Appendix 17

Population Viability Analysis of Northern Quoll (*Dasyurus hallucatus*) populations in far north Queensland

Prepared by University of the Sunshine Coast

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Report Compiled by

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Executive Summary

- Population viability modelling of the quoll population occupying the Mt Emerald site was undertaken using RAMAS GIS V5. This exercise modelled the likelihood of extinction of the Mt Emerald quoll population under three scenarios, ranging from no change in mortality rate up to a 10% increase in mortality.
- PVA modelling reveals the high susceptibility of northern quoll populations to increased extinction risk with even modest increases in extrinsic mortality. The results suggest that an increase in local mortality as low as 2.5% results in a greater risk of extinction of the population and a 10% increase in local mortality may lead to localized extinction of the Mt. Emerald population within 20 years.
- Without knowing the nature and extent of impacts on quolls from the MEWF project it isn't possible to quantify the level of impact on population viability, however it is clear that any activity which results in any additional mortality of quolls will threaten the Mt Emerald population.
- The strength of the models run during this study is compromised by a lack of data on extent of dispersal into and out of the Mt Emerald population, and by the fact that various elements of the model input data are based on non-local, published data which are not necessarily indicative of far north Queensland population dynamics.
- Further, field derived data from the far north Queensland metapopulation is required

in order to examine *D. hallucatus* population viability at a range of spatial scales and to effectively model metapopulation dynamics.

Introduction

The northern quoll (*Dasyurus hallucatus)* is one of four quoll species) endemic to Australia (Braithwaite and Griffiths, 1994; Hill and Ward, 2010). *Dasyurus hallucatus* once occurred across northern Australia, however, much of their distribution range has contracted with substantial habitat fragmentation also occurring throughout the species range (Braithwaite and Griffiths, 1994; Pollock, 1999; Woinarski and Hill, 2012; Woinarski *et al*., 2008). Habitat destruction and urban development are considered one of the main threats for *D. hallucatus*, with habitat fragmentation also leading to a range of secondary threats including increased vehicle mortality and predation by introduced species (Hill and Ward, 2010). Several studies have also suggested that the species is declining at a rapid rate in association with the spread of the introduced Cane Toad *Rhinella marina* (Burnett, 2012; Woinarski *et al*., 2008). Although *D. hallucatus* is listed as Least Concern in Queensland under the Nature Conservation Act 1992 (Queensland Government, 1992), it is listed as nationally Endangered under the Environment and Biodiversity Conservation Act 1999 (Australian Government, 1999).

Due to the proposed development of Mt. Emerald Wind Farm (MEWF) in the northern Atherton Tablelands, Far North Queensland , the University of the Sunshine Coast (USC) has been commissioned to undertake simulation modeling and population viability analysis (PVA) of *D. hallucatus* in the region. Simulation modelling and population viability analysis (PVA) are extremely useful tools for the management of threatened species at the landscape scale (Akcakaya, 2000b; Baguette and Schtickzelle, 2003; Brook *et al.*, 2000). PVA provides a systematic approach to evaluate short and long-term risks of decline or extinction associated with the effects of extrinsic ecological processes of a target species based on species-specific data (Akcakaya, 2000a; Conroy, 2012; Matsinos and Papadopoulou, 2004). Although simulation modelling has limitations in predicting absolute estimates of extinction risks due to uncertainties that arise during model formulation and data parameterization, they are considered to be useful to assess simple population dynamics and to compare the impacts of differing management options or risk factors upon these population dynamics (Conroy, 2012; Driscoll *et al.*, 2010; Freckleton *et al.*, 2008; Lindenmayer *et al.*, 2003).

This report aims to undertake population viability modeling of *D. hallucatus* populations at several spatial scales in order to assess the potential impacts associated with the construction and operational phases of the proposed MEWF. Specifically, this report aims to investigate whether access and construction of the MEWF affects the survival probability of *D. hallucatus* populations in the Mt. Emerald quoll area. Due to lack of landscape level population and distribution data throughout far north Queensland and beyond, it is not possible to undertake PVA at scales beyond the Mt Emerald site scale.

Methods

Demographic data collection

Population viability models were developed using population and life history data for northern quolls. Some north Queensland specific data were obtained during this study, and other data were inferred or extrapolated from published data from other regions of Australia. Data specific to the quoll study population were collected via camera- and cage-trapping from Mt. Emerald and adjacent quoll sub-populations (Burnett, Shimizu and Middleton 2013), between July and September, 2012 (Figure 1). Data generated from this study included information pertaining to population abundance, gender and age breakdown, and population density in the study area. Some of the parameters required for the PVA model were not able to be collected in the field due to time and logistical constraints. Gender and age-specific survivorship and mortality, and reproductive information were therefore sourced from the published literature (e.g. Burnett 2012; Oakwood, 2000, 2002). In addition, the short duration of field work for this project meant that we could not construct spatially explicit models that incorporate metapopulation dynamics and dispersal. Reliable data for these aspects was also unavailable from published sources, and as such the PVA models utilized do not examine a range of spatial scales and focus purely on the Mt Emerald population.

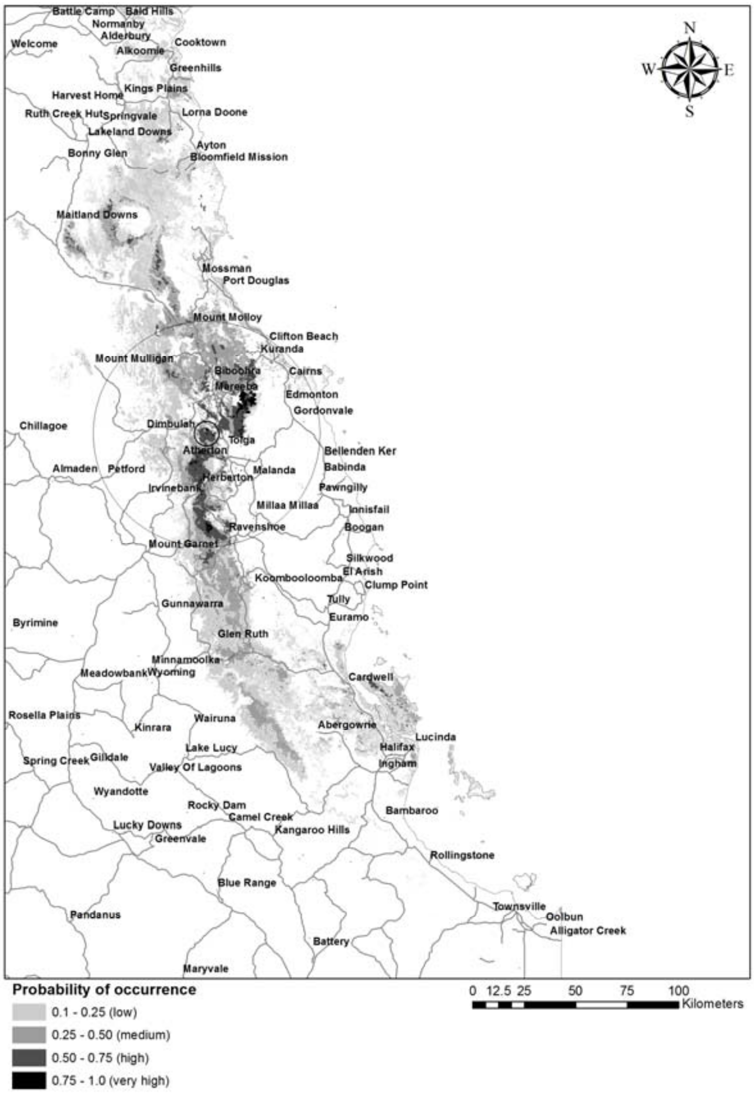


Figure 1: Map of the study region. The Mt Emerald area is indicated within the smaller circle, while the larger circle indicated areas within a 55km radius. The probability of D. *hallucatus* occurrence, based on Maxent habitat suitability modeling is indicated with shading (see legend)(see Burnett, Shimizu and Middleton 2013 for details of MaxEnt modelling).

Life history data, model parameterization and stochastic population modelling

The development of a PVA model requires the establishment of age specific life-history parameters for each sex. For females, twenty four life-history stages (at monthly time-steps) were tabulated, with 12 life-history stages identified for males, which typically die after one year of age (Appendix 1). Broad age classes used were pouch young for both sexes (first 2 steps/months), den young for both sexes (4 steps), adult male stages (6 steps comprising 4 distinct survival rates) and adult female stages (18 steps and 4 survival rates), respectively (Appendix 1); Burnett, 2012; Hill and Ward, 2010; Oakwood, 2000). Based on published data (Oakwood, 2000), the field data collected here, and the advice of experts (Martin Fingland, Geckoes Wildlife Presentations and Lynda Veyret Territory Wildlife Park), assumptions were made that (1) second year females do not contribute to reproduction in the wild, and (2) the number of females that live up to three years is negligible.

Survival rates and fecundity

Stage-transition survivorships for pouch young (S_p) and den young (S_i) were estimated using mortality data published in Oakwood (2000), as were the first-year adult female stage-transition survivorships (S_{f1}, S_{f2}, and S_{f3}; Table1). The adult female survival rate after second breeding (S_{f4}) was set to a negligible background rate to reflect the assumption that these females will not contribute reproductively in a third breeding season and will not survive beyond that year (Table1). As no field or published data was available for adult male survival rates between 7 to 9 months (S_{m1}), available pooled female survivorship data was also used for males between these time steps (Table 1).

Adult male mortality is known to be higher during both pre-mating and the mating period (10 to 11 months), due to higher incidence of fatalities by misadventure as males become muchmoreactive and mobile during this time. Oakwood (2000) states that mean home range of males can be expanded to as much as 1198ha from their normal mean range size of 99ha during this period. As no data has been published on adult male mortality during the 10 -11 month period (S_{m2} and S_{m3}), information on the number of monthly road-kill deaths for *D. hallucatus* was used to estimate stage-specific transition survivorship of S_{m2} and S_{m3} (Oakwood 2000, Table1). For adult male mortality at 12 months (S_{m4}), an assumption was made that the overall survival rate is 0.001 (negligible survival rate after one year, Table1). Unless specified, each monthly stage-transition survivorship was calculated using the following formula to convert longer (pooled) survivorship periods into monthly survivorships':

$$S_m = S_t^{1/m}$$

Where S_m is the monthly survival rate, S_t is the total survival rate over a specific period, and m is the number of months that the total survival was based on.

Fecundity values (number of males born to each first year female (F_{m1}) and number of females born to each first year female (F_{f1}) were calculated using the mean *D. hallucatus* litter sizes and offspring sex ratio from published data (Oakwood, 2000).

Model structure

In order to create a baseline PVA for the Mt Emerald population, the life-history table and parameters therein were used to construct a spatially explicit, stochastic, stage-based matrix model in RAMAS GIS version 5.0 (Akcakaya, 2005; Appendix 2). Density dependence (*DD*) was implemented to affect all vital rates using a scramble model. This ensures that simulated population densities remained within biologically realistic bounds. Environmental and demographic stochasticity were activated and set to lognormal with a within-population correlation on fecundities, survivorships and carrying capacity (*K*). Dispersal was set to nil due to lack of dispersal data. However, it should be noted that genetic analyses have shown substantial gene flow between populations of *D. hallucatus* within a 55km radius of the Mt. Emerald region (Conroy and Lamont, 2013). As such, the lack of dispersal data is a limitation of the model and its omission will most likely lead to an overestimation of extinction probabilities.

Population-specific parameter values

The spatial location and boundaries of the Mt. Emerald population were incorporated into the model structure (UTM; Datum: GDA1994 UTM Zone 55). Initial abundance of *D. hallucatus* in Mt. Emerald local area was estimated from field data (Burnett, Shimizu and Middleton 2013). The initial abundance value was then divided using the following gender breakdown ratio (proportion) based on field observations: 0.49 male (at 11months):0.49 female (at 11months):0.02 female (at 23months, Burnett *pers comm*. 2013). Carrying capacity (*K*) was estimated using the area of extent of Mt. Emerald and calculated population densities based on terrain information

Population viability analysis (PVA)

The potential impacts associated with the construction and operational phases of the proposed Mt. Emerald Wind Farm (MEWF) on the population viability of *D. hallucatus* in the Mt Emerald local area are unknown. As such, hypothesized impacts were examined in order to explore possible thresholds where population viability may be affected. To this end, customized PVA models were used to assess the potential impacts of increased mortality on population viability of *D. hallucatus* population in Mt. Emerald local area. Each model was run for 1000 replications with a 360-month time interval (30 years, 2013 – 2043) under the following simulation scenarios:

- Baseline – This simulation scenario used only the baseline matrix to examine population viability with no impacts occurring from the proposed development throughout the duration of the simulation period (30 years, 2013 – 2043).
- Simulation 1: Increased mortality (2.5%) – This simulation scenario examines the effect of a 2.5% increase in *D. hallucatus* mortality in all stages throughout the simulation period.
- Simulation 2: Increased mortality (5%) – This simulation scenario examines the effect of a 5% increase in *D. hallucatus* mortality in all stages throughout the simulation period.
- Simulation 3: Increased mortality (10%) – This simulation scenario examines the effect of a 10% increase in *D. hallucatus* mortality in all stages throughout the simulation period.

Carrying capacity (*K*) was set as default in all of the aforementioned simulation scenarios. This is justified because the areas expected to be cleared for the development of MEWF are only 0.4% (approximately 45ha) of the total Mt. Emerald local area. As such, given the current population abundance and estimated average population density, it is unlikely that the MEWF development would directly affect the carrying capacity of the site.

PVA data analysis and sensitivity analysis

Viability of the *D. hallucatus* population in the Mt. Emerald local area under each simulation model was assessed using expected minimum abundance (EMS) at the 30th year by averaging the abundance during the last 12 monthly time-steps of the simulation (McCarthy and Thompson, 2001). The proportional change in population size (Appendix 4) was calculated in order to examine any changes in population abundance within the PVA model duration. Expected minimum abundance of each simulation model was then compared using the non-parametric Kruskal-Wallis test to examine any differences in EMS between the models. The models were then compared against the baseline model using the non-parametric Mann-Whitney U test to examine any differences in EMS that may be ascribable to differences in the model-specific mortality rates. A probability of extinction curve was also presented for each simulation model to evaluate short and long-term risks of decline or extinction of the *D. hallucatus* population under the projected scenarios.

To validate model parameterization, a sensitivity analysis was performed on all baseline model parameters except for S_{m4} and S_{f4} stage. These parameters were excluded because they have negligible values (Table 1). Each parameter was modified to 10% above and 10% below their original baseline value, and the model was run for a 360-month simulation period with 1000 replicates. For each simulation, the resulting proportional change in final population abundance averaged over the last 12months period of simulation was calculated (Appendix 4).

Results and Discussion

All models predicted that the *D. hallucatus* population at the Mt. Emerald site will decline in abundance over the next 30 years regardless of the simulation scenario tested (level of increased mortality). On average, the population is predicted to decline by 47.17% under the baseline (no impact) scenario, 64.15% under simulation1, 98.11% with simulation 2, and 99.92% with simulation 3 by 2043 (Table 2). It is likely that these absolute values are in error, however the trend of significantly higher extinction risk as a result of elevated mortality rates are relevant to this discussion.

Table 2: Mean population size for the last 12 monthly time-steps of the *D. hallucatus* PVA model duration, and the proportional change in EMS (population size) relative to initial population size for all simulation models.

Scenario Mortality	Baseline Baseline		Simulation 1 2.5%+		Simulation 2 5%+		Simulation 3 10%+	
	EMS	*% Change*	*EMS*	*% Change*	*EMS*	*% Change*	*EMS*	*% Change*
D. hallucatus Mt. Emerald population (Initial *N*=53)	25	-47.17	19	-64.15	1	-98.11	0.04	-99.92

The expected minimum abundance (EMS) of the Mt Emerald population at the 30th year ranged from 25 to 0 (Table 2, Figure 2). Results of the non-parametric Kruskal-wallis test indicate a statistically significant difference in EMS when all scenarios were compared en masse (H=40.49, $p<0.01$), with a mean rank of 39.00 for the Baseline, 34.00 for simulation1, 18.50 for simulation2, and 6.50 for simulation 3. Further interrogation of the data with the Mann-Whitney U test revealed a statistically significant difference in EMS between the baseline and simulation 2 and 3 (Simulation 2, U<0.001, $p<0.01$; Simulation 3, U<0.001, $p<0.01$). The probability of extinction curves suggest that, under any simulation scenarios, the probabilities of quasi-extinction at the end of the PVA simulation duration are expected to be greater than 80% (Figure3). The figure also suggests that increased local mortality rate at 10% would severely affect the population viability and, the population is predicted to become extinct in approximately 20 years (Figure 3.1, 3.2).

Average final abundance of *D. hallucatus* in Mt. Emerald

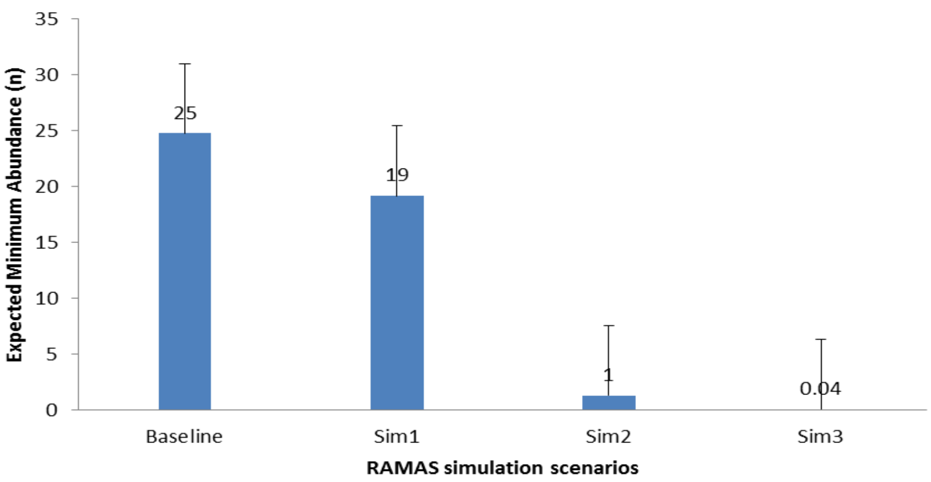
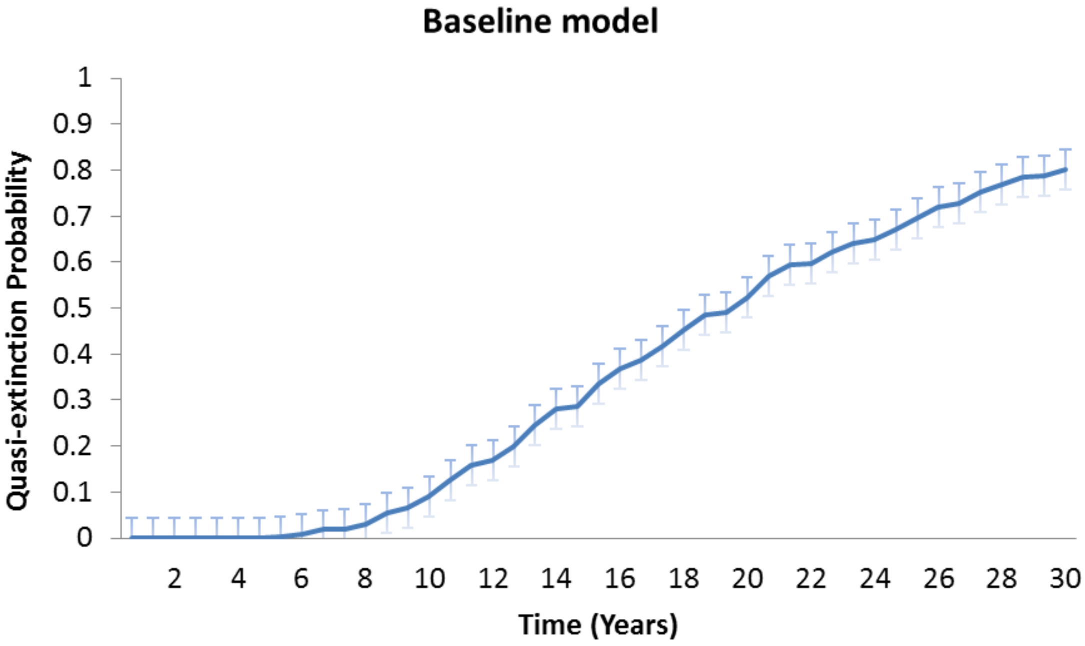


Figure2: Variation in expected minimum abundance for baseline and simulation scenarios (increased mortality). Error bars are 95% confidence intervals (CIs) averaged over 1000 replications. Sim1 was modelled with 2.5% increase in mortality, Sim2 with 5% increase in mortality, and Sim3 with 10% increase in mortality across all stages.



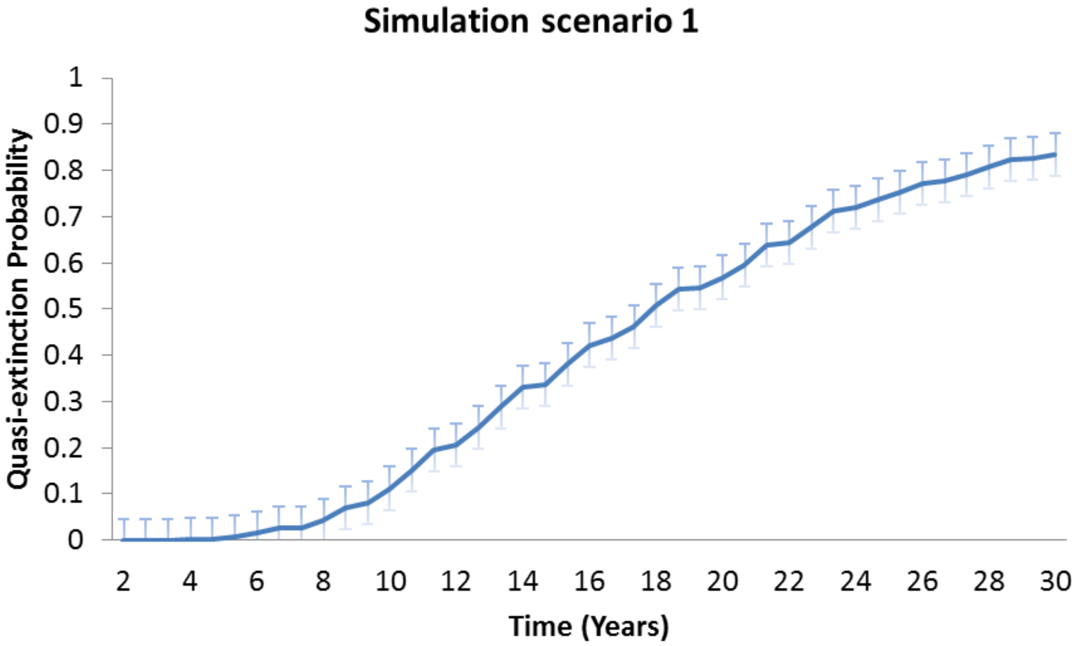
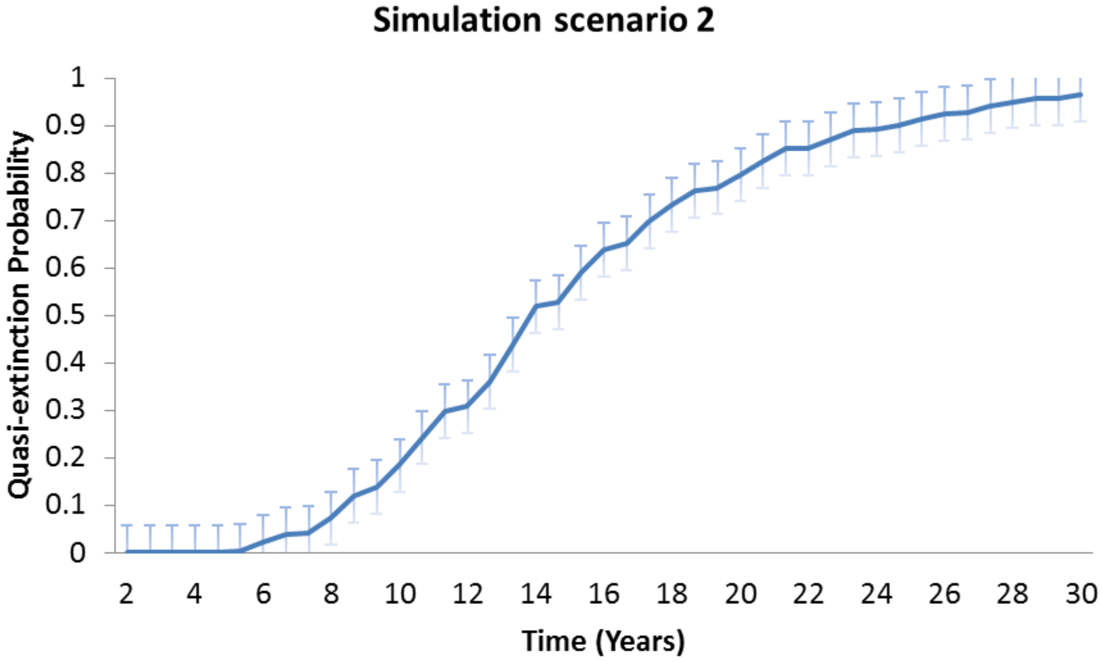


Figure3.1: Quasi-extinction probability curves for *D. hallucatus* population in Mt. Emerald throughout the 360 monthly-time step (30 year) period under the Baseline scenario and simulation scenario 1 (2.5% increase in mortality). Error bars are 95% confidence intervals (CIs) averaged over 1000 replications.



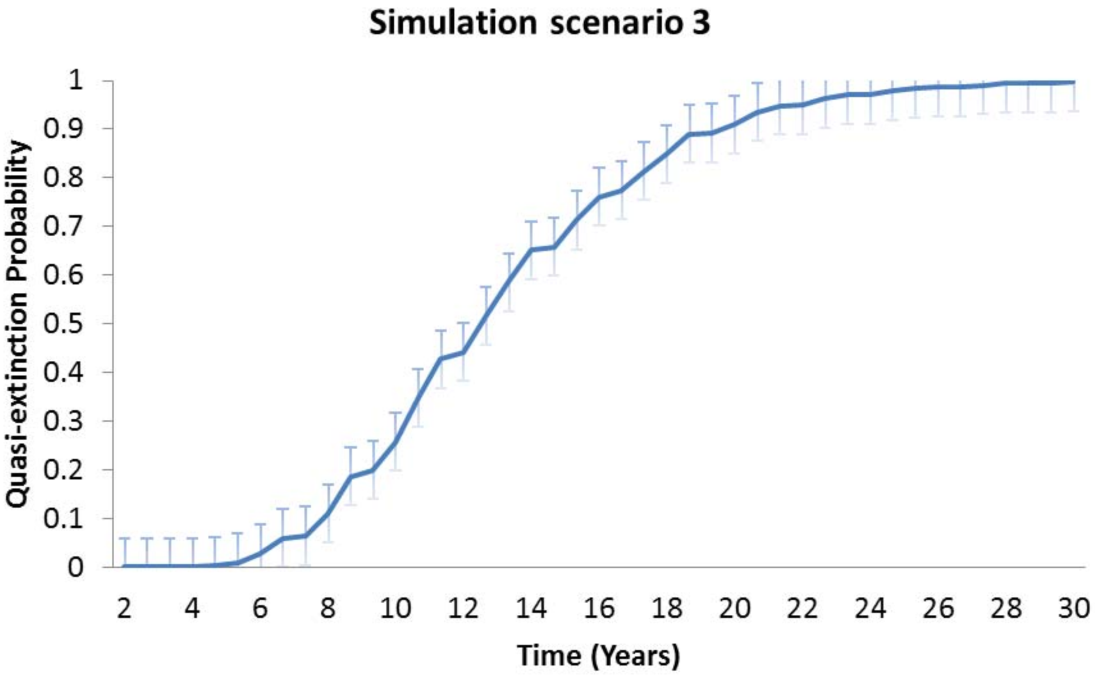


Figure 3.2: Quasi-extinction probability curves for *D. hallucatus* population in Mt. Emerald throughout the 360 monthly-time step (30 year) period under the simulation scenario 2 (5% increase in mortality) and simulation scenario 3 (10% increase in mortality). Error bars are 95% confidence intervals (CIs) averaged over 1000 replications.

Conclusions

Although the absolute values for extinction probability are likely to be exaggerated, the trends, towards significantly lower final population sizes and increased extinction risk from minor increases in mortality. This suggests that even relatively minor impacts resulting from the MEWF project could impact the viability of the Mt Emerald quoll population.

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Appendices

Appendix 1: Annual life history cycle of *D. hallucatus* used to generate PVA models; where S_p, survival rate of pouch young; S_i, survival rate of den young; S_{m1}, adult male survival between 7-9 months; S_{m2}, adult male survival in 10^{th} month; S_{m3}, adult male survival in 11th month; S_{m4}, adult male mortality during 12th month; S_{f1} adult female survival rate between 7-11 months; S_{f2},adult female survival rates between 12-18 months; S_{f3}, adult female survival rates between 19-23 months; S_{f4}, adult female survival rate after 24 months; F_{m1}, number of males born to each first year female; F_{f1}, number of females born to each first year female.

Time step (month)	1 (13)	2 (14)	3 (15)	4 (16)	5 (17)	6 (18)	7 (19)	8 (20)	9 (21)	10 (22)	11 (23)	12 (24)
Stage classes	Pouch young	Pouch young	Den young	Den young	Den young	Den young	Adult	Adult	Adult	Adult	Adult (Mating)	Adult (Death)
Survivorship (shared)	S_p	S_p	S_j	S_j	S_j	S_j						
Male	-	-	-	-	-	-	S_{m1}	S_{m1}	S_{m1}	S_{m2}	S_{m3}	S_{m4}
Females 1st year	-	-	-	-	-	-	S_{f1}	S_{f1}	S_{f1}	S_{f1}	S_{f1}	$F_{m1}/F_{f1}/S_{f2}$
Females 2nd year	S_{f2}	S_{f2}	S_{f2}	S_{f2}	S_{f2}	S_{f2}	S_{f3}	S_{f3}	S_{f3}	S_{f3}	S_{f3}	S_{f4}

Appendix 2: Demographic information for *D. hallucatus* populations in the far north Queensland region derived from the results of this study.

Population-specific data	Unit	
Location	UTM	328802, 8101815
Initial Abundance	n	53
Gender breakdown:	n	
Male (11 month)		26
Female 1st year (11 month)		26
Female 2nd year (23 month)		1
Area of Extent	Ha	11486
Population density	Ha	1.66/100ha
Carrying Capacity (K)	n	190

Appendix 3: Values of each life history stage of *D. hallucatus* used to generate the baseline (natural survivorship levels) matrix model.

Time step (month)	1 (13)	2 (14)	3 (15)	4 (16)	5 (17)	6 (18)	7 (19)	8 (20)	9 (21)	10 (22)	11 (23)	12 (24)
Stage classes	Pouch young	Pouch young	Den young	Den young	Den young	Den young	Adult	Adult	Adult	Adult	Adult (Mating)	Adult (Births)
Survivorship (shared)	0.9912	0.9912	0.7224	0.7224	0.7224	0.7224						
Male	-	-	-	-	-	-	0.9691	0.9691	0.9691	0.864	0.729	0.00
Females 1st year	-	-	-	-	-	-	0.9813	0.9813	0.9813	0.9813	0.9813	4.35/3.05/0.9281
Females 2nd year	0.9281	0.9281	0.9281	0.9281	0.9281	0.9281	0.9222	0.9222	0.9222	0.9222	0.9222	0.001

Appendix 4. Average percentage change in population size resulting from baseline population viability model.

Parameters		Average % change from Baseline	
Pouch Young	S_p	10%+	1.4
		10%-	28.4
Den Young	S_j	10%+	2.6
		10%-	15.2
Adult male 7 - 9	S_{m1}	10%+	89.6
		10%-	24.6
Adult male 10	S_{m2}	10%+	125.6
		10%-	9.8
Adult male 11	S_{m3}	10%+	2.7
		10%-	18.4
Adult female 7 - 11	S_{f1}	10%+	80.1
		10%-	20.6
Adult female 12 - 18	S_{f2}	10%+	10.2
		10%-	7.5
Adult female 19 - 23	S_{f3}	10%+	15.5
		10%-	19.5
Fecundity (Male)	F_{m1}	10%+	115.6
		10%-	18.3
Fecundity (Female)	F_{f1}	10%+	88.7
		10%-	17.8