy (i.e. the number of camera stations at which quolls were detected, expressed as a proportion of all stations), and, (iv) an occupancy estimate generated using the R-package *unmarked* (Fiske and Chandler 2011).

R-package *RMark* (Laake 2013), an interface of the program MARK (White, G. C., & Burnham, K. P. (1999)), was used to build and implement capture–recapture models for closed populations (Otis *et al.* 1978). Closed-population models assume that a population remains unchanged during the sampling period (i.e., that there are no gains or losses of individual quolls during the 14 nights). *RMark* utilizes individual capture histories to estimate the number of quolls within the area covered by the camera traps. The capture-recapture models account for imperfect detection rates to estimate the numbers of individuals likely to be present but which were not detected. These are added to the individuals that were detected to estimate total population size.

*RMark* input files were generated using *camtrapR*. We built three closed-capture models: the null model (where probability of capture and recapture are constant and the same), the behavioural model (where probability of capture and recapture are constant but different) and the time-varying model (where probability of capture and recapture over with time). Goodness of fit was assessed using $AIC_c$. When more than one model seemed plausible, model averaging was performed (White *et al.* 2001).

Model averaging entails a weighted average of the estimates of a parameter for several models, including model selection uncertainty in the estimate of precision of the parameter, and thus producing unconditional estimates of sampling variances and covariances and standard errors.

Site occupancy was estimated using the R package *unmarked* (Fiske and Chandler 2011) using occupancy models. These models are hierarchical, in that the ecological process that influences occupancy is modelled separately from the detection process. The models produce estimates for the state variable occupancy (*psi*) and detection probability (*p*), therefore accounting for imperfect detection (MacKenzie *et al.* 2017). Input files for *unmarked* were also generated within *camtrapR* and a simple null occupancy model was run. This produced estimates of *psi* (occupancy) and *p* (detection) probability for each site at which enough data were obtained to do so.

To assess the impacts of MEWF project on quolls, trends in quoll population size and site occupancy over time were modelled. Population size estimates (as calculated using capture-recapture models in *Rmark*) were modelled using general linear modelling. Due to seasonal changes in quoll populations, the natural variation across the three life-stage seasons (surveys in February, July and October) needed to be considered. To do so, we assessed whether population of quolls had changed from the same season to the next one (July 2017 vs July 2018, October 2017 vs October 2018 and February 2018 vs February 2019). In other words, we modelled the differences in population size between first and second visit for a particular time of the year. To determine a potentially different impact in MEWF sites compared to other monitoring sites we also included the site type (impact vs control sites) as a predictor. Finally, to account for natural differences across sites and seasons, we included both variables as predictors in the model. To allow time trends and impact to differ depending on site, all interactions between predictors were included, except with time of the year. The model was simplified using single-term deletions and subsequent assessment of changes in AIC, and further tests of significance of model fit deterioration using a Fisher-test. See Table xxx for more information on model structure. Occupancy was modelled in the same way. However, because not enough data were available to obtain sufficient occupancy estimates in *unmarked* for construction of robust models, we used naïve occupancy. Because occupancy is a proportion (proportion of the site inhabited by quolls), generalised linear modelling was used, with the family structure Binomial. Model simplification was conducted by single-term deletions and subsequent assessment of AIC, with further testing of significance of model fit deterioration using $\chi^2$-tests. See Table 3 for more information on model structure.

Cat, dingo/dog, feral pig and cane toad populations were assessed using the number of independent detections and naïve occupancy, as data for these species were too sparse for effective model-building approaches to population estimation.

### *Habitat data*

Key habitat data were summarised at each station by taking; (1) the number of fire events detected, (2) the total length of coarse woody debris at 20 x 100 plots, (3) species richness of trees, shrubs, grasses and forbs, (4) the average percent bare ground cover across nine 1-$m^2$ quadrats separated by 10 m along a 100 m transect, (5) and the length of canopy cover and (6) shrub cover along the same 100 m transect.

Changes in key habitat variables were modelled using generalised linear modelling. Canopy and shrub cover, coarse woody debris and percent bare ground were modelled as a function of survey number to investigate any trends over the two-year period in which surveys were conducted. Similar to quoll models, we also included the site type (impact vs control sites) as a predictor to quantify differences between MEWF sites and other monitoring sites. Also, to account for natural differences across sites and seasons, we included both variables as predictors in the model. To allow trends to differ depending on sites, all interactions between predictors were included, except with time of the year. The model was simplified using single-term deletions and subsequent assessment of changes in AIC, and further tests of significance of model fit deterioration using a Fisher-test.

## Results

### Quoll populations

Across the two-year project, camera trapping resulted in 712 independent detections of northern quolls (Fig. 4). Between 33 and 74 total individual quolls (mean = 56.5, SD = 14.77) were detected across the five sites during any session, and the numbers of individuals detected at any site varied from 0 to 29 individuals (mean = 11.3 individuals, SD = 1.47) (Fig. 4, Appendix A & B).

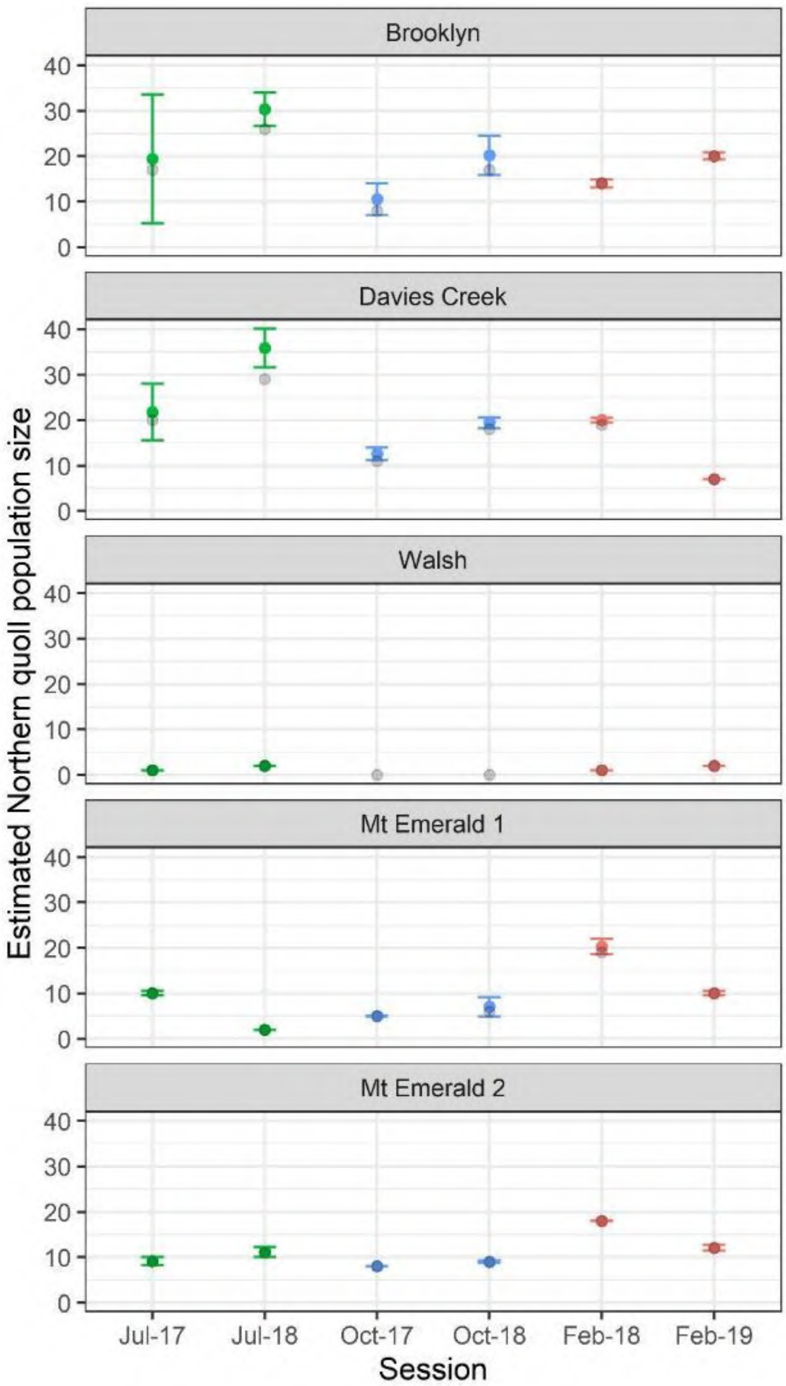


**Fig. 4. The number of individuals detected (grey dots) and the estimated population size with standard errors (coloured symbols), as produced by *RMark*, at each of the five sites during each monitoring session. Where only the coloured symbol is visible this is because minimum observed and estimated population size are the same. Because of the highly seasonal changes in quoll populations, the x-axis is arranged to display comparable seasons adjacent to one another. Green symbols (July) represent the quoll breeding season, blue symbols (October) represent the post-breeding season, and red symbols (February) represent the juvenile pre-breeding season. Both Mt Emerald sites and Davies Creek show a decrease in juvenile quolls.**

The proportion of stations at which quolls were detected at any site varied from 0 – 0.818 (mean = 0.328, SD = 0.217) (Fig. 5). Where it could be modelled using an occupancy modelling approach, the occupancy at each site ranged 0 to 0.81201 (mean = 0.51037, SD = 0.19168) (Fig. 5).

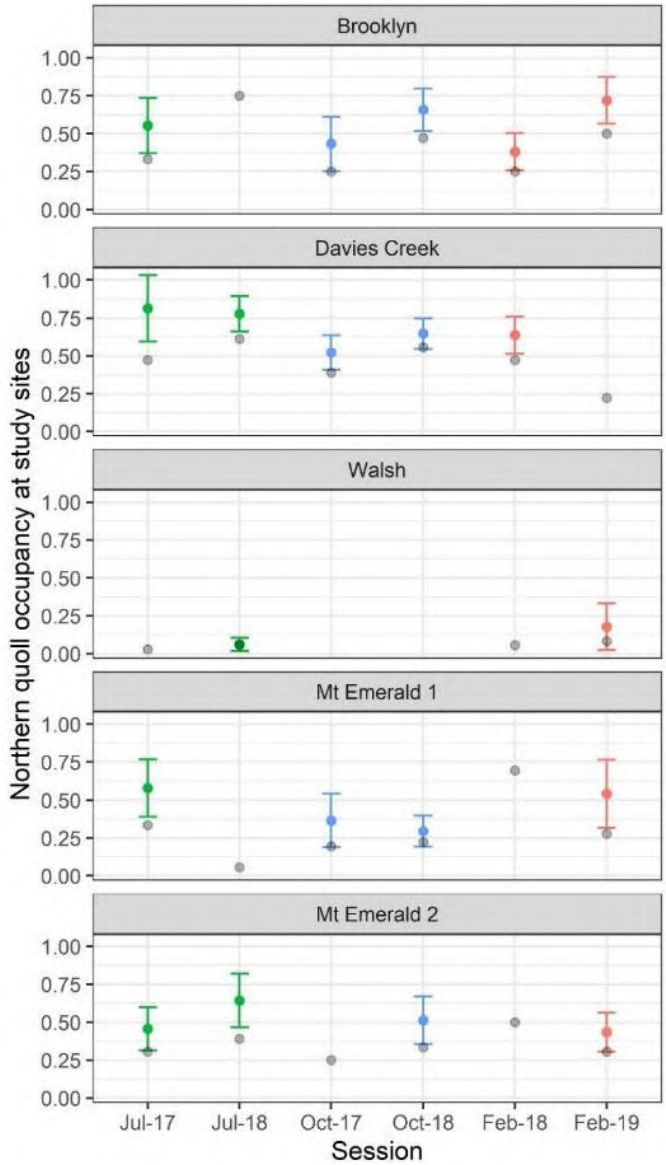


**Fig. 5. The naive occupancy (grey dots) and the modelled population size with standard error bars (coloured symbols) of northern quolls at each of the five sites during each monitoring session. Because of the highly seasonal changes in quoll populations, the x-axis is arranged to display comparable seasons adjacent to one another. At some sites where occupancy couldn't be modelled due to the small number of detections, we display naive occupancy only. Green symbols (July) is the quoll breeding season, blue symbols (October) is the post-breeding season, and red symbols (Feb) the juvenile pre-breeding season. Mt Emerald sites and Davies Creek show a decrease in occupancy during the juvenile pre-breeding season.**

When seasonal variation is considered, there is no statistical evidence for an impact of the MEWF activities on the number of northern quolls on the Mt Emerald monitoring sites (Table 2). However, there is a strong significant effect of time on occupancy at one Mt Emerald site (ME1) (Fig. 6, Table 3). In effect, this shows that the distribution of quolls across the Mt Emerald site was significantly less at each seasonal resampling time than during the first sample. We also note that at both MEWF sites, the observed abundance breeding age adults in July 2018 and juveniles in the subsequent pre-breeding phase (February 2019) is lower (though not statisticaly significantly so) compared to the first round of sampling in these months in the previous years (Figs. 4 & 5). The implications of this are explored in the Discussion below.

**Table 2: Outputs of quoll population models (N = 28). Population size (as calculated using *RMark* models, see Methods section) was modelled as a function of time (visit number: first or second visit for a particular time of the year) and site type (control vs impact sites) while considering the effects of seasonality (time of the year) and site using a general linear model. The only significant predictors of population size in our data were monitoring site (Site) and time of the year (Month). Both Mt Emerald sites and Walsh show smaller estimated quoll populations.**

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| Intercept (Brooklyn in February) | 19.80368 | 3.059293 | 6.473286 | 2.05E-06 |
| Site = Davies Creek | 0.343104 | 3.624338 | 0.094667 | 0.925477 |
| Site = Mt Emerald 1 | -10.0456 | 3.624338 | -2.77171 | 0.011431 |
| Site = Mt Emerald 2 | -7.86523 | 3.624338 | -2.17012 | 0.041615 |
| Site = Walsh | -19.2246 | 4.1522 | -4.62998 | 0.000144 |
| Month = July | 1.841883 | 2.8074 | 0.656082 | 0.518896 |
| Month = October | -3.91962 | 3.059293 | -1.28122 | 0.214085 |

*The model included 28 observations (6 sessions over 5 sites, except Walsh which had only 4 observations due to no quoll detections on October 2017 and 2018 sessions). The model equation is N ~ Site + Month, where N is population size (continuous variable), Site is the monitoring site (discrete variable: Brooklyn, Davies Creek, Walsh, Mt Emerald 1, Mt Emerald 2) and Month is the time of the year in which the surveys were conducted (discrete variable: February, July, October). Initially, also the variables for time (continuous variable: field session number), and type of site (discrete variable: control, impact) were included, as well as the interactions between all variables except with Month. However, time and type of site, as well as interactions, were dropped due to non-significant contribution to model fit.*

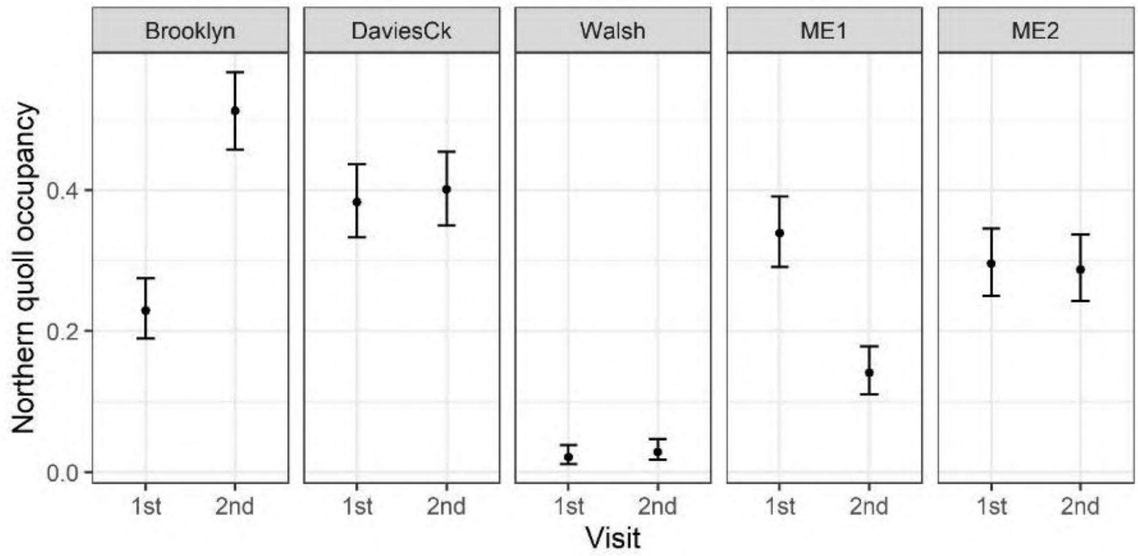


**Fig. 6. Pooled estimated (modelled) occupancy (and standard error) of northern quolls at each visit at each site. 1st visit refers to the July 2017, October 2017, February 2018 surveys; 2nd visit refers to the July 2017, October 2017, February 2018 surveys at each site. Mt Emerald sites show a decrease in quoll occupancy from the first to the second visit.**

**Table 3: Outputs of quoll occupancy models (N = 30). Observed site occupancy was modelled as a function of time (visit number: first or second visit for a particular time of the year) and site type (control vs impact sites) while considering the effects of seasonality (time of the year) and site using a Binomial generalised linear model. The only significant predictors of population size in our data were monitoring site (Site) and time of the year (Month). Mt Emerald sites, especially site 1, show less occupancy on the second visit compared to the first.**

| Variable | Estimate | Std. Error | z value | Pr(>\|z\|) |
|---|---|---|---|---|
| Intercept (Brooklyn in February on the first visit) | -0.82968 | 0.236238 | -3.51204 | 0.000445 |
| Second visit | 1.263187 | 0.290948 | 4.34163 | 1.41E-05 |
| Site = Davies Creek | 0.737445 | 0.290232 | 2.540885 | 0.011057 |
| Site = Walsh | -2.60701 | 0.624145 | -4.17693 | 2.95E-05 |
| Site = Mt Emerald 1 | 0.545968 | 0.29217 | 1.868666 | 0.061669 |
| Site = Mt emerald 2 | 0.34683 | 0.295492 | 1.173739 | 0.2405 |
| Month = July | -0.01471 | 0.171534 | -0.08577 | 0.931652 |
| Month = October | -0.38424 | 0.176003 | -2.18312 | 0.029027 |
| Second visit : Site = Davies Creek | -1.18789 | 0.399954 | -2.97005 | 0.002977 |
| Second visit : Site = Walsh | -0.96568 | 0.829208 | -1.16458 | 0.244189 |
| Second visit : Site = Mt Emerald 1 | -2.40083 | 0.433377 | -5.53982 | 3.03E-08 |
| Second visit : Site = Mt Emerald 2 | -1.30432 | 0.408569 | -3.19241 | 0.001411 |

*The model included 30 observations (6 sessions over 5 sites). The response variable was modelled as the proportion of detectors with quoll sightings (naïve occupancy: proportion of sites occupied) using the binomial family structure (bound between 0 and 1). Note, therefore, that the estimates are in the* *logit link space. The model equation is cbind(Sites occupied, sites not occupied) ~ Visit number + Site + Month + Visit number:Site, where Visit number represents time (discrete variable: first or second visit), Site is the monitoring site (discrete variable: Brooklyn, Davies Creek, Walsh, Mt Emerald 1, Mt Emerald 2) and Month is the time of the year in which the surveys were conducted (discrete variable: February, July, October). Initially, also the variable for type of site (discrete variable: control, impact) was included, as well as the interactions between all variables except with Month. However, type of site, as well as all interactions except that between Visit number and Site, were dropped due to non-significant contribution to model fit.*

## Dingo/wild dog, cat and cane toad populations

There is no evidence for any change in populations of any of these species at the two MEWF sites beyond that which was observed at the control sites (Figs. 7 & 8).

The numbers of feral domestic cats and dingoes/wild dogs detected during these surveys was consistently very low, ranging from a total of 0 to 2 detections at any site in any one session (Fig. 7). Further, there was no indication of any change in occurrence on the sites during this project (Fig. 8, Appendix C).

Detections of feral pigs were variable across the sites and surveys, and there was no pattern of increasing pig detections or occupancy in response to MEWF (Fig. 7 & 8).

Cane toads were the most frequently detected of the four non-quoll target species, but generally occurred as low numbers of detections at each site and time. There was a sharp increase in cane toad detections at several sites Brooklyn, Davies Ck and Mt Emerald 1 sites during the last sampling occasion (February 2019). This was matched by increases in the observed (naïve) occupancy of cane toads at these sites (Fig. 8).

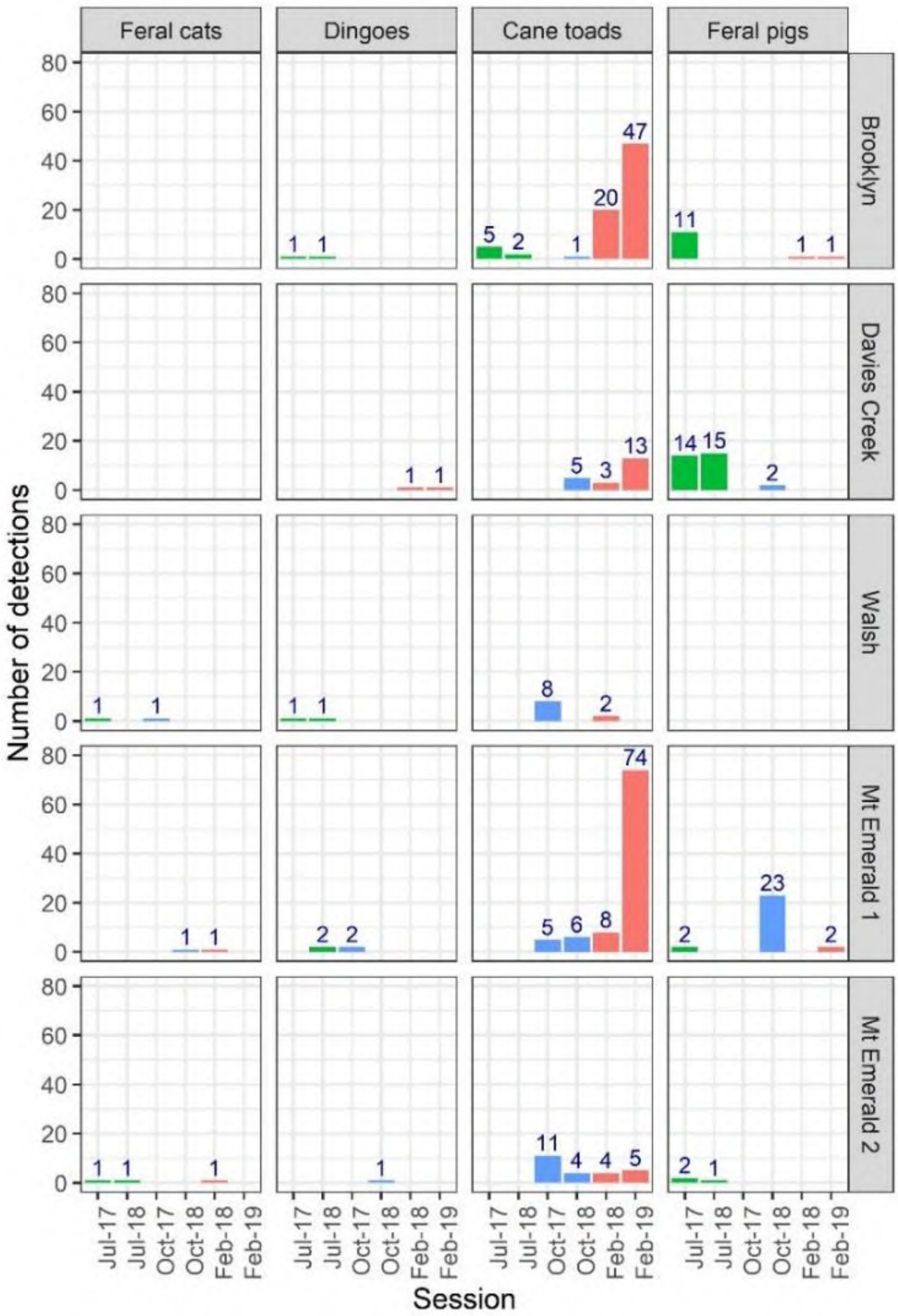


**Fig. 7. The number of detections of the four non-quoll target species at each of the five sites during each monitoring session. The x-axis is arranged to display comparable seasons adjacent to one another for easy comparison. Numbers above each bar are the number of detections of each species at that site and Session.**

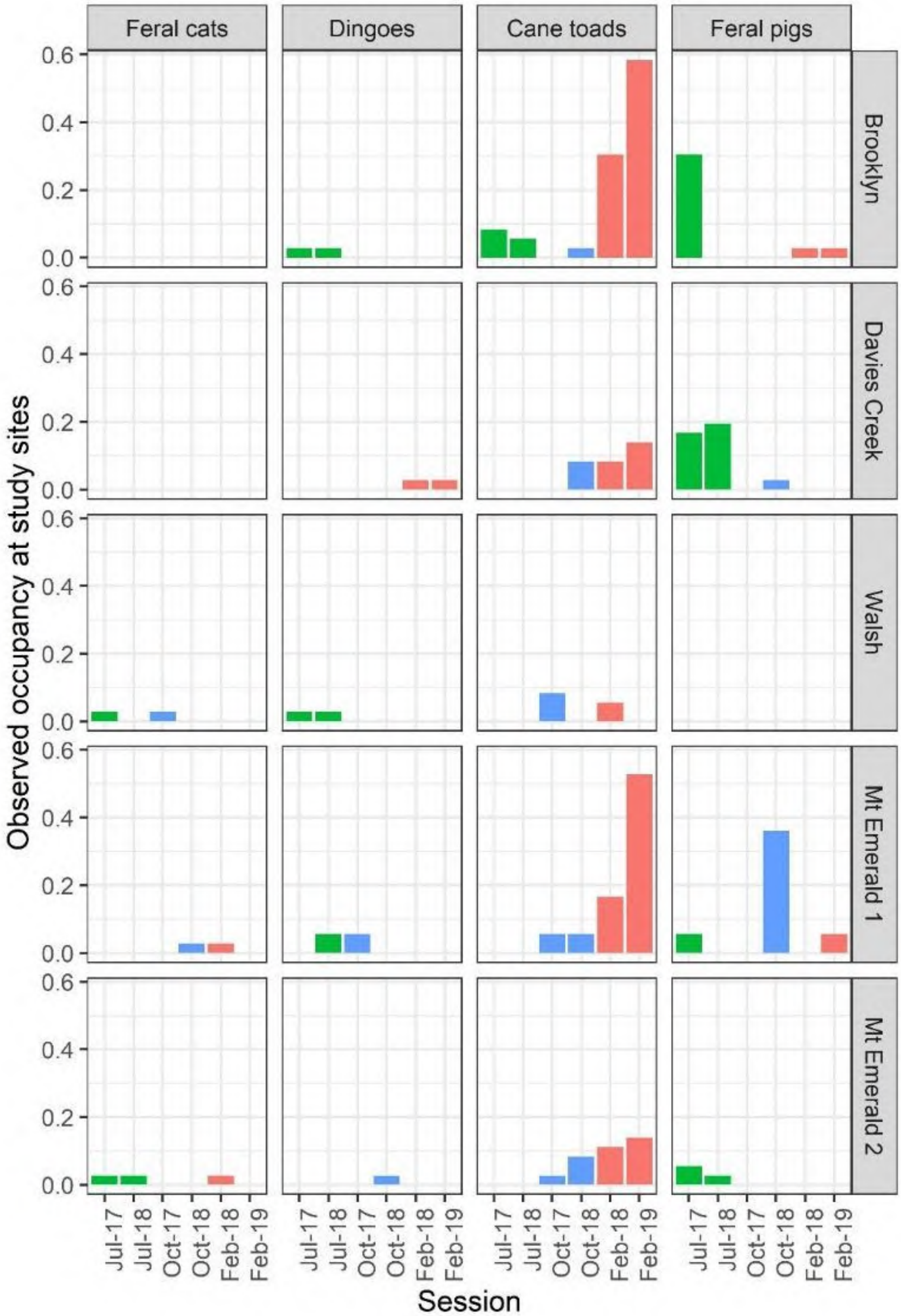


**Fig. 8. The proportion of camera stations at which each non-quoll target species was detected at each site (observed or naïve occupancy) during each monitoring session. The x-axis is arranged to display comparable seasons adjacent to one another for easy comparison.**

## Changes in quoll habitat associated with the MEWF project

There were no changes in vegetative habitat on the quoll monitoring sites during the construction phase of the MEWF. Canopy cover remained relatively constant across the two-year monitoring program in all sites (Figs 7 and 8, Table 4). Shrub cover increased in all sites except Brooklyn, a control site (Figs 7 and 9, Table 5).

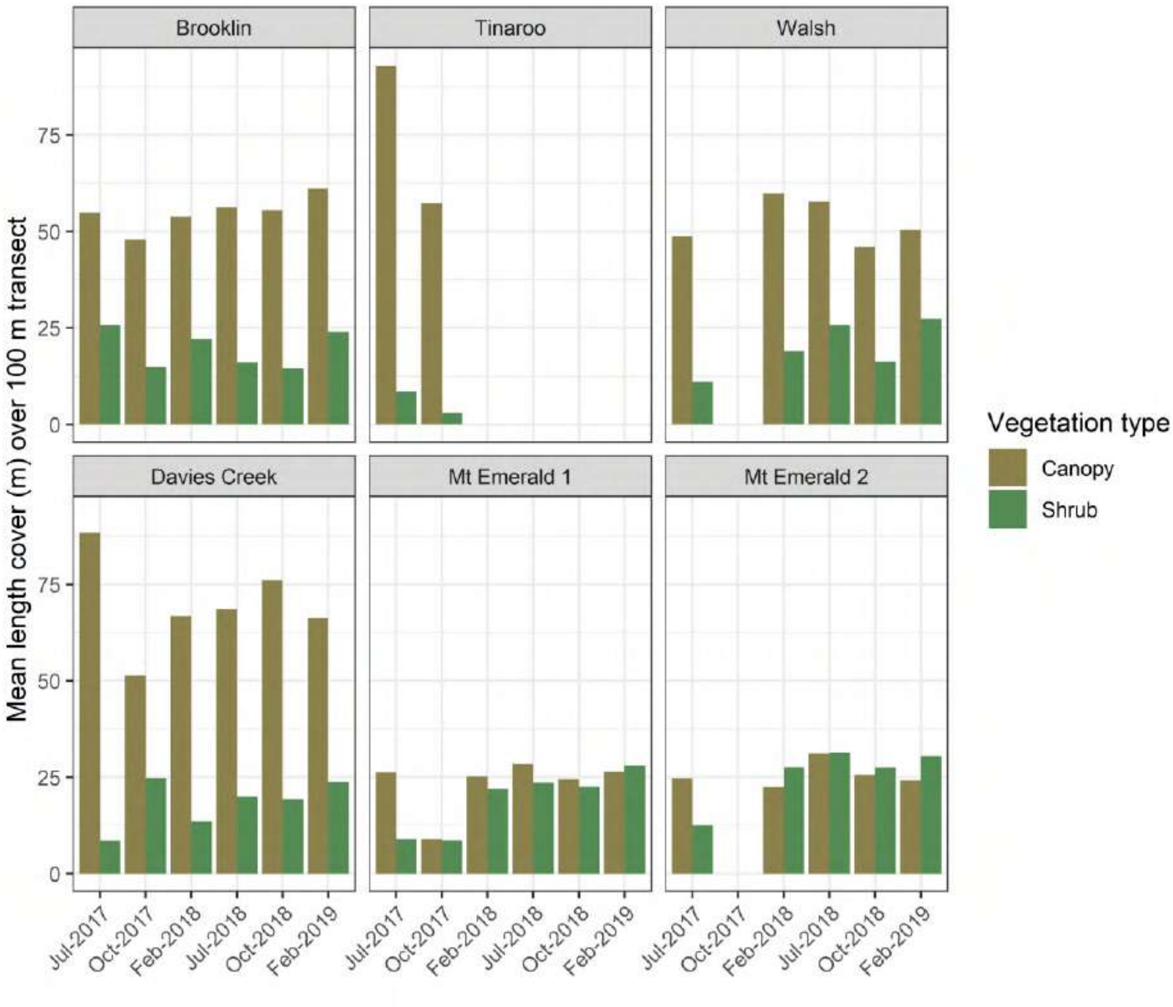


**Fig. 7. Canopy and shrub cover on the 18 BioCondition plots at each of the six quoll monitoring sites surveyed between July 2017 and February 2019. Data was not collected from sites on some occasions due to site access or other logistic issues. Note that site Tinaroo has been unavailable from February 2018.**

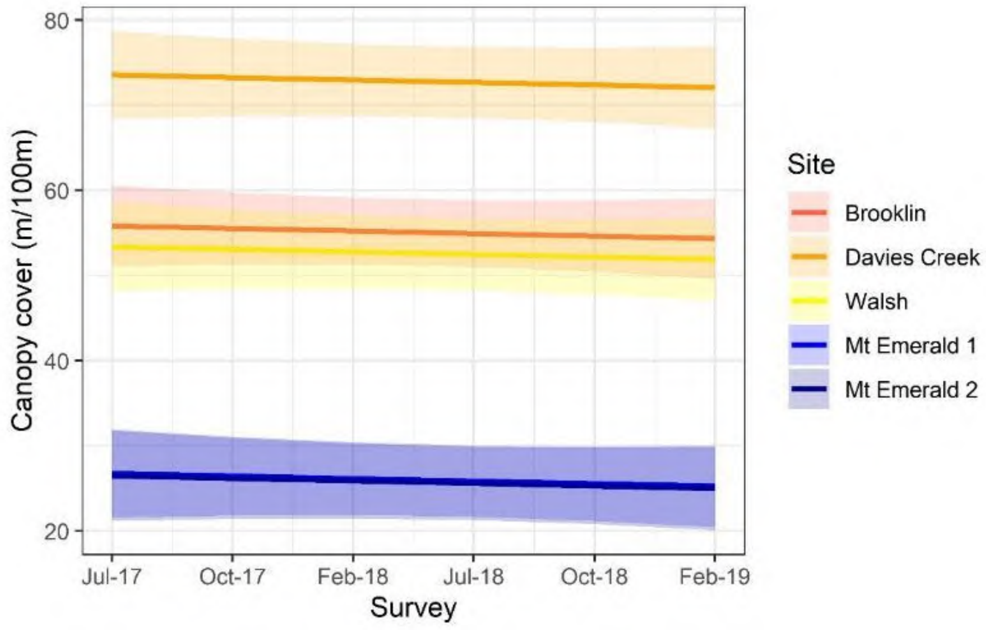


**Fig. 8. Outputs of general linear model to predict canopy cover over time at the five monitoring sites. No time trend was detected at any site.**

**Table 4: Outputs of canopy cover models (N = 460). Canopy cover (m/100m) was modelled as a function of time (survey number) and treatment type (control vs treatment sites) while considering the effects of seasonality (time of the year) and site using a general linear model. The only significant predictor of canopy cover was study site (Site). There were no changes over time in any of the study sites.**

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 55.07229 | 1.969923 | 27.95657 | ######## |
| Site = Davies Creek | 17.67 | 2.882626 | 6.129826 | 1.91E-09 |
| Site = Mt Emerald 1 | -29.1458 | 2.899647 | -10.0515 | 1.34E-21 |
| Site = Mt Emerald 2 | -29.4288 | 2.945212 | -9.99207 | 2.19E-21 |
| Site = Walsh | -2.53672 | 2.917336 | -0.86953 | 0.385015 |

*The model included 460 observations (6 surveys over 18 stations in 5 sites, minus 80 instances when canopy cover not recorded). The model equation is Canopy cover ~ Site, where Site is the study site (discrete variable: Brooklyn, Davies Creek, Walsh, Mt Emerald 1, Mt Emerald 2). Initially, also the variables for time (continuous variable, survey number starting July 17 and finishing February 19), type of site (discrete variable: control, treatment) and time of the year in which the surveys were conducted (discrete variable: February, July, October) were included, as well as the interactions between all variables except with time of year. However, all variables and interactions except for the variable Site, were dropped due to non-significant contribution to model fit.*

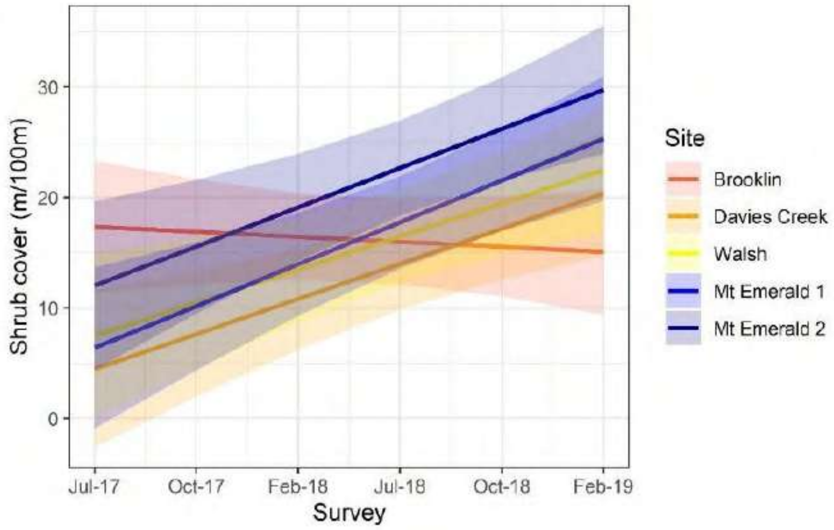


**Fig. 8. Outputs of general linear model to predict shrub cover over time at the five monitoring sites. Shrub cover increased in all sites except Brooklyn, a control site.**

**Table 5: Outputs of shrub cover models (N = 460). Shrub cover (m/100m) was modelled as a function of time (survey number) and treatment type (control vs treatment sites) while considering the effects of seasonality (time of the year) and site using a general linear model. Significant predictors of shrub cover in our data were survey number (SurveyN), study site (Site) and time of the year (Month). Shrub cover similarly increased in all sites over time, except in Brooklyn.**

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 22.92777 | 3.858197 | 5.942612 | 5.64E-09 |
| SurveyN | -0.45393 | 0.903769 | -0.50226 | 0.615728 |
| Site = Davies Creek | -16.5079 | 5.201062 | -3.17395 | 0.001607 |
| Site = Mt Emerald 1 | -15.2066 | 5.294832 | -2.87197 | 0.004273 |
| Site = Mt Emerald 2 | -9.3253 | 5.46902 | -1.70511 | 0.088866 |
| Site = Walsh | -13.3178 | 5.34953 | -2.48952 | 0.013153 |
| Month = July | -0.14169 | 1.905334 | -0.07436 | 0.940754 |
| Month = October | -5.11411 | 1.88828 | -2.70834 | 0.007021 |
| SurveyN : Site = Davies Creek | 3.630685 | 1.281238 | 2.833732 | 0.004809 |
| SurveyN : Site = Mt Emerald 1 | 4.242049 | 1.296201 | 3.272679 | 0.001148 |
| SurveyN : Site = Mt Emerald 2 | 3.9995 | 1.327864 | 3.011981 | 0.002742 |
| SurveyN : Site = Walsh | 3.45294 | 1.303019 | 2.649954 | 0.008335 |

*The model included 460 observations (6 surveys over 18 stations in 5 sites, minus 80 instances when shrub cover was not recorded). The model equation is Shrub cover ~ SurveyN + Site + Month + SurveyN:Site, where SurveyN represents time (continuous variable, survey number starting July 17 and finishing February 19), Site is the study site (discrete variable: Brooklyn, Davies Creek, Walsh, Mt Emerald 1, Mt Emerald 2) and Month is the time of the year in which the surveys were conducted (discrete variable: February, July, October). Initially, also the variable for type of site (discrete variable: control, treatment) was included, as well as the interactions between all variables except with Month. However, type of site, as well as all interactions except between SurveyN and Site, were dropped due to non-significant contribution to model fit.*

There were no changes in coarse woody debris in any sites except Walsh, where debris decreased substantially, and Mt Emerald site 2, where debris increased (Figs 10 and 11, Table 5). The decrease in Walsh coincided with intense fire events, which may have burnt the woody debris down. The increase in Mt Emerald may be attributed to construction of mill pads and roads, in which cut-down and grounded trees were pushed to the side to form mounts of debris.

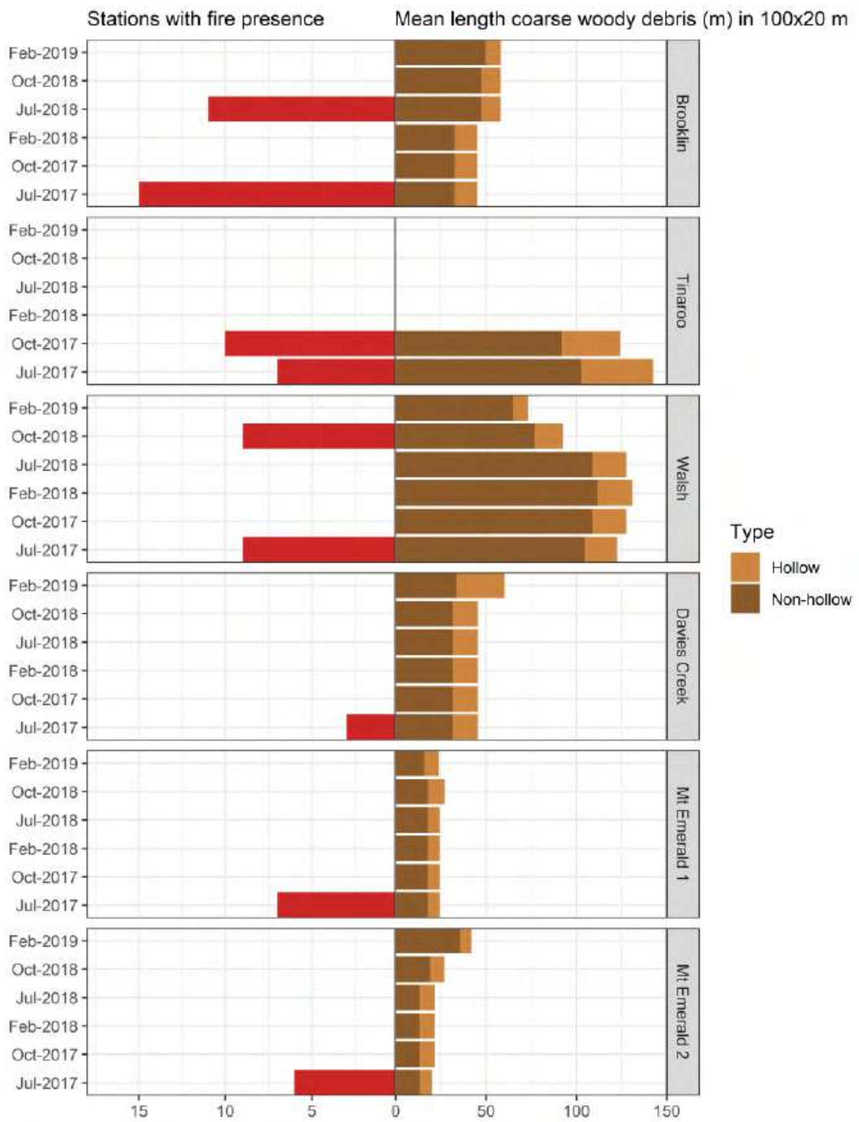


**Fig. 10. Number of stations (out of 18 at each site) on which there was evidence of recent fire and mean length of hollow and non-hollow course woody debris at each site between July 2017 and February 2019. Note that site "Tinaroo" has been unavailable from February 2018.**

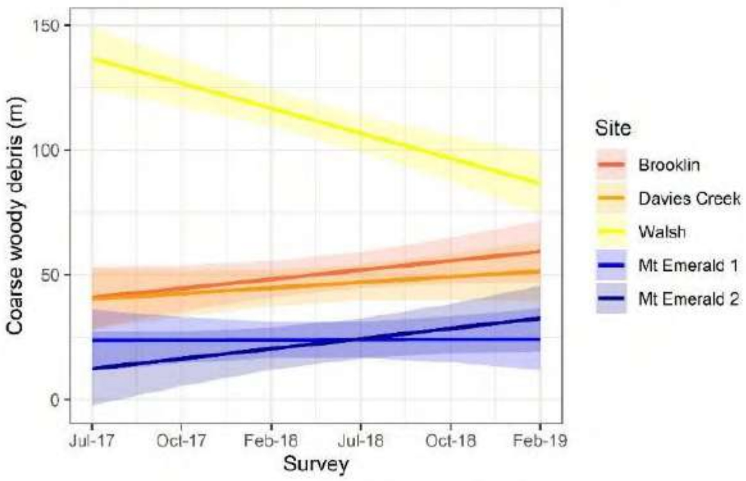


**Fig. 11. Outputs of general linear model to predict coarse woody debris over time at the five monitoring sites. Coarse woody debris remained unchanged in all sites except Walsh, where it decreased and Mt Emerald 2, where it increased.**

**Table 5: Outputs of coarse woody debris models (N = 515). The total length of coarse woody debris found on a 100 x 20 m area surrounding each detector was modelled as a function of time (survey number) and treatment type (control vs treatment sites) while considering the effects of seasonality (time of the year) and site using a general linear model. Significant predictors of coarse woody debris in our data were survey number (SurveyN) and study site (Site). Coarse woody debris remained unchanged in all sites except Walsh, where it decreased and Mt Emerald 2, where it increased.**

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| Intercept (time zero in Brooklyn) | 37.10264 | 8.033169 | 4.61868 | 4.91E-06 |
| SurveyN | 3.69286 | 2.062727 | 1.79028 | 0.074008 |
| Site = Davies Creek | 0.864585 | 11.36062 | 0.076104 | 0.939367 |
| Site = Mt Emerald 1 | -13.4412 | 11.36062 | -1.18314 | 0.237312 |
| Site = Mt Emerald 2 | -28.8127 | 12.45972 | -2.31247 | 0.021153 |
| Site = Walsh | 109.6605 | 11.45753 | 9.571037 | 4.70E-20 |
| SurveyN : Site = Davies Creek | -1.46167 | 2.917137 | -0.50106 | 0.616545 |
| SurveyN : Site = Mt Emerald 1 | -3.6054 | 2.917137 | -1.23594 | 0.217056 |
| SurveyN : Site = Mt Emerald 2 | 0.339633 | 3.121974 | 0.108788 | 0.913414 |
| SurveyN : Site = Walsh | -13.7328 | 2.932666 | -4.68271 | 3.64E-06 |

*The model included 515 observations (6 surveys over 18 stations in 5 sites, minus 25 instances when coarse woody debris were not recorded). The model equation is CWD ~ SurveyN + Site + SurveyN:Site, where SurveyN represents time (continuous variable, survey number starting July 17 and finishing February 19) and Site is the study site (discrete variable: Brooklyn, Davies Creek, Walsh, Mt Emerald 1, Mt Emerald 2). Initially, also the variables for time of the year in which the surveys were conducted (discrete variable: February, July, October) and type of site (discrete variable: control, treatment) were included, as well as the interactions between all variables except with time of year. However, time of year and type of site, as well as all interactions except between SurveyN and Site, were dropped due to non-significant contribution to model fit.*

The percent vegetative ground cover decreased in all five sites across the two-year monitoring period. However, the decrease was less prominent in Mt Emerald sites and Davies Creek (Figs 12 and 13, Table 6).

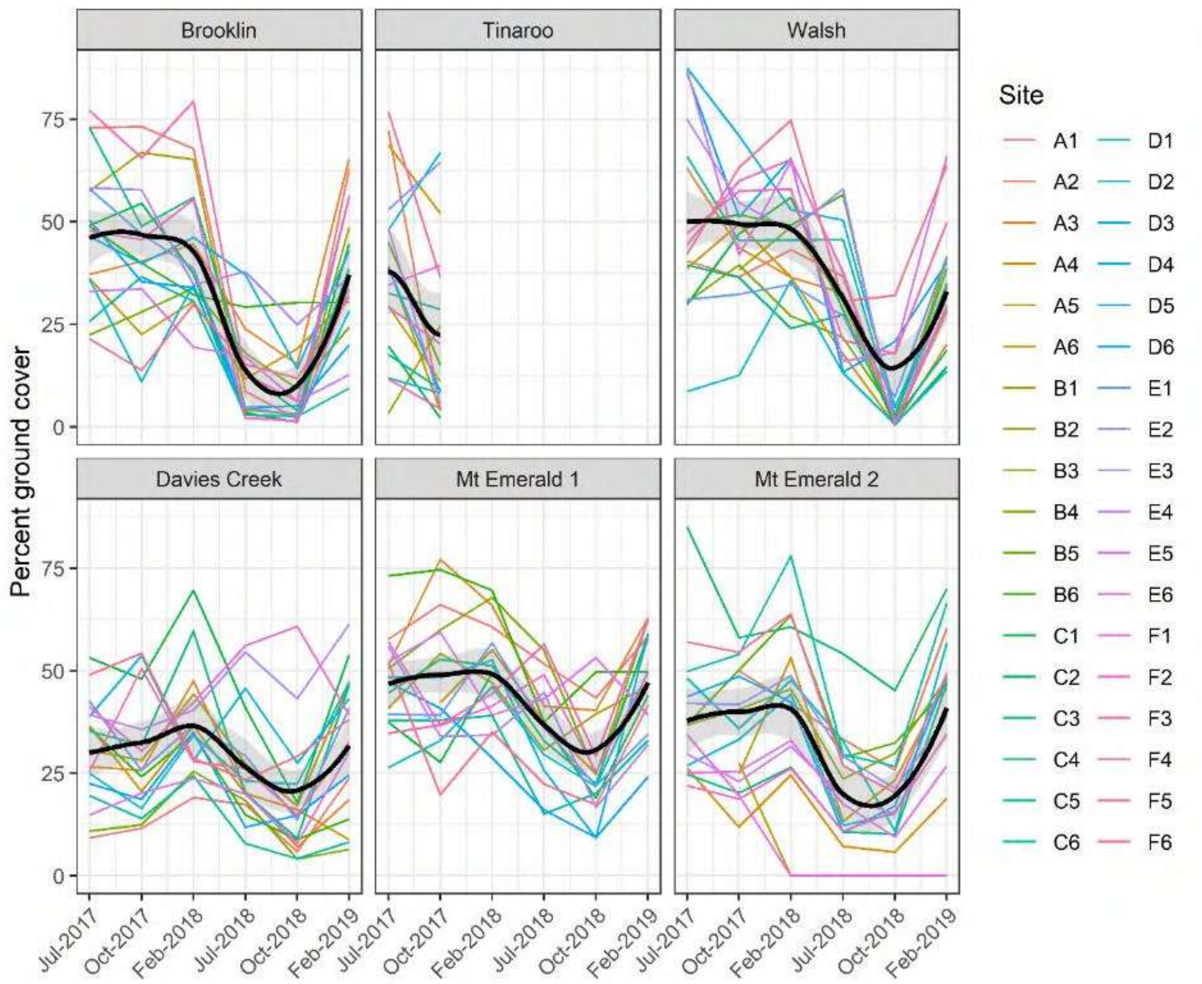


**Fig. 12. The percentage of vegetative ground cover at each BioCondition station at each quoll monitoring site between July 2017 and February 2019. Individual plot measurements at each site are individually labelled for each site. Alphanumeric site numbers relate to the labelled stations in Fig 2. The thick black line represents an average value for each site, and the grey margin the standard error of that mean. Note that site "Tinaroo" has been unavailable from February 2018.**

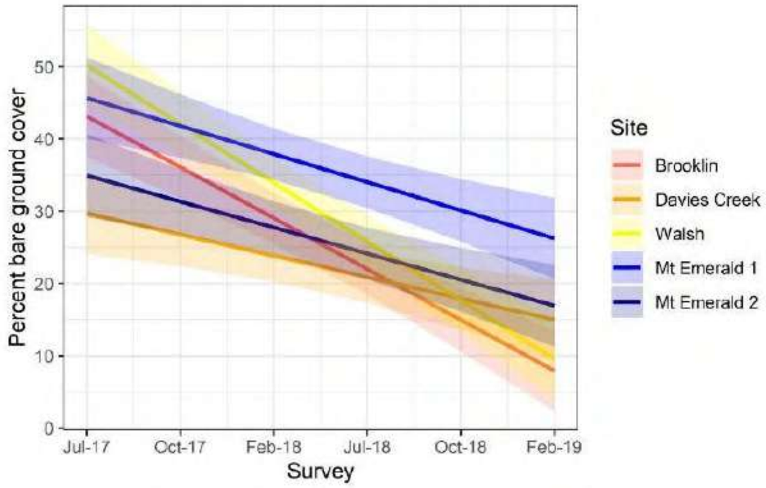


**Fig. 13. Outputs of general linear model to predict shrub cover over time at the five monitoring sites. Shrub cover increased in all sites except Brooklyn, a control site. Percent bare ground cover decreased in all sites, but less so in Mt Emerald sites and Davies Creek.**

**Table 6: Outputs of bare ground cover models (N = 533). The percent cover of bare ground in 1 m² plots was modelled as a function of time (survey number) and treatment type (control vs treatment sites) while considering the effects of seasonality (time of the year) and site using a general linear model. Significant predictors of percent bare ground in our data were survey number (SurveyN), study site (Site) and time of the year (Month). Percent bare ground cover decreased in all sites, but less so in Mt Emerald sites and Davies Creek.**

| | Estimate | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| Intercept (time zero in Brooklyn in February) | 68.55356 | 3.797852 | 18.05061 | 6.24E-57 |
| SurveyN | -7.04231 | 0.89306 | -7.8856 | 1.85E-14 |
| Site = Davies Creek | -17.5041 | 4.777893 | -3.66356 | 0.000274 |
| Site = Mt Emerald 1 | -0.6197 | 4.812874 | -0.12876 | 0.897598 |
| Site = Mt Emerald 2 | -11.6296 | 4.890588 | -2.37795 | 0.017769 |
| Site = Walsh | 8.111173 | 4.818719 | 1.683263 | 0.092923 |
| Month = July | -17.0104 | 1.855669 | -9.1667 | 1.12E-18 |
| Month = October | -18.3646 | 1.68924 | -10.8715 | 5.97E-25 |
| SurveyN : Site = Davies Creek | 4.092762 | 1.22685 | 3.335993 | 0.000911 |
| SurveyN : Site = Mt Emerald 1 | 3.157849 | 1.233112 | 2.560878 | 0.010721 |
| SurveyN : Site = Mt Emerald 2 | 3.438911 | 1.249092 | 2.753128 | 0.006109 |
| SurveyN : Site = Walsh | -1.07932 | 1.233391 | -0.87509 | 0.38193 |

*The model included 533 observations (6 surveys over 18 stations in 5 sites, minus 7 instances when percent bare ground was not recorded). The model equation is Percent ground ~ SurveyN + Site + Month + SurveyN:Site, where SurveyN represents time (continuous variable, survey number starting July 17 and finishing February 19), Site is the study site (discrete variable: Brooklyn, Davies Creek, Walsh, Mt Emerald 1, Mt Emerald 2) and Month is the time of the year in which the surveys were conducted (discrete variable: February, July, October). Initially, also the variable for type of site (discrete variable: control, treatment) was included, as well as the interactions between all variables except with Month. However, type of site, as well as all interactions except between SurveyN and Site, were dropped due to non-significant contribution to model fit.*

These habitat monitoring plots do not suggest any disproportionate change in key vegetation parameters at the Mt Emerald sites (although there would obviously have been localised impacts from construction of wind turbines and road infrastructure through the site), other than a modest increase in CWD and percent bare ground cover. Otherwise, the temporal trends observed in vegetative variables are generally similar between Mt Emerald and control sites, so likely represent broadscale weather patterns rather than any site-specific process.

## Discussion/Conclusion

The analyses presented above produced no unambiguous evidence for a negative impact of the MEWF project on the number of individual northern quolls; however, we did detect a statistically significant decline in site occupancy on the MEWF sites between the first and second surveys (especially between February 2018 and 2019).

Our data also hint at a decline in the number of individual northern quolls on both MEWF monitoring sites (and the Davies Creek site) between the 2018 and 2019 juvenile pre-breeding phase and a a possible increase in cane toads at one MEWF site (ME1), an increase in course woody debris at the MEWF site ME2, and a relative increase of bare ground cover at both MEWF sites (and the Davies Creek site) were also detected.

No changes in populations or occupancy of the other target fauna species were detected.

The decline in quoll occupancy observed at both MEWF project sites cannot be directly attributed to MEWF works given that the decline was statistically significant in one MEWF site, but statistical significance could not be inferred for the decline in the other MEWF site. However, this combined with the indication of a drop in the number of juveniles between the 2018 and the 2019 juvenile pre-breeding season should be the cause of some concern. The fact that this same pattern was also observed at one of the three control sites (Davies Creek) is somewhat ambiguous evidence that these changes are not caused by MEWF activities, especially given that a strong reverse trend was observed at the Brooklyn control site. Unfortunately, another of our control sites (Walsh) experienced an unexplained crash in quoll numbers at the July 2017 breeding season when our project started and so, although it also demonstrated an increase in numbers counter to that observed at the two MEWF sites, the numbers there are so low as to make any statistical trend impossible to identify. It must be noted that the models utilized are very conservative due to the low sample size. The strong seasonality in quoll numbers means that the population can only be compared between the same season (i.e., same time of year) across years. This, in turn, means that each year only one sample can be collected each breading season, resulting in a sample size of two for the two-year monitoring period. With such low sample size, it is very difficult to infer statistical significance on trends over time. Yet, we were able to infer significance on the decrease in quoll occupancy at one MEWF sites, which indicates a strong decline. The collection of more samples in the coming years may allow the identification of population trends that are too early to be inferred with the present data.

It is reasonable to expect that local construction activity could have caused temporary (or longer term) shifts in the activity patterns of quolls at the MEWF sites, which may not necessarily lead to a longer-term decline in the species there. Moreover, the hinted decline in juvenile quolls during the last survey could affect population dynamics of quolls in the coming years. But this is speculation until further monitoring is undertaken during the post-construction phase of windfarm operation.

We identified no trend in cat, dingo/wild dog or pig abundance (number of detections) or occupancy (number of stations). The presence of all of these species was generally very low on the sites, and there is no reason to expect any changes arising from the MEWF project. They were included here because our method detected them without any extra effort and it was decided, *a priori*, that it would be useful to know how their populations had trended in the event that an unambiguous change in quoll populations had been detected. The camera trapping method used here has not been calibrated for any of these species, and there is reason to suspect that it underestimates cat abundance (cats are not normally thought to be particularly attracted to carrion-baits (e.g. Clapperton *et al.* 1994). On the other hand, we would expect dingoes/wild dogs and feral pigs to be attracted to these lures, and our unpublished data from several years of similar field work support this (S. Burnett unpubl. data). Of these species, the feral cat is likely the most serious threat to individuals and populations of the northern quoll (e.g. Woinarski et al. 2012). Therefore, it is perhaps relevant that at these sites where quolls are abundant, cats are seemingly scarce. An increasing body of research suggest that dingoes/wild dog play an important role in limiting feral cat abundance, and dingoes should be treated as an important part of the ecology of the MEWF sites. For that reason, it would be inappropriate to undertake any dingo or wild dog control on the MEWF site.

The most widespread of the non-quoll target species on the sites was the cane toad. No doubt cane toad detections are inflated compared to those of other species by the toad's habitat of remaining almost motionless beside the bait cannister (where they feed on insects attracted by the bait) for extended periods. All other animals whose primary focus is the bait itself, tend to give up after relatively few detections, after they fail to extract it from the cannister. The spike in cane toad numbers at one of the MEWF sites (ME1) in February 2019 has a parallel at the Brooklyn and, to a lesser extent, the Davies Creek sites at the same time. This suggests that it is a seasonal effect being the result of the hot and humid weather at this time compared to the previous February and other survey sessions which were much drier when cameras where set. Although there are parallels between the sites, the spike in numbers at the ME1 sites may indicate that earthworks have created better toad habitat, i.e. bare ground and possibly artificial breeding sites. As toads are already present at the MEWF sites, and quolls have coexisted with them here for many generations, it is unlikely that an increase in toad numbers will directly affect quolls via poisoning, as happens when naïve quolls interact with toads (e.g. Burnett 1997)(and see cover image for an example of quoll habituation to cane toads at ME1), but they could represent a competition for invertebrate prey if their numbers boom. We point out that ME1 is the site from which quolls unambiguously decreased in distribution and so an impact of high-density toad populations on naïve young quolls can't be ruled out as a driver from this apparent contraction of quoll range on this site.

Finally, given the spatial scale of the habitat monitoring which we conducted (confined to a 100 x 20m plot centred on every second camera station) it is not surprising that we didn't detect any pervasive habitat changes at the Mt Emerald sites indicative of project works. At all sites, ground cover decreased each year from the February late wet season survey to the October late dry season survey as a function of the seasonal changes that typify the northern Australian annual wet-dry seasons. Other changes at various sites could be attributed to wildfires at these sites. The only habitat change that we detected which could be attributed to MEWF project works was an increase in course woody debris on our plots. As noted at the time, this was a function of clearing for access roads and turbine pads leading to trees being felled into our monitoring plots. Perversely (and not withstanding deleterious impacts on other species), this may benefit quolls by providing denning habitat and nocturnal shelter sites from predators on the MEWF sites. The strength of our habitat monitoring lies in its baseline nature, which includes visual observations and a photographic record of ground cover and ground layer species samples, and will be useful for detecting pervasive changes to the sites due to the spread of weeds and possibly changed fire regimes.

## Recommendations

Recommendations arising from this work are designed to clear up ambiguities in the data and to facilitate the continued presence and health of the northern quoll population at the MEWF site;

- A 3-season 2020 monitoring session is recommended to assess whether there has been a continued decline in breeding success of quoll on the Mt Emerald sites and to establish whether quoll occupancy has stabilised. This should follow the protocols used here in order to render data comparable with that collected here.

- Conduct early wet season acoustic surveys for artificial cane toad breeding sites and decommission where possible. The spike in toad numbers at the ME1 site in February 2019 may indicate the inadvertent creation of artificial toad breeding ponds. A survey of these sites to identify any such sites, and their decommissioning would be a technically simple operation with potentially great ecological outcomes for quolls and the entire MEWF site.
- Maintain a healthy dingo population at MEWF. The two MEWF sites had the highest incidence of cats of any of the five sites monitored (though still low). Cats are a known predator of northern quolls and the best option for keeping them in low numbers is helping to maintain a healthy Dingo population at these sites.
- Full BioCondition should be repeated whenever quoll monitoring is repeated in order to detect pervasive vegetative habitat changes (such as intrusion of weeds or deleterious changes in fire frequency and intensity).

## Acknowledgements

Thank you to the many staff who worked in the field at various times throughout this project. In particular, we thank Carissa Gill, Glenn Kvassay, Jesse Rowland and Daniel Nugent who lead the field teams at various times.

Land managers, Rob Miller (QPWS, Mareeba) and Dr John Kanowski and Andrew Francis of the Australian Wildlife Conservancy provided permissions, flexibility and other support with our work at Danbulla National Park and Brooklyn Sanctuary respectively. Paul McDonald (Ratch Australiasia) was very helpful with site access and other logistics around the MEWF site.

Mark Newton (Qld Herbarium) provided field training on the BioCondition Assessment method and provided the modified form which we required for this project.

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# APPENDICES

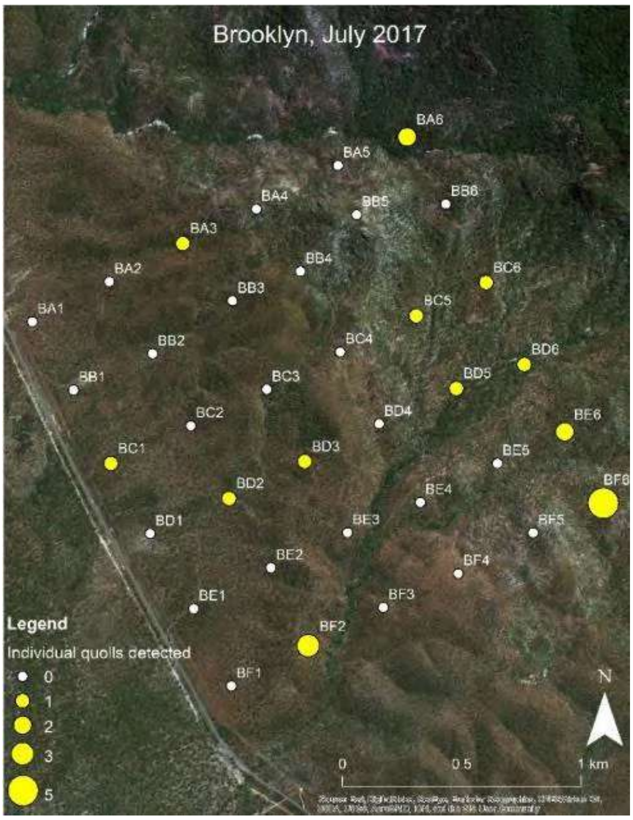
## Appendix A. Summarised northern quoll detection data from this project.

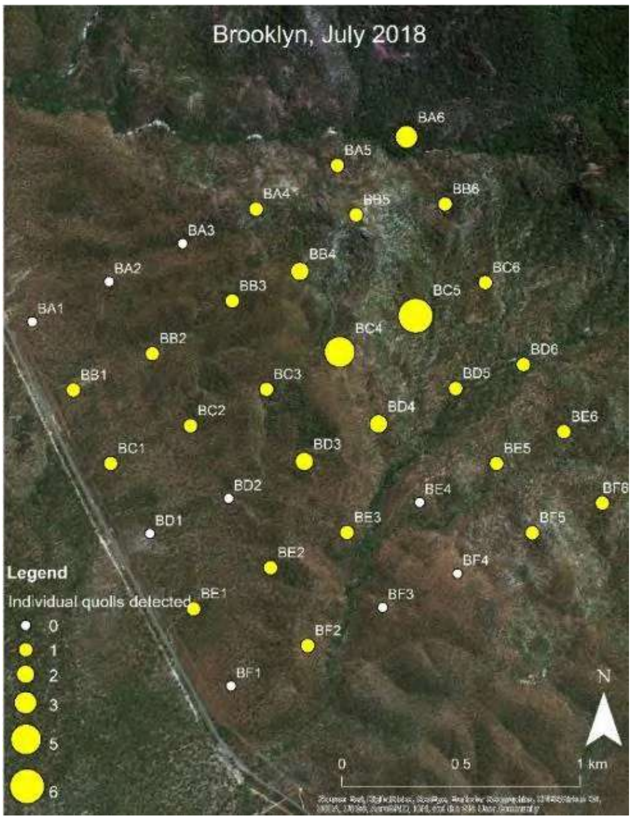
"Site" refers to the monitoring site in question (refer to Fig. 1, Table 1 for details). "Revisit" refers to whether it was the first or second sample made for each site. "Nmark" and "SE(Nmark)" refer to population estimates generated using the r- package RMark and the standard error of those estimates. "Psi" and "P" and "SE(psi)" and "SE(p)" refer to the estimates and their standard errors of occupancy and detection probability calculated using r-package unmarked. "Naïve" refers to the naïve or observed occupancy of quolls on each site. "Events" refers to the number of independent detection events, "Stations" refers to the number if camera stations at which quolls were detected and "N-ind" refers to the number of individual quolls captured for each Site and session.

| Site | Session | Nsession | Month | Revisit | Type | Nmark | SE(Nmark) | Psi | SE(psi) | P | SE(p) | Naive | Events | Stations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brooklyn | Jul-17 | 1 | Jul | 0 | Control | 19.44413 | 14.17536 | 0.553582 | 0.182015 | 0.065492 | 0.024157 | 0.333333 | 25 | 12 |
| DaviesCk | Jul-17 | 1 | Jul | 0 | Control | 21.78095 | 6.194638 | 0.81201 | 0.219681 | 0.061991 | 0.019916 | 0.472222 | 33 | 17 |
| ME1 | Jul-17 | 1 | Jul | 0 | Treatment | 10.04315 | 0.552512 | 0.579008 | 0.189644 | 0.065398 | 0.024172 | 0.333333 | 21 | 12 |
| ME2 | Jul-17 | 1 | Jul | 0 | Treatment | 9.172597 | 0.847394 | 0.456505 | 0.141951 | 0.080593 | 0.027036 | 0.305556 | 26 | 11 |
| Walsh | Jul-17 | 1 | Jul | 0 | Control | 1 | 3.07E-11 | NA | NA | 0.002037 | 0.002035 | 0.027778 | 1 | 1 |
| Brooklyn | Oct-17 | 2 | Oct | 0 | Control | 10.59584 | 3.478958 | 0.434279 | 0.179859 | 0.059394 | 0.027068 | 0.25 | 17 | 9 |
| DaviesCk | Oct-17 | 2 | Oct | 0 | Control | 12.588 | 1.371354 | 0.522901 | 0.114794 | 0.111078 | 0.025455 | 0.388889 | 32 | 14 |
| ME1 | Oct-17 | 2 | Oct | 0 | Treatment | 5.002425 | 0.115888 | 0.365276 | 0.177158 | 0.057514 | 0.030344 | 0.194444 | 13 | 7 |
| ME2 | Oct-17 | 2 | Oct | 0 | Treatment | 8 | 4.36E-07 | NA | NA | 0.018336 | 0.006062 | 0.25 | 10 | 9 |
| Walsh | Oct-17 | 2 | Oct | 0 | Control | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 |
| Brooklyn | Feb-18 | 3 | Feb | 0 | Control | 14.01325 | 0.833022 | 0.380695 | 0.123328 | 0.095535 | 0.031482 | 0.25 | 18 | 9 |
| DaviesCk | Feb-18 | 3 | Feb | 0 | Control | 20.02896 | 0.50929 | 0.63714 | 0.122318 | 0.111855 | 0.024586 | 0.472222 | 39 | 17 |
| ME1 | Feb-18 | 3 | Feb | 0 | Treatment | 20.2647 | 1.681446 | NA | NA | 0.087432 | 0.013038 | 0.666667 | 49 | 24 |
| ME2 | Feb-18 | 3 | Feb | 0 | Treatment | 18.00013 | 0.049557 | NA | NA | 0.054063 | 0.010099 | 0.5 | 30 | 18 |
| Walsh | Feb-18 | 3 | Feb | 0 | Control | 1 | 5.53E-06 | NA | NA | 0.004462 | 0.003344 | 0.055556 | 3 | 2 |
| Brooklyn | Jul-18 | 4 | Jul | 1 | Control | 30.35751 | 3.7036 | NA | NA | 0.095219 | 0.013656 | 0.75 | 59 | 27 |
| DaviesCk | Jul-18 | 4 | Jul | 1 | Control | 35.8674 | 4.260872 | 0.77774 | 0.116527 | 0.123554 | 0.023276 | 0.611111 | 69 | 22 |
| ME1 | Jul-18 | 4 | Jul | 1 | Treatment | 2 | 6.62E-07 | NA | NA | 0.004636 | 0.003562 | 0.055556 | 2 | 2 |
| ME2 | Jul-18 | 4 | Jul | 1 | Treatment | 11.20513 | 1.111279 | 0.641837 | 0.176944 | 0.073453 | 0.023286 | 0.388889 | 27 | 14 |
| Walsh | Jul-18 | 4 | Jul | 1 | Control | 2 | 0.000429 | 0.061764 | 0.042498 | 0.238781 | 0.115224 | 0.027778 | 5 | 1 |

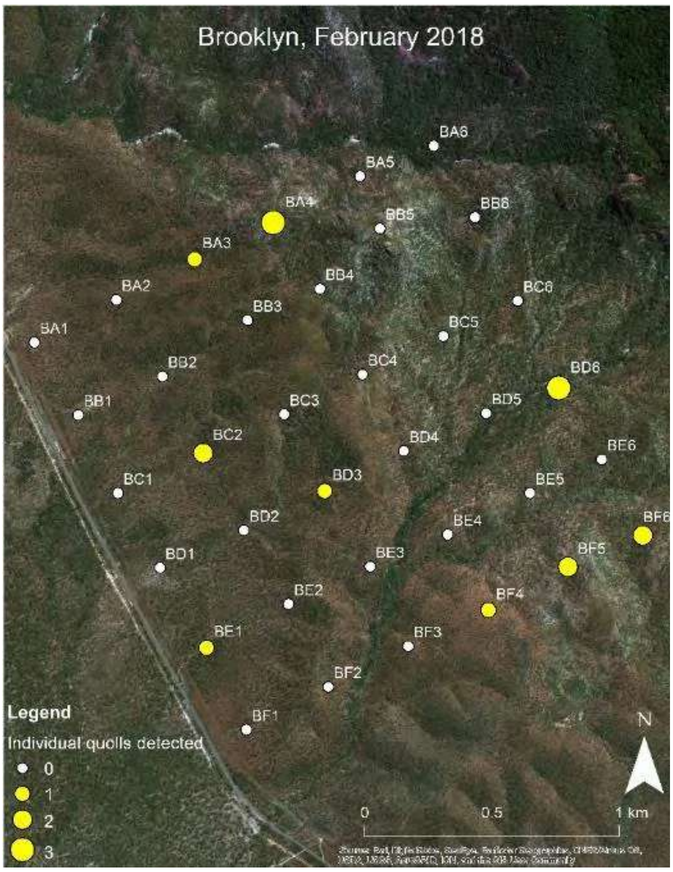
| Site | Session | Nsession | Month | Revisit | Type | Nmark | SE(Nmark) | Psi | SE(psi) | P | SE(p) | Naive | Events | Stations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brooklyn | Oct-18 | 5 | Oct | 1 | Control | 20.22236 | 4.36571 | 0.658151 | 0.140504 | 0.09355 | 0.023452 | 0.472222 | 39 | 17 |
| DaviesCk | Oct-18 | 5 | Oct | 1 | Control | 19.45991 | 1.198917 | 0.646489 | 0.100585 | 0.141559 | 0.023507 | 0.555556 | 60 | 20 |
| ME1 | Oct-18 | 5 | Oct | 1 | Treatment | 7.065426 | 2.14994 | 0.295176 | 0.103624 | 0.101414 | 0.035518 | 0.194444 | 19 | 7 |
| ME2 | Oct-18 | 5 | Oct | 1 | Treatment | 9.002987 | 0.207405 | 0.512131 | 0.156339 | 0.074872 | 0.025276 | 0.333333 | 19 | 12 |
| Walsh | Oct-18 | 5 | Oct | 1 | Control | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 |
| Brooklyn | Feb-19 | 6 | Feb | 1 | Control | 20.03351 | 0.785339 | 0.719544 | 0.154821 | 0.085411 | 0.02251 | 0.5 | 35 | 18 |
| DaviesCk | Feb-19 | 6 | Feb | 1 | Control | 7 | 8.14E-06 | NA | NA | 0.016925 | 0.005946 | 0.222222 | 11 | 8 |
| ME1 | Feb-19 | 6 | Feb | 1 | Treatment | 10.01713 | 0.494882 | 0.54078 | 0.224186 | 0.053343 | 0.024546 | 0.277778 | 15 | 10 |
| ME2 | Feb-19 | 6 | Feb | 1 | Treatment | 12.09436 | 0.66156 | 0.43458 | 0.128307 | 0.090149 | 0.027946 | 0.305556 | 25 | 11 |
| Walsh | Feb-19 | 6 | Feb | 1 | Control | 2 | 2.13E-05 | 0.177755 | 0.154625 | 0.045924 | 0.042664 | 0.083333 | 7 | 3 |

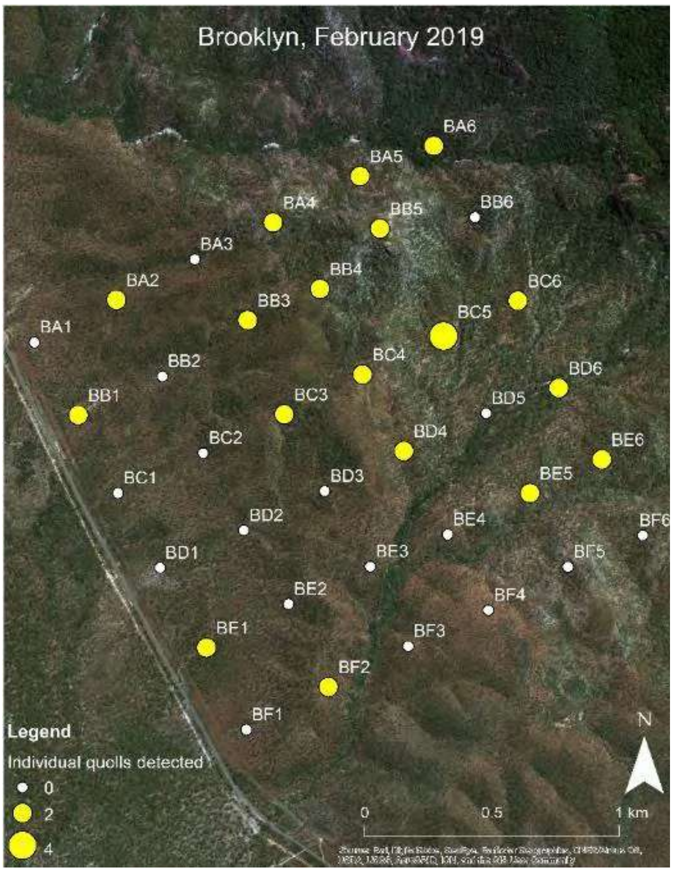
## Appendix B. Quoll detections at each of the six monitoring sites during each survey period. Maps are arranged on the page to allow direct comparison between comparable seasonal surveys.



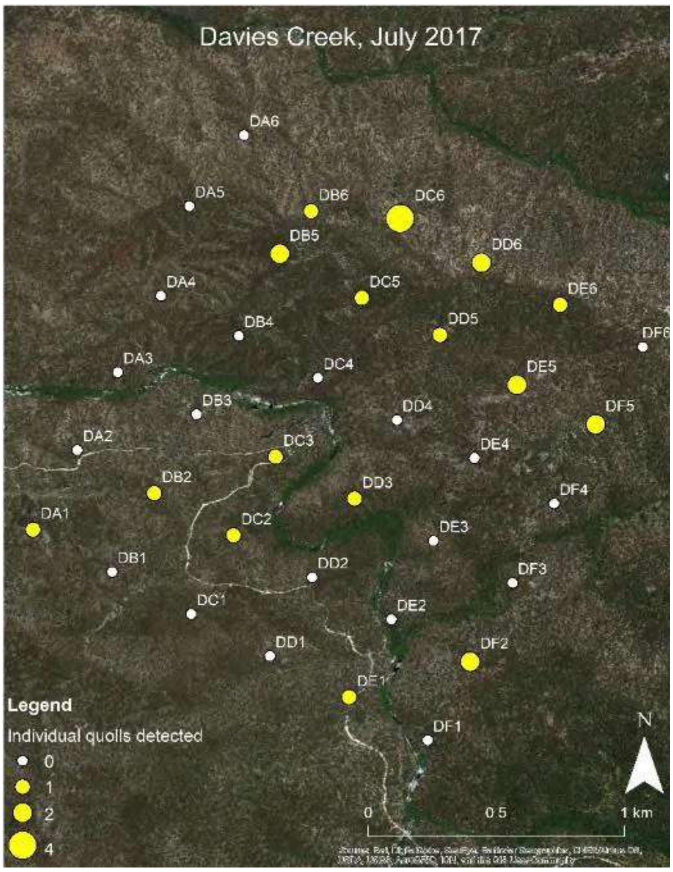



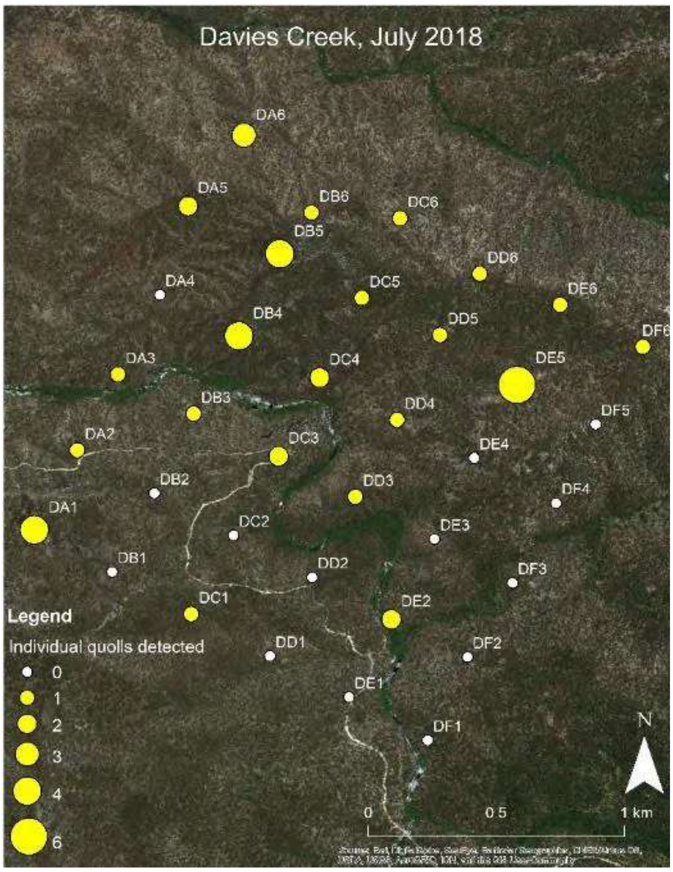


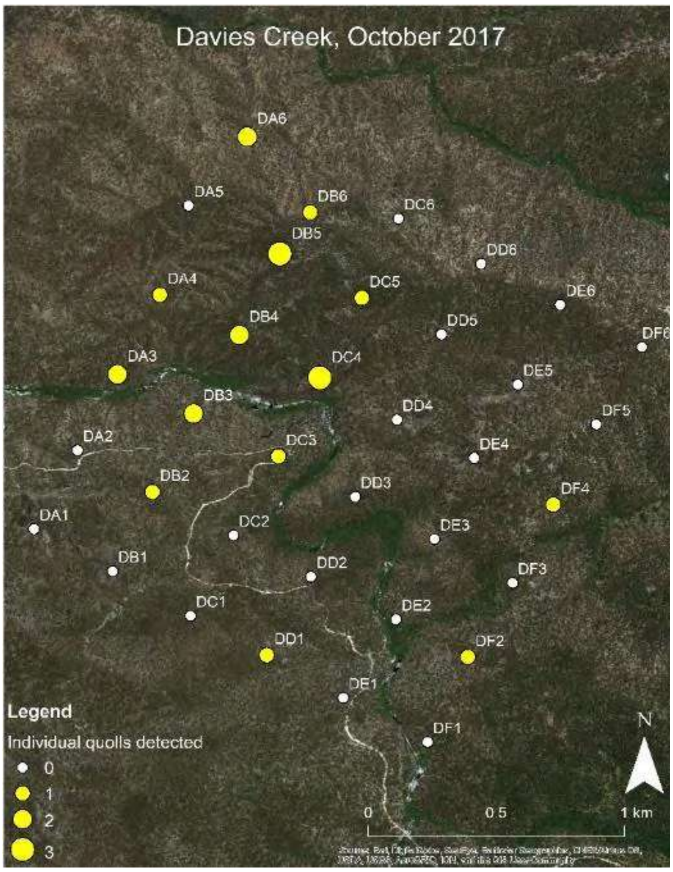


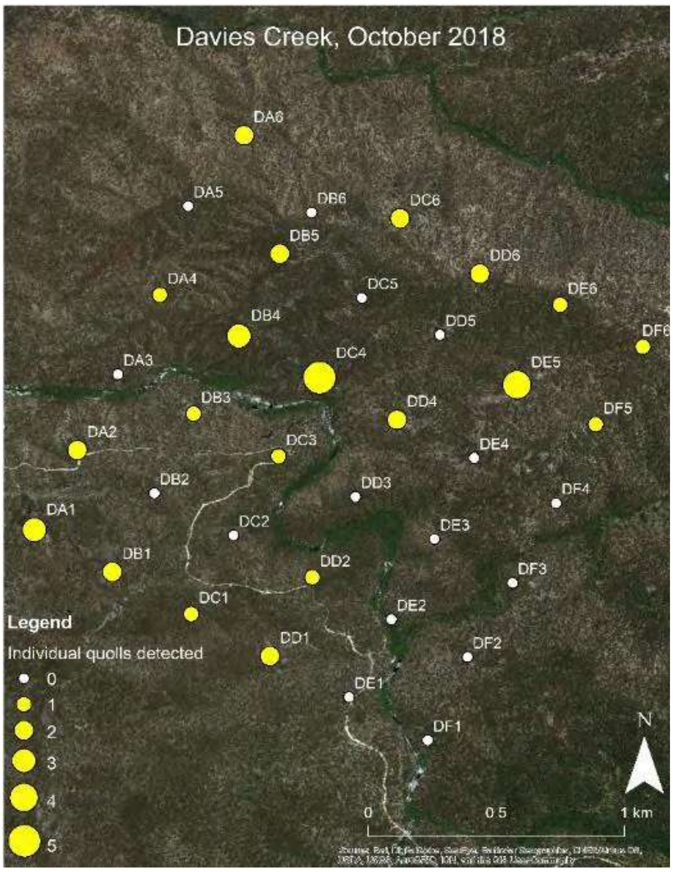



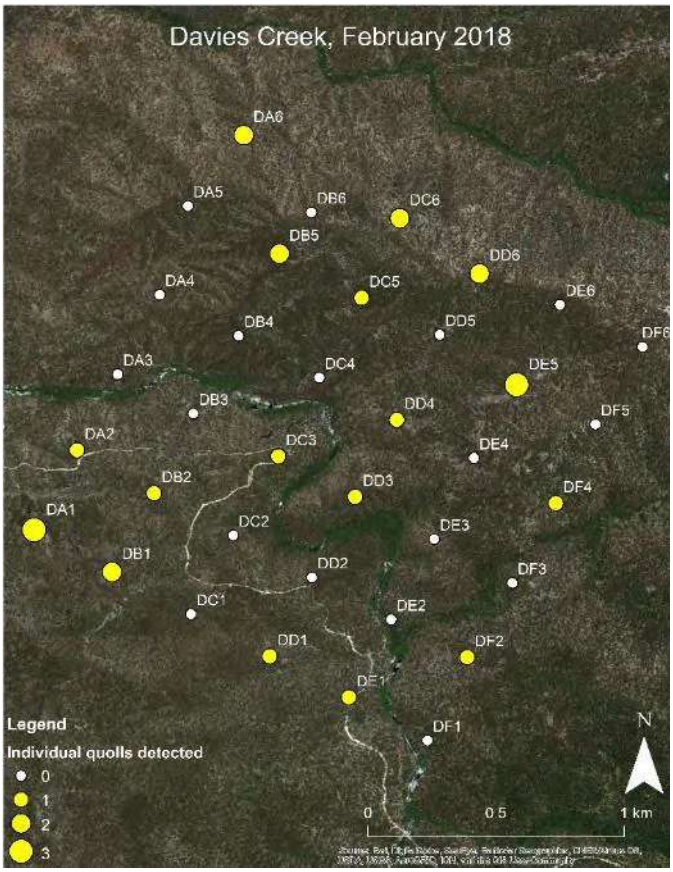

**Appendix B1. The distribution of quolls, and the number of individuals detected at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Brooklyn".**

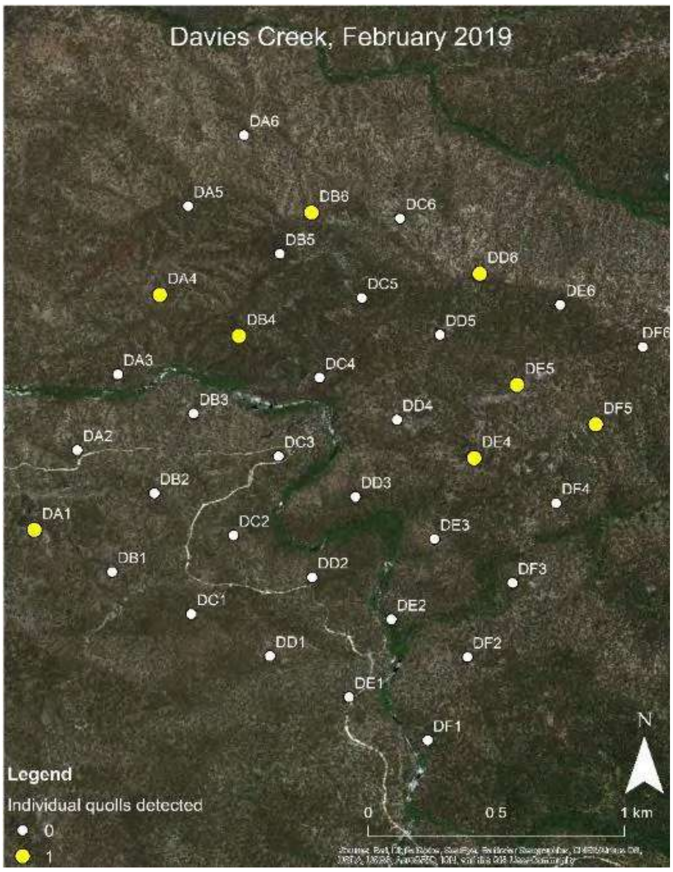

Davies Creek, July 2017
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Individual quolls detected
0
1
2
4
N
0
0.5
1 km


Davies Creek, July 2018
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Individual quolls detected
0
1
2
3
4
6
N
0
0.5
1 km

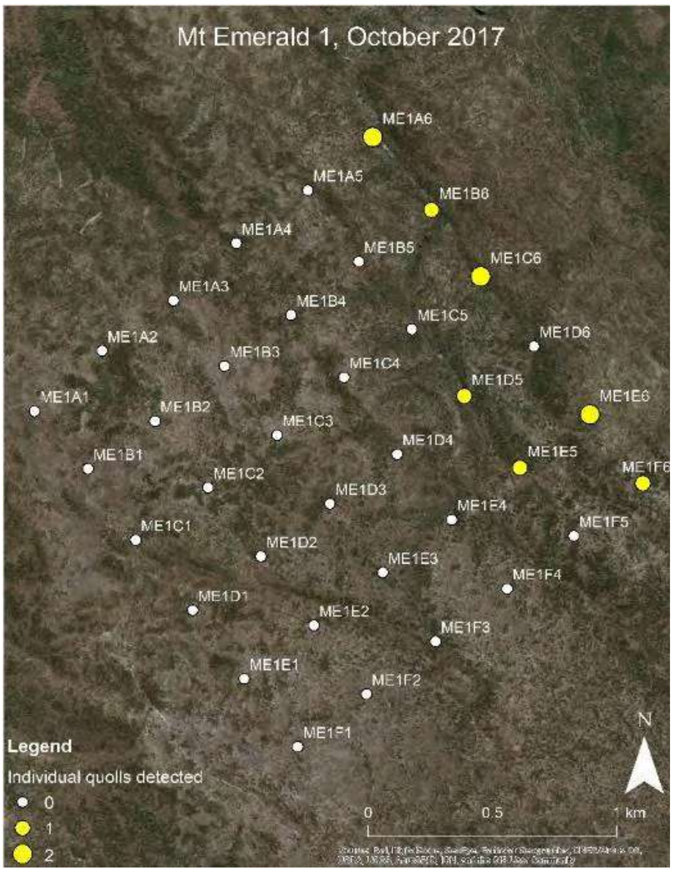

Davies Creek, October 2017
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Individual quolls detected
0
1
2
3
N
0
0.5
1 km

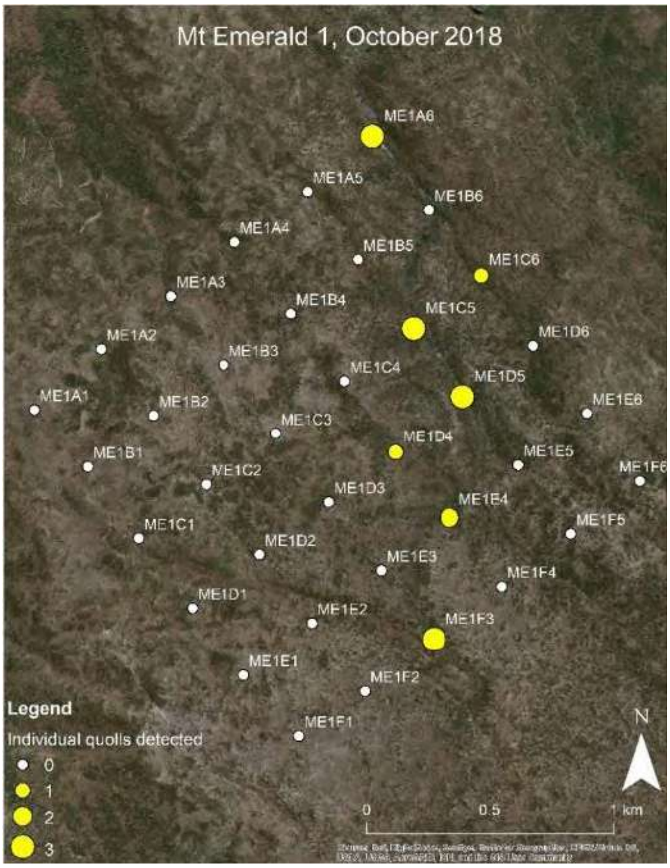

Davies Creek, October 2018
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Individual quolls detected
0
1
2
3
4
5
N
0
0.5
1 km

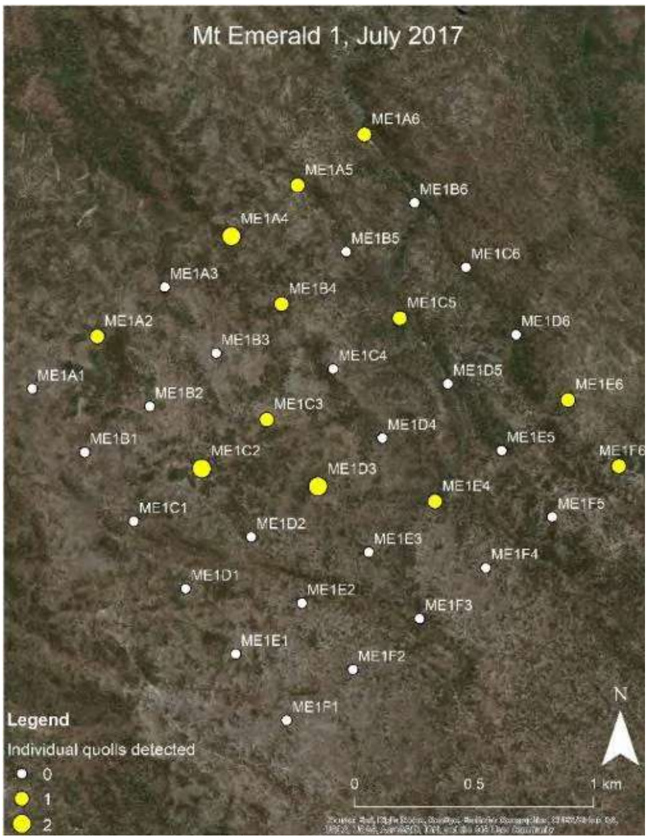


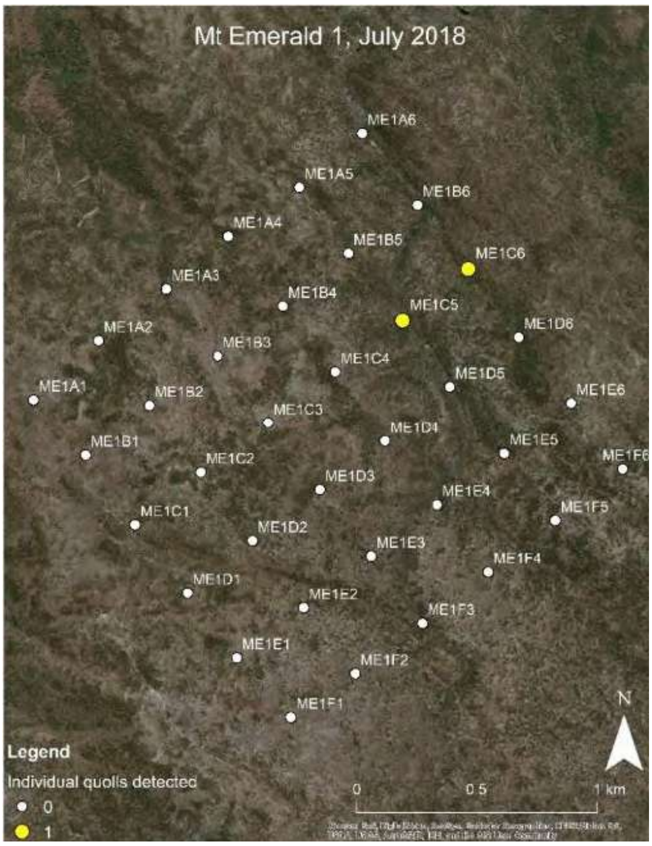



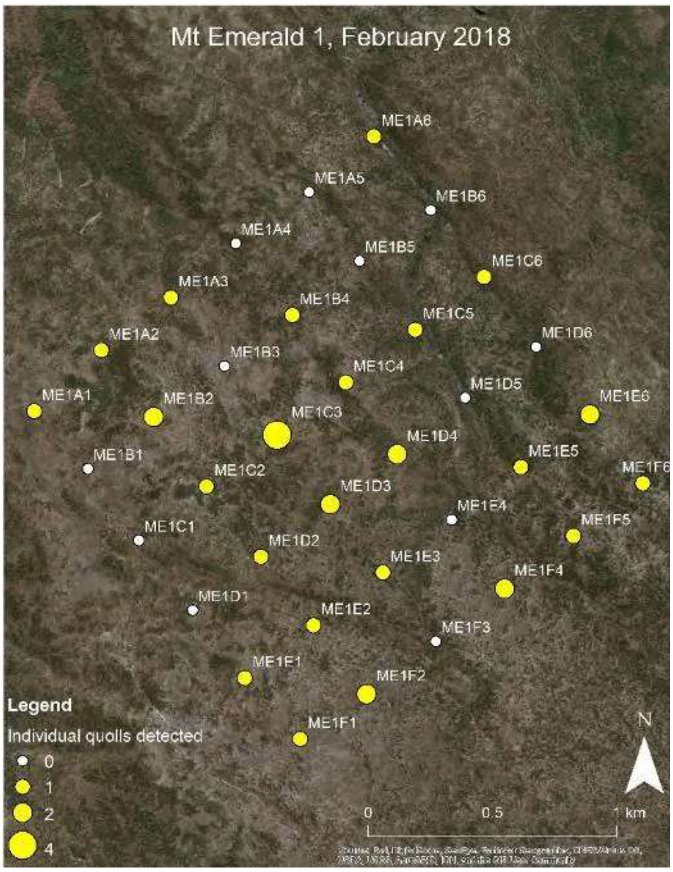

**Appendix B2. The distribution of quolls, and the number of individuals detected at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Davies Creek".**

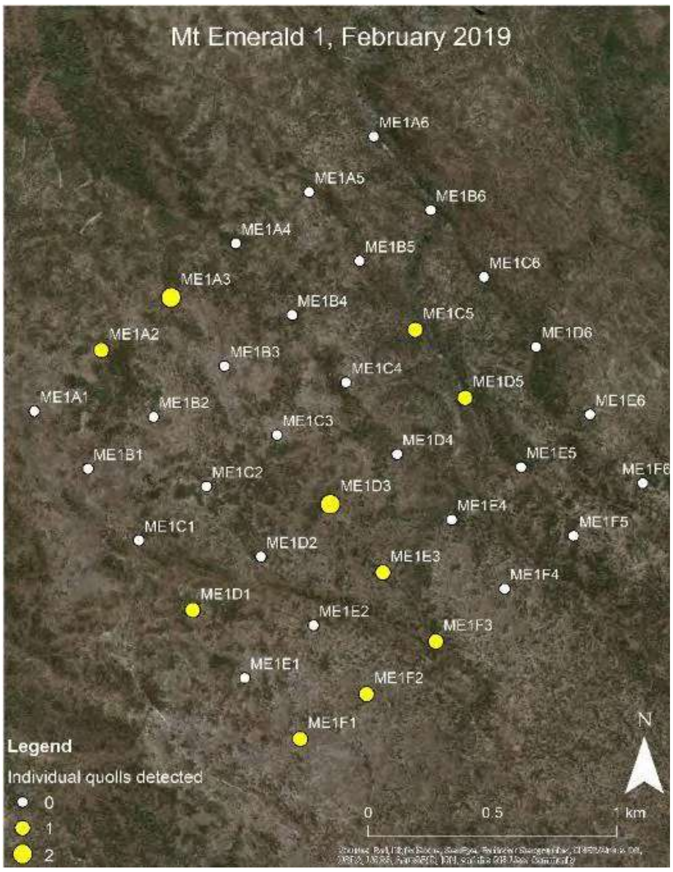

Mt Emerald 1, October 2017
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Individual quolls detected
0
1
2
N
0 0.5 1 km


Mt Emerald 1, October 2018
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Individual quolls detected
0
1
2
3
N
0 0.5 1 km

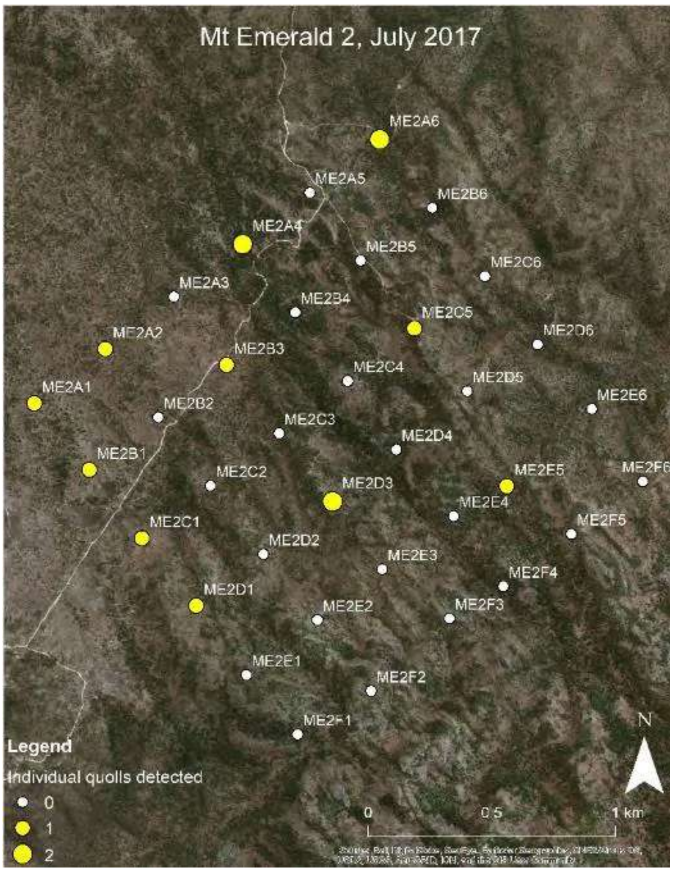

Mt Emerald 1, July 2017
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Individual quolls detected
0
1
2
N
0 0.5 1 km

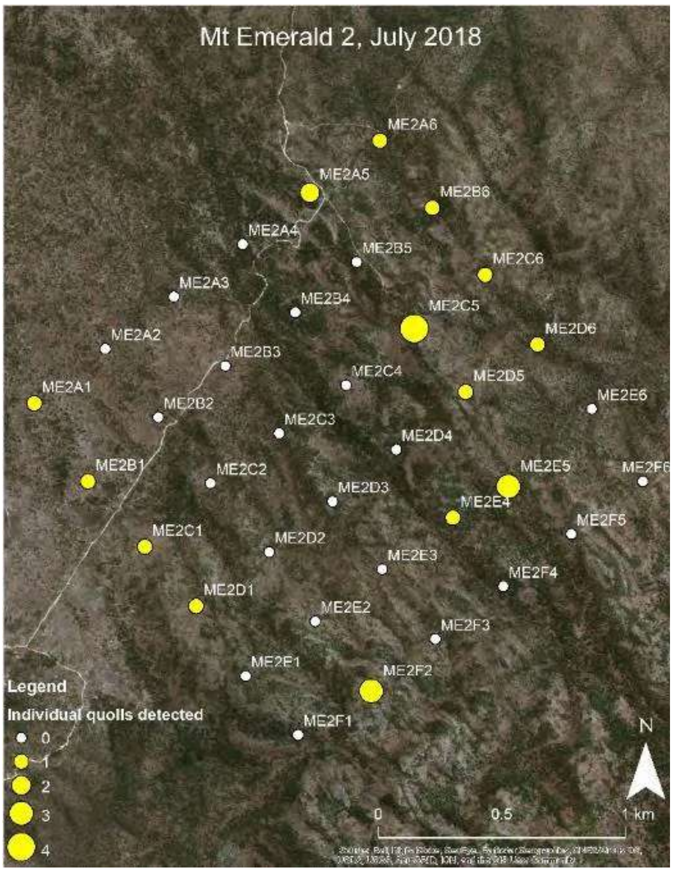

Mt Emerald 1, July 2018
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Individual quolls detected
0
1
N
0 0.5 1 km

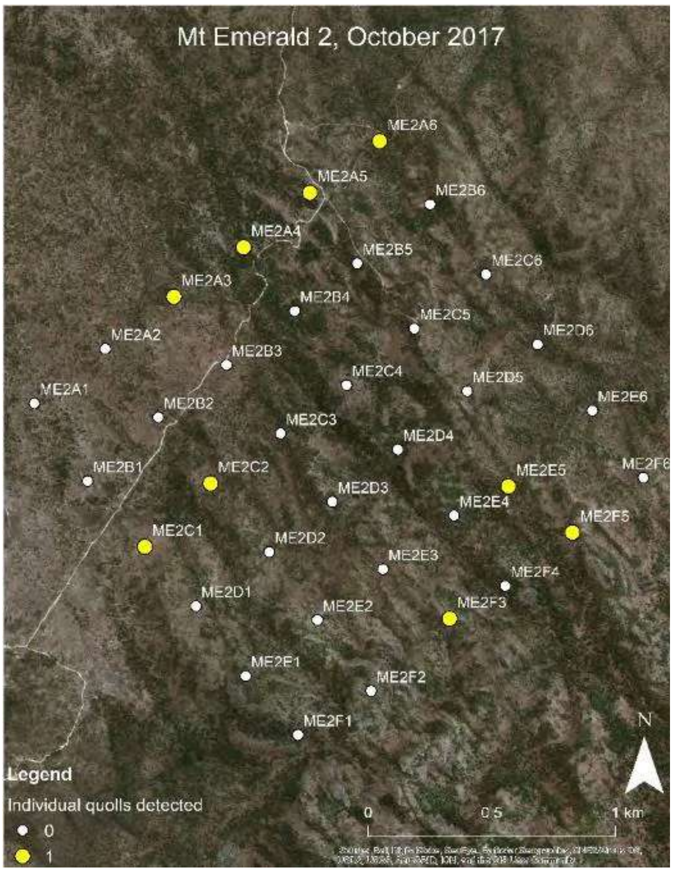


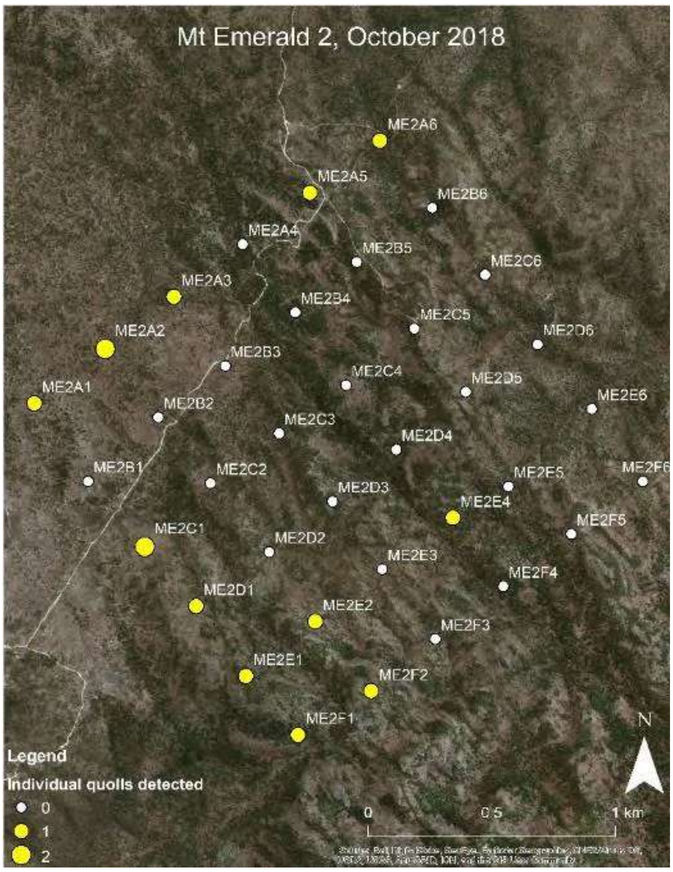



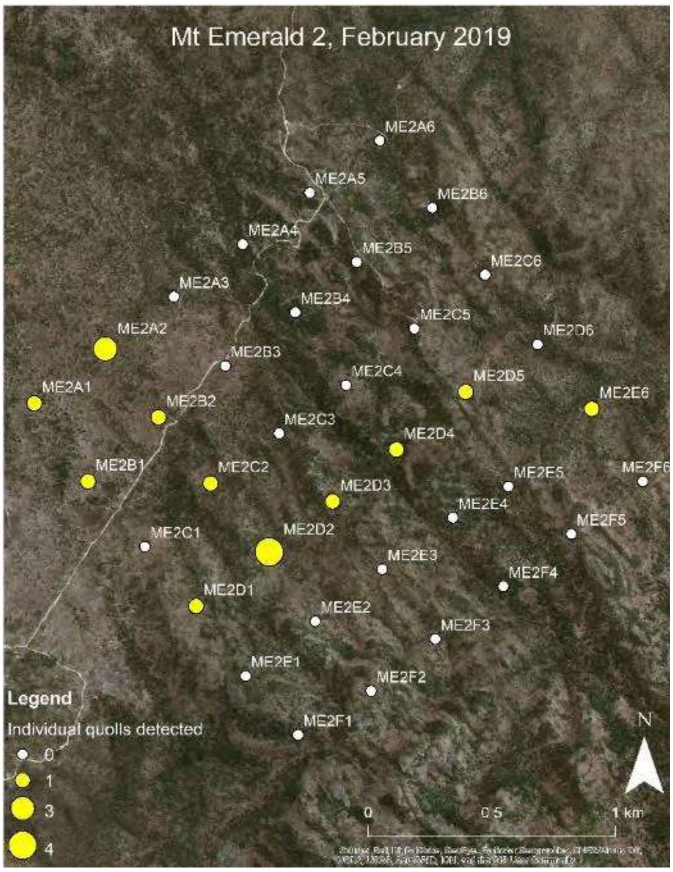

**Appendix B3. The distribution of quolls, and the number of individuals detected at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Mt Emerald 1".**


Mt Emerald 2, July 2017
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2A2
ME2B3
ME2D6
ME2C4
ME2A1
ME2D5
ME2B2
ME2E6
ME2C3
ME2D4
ME2B1
ME2C2
ME2D3
ME2E5
ME2F6
ME2E4
ME2C1
ME2F5
ME2D2
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
N
Legend
Individual quolls detected
0
1
2
0
0.5
1 km

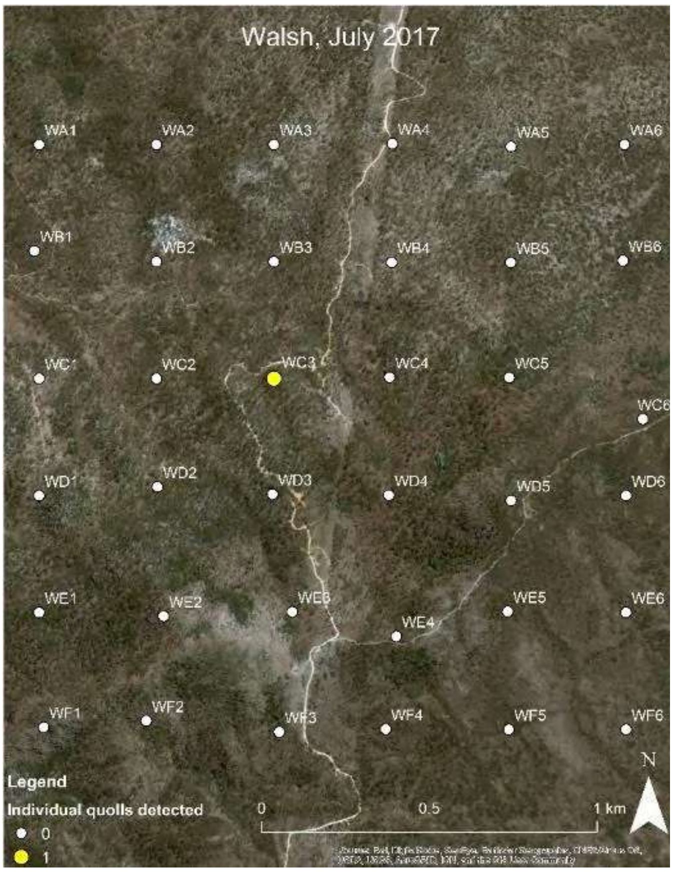

Mt Emerald 2, July 2018
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2A2
ME2D6
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2E6
ME2C3
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2C1
ME2F5
ME2D2
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
Legend
Individual quolls detected
0
1
2
3
4
N
0
0.5
1 km

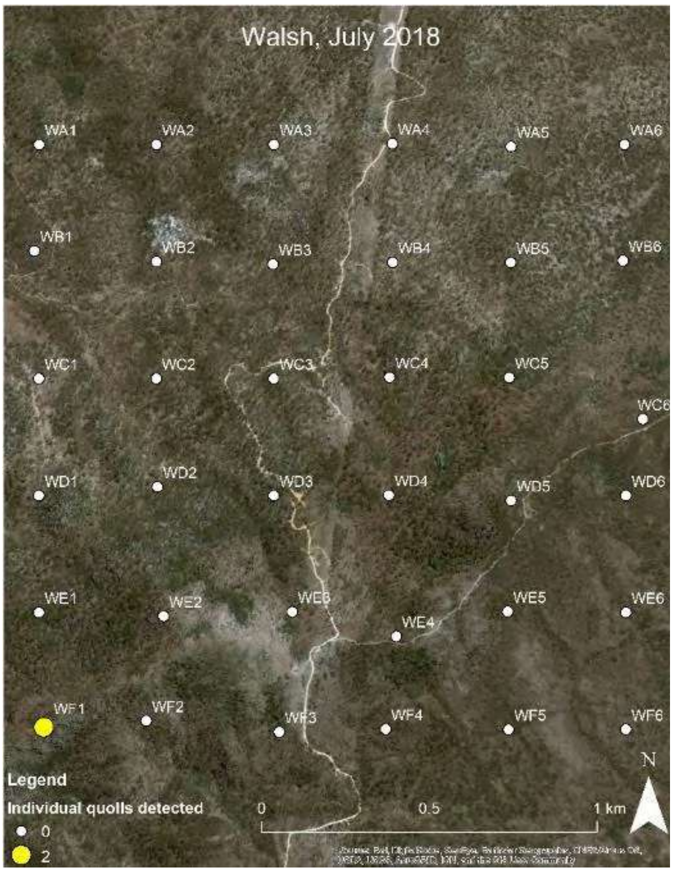

Mt Emerald 2, October 2017
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2A2
ME2D6
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2E6
ME2C3
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2F5
ME2C1
ME2D2
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
N
Legend
Individual quolls detected
0
1
0
0.5
1 km

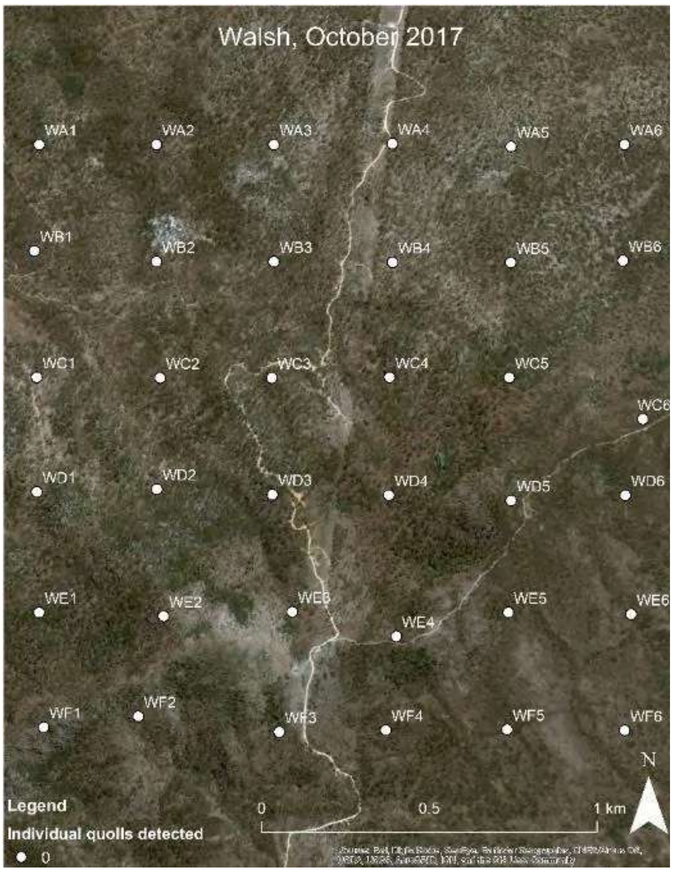

Mt Emerald 2, October 2018
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2A2
ME2D6
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2E6
ME2C3
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2C1
ME2F5
ME2D2
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
N
Legend
Individual quolls detected
0
1
2
0
0.5
1 km

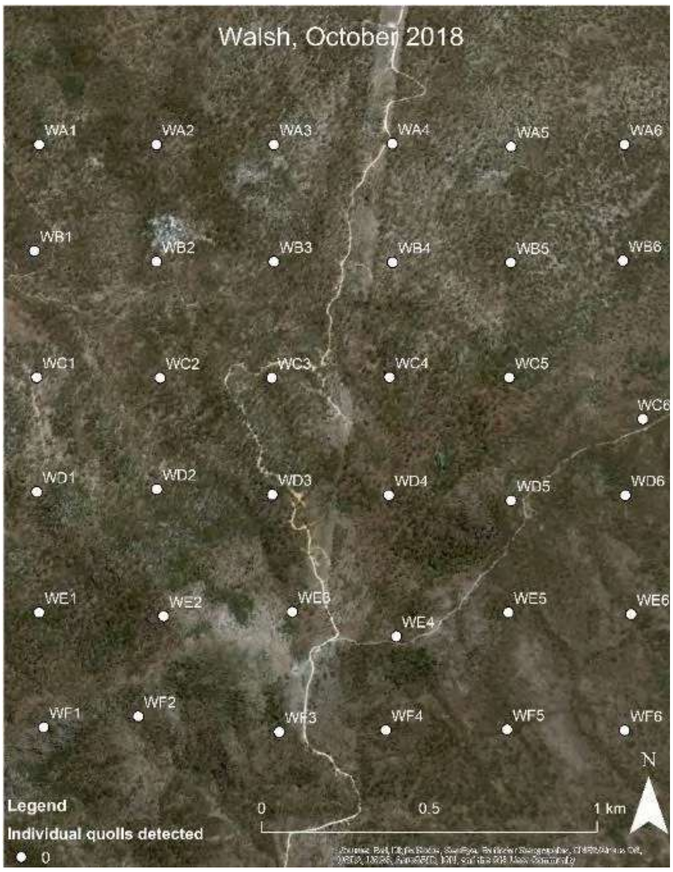



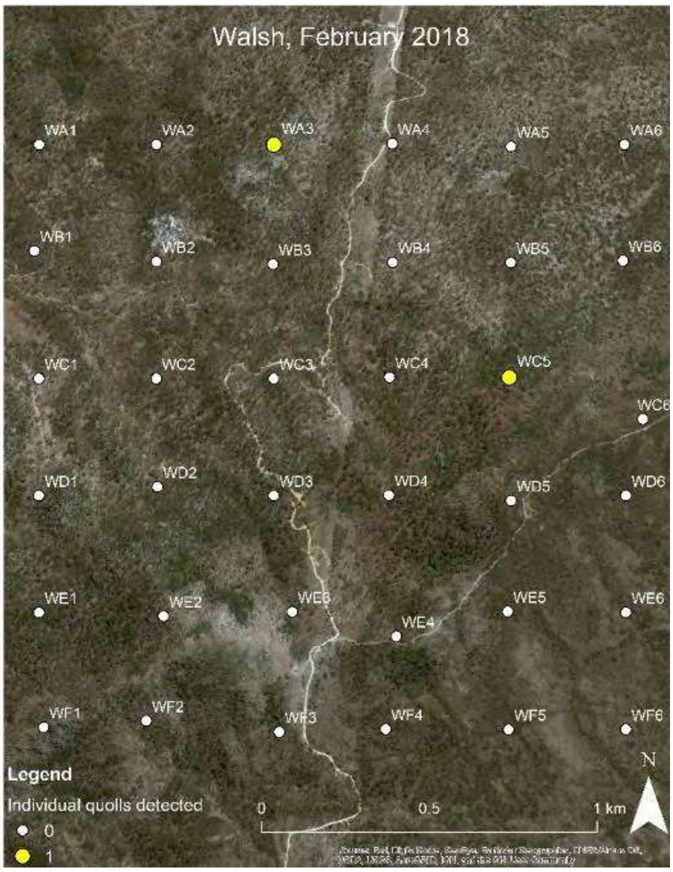

**Appendix B4. The distribution of quolls, and the number of individuals detected at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Mt Emerald 2".**

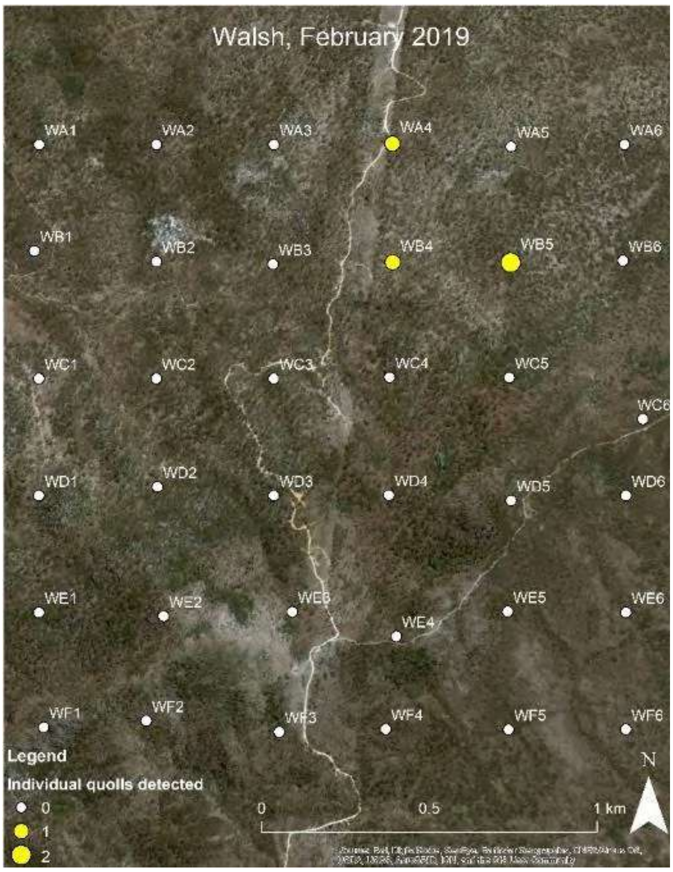

Walsh, July 2017
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
N
Legend
Individual quolls detected
0
1
0 0.5 1 km


Walsh, July 2018
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
N
Legend
Individual quolls detected
0
2
0 0.5 1 km

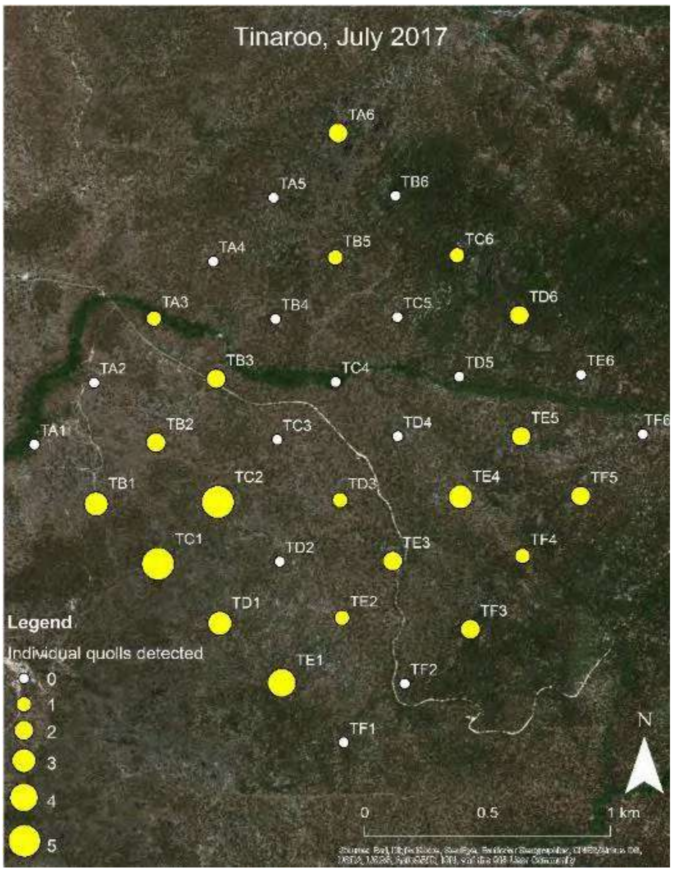

Walsh, October 2017
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
N
Legend
Individual quolls detected
0
0 0.5 1 km

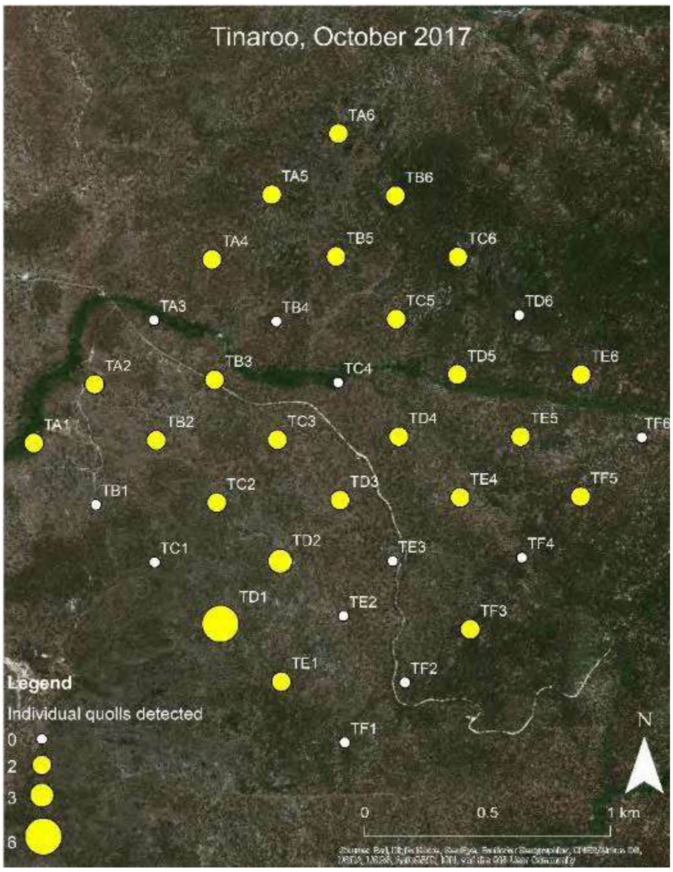

Walsh, October 2018
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
N
Legend
Individual quolls detected
0
0 0.5 1 km




**Appendix B5. The distribution of quolls, and the number of individuals detected at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Walsh".**



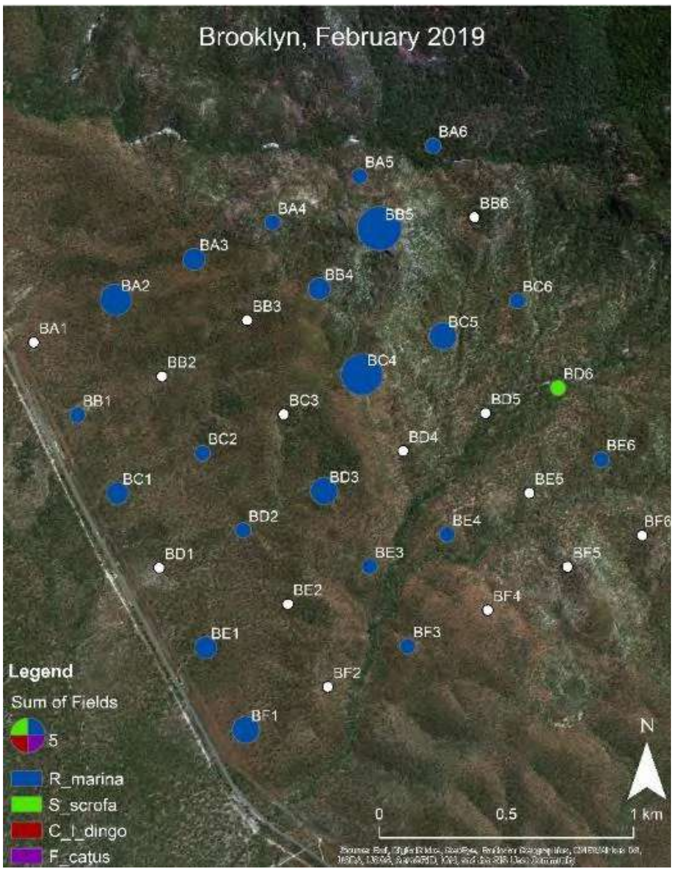

**Appendix B6. The distribution of quolls, and the number of individuals detected at each camera trap station during July 2017 and October 2017 at Site "Tinaroo". Sampling at this site was discontinued after October 2017 due to our inability to obtain research permits due to Native Title considerations.**

## Appendix C. Detections of non-quoll target species (cat, dingo/dog, feral pig and cane toad) at each of the six monitoring sites during each survey period.

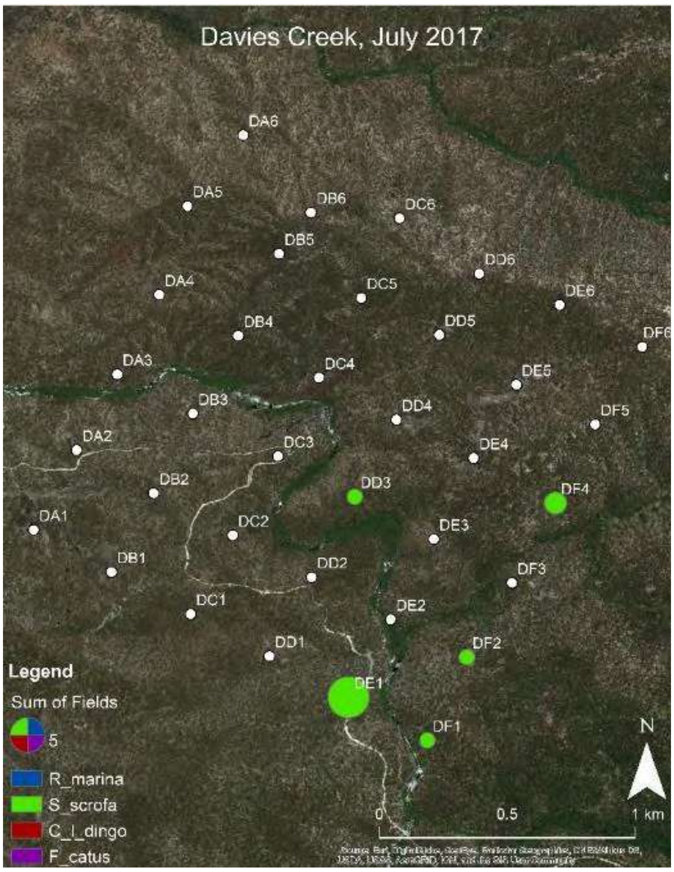
Maps are arranged on the page to allow direct comparison between comparable seasonal surveys. Refer to Fig. 7 for the absolute no. of detections of each species per site and time.

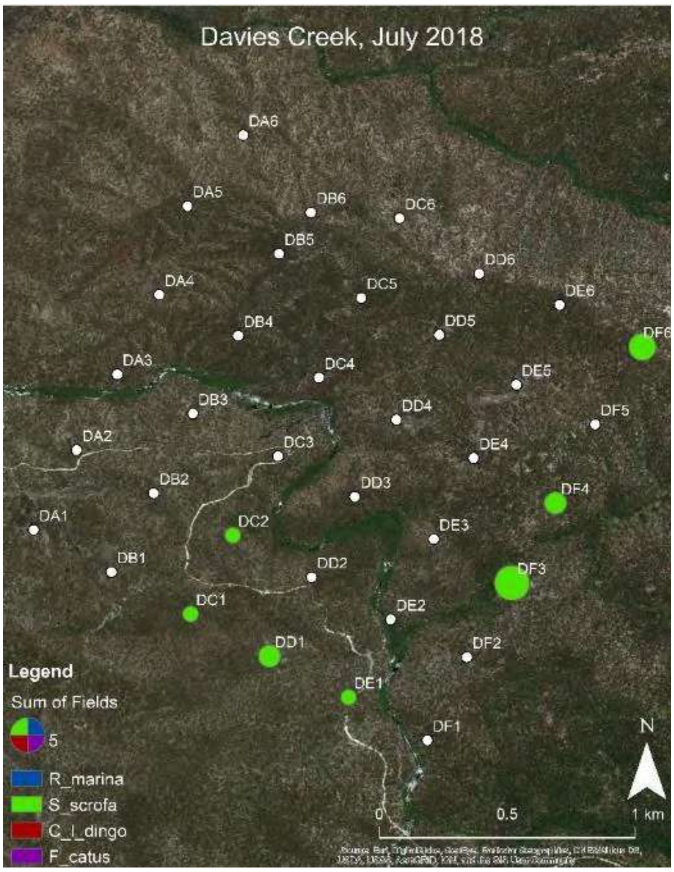






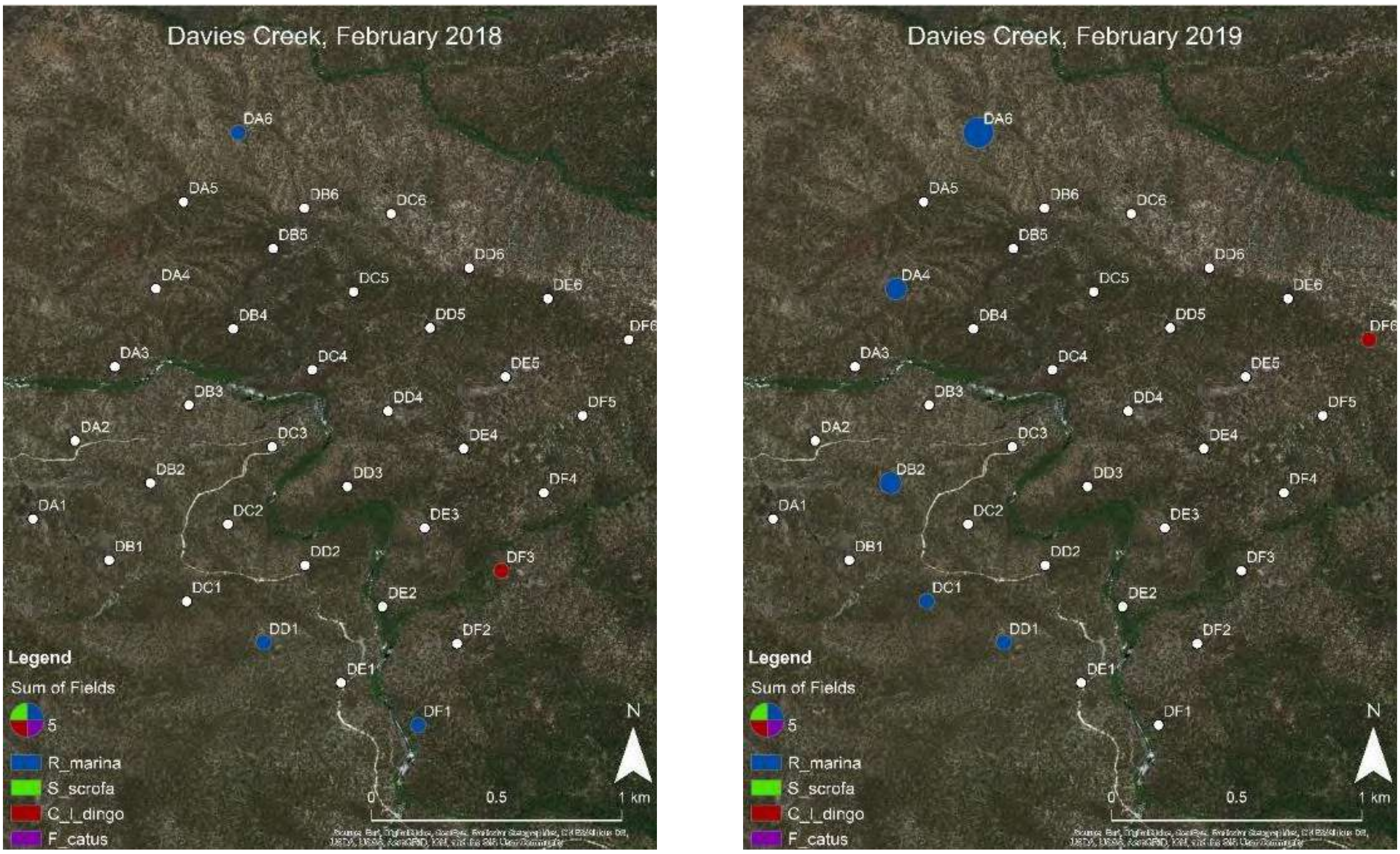

**Appendix C1. The distribution of cane toads, feral pigs, dingoes/wild dogs and feral cats, and the proportional number of detections of each species at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Brooklyn".**


Davies Creek, July 2017
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

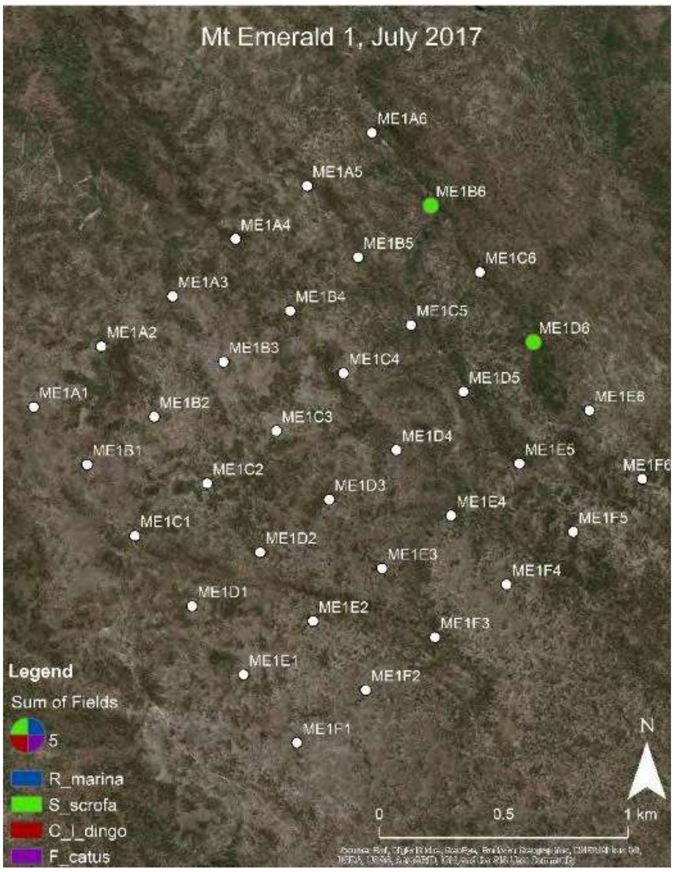

Davies Creek, July 2018
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

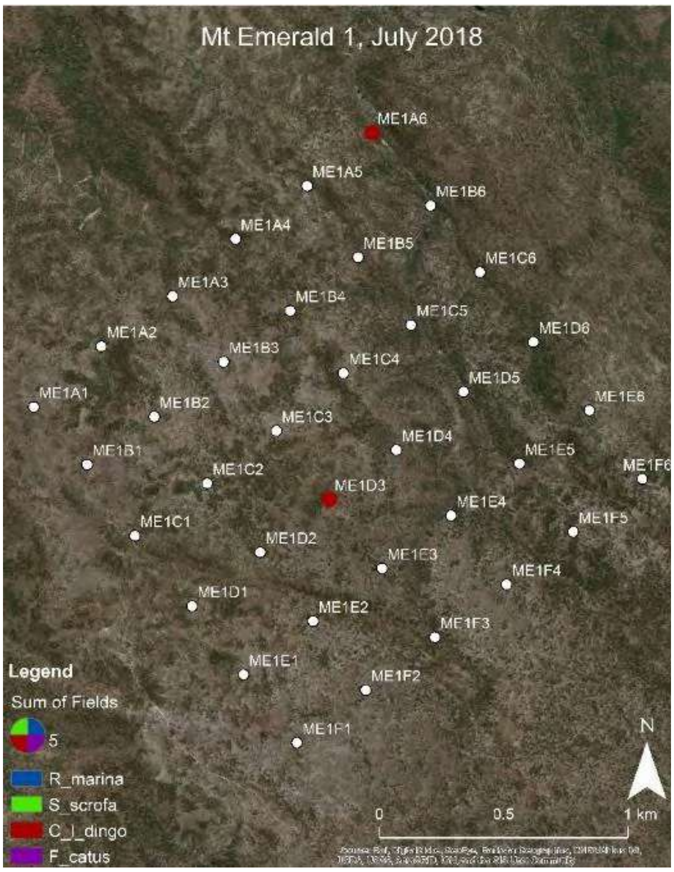

Davies Creek, October 2017
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

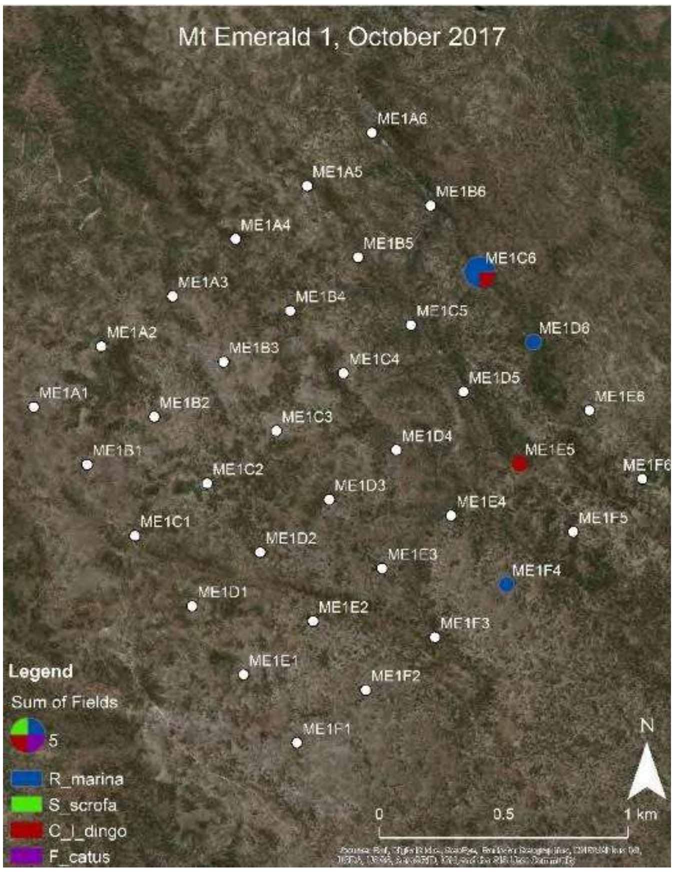

Davies Creek, October 2018
DA6
DA5
DB6
DC6
DB5
DD6
DA4
DC5
DE6
DB4
DD5
DF6
DA3
DC4
DE5
DB3
DD4
DF5
DA2
DC3
DE4
DB2
DD3
DF4
DA1
DC2
DE3
DB1
DD2
DF3
DC1
DE2
DD1
DF2
DE1
DF1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

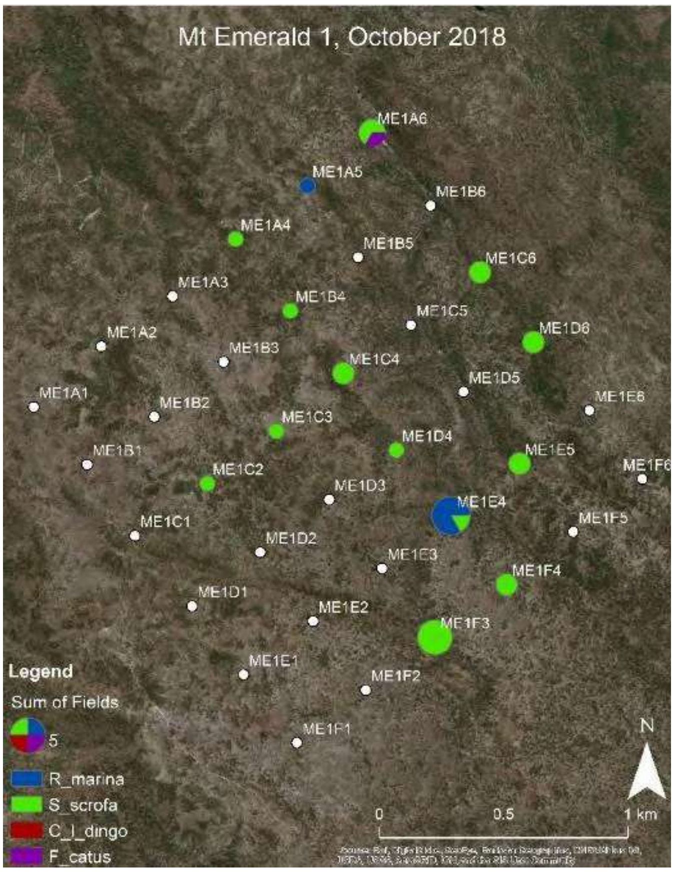


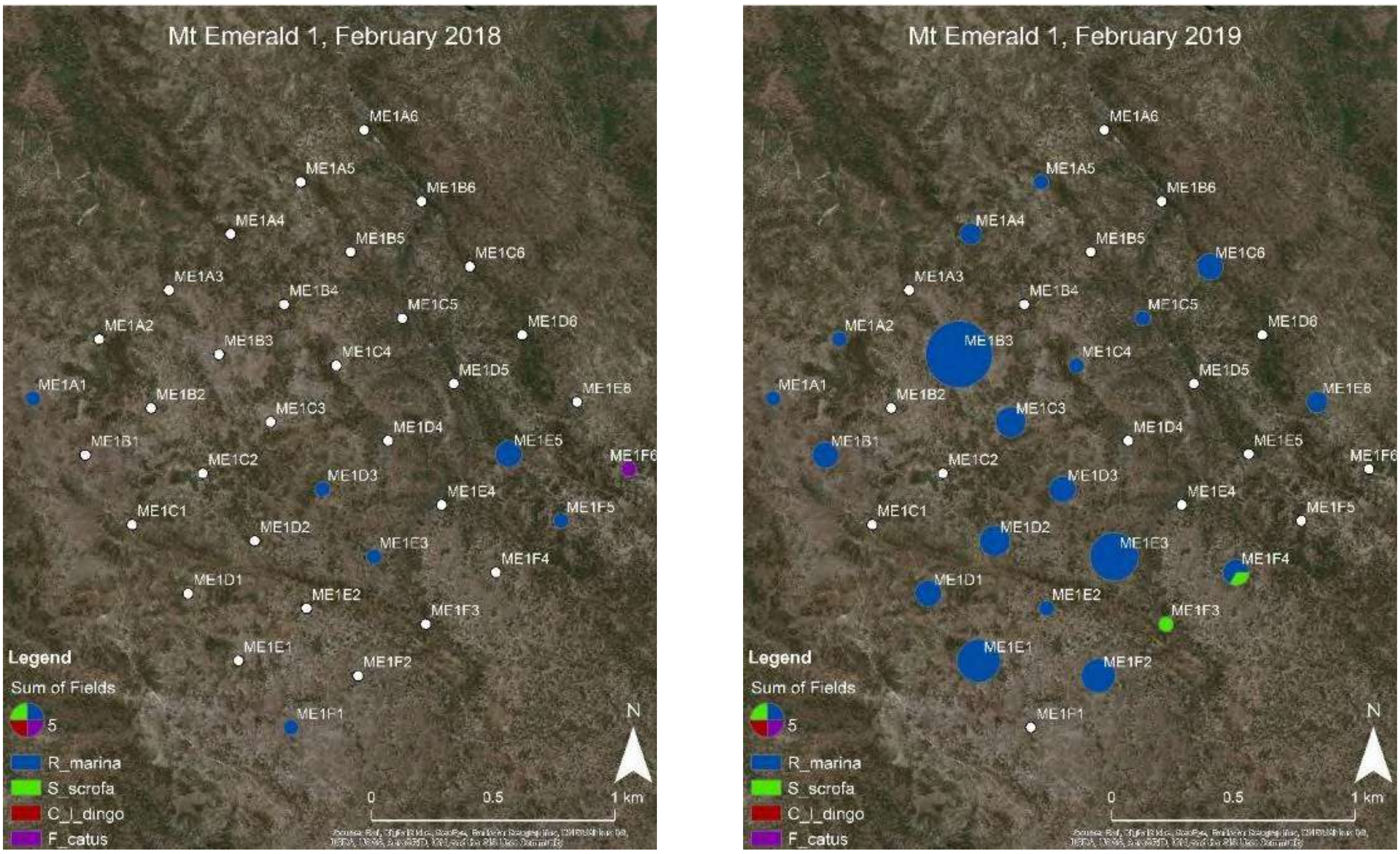

**Appendix C2. The distribution of cane toads, feral pigs, dingoes/wild dogs and feral cats, and the proportional number of detections of each species at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Davies Creek".**


Mt Emerald 1, July 2017
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km


Mt Emerald 1, July 2018
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

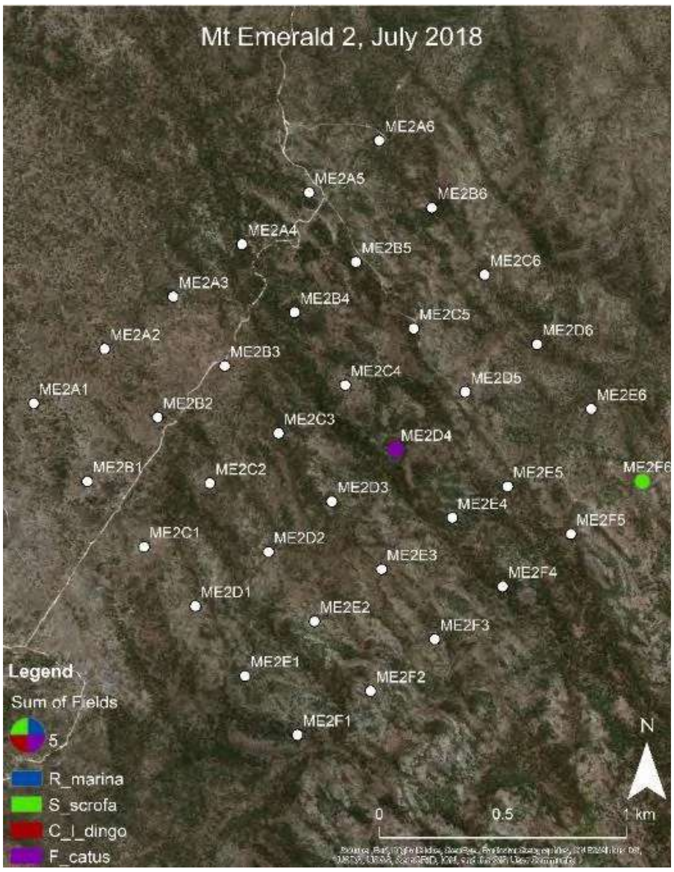

Mt Emerald 1, October 2017
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

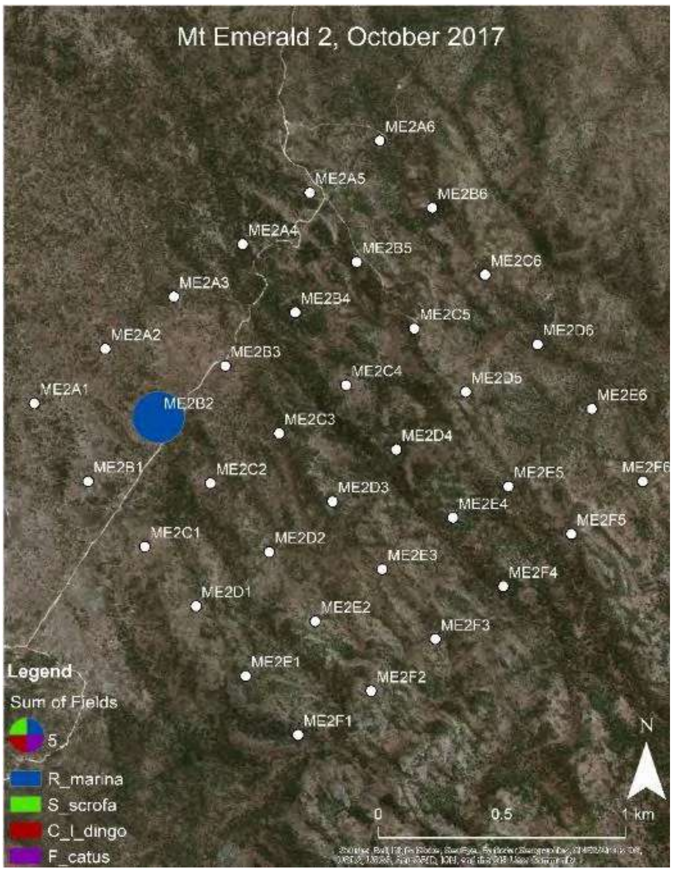

Mt Emerald 1, October 2018
ME1A1
ME1A2
ME1A3
ME1A4
ME1A5
ME1A6
ME1B1
ME1B2
ME1B3
ME1B4
ME1B5
ME1B6
ME1C1
ME1C2
ME1C3
ME1C4
ME1C5
ME1C6
ME1D1
ME1D2
ME1D3
ME1D4
ME1D5
ME1D6
ME1E1
ME1E2
ME1E3
ME1E4
ME1E5
ME1E6
ME1F1
ME1F2
ME1F3
ME1F4
ME1F5
ME1F6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km

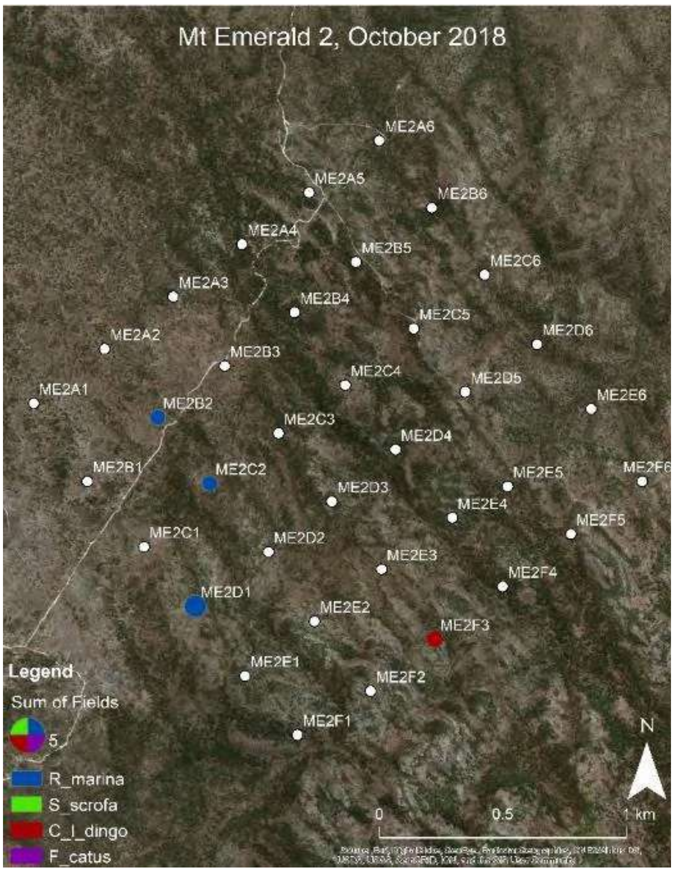



**Appendix C3. The distribution of cane toads, feral pigs, dingoes/wild dogs and feral cats, and the proportional number of detections of each species at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "ME1".**


Mt Emerald 2, July 2017
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2D6
ME2A2
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2C3
ME2E6
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2C1
ME2D2
ME2F5
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km


Mt Emerald 2, July 2018
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2D6
ME2A2
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2C3
ME2E6
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2C1
ME2D2
ME2F5
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km


Mt Emerald 2, October 2017
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2D6
ME2A2
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2C3
ME2E6
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2C1
ME2D2
ME2F5
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km


Mt Emerald 2, October 2018
ME2A6
ME2A5
ME2B6
ME2A4
ME2B5
ME2C6
ME2A3
ME2B4
ME2C5
ME2D6
ME2A2
ME2B3
ME2C4
ME2D5
ME2A1
ME2B2
ME2C3
ME2E6
ME2D4
ME2B1
ME2C2
ME2E5
ME2F6
ME2D3
ME2E4
ME2C1
ME2D2
ME2F5
ME2E3
ME2F4
ME2D1
ME2E2
ME2F3
ME2E1
ME2F2
ME2F1
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
N
0
0.5
1 km



**Appendix C4. The distribution of cane toads, feral pigs, dingoes/wild dogs and feral cats, and the proportional number of detections of each species at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "ME1".**


Walsh, July 2017
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
0 0.5 1 km
N

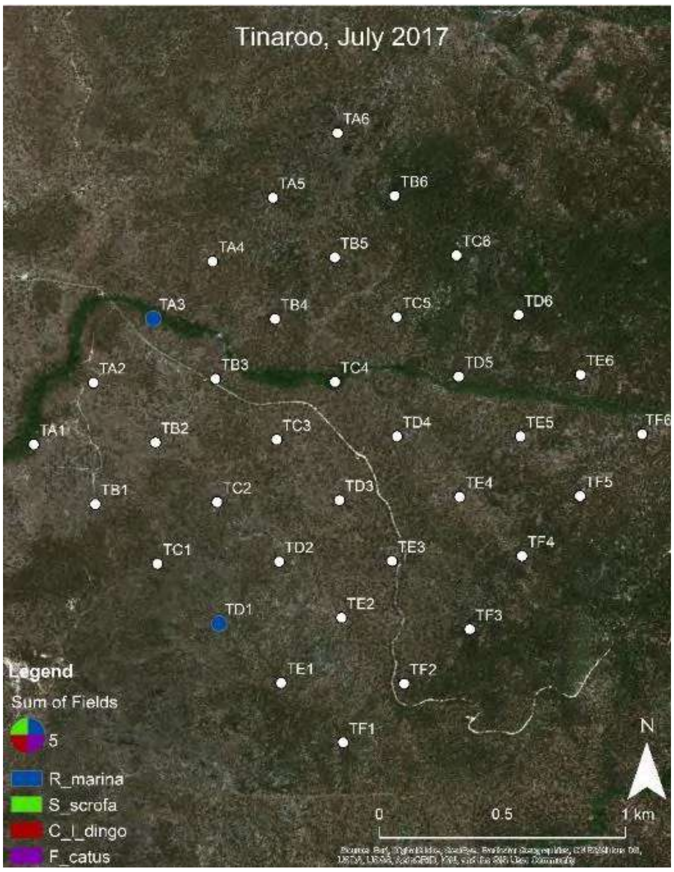

Walsh, July 2018
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
0 0.5 1 km
N

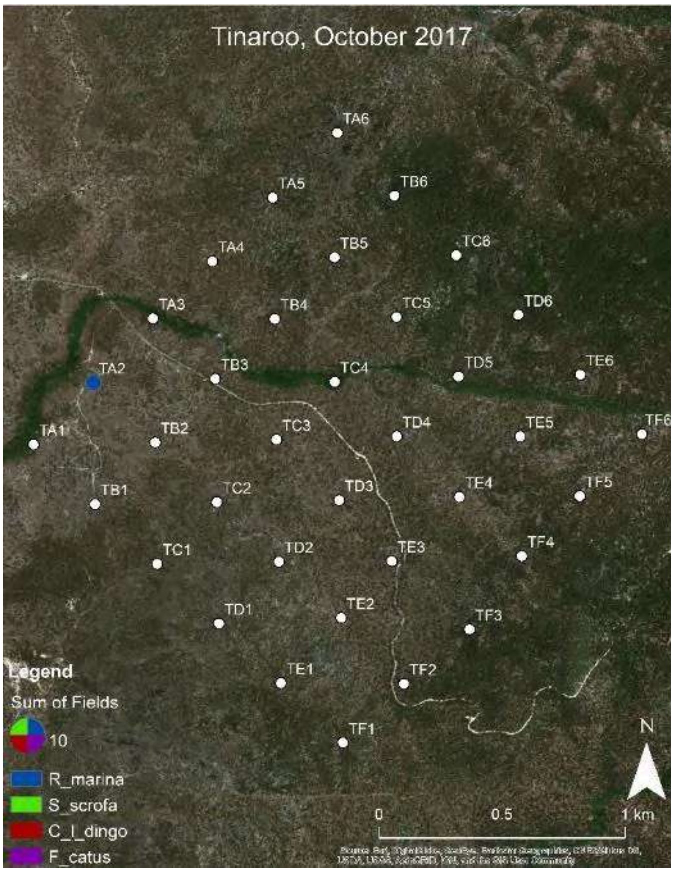

Walsh, October 2017
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
Legend
Sum of Fields
5
R_marina
S_scrofa
C_l_dingo
F_catus
0 0.5 1 km
N


Walsh, October 2018
WA1 WA2 WA3 WA4 WA5 WA6
WB1 WB2 WB3 WB4 WB5 WB6
WC1 WC2 WC3 WC4 WC5 WC6
WD1 WD2 WD3 WD4 WD5 WD6
WE1 WE2 WE3 WE4 WE5 WE6
WF1 WF2 WF3 WF4 WF5 WF6
Legend
R_marina
S_scrofa
C_l_dingo
F_catus
FezWalshOct17
0 0.5 1 km
N



**Appendix C5. The distribution of cane toads, feral pigs, dingoes/wild dogs and feral cats, and the proportional number of detections of each species at each camera trap station during comparable monitoring times. July 2017 and July 2018 (top row previous page), October 2017 and 2018 (bottom row previous page) and February 2018 and February 2019 (this page) at Site "Walsh".**




**Appendix C6. The distribution of cane toads, feral pigs, dingoes/wild dogs and feral cats, and the proportional number of detections of each species at each camera trap station during July 2017 and October 2017 at Site “Tinaroo”. Sampling at this site was discontinued after October 2017 due to our inability to obtain research permits due to Native Title holder veto of permits.**

## B. BIRD AND BAT COLLISION MORTALITY STUDIES PROGRESS REPORT

# Bird and Bat Collision Mortality Studies Progress Report

*Mount Emerald Wind Farm (2019-2021)*

4 elements

**Bird and Bat Collision Mortality Studies Progress Report Progress Report**

*Mount Emerald Wind Farm (2019-2021)*

**Revision History**

| Version | Purpose | Issued by | Date | Reviewer | Date |
|---|---|---|---|---|---|
| 1 | Draft | C Starr | 21/11/2019 | M. Brown | 31/11/2019 |
| | | | | | |



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# Contents

# 1.0 Introduction

Wind farms are generally considered an environmentally friendly source of energy, however there is some concern in terms of bird and bat mortality associated with turbines. Mortality may occur through direct impact with a wind turbine, or barotrauma (Kunz, Arnett et al. 2007). International studies have identified tree roosting and migratory bats were most susceptible to collision at wind farms (Cryan and Barclay 2009). Assessing these impacts, alongside trialling methods to reduce impact such as curtailment are important to understand how best to manage the potential environmental impact of this energy source. Currently, there are very few published studies of the impact of wind farms on Australian bats, and on-ground assessments of the benefits of available mitigative measures.

These studies follow the recommendations of the approved *'Implementation plan for two species of bats at Mount Emerald Wind Farm'* (BIOSIS 2018). This work meets the requirements of Condition 13 of approval for Mount Emerald Wind Farm under the provisions of the EPBC Act 1999. The primary objective is to ensure the wind farm does not have a significant impact on the population viability of Spectacled flying fox *(Pteropus conspicillatus*) and/or Bare-rumped sheathtail bat (*Saccolaimus saccolaimus nudicluniatus*).

The Implementation Report (BIOSIS 2018) concluded that based on criteria identified to determine 'significant impact' on nationally listed Vulnerable species under the *Matters of National Environmental Significance: Significant impact guidelines 1.1. (2013)* the works were unlikely to result in the specified impact determined for either species. The *EPBC Act Policy Statement 2.3 Wind Farm Industry* (Commonwealth of Australia, 2009) provided further potential impact criteria specifically from wind farms based on forming an 'important population', neither of the Vulnerable species at Mount Emerald were likely to fall under the set criteria identified (BIOSIS 2018).

The concept of impact on an 'ecologically significant proportion' of a population has been elaborated in the *Draft referral guideline for 14 birds listed as migratory species under the EPBC ACT* (Commonwealth of Australia 2015) and may be useful for establishing what is considered a significant impact for the two-priority species at Mount Emerald, as well as setting performance criteria for the assessments. This draft identifies an annual mortality rate which meets or exceeds 1% of the population of individual animals would be considered as a significant impact to the species. Further, it suggests any impact which met or exceeded 0.1% of the population requires further investigation and may be subject to mitigation. Therefore, for Mount Emerald Wind Farm the Implementation Plan (BIOSIS 2018) recommended for the two species; mortalities of ≥1% would be significant, and any impact ≥0.1% would instigate a management response. Recent population estimates for the Australian populations for these species are: greater than 10,000 individuals for Bare-rumped sheathtail bat (Woinarski, Burbidge et al. 2014); and 44,000 individuals for Spectacled flying-fox following a heat event in October 2018 (Westcott 2019). Using these coarse estimates, annual thresholds must not exceed 10 Bare-rumped sheathtail bats and 44 Spectacled flying foxes (BIOSIS 2018). If these numbers are reached/exceeded a management response is to be instigated.

Monitoring the performance against this criterion requires a monitoring protocol which determines the mortalities resulting from collision. Carcass studies rely on counting carcasses under turbines, however without careful consideration these are unlikely to reflect the actual number of birds and bats struck, as:

- only a partial area of the turbine radius is often searched;
- carcasses are often removed through scavenging or decay; and
- observers will not always detect every carcass during surveys.

Additionally, the removal of carcasses or detection variability in surveyors may also be influenced by topography, size of carcass, season, and vegetation cover (Morrison 2002). Recent published studies have developed distance-based carcass-density models which include a methodology to account for these factors when generating estimates (e.g. Bernardino, Bispo et al. 2013). This study will follow the recent methods outlined by Huso *et al.* (Huso, Dalthorp et al. 2017), whereby data from turbine carcass surveys, carcass persistence trials and searcher efficiency trials will be used to develop estimates of collision mortality at Mount Emerald Wind Farm.

Review of Potential Mitigative Measures for Collision by Bats (BIOSIS 2018) identified the most suitable method for Mount Emerald Wind Farm is likely to be turbine curtailment at times when bats are most likely to be struck. Wind turbines do not turn under zero wind condition, as wind increases the rotating speed will also increase until a point where it is affective at generating electricity, this point is referred to as the 'cut-in' speed. The cut-in speed for turbines at Mount Emerald Wind Farm is 3.0m/sec (BIOASIS 2018). Low wind-speed turbine curtailment involves programming turbines to not turn at night under low wind speeds, which is when bats are often most active (Arnett, Schirmacher et al. 2009). There are two recognised phases of curtailment, these are:

- **Phase 1**- At wind speeds between zero and cut in speed, where the turbine 'freewheels' potentially killing bats, however no electricity is generated. Feathering of rotor blades prevent turning until cut in speed. This method has been identified to be extremely effective in studies in the USA and Canada. All turbines at Mount Emerald Wind Farm will be programmed so the rotor blades remain feathered to prevent turning at wind speeds of 0 to 3.0 m/s, therefore permanently operating at Phase 1; and

- **Phase 2**- Rotors are prevented from turning until a specific, pre-determined speed is reached, above the cut in speed. This results in loss of electricity between cut-in and the determined higher wind speed. The suggested cut-in speed for trials on Mount Emerald Wind Farm are 4.5 m/s (BIOSIS 2018).

This study will compare the benefit of Phase 2 (relative to Phase 1) curtailment to reduce collision by the two-target species, which is pertinent if the performance thresholds for either species are reached or exceeded to inform adaptive management actions. The study would also be the first in Australia to provide insight into minimisation of collision by birds and bats at wind farms. Curtailment studies will take place in year 2 of the project, enabling full analysis of Phase 1, year 1 data prior to commencement of trials. Wind data collection commenced at Mount Emerald in 2010, and it suggests wind speeds below 3 m/s occur 5% of the year, whereas speeds of 4.5 m/s are likely to occur ~12% of the year.

In summary, the project aims are to:

1. Establish estimates of how many bird and bat fatalities occur due to collision/barotrauma at the Mount Emerald Wind Farm;
2. Assess generated collision estimates in relation to pre-established performance measures for Spectacled flying fox and Bare-rumped sheathtail bat (i.e. not exceeding ≥ 0.1 % of current population estimates); and
3. Determine if there is a significant mitigative benefit in reducing collision fatalities between Phase 1 and Phase 2 curtailment at Mount Emerald Wind Farm in the projects second year.

This report provides a summary of the data collected thus far, with modelled fatality estimates provided at the completion of the first 12 months of field assessments.

# 2.0 Collision mortality

## 2.1 Experimental design

### 2.1.1 Carcass surveys

Field surveys for carcasses are carried out by ecologists across all 53 turbines in the 'fall zone'. Huso and Dalthorp (2014) identified that when assessing numerous carcass survey models, carcass density reached zero at approximately 70 m horizontally from the turbine base, and this radius will be used in the study. Surveys are to be carried out on day 1, 4 and 28 of each month, for two consecutive years. One month prior to commencing the study, each turbine should be swept to remove any carcasses before starting the surveys, to account for animals which have perished prior to the monthly survey schedule in the first sampling period.

It is important to ascertain the frequency of collision. This is necessary for use in extrapolation to estimate total fatality. Therefore, a 3-day interval between two searches at the beginning of the search cycle is designed to provide information on collision frequency to feed into the model, as there is a high probability a new carcass found on day 4 must have collided in the preceding three days. Animals detected on day 1 should be marked by surveyor tape/paint to identify them as an old animal on subsequent survey days. There is a 27-day interval before the next round of sampling (day 28). The survey on day 28 becomes day one on the next survey cycle. This cycle is repeated across the life of the project and consistency is vital for the data analysis.

Records of all birds and bats are logged; however, the any implications of collisions in regard to management responses relate only to Bare-rumped sheathtail bat and Spectacled flying-fox. Photographs are to be taken of all animals recorded in the study. All threatened taxa are to be collected on day 4 and stored in a deep freezer on-site and sent to the QLD Museum at the completion of the study.

### 2.1.2 Carcass persistence trials

Carcasses of small microbats are unlikely to persist in the field for long periods; therefore, extrapolation will be required from those detected to more accurately estimate total deaths. Carcass persistence trials will be carried out to determine a 'correction factor' in the analysis. This will require two field trials per year, over two years (one wet, one dry season). Bat carcasses of similar size to the target species will be used, and these are to be marked to ensure no confusion with genuine collisions on the site. RFID microchips may be inserted if required.

Persistence trials will be carried out at a minimum of 20 representative turbines, and will utilise 10 microbats and 10 flying foxes for each sampling period. Camera traps will be placed in front of the carcasses and set to record all movement, and take a photograph every hour (day and night). Censored analysis must be used to account for carcasses that persist longer than the trial period (Klein and Moschberger 2003).

To improve the likelihood of detecting any moved carcass, these surveys will be undertaken one week prior to the next targeted carcass survey. This enables locating any moved animals so they are not lost from the trial and can be reused/placed. Each trial will run for one month, with an ecologist checking all stations are operational at 14 days. Removed carcasses which cannot be found should be replaced on day 14 with a new carcass to maximise the data collected.

This data will be used for calculation of average carcass persistence times for the collision estimates.

### 2.1.3 Searcher Efficiency Trials

Correction factors are required in the analysis to account for searchers not always finding all carcasses. This is done through blind trials, where a number of carcasses are placed prior to a search (minimum of 10 flying foxes, 10 microbats at a minimum of 10 turbines). Two searcher trials are to be carried out each year; one in the wet and one in the dry season. The number of detected animals for 3 surveyors will be used to develop correction factors for the final analysis.

## 2.2 Analysis

Annual collision mortalities will be calculated by a biometrician for the two key threatened species accounting for carcass persistence times relative to search interval and searcher efficiency. Current best practice follows Huso et al. (2017) and 95% confidence intervals will also be provided as a measure of variance.

# 3.0 Low Wind-speed Curtailment Study

## 3.1 Experimental Design

In the second year of the study, the Implementation Plan (BIOSIS 2018) recommends half of the turbines be programmed to cut-in at 4.5 m/s wind speed. This will enable comparison of collision rates across the turbines to ascertain if reduced collision may occur utilising this strategy. The methodology for carcass surveys which was utilised in the first year will continue and be used for analysis. This study will be applicable if Spectacled flying fox and/or Bare-rumped sheathtail bat are identified in the first year to collide with the moving turbines.

## 3.2 Analysis

For the purpose of this analysis, numbers collected during surveys can be compared statistically, rather than using the derived estimates from the collision model analysis as the aim is to detect significant change between phase 1 and 2.

# 4.0 Results

## 4.1 Carcass surveys

14 carcasses were identified during the field surveys from May to November 2019. Details of identified carcasses are provided in Table 1. Some animals exhibited significant decay, making species level identification impossible at the time of detection.

**Table 1. Carcasses identified during census at turbine bases from May to November 2019.**

| Survey date | Turbine | Common name | Scientific name |
|---|---|---|---|
| 21/5/2019 | 16 | Little red flying-fox | *Pteropus scapulatus* |
| 21/5/2019 | 17 | Northern freetail bat | *Chaerephon jobensis* |
| 20/5/2019 | 52 | Wedge-tail eagle | *Aquila audax* |
| 16/6/2019 | 3 | Bird. | *Unidentified.* |
| 19/6/2019 | 49 | Freetail Bat | *Unidentified.* |
| 13/7/2019 | 15 | Freetail Bat | *Unidentified.* |
| 9/8/2019 | 9 | Northern freetail bat | *Chaerephon jobensis* |
| 12/8/2019 | 4 | Northern freetail bat | *Chaerephon jobensis* |
| 12/8/2019 | 9 | Northern freetail bat | *Chaerephon jobensis* |
| 6/9/2019 | 23 | Little red flying-fox | *Pteropus scapulatus* |
| 8/9/2019 | 46 | Spectacled flying fox | *Pteropus conspicillatus* |
| 3/10/2019 | 25 | Little red flying-fox | *Pteropus scapulatus* |
| 3/10/2019 | 28 | Glossy ibis | *Plegadis falcinellus* |
| 6/10/2019 | 28 | Brown falcon | *Falco berigora* |

76 carcasses were incidentally recorded on the wind farm from the 10$^{th}$ of February 2018 to the 13$^{th}$ February 2019 prior to the study are provide in Table 2.

**Table 2. Incidental records of carcasses obtained from 2018 to 2019 prior to the studies**

| Common name | Scientific name | No. |
|---|---|---|
| Northern freetail bat | *Chaerephon jobensis* | 36 |
| Black-shouldered kite | *Elanus axillaris* | 1 |
| Nankeen Kestrel | *Falco cenchroides* | 2 |
| Flying-fox | *Pteropus sp.* | 1 |
| White-throated needletail | *Hirundapus cuadacutus* | 1 |
| Microbat sp. | *Unidentified.* | 7 |
| Black kite | *Milvus migrans* | 1 |

| | | |
|---|---|---|
| Northern myotis | *Myotis moluccarum* | 1 |
| Spectacled flying fox | *Pteropus conspicillatus* | 6 |
| Little red flying fox | *Pteropus scapulatus* | 15 |
| Unidentified flying fox | *Pteropus sp.* | 1 |
| Yellow-bellied sheath-tail bat | *Saccolaimus flaviventris* | 1 |
| Forest Kingfisher | *Todiramphus macleayii* | 3 |
| **Total** | | **76** |

## 4.2 Carcass persistence trials

Two trials were carried out, the first in February and the second in August 2019, using 10 spectacled flying foxes and 10 rodents (surrogates for smaller bats) in each trial (n = 40). 60% of carcasses were removed by scavengers before the 14-day survey effort was complete. This data will feed into the annual mortality estimates at the end of the 12-month study period.

## 4.3 Searcher efficiency trials

One surveyor efficiency trial was carried out in February 2019. Results of this trial showed surveyors detect on average 22% of placed carcasses. This data will be used in the fatality estimate to account for the animals potentially missed on the site. This figure is on par with most surveyor trials on wind farms using human surveyors. Prior studies in Portugal have identified carcass dogs were able to detect 96% of carcasses in wind farm trials, whilst the human surveyors on the same site only detected 9% of placed carcasses (Paula, Costa Leal et al. 2011). Whilst the model is able to correct for low efficiency, the use of detection dogs is likely to greatly improve efficiency and final fatality estimate on the site. Currently, no detection dogs are trained for this work in Queensland. 4 Elements Consulting is underway at training a dog to carry out this work, with plans of deployment at the Mount Emerald Wind Farm in mid-2020.

# 5.0 Discussion

Currently, the numbers of target threatened species appear to be well below the threshold where a management action will be required.  Caution is required in interpreting actual numbers at this stage of the study, due to poor persistence of carcasses and poor detection by surveyors identified in the field trials. These numbers are likely to inflate when used in the model at the end of the 12-month period. Future inclusion of detection dogs into the fatality studies are likely to increase the searcher efficiency on these sites.

# 6.0 References

Arnett, E. B., et al. (2009). Effectiveness of changing wind turbine start-up speed to reduce bat fatalities at wind facilities. An annual report submitted to the Bats and Wind Energy Cooperative. Austin, Texas, USA, Bat Conservation International.

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# Offset Monitoring Program 2019 – Mount Emerald Wind Farm

*RATCH Australia Corporation Limited*

4 elements

**Offset Monitoring Program 2019 – Mount Emerald Wind Farm**

*RATCH Australia Corporation Limited*

**Revision History**

| Version | Purpose | Issued by | Date | Reviewer | Date |
|---|---|---|---|---|---|
| 1 | Draft | Matthew Hemmings | 31/05/2019 | Mellissa Brown | 10/06/2019 |
| 2 | Final | Matthew Hemmings | 25/06/2019 | Mellissa Brown | 28/06/2019 |



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# 1.0 Introduction

## 1.1 Background

The Mount Emerald Wind Farm (MEWF) Offset Site (the site) is located within land described as Lot 22 SP210202, which comprises approximately 434.9 ha (**Figure 1**). It is located immediately to the south west of the MEWF site at Mutchilba within the Mareeba Shire Council Area at the end of Lemontree Drive. The lot tenure is freehold and the primary land use is vacant. The area fringes the Baldy Mountain Forest Reserve and the Herberton Range National Park, via the Herberton Range (Queensland Government 2016).

On 26 November 2016, approval under the provisions of the Environmental Protection and Biodiversity Conservation (EPBC) Act, was granted to RATCH Australia Corporation Limited (RACL). As a requirement of the EPBC Act approval 2011/6228, issued by the Federal Department of the Environment and Energy (DEE), a Biodiversity Offset Area was developed to compensate for the clearing of 73 ha of habitat on the MEWF Project Site.

This site has been protected as a Nature Reserve through a statutory process through consultation with the Queensland Department of Environment and Science.

The offset site lies completely within the wet tropics bioregion. The site is mountainous with narrow ridges and rocky terrain that are steeply dissected along three dominant ridge lines falling towards Lemontree Drive at the entrance to the site. The offsets site lies adjacent to the MEWF project site.

The majority of the site consists of remnant vegetation with approximately 192.89 ha consisting of 'Least Concern' vegetation and the remaining 242 ha listed as 'Of Concern' vegetation.

4 Elements Consulting was commissioned by RACL to conduct the annual ecological monitoring surveys on the MEWF Offsets Site and this report has been prepared to comply with the requirements outlined in the Mount Emerald Wind Farm Offset Area Management Plan (RPS, 2016), which details monitoring management actions. The data collected in 2016 provided baseline data for future monitoring to be compared against and enables targeted and adaptive management procedures to be implemented to ensure the biological integrity of the biodiversity area is maintained or improved and conserved into the future.

The actions required include:

- Targeted survey of threatened fauna species to determine changes to species diversity on the site over time;

- Pest species presence/absence assessments;
- Photo-monitoring points to determine variation in trends over time; and
- Targeted weed surveys.

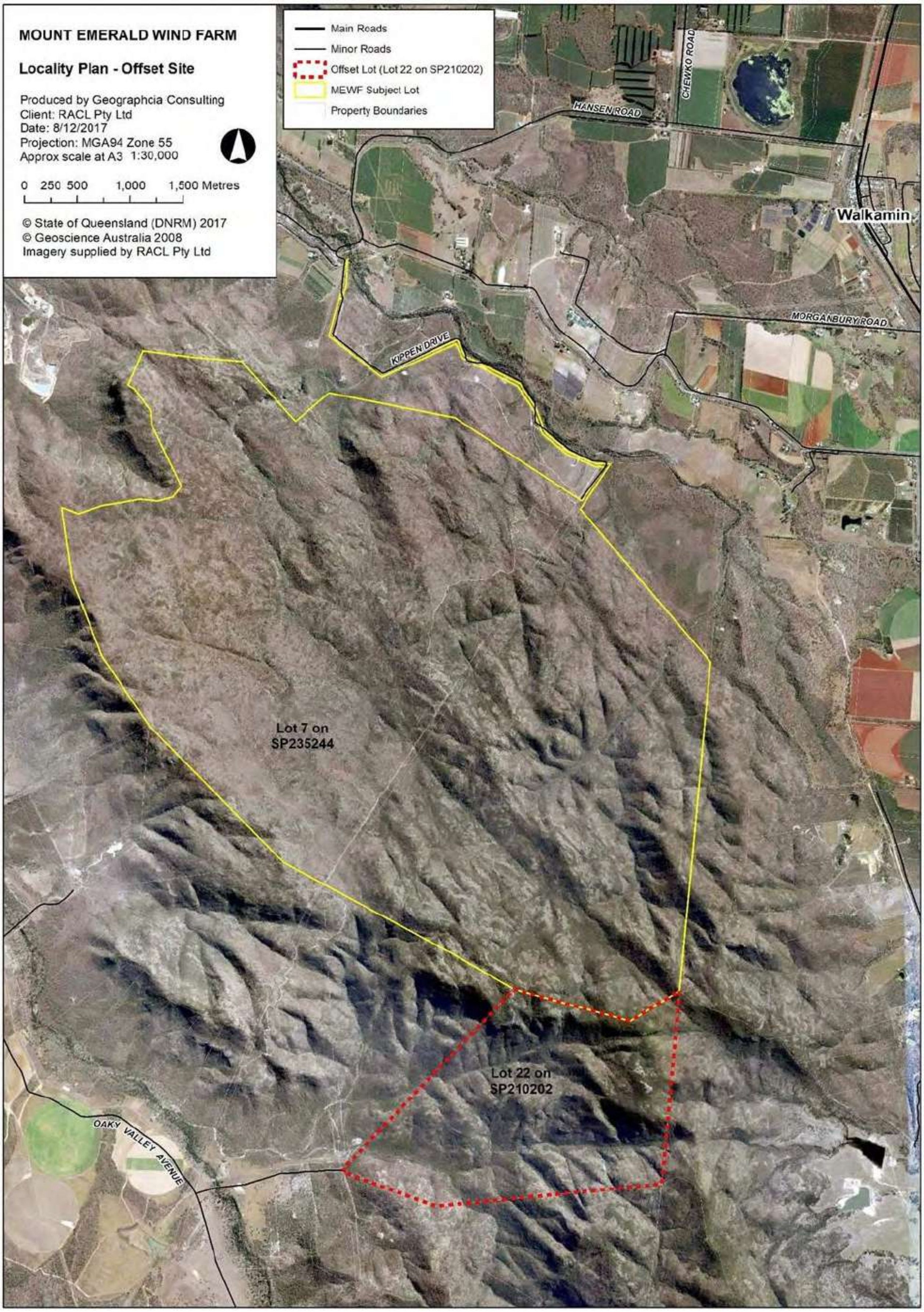


**Figure 1 Project Location**

## 1.2 Objectives and Outcomes

As identified in the Offset Area Management Plan (RPS, 2016), the offset area provides for the long-term protection of habitat for seven threatened species and through the implementation of adaptive management practices the quality of the habitat will be improved and maintained over time. The offset area is to be protected in perpetuity as a Nature Refuge. The management plan objectives and outcomes are to:

- Protect all vegetation within the offset area from future clearing;
- Protect all fauna within the offset area from introduced weeds and pests;
- Protect the site vegetation and fauna from un-prescribed burn and wildfire;
- Maintain the ecological condition of remnant of-concern and least concern vegetation within the Offset area where the BioCondition Class is of 1 for each assessment unit does not change;
- Implement of a translocation plan based on the criteria and guidelines detailed in the *Guidelines for the Translocation of Threatened Plants in Australia* (Vallee et al, 2004). This should be developed to identify MNES plant species appropriate for relocation as well as target and recipient sites.

This ecological monitoring report presents the methods and results of the 2018 ecological monitoring program at the MEWF Biodiversity Offset Area, including a discussion of the findings and comparisons with the results of the baseline data conducted in 2016. Management recommendations that relate to the current monitoring phase are documented in **Section 4.0**.

### 1.2.1 Regional Ecosystems:

The RE's mapped for the offset site are described in **Table 1** and shown on the mapping in **Figure 2**. Baseline surveys in 2016 identified that RE mapping was consistent with ground-truthed vegetation assessments.

**Table 1 Regional Ecosystems Present Within the Proposed Offset Site**

| RE | RE Description | VMA[1] | Bio.[2] | Area[3] |
|---|---|---|---|---|
| 7.3.26a | *Casuarina cunninghamiana* (river oak) woodland to open forest on alluvium fringing streams. Occurs on channel benches, levees and terraces on deep loamy sands or sandy clay loams (often with loose surface gravel). (BVG1M: 16a). Vegetation communities in this regional ecosystem include: 7.3.26a: Riverine wetland or fringing riverine wetland. *Casuarina cunninghamiana*, *Eucalyptus tereticornis*, *Lophostemon suaveolens*, *Melaleuca leucadendra*, *M. fluviatilis*, *Buckinghamia celsissima*, *Mallotus philippensis* woodland and forest with an understorey of *Melaleuca viminalis* and *Bursaria tenuifolia*. Fringing forests of larger streams. (BVG1M: 16a). | OC | E | 2.63 |
| 7.12.7c | Simple to complex microphyll to notophyll vine forest, often with *Agathis robusta* (kauri pine) or *A. microstachya* (bull kauri). Granites and rhyolites of foothills and uplands, of the moist rainfall zone. (BVG1M: 5c). Vegetation communities in this regional ecosystem include: 7.12.7c: Simple notophyll semi-evergreen vine forest. Uplands of the dry rainfall zone. Rhyolite. (BVG1M: 5c). | LC | NCP | 1.24 |
| 7.12.9 | *Acacia celsa* (brown salwood) open forest to closed forest. Foothills, uplands and highlands on granites and rhyolites, of the very wet and wet rainfall zone. (BVG1M: 5d). | OC | OC | 1.16 |
| 7.12.16a | Simple to complex notophyll vine forest, including small areas of *Araucaria bidwillii* (Bunya pine). Uplands and highlands on granites and rhyolites, of the cloudy wet to moist rainfall zones. (BVG1M: 6b). | LC | NCP | 9.34 |
| 7.12.26a | *Syncarpia glomulifera* (turpentine) +/- *Corymbia intermedia* (pink bloodwood) +/- *Allocasuarina* spp. (sheoaks) closed-forest to woodland, or *Lophostemon suaveolens* (swamp mahogany), *Allocasuarina littoralis* (black sheoak), *C. intermedia* shrubland, (or vine forest with these species as emergents). Exposed ridgelines or steep rocky slopes, on granite and rhyolite. 7.12.26a: *Syncarpia glomulifera*, *Allocasuarina torulosa* and/or *A. littoralis* open-forest and woodland. Uplands and highlands, often on steep slopes, of the wet rainfall zone. Granite and rhyolite. (BVG1M: 28e). | LC | NCP | 4.41 |

| RE | RE Description | VMA[1] | Bio.[2] | Area[3] |
|---|---|---|---|---|
| 7.12.26e | *Syncarpia glomulifera* (turpentine) +/- *Corymbia intermedia* (pink bloodwood) +/- *Allocasuarina* spp. (sheoaks) closed forest to woodland, or *Lophostemon suaveolens* (swamp mahogany), *Allocasuarina littoralis (bla*ck sheoak), *C. intermedia* shrubland, (or vine forest with these species as emergents). Exposed ridgelines or steep rocky slopes, on granite and rhyolite. (BVG1M: 9d). Vegetation communities in this regional ecosystem include: 7.12.26e: *Syncarpia glomulifera* low open forest and low woodland. Uplands on steep rocky slopes, of the moist and dry rainfall zone. Granite and rhyolite. (BVG1M: 28e). | LC | NCP | 8.99 |
| 7.12.29a | *Corymbia intermedia* (pink bloodwood) and/or *Lophostemon suaveolens* (swamp mahogany) open forest to woodland +/- areas of *Allocasuarina littoralis* (black sheoak) and *A. torulosa* (forest sheoak). Uplands, on granite and rhyolite. (BVG1M: 9c). Vegetation communities in this regional ecosystem include: 7.12.29a: *Corymbia intermedia*, *Eucalyptus tereticornis*, *E. drepanophylla* open forest to low open forest and woodland with *Allocasuarina torulosa*, *A. littoralis*, *Lophostemon suaveolens*, *Acacia cincinnata*, *A. flavescens*, *Banksia aquilonia* and *Xanthorrhoea johnsonii*. Uplands, on granite and rhyolite. (BVG1M: 9c). | LC | NCP | 4.60 |
| 7.12.30d | *Corymbia citriodora* (lemon-scented gum) +/- *Eucalyptus portuensis* (white mahogany) woodland to open forest. Granite and rhyolite (often coarse-grained red earths and lithosols with much surface rock). (BVG1M: 10b). Vegetation communities in this regional ecosystem include: 7.12.30d: Open woodland to open forest (10-20m tall) mosaic with variable dominance, often including *Eucalyptus cloeziana*, *C. citriodora*, *E. portuensis*, *E. lockyeri*, *C. leichhardtii*, *E. atrata*, *E. pachycalyx*, *E. reducta*, *C. intermedia* and *E. shirleyi*. There is often a very sparse to mid-dense secondary tree layer of *C. abergiana* and/or *C. stockeri*. A very sparse to sparse tall shrub layer may be present and can include *Acacia flavescens*, *Persoonia falcata*, *Bursaria spinosa* subsp. *spinosa*, *Allocasuarina inophloia*, *Petalostigma pubescens* and *Grevillea glauca*. A sparse to dense lower shrub layer may include *Jacksonia thesioides*, *Acacia calyculata*, *Xanthorrhoea johnsonii* and *Grevillea glossadenia*. The ground layer may be dominated by species such as *Themeda triandra*, *Heteropogon triticeus*, *Mnesithea rottboellioides*, *Arundinella setosa*, *Cleistochloa subjuncea*, *Eriachne pallescens* var. *pallescens*, *Lepidosperma laterale* and *Xanthorrhoea johnsonii*.<br>Rocky slopes on granite and rhyolite. (BVG1M: 9d). | LC | NCP | 133.42 |

| RE | RE Description | VMA[1] | Bio.[2] | Area[3] |
|---|---|---|---|---|
| 7.12.34 | *Eucalyptus portuensis* (white mahogany) and/or *E. drepanophylla* (ironbark), +/- *C. intermedia* (pink bloodwood) +/- *C. citriodora* (lemon-scented gum), +/- *E. granitica* (granite ironbark) open woodland to open forest. Uplands on granite, of the dry rainfall zone. (BVG1M: 9d). | LC | NCP | 23.76 |
| 7.12.57a | Shrubland and low woodland mosaic with *Syncarpia glomulifera* (turpentine), *Corymbia abergiana* (range bloodwood), *Eucalyptus portuensis* (white mahogany), *Allocasuarina littoralis* (black sheoak) and *Xanthorrhoea johnsonii* (grasstree). Uplands and highlands on granite and rhyolite, of the moist and dry rainfall zones. (BVG1M: 9d). Vegetation communities in this regional ecosystem include: 7.12.57a: Shrubland and low woodland mosaic with *Syncarpia glomulifera*, *Corymbia abergiana*, *Eucalyptus portuensis*, *Allocasuarina littoralis* and *Xanthorrhoea johnsonii*. Uplands and highlands on granite and rhyolite, of the moist and dry rainfall zones. (BVG1M: 9d). | OC | OC | 58.60 |
| 7.12.57c | Shrubland and low woodland mosaic with *Syncarpia glomulifera* (turpentine), *Corymbia abergiana* (range bloodwood), *Eucalyptus portuensis* (white mahogany), *Allocasuarina littoralis* (black sheoak) and *Xanthorrhoea johnsonii* (grasstree). Uplands and highlands on granite and rhyolite, of the moist and dry rainfall zones. (BVG1M: 9d). Vegetation communities in this regional ecosystem include: 7.12.57c: Shrubland/low woodland (1.5-9 m tall) mosaic with variable dominance, often including *Eucalyptus cloeziana*, *Corymbia abergiana*, *E. portuensis*, *E. reducta*, *E. lockyeri*, *C. leichhardtii*, *Callitris intratropica*, *E. atrata*, *E. pachycalyx*, *E. shirleyi*, *E. drepanophylla* and *Homoranthus porteri*, on rhyolite and granite. There is occasionally a very sparse to sparse secondary tree layer of *C. abergiana* and/or *C. stockeri*. A very sparse to sparse tall shrub layer may be present and can include *Persoonia falcata*, *Exocarpos cupressiformis* and *Melaleuca viridiflora* var. *viridiflora*. A sparse to dense lower shrub layer may include *Jacksonia thesioides*, *Acacia calyculata*, *Coelospermum reticulatum*, *Xanthorrhoea johnsonii*, *Acacia humifusa*, *Dodonaea lanceolata* var. *subsessilifolia*, *Grevillea dryandri* subsp. *dryandri*, *Grevillea glossadenia*, *Acacia umbellata* and Ericaceae spp. The ground layer may be dominated by species such as *Themeda triandra*, *Xanthorrhoea johnsonii*, *Eriachne pallescens* var. *pallescens*, *Cleistochloa subjuncea*, *Borya septentrionalis*, and *Eriachne* spp. Includes open rocky dominated by herbs and grasses. This RE includes areas of 7.12.65k (rocky areas with shrubby/herbaceous cover) which are too small to map. Rocky slopes on granite and rhyolite. (BVG1M: 9d). | OC | OC | 107.32 |

| RE | RE Description | VMA[1] | Bio.[2] | Area[3] |
|---|---|---|---|---|
| 7.12.58 | *Eucalyptus reducta* woodland to open forest (6-18m tall). Common associated species include *E. granitica*, *Corymbia dimorpha*, *C. citriodora*, *E. cloeziana* and occasionally *C. intermedia*. There is often a sparse secondary tree layer of *C. abergiana* and/or *E. lockyeri*. There may be a very sparse tall shrub layer of species such as *Acacia flavescens*, *Persoonia falcata*, *Allocasuarina littoralis* and *Acacia simsii*, and a very sparse to dense lower shrub layer of *Acacia calyculata*, *Pultenaea millarii*, *Jacksonia thesioides*, *Grevillea glossadenia*, *Grevillea dryandri* subsp. *dryandri*, *Homoranthus porteri* and *Dodonaea lanceolata* var. *subsessilifolia*. The ground layer is often dominated by species such as *Themeda triandra*, *Eriachne* spp., *Cleistochloa subjuncea*, *Lomandra longifolia*, *Mnesithea rottboellioides*, *Xanthorrhoea johnsonii*, *Heteropogon triticeus* and *Coronidium newcastlianum*. Granite and rhyolite. (BVG1M: 9d). | OC | OC | 72.45 |
| 7.12.65k | Rock pavements or areas of skeletal soil, on granite and rhyolite, mostly of dry western or southern areas, often with shrublands to closed forests of *Acacia* spp. (wattles) and/or *Lophostemon suaveolens* (swamp mahogany) and/or *Allocasuarina littoralis* (black sheoak) and/or *Eucalyptus lockyeri* subsp. *exuta*. (BVG1M: 28e). 7.12.65k: Granite and rhyolite rock outcrop, of dry western areas, associated with shrublands to closed forests of *Acacia* spp. and/or *Lophostemon* spp. and/or *Allocasuarina* spp. In the Mount Emerald area, shrubs may include *Acacia umbellata*, *Melaleuca borealis*, *Homoranthus porteri*, *Leptospermum neglectum*, *Melaleuca recurva*, *Melaleuca uxorum*, *Grevillea glossadenia*, *Corymbia abergiana*, *Eucalyptus lockyeri*, *Sannantha angusta*, *Pseudanthus ligulatus* subsp. *ligulatus*, *Acacia aulacocarpa*, *Leptospermum amboinense*, *Xanthorrhoea johnsonii* and *Jacksonia thesioides*. Ground-cover species may include *Borya septentrionalis*, *Lepidosperma laterale*, *Eriachne* spp., *Cleistochloa subjuncea*, *Boronia occidentalis*, *Cheilanthes* spp., *Coronidium newcastlianum*, *Schizachyrium* spp., *Tripogon loliiformis*, *Gonocarpus acanthocarpus* and *Eragrostis* spp. Dry western areas. Granite and rhyolite. (BVG1M: 29b). | LC | OC | 7.03 |
| 9.5.8 | Woodland to open-woodland of *Eucalyptus cullenii* (Cullen's ironbark) and/or *E. leptophleba* (Molloy red box) +/- *Corymbia erythrophloia* (red bloodwood) +/- *Erythrophleum chlorostachys* (Cooktown ironwood). *Eucalyptus tardecidens* (box) may also occur as a subdominant in northern extent of this regional ecosystem. A sparse shrub layer includes *Petalostigma* spp., *Melaleuca* spp., *Grevillea* spp., *Alphitonia pomaderroides* and *Maytenus cunninghamii* (yellowberry bush). The sparse to dense ground layer is dominated by *Heteropogon contortus* (black speargrass) and *Sarga plumosum* (plume sorghum). Occurs on undulating plains in valleys in ranges on Tertiary/Quaternary soils overlying granite and metamorphic geologies. (BVG1M: 13a) | LC | NCP | 0.01 |

| RE | RE Description | VMA[1] | Bio.[2] | Area[3] |
|---|---|---|---|---|
| 9.5.9a | Woodland to open-woodland of *Corymbia clarksoniana* (Clarkson's bloodwood) and/or *Eucalyptus leptophleba* (Molloy red box) and/or *E. platyphylla*. A sparse to mid-dense shrub layer including *Melaleuca* spp., *Grevillea* spp., and *Planchonia careya* (cocky apple) can occur. The ground layer is dominated by *Themeda triandra* (kangaroo grass) and *Heteropogon* spp. Occurs on plains, undulating plains and outwash deposits and Tertiary to Quaternary locally consolidated high-level alluvium and colluvium. Major vegetation communities include:<br>9.5.9a: Woodland to open-woodland of *Corymbia clarksoniana* (Clarkson's bloodwood) +/- *Eucalyptus platyphylla* (poplar gum) +/- *E. leptophleba* (Molloy red box) +/- *C. tessellaris* (Moreton Bay ash) with a distinct to sparse sub-canopy layer often including *Melaleuca viridiflora* (broad-leaved paperbark), *Grevillea glauca* (bushman's clothes peg), *Petalostigma pubescens* (quinine) and *Alphitonia pomaderroides* (soapbush). An open to sparse shrub layer includes *Melaleuca* spp., *Persoonia falcata*, *Grevillea* spp. and *Petalostigma pubescens* (quinine). The sparse to mid-dense ground layer is dominated by *Themeda triandra* (kangaroo grass), *Aristida* spp., *Heteropogon contortus* (black speargrass), *H. triticeus* (giant speargrass), and *Sarga plumosum* (plume sorghum). Occurs on undulating plains. (BVG1M: 9e). | LC | NCP | |
| 9.12.7a | Woodland to low open-woodland of Eucalyptus cullenii (Cullen's ironbark) +/- Erythrophleum chlorostachys (Cooktown ironwood) +/- C. leichhardtii (yellowjacket) +/- Corymbia erythrophloia (red bloodwood). The mid-layer is generally absent but a subcanopy and/or shrub layer can occur. The ground layer is sparse to dense and dominated by Heteropogon contortus (black speargrass) and Themeda triandra (kangaroo grass). Occurs on predominantly felsic volcanic rocks, on rolling to steep hills. Major vegetation communities include:<br>9.12.7a: Woodland to open-woodland of *Eucalyptus cullenii* (Cullen's ironbark) +/- *Corymbia erythrophloia* (red bloodwood) +/- *Erythrophleum chlorostachys* (Cooktown ironwood) +/- *C. dallachiana* (Dallachy's gum). An open to mid-dense subcanopy can occur and includes a variety of species. The shrub layer is absent to open and dominated by *Maytenus cunninghamii* (yellowberry bush), *Alphitonia pomaderroides* (soapbush), *Petalostigma* spp., and *Acacia* spp. The ground layer is sparse to dense and dominated by *Heteropogon contortus* (black speargrass), *H. triticeus* (giant speargrass), *Themeda triandra* (kangaroo grass) and *Sarga plumosum* (plume sorghum) with a *Xanthorrhoea* sp. (grasstree) occurring in some areas. Occurs on rhyolite hills. (BVG1M: 13a). | LC | NCP | 0.01 |

| RE | RE Description | VMA[1] | Bio.[2] | Area[3] |
|---|---|---|---|---|
| 9.12.40 | Low open-woodland to low woodland of *Melaleuca citrolens* (scrub teatree) +/- *Terminalia platyptera* (yellow-wood) +/- *Corymbia dallachiana* (Dallachy's gum) +/- *Erythrophleum chlorostachys* (Cooktown ironwood). The sparse shrub layer consists of *Petalostigma banksii* (smooth-leaved quinine), *M. citrolens* and *Gardenia vilhelmii* (breadfruit). The ground layer is frequently bare, with patches of short grasses including *Eriachne* spp., *Aristida* spp. and *Schizachyrium* spp. (firegrass). This community also occurs as short open-tussock grassland wooded with low trees and shrubs of *Melaleuca citrolens* +/- *Terminalia* spp. Occurs on gentle slopes, footslopes, rolling hills and colluvial low slopes. (BVG1M: 21b). | LC | NCP | |
| Non-rem | Non-remnant: modified land, roads, clearings and tracks. | | | 0.08 |

[1] Status under Vegetation Management Act 1999: OC - Of Concern; LC - Least Concern.

[2] Biodiversity management status: E - Endangered; OC - Of Concern, NCP - No Concern at Present.

[3] Area - total area in hectares of RE type within offset site.

Conservation status of EVNT species: *Acacia purpureopetala* (CE - EPBC Act, V - NCA); *Grevillea glossadenia* (V- EPBC Act, V - NCA); *Homoranthus porteri* (V - EPBC Act, V - NCA); *Melaleuca uxorum* (E - NCA); *Plectranthus amoenus* (V - NCA); *Prostanthera albohirta* (CE - EBC Act, E - NCA); *Prostanthera clotteniana* (CE - EBC Act, E - NCA).

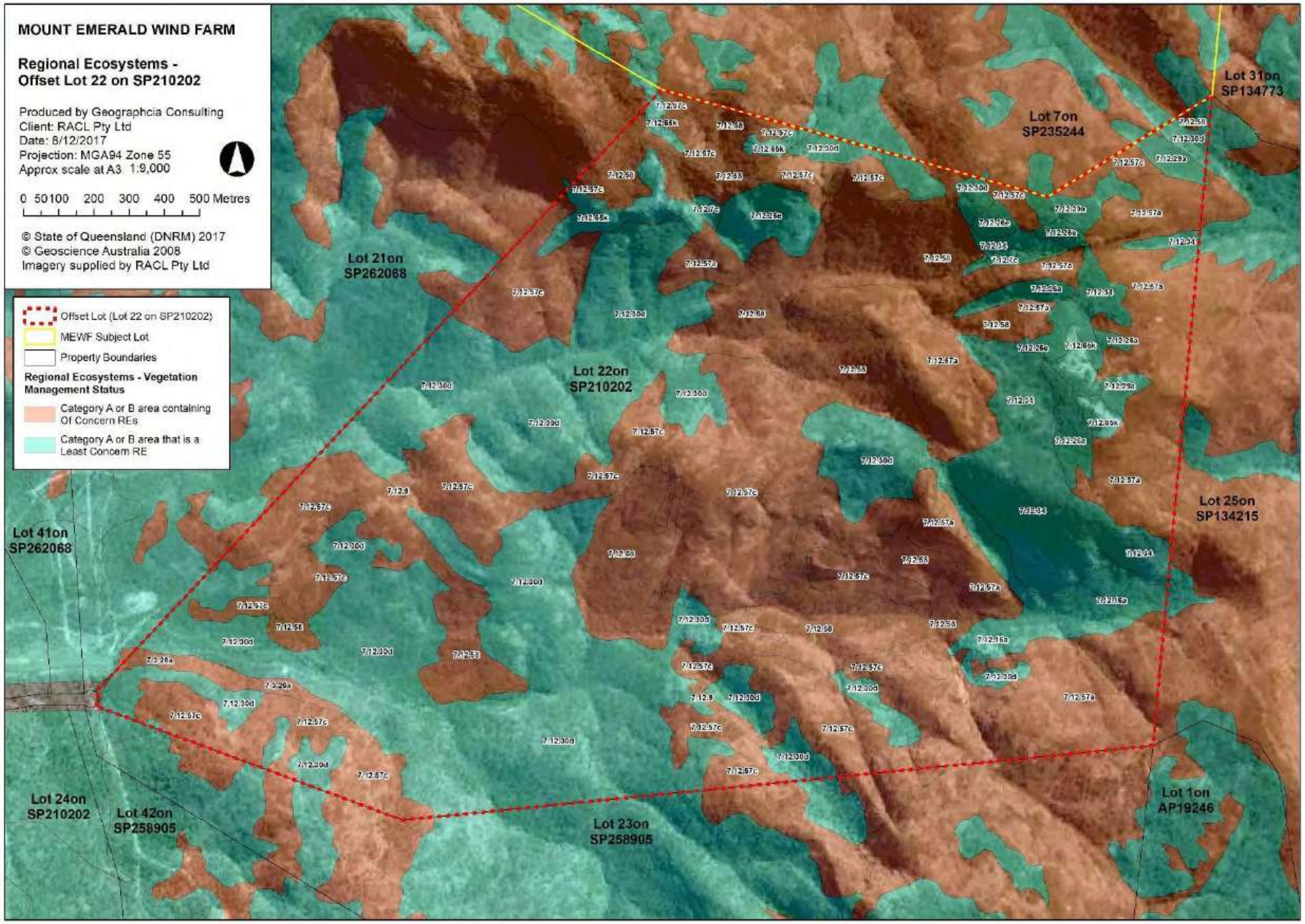


**Figure 2 MEWF Regional Ecosystems on Offset Lot**

# 2.0 Methods

The following sections detail the methods employed for the 2019 ecological offset area monitoring program. The methods employed as part of this monitoring program are consistent with those outlined in the MEWF Offset Area Management Plan (RPS, 2016).

Field surveys were conducted on site over six days between 26 February - 15 March 2019 with additional song meter surveys from the 25 March to the 11 April.

Total rainfall across the Mount Emerald range was recorded as 12 mm over that period. Minimum temperatures were 19.0°C and maximum temperatures were 32°C with the average nightly temperature falling to 19.7°C. Daily temperatures averaged 29.29°C. Wind speeds varied over the survey period with a minimum of 6 km/hr and a maximum 28 km/hr. Five days over the survey period resulted in calm winds. There was a mix of overcast and sunny days throughout the survey.

## 2.1 Targeted Fauna Surveys for Conservation Significant Fauna

### 2.1.1 Northern Quoll (*Dasyurus hallucatus*)

#### 2.1.1.1 Methods

**Camera Traps**

The most suitable method for determining the presence of Northern Quoll is by undertaking a Camera Trapping Survey. This method follows that of Eyre *et al* (2014). Survey sites replicated those of the 2016 surveys conducted by RPS (2016) and 4 Elements Consulting (2017) shown in **Figure 3**.

A total of 19 camera traps (Scout Guard Boly units) were used for the camera trapping survey. At each survey site a single camera trap was attached horizontally to the trunk of a tree with a 'dbh' (diameter at breast height) of at least 15 cm with a metal angle bracket, at ~1 m above the ground so the camera faced the ground. Directly beneath the camera, a bait holder, consisting of a Rain Harvesting ™ PVC toilet vent pipe cap with a 50 mm PVC pipe insert, baited with two chicken necks and a single hand rolled ball of general fauna bait (oats, honey and peanut butter) was affixed to the ground with a 30 cm, 5 mm diameter tent peg.

Each camera was set at the medium-level trigger sensitivity. All loose vegetation (e.g. grass stalks, forbs and shrub branches) within the field of view of each camera were removed to minimize false triggers. Camera traps were active for a minimum period of 14 days.

**Habitat Assessments**

Habitat assessments were conducted at each site.

Measurements of habitat variables were made. Parameters monitored:

- Evidence of fire;
- Nature and extent of erosion;
- Extent of weed species;
- Presence of feral animals;
- Type of groundcover;
- Structure and floristics of vegetation cover; and
- Number of habitat trees.

### 2.1.2 Spectacled Flying-fox (*Pteropus conspicillatus*)

#### 2.1.2.1 Methods

Diurnal searches for roosts and feeding signs were undertaken over a large proportion of the project site per Eyre *et al* (2014). Surveys followed meandering transects while completing camera trapping, and target surveys concentrated on regional ecosystems with a high likelihood of flowering myrtaceous species. A botanical assessment of the presence of feed trees and the percentage currently flowering (during this survey) across the site was undertaken by a qualified botanist.

Previously, survey efforts by both RPS (2016) and 4 Elements Consulting (2017 and 2018) have focused on foraging of Spectacled Flying-fox in suitable forage trees located during diurnal site traverse for nocturnal spotlighting efforts. This year, the survey effort relied solely on recording availability of forage trees as an indicator of habitat suitability for the Spectacled Flying-fox and nocturnal spotlighting was not conducted.

### 2.1.3 Bare-rumped Sheathtail Bat (*Saccolaimus saccolaimus nudicluniatus*)

#### 2.1.3.1 Methods

Four ultrasonic bat call detectors (SM4 Songmeter, Wildlife Acoustics) were placed across the site (**Figure 3**), to determine presence and species composition of bats within the Offset Site. The bat call detectors were programmed to turn on automatically at 6 pm each evening and record for a 12-hour period.

All call analyses were conducted by Kelly Matthews from Green Tape Solutions, Brisbane. Ms Matthews is a recognised expert on bat call analysis and has an extensive library of reference calls from the FNQ Bioregion.

Due to equipment malfunction and limitations the Bare-rumped sheathtail bat survey was temporally separated into two survey periods, the first survey period ran from 26 February until 18 March and encompassed sites SM2 and SM4. The second survey period ran from 25 March until 11 April and encompassed Site 12 and Creek site.

## 2.2 Targeted Weed Surveys

The weed assessment of the offset site concentrated on the access track from Lemontree Drive to the small clearing adjacent to a tributary of Oaky Creek. The entire length of the track was traversed on foot. Additional spot observations of weed presence in remnant, undisturbed vegetation was undertaken previously in 2016, 2017, 2018 and during the current survey effort.

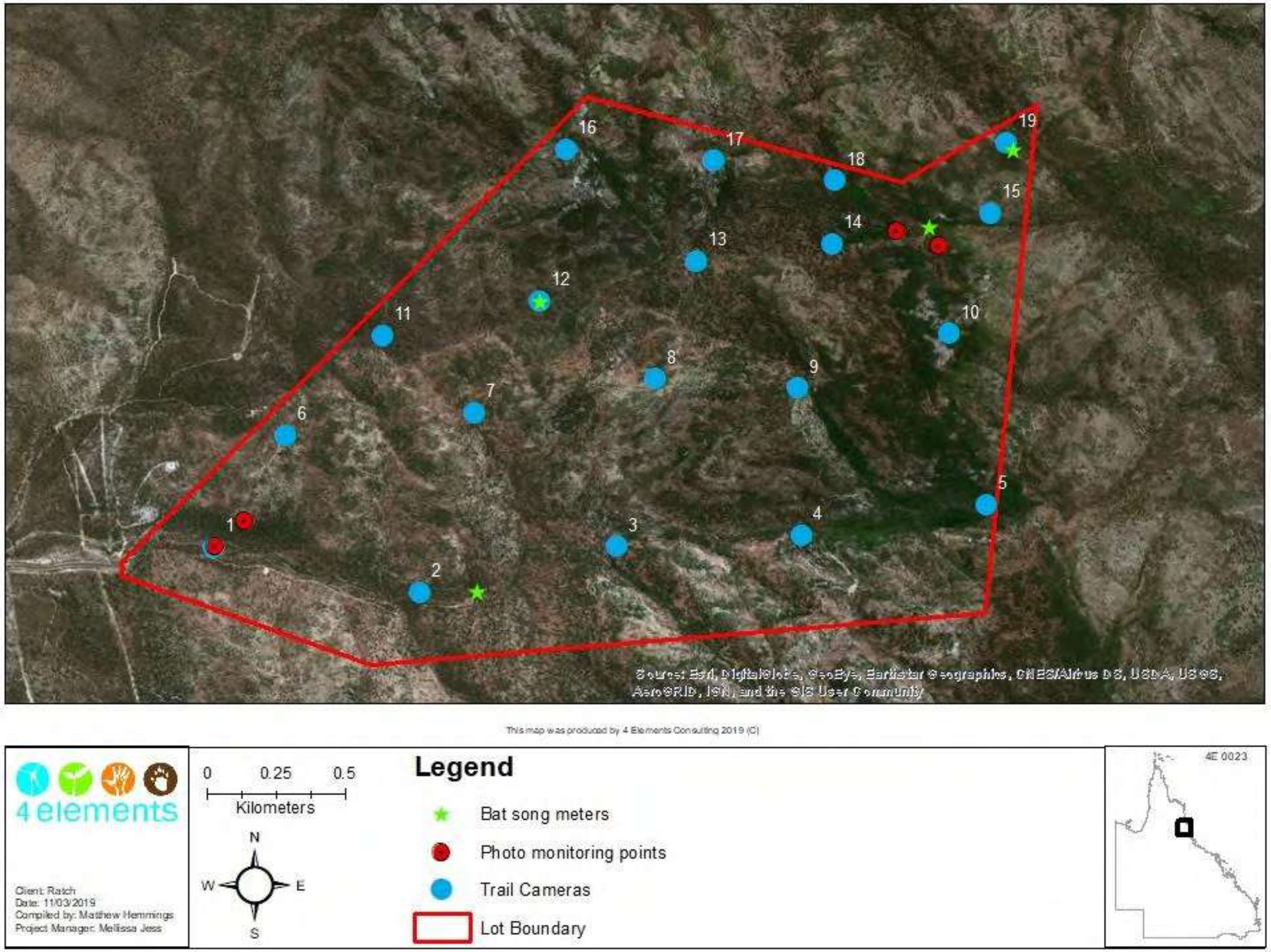


**Figure 3 Monitoring Points on Offset Lot**

## 2.3 Opportunistic Assessment

Fauna was monitored at 19 sites. Parameters monitored:

- Diurnal birds;
- Herpetofauna;
- Terrestrial mammals; and
- Threatened species presence.

## 2.4 Photo-monitoring Points

Four photo monitoring points were established within the offset area to enable a visual assessment of changes over time (**Figure 3**). Each point was:

- Marked with flagging tape and the GPS points recorded; and
- Photographed in north, south, east and west directions.

## 2.5 Pest Vertebrate Assessment

### 2.5.1 Camera Trap Locations

Secondary monitoring data was achieved from camera traps set at 19 Quoll monitoring traps (refer to **Section 2.1**). Pigs, feral dogs and cats are all known to be attracted to this bait.

Data collection included:

- Species identification (feral pigs and other animals);
- Number of each species;
- Age class of feral pigs; and
- Sex of feral pigs.

## 2.6 Results and Discussion

### 2.6.1 Northern Quoll

A total of 266 camera trap nights were conducted on the offset site and all units captured images. Northern Quolls were captured at 9 of the camera trap sites, and all animals showed evidence that they were in a healthy condition. A total of 12 Northern Quoll individuals were recorded during the current camera trapping survey and several quolls revisited the same site on multiple nights. While fewer individuals than the previous years' survey ( 4 Elements, 2018) this is not a substantial variation to other years. Individual quoll counts over the previous survey periods are presented in **Table 2**. A possible explanation for the lower individual quoll count is possibly due to the season in which quolls were surveyed. A higher number is expected to be recorded earlier in the breeding season (July 2018) as opposed to later in the season (September 2018) with males rapidly dying off after completion of their breeding season (Burnett *et al*, 2013). Additionally, the difference is quite small, and unlikely to be statistically significant.

**Table 2 Northern Quoll Annual Count Comparison**

| Year | Individual Quoll count |
|---|---|
| 2016 (RPS) | 13 |
| 2017 (4 Elements) | 10 |
| 2018 (4 Elements) | 16 |
| 2019 (4 Elements) | 12 |

Site 17 recorded the highest number (4) of individual Northern Quolls. The remainder of Quolls were detected at sites 1, 3, 4, 6, 7, 8, 13 and 14. This identifies that Northern Quolls in the current survey were distributed over a relatively large proportion of the offset site, which is likely due to the large extent of optimal habitat resulting from the extended wet season.


**Plate 1 Northern Quoll**

The Offset Site has maintained its integrity and the habitat was observed to be high quality with large refugial areas of rock outcrops, tree hollows and fallen logs for Northern Quoll. The seasonal creeks from the Mt Emerald massif have had sufficient water flow from the wet season, with an abundance of fish and crustaceans observed within the creek system.

### 2.6.2 Spectacled Flying-fox

Targeted diurnal search for the SFF habitat was undertaken across the entire site whilst conducting camera trapping surveys, however searches were concentrated in areas where vegetation was considered optimal for this species. No Spectacled Flying-foxes were observed in the current survey effort. As with the previous year, the lower creek lines were considered important as they contained fruiting Burdekin Plum (*Pleigynium timorense*) which is a food source for Spectacled Flying-foxes. Fruits from this species were small and not yet ripe. Furthermore, no Eucalypt species were observed as flowering on site which is counter to the previous years survey findings. As identified the OAMP (RPS, 2016) and 4 Elements (2017) foraging habitat is available across the offset site and is considered in moderate to high quality. It is highly likely each species will utilise the site widely when available vegetation is flowering.

### 2.6.3 Bare-rumped Sheathtail Bat (*S. saccolaimus*)

A total of 36 detector nights of microchiropteran bat call surveys were conducted within the project site between 26 February and 11 April 2019.

A total of nine microbat species were detected as a definite occurrence on the site. Four microbat species were identified to be probably occurring on site, whilst 2 species were identified as possibly occurring on site (**Table 3**).

The presence of Bare-rumped Sheathtail Bat (BRSB), listed as 'Endangered' under NC Act, and listed as 'Vulnerable' under EPBC Act, was analysed. AS in previous years this species could not be definitely confirmed due the similarity in call with sympatric species and overlap in their distribution. This species also presents a number of call variations which makes it difficult to confirm its presence using only echolocation techniques. However, a number of calls presented harmonics that were a highly probable match for BRSB. Based on previous confirmed records of this species within the locality in recent years, we would consider BRSB is highly likely to occur within the surveyed area (**Appendix A**).

Characteristic call attributes of BRSB include:

- A dominant harmonic with characteristic frequency around 22-25 kHz;

- At least three and up to five distinct harmonics at approximately 13 kHz intervals (1 below and up to 3 above the dominant harmonic); and
- Call pulses sometimes in "triplet" sets with pulse intervals of approximately 10-20 ms between first and second pulses and 20-40 ms between second and third pulses and an inter-triplet interval of about 80100 ms (**Appendix A**).

In both 2016 and 2017, probable calls were recorded at Site 19 which is the high altitude *Corymbia citriodora* (lemon scented gum) +/- *Eucalyptus portuensis* (white mahogany) woodland to open forest aspect of the site. Again, in this round of survey the Bat was a probable detection in the same location Site 19 and possibly Site 14 which is also a higher elevation site.

All bats identified on the site were expected to be present within the region. Bat activity levels at the site are considered to be similar compared to other surveys within similar areas in the surrounding region. A total of fifteen (15) species were recorded this year which is six (6) more species than were identified during the previous year's effort. Baselines surveys in 2016 recorded the lowest number with seven (7) species being recorded, therefore no trend can be concluded other than general microchiropteran bat diversity is relatively consistent on site. Weather conditions indicated low wind, and good insect availability due to relatively recent rains which provided ideal conditions for collecting bat call data during this survey period.

**Table 3** summarises the Call Analysis.

**Table 3 Summary of Call Analysis**

| Species | Status NCA | Status EPBC | Confidence |
|---|---|---|---|
| *Austronomus australis* | Least Concern | Not of Concern | Definite |
| *Chaerophon jobensis* | Least Concern | Not of Concern | Definite |
| *Chalinobus nigrogiseus* | Least Concern | Not of Concern | Definite |
| *Myotis macropus* | Least Concern | Not of Concern | Probable |
| *Miniopterus australis* | Least Concern | Not of Concern | Definite |
| *Miniopterus orianae oceanensis* | Least Concern | Not of Concern | Definite |
| *Mormopterus lumsdenae* | Least Concern | Not of Concern | Probable |
| *Mormopterus ridei* | Least Concern | Not of Concern | Definite |
| *Nyctophilus sp* | Least Concern | Not of Concern | Probable |
| *Saccolaimus flaviventris* | Least Concern | Not of Concern | Possible |

| Species | Status NCA | Status EPBC | Confidence |
|---|---|---|---|
| *Saccolaimus saccolaimus* | Endangered | Vulnerable | Probable |
| *Taphozous troughtoni* | Least Concern | Not of Concern | Possible |
| *Rhinolophus megaphyllus* | Least Concern | Not of Concern | Definite |
| *Vespadelus pumilus* | Least Concern | Not of Concern | Definite |
| *Vespadelus troughtoni* | Least Concern | Not of Concern | Definite |

## 2.7 General Fauna

A combination of camera trap surveys and opportunistic diurnal sightings resulted in 36 species being positively identified on site. One rodent and a *Eulamprys* skink could not be identified to species level. The 36 species identified comprised of 20 birds, 10 mammals, 5 reptiles, and one amphibian (Cane toad).

Bird species commonly observed in the current survey effort included honeyeaters such as Bridled and Yellow-faced honeyeaters. These species were not observed in the previous surveys. Other species commonly observed included the Rainbow bee-eater, Grey and Rufous fantail, Spotted and Striated Pardalotes and the Pale-headed Rosella. Raptors on site included the Black Kite (*Milvus Migrans*) and the Nankeen Kestral (*Falco cenchroides*).

The cryptic Mareeba rock-wallaby (*Petrogale mareeba*) was located on the mid to low mountain slopes at sites 3, 5, 14 and 16. This is an increase to the previous years' findings where this species was located only at site 14. The Echidna (*Tachyglossus aculeatus*) was identified at several locations across the site.

Five reptiles were identified. One reptile (water skink) could only be identified to genus level (*Eulamprus spp.)*. The remainder comprised the Eastern water dragon (*Intellagama lesueurii*), Freckled monitor (*Varanus tristis*), Lace monitor (*Varanus varius*) and Two-lined dragon (*Diporiphora bilineata*).

Several tadpoles were observed in the creeks and are believed to be the Bumpy Rocket frog (*Litoria inermis*).

A complete list of the fauna species identified on site is provided in **Appendix B**.

## 2.8 Baseline Bio-Condition Surveys

Bio-Condition monitoring was undertaken in April 2019. In the previous year a total of eight (8) sites were completed. This survey effort did not capture baseline measurements of all discreet remnant vegetation communities represented on the site. Therefore, a further effort was undertaken this year to include an additional ten (10) Bio-condition sites. This brings the combined total of Bio-condition sites to 18, which completes baseline collection all of the remnant vegetation communities that occur on the MEWF Biodiversity Offset Site. The next planned biennial assessment of all sites will continue from late in the wet season 2020. These sites were assessed using the Bio-Condition methodology (Eyre *et al* and Nelder *et al* 2017) and were all deemed to be in high ecological condition. These results are used to monitor for any changes in these communities across site in future annual monitoring. Full report is attached in Error! Reference source not found..

## 2.9 Weed Control

Several weeds were observed on the main access track from Lemontree Drive. A high proportion of mature invasive grasses were recorded along the access track growing with native grasses. The invasive grass species of concern were Grader Grass (*Themeda quadrivalvis*) and Rhodes Grass (*Chloris gayana*). Grader Grass is considered a priority weed species to be managed for the MEWF Offset Site. It is a prolific species and is quick to establish. It initially colonises disturbed areas such as vegetation clearing and track formation. This species, once established, has the potential to penetrate areas of undisturbed open woodland where it can outcompete native flora species and alter recruitment of native vegetation.

This infestation was removed (14 March 2019) by hand pulling all plants by carefully removing roots, leaf and seed material. This was then placed into large 80 L garbage bags and disposed of off-site. A total of five (5) 80 L garbage were filled with material during this process. A subsequent visit to the site after the wet season (in April) was required to remove any more exotic grasses that had matured in the moist soil.

Seveal broadleaf species of weeds were also identified along the access track from Lemontree Drive. These species are:

- Mint Bush (*Hyptis Sauveolens*)
- Wynn Cassia (*Chamaecrista rotundifolial)*
- Praxelis (*Praxelis clematidea*) and
- Common Stylo (*Stylosanthes guianensis)*

Selective targeted back-pack weed spraying was undertaken over several days to control these species. Herbicide used was Grazeon, which was diluted at a rate of 75ml herbicide/15litre water. A total of 90 litres Grazon mixture was used on the Lemontree Drive access track.

# 3.0 Pest Vertebrate Monitoring

The availability of freshwater pools throughout the site appears to have influenced the presence of large feral animals in the 2019 monitoring season. Evidence of pig (*Sus scrofa*) activity was found close to Site 9, Site 16 and Site 18. This included a recently constructed grass nest and some extensive foraging.

Feral pig observations are provided in **Table 4** below.

**Table 4 Evidence of Feral Pigs on Offset Site**

| Survey | Location | Species | Number |
|---|---|---|---|
| Rooting | Site | Pig | Unknown |
| Nesting | Site 19 | Pig | 1 |

**Plate 2 Evidence of pig rooting 14 March, 2019**

**Plate 3 Pig nest recorded 13 March, 2019**

Feral cats were camera trapped during the current survey period at sites 4, 11 and 17. This is likely to be from two individual cats.


**Plate 4 Feral Cat**

## 3.1 Photo Monitoring Points

A visual assessment was undertaken at four photo monitoring points. These locations were selected based on habitat quality, Regional Ecosystem attribute and location. **Table 5** below summarises the characteristics of these sites where photographs are oriented towards the North, South, East and West. Whilst the photo will aid in the broad structural comparisons over time, they are best used in combination with floristic data (Gleed, 2017) as they are unlikely to show fine scale changes on their own.

**Table 5 Photo Monitoring Points**

| Site ID | Description | Photograph from North, South, East, West | |
|---|---|---|---|
| **Photo Point 1**<br>Location :0327999, 8096486 | Mapped as RE 7.3.26a<br>Site only partially conforms to mapped RE absence of *Allocasuarina cunninghammii* in community however some key associates were present in canopy and shrub layer.<br>Alluvial sandy loam on riverine wetland.<br>Canopy of *Eucalyptus tereticornis*, *Corymbia Leichardtii* with a sparse shrub layer containing *Lophostemon grandiflorus*, *Bursaria tenuifolia*, *Exocarpus cupressiformis, Callitris intratropica, Acacia spp.* with a ground layer containing *Heteropogon triticeus*, *Sarga spp.* and *Themada triandra*.<br>Weeds present: *Stylo guianensis* | <br>North | <br>South |
| | | <br>East | <br>West |

| Site ID | Description | Photograph from North, South, East, West | |
|---|---|---|---|
| **Photo Point 2** Location: 0328099, 8096579 | Mapped 7.12.30d<br>Site conforms to RE containing dominant canopy and key lower level associates.<br>Rocky slopes on granite and rhyolite. Canopy *Eucalyptus cloeziana*, *Corymbia leichardtii* and Eucalyptus *crebra* with a very sparse shrub layer containing *Petalostigma pubescens, Coelospermun reticulatum, Persoonia falcata, Grevillea parrallela* and a ground layer containing *Heteropogon triticeus, Sarga spp.* and *Themada triandra*.<br>Weeds present<br>*Melenis repens* | <br>North | <br>South |
| | | <br>East | <br>West |

| Site ID | Description | Photograph from North, South, East, West | |
|---|---|---|---|
| **Photo Point 3** Location 0330501, 8097591 | Site conforms to RE 7.12.57a containing low open woodland to shrubland containing key canopy and lower level associates.<br><br>High uplands slopes on granite and rhyolite. Tall shrub/ low tree layer *Syncarpia glomulifera, Corymbia abergiana, Eucalyptus portuensis,*<br>*Eucalyptus crebra, Allocasuarina littoralis. Banksia aquilonia. Ground layer Xanthorrea johnsoni, Themeda triandra, Imperata cylindrical, Pteridium esculentum,* | <br>North | <br>South |
| | | <br>East | <br>West |

| Site ID | Description | Photograph from North, South, East, West | |
|---|---|---|---|
| **Photo Point 4**<br>Location: 0330355, 8097647 | Mapped as RE 7.12.16a<br><br>Site conforms to mapped RE containing simple to complex notophyll vine forest with emergent *Agathis microstachya* on granite and rhyolite in the uplands of the moist rainfall zone. | <br>North | <br>South |
| | | <br>East | <br>West |

# 4.0 Management Actions

## 4.1 Comparison to Previous Monitoring

Since the baseline monitoring collection in 2016 and previous years field investigations the conditions of the site have changed very little. The absence of fire improving the condition of some habitat on the site in combination with the availability of freshwater pools which has increased the availability of resources and mobility for some species. Fauna distribution and population of target species is very similar and although no statistical analysis could be undertaken, there was no indication of a population decline in Northern Quoll, Spectacled Flying-fox, or Bare-rumped Sheathtail Bat due to habitat impacts on the offset site.

## 4.2 Biodiversity Management Issues

Several minor biodiversity management issues were identified during monitoring. These include the state of the access track, and signs of feral pigs within the Biodiversity Offset Area.

### 4.2.1 Access Track

Since collection of baseline monitoring data in 2016, the conditions of access tracks within the Biodiversity Offset Site have been improved through the establishment of perimeter fencing. The tracks were however, showing signs of rill erosion, as well as disturbance by unauthorised vehicular access (primarily motorbikes). Unauthorised access by vehicles has not stopped with fencing however as the main entrance gate to the site remains unlocked. Several weeds have been identified on the access track, with particular concern - Grader grass (*Themeda quadrivalvis*). Manual and chemical control has resulted in a reduction of weeds on the access track however manual removal of any new weed growth will be ongoing. This management action will likely lead to the overall reduction of weeds on the access track.

### 4.2.2 Pest Species

The biodiversity offset area is considered to contain a low density of pest fauna species. Feral cats were recorded on site during the current survey effort and have been recorded on previous surveys. There is no evidence to suggest that feral cat presence on site has changed over time. Feral pig signs were recorded on site during the current and previous survey periods. On ground evidence of feral pigs reveals uprooting of vegetation and soil disturbance. Left unmanaged, these impacts can become severe. Aerial shooting and the MEWF pest management plan should target this offset site in the next round of pest management activities, particularly in the vicinity of Camera site 19 and the Mt Emerald proper area which backs onto the MEWF project.

Camera traps should be selectively used to record feral pig activity across the site. This will give an indication of the proportion of pigs which are impacting the habitat. The employment of bait stations will assist in obtaining more accurate records of feral pig visitation rates.

# 5.0 Summary

The ecological surveys undertaken in the MEWF offset site during 2019 provided the fourth round of annual monitoring data. The ecological monitoring surveys include information that will be used with weed survey information to fulfil obligations to include in the annual reporting required for the conservation agreement with DEE and DES. A total of three threatened species were recorded in the MEWF Offset site in 2019:

- Northern Quoll (*Dasyurus hallucatus*);
- Bare-rumped Sheathtail Bat (*Saccolaimus saccolaimus*).
- Spectacled Flying Fox (*Pteropus conspicillatus*)

Fauna habitat resources remain abundant within the MEWF offset site and the habitat is of high quality.

The site has a high density of the large hollows that several nocturnal birds of prey, bat and large mammal species require for breeding. In addition, small mammals (terrestrial and arboreal), which are the respective prey of a number of predatory species, were identified throughout the site. Canopy tree species and understorey shrubs within the site provide abundant foraging resources such as foliage, seeds, pollen, nectar and invertebrates for variety of species on a seasonal basis and may potentially influence the occurrence and abundance of arboreal mammal species and birds.

Groundcover has improved since baselines surveys due to increased rainfall and rehabilitation since a fire event therefore small reptiles and amphibians have increasingly utilised a wider distribution of the offsets site.

Feral pigs are evident on the site and are at a stage that management actions require appropriate measures.

Weed surveys indicated there are currently no priority listed weed species on site, however vigilance will be required along the access track and road entry to ensure there are no access points for these threats. Continued management measures to remove weeds from tracks and external site boundaries will reduce the risks significantly.

The ecological condition of the MEWF Offset site has been maintained since baselines surveys were conducted in 2016.

# 6.0 References


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# Appendix A Bat Call Analysis Report

Greentape Solutions – 31/05/2019

# Appendix B Biocondition Report

# Appendix C Fauna List

A summary of species identified during survey on the MEWF Offset Site

| Species | Common Name |
|---|---|
| **Bird** | |
| *Milvus migrans* | Black kite |
| *Coracina novaehollandiae* | Black-faced cuckoo shrike |
| *Bolemoreus frenatus* | Bridled honeyeater |
| *Lichmera indistincta* | Brown honeyeater |
| *Eudynamys orientalis* | Eastern koel |
| *Rhipidura albiscapa* | Grey fantail |
| *Dacelo novaeguineae* | Laughing kookaburra |
| *Myiagra rubecula* | Leaden flycatcher |
| *Meliphaga lewinii* | Lewins honeyeater |
| *Colluricincla megarhyncha* | Little shrike-thrush |
| *Falco cenchroides* | Nankeen kestral |
| *Platycercus adscitus* | Pale-headed Rosella |
| *Merops ornatus* | Rainbow bee-eater |
| *Rhipidura rufifrons* | Rufous fantail |
| *Chalcites lucidus* | Shining bronze-cuckoo |
| *Dicrurus bracteatus* | Spangled drongo |
| *Pardalotus punctatus* | Spotted pardalote |
| *Lalage leucomela* | Varied triller |
| *Hirundapus caudacutus* | White-throated needletail |
| *Caligavis chrysops* | Yellow faced honeyeater |
| **Terrestrial Mammal** | |
| *Trichosurus vulpecula* | Common Brushtail Possum |
| *Felis catus* | Feral Cat |
| *Uromys caudimaculatus* | Giant white-tailed rat |
| *Petrogale mareeba* | Mareeba rock-wallaby |
| *Isoodon macrourus* | Northern brown Bandicoot |
| *Dasyurus hallucatus* | Northern Quoll |
| *Melomys cervinipes* | Fawn-footed Melomys |

| Species | Common Name |
|---|---|
| | Rodent sp |
| *Tachyglossus aculeatus* | Short-beaked Echidna |
| **Microbats** | |
| *Austronomus australis* | White-striped free-tailed bat |
| *Chaerophon jobensis* | Northern freetail bat |
| *Chalinobus nigrogiseus* | Hoary wattled bat |
| *Myotis macropus* | Large-footed myotis |
| *Miniopterus australis* | Little bent-wing bat |
| *Miniopterus orianae oceanensis* | Eastern bent-wing bat |
| *Mormopterus lumsdenae* | Northern free-tailed bat |
| *Mormopterus ridei* | Ride's Free-tailed Bat |
| *Nyctophilus sp* | Long-eared bat |
| *Saccolaimus flaviventris* | Yellow-bellied sheathtail bat |
| *Saccolaimus saccolaimus* | Bare-rumped sheathtail bat |
| *Taphozous troughtoni* | Troughton's sheathtail bat |
| *Rhinolophus megaphyllus* | Eastern horseshoe-bat |
| *Vespadelus pumilus* | Eastern forest-bat |
| *Vespadelus troughtoni* | Eastern cave bat |
| **Reptile** | |
| *Intellagama lesueurii* | Eastern water dragon |
| *Varanus tristus* | Feckled Monitor |
| *Varanus varius* | Lace Monitor |
| *Diporiphora bilineata* | Two-lined dragon |
| *Eulamprus sp.* | Water Skink |

## C. MEWF OFFSET AREA MONITORING PROGRAM REPORT 2019