Australian Government
Director of National Parks

Status Report – September 2014

Monitoring, Research and Management of the Christmas Island flying-fox (*Pteropus melanotus natalis*)

Parks Australia – Internal Report

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September 2014

Contents

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Summary

1. The Christmas Island flying-fox, *Pteropus melanotus natalis* was listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* in January 2014. It is a species of high conservation concern because (a) its population has declined by about 75% since the mid-1980s; (b) is thought to have an important ecosystem or 'keystone' role as a pollinator and seed disperser for several tree species, including some endemic species and (c) it is the last of five known endemic native mammals to occur on Christmas Island.

2. The 2014 nocturnal monitoring program used monitoring protocols developed in 2006 and was compared to the 2006, 2012 and 2013 monitoring results. There was a **41.4% decrease in mean incidence from 2006 to 2013** and a **52.4% decrease from 2006 to 2014** (based on comparison of 107 sites).

3. Since 2012, a total of 124 sites were sampled and used in comparative analyses for years 2012 to 2014. From 2012 to 2014, the annual mean incidence scores were 0.468, 0.460 and 0.331 respectively. This equates to a 29.3% decrease in mean incidence over the three years. If broken down annually, a decrease in incidence of 1.7% was recorded between 2012 and 2013 and a 28% between 2013 and 2014.

4. Statistical modelling using distance sampling theory suggests an overall abundance estimate of 900 ± 569 individuals in 2014. Compared to the 2013 estimates, this translates to a **37.8% decline in population size in one year**.

5. It is speculated that the accelerated rate of annual decline and estimated abundance was largely influenced by the direct and indirect impacts of the Category 1 Cyclone that passed north-west of Christmas Island in March 2014. Ground and exit counts in April and July 2014 were also low (417 and 440 individuals on each respective count) and may support this theory or suggest that the population was more widely distributed across the island post-cyclone.

6. In November 2012, a risk-based decision analysis was undertaken to identify potential threats driving population decline in *P. melanotus natalis.* This process drew on the expert knowledge of a number of flying fox ecologists, a captive breeding specialist and Parks Australia managers. A total of 19 threats were identified and subsequently prioritised and shortlisted to eight. Cadmium poisoning was considered the highest risk. Management scenarios were determined for each threat and examined to estimate the risk of extinction over a 20 year period. The probability of *P. melanotus natalis* extinction under a 'business as usual' scenario is 0.82. The reduction in risk of extinction under the various alternative management strategies was modest with the greatest expected reduction being associated with the implementation of cadmium mitigation (0.68 probability of extinction).

7. Future research priorities will be guided and supported by a collaborative research initiative involving Parks Australia, CSIRO, Taronga Zoo, University of Western Sydney, University of Sydney, EcoHealth Alliance and the Royal Botanic Gardens. Research priorities will focus on ecological-based research and threats. Each collaborative partner has committed cash and/or in-kind support to progress this work.

8. In June 2014, the Director of National Parks sought exemption under sections 158 and 303A of the EPBC Act from the application of all of the provisions in Part 3 (Requirements for environmental approvals), Chapter 4 (Environmental assessments and approvals) and Part 13 (Species and Communities) in respect to actions relating to the implementation of a captive management program for *P. melanotus natalis.* Exemption was granted on 26 June 2014.

9. This continued decline serves as a reminder that focused conservation and research effort is needed to support the recovery of *P. melanotus natalis* beyond the insights gained through existing monitoring. The following recommendations are aimed at improving the level of information known about this species, improving future monitoring outcomes and progressing with targeted on-ground management that will aid recovery. They include:

    a. Continued annual nocturnal monitoring in 2015 and possibly during 2016 and 2017 (depending on the development of remote monitoring techniques) AND continued ground and exit counts using a different time cycle for monitoring.
    b. Supporting research focused on accurately assessing the population size, distribution, and roosting and foraging requirements of *P. melanotus natalis* using acoustic and remote monitoring techniques.
    c. Sourcing adequate funding to support a three-year pilot captive management program to be implemented by December 2015.
    d. Supporting targeted ecological and threat-based research on *P. melanotus natalis* proposed by collaborative research partners.
    e. Continued threat mitigation including on Yellow Crazy Ants and feral cats.

1.0 Introduction

In January 2014, the endemic Christmas Island flying-fox, *Pteropus melanotus natalis* was listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is considered a species of high conservation concern because (a) its population has declined by about 75% since the mid-1980s; (b) is thought to have an important ecosystem or 'keystone' role as a pollinator and seed disperser for several tree species, including some endemic species and (c) it is the last of five known endemic native mammals to occur on Christmas Island.

Historical accounts of *P. melanotus natalis* note how numerous and common it was across the island (Andrews, 1990) around the time of settlement, and how the population continued to 'flourish' for decades thereafter (Gibson-Hill, 1947). However, with the introduction of semi-regular and systematic monitoring in the mid-1980s (Tidemann, 1985; Corbett *et al.,* 2003; James *et al*., 2007; Woinarski *et al.,* 2014), it became increasingly clear, that *P. melanotus natalis* was no longer the flourishing population documented in the early to mid-1900s.

In 2014, Woinarski *et al.* (2014) reported a decline of 39% between 2006 and 2012 based on an island-wide nocturnal survey methodology developed by James *et al.* (2007) in 2006. Reports of this decline triggered concern about the long-term viability of *P. melanotus natalis* without management intervention and its priority for management was elevated accordingly. Subsequently, this survey was repeated in 2013 (Parks Australia, 2013) and 2014 to confirm and monitor the extent of the decline and to inform future management action. The results of the 2014 survey are presented in this report.

Following the 2012 survey, a risk-based decision analysis was undertaken through expert elicitation to identify and prioritise potential threats to *P. melanotus natalis* and evaluate the species risk of extinction under alternative management scenarios. This process was based on the International Standard for Risk Management (ISO 31000:2009) and involved: establishing the context, risk identification, risk analysis, risk evaluation, risk treatment, monitoring and review.

In addition to this risk assessment, other management and research initiatives have progressed since 2012 including an exemption being granted under the EPBC Act to allow for captive management of *P. melanotus natalis* on Christmas Island and the establishment of a collaborative research group focusing on investigating high priority threats and initiating priority ecological based research.

The results of the risk assessment and more detailed information about these other management and research initiatives are also presented in this report.

2.0 Monitoring

2.1 Methods - nocturnal flying-fox survey

The survey methodology used in 2014 was consistent with the methods described by Parks Australia (2013) and Woinarski *et al.* (2014) but for convenience have been summarised here. Table 1 provides an overview of the total number of sites sampled each year since 2006 and Figure 1 shows the distribution of sites across the island. Sites were generally spaced between 0.5 and 1km apart.

Table 1: Number of sites sampled in 2006 and 2012-2014

Year	Number of sites	Notes
2006	107	
2012	124	An additional 17 sites were surveyed in 2012 but not used in the 2006-2012 comparative analysis.
2013	124	All 124 sites were included in the 2012-2013 comparative analysis. Only 107 sites were included in the 2006-2013 analysis.
2014	124	All 124 sites were included in the 2013-2014 comparative analysis and in determining the average annual change in incidence. Only 107 sites were included in the 2006-2014 analysis.

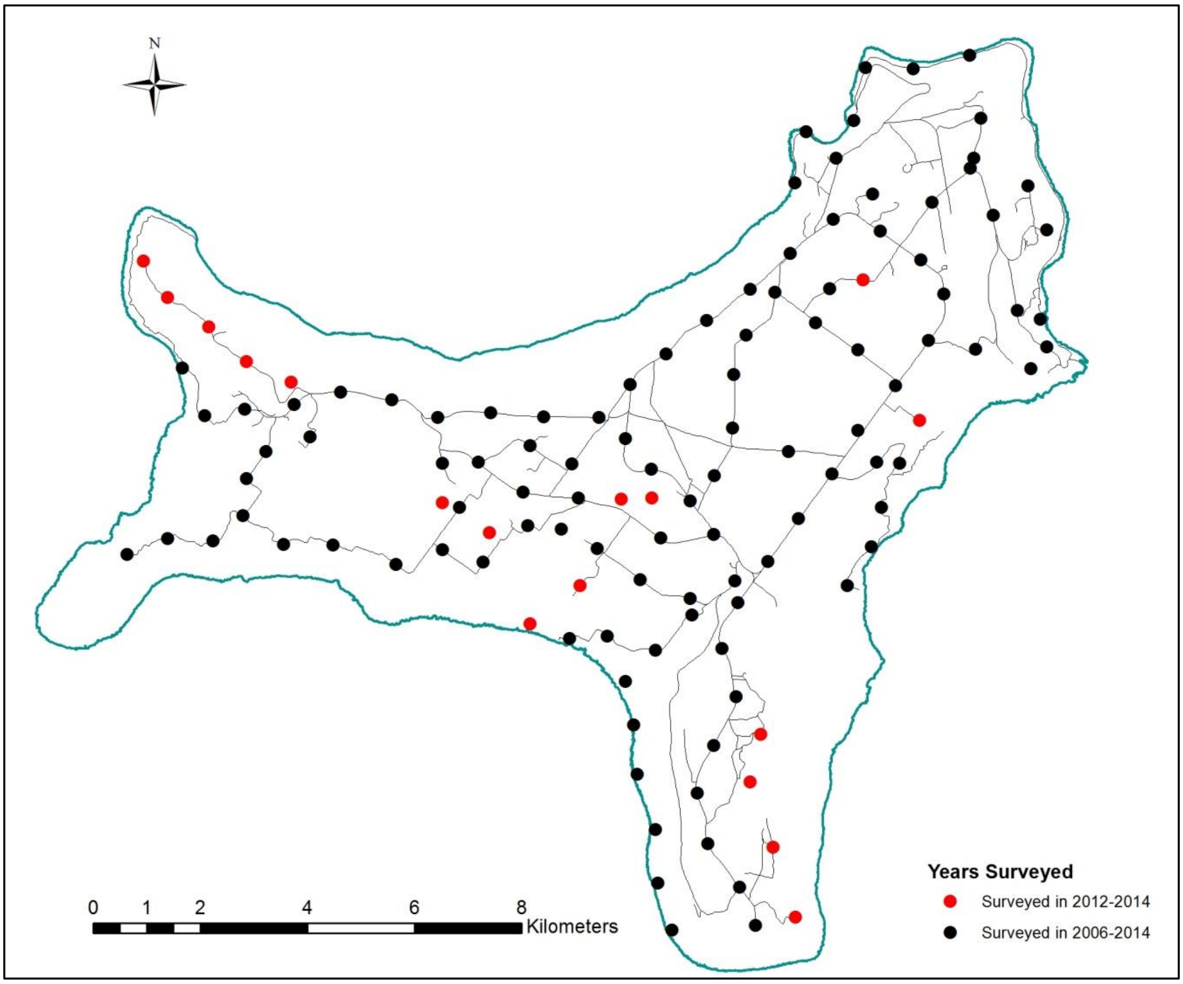

Figure 1: Map of Christmas Island showing distribution of survey sites

As per the 2006, 2012 and 2013 survey, the 2014 survey was undertaken during June-July with all observations occurring after nightfall between 18:00 and 23:00 hrs. Each site was surveyed four times throughout the monitoring period and no site was visited more than once on each night. Surveys were not conducted on nights with rain or high wind speed (class 5 or above on the adapted Beaufort scale, Appendix A) as it was difficult to audibly detect the presence of flying foxes over the noise of the wind or rain. If it began to rain during a 10 minute survey, that survey continued and the start time of the rain was recorded.

To access sites, observers navigated to within 10 meters of the site using a Garmin GPS 62s loaded with site waypoints. Following arrival at a site the observer(s) shut-off and exited the vehicle. Surveys were conducted within the immediate vicinity of the vehicle (with the exception of 10 sites that were 'walk to' sites). Access method, recorder details, and wind speed (adapted Beaufort scale) were recorded. Survey observations were 10 minutes in duration with the start time of each survey being noted. If a flying-fox was seen or heard, the time from the start of the survey was recorded along with the distance from the observer and the number of flying foxes present in a group. Any subsequent flying-fox activity within the 10 minute period was recorded in the same way.

The survey area was not circumscribed, that is, no matter how distant from the observation point, any flying-fox that was heard or seen was recorded. Flying-fox calls were probably detectable over up to 200m away, depending on vegetation density, topography, wind direction and intensity and surrounding environmental noise (e.g. ocean noise or other rainforest noise). Throughout all survey observations, observers did not actively search for flying-foxes or other target species (i.e. they did not wander far from the vehicle or designated survey point trying to detect flying-foxes or other species, only to confirm species identification following an eye-shine or other detection).

Since 2012, approximately 40 sites were surveyed in teams of two for Workplace Health and Safety reasons. At these sites one member of the team was randomly nominated to be the primary observer with the secondary observer also recording their observations. Analysis only considers the results from primary observers.

Other targeted species included *Ninox natalis* (the Christmas Island hawk-owl), *Cyrtodactylus sadleiri* (giant gecko), *Scolopendra morsitans* (giant centipede), *Lycodon aulicus capucinus* (wolf snake), and *Hemidactylus frenatus* (barking gecko).

2.2 Flying-fox incidence analysis

Following the methodology in previous years, every site was sampled four times in 2014. An incidence score was determined for each site. This was the number of samples in which one (or more) flying-foxes were recorded; hence, this score varied from 0 (if flying-foxes were not recorded at all at the site across its four samples) to 4 (if flying-foxes were recorded at each visit). For cross-year comparison and analysis an incidence change value (*d*) was calculated for each site by subtracting the incidence value from previous years for each site from the 2014 incidence value for the same site. Change values could vary from -4 (if flying-foxes were recorded at every visit to that site in 2006, 2012 or 2013 but not at all at that site in 2014) to +4 (if flying-foxes were recorded at every visit to that site in 2014 but not at all at that site in previous years). A two-sampled Z-test was used to assess the significance of changes in incidence values across survey years.

2.3 DISTANCE density modelling

The inclusion of distance and abundance estimates in 2013 and in this year's survey data allowed for statistical modelling using the DISTANCE software package to be carried out. This modelling method allows for density estimates to be made from point transect data.

Due to the clustered nature of distance estimates and the tendency for observers to round estimates to the nearest 20m (approx), distance data was truncated (or grouped) into 5 equal clusters for analysis (from 0-102m. The truncation point of 102m was used to 'offset' the clusters and hep to minimise any inadvertent grouping of observations). There were four outlying observations (beyond 100m) which were excluded from the modelling. The practise of truncating up to 10% of the 'furthest' data points is well used and accepted in Distance analysis as they can 'force' the use of extra explanatory parameters which increase model complexity whilst decreasing the 'real world' accuracy of the model.

For data included in the modelling, a hazard-rate, simple-polynomial model was fitted to the data and the Conventional Distance Sampling (CDS) analysis engine was used to produce density estimates. Model selection was based upon Akaike Information Criterion (AIC) comparisons, Chi-squared goodness of fit analyses, and model summaries/histograms that indicated if the model fitted made 'biological sense'.

Extrapolations of overall abundance from DISTANCE derived density estimates took all terrestrial areas of Christmas Island to be suitable habitat regardless of the current state, use, or quality of the land (i.e. the total land mass, $135km^2$, was used in calculations). It is likely that this methodology provided an overall abundance estimate that was conservatively high.

All Analyses were conducted using 'DISTANCE' version 6.2 – release 1 (Thomas *et al.*, 2009) as well as R (version 3.1.0) and Microsoft Excel 2007.

3.0 Results

3.1 Nocturnal survey results

A total of 124 sites were sampled in 2014, however only the original 107 sites sampled in 2006 were included in the comparative analysis that looked at overall change in incidence since 2006. For annual comparisons of change in incidence between 2012 and 2014, the entire 124 sites were included in the analysis.

The mean incidence score at the 107 sites was 0.766 in 2006, 0.449 in 2013 and 0.365 in 2014. This equates to a 41.4% decrease in mean incidence from 2006 to 2013 and 52.4% decrease from 2006 to 2014. The decrease recorded from 2006 to 2014 is statistically highly significant (z=.3.67; p=0.0002) which is consistent with that reported in 2013.

In 2006, *P. melanotus natalis* was recorded at least once at 47.7% of the 107 sites sampled. In 2012 and 2013 this had reduced to 32.7% of the 107 sites sampled and in 2014 a further reduction in incidence was seen with *P. melanotus natalis* being recorded at only 29% of the sites sampled (Figure 2). A summary of incidence rates of the survey for each year is presented in Table 2. The incidence rates for each site and each year are presented in **Appendix D**.

Table 2: Incidence scores for *P. melanotus natalis* at 107 sites sampled in 2006, 2013 and 2014

Year	Incidence score				
	0	1	2	3	4
2006	56	27	17	7	0
2013	72	27	3	5	0
2014	76	23	8	0	0

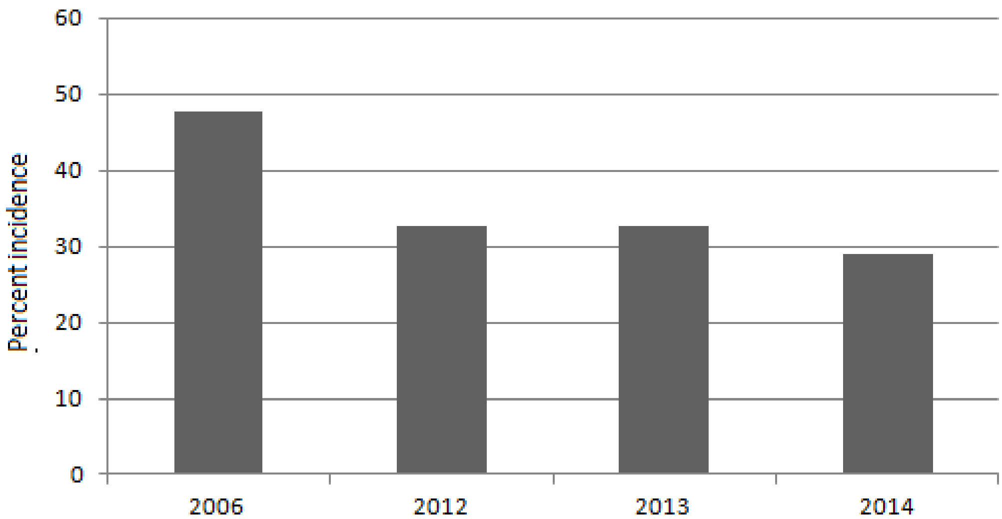

Figure 2: Percent of the 107 sites at which *P. Melanotus natalis* were recorded at least once from 2006 to 2014

Using the 124 sites sampled annually since 2012, the same analysis was undertaken to assess the annual rate of decrease in incidence. The mean incidence score at the 124 sites was 0.468 in 2012, 0.460 in 2013 and 0.331 in 2014. This equates to a 29.3% decrease in mean incidence over the three years. If broken down annually, a decrease in incidence of 1.7% was recorded between 2012 and 2013 (not statistically significant; z=0.084, p=0.933) and a 28% decrease between 2013 and 2014 (not statistically significant; z=1.49, p=0.136).

The distribution of incidence in 2014 is shown in Figure 3a. The distribution of change in incidence across the island from 2006 to 2014 is shown in Figure 3b.

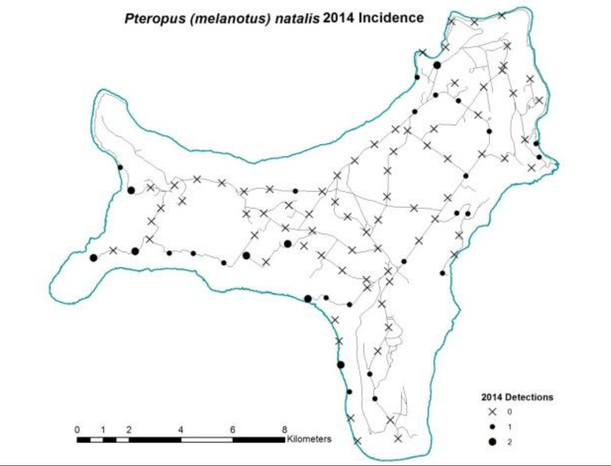

Figure 3a: Flying fox incidence from all sites sampled in 2014

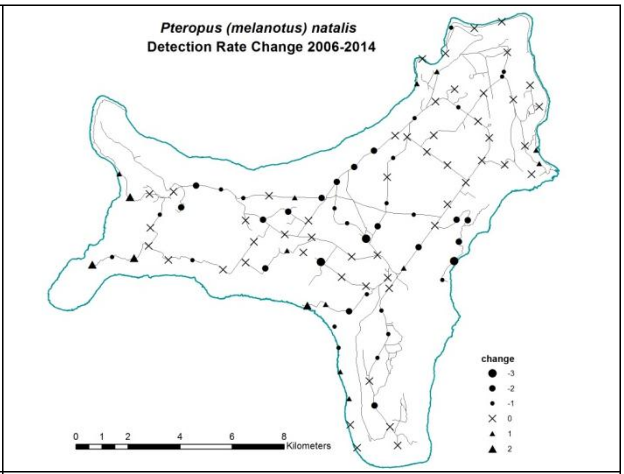

Figure 3b: Change in flying fox detections at all sites from 2006 to 2014

3.2 Density modelling

A hazard-rate simple-polynomial function was fitted to the data and analysed using the Conventional Distance Sampling (CDS) engine in DISTANCE. Grouping provided a much better model fit compared to when exact distances recorded were utilised (AIC: 158.36 as opposed to AIC: 501.74) in the model analysis suggesting that recorded data may have been subject to some rounding/approximation error. This was supported by q-q plot analysis of exact data which suggested exact data provided a poor fit to the model whereas a chi-squared goodness of fit test indicated that grouped data provided a good model fit (chi-sq = 0.1478; df = 2; p = 0.929).

Modelling produced an expected cluster size of 1.245 individuals (se = 0.080) and an expected density of 5.354 clusters/km^2 (se = 3.371). The density of individuals was estimated to be 6.665 individuals/km^2 (se = 4.219) (Table 3). When multiplied by the total land-mass of Christmas Island (135km^2), an overall abundance estimate of 900 ± 569 individuals was obtained (note: 569 is equal to one standard error). Compared to the 2013 estimates, this translates to a 37.8% decline in population size in one year.

Table 3: Table of density estimates provided by fitting a hazard-rate simple-polynomial function to the 2014 survey data. DS – estimate of density of clusters; E(S) – estimate of expected value of cluster size; D- estimate of density of animals. The 63.3% coefficient of variation seen in the density of animals (D) was comprised of: 90.8% detection probability; 8.1% encounter rate; and 1.0% cluster size.

Parameter	Point estimate/km-2	SE	% Coefficient of variation	95% Confidence Interval	
DS	5.354	3.371	62.98	1.682	17.042
E(S)	1.245	0.080	6.43	1.094	1.417
D	6.665	4.219	63.30	2.084	21.313

Figure 4 presents histograms that are useful in the model selection process. Both the modelled detection function (*a*) and the corresponding density function (*b*) are presented. Bars represent data collected as part of the 2014 survey whilst the line represents the modelled detection (*a*) or density (*b*) functions. The close fit of the modelled lines to the observed data, and the fact that the modelled lines make 'biological' sense (i.e. there are no unrealistic spikes or dips in detection probability as it relates to distance from the observer), support the model choice. Full DISTANCE modelling output can be found in **Appendix C**.

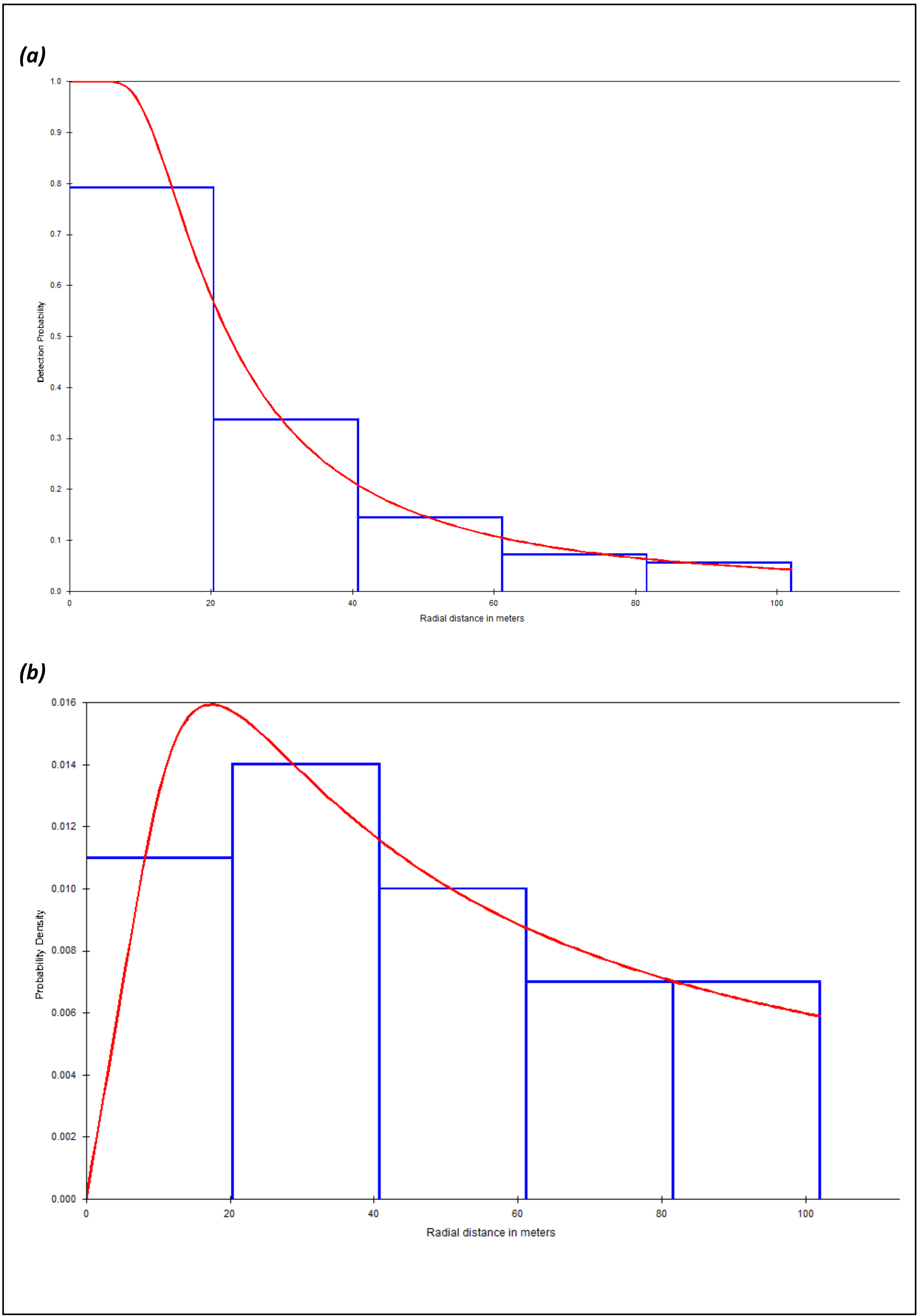

Figure 4: Diagnostic histograms used to help determine model fit. The fit of the modelled detection function is shown in *(a)* and the corresponding density function is shown in *(b)*. Bars represent observed data (divided into 5 intervals for analysis). Lines represent the curves fit by the model. The close fit of the curves fit by the model to the observed data support the choice of model.

4.0 Research and management

4.1 Risk-based decision analysis

On 28-29 November 2012, a workshop was held to elicit expert opinion on the potential threats driving population decline in *P. melanotus natalis* and to estimate the risk of extinction under six different management scenarios. The workshop was facilitated by Terry Walsh, Eve McDonald-Madden and Darren Southwell from the NERP Environmental Decisions Hub and hosted at the Melbourne University. Participants included experts in flying fox ecology (David Westcott – CSIRO, John Woinarski – Charles Darwin University and Norm McKenzie – WA DPaW) and captive breeding (Marissa Parrott – Zoos Victoria), as well as Parks Australia managers (Judy West, Mike Misso and Samantha Flakus). The results presented here are from the final workshop report prepared by Walshe *et al.,* (2012).

The main purpose of the workshop was to:

a) Identify and rank the relative contribution of speculative threats to past decline;
b) Estimate the risk of extinction over the next 20 years under a business as usual scenario;
c) Estimate the risk of extinction over the next 20 years under alternative management scenarios, and estimate the costs of implementing each management arrangement;
d) Use insights from these analyses to guide decision-making around species recovery.

A total of 19 potential threats (or hypotheses) were identified and subsequently eight were shortlisted and prioritised for further consideration (Table 4). To rank the potential threats and screen out those that were least likely, experts independently estimated the likelihood and consequence of each threat in the context of how it has contributed to the *P. melanotus natalis* decline. Uncertainty was accounted for through the assignment of an interval for likelihood and/or consequence judgements (Burgman, 2005; **Appendix E**). Figure 5 provides a summary of the rankings and the uncertainty. There was more certainty of a particular threat contributing to the decline if experts had a better understanding of the threat or if it was of least concern (i.e. impacts of trace element deficiency, climate change, emigration, hunting, predation by wolf snakes and non-detection). Conversely there was a high level of uncertainty concerning impacts that were not well understood such as cadmium poisoning and genetic loss. The threats resulting in low risk scores were omitted from further analysis. The remaining threats were simplified, clarified, merged or deleted (Table 5) to come up with the eight shortlisted hypotheses.

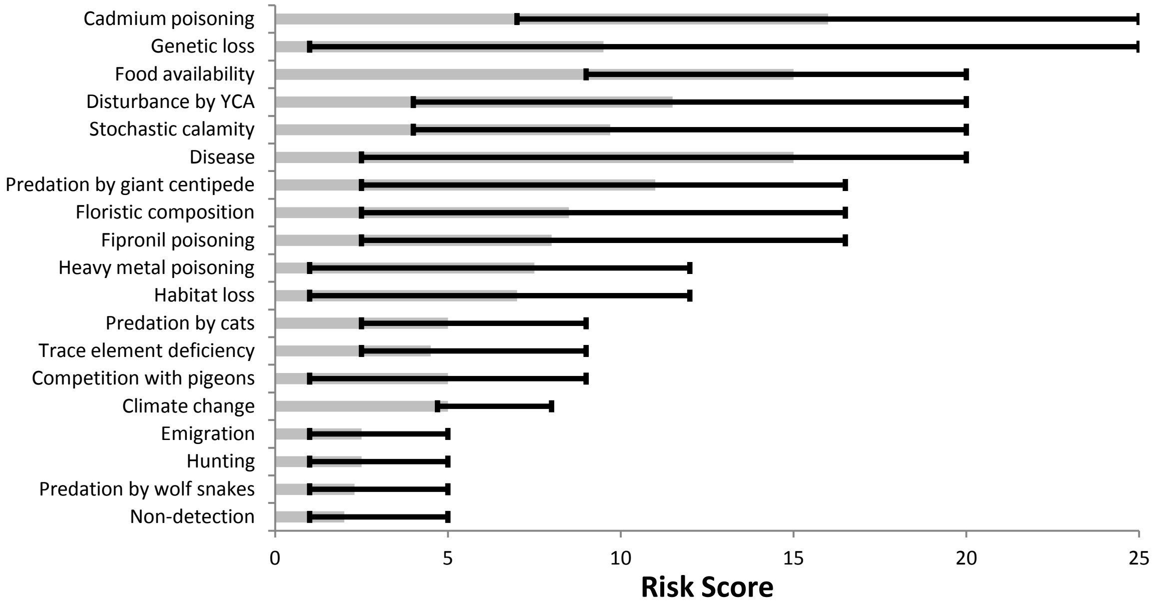

Figure 5: Risk scores for 19 potential threats that are likely contributors to population decline in *P. melanotus natalis.* Grey bars represent the average of assessors' midpoint scores. Error bars capture the full breadth of opinion.

Table 4: Identified and prioritised threats of *P. melanotus natalis*

	Identified threat	Rationale	Shortlisted as feasible
1.	Hunting	A historical impact and not considered to be an issue now. Some hunting may still occur but most likely on a small scale.	
2.	Predation by feral cats	Cat dietary studies confirm flying foxes as a prey item. With the continued presence of feral cats on the island there is still likely to be some level of impact.	✓
3.	Decline in food resources	Food resources may have declined as a result of cumulative clearing impacts, changes in floristic composition from yellow crazy ants as well as changes in climate patterns (i.e. particularly wet or dry seasons).	✓
4.	Disturbance by yellow crazy ants (YCA)	YCA activity is likely to disturb roosting flying foxes if ants are at super-colony densities. This is likely to cause increased movements during the day, stress, reduced fecundity or survivorship.	✓
5.	Cadmium poisoning	Cadmium is naturally found in the soil but is mobilised through soil disturbances such as mining. Flying foxes may be exposed to high/toxic levels of cadmium through the ingestion of dust on fruits/flowers, when cleaning their fur, and when drinking at temporary ponds around mined areas.	✓
6.	Disease and parasites	It is possible that novel disease is having population level impacts.	✓
7.	Stochastic events	Historical records suggest that severe weather and cyclones have significantly impacted on the population.	✓
8.	Habitat loss	Land clearing was likely to have impacted on flying foxes during the 1960s and 1970s however this is thought to have preceded the decline and was not thought to be a current impact.	
9.	Loss of genetic health	Small population size may impact on how the population functions and could result in loss of genetic diversity, reduced fitness, adaptability and/or reproductive success. This was not considered a significant problem.	
10.	Predation by the Asian wolf snake	An invasive species that may have an impact on unguarded young flying foxes. Not considered to be a main driver of decline.	
11.	Poisoning by giant centipedes	The venomous bite of the invasive giant centipede was thought to be a real and potential threat when interacting with flying foxes at roosting or foraging sites.	✓
12.	Poisoning by Fipronil	The broad-scale application of Fipronil for controlling yellow crazy ants was thought to be a potential threat contributing the current/continued decline if the bait was ingested when foraging or fur-grooming during aerial applications.	✓
13.	Emigration	Dispersal away from the island was considered as a potential driver of population change but it was thought to be very unlikely given the closest land mass is about 300km away.	
14.	Climate change	Although there is no evidence that climate change is contributing to population decline it may have long-term impacts on floristic change and food availability.	

15.	Competition with the Christmas Island pigeon	The flying fox has similar food requirements to the pigeon and there may be some competition for resources but not a significant driver of population decline.
16.	Trace element deficiency	It was thought that preferential foraging of exotic fruit and ornamental trees may lead to deficiencies in important trace elements. This was not considered a major threat.
17.	Floristic change	Possible changes to floristic composition since European settlement was thought to be a possible but insignificant threat.
18.	Non-detection	Although not a threat, non-detection during surveys was considered a potential cause for misrepresenting the magnitude of decline.
19.	Heavy metal poisoning	Toxicity from heavy metals other than cadmium was discussed but not considered to be an issue.

Table 5: Reasoning behind consolidation or removal of hypotheses

Hypothesis	Reason	Simplified	Clarified	Merged	Deleted
Genetic loss	Whilst considered an important factor in population viability, this hypothesis was removed as it was agreed that the magnitude of the threat was conditional on population decline through manifestation of other hypotheses.				✓
Heavy metal poisoning	Closely related to the threat of cadmium poisoning and was therefore combined with this threat.			✓	
Habitat loss	It was thought that further land clearing of previously uncleared rainforest was unlikely and that change in food availability would be linked closely to habitat loss if it occurred. It was therefore combined with food availability.			✓	
Floristic change	Like habitat loss any changes in food availability would be linked to floristic change therefore it was combined with the food availability hypothesis.			✓	
Food availability	This hypothesis was refined to specifically refer to food bottlenecks during critical periods of breeding (e.g. when females were lactating) as it is during these times when resource depletion may have greater affects on population dynamics. As mentioned above it was also merged with habitat loss and floristic change.		✓	✓	
Disturbance by YCA	This was simplified and clarified to include only direct impacts such as disturbance at roost and feeding sites as opposed to indirect and more complex impacts that may include changes to floristic composition and abundance of invasive species such as the Giant centipede.	✓	✓		
Giant centipedes	It was thought that centipedes may directly interact with flying foxes at roost sites or when encountered whilst feeding. Despite the risk being considered low it was retained as a potential threat.		✓		
Disease	Whilst disease is difficult to detect and manage it was still considered a possibility and a useful area of research. It was retained as a hypothesis.		✓		

The next step in the process was to determine a range of management scenarios in which each of the hypotheses could be examined, in order to estimate the risk of extinction over a 20 year time period. Six management scenarios were explored (Table 6). Experts collectively provided nominal estimates and plausible bounds for the probability of extinction for each of the scenarios over the 20 year time horizon. To estimate the aggregate probability of extinction, *E*, under each scenario, estimated threat-specific probabilities were assumed to be independent such that,

$$Pr\{E\} = 1 - \prod_{i=1}^{N} p_i$$

where p_i is the estimated probability of threat *i* and *N* = 8 shortlisted threats. The aggregate risk of extinction under each management scenario is shown in Figure 6. The risk of extinction posed by each of the shortlisted threats under each management scenario is shown in **Appendix F**.

Under a business as usual scenario the probability of extinction for *P. melanotus natalis* is 0.82 over 20 years with plausible bounds of [0.43, 1.00]. This estimate is broadly consistent with a geometric model parameterized using the inferred decline of 35% from detection surveys conducted in 2006 and 2012. If we say the rate of decline over six years is 0.35, then over 20 years (20/6 = 3.33 time steps), the estimated probability of extinction is $1 - (1 - 0.35)^{3.33} = 0.76$.

The reduction in risk of extinction under the various alternative management strategies is modest with the greatest expected reduction being associated with the implementation of cadmium mitigation (0.68 probability of extinction). Disease management was the next best strategy reducing the risk of extinction to 0.72. Food management was the worst strategy, where the anticipated benefits gained through increased food availability were judged to be insufficient to offset escalated risks posed by feral cat predation, as an unwanted side-effect of rat control.

There was considerable uncertainty in estimates of extinction risk for all management strategies, with all strategies other than cadmium mitigation falling within a range of 0.36 to 1.00. While the cadmium mitigation strategy resulted in the greatest uncertainty interval in the probability of extinction, the lower (or optimistic) bound was considerably lower than all other strategies at 0.17.

Table 6: Management scenarios

Management scenario		Explanation	Estimated cost over 20 years
1.	Do nothing (business as usual)	This strategy involved maintaining the current management of YCA control around roost sites and pursuing research and implementation of YCA biological control and rehabilitation of relinquished phosphate mine fields (up to 10 hectares per year).	$2.53 million
2.	Cadmium mitigation	This strategy was based on developing a cadmium regulation strategy that would address the concerns of cadmium poisoning and/or heavy metal contamination from mining activities. It involved improving cadmium regulation and dust control plus implementation of other controls that were thought necessary as well as enforcement. This also involved captive breeding (with diagnostic testing for disease) with the aim of supplementing the population.	$4.17 million
3.	Food management	This strategy was developed to address concerns about food availability and involved supplementary feeding regimes (i.e. installation of food stations across island) that would also provide trace elements and carbohydrates. It also involved the continuation of mine-site to forest rehabilitation activities with an emphasis on replanting appropriate native and cultivated food trees as well as continued YCA control to mitigate long-term impacts on floristic composition.	$1.285 million
4.	Protection of roost sites	This strategy focused on protecting known roost sites through cat eradication and high intensity YCA control. To further protect roosting populations from YCA disturbance, trees would be banded to prevent ants moving up them. Control of centipedes was also considered in this strategy however no feasible control method has yet been identified so it was not included.	$22.84 million
5.	Food management and captive breeding	This strategy was a combination of Strategy 3 above and captive management. This involved supplementing the wild population through captive breeding of about 20-25 flying foxes (with diagnostic testing for disease) over a 20 year period. It also involved rat control.	$4.34 million
6.	Disease management	This strategy involved establishing an on-island captive management program at a medium intensity with the aim of testing individuals for disease and parasites. Running parallel to this would be improvements in bio-security and border protection (implemented by Department of Agriculture). It was acknowledged that this strategy would depend on the type and nature of the disease.	$11.2 million

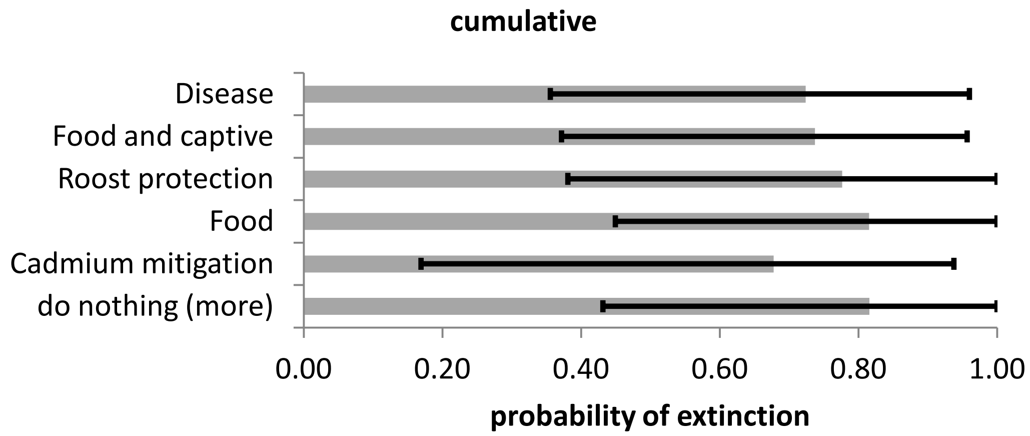

Figure 6: Risk of extinction aggregated over eight threats for each of six management scenarios. Grey bars show nominal best estimates. Error bars report plausible bounds.

To complement the risk analysis of candidate management strategies a simple cost-benefit analysis was also undertaken to assess the cost-effectiveness of each management strategy in reducing the risk of extinction. Based on the nominal best estimates of extinction and the change in this value from the 'Business as Usual (BAU)' scenario, and using the following equation, cadmium mitigation was the most cost-effective strategy (Figure 7).

$$\frac{\text{(estimated probability of extinction under BAU – estimated probability of extinction under strategy } i\text{)}}{\text{(cost of strategy } i \text{ – cost of BAU)}}$$

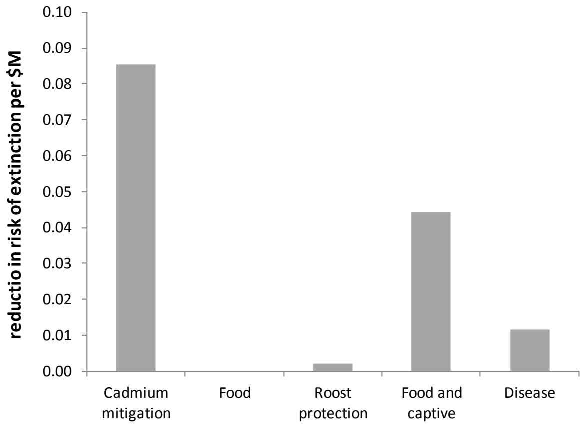

Figure 7: Cost-effectiveness of alternative strategies relative to the base case of 'Business as Usual'

4.2 Future management and research

Following the risk-based decision analysis and the identification of priority threats in 2012, Parks Australia Taronga Conservation Society Australia (hereafter referred to as Taronga) and flying fox experts held several discussions to plan conservation research and management directions. This resulted in the need to:

a) Identify future management options for managing the Christmas Island flying fox population, in particular the feasibility of captive management;

b) Better understand captive management requirements in the context of managing a captive population on Christmas Island (i.e. what will it involve and mean for on-ground staff); and

c) Identifying the gaps in knowledge about flying fox biology and ecology (including threats) and collaboratively developing an appropriate research proposal.

The outcome of these discussions led to five main actions (Table 7) and the start of a long-term research collaboration between Parks Australia, CSIRO, Taronga, University of Western Sydney, University of Sydney, EcoHealth Alliance and the Royal Botanic Gardens. This research collaborative aims to better understand the ecology, population trends, and microbial diversity of *P. melanotus natalis,* to mitigate the factors driving decline.

The first meeting of this collaborative group was held on 31 January 2014 to discuss the current status of *P. melanotus natalis,* current funding commitments (in-kind and cash) and opportunities, research priorities and the overarching research framework and timelines. Taronga reported that in August 2013, they applied for $124,800 over three years through their internal Conservation Science Initiative program to support interdisciplinary research on *P. melanotus natalis*. The funding was aimed at either leveraging further funds to support the broader research initiatives or top-up existing in-kind and cash contributions to proceed with certain aspects of the research. Taronga was successful in this grant application and subsequently applied for $37 million through the Australian Research Council to create a Centre of Excellence in Microbial Diversity, Ecology and Control under which the *P. melanotus natalis* research would sit. Their funding application was unsuccessful. A third funding application was submitted to the Australasian Bat Society for $1,000 to support research into developing non-invasive methods for the detection of toxic heavy metals (e.g. cadmium) in *P. melanotus natalis* using the Grey-headed flying fox (*P. poliocephalus*) as an analogue species. At the time of writing, this application was still pending and an Australian Research Council (ARC) Linkage Projects grant application was also in preparation for submission in November 2014.

The University of Western Sydney also applied for funding ($90,000) through the Hermon Slade Foundation to support an ecological based project focusing on determining movement and home ranges of *P. melanotus natalis.* They were also unsuccessful in their application but have since secured internal university funding to support one PhD student with a total value of $193,959 over three years. A PhD focusing on population ecology and impacts was advertised on 22 September 2014.

A summary of funding commitments and grant applications to September 2014 is shown in Table 8.

Table 7: Actions from a *P. melanotus natalis* meeting on 17 June 2013

Action #	Description	Status
1	Taronga to develop a disease research proposal that can be implemented in conjunction with other future research programs that involve the capture of flying foxes	Completed July 2013 and funding granted through the Taronga Conservation Science Initiative to support the program
2	Parks Australia to send any flying fox samples to Taronga for disease analysis.	Samples will be sent when quarantine permits are finalised
3	CSIRO and UWA to collaboratively develop a research project proposal focusing on aspects of *P. melanotus natalis* ecology, biology and threats.	Draft completed and PhD advertised in September 2014 for immediate commencement
4	Taronga to develop a proposal for a pilot captive management plan for *P. melanotus natalis*.	Completed July 2013
5	Parks Australia to investigate possible funding options for *P. melanotus natalis* research and captive management.	Ongoing – options being explored

Table 8: Summary of committed funding over a three year period and funding applications to August 2014

Partner	Cash contribution	In-kind contribution	Funding applications
Taronga	$124,800	$164,400	Australian Research Council ($37 million) – unsuccessful Australasian Bat Society ($1,000) – pending
University of Western Sydney	$198,959	$193,652	Hermon Slade Foundation ($90,000) – unsuccessful
Parks Australia	Up to $8,000	$216,000	Foundation for National Parks & Wildlife ($459,500) – pending
CSIRO	$30,000	-	
University of Sydney	>$9,500	$32,500	
NSW Office of Environment & Heritage	-	$49,100	
TOTAL	**$371,259**	**$655,652**	

The immediate priorities for research identified by the group were:

1. Ecological research focusing on population assessments and demographics, identifying roosting sites and social context of roosting, interactions between animals and sub-populations (if any), characterising animal behaviour, investigating habitat utilisation across seasons, nutritional resource use, foraging patterns and low resolution assessments of some population threats.

2. Health research focusing on disease and parasites, heavy metal contamination, diversity and evolution of viruses and additional phylogenetic characterisation.

If further funding is secured, then the following research priorities will be pursued:

1. Additional ecological research focusing on threat identification and mitigation.

2. Nutritional studies with respect to how heavy metal contamination may affect nutrient absorption/in-take and its implications for reproduction and survivorship.

3. Reproductive ecology and life history of captive populations.

4. Socio-economic research and community engagement to quantify the value of *P. melanotus natalis* as a keystone species and to develop a framework for effective community and industry engagement in species recovery.

4.3 EPBC Act exemptions

In June 2014 the Director of National Parks sought exemption under sections 158 and 303A of the EPBC Act from the application of all of the provisions in Part 3 (Requirements for environmental approvals), Chapter 4 (Environmental assessments and approvals) and Part 13 (Species and Communities) in respect to actions relating to the implementation of a captive management program for *P. melanotus natalis.*

Justification for the exemption was based on the recorded rapid decline of 41 per cent over a period of seven years (2006-2013), its status as the last of five native mammals on the island, the recent listing of the species as Critically Endangered, its important role in the ecosystem and the potential need for urgent ex-situ management if a continued decline is recorded.

On 26 June 2014 the Minister for the Environment granted the relevant exemptions for:

> The establishment and operation of a captive management program for *P. melanotus natalis,* including but not limited to:
>
> - The capture of a sufficient number of *P. melanotus natalis* individuals on Christmas Island so as to meet the objectives of the captive management program as recommended by expert advisors;
> - Holding *P. melanotus natalis* in captivity for a minimum of three years;
> - Captive husbandry of *P. melanotus natalis;* and
> - Release of individual *P. melanotus natalis* that may be reared in captivity into natural habitat on Christmas Island.

5.0 Discussion

The results of the 2014 monitoring program provide further evidence that there is an ongoing and accelerated decline in the *P. melanotus natalis* population and that more focused management is required to stop or reverse this trend. Some progress has been made towards identifying the threats and prioritising them for further investigation through the risk-based decision analysis and through developing collaborations with research institutions. However, the urgency in progressing such proposed research and management actions has now hit a critical threshold.

With respect to the accelerated rate of annual decline recorded between 2013 and 2014 (i.e. 28% in incidence and 37.8% in estimated abundance), it is speculated that the Category 1 cyclone that passed north-west of Christmas Island in March 2014 was largely responsible for the significant change in incidence and abundance recorded. This cyclone caused severe tree and canopy loss to the north-western side of the island and minor to moderate tree loss and canopy damage to all other areas, which in other studies, have been known to change flying fox activity and foraging patterns (David Westcott, pers. comm., 2014).

For example, similar impacts to flying fox populations have been documented in American Samoa following three cyclonic events between 1987 and 1991 (Craig *et al.,* 1994). In this study a population decline of 80-90% was recorded. Other studies in American Samoa focused on the change in foraging behaviour following cyclonic events. Gilbert *et al.* (2014) found that flying foxes increased their search time and decreased their 'tree time' indicating that the availability of food resources per tree had reduced following a cyclone. This lead to a significant change in foraging behaviour with flying foxes seeking out other areas that were less affected by the cyclone. In studies closer to home, Shilton *et al.* (2008) reported that the spectacled flying fox (*P. conspicillatus*) in north-east Queensland roosted in smaller camps post-cyclone, were found in 'new' areas and that up to 90% of their pre-cyclone population was unaccounted for up to six months following the event. They also reported that within 12 months of the cyclone, flying fox numbers were comparable to pre-cyclone estimates suggesting that redistribution was a logical response mechanism for flying foxes to employ in the event of major disturbance to habitat and resource availability. Corbett *et al.* (2003) also suggested that a severe storm event on Christmas Island in 1988 was responsible for mass mortality in *P. melanotus natalis,* which the population never seemed to recover from.

Whilst the true impact of the recent cyclone on *P. melanotus natalis* cannot be quantified, subsequent field surveys conducted by Park staff around known camps found that while the known camp at Hosnies Springs fared well, with only minor tree loss and canopy damage, the large roost trees in the camp at McMicken Point were devastated and one of the two main roost trees at the Golf Course camp was destroyed. Therefore it is not unreasonable to assume that the cyclone caused some level of mortality and/or redistribution either during or after the cyclone as a result of the notable changes in habitat quality and food availability. This may have inadvertently resulted in fewer detections during this survey and at least partly explain why an accelerated rate of decline in incidence was reported this year. It is also interesting to note that in the months after the cyclone, Park staff reported finding 2 dead flying foxes (one on the forest floor and one hanging in a tree at a known roost site) as well as another sick individual on the forest floor (unfortunately in a location too isolated to carry it out). Two reports from local residents of 'disorientated' flying foxes foraging very close (<1m) to the ground were also received though the animals were not observed by Park staff. The longest serving Park staff revealed that only 2 dead individuals have previously been observed in the last 7 years of extensive field work (and one of those individuals was on a powerline in town).

Without trying to downplay the seriousness of the decline, it is also important to acknowledge that the nocturnal monitoring method adopted here does have its limitations despite being designed to provide a more robust method of detecting change over time compared to the variability seen in roost-based counts (Woinarski *et al*., 2014). Limitations such as distribution of sampling points, time of sampling, variability in reporting conditions (i.e. weather) and the reliance of flying foxes being active and vocal during the 10 minute survey period, all influence the detectability on a nightly basis which may well be amplified during times when activity patterns and feeding regimes are in a state of flux. Regardless of this, without an alternative monitoring regime in place to minimise the 'noise' in the data, the precautionary principle must still apply and this continued decline should serve as a reminder that a more focused conservation and research effort is needed to support the recovery of this species.

Identifying the potential threats and developing realistic management strategies through a risk assessment process has been an important first step in providing a more transparent and structured foundation for prioritising research and management needs. This approach is becoming more widely accepted in threatened species management as it provides better qualitative guidance (McDonald-Madden *et al.,* 2010) and quantitative approaches (Runge *et al.,* 2011) to assist in evaluating the value of information used in decision making.

This is a positive step forward and together with the EPBC exemptions noted above, the broader support from research collaborators and the recommended recovery actions identified in the Australian Mammal Action Plan (Woinarski *et al*., 2014); Christmas Island National Park Management Plan (2014-2024) and the Draft Christmas Island Biodiversity Conservation Plan (Parks Australia, 2014), we are well placed to move forward with on-ground action when adequate resourcing becomes available.

6.0 Recommendations

Some of the recommendations identified in 2013 still apply and have been included here along with new and emerging priorities.

1. Continued monitoring

a. Annual nocturnal monitoring
Continuation of the nocturnal monitoring program for <u>at least</u> one more year is important in order to maintain a consistent approach in assessing population change until telemetry work is used to ground truth flying fox distribution and activity patterns (see Recommendation 2). Such research will aid in assessing the effectiveness of the current monitoring program and inform the development of alternative methods if necessary. This monitoring method should also be conducted during any transition period in monitoring so that existing and new monitoring outcomes can be compared and therefore may need to be continued in 2016 and possibly 2017.

b. ***Ground and exit counts***
To support the annual nocturnal monitoring program and to provide a robust minimum population estimate, the continuation of ground and exit counts using a slightly different approach is recommended. Currently counts are undertaken quarterly and results are highly variable between seasons, particularly during the wet season when canopy cover affects ground-based observations and wind direction/speed can alter the course of exiting flying fox (which may not be seen from vantage points). Therefore, it is recommended to conduct

fortnightly ground and exit counts during the height of dry season for a period of two months (i.e. starting mid-August to mid-October).

2. ***Support research into accurately assessing the population size, distribution, and roosting and foraging requirements of* P. melanotus natalis *using acoustic and remote monitoring techniques***

Determining the exact population status of *P. melanotus natalis* confirming the exact rate of decline is a fundamentally important issue that needs to be resolved. Proposed telemetry studies will work towards addressing this issue and form the basis for subsequent ecological and management focused research. This research will help determine, (a) the dispersal patterns of flying foxes across seasons, (b) if there are changes in the size and number of camps occupied at different times of the year, and (c) if the detection rate of animals at night does indeed indicate a decrease in abundance. The outcomes of the research will lead to developing a more robust monitoring method that is potentially more resource efficient.

It is recommended that Parks Australia partner with relevant organisations (i.e. CSIRO and the University of Western Sydney) by investing personnel and resources (cash and in-kind) into this research to improve (a) future population monitoring of *P. melanotus natalis,* and (b) gain a better ecological understanding of this species.

3. ***Source adequate funding to support a three-year pilot captive management program and implement by December 2015.***

All of the administrative arrangements that support captive management of *P. melanotus natalis* are in place including the relevant EPBC exemptions and expert support. It is now critical that adequate funding is secured to implement a three-year pilot program by December 2015 as precautionary approach to managing the recovery of this species whilst threats are mitigated and a better understanding of the species' in-situ ecology is gained.

4. ***Parks Australia to support targeted research on P. melanotus natalis* proposed by the collaborative research partners**

   a. ***Ecology-based research***
   This should include gaining a better understanding of (a) spatial and foraging ecology (including roosting behaviour, habitat use and foraging resources), (b) population ecology (including life history, population genetics, social behaviour and mating systems) to inform better monitoring and management actions.

   b. ***Threats-based research***
   This should focus on conservation management interventions including (a) investigating the various threats identified in the risk-based decision analysis as a priority, (b) assessing landscape-scale ecological consequences of further decline or loss of *P. melanotus natalis*, (c) determining in-situ management options (i.e. threat mitigation), (d) undertaking a Population Viability Analysis, and (e) working towards captive management.

5. ***Continuation of invasive species control and threat mitigation programs including Yellow Crazy Ant control and feral cat management.***

Yellow crazy ant and predation by feral cats are both listed under the EPBC Act as Key Threatening Processes that impact Christmas Island's biodiversity. The maintenance of a healthy, functioning ecosystem on Christmas Island, by managing these threats, is likely to prove requisite to the continued persistence of the flying-fox population. The efficacy of these existing programs and the benefit that they have to the functioning of the Island ecosystem as a whole (including flying-fox persistence) necessitates their continuation. Therefore, the scaling back or termination of these programs is not recommended. This same recommendation, of invasive species control, should be applied to any other invasive species and/or threatening processes that may be identified by any research efforts directed at *P. melanotus natalis*.

7.0 Acknowledgements

Thank you to all the researchers and other experts who provided input into the threat assessment workshop and the development of research and management projects for the conservation of the Christmas Island Flying Fox.

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Appendix A

Wind speed
An adapted beaufort scale was used to ensure that wind speed was judged consistently across the survey period by different observers. Surveys were not conducted in winds rated higher than '4' in order to ensure that flying-fox detectability was maintained.

Beaufort	Knots	km/h	Description
0	<1	<1	"Calm"
1	1 - 3	1 - 6	"Gentle" Rising smoke would drift. Leaves are almost completely stationary.
2	4 - 6	6 - 11	"Light" Wind felt on exposed skin. Leaves rustle and thin, exposed trees may sway. Very little to no movement in dense canopy areas although exposed/emergent's may rustle.
3	7 - 10	12 - 19	"Breeze" Leaves constantly moving but not violently. A light flag would be consistently extended. Tops of trees in dense stands/canopies move and make some noise. Trees may sway.
4	11 - 16	20 - 28	"Moderate" Leaves constantly moving. Small to moderate sized branches move. Tops of trees in stands/canopies move and may make substantial noise. Trees may sway noticeably.
5	17 - 21	29 - 38	Loud wind noise Substantial tree movement Noticeable inconvenience to walk into the wind

Appendix B

DISTANCE software package modelling output

Apart from the 'Model definition' and 'Data filter' summaries below, all output is provided 'as-is' from the DISTANCE statistical software package.

Model definition

Analysis engine: Conventional Distance Sampling
Key function: Hazard-rate
Series expansion: Simple polynomial
Cluster size estimation: regression of log (s(i)) on g(x(i)), if not significant, mean of observed clusters sizes will be used.
Variance estimation: empirical estimate from sample
Multipliers: None

Data filter

Distance data transformed into 5 equal intervals for analysis (cut points: 0-102m)
Data truncated at 102m (4 data points excluded from modelling)

Model fit

```
** Warning: The number of adjustment parameters allowed has
  been reduced to   2 because of limited number of intervals. **


 Model  1
    Hazard Rate key, k(y) = 1 - Exp(-(y/A(1))**-A(2))
       Results:
       Convergence was achieved with   12 function evaluations.
       Final Ln(likelihood) value =  -77.181603
       Akaike information criterion =   158.36320
       Bayesian information criterion =   162.14685
       AICc =   158.62407
       Final parameter values:   18.480283      1.8374322


 Model  2
    Hazard Rate key, k(y) = 1 - Exp(-(y/A(1))**-A(2))
    Simple polynomial adjustments of order(s) :  4
       Results:
       Convergence was achieved with   13 function evaluations.
       Final Ln(likelihood) value =  -77.181171
       Akaike information criterion =   160.36234
       Bayesian information criterion =   166.03780
       AICc =   160.89568
       Final parameter values:   18.813181      1.8519863    -0.16751709E-04
      ** Warning: Parameters are being constrained to obtain monotonicity. **

    Likelihood ratio test between models  1 and  2
       Likelihood ratio test value    =     0.0009
       Probability of a greater value =   0.976543
 *** Model  1 selected over model  2 based on minimum AIC
```

Chi-squared goodness of fit test

Cell i	Cut Points		Observed Values	Expected Values	Chi-square Values
1	0.000	20.4	11	11.10	0.001
2	20.4	40.8	14	13.64	0.009
3	40.8	61.2	10	10.02	0.000
4	61.2	81.6	7	7.82	0.085
5	81.6	102.	7	6.42	0.052

```
Total Chi-square value =     0.1478  Degrees of Freedom =  2.00

Probability of a greater chi-square value, P = 0.92878
```

Cluster size estimates

```
Expected cluster size estimated based on regression of: log(s(i)) on g(x(i))
** Warning: Exact distance values, rather than distance intervals,
have been used in size bias regression calculations. **


 Regression Estimates
 --------------------
 Slope      =    0.169669E-02   Std error   =    0.148551
 Intercept  =    0.155067       Std error   =    0.663927E-01
 Correlation=    0.0017         Students-t  =    0.114216E-01
 Df         =     47            Pr(T < t)   =    0.504532


 Expected cluster size =   1.2421     Standard error    =  0.63330E-01

 Mean cluster size     =   1.2449     Standard error    =  0.80022E-01

 Test p-value greater than specified significance level= 0.150
 Average cluster size will be used.
```

Density estimates

```
Model  1
    Hazard Rate key, k(y) = 1 - Exp(-(y/A(1))**-A(2))
```

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
DS	5.3536	3.3716	62.98	1.6818	17.042
E(S)	1.2449	0.80022E-01	6.43	1.0941	1.4165
D	6.6647	4.2191	63.30	2.0841	21.313

```
 Measurement Units
 ---------------------------------
 Density: Numbers/Sq. kilometers
     EDR: meters

 Component Percentages of Var(D)
 -------------------------------
 Detection probability   :  90.8
 Encounter rate          :   8.1
 Cluster size            :   1.0
```

Detection probability

		Estimate	%CV	df	95% Confidence Interval	
Hazard/Polynomial						
	m	2.0000				
	LnL	-77.182				
	AIC	158.36				
	AICc	158.62				
	BIC	162.15				
	Chi-p	0.92878				
	h(0)	0.13620E-02	60.33	47.00	0.44402E-03	0.41778E-02
	p	0.14114	60.33	47.00	0.46013E-01	0.43294
	EDR	38.320	30.17	47.00	21.164	69.385

Expected cluster size

		Estimate	%CV	df	95% Confidence Interval	
Average cluster size		1.2449	6.43	48.00	1.0941	1.4165
Hazard/Polynomial						
	r	0.16660E-02				
	r-p	0.50453				
	E(S)	1.2449	6.43	48.00	1.0941	1.4165

Density and abundance

		Estimate	%CV	df	95% Confidence Interval	
Hazard/Polynomial						
	DS	5.3536	62.98	55.76	1.6818	17.042
	D	6.6647	63.30	56.92	2.0841	21.3

Appendix C

Database of flying-fox survey results from 2006, 2012, 2013 and 2014

Site no.	Location (UTM 48S WGS84)		Site name	Flying- fox incidence			
	Easting	Northing		2006	2012	2013	2014
1	568883	8841814	Central Area Workshop	2	0	0	0
2	567847	8841828	NW Pt Rd	0	0	0	1
3	566852	8841912	NW Pt Rd	0	0	0	0
4	565863	8841820	LB4 rehab	1	0	0	0
5	565011	8842153	NW Pt Rd	1	0	0	0
6	564050	8842290	Rc2 NW Pt Rd	2	0	0	0
7	563127	8842482	IRPC	NA	0	0	0
8	562292	8842860	SW1A2 IRPC	NA	0	0	0
9	561592	8843514	Toms Ridge Rd	NA	0	1	0
10	560814	8844060	Toms Crack Trk	NA	0	0	0
11	560366	8844748	Toms Crack Trk	NA	1	0	0
12	563189	8842062	Dales Rd	0	0	1	0
13	562264	8841978	Dales National Park sign	0	0	0	0
14	561516	8841856	Dales Rd	0	1	0	2
15	561095	8842738	Martin pt Carpark	0	0	0	1
16	562658	8841176	Winifred Track	1	3	0	0
17	563485	8841454	Jacks Hill Minefield	2	0	1	0
18	562293	8840678	Winifred Track	0	0	1	0
19	562226	8839982	Cnr WTK & Winifred Tk	0	1	0	0
20	561669	8839510	Winifred Track	0	2	0	2
21	560816	8839548	Winifred Track	1	0	1	0
22	560058	8839252	Winifred walking track	0	1	0	2
23	562991	8839438	Western Circuit Track	1	1	1	1
24	563911	8839428	Western Circuit Track	2	1	0	1
25	565957	8840962	Field 23 Rehab	0	0	1	0
26	565950	8840224	23 Rehab Southern	NA	1	0	0
27	566624	8840980	Lb4 Road btwn 22s and lb4	2	0	0	0
28	569468	8842436	Pink House/ Murray R cnr	2	1	0	0
29	569374	8841428	Research Station trk	1	1	0	0
30	569859	8840854	Research Station trk	1	0	1	0
31	570590	8840254	Research Station trk	3	0	1	0
32	571034	8840734	Pink House/ Grants Well trk	2	0	0	0
33	571378	8841622	Grants Well Telegraph Trk	1	0	3	0
34	569874	8840316	Janeup Trk	NA	2	1	0
35	571403	8842618	Grants Well Telegraph Trk	0	2	0	0
36	571626	8843358	Grants Well Telegraph Trk	1	2	0	0
37	572167	8844156	Cnr Plateau rd/Grants well	0	1	0	0
38	572460	8844886	Kim Cheys	2	0	0	1
39	573231	8840758	Greta/NS Baseline Cnr	0	0	1	0
40	574072	8840988	Greta Beach Trk	3	1	0	1
41	574504	8840958	Greta Beach Trk	3	2	0	1
42	574155	8840132	Greta Beach Trk	2	0	2	0
43	573968	8839394	Greta Beach Trk	3	0	1	0
44	573519	8838674	Dolly Beach Trk	2	2	3	1
45	573718	8841578	NS Baseline	0	0	0	0
46	574419	8842412	NS Baseline	1	0	0	1
47	575039	8843254	NS Baseline	0	0	0	0
48	575323	8844128	NS Baseline	1	0	0	1
49	575920	8843090	Waddell Hill	0	1	0	0
50	576955	8842733	Waddell Hill Mine	0	0	0	0
51	571704	8844212	Murray Rd	0	1	0	0

Site no.	Location (UTM 48S WGS84)		Site name	Flying- fox incidence			
	Easting	Northing		2006	2012	2013	2014
52	570892	8843634	Murray Rd	2	0	0	0
53	570129	8843008	Murray Rd	2	0	0	0
54	568372	8840954	Murray Rd	0	2	3	0
55	567599	8841292	23 Mango Trk	2	0	0	0
56	567457	8840422	Cnr 22S and LB4 Rd	0	0	1	0
57	568492	8840316	EW Baseline	0	0	0	0
58	569302	8840288	Old Rehab Field 21	NA	1	0	0
59	570031	8839568	EW Baseline	0	2	1	0
60	571021	8839630	Research Stn/EW Baseline cnr	0	0	0	0
61	571417	8838766	Telegraph Trk Opp. ML 106	0	0	0	0
62	570584	8838432	Trk to Field 20E rehab	0	0	0	0
63	569655	8838778	Trk to Field 20E rehab	0	2	0	0
64	568851	8839364	Trk to 20 central rehab	3	1	0	0
65	568180	8839728	Field 20 rehab	0	0	0	0
66	568534	8838670	Old Blowholes Trk A	NA	0	0	0
67	570617	8838120	Blowholes Rd	1	0	0	0
68	569940	8837462	Blowholes Rd	3	1	0	1
69	569030	8837732	Blowholes Rd	0	0	0	1
70	568331	8837682	Blowholes	0	1	1	2
71	567597	8837956	Western Blowholes	NA	0	1	1
72	572612	8839922	NS Baseline	2	0	0	0
73	572036	8839128	NS Baseline	0	0	0	1
74	571472	8838356	NS Baseline	0	0	1	0
75	571181	8837492	NS Baseline	1	0	1	0
76	571439	8836590	NS Baseline	1	0	0	0
78	571909	8835896	Eastern Field 17	NA	1	0	0
79	573263	8845522	Irvine Hill	1	0	0	1
80	574142	8845304	Irvine Hill	2	0	1	1
81	574898	8844762	Airport Rd	0	0	0	0
82	574876	8841760	Margaret Knoll	NA	0	2	0
83	571028	8835686	Field 17 NS Baseline	1	0	0	0
84	570720	8834796	NS Baseline	1	1	1	1
85	570920	8833842	NS Baseline	3	0	0	1
86	571513	8833032	South Point	0	1	0	0
87	571804	8832316	South Point	0	0	1	0
88	572552	8832472	South Point Fishermans Trk	NA	0	1	0
89	572132	8833780	APSC Site	NA	2	2	0
91	571703	8835004	Field 17	NA	0	0	0
93	573820	8844395	Hanitch Hill Rd Airport Side	NA	0	1	0
94	575106	8845840	Airport road	0	0	0	0
95	575820	8846482	Airport mine ML 135	1	1	0	0
96	576249	8845600	Lily Beach Rd	0	0	0	0
97	575889	8846667	Entrance to ML 132	1	0	0	0
98	577252	8845322	ML132	0	1	1	0
99	576901	8846156	ML132	0	1	1	0
100	576696	8843820	Cnr Lily Beach Rd and Link Rd	0	0	1	0
101	577248	8843142	Lily Beach Rd	0	0	0	1
102	577128	8843658	Ethel Beach Rd	0	0	0	1
103	572928	8843594	Hanitch Hill plateau trk	0	0	0	0
104	573718	8843078	Hanitch Hill plateau trk	0	0	1	0
105	573188	8844228	Hanitch Hill/Airport trk	0	0	0	0
106	573992	8846002	Irvine Hill Radio Mast Trk	0	0	0	0
107	576020	8847420	Phosphate Hill Cemetery trk	0	1	0	0
108	575145	8847722	ML136	0	NA	NA	NA
109	573308	8846664	PANCI Office	1	0	1	2
110	566830	8839668	Field 22 Central	NA	0	0	1

Site no.	Location (UTM 48S WGS84)		Site name	Flying- fox incidence			
	Easting	Northing		2006	2012	2013	2014
111	567548	8839790	Eastern arm of 22South Rd	1	0	1	2
112	566718	8839114	Eastern Circuit Trk	2	0	0	0
113	565957	8839342	Circuit Trk	2	0	0	2
114	566278	8840134	Circuit trk & Aldrich Hill	0	0	0	0
115	565088	8839064	Western Circuit Track	1	0	0	1
116	572546	8846206	Daniel Roux Trk	0	0	1	1
117	572752	8847166	Buck House	0	2	3	0
118	573639	8847368	Post Office Carpark	0	1	1	0
119	573860	8848358	Cocos Padang	1	0	0	0
120	574758	8848336	Opposite Mango tree Lodge	0	0	1	0
121	575813	8848592	Golf Course Rd	0	0	0	0
122	572425	8841181	Grants well trk/1km from NS	1	2	0	0
123	569372	8836878	1km down Boulder track	1	0	3	0
124	569593	8835144	2km down Boulder Track	1	3	2	2
125	569533	8836071	3km down Boulder track	1	1	0	0
126	569941	8834112	4km down Boulder Track	0	2	2	1
127	569984	8833109	5km down Boulder Track	0	0	0	0
128	570245	8832230	6km down Boulder track	0	0	0	0

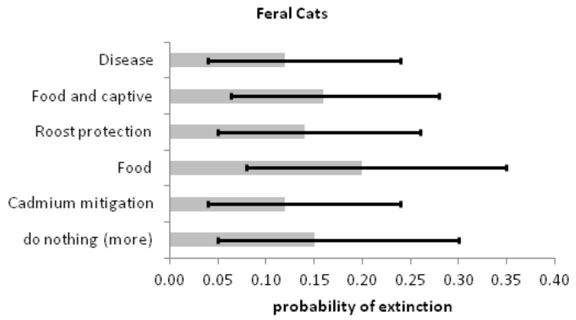
Appendix D

Likelihood		Consequence				
		Insignificant **(1)**	Minor **(2)**	Moderate **(3)**	Major **(4)**	Catastrophic **(5)**
Almost certain	**(5)**	5	10	15	20	25
Likely	**(4)**	4	8	12	16	20
Moderately likely	**(3)**	3	6	9	12	15
Unlikely	**(2)**	2	4	6	8	10
Rare	**(1)**	1	2	3	4	5

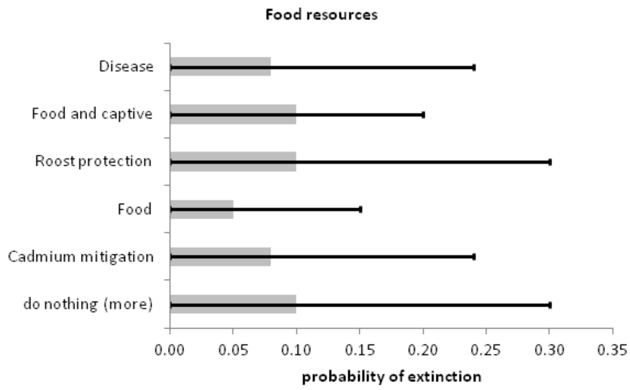
Likelihood
1 0.00 – 0.01
2 >0.01 – 0.05
3 >0.05 – 0.10
4 >0.10 – 0.50
5 >0.50 – 1.00

Consequence (Ecological Risk)
1 no decline
2 < 5% decline
3 5 – 10% decline
4 10 – 50% decline
5 >50% decline

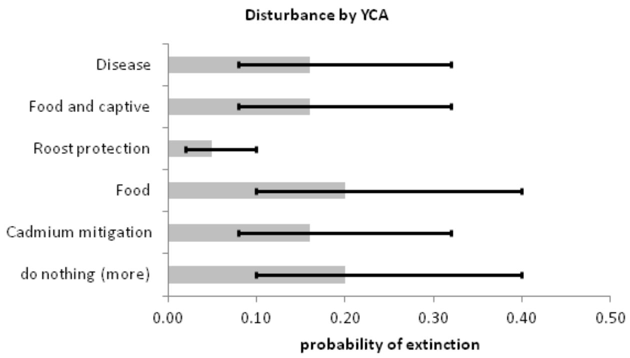
Appendix E



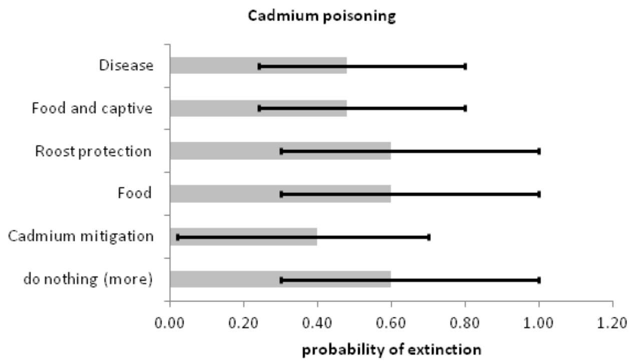
Feral Cats
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
probability of extinction



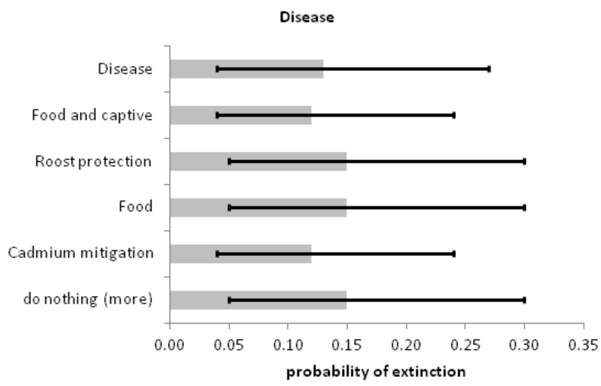
Food resources
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35
probability of extinction

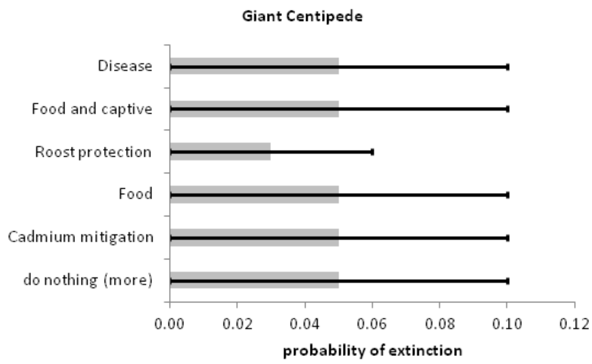


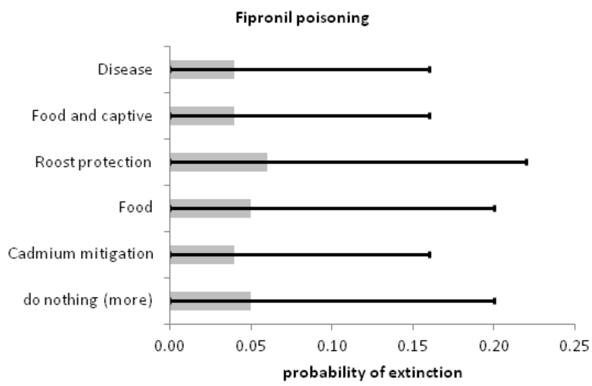
Disturbance by YCA
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.10 0.20 0.30 0.40 0.50
probability of extinction

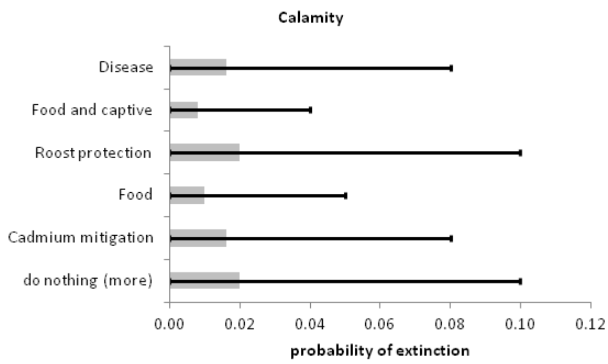


Cadmium poisoning
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.20 0.40 0.60 0.80 1.00 1.20
probability of extinction


Disease
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35
probability of extinction


Giant Centipede
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.02 0.04 0.06 0.08 0.10 0.12
probability of extinction


Fipronil poisoning
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.05 0.10 0.15 0.20 0.25
probability of extinction


Calamity
Disease
Food and captive
Roost protection
Food
Cadmium mitigation
do nothing (more)
0.00 0.02 0.04 0.06 0.08 0.10 0.12
probability of extinction