Ella Bay Integrated Resort Development

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VOLUME III

POPULATION VIABILITY ANALYSIS

10. CASSOWARY POPULATION VIABILITY ANALYSIS (PVA)

The impacts of the two landuse options at Ella Bay are discussed in detail in Volume II: Impact Assessment and Mitigation Strategies and comprise: Option A: developing the Ella Bay Integrated Resort (EBIR); Option B: continued pastoral use. The major impacts associated with Option A (EBIR) relate to the threats posed by increased traffic along Ella Bay Road and the concomitant flow-on impacts associated with a large permanent human population using the Ella Bay Property. There is a range of strategies available to mitigate the major impacts within the development footprint to that approximating those for existing pastoral landuse. They include cassowary-proof fencing, cassowary road management strategies for the Ella Bay access road, and strict dog control. Effective people management at the EBIR, however, is an area of mitigation that will need further examination.

While able to mitigate the on-site impacts to individual birds, the cassowary impact assessment of the Ella Bay property concluded that both landuse options i.e., continued pastoral landuse and the Ella Bay Integrated Resort, posed threats to the cassowary population of Seymour Range. Using population viability analysis (PVA), this part of the report addresses the potential direct and indirect impacts of the EBIR on the viability of the cassowary population of the Seymour Range.

10.1 WHAT IS PVA?

Population viability analysis (PVA) is the quantitative evaluation of all known factors and their interactions that act on populations and contribute to their risks of short and long-term decline or extinction (Boyce 1992). In PVA, extinction vulnerabilities of small populations (generally <500 individuals) are estimated using computer simulation modelling (Clark *et al* 1991; Lindenmayer *et al* 1993). The ready availability of generic computer packages for running PVA has increased its use and subsequent application in conservation planning and endangered species management over the past decade.

PVA requires a sophisticated understanding of the biology of the species in question e.g., an extensive knowledge of its population dynamics, genetics, and spatial and temporal dimensions of population change (Noon *et al* 1999). As software programs become more accessible e.g., VORTEX, RAMAS, ALEX, etc., this basic biological knowledge is a prerequisite for conducting a PVA. Many Australian and overseas studies have shown that compared to other alternatives for making conservation decisions, PVA provides a rigorous methodology that can use different types of data, and incorporate uncertainties and natural variabilities that are relevant to specific conservation goals. (Akçakaya and Sjögren-Gulve 2000). The major disadvantages of PVA are its single-species focus and a requirement for data that may not be available for many species. However, in this study, we are dealing with the southern cassowary only, and extensive ecological data is available from previous studies of this species (Crome 1975, Crome and Benntrupperbaumer 1982, Moore 1998, 1999, 2000, 2003, 2007a-c).

10.2. THE USE OF PVA IN IMPACT ASSESSMENT

Population viability analysis has been used to assess the impact of human activities by comparing results of models with and without the population-level consequences of the human activity (Akçakaya and Sjögren-Gulve. 2000). In impact assessment, the greatest value of PVA lies with the fact that it focus on relative rather than absolute results, and the risks of decline rather than extinction (Akçakaya and Sjögren-Gulve 2000, Noon *et al* 1999). However, PVA is not a tool ideally suited for most impact assessment studies. This is primarily because the population dynamics are modelled at the 'population' level, rather than the 'local' level usually required for environmental impact assessments. As such, its application in impact assessment requires that specific biological and statistical conditions be met for its use to be valid. Even when those conditions are met, careful and cautious interpretation of the results is necessary to prevent the analyses becoming more confounding than they are constructive.

10.3 DEFINING THE STUDY BOUNDARIES

In the Terms of Reference for an Environmental Impact Statement for the EIS of Ella Bay Integrated Resort Project (EBIR) require:

- '*PVA at the local population level. This should include a clear indication of the sources and reliability of the relevant life history parameters used. Where possible, the parameters should include data that has been researched from the local population. It should include a discussion of the limitations of the results*.' (Coordinator General 2005).

To address this it is necessary to first define what area of cassowary habitat represents the 'local population level'.

10.3.1 Spatial context of Ella Bay Integrated Resort (EBIR)

The coastal cassowary habitat south of Cairns predominantly occurs as a narrow strip on the coastal ranges, which parallel the coast. This discontinuous band of vegetation varies from one to four kilometres in width over most of its 200-kilometre length. These forested coastal ranges are separated from the main rainforest blocks of the Wet Tropics region by extensive agricultural and urban clearing, and a major highway, forming a substantial obstacle to east-west cassowary movement. As a result, coastal populations of cassowaries have lost connectivity with the World Heritage Area to the west. Similar impediments to north-south movement by cassowaries along the coast exist at an increasing number of points along their coastal distribution, creating a series of eight small subpopulations faced with declining habitat and growing threats (Moore and Moore 2007b). The majority of these populations are either already isolated e.g., Moresby Range, or their connectivity is severely limited and at risk e.g., Mission Beach. Of the eight subpopulations, only five (Malbon-Thompson Range, Graham-Seymour Range, Moresby Range, Mission Beach and Hinchinbrook Island) are within the protected estate. The EBIR is located at the southern end of the Graham-Seymour Range subpopulation. In this study, the eight cassowary subpopulations are considered to make up the 'coastal metapopulation'.

The Graham-Seymour Range cassowary population is currently at risk of being separated into two smaller isolated populations. Figure 19 identifies the narrow vegetated corridors, which are all that now connects this population, and Appendix C contains photographs taken at each site. The corridors comprise:

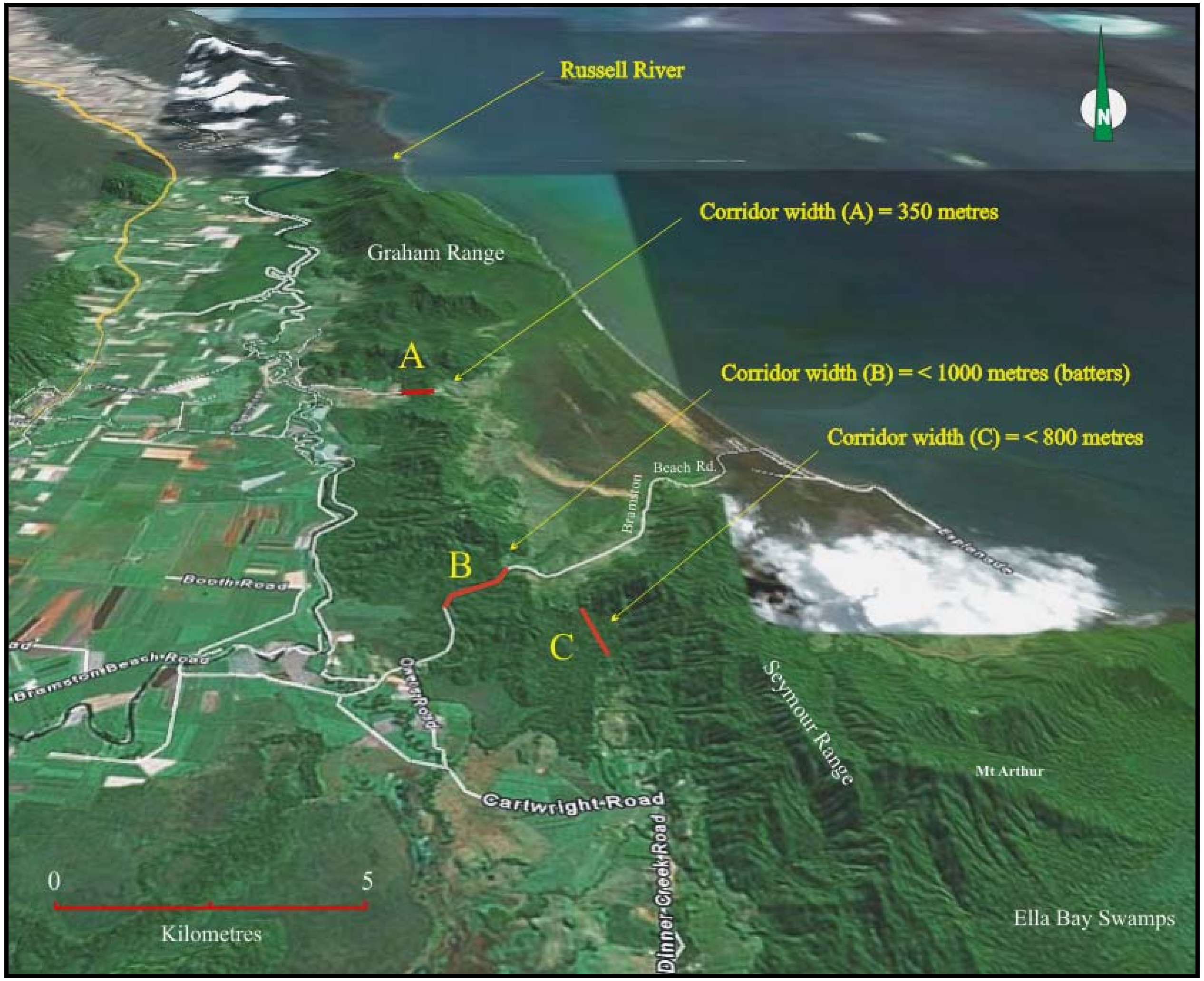
Corridor A = habitat bisected by the Buttigieg Access Road (<350 metres);

Corridor B = habitat bisected by the Bramston Beach Road (<1200 metres);

Corridor C = steep degraded hillside (<800 metres).

Figure 19

Cassowary 'at risk' movement corridors



As PVA deals with populations of animals or plants, it is not valid to subject only those birds identified in and surrounding the Ella Bay Property to a PVA, as they interact with, and are influenced by, the remainder of the Seymour Range cassowary population. Further, it is necessary to include Graham Range to the north in the population analyses, as the birds in this area constitute a functional part of the population. Therefore, the greater study area (located within the yellow rectangle), is bounded in the north by Russell River and to the south by the Johnstone River, and comprises both Graham Range and Seymour Range. While the local cassowary population potentially impacted by the EBIR i.e. Seymour Range, is located within the red rectangle (Figure 20).

11. METHODOLOGY

11.1 SIZE OF GRAHAM-SEYMOUR RANGE CASSOWARY POPULATION

Based on the approximate area of available habitat and using the population density measurements determined for the nearby Mission Beach population (Moore, 2003, 2007a) the estimated maximum population size of adult and independent cassowaries has been calculated for the Graham Range and Seymour Range populations (Table 7). The figures within brackets represent the minimum and maximum ranges for each calculation.

FIGURE 20

GRAHAM –SEYMOUR RANGE STUDY AREA

TABLE 7

ESTIMATED POPULATION SIZES

Cassowary Population	Approx area (km^2)	Estimated No. Adults[1] (min-max)	Estimated Total Population[2]	K (carrying capacity)	Comments
Graham-Seymour Range	93	38 (*31-45*)	61 (*51-73*)	73	Reduced carrying capacity due to steep terrain (25%) and *Acacia* spp. dominated mesophyll vine forest. Population density similar to Mission Beach. Probable cyclone refuge area. Northern end of Graham Range is severely disturbed.
Graham Range	42	17 (*14-20*)	27 (*23-33*)	33	
Seymour Range	51	21 (*17-25*)	34 (*28-4*0)	40	

[1] Moore 2003, 2007a; [2] Adults and subadults i.e., independent birds

11.2 THE PVA SIMULATION PACKAGE

Version 9.72 of the VORTEX simulation software package (Lacy, 1993) was used to assess the viability of the Graham-Seymour Range subpopulation. VORTEX is an *individual-based* model i.e., it creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime (Lacy 1993). It keeps track of the sex, age, and parentage of each animal, modelling demographic events (birth, sex determination, mating, dispersal and death) by determining whether any of the events occur for each animal in each year of the simulation. Events occur according to a Monte Carlo simulation of the effects of deterministic forces, as well as demographic, environmental, and genetic stochastic (chance) events on wild populations (Miller and Lacy 1999).

It is important to understand that VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters used as input to the model, and because of the random processes involved in nature. Interpretation of the output depends upon knowledge of the biology of the southern cassowary, the environmental conditions affecting the species, and possible future changes in these conditions (Noon et al 1999). For a more detailed explanation of VORTEX and its use in population viability analysis, refer to Lacy (2000) and Miller and Lacy (2003).

11.3 INPUT PARAMETERS FOR PVA MODELS

Input parameters for the PVA modelling are summarised in Table 8, with background explanation for all parameters provided in Appendix C.

TABLE 8

BASELINE PVA INPUT PARAMETERS

Model parameter	Data	Comments
Iterations	1000	
Years of population projection	100	
Mating system	Polygynous	Both male and females have multiple partners.
Age of first reproduction	4 years	Adult plumage is attained at approximately 4 years and birds are capable of breeding age in their fifth year.
Reproductive senescence	35 years	A conservative model using 35 years as the age of last breeding was selected.
Max. no. young	5	Offspring as percentage occurrence: 1 = 5% 3 = 40% 5 = 5% 2 = 20% 4 = 30%
Male breeding pool % (= Female parameter in Vortex)	33	This parameter has been modified to reflect the reversed sex roles in cassowaries (Lacy pers. comm. 2002). Male breeding numbers were calculated as follows: • 33% = breeding once in three years
Female breeding pool % (= Male parameter in Vortex)	100	As they have no commitment to parental responsibilities, it has been assumed that all adult females are available for breeding in a given year.
Mortality	Table 9	All models are based on age-specific mortalities using ‘Low’ or ‘Moderate’ mortality rates (Table 4: *sensu* Moore 2007c).
Initial population size	N	Based on overall density of independent birds i.e. adults and subadults was 0.78 birds/km^2 reduced by 25% (Table 8).
Carrying capacity (K)	N	The carrying capacity (K) is calculated as maximum density of independent birds i.e., 0.78 birds/km^2 (Moore 2007a).
Catastrophes	2	Two major parameters were modelled: Catastrophe 1: 5 % - Reproduction 0.05, Survival 0.65. Catastrophe 2: 3 % - Reproduction 0.50, Survival 90.
Genetic drift and in-breeding	No	Not included as uncertainty as to the exact role this would play in a long-lived species within a short timeframe.
Immigration/Supplementation	No	
Definition of extinction	Absence of one sex	

The input parameters of mortality rates and catastrophes are described separately and in more detail, as they are the foundation of the models analysed in this study.

11.3.1 Iterations and years of population projection

All models were simulated 1000 times over a 100 year projection period. Output results were summarised at 10 year intervals for use in the tables and figures that follow. All simulations were conducted using VORTEX version 9.72 (Miller and Lacy 2007).

11.3.2 Mortality rates

Although data suggest there may be differential mortality by sex, all models are based on age-specific mortalities which presume the same mortality rates for both sexes. Due to a lack of data on age-specific mortality rates in wild populations of cassowaries, the annual mortality figures used in the simulations are broad estimates reflecting a range of potential mortality rates. In a population viability study of the cassowary subpopulation of Mission Beach (Moore 2003, 2007b, 2007c), four models were developed in which mortality rates were designated as 'Low' , 'Moderate', 'High' and 'Study'. These are shown in Table 9 and described below.

'Low' mortality

It was concluded from past studies (Bentrupperbaumer 1998, Moore 2003, 2007a, Moore and Moore 2007b) that 'Low' mortality rates were ecologically unrealistic for Mission Beach, and for the majority of the coastal cassowary subpopulations (Moore and Moore 2007b. As such, the results of 'Low' mortality models in this study are better viewed as a theoretical benchmark with which to evaluate changes in the models, or as a desired management target.

'Moderate' mortality

'Moderate' mortality rates are based on a study of long-lived marine animals (Musick 1999), which concluded that k-selected groups with annual increase rates less than 10% were at particular risk of extinction. As such, 'Moderate' mortality rates were formulated to attain an annual recruitment of at least 10% (*sensu* Musick 1999) i.e., borderline reproductive success. In this way, small changes in the values of input parameters should reflect corresponding changes in cassowary population dynamics.

'High' and 'Study' mortality

'High' mortality rates were constructed to reflect the perceived high level of adult cassowary death at Mission Beach. An additional mortality estimate calculated by Moore (2003) i.e., 'Study', was based on data from previous studies (Bentrupperbäumer 1998; Crome and Moore 1990; Moore 1998, 1999, 2003, 2007a, 2007c) and was considered to most closely represent the true field situation at Mission Beach. This excessive mortality is due to the anthropogenic impacts associated with extensive urban development and high-use roads located within and adjoining cassowary habitat at Mission Beach. As 'High' and 'Study' mortality rates are currently not appropriate for the relatively undeveloped Graham-Seymour Range area area, 'Low' and 'Moderate' mortality rates have been used in this study.

The mortality columns in Table 9 comprise an estimated percentage mortality rate followed by a standard deviation (SD) due to estimated environmental variability e.g., 50 *(10)*. To assist in evaluating the likelihood of each set of mortality rates, the predicted offspring survival to adulthood resulting from each mortality model (i.e., recruitment), is given at the bottom of the table (Offspring Survival). The BLUE columns show the age-structured mortality rates used in these analyses.

TABLE 9

Percentage Mortality Rates (Percent/SD)

Age Class (yrs)	**STUDY (Moore 2003, 2007c)**	**% Mortality (± SD)**		
		High	**Moderate**	**Low**
0 - 1	70 *(10)*	75 *(10)*	**60 *(10)***	**50 *(10)***
1 – 2	50 *(10)*	60 *(10)*	**40 *(10)***	**40 *(10)***
2 - 3	40 *(10)*	40 *(10)*	**40 *(10)***	**30 *(10)***
3 – 4	30 *(10)*	30 *(10)*	**30 *(10)***	**20 *(7.5)***
Adults	4 (*1.5*)	7 *(3)*	**5 *(2)***	**3 *(1)***
Offspring Survival (Recruitment)	**6.3%**	**4.2%**	**10.0%**	**16.8%**

[1] Moore (2007c).

11.3.3 Natural catastrophes

In this study, environmental variability is incorporated as the standard deviation in mortality rates and the influence of catastrophic events. Located in tropical eastern Australia, Graham-Seymour Range is subject to severe climatic events such as cyclones, with heavy rains and strong winds (e.g., Cyclone Winifred in 1986, Cyclone Larry in 2006). In addition, “droughts” of lower than expected rainfall can occur, which reduce the amount of rainforest fruit and restrict the availability of water. Although rainfall figures can help identify drier cycles, an accurate measurement of the impacts of cyclones or other natural disasters on rare and endangered species is difficult to obtain. However, a comprehensive field survey at nearby Mission Beach prior to Cyclone Larry (Moore 2003, 2007a), had established that 110 cassowaries existed within the 102 km^2 study area, comprising 31 juveniles (28.8%), 28 subadults (27.3%), and 49 adults (43.9%). Using records of cassowary deaths and injuries kept by Queensland Parks and Wildlife Service (QPWS) following Cyclone Larry, it was estimated that approximately 35% of the known adult and subadult population died at Mission Beach as a result of the cyclone (Moore and Moore 2007b). Most dependent young i.e., juveniles, are believed to have died during or immediately following the cyclone. Using the 2006 cyclone mortality figures as representative of the Graham-Seymour Range population, two major catastrophes were included in all scenarios:

<u>Catastrophe 1: 5%</u> - Reproduction 0.05, Survival 0.65 (severe cyclones simulated as a 1:20 year event). This scenario results in a loss of 95% reproductive capacity and a 35% increase in mortality across all age classes.

<u>Catastrophe 2: 3%</u> - Reproduction 0.50, Survival 0.90 (severe drought or poor fruiting event simulated as a 1:33 years event). This scenario results in a loss of 50% of reproductive capacity and a 10% increase in mortality across all age classes.

11.4 MODELLED SCENARIOS

Three scenarios were modelled to explore the potential impact of the Ella Bay Integrated Resort (Table 10).

TABLE 10

PVA models – Graham-Seymour Range Cassowaries

Model	Scenario
1	PVA of the Graham Range and Seymour Range as a connected population i.e., dispersal between areas. To evaluate the viability of the connected population, the simulations were run with both 'Low' and 'Moderate' Mortality rates (Table 9).
2	PVA of Graham Range and Seymour Range as isolated populations i.e., connectivity lost and no dispersal between areas. Mortality rate is categorised as 'Low' (Table 9) i.e., no change in levels of threats.
3	PVA of Seymour Range as an isolated population i.e., connectivity lost and no dispersal between Graham and Seymour Ranges, and with an increased level of anthropogenic threats i.e., 'Moderate' mortality. Moore and Moore (2007b) concluded that the Graham-Seymour Range was currently experiencing this higher level of threat.

Although not specifically modelled for the Graham Range and Seymour Range populations in this study, the potential impacts of climate change on the coastal cassowary metapopulation were explored by Moore and Moore (2007b). Those findings are discussed in Section 13.1.

Model 1: Graham Range and Seymour Range as a connected population

Model 1 - 'Low' mortality

Graham Range and Seymour Range are currently connected by cassowary movement corridors, enabling birds to move freely within the entire area. In this analysis, therefore, the cassowary population is modelled as a single population. The results were then compared to Model 2 to evaluate the effect on the population of losing connectivity between the two areas. The model was first run with 'Low' mortality, representing the 'best-case' scenario of sufficient population recruitment and no significant habitat loss. As these conditions are not met for the Graham-Seymour Range population (loc. cit.), this scenario is considered in all models as a best-case scenario or desired management target, rather than an existing circumstance.

Model 1 - 'Moderate' mortality

A second scenario, 'Moderate' mortality, was then modelled to reflect the current level of population decline identified by Moore and Moore (2007b). That study and its implications for coastal cassowary persistence are discussed further in Section 13.

Model 2: Graham Range and Seymour Range as isolated populations

This model treats both populations i.e., Graham Range and Seymour Range, as two isolated populations with no opportunities for dispersal. Connectivity between the two range populations currently relies on three narrow movement corridors, all of which are compromised by different threat types (Section 10.3.1). This model looks at the capacity of each smaller population to survive in the event of a permanent loss of connectivity i.e., no dispersal between areas. As we are looking at the potential viability of a reduced population size only, this model has been simulated with ‘Low’ mortality rates (Table 9) i.e., lowest level of anthropogenic threats.

Model 3: Isolated Seymour Range with increased threatening processes

Due to the fragmented and isolated character of the coastal cassowary subpopulations, climatic, stochastic (chance) and anthropogenic impacts are the primary drivers of current population decline (loc. cit.). It is necessary, therefore, to determine the viability of the Seymour Range cassowary population under the current threat level i.e., ‘Moderate’ mortality, before assessing the potential contribution made by either of the two landuse options at Ella Bay. The impact of both landuse options can then be evaluated within the context of the cassowary population dynamics that will occur regardless of any direct or indirect impacts resulting from the intensification of development at the southern end of Seymour Range.

12. RESULTS

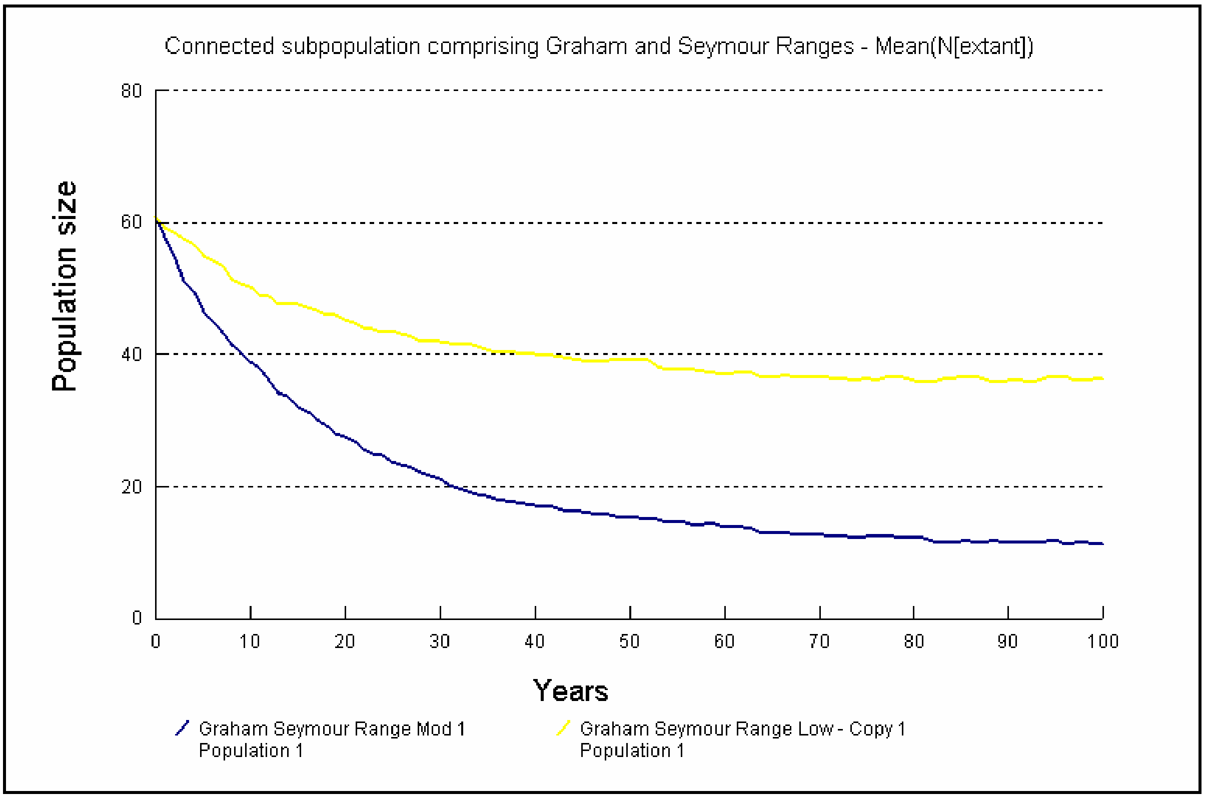
12.1 MODEL 1: GRAHAM RANGE AND SEYMOUR RANGE AS A CONNECTED POPULATION

Low mortality rates

Although mean deterministic growth remains positive over the 100 year simulation i.e., det.r = 0.012, this model indicates the Graham-Seymour Range subpopulation is already in decline. Under ‘Low’ mortality rates, population size is predicted to decrease by 41% i.e., a loss of 25 birds (Figure 21). Although this represents a significant decline, however, the connected subpopulation is still extant at the end of the 100-year projection period. While the probability of extinction (PE) of 0.17 is relatively low (Figure 22), Figure 23 demonstrates the stochastic variability inherent in all small animal populations. Due to the low PE, the predicted median time to extinction (MTE) has not been generated by Vortex.

Figure 21

Mean Number Extant of Connected Subpopulation – 'Low' and 'Moderate' Mortality



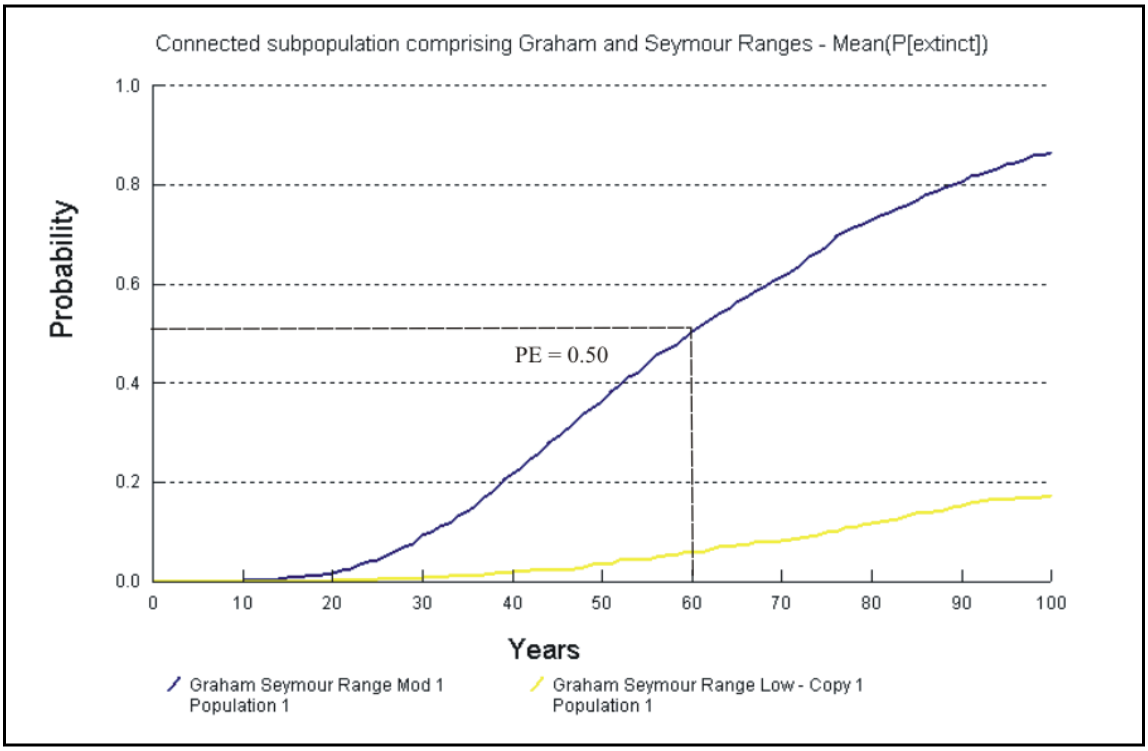
Moderate mortality rates

Under 'Moderate' mortality rates, deterministic and stochastic growth rates are strongly negative i.e., r_d = -0.036 and r_s = -0.040. As the deterministic growth rate (r_d) is negative, the connected population is considered to be in deterministic decline i.e., the number of deaths exceeds the number of births and the subpopulation will become extinct even in the absence of stochastic fluctuations (Miller and Lacy 1999)[1].

The combined negative growth rates culminate in a probability of extinction (PE) of 0.86 (Figure 22), approximately five times that of 'Low' mortality at 0.17. PE exceeds 0.50 at 60 years and population size is predicted to decrease by 82% i.e., a loss of 50 birds (Figure 21), Figure 23 shows the striking influence of stochastic growth rate on the subpopulation when the level of anthropogenic threats is increased in Model 2 ('Moderate' mortality). The predicted median time to extinction (MTE) at 'Moderate' mortality is 62 years.

Figure 22

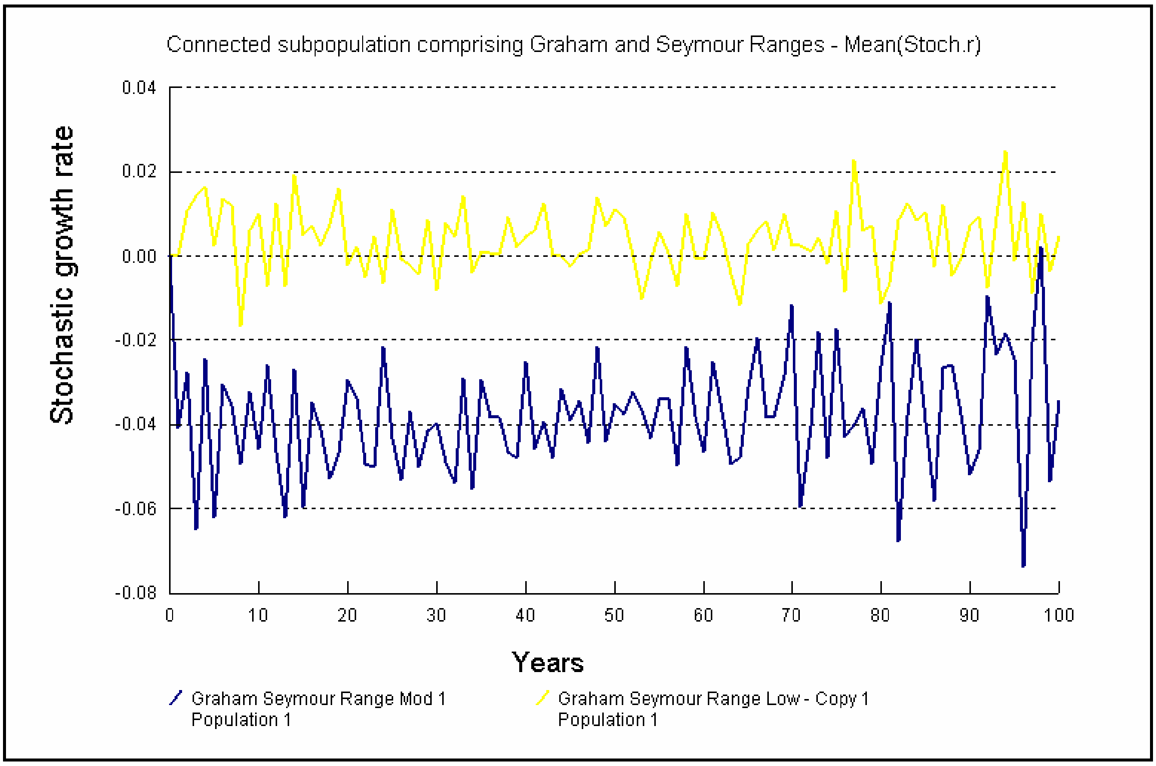
Probability of Extinction for Connected Subpopulation – 'Moderate' mortality



1 Positive values indicate population growth, while negative values indicate population decline. A population with r_d<0 is in deterministic decline (deaths >births) and will go extinct. The difference between the deterministic population growth rate (r_d) and the stochastic population growth rate (s_d) resulting from simulations can give an indication of the impact of stochastic factors on population persistence.

Figure 23

Mean Stochastic Growth Rate of Connected Subpopulation



12.1.1 Model 1 - Summary

The model indicates there is a high probability the connected cassowary population of Graham-Seymour Range may become extinct within the 100-year projection period, or survive as a non-viable population whose persistence is due to the extended longevity of the species (>40 years). The PVA shows the connected population is already declining, even under ‘Low’ mortality rates, with a predicted loss of 41% of its cassowary population within 100 years. Unfortunately, this population is currently experiencing ‘Moderate’ mortality (Moore and Moore 2007b). At ‘Moderate’ mortality both deterministic and stochastic growth rates are strongly negative, resulting in a severe deterministic decline. Reflecting this negative growth, population size decreases by 82% over the 100 years population projection and, as the population decreases in size, the dominating influence of stochastic events increases and the extinction spiral is firmly in place.

12.2 MODEL 2: GRAHAM RANGE AND SEYMOUR RANGE AS ISOLATED POPULATIONS – 'LOW' MORTALITY

This model shows the two halves of the subpopulation will experience great instability and rapid population loss if isolated from each other, even when the mortality rate is 'Low'. Total size of the two isolated populations is predicted to decrease by 33 birds i.e., a decline of 54%, compared with a decline of 41% if the two populations remained connected (Figure 24). The most marked effect of isolating the two populations, however, is the large increase in the probability of extinction, which rises from 0.17 when the two populations are connected, to 0.77 (Graham Range) and 0.54 (Seymour Range) when isolated (Figure 25). PE exceeds 0.50 at 55 years (Graham Range) and 92 years (Seymour Range) with mean times to extinction of 46 years and 56 years respectively.

Figure 24

Comparison of Mean Number Extant – 'Low' mortality

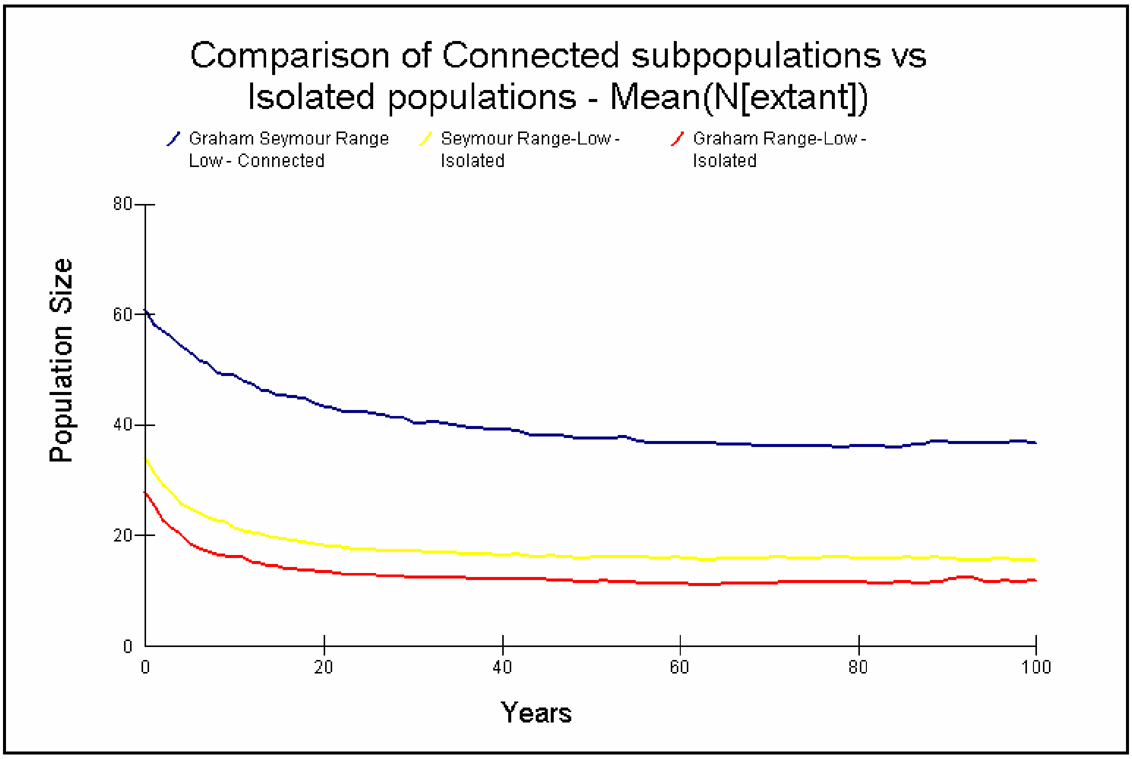
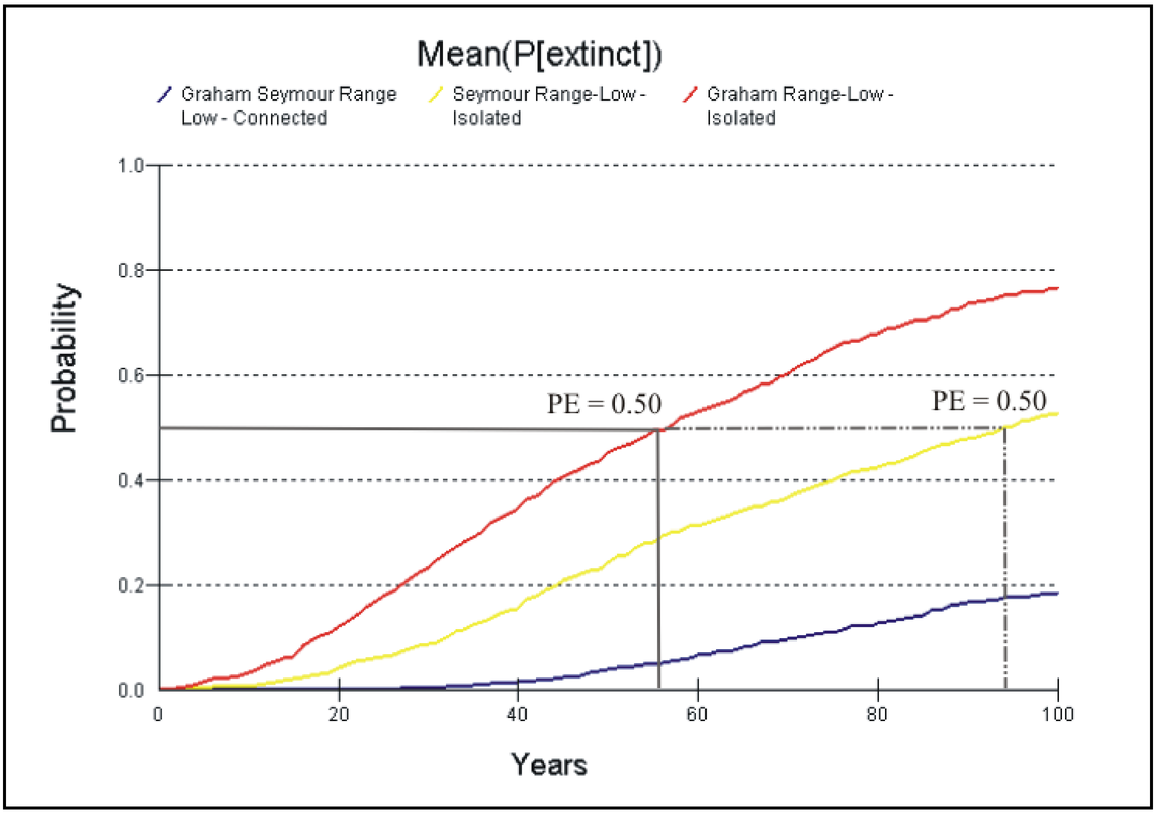


Figure 25

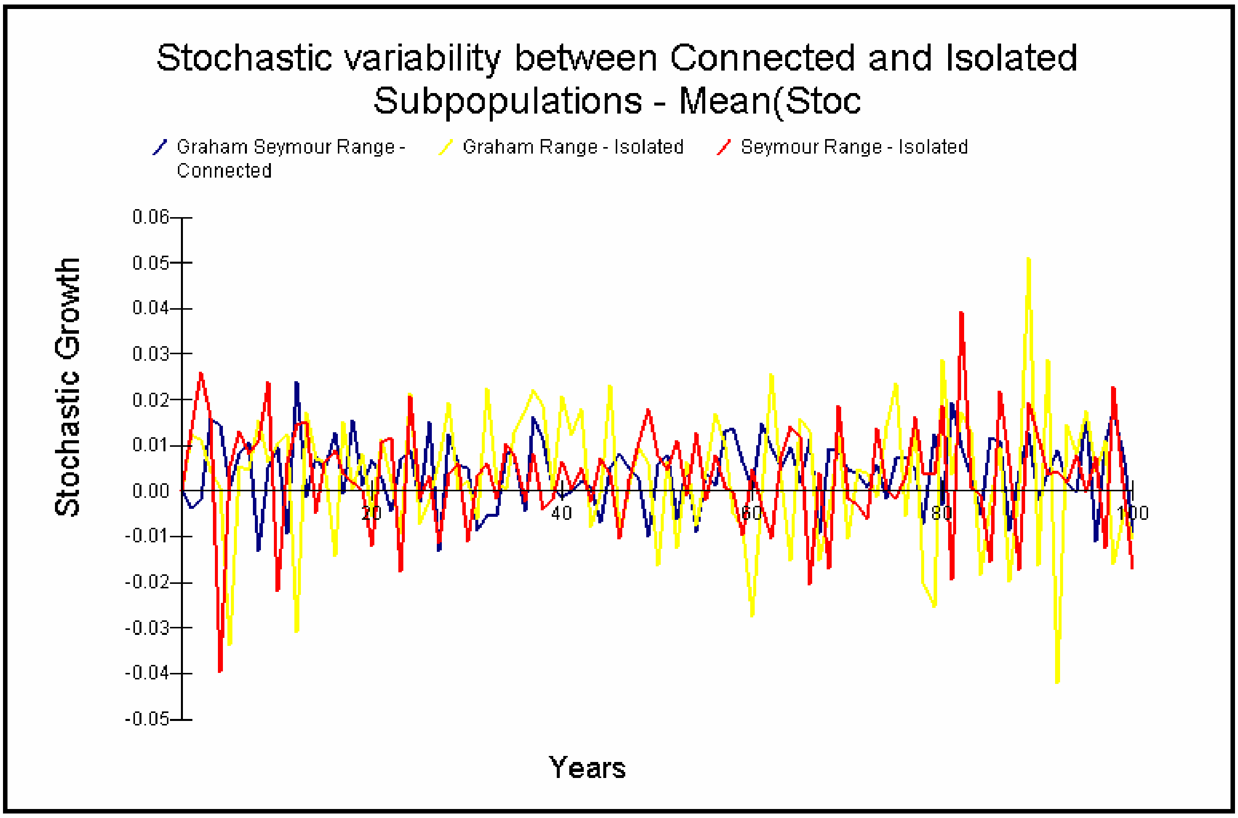
Comparison of Mean PE for Connected vs Isolated Populations



Population instability increases dramatically when the two populations are isolated from each other (Figure 26). The BLUE line on the graph represents the stochastic growth pattern when the two populations are functioning as a connected population. Although variable, it can be seen that growth predominantly oscillates around the neutral growth boundary (i.e., 0.00 growth rate). In contrast, the RED and YELLOW lines, which represent the two cassowary populations of Graham Range and Seymour Range when isolated, fluctuate widely, particularly in the case of the smaller Graham Range population. This deviation illustrates the theory that extinction may occur as a consequence of low population size.

Figure 26

Stochastic variability between Connected and Isolated Populations



12.2.1 Model 2 – Summary

Predictably, even under 'Low' mortality rates, the two isolated populations are extremely vulnerable to the effects of natural catastrophes such as severe cyclones. This is clearly demonstrated by the large spikes of stochastic variation indicative of small populations in trouble. As two small isolated populations, there is approximately 13% greater loss of cassowaries than if the two populations were functioning as a single connected population. In addition, the risk of extinction (PE) increases four-fold with the predicted mean time to extinction (MTE) dropping to 46 years. It is apparent that the isolated populations are significantly influenced by a smaller habitat area, which naturally results in small population ceilings, and the subsequent vulnerability of small cassowary populations to chance events. If connectivity is permanently lost, therefore, environmental stochasticity in the form of continued habitat degradation, variable fruiting regimes, and natural catastrophes such as severe cyclones, will dominate the population dynamics of the two small populations.

12.3 MODEL 3: SEYMOUR RANGE POPULATION WITH 'MODERATE MORTALITY (CURRENT LEVEL OF THREATENING PROCESSES)

Under 'Moderate' mortality rates, deterministic and stochastic growth rates are strongly negative i.e., r_d = -0.036 and r_s = -0.039. As the deterministic growth rate (r_d) is negative, the isolated Seymour Range population is considered to be in deterministic decline i.e., the number of deaths exceeds the number of births. Population size is predicted to decrease by 77% i.e., a loss of 26 birds (Figure 27) over the 100 years population projection and the combined negative growth rates culminate in a probability of extinction (PE) of 0.97 (Figure 28), approximately twice that of 'Low' mortality which is 0.54. PE exceeds 0.50 at 38 years. Figure 29 shows the influential role exerted by stochastic events at this higher mortality rate, resulting in a reduction in mean time to extinction from 92 years at 'Low' mortality, to 42 years at 'Moderate' mortality.

Figure 27

Comparison of Mean Number Extant – Isolated Seymour Range

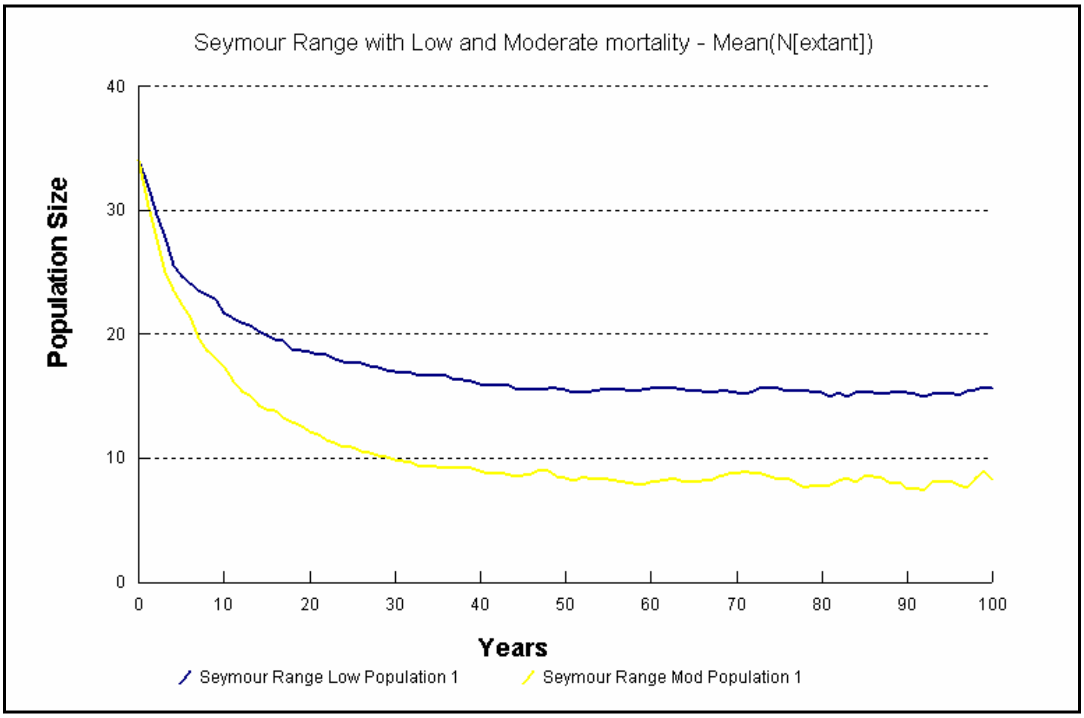


Figure 28

Comparison of Mean Probability of Extinction - Isolated Seymour Range

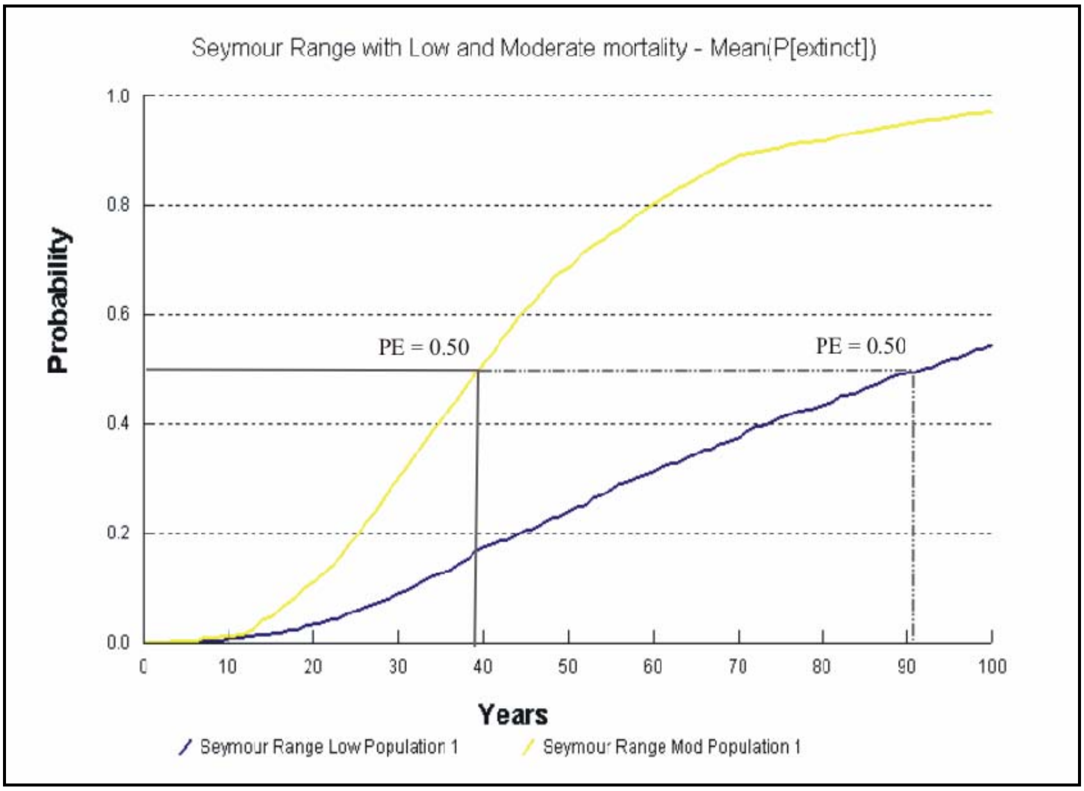
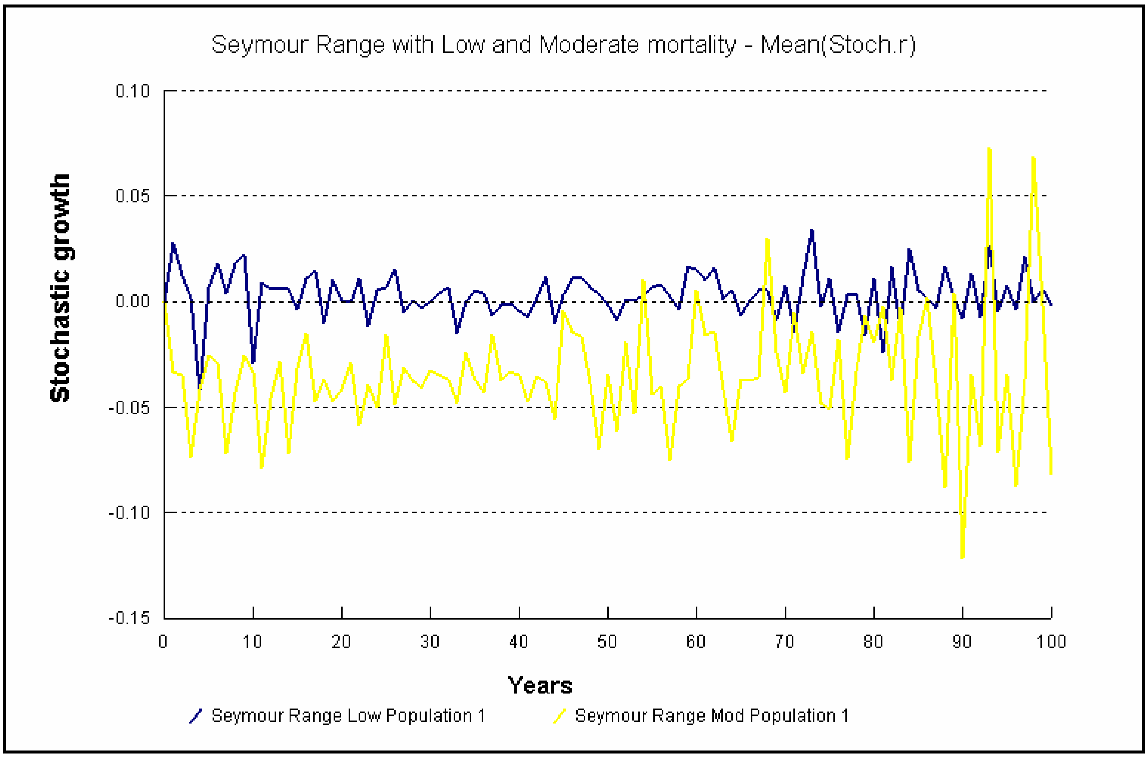


Figure 29

Comparison of Mean Stochastic Growth Rate - Isolated Seymour Range



12.3.1 Model 3 – Summary

With an estimated probability of extinction of 0.97, this model concludes that the disappearance of the isolated cassowary population of Seymour Range is certain at 'Moderate' mortality, possibly occurring in less than 50 years (mean time to extinction of 42 years).

12.4 SUMMARY OF ALL MODELS

Model 1 shows that deterministic and stochastic processes are forcing the connected population of Graham-Seymour Range into an extinction spiral. In a study on grizzly bear population dynamics Shaffer (1981), showed that populations in the size range of 50 to 100 animals would have difficulty surviving the joint action of these forces for more than a century. This PVA has shown Shaffer's findings also apply to small cassowary populations.

In the absence of future dispersal between the two currently connected coastal populations of Graham Range and Seymour Range, all PVA models indicate there is a high probability that both populations will die out within 60 years. However, if the levels of threat can be reduced to 'Low' and connectivity between the two protected and enhanced, the connected cassowary population should still be extant in 100 years, albeit with its population reduced to approximately 57% of the current estimated size (Figure 30). The predicted mean probability of survival over the 100 years for all models is shown in Figure 31.

Figure 30

Mean Number Extant - Summary of all PVA Models

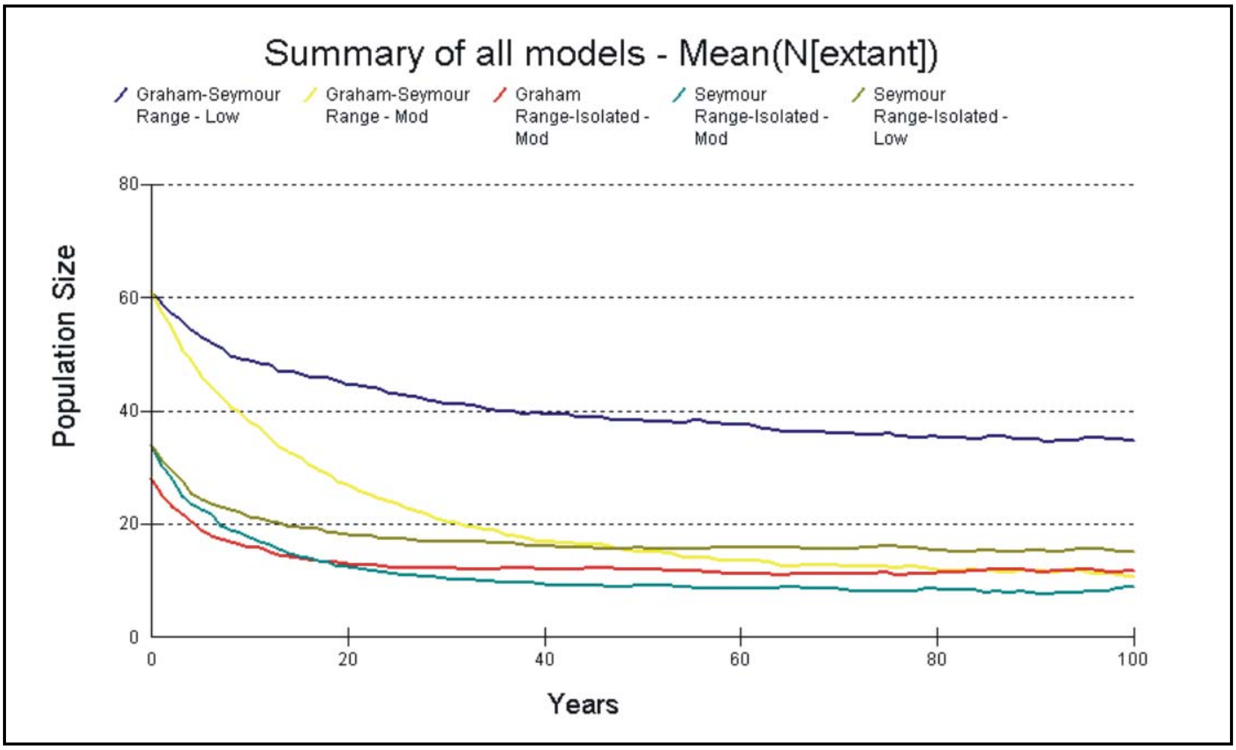


Figure 31

Mean Probability of Survival - Summary of all PVA Models

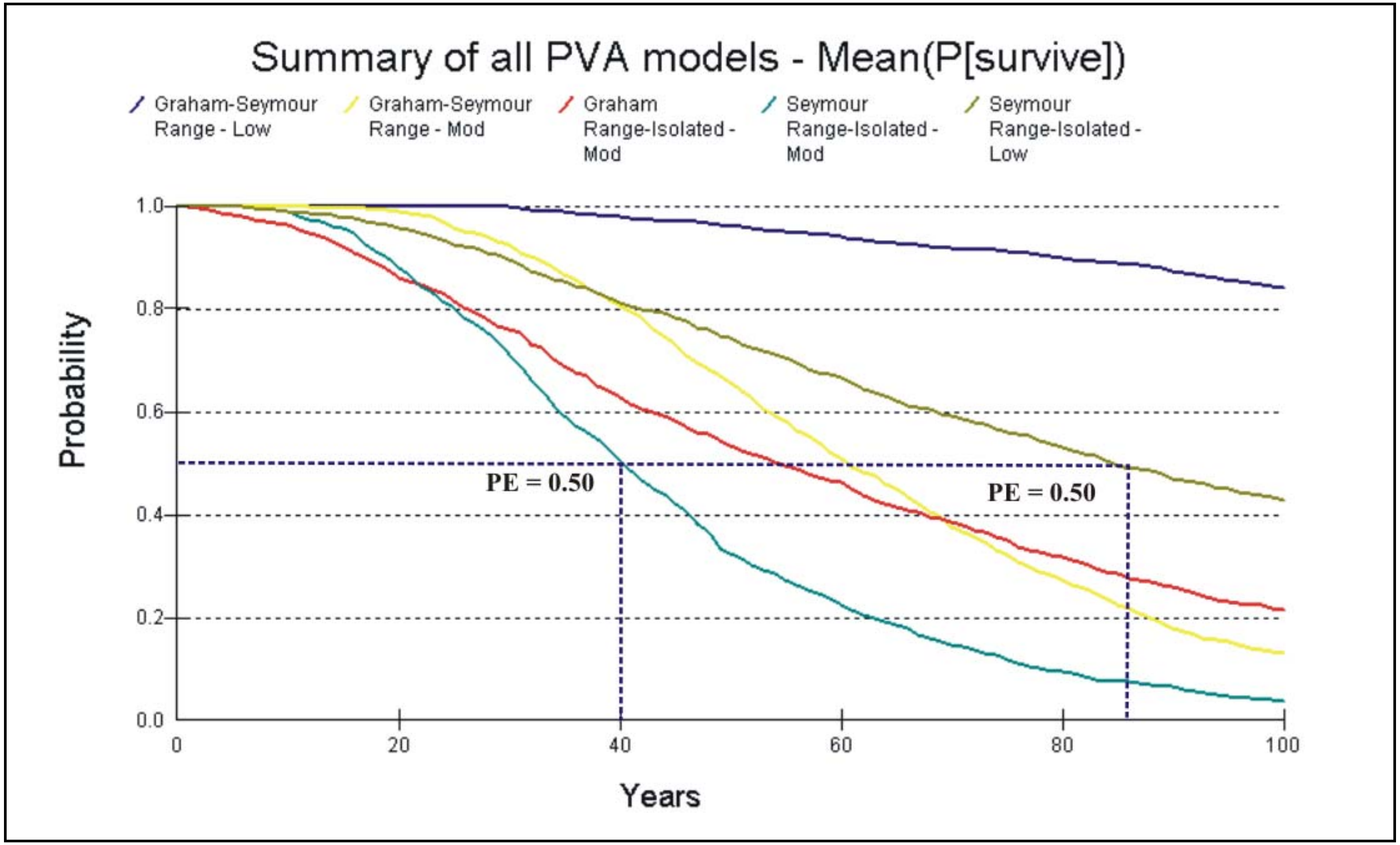


Table 11

Summary of PVA results

Population	Est. population (Ind. birds)	K	Mortality Rates	Det.r	Stoch.r	PE	Mean(N) Extant	MTE (Yrs)	Mean TE (Yrs)	Pop'n Loss (%)
Connected population (Seymour-Graham Range)	61	73	Low	0.012	0.004	0.17	36	0	68	41.0
			Moderate	-0.036	-0.040	0.86	11	62	57	82.0
Isolated **-** Graham Range	27	33	Low	0.012	0.003	0.77	12	55	46	57.0
Isolated – Seymour Range	34	40	Low	0.012	0.003	0.54	16	92	56	53.0
			Moderate	-0.036	-0.039	0.97	8	40	42	77.0

- **K** = Carrying capacity
- **Det.r** = Deterministic growth rate. If "r" is negative then the population is in deterministic decline (deaths outpace births).
- **Stoch.r** = Stochastic growth rate. The difference between the det.r population growth and the stoch.r growth rate can give an indication of the importance of stochastic factors as threats to population viability.
- **PE** = The probability of population extinction. Determined by the proportion of simulated populations that became extinct during the model's 100 years time frame.
- **Mean (N)Extant** = Mean final size of those populations remaining extant after 100 years.
- **MTE** = Median predicted time to extinction for those populations becoming extinct during the simulations.
- **Mean TE** = The mean predicted time to extinction for those populations becoming extinct during the simulations.

13. OTHER IMPACTS OPERATING ON CASSOWARY POPULATION

13.1 CLIMATE CHANGE IMPACTS ON COASTAL CASSOWARIES

The potential impacts of climate change on the viability of the Wet Tropics coastal cassowary subpopulations must be factored into the ominous predictions of Model 1 under ‘Moderate’ mortality rates. Climate change is predicted to have a significant impact on montane tropical ecosystems due to their steep environmental gradients and the limited ability of specialised species to relocate to more climatically suitable elevations or latitudes (Still et al 1999 *in Williams 2006;* Shoo *et al* 2004; Williams 2006). On the wet tropics lowlands, however, there is uncertainty among researchers about both the direction and extent of change. Most agree that the main drivers of change in forest structure and species composition will relate to increased cyclonic disturbance and more prevalent and longer dry periods (Kursar, 1998; Borchet 1998; Boose et al 2004). However, while rainforest ecosystems as an aggregate are very sensitive to decreased rainfall, Hilbert et al (2001) predict an increase in the extent of lowland mesophyll vine forest communities (*sensu* Tracey and Webb 1975) in the wet tropics with warming, even if accompanied by a 10% decrease in annual rainfall. Despite this, the reality for the majority of the coastal lowlands of the southern wet tropics is that there is little available area into which forest can either expand or shift in response to climatic change, as the surrounding land matrix is highly modified.

The linear nature of the majority of the remaining coastal fragments makes them particularly exposed to edge effects. When habitat patches decrease in size through fragmentation, the populations inhabiting them become more vulnerable to adverse environmental conditions prevalent at the edges of the habitat patch (Akcakaya et al 1999). The sharp contrast between forest and the adjoining farmland significantly increases the impacts of edge disturbance, resulting in a highly reduced interior of undisturbed habitat. As a result, any increase in severity or frequency of cyclones due to climate change will exacerbate disturbance impacts in these linear lowland fragments, leading to changes in both tree species composition and structure of lowland forests. It is probable that such changes will reduce habitat quality and thus, carrying capacity, for specialist fauna species dependent on high quality rainforest habitat. The cassowary is one such species.

The effects of predicted climate change scenarios on the metapopulation comprising the eight coastal cassowary subpopulations south of Cairns, were explored by Moore and Moore (2007b). In that study, the following scenarios were simulated to represent the loss or decline in the quality of cassowary habitat as a consequence of climate change:

Scenario 1. No climate change incorporated and no change to K (carrying capacity) for any subpopulation;

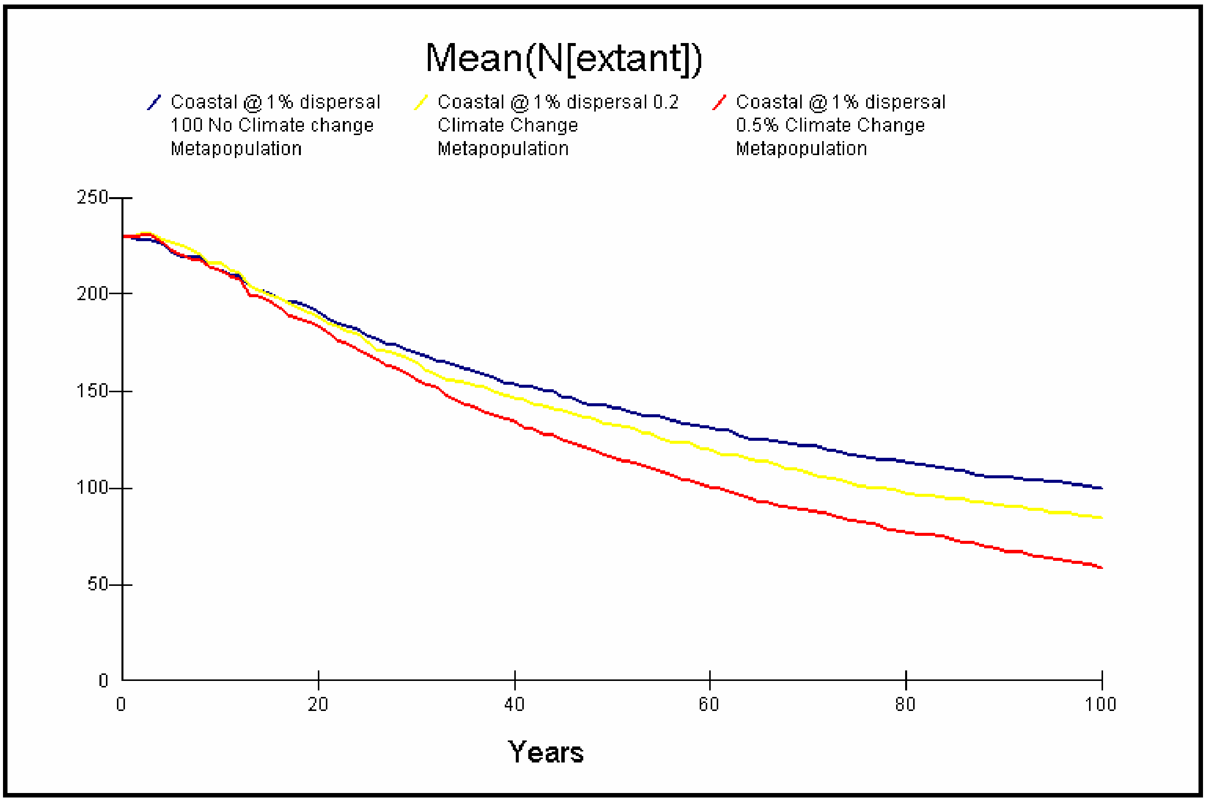
Scenario 2. 0.2% decrease in carrying capacity (K) per subpopulation per year i.e., 10% reduction in K over 50 years;

Scenario 3. 0.5% decrease in K per subpopulation per year i.e., 25% reduction in K over 50 years.

In the absence of climate change, the coastal cassowary metapopulation was predicted to decrease by 48% or 142 birds (Figure 32). However, decreases in carrying capacity of 0.2% and 0.5% per subpopulation per year due to climate change reduces the metapopulation by 69% and 79% respectively, i.e., a further 20-30% decrease in metapopulation size due to climate change.

FIGURE 32

Impact of climate change on the coastal cassowary metapopulation



13.2 OTHER IMPACTS OUTSIDE ELLA BAY INTEGRATED RESORT (EBIR)

The major processes influencing the rate of cassowary decline in the Graham-Seymour Range cassowary subpopulation are briefly discussed below.

Connectivity and Degradation

The PVA indicated that the major risk to the persistence of the Graham-Seymour Range cassowary subpopulation is the loss of connectivity between birds on the two ranges. This would create two small and non-viable populations with a greatly reduced persistence and a probability of extinction even at 'Low' mortality raised from 0.17 (connected populations), to 0.54 (Seymour Range) and 0.77 (Graham Range), once connection is lost.

Exacerbating the threat of connectivity loss is the degradation of much of the western side of the Graham Range. This reduction in the quality of cassowary habitat will certainly increase as coastal development and associated activities expand. The recurring cyclone damage to rainforest along this range has contributed by reducing both the available habitat and quality for cassowaries. The many weed-filled clearings are shifting the vegetation from rainforest to pioneering and secondary tree species, with limited food potential for cassowaries. Photographs of these impacts are provided in Appendix D.

Habitat loss

Cassowary habitat is still being cleared or modified by landowners on the Graham-Seymour Range, particularly along the western side of the Graham Range. Domestic stock, edge effects and weed infestations are contributing to this habitat loss and degradation. Photographs of these impacts are provided in Appendix B.

Roads and cassowaries

The threat of cassowary road death is greatest on the Bramston Beach Road where it crosses the Graham Range, and at the southern end of Seymour Range. Records from Mission Beach over 20 years (Moore 2003, 2007a, 2007c) indicate that road death accounts for >70% of all known cassowary mortality. As the Bramston Beach Road is similar in form to the high-speed roads which traverse cassowary habitat at Mission Beach (Appendix D), cassowary road death will increase as coastal development grows. To avoid duplicating the high number of cassowary road deaths that occur annually at Mission Beach, therefore, an effective cassowary road management strategy that includes traffic calming is essential to protect road-crossing cassowaries.

Dog attack

The incidence of dog attacks on cassowary in the Graham-Seymour Range is difficult to determine. The areas of Flying Fish Point and Ella Bay would appear to pose the greatest risk of attack, particularly as the human population increases. It has been estimated that dog attack in the more urbanised areas of Mission Beach is responsible for >22% of all known cassowary deaths (Moore 2003, 2007a, Moore and Moore 2007b).

Little Cove development

Although not part of the original Impact Assessment (Volume II), the approved subdivision of Little Cove impacts on the viability of the local Seymour Range cassowary population. The subdivision is located to the immediate south of the Ella Bay Property and in relatively close proximity to the eastern boundary of Ella Bay National Park. The Ella Bay Cassowary Survey (Volume I) showed that the area of the subdivision was used by cassowaries for foraging, and as a movement corridor to the foreshore of Little Cove.

13.3 RECOMMENDED MITIGATION ACTIONS TO CONTAIN POPULATION DECLINE

Mitigation strategies to reduce the potential direct and indirect impacts on the cassowary population living on and around the Ella Bay Property are presented in Volume II, and should be implemented as outlined. To these is added the following recommendations to mitigate existing development impacts on the Graham-Seymour Range cassowary population identified in this PVA:

1. A detailed cassowary management strategy for the Graham-Seymour Range coastal subpopulation should be developed, and its implementation supported by adequate funding. This management strategy should include:
   a. the maintenance and protection of the existing movement corridors linking the two range populations;
   b. the development and implementation of a cassowary road management strategy for the Bramston Beach Road;
   c. the implementation of an effective dog control program for the communities adjoining the Graham-Seymour Range. As council funding is limited for policing uncontrolled dogs, it may be necessary to request support from the developers for this action;
   d. as many of the indirect impacts outside of the EBIR are cumulative and thus cannot be avoided, appropriate land trade-offs and offsets should be explored.

14.0 REPORT SUMMARY

Determining the specific impacts on the isolated Seymour Range cassowary population from changing landuse options at Ella Bay is confounded by the population decline already in place. As a linear subpopulation which has lost all connectivity with the larger cassowary populations to the west, the Graham-Seymour Range population is currently experiencing high levels of anthropogenic impact, and declining rapidly as a result. Natural catastrophes in the form of severe cyclones and the environmental uncertainties of climate change, are hastening this decline. Regardless of the landuse choices made at Ella Bay, it is likely that the more localised of these impacts will be over-whelmed by the significant extinction vortex already in place. As such, trying to quantify the extent of the additional impact of either Ella Bay landuse options on the cassowary population is meaningless and thus, was not specifically modelled.

It is recognised, however, that the anthropogenic impacts associated with the Ella Bay Integrated Resort e.g., increased human population, road upgrades, increased traffic, and the increased presence of domestic dogs, are cumulative impacts on an already declining cassowary population. As such, any approval for the EBIR development to proceed may provide an opportunity for offsets to address the connectivity issues that are contributing to the population decline, as well as strategic land purchase, and scientific studies aimed at conserving the species in the Graham-Seymour Range and elsewhere along the Wet Tropics coast.

14.1. CAVEAT

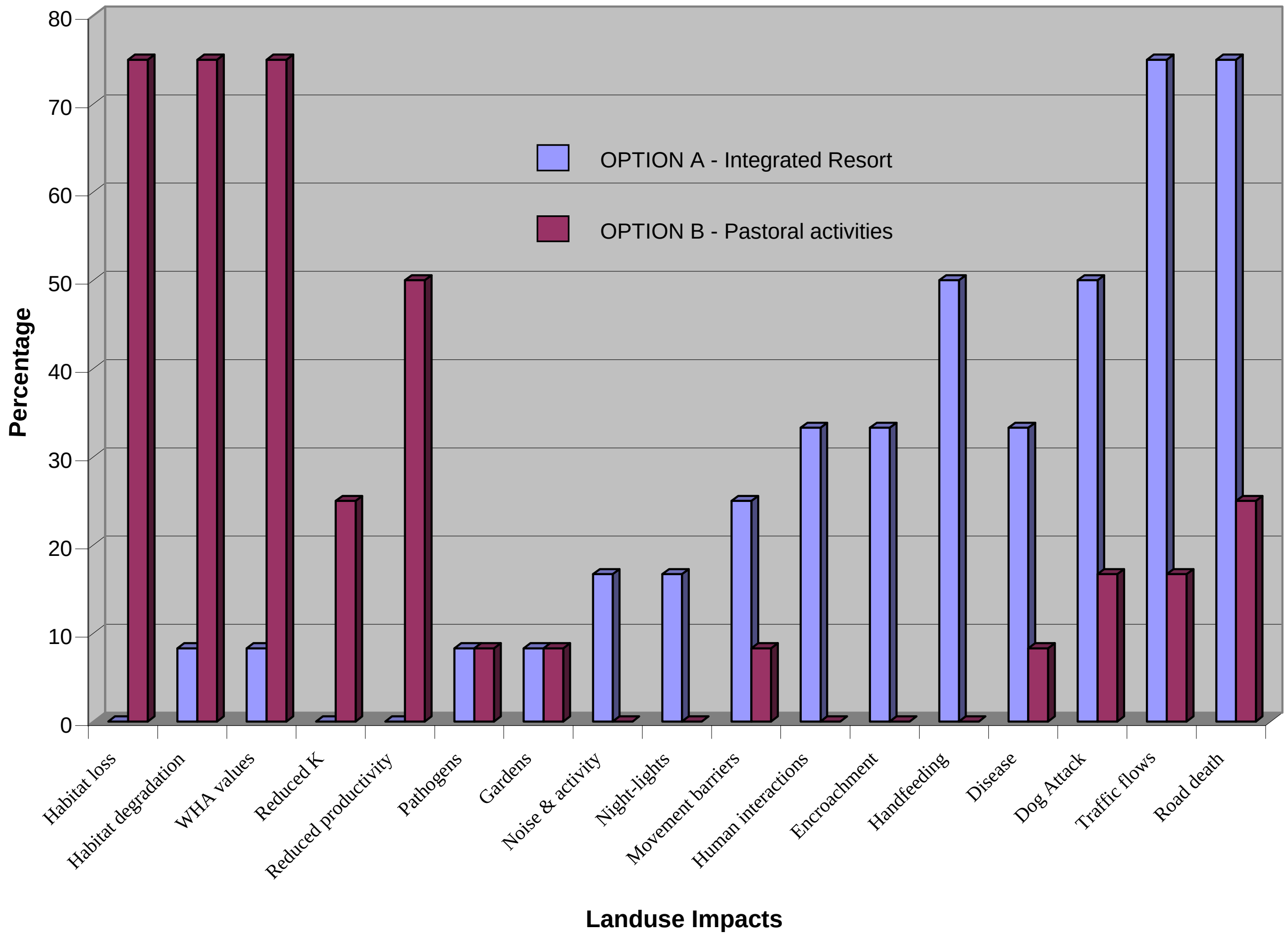
This report on the impacts of the Ella Bay Integrated Resort development on the endangered cassowary comprises three volumes:

1. Volume I – Cassowary field survey.
2. Volume II – Impacts and mitigation.
3. Volume III – Population viability analysis.

As such, it represents a consistent and coherent treatment of the potential impacts and outcomes on the local cassowary population of changing the landuse of the Ella Bay Property. All conservation recommendations and PVA findings made in this last volume (Volume III) are based on the interpretation of the results from the field survey (Volume I: Cassowary Field Survey), and the environmental impacts identified for Option A and Option B at Ella Bay (Volume II: Impacts and Mitigation). Thus, changes to the level and detail of mitigation actions recommended in Volume II may affect the outcome of the subsequent impact assessment, PVA analyses, and suggested management strategies. It is recommended, therefore, that any such changes to the mitigation actions outlined in that report should be assessed and justified as a separate report supplement, and attached to the final EIS document. Additionally, should any significant changes to the scale and design of the EBIR be proposed in the future, this cassowary impact assessment may not be valid and should be reviewed prior to decision making occurring.

Figure 13 (Refer Volume II: Impact Assessment and Mitigation Strategies)

Comparison of Environmental Impacts for Option A and Option B`



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Volume 3: *Techniques. An assessment of counting, trapping and handling methods and husbandry*.

Volume 4: *Summary and Management options.*

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APPENDIX C

PVA INPUT PARAMETERS

Mating system

The mating system in cassowaries is poorly understood but appears to be a complex arrangement of simultaneous polygony (pair bond between a male and more than one female) and sequential polyandry (sexual relationship between a female and two or more males such that the incubating and caring for the young are left to the males) (Crome 1975; Bentruppperbaumer 1998; Moore 2003, 2007c). This is yet to be confirmed by long-term field studies and/or DNA investigation.

Age of first reproduction

The exact age of first breeding is unknown but adult plumage is attained at approximately 4 years of age (Crome 1975; Crome and Moore, 1990; Bentrupperbäumer, 1998; Moore, 2003, 2007a, 2007c). Although it is not certain that the birds can successfully breed at that age, it is probable they are capable of breeding within their fifth year. A minimum breeding age of four years has been used in this PVA.

Age of reproductive senescence

This is unknown. Cassowaries are known to live up to 50 years in captivity (Crome and Moore 1988), and observations at Mission Beach (Jorrisen 1978) have recorded males breeding for at least 14 years i.e., >19 years old. There are reports (with accompanying photographs) of an individual male cassowary breeding on Mt Whitfield Cairns over a 25-year period (Moore and Crome 1992) prior to being killed by dogs in 1995.

Owing to the known longevity of cassowaries and the uncertainty surrounding the age of reproductive senescence, a conservative model using 35 years as the age of last breeding was selected. By this age an individual would have only nested 10 times at 33% breeding

(1 in 3 years) or 15 times at 50% breeding (2 in 3 years). Given Bentrupperbaumer's data from Kennedy Bay (Bentrupperbaumer 1998), this could result in an individual male successfully producing from 7-10 young in his reproductive lifetime (33% and 50% @ 0.67 young/year).

Maximum number of young per breeding cycle

The maximum number of possible offspring per year was set at five. This variable remained constant in all simulations and comprised an estimate based on known breeding records and sightings of family parties at Mission Beach and elsewhere. Crome and Moore (1988) gathered data from the literature on twelve cassowary clutches from the wild, resulting in a mean clutch size of 3.9 (SD=0.99). They also documented four clutches laid in captivity comprising three sets of 3 eggs, and one each of 4 and 5. Three of the four nests found by Bentrupperbaumer (1998) had three eggs, the fourth having just two. Box 2 presents the offspring estimate based on these data and used in all simulations.

Box 4

Offspring as percentage occurrence

1 = 5%

2 = 20%

3 = 40%

4 = 30%

5 = 5%

Female breeding numbers (= male parameter in VORTEX)

The sex roles are reversed in cassowaries. Following advice (Lacy *pers. comm*. 2002) this parameter was used to reflect the male cassowary breeding numbers. Studies indicate that approximately 80% of cassowary males breed only once every 2-3 years, with only approximately 20% completing two breeding sequences within the three-year period (Bentrupperbaumer 1998). As such, male breeding numbers were calculated as 33% i.e., breeding once in 3 years.

Male breeding pool (= female parameter in VORTEX)

As above, this parameter was reversed to reflect the reversed sex roles in cassowaries. Although no data are available for this parameter, it has been assumed that all adult females are available for breeding in a given year, as they have no commitment to parental responsibilities. Bentrupperbaumer (1998) recorded one female in her study area laying eggs in at least two out of three years.

Sensitivity analysis

In this study, sensitivity analyses are encapsulated within the three simulated models (Section 12.4). Due to a lack of long-term field studies, some of the parameters used in the simulations were based on assumptions derived from previous studies, and augmented with data from this field survey. The baseline input parameters used in all analyses are presented in Table H.

APPENDIX D

PHOTOGRAPHS OF GRAHAM-SEYMOUR RANGE

CASSOWARY HABITAT

Plate 31 Corridor 1: Disturbed narrow vegetation corridor just south of Bramston Beach Road.

Plate 32 Corridor 2: Bramston Beach Road (looking east).

Plate 33 Corridor 3. Looking east towards the narrow corridor at Buttigieg Road, Graham Range. The remaining vegetation forming the corridor appears to be approximately 350m wide at this point (aerial map) and frequented by cattle.

Plate 34 Habitat degradation: western slopes of Graham range showing highly disturbed and weed infested clearings.

Plate 35 Habitat degradation: west side of Graham Range near Clyde Road showing high levels of disturbance and vegetation shift.

Plate 36 Recent clearing at the north end of Graham Range.

Plate 37 Loss of cassowary habitat due to property clearing and edge effect (western face of Graham Range).

Plate 38 Looking west to the longest section of cassowary crossing area along the Bramston Beach Road showing a stretch of road similar to that found in the Mission Beach area. The high speed environment of this road makes crossing extremely dangerous for cassowaries.

Plate 39 Section of Bramston Beach Road looking east. Note the cassowary road crossing point at the road curve and the 'blind' nature of the crossing point.

APPENDIX E

CASSOWARY PAPERS IN PRESS OR AT REVIEW

In press – Journal of Ornithology

Population Ecology of the Southern Cassowary *Casuarius casuarius johnsonii*, Mission Beach, north Queensland.

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Abstract:

Little is known of the ecology and population dynamics of the world's largest avian frugivore. This study investigates the population of endangered southern cassowary at Mission Beach in northeast Australia, and examines the problems associated with determining population size and density of this keystone species. Using the results of an intensive field survey aimed at estimating absolute numbers of individual cassowaries, it explores the appropriate sampling methodology for rare and elusive species. Approximately 102 km^2 of rainforest was surveyed, using 346 kilometres of search transects. A total of 110 cassowaries comprised of 49 adults (28 male, 19 female, 2 unknown), 28 subadults, 31 chicks, and 2 independent birds of unknown status were identified. This is approximately 35% of the adult population previously estimated for the Mission Beach area. Overall adult cassowary density was 0.48 adults/km^2; density of independent birds i.e. adults and subadults was 0.78 birds/km^2. Mean indicative home range for adult females and males was 2.13 km^2 and 2.06 km^2 respectively. Mean indicative home range of subadults was smaller at 0.95 km^2. It was concluded that the previous practice of surveying small areas at Mission Beach (<4 km^2) has led to consistent over-estimation of cassowary population density, up to six times its real number. It is shown that a sample plot between 5-15 km^2 is necessary to approximate true cassowary density. These findings have significant application to the conservation of cassowaries in New Guinea and in the Wet Tropics World Heritage Area of Australia.

Key words:
Endangered, keystone, population size, density, home range, sample area

At review – Austral Ecology

Implications of environmental catastrophes and climate change for the management of an endangered species: the Southern Cassowary *Casuarius casuarius johnsonii.*

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ABSTRACT

This study details the effect of severe Cyclone Larry on eight isolated cassowary subpopulations on the coast south of Cairns. The impacts of increased frequency and severity of similar environmental catastrophes as a result of climate change are also explored. At Mission Beach, Cyclone Larry caused the death of approximately 35% of the known adult and subadult population. Approximately 70% of these deaths were from vehicle strike and 22% from dog attack. PVA indicated that catastrophes in the form of severe cyclones double the probability of extinction for coastal cassowary subpopulations. All models revealed that the coastal subpopulations are in deterministic decline and that this will intensify as individual subpopulations decrease, leading to the extinction of five of the eight subpopulations within 100-years. The decline is caused by a combination of inadequate patch size, isolation from the main habitat blocks to the west, and high anthropogenic threats exacerbating the naturally low reproductive rate of cassowaries. Models showed that re-establishing connectivity between coastal subpopulations would accelerate the decline of the coastal metapopulation as a result of source-sink dynamics. All models indicate that subpopulations >45 birds are more stable without inter-patch dispersal, particularly when it involves interaction with smaller subpopulations of less than 10 birds. These smaller subpopulations, however, would not persist in the absence of dispersal from larger source populations. The PVA showed that climate change in the form of severe cyclones and modified habitat will speed up the current decline of coastal cassowary subpopulations by approximately 20-30% over the 100-year period. Management options are presented and discussed.

Keywords

Cyclone, deterministic decline, extinction, slow-fast continuum, inter-patch dispersal, PVA

At review – Animal Conservation

Does the history of the Moas suggest a future for the cassowary? The dilemma of slow birds in a fast world.

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Abstract

This study explores the life history strategies of the cassowary using population viability analysis and contrasts the results with studies of the life-history and rapid extinction of the New Zealand Moa. It is concluded that the underlying mechanisms influencing the decline of the Australian southern cassowary are the same as those which caused the disappearance of the moas. The analyses indicate the isolated Mission Beach cassowary population is in deterministic decline and predicts this will intensify as the population decreases, leading to the extinction of the population within the 100-year projection period. Extinction of the Mission Beach cassowary population is predicted under most mortality values, with PE ranging from 0.85 – 0.98 and a median time to extinction from 34 to 72 years. To retain the existing population size in the absence of immigration requires 'Low' mortality rates across all age classes; male cassowaries to breed once in every two years; and a minimum offspring survival of approximately 27%. This is not achievable within the limitations imposed by the cassowary's K-selected reproductive strategies. The PVA simulations indicate that although strongly associated, PE is more influenced by age of first breeding than by the death of adults. The transition from the breeding at two years to breeding at three years is a critical population dynamic, significantly lowering population viability and taking the population into negative growth. This study demonstrates that the extant southern cassowary is a contemporary analogue of its extinct New Zealand relative the moa, and shows that its k-selected life history strategies prevent it from adapting to the environmental instability created by current human activities.

Key words:

slow-fast continuum, k-selected, deterministic decline, extinction, breeding age, moa, ratite