Christmas Island Flying Fox

Risk-based decision-support

OUTCOMES OF A WORKSHOP HELD 28TH AND 29TH NOVEMBER 2012

at The University of Melbourne

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Executive summary

The Christmas Island Flying Fox is an endemic bat to Christmas Island. Surveys suggest the species has declined by approximately 35% over the last 6 years. While the threats driving this decline are poorly understood, it is timely to consider management actions that may improve the long term persistence of the species and investigative work that may best guide ongoing decision-making. This report summarises outcomes of a workshop exploring the potential threats to Christmas Island Fruit Bats and the merit of a candidate set of management strategies.

Experts in flying fox ecology and the management of Christmas Island National Park were present at the workshop. They estimated the extinction risk for the Christmas Island Flying Fox under six alternative management strategies and eight hypotheses about drivers of population decline. Under a business as usual scenario, the extinction risk for the Christmas Island Flying Fox was estimated at 0.82 over a 20 year time horizon, although there was considerable uncertainty surrounding this estimate. A management strategy focused on cadmium mitigation had the most potential to improve the persistence of the species if uncertainty was resolved and was also the most cost-effective management strategy for implementation. Based on these results a decision tree outlining a sequence of research and management recommendations was outlined. We discuss the potential for further investigative work to inform management if cadmium impacts are proven to be a non-significant threat to the Christmas Island Flying Fox.

Contents

1.0 INTRODUCTION

This report documents outcomes of an expert workshop exploring management options for the recovery of the Christmas Island Flying Fox. Participants at the workshop are listed at Appendix 1.

A risk-based approach built around the International Standard for Risk Management (ISO 31000:2009) was adopted at the workshop. Steps in the framework include:

1. Establishing the context
2. Risk identification
3. Risk analysis
4. Risk evaluation
5. Risk treatment (i.e. implementation)
6. Monitoring and review

The workshop focussed on Steps 2 – 4. Below we outline the context. In the *Methods* section we describe the risks identified and methods used in their analysis. After presenting results, the *Discussion* provides commentary on risk evaluation, together with a decision tree to guide future decision-making.

1.1 Establishing the context

The Christmas Island Flying Fox (CIFF) is a small (220 – 500 g) bat endemic to Christmas Island. Detection surveys conducted across the island suggest that populations of this species have declined by approximately 35% from 2006 to 2012 (Figure 1). The magnitude of this decline is coarsely consistent with temporal trajectories suggested in other data sets. While there is strong evidence of temporal decline in flying fox populations over the last 6 years, the presence of any spatial structure in population decline is less apparent. Figure 1 provides weak evidence of fewer individuals along major roads in 2012 relative to 2006, particularly the main transport route between the settlement and the detention centre. Although the historical fecundity and survivorship of the CIFF is relatively well understood from earlier work by Tidemann (1985), no information is available on the demography of the decline.

A number of postulated threats are associated with the decline in CIFF. While the island has witnessed significant land use and ecological change in recent decades, none of these factors have been clearly demonstrated to have a significant impact on flying foxes. Disturbance or predation by invasive species such as cats, rats, centipedes or yellow crazy ants (YCA), might be contributing to population decline. It is possible that diseases, parasites or current mining activities might be impacting on populations. Alternatively, past land clearing, habitat loss or catastrophic events such as cyclones might be having delayed effects on population dynamics. One of these threats might be driving population decline or the cumulative and interactive effects of a subset (or all) of these threats may be responsible.

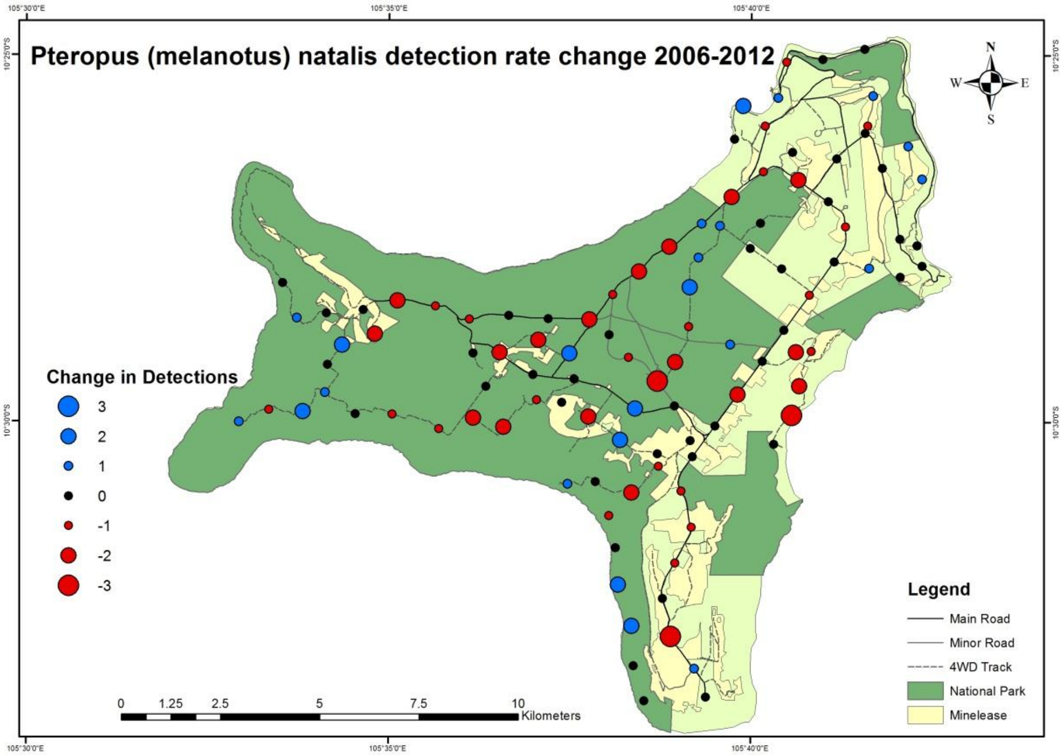


Figure 1: Change in detections at all sampled sites from 2006 to 2012. Source: Woinarski et al. (2012).

The tasks of the workshop were to

(a) Rank the relative contribution of speculative threats to past decline of CIFF
(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 alternative.
(d) Use insights from these analyses to guide decision-making around species recovery.

2.0 METHODS

2.1 Risk identification

A list of twelve candidate risks (or hypotheses or threats) explaining why populations of the CIFF have declined was prepared prior to the workshop by John Woinarski. Participants discussed the plausibility of the hypotheses given current knowledge about the Christmas Island ecosystem, past disturbances, invasion history and flying fox biology. A summary of the hypotheses is provided below with more detailed provided at Appendix 2.

1. Hunting

Historically, the species was subjected to a high rate of hunting, extending to at least the 1980s when Tidemann (1985) noted that 'catches of 200 at a time may not be uncommon. But it is unknown how frequently hunting is indulged in nor by how many'. It is now illegal, although it is thought to still occur, but probably at very small scale.

2. Predation by feral cats

There is a high density of feral cats on Christmas Island and flying-foxes have been reported as a major prey item. Flying-foxes may be especially vulnerable when foraging near ground in the exotic shrub *Muntingia*.

3. Decline in food resources

Flower or fruit resources may have declined due to cumulative clearing impacts (to 25-30% of Island area), selective mortality of tree species associated with Yellow Crazy Ant ("YCA") super-colonies, changed flowering or fruiting patterns (or productivity) associated with YCAs, and control of some non-native plant species. It is possible that changed climatic conditions (or periods of unusually wet or dry seasons) may have had long-term (or short-term) impacts on food availability. It was noted that the energy requirements of CIFFs were high throughout the year, so that an acute temporal bottleneck in food availability over several consecutive days may imply severe population-level impacts.

4. Disturbance by yellow Crazy ants (YCA)

YCA forage in very large numbers in tree canopies. In such situations, they may encounter CIFF and swarm over them in large numbers. This may cause CIFFs to move frequently when resting during the day, increase stress levels, and reduce fecundity or survivorship.

5. Cadmium poisoning

Cadmium naturally occurs within the phosphate rich soils on Christmas Island. Generally the release of cadmium into the environment is mobilised by soil disturbance from activities such as mining. It is plausible that wildlife is exposed to elevated levels of cadmium via direct and indirect pathways associated with the circulation and settling of dust. CIFFs may be exposed to lethal or sub-lethal doses through ingestion when foraging on fruit/flowers, when cleaning fur, and when drinking at temporary ponds in scrapes around mined areas. Elevated cadmium has been implicated in population-level impacts in several wildlife species, including moose and white-tailed deer in Nova Scotia (Pollock and Roger 2007), white-tailed ptarmigan in Colorado (Larison et al. 2000) and caribou in Quebec (Robillard et al. 2002).

6. Disease and parasites

It is possible that a novel disease has led to an increase in CIFF morbidity and mortality.

7. Stochastic events

A near-cyclonic strength storm in March 1988 knocked over many trees and may have killed or blown away much of the population. It was agreed that this hypothesis might affect long lived species with low fecundity rates. Rare catastrophic events have also been responsible for drastic declines in Flying Foxes on other oceanic islands (Piersen et al. 1996).

8. Habitat loss

Twenty five to thirty percent of Christmas Island has been cleared (mostly for mining), with high rates of clearing in the 1960s and 1970s, preceding the probable onset of the recent decline of CIFF. This clearing may have eliminated some traditional maternity (and other) roost sites, and reduced Island-wide resource availability, possibly exceeding some threshold in minimum forested area for population viability.

9. Loss of genetic health

Species with small population size face a range of conservation challenges, including some demographic aberrations (e.g. colony size becomes too small to function effectively) and loss of genetic diversity, and consequential reduced fitness, adaptability and/or reproductive success.

10. Predation by wolf snakes

The Asian wolf snake was introduced (accidentally) to Christmas Island in the 1980s and has subsequently spread across the entire Island, reaching high densities in some areas. It grows to c. 1.5 - 2 m and large specimens may consume unguarded young CIFFs, thereby reducing reproductive success.

11. Poisoning by giant centipedes

Although present on Christmas Island since at least the 1890s, the non-native Giant Centipede has probably increased in abundance over the last 20 to 30 years (probably because of YCA). It is large, has a venomous bite, is aggressive, partly arboreal and very abundant. When interacting with CIFF at roosting or foraging sites, giant centipede bites may paralyse or kill CIFFs.

12. Poisoning by Fipronil

The insecticide fipronil has been applied aerially (in pellet form) across large parts of the Island on at least three occasions as part of YCA control efforts. CIFFs may have ingested this directly when foraging, or when fur-grooming. However, the decline in populations of the flying fox pre-date the application of fipronil, suggesting the chemical is not responsible for any initial decline, although it might contribute to current or future decline.

After discussing the 12 hypotheses prepared prior to the workshop, further drivers of a population decline were suggested and included:

13. Emigration

A decline in CIFF might be due to individuals dispersing from the island. The closest land to Christmas Island is Java, approximately 300 km away.

14. Climate change

Although there is no evidence to suggest that climate change is driving population declines, it is possible that climate change is affecting Christmas Island, through changes in floristic composition or phenology and in turn food availability.

15. Competition with pigeon

The Christmas Island pigeon has similar food requirements to CIFF. It is possible that the pigeon is out-competing populations of flying foxes for food resources.

16. Trace element deficiency

Preferential foraging of exotic fruit and ornamental trees may lead to deficiencies in physiologically important trace elements.

17. Floristic change

Christmas Island is believed to have undergone a series of state transitions since European settlement. It is believed that native rats were abundant prior to European settlement in the 1890's. The native rats became extinct soon after settlement. The red crab is a keystone species on the island, having an important influence on rainforest vegetation structure. More recently, as invasive crazy ants have spread across the island, red crab populations have been reduced, changing the lower storey vegetation structure in the rainforest. These changes in the vegetative state of the system might be driving changes in flying fox populations.

18. Non-detection

Participants discussed the possibility that (a) surveys are not detecting flying foxes because they have moved roosting sites, and (b) the magnitude of the speculative decline may be a spurious outcome arising from survey methodology.

19. Heavy metal poisoning

Toxicity from elements other than Cadmium.

2.2 Risk analysis

2.2.1 Ranking the relative contribution of speculative threats to past decline of CIFF

To simplify analyses, a ranking process was conducted to screen out hypotheses believed to pose the least threat to CIFF. Experts independently estimated the likelihood and consequence of each hypothesis in the context of their capacity to explain past decline. Experts were encouraged to account for uncertainty through assignment of an interval for likelihood and/or consequence judgments (Burgman 2005). Risk scores were obtained using a simple risk matrix, which characterises risk as the product of ordinal descriptors for likelihood and consequence (see Appendix 3).

Summary results of the risk ranking exercise are shown in Figure 2. Histograms showing the spread of opinion among experts for each hypothesis are presented in Appendix 4.

Figure 2 reports high uncertainty among experts about the risk posed by cadmium poisoning and genetic loss to Flying Fox populations. However, the median risk scores were high for these threats. High uncertainty concerning the impact of genetic loss on the species was largely due to one outlier (see Appendix 4). In a relative sense, experts were more certain about the impacts of trace element deficiency, climate change, emigration, hunting, predation by wolf snakes and non-detection. Hypotheses resulting in low risk scores (trace element deficiency, competition with pigeons for fruit, climate change, emigration, predation by the wolf snake, hunting and non-detection) were omitted from further analysis.

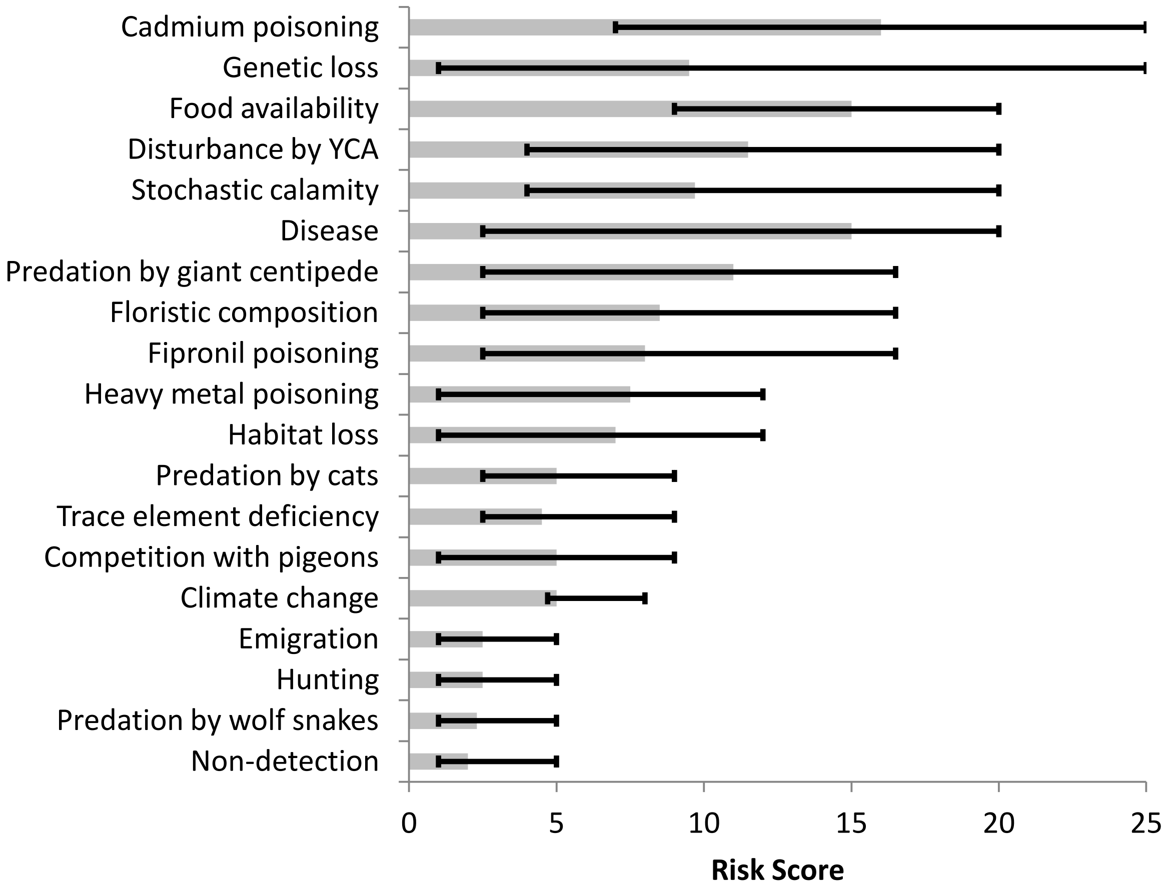


Figure 2. Risk scores for 19 hypotheses concerning a decline in the Christmas Island Flying Fox elicited from 6 experts. Grey bars represent the average of assessors' midpoint scores. Error bars capture the full breadth of opinion.

The remaining hypotheses were discussed. A number of hypotheses were simplified, clarified, merged or deleted from the list, as follows:

- The genetic loss hypothesis was removed from the list because participants agreed that while being a potentially important factor in population viability, the magnitude of the threat was conditional on population decline through manifestation of other hypotheses.
- The hypothesis of heavy metal poisoning was combined with cadmium poisoning.
- The habitat loss hypothesis was merged into the food availability hypothesis based on the belief that further land clearing of previously uncleared rainforests on the island is unlikely.
- The floristic change (state transition) hypothesis was combined with the food availability hypothesis. Flying foxes have little preference in vegetation type for roosting sites - sites are socially important rather than floristically important.
- The food availability hypothesis was clarified and refined. There is likely to be a critical time when lactating female flying foxes require sufficient resources. The experts discussed that resource depletion during this critical period might affect population dynamics and contribute to a population decline. The food availability hypothesis was narrowed to

specifically refer to a bottleneck or critical period in food availability. Whether or not such bottlenecks in food availability occur is unknown.

- The disturbance by YCA hypothesis was discussed and only direct impacts of YCA were considered in further analysis. YCA pose direct and indirect effects to both adult and juvenile flying foxes. Direct effects include a nuisance to adults while they feed and roost or increased mortality to juveniles at roosting sites. Indirect impacts of YCA might include changes in floristic composition and abundance of invasive species such as the Giant centipede.
- Experts discussed the likelihood of giant centipedes posing a threat to the CIFF. Discussion around this hypothesis focused on whether or not giant centipedes interact with flying foxes on distal branches where CIFF roosts. Parks Australia staff suggested that it was highly likely that centipedes are found in the canopy favoured by flying foxes. Other species of flying fox are known to have very thick skin suggesting that even if there is interaction, centipedes may cause little injury.
- Experts discussed the difficulty of detecting and managing disease in populations of flying fox and consider it a useful area for research. There are many types of diseases that might be acting on populations. Diseases have the potential to mutate and become more virulent or individuals can form immunity to them.

As a result of the discussion, a short-list of hypotheses was identified for further consideration.

1. Cadmium poisoning (+ heavy metals)
2. Food bottleneck
3. Disturbance by YCA – direct nuisance, to adults and young, possibility of mortality among young
4. Stochastic calamity
5. Disease
6. Poisoning by Giant Centipedes
7. Poisoning by Fipronil
8. Predation by cats

2.2.2 Estimating the risk of extinction over the next 20 years under alternative management scenarios

Experts considered combinations of actions that could be undertaken to mitigate the short list of hypothesised threats, including a ‘business as usual scenario’. The estimated cost of alternative strategies was documented. The break-down of the cost of each action under each strategy is provided in Appendix 5. We note the following assumptions regarding cost estimates:

- Actions are often effective in the mitigation of threats associated with two or more species. The proportion of costs motivated by conservation management of the flying fox had to be estimated. Given that half of current species-specific management is dedicated to the conservation of some 13 EPBC listed native species (with the other half motivated by red crab conservation, due to their keystone role), it was estimated that 5% of management costs are dedicated to the flying fox.

- The likelihood of feasible biocontrol methods being made available in the next 20 years was estimated at 50 - 60%.
- Flying fox roost sites were assumed to occupy 1% of Christmas Island.
- Costs estimates refer only to those borne by the public sector.

The following six management scenarios were explored:

i. **Do nothing more - Business as usual (BAU)**

A BAU strategy would involve YCA baiting at roost sites at low levels, rehabilitation of mine sites (approximately 10 ha per year), research and implementation of YCA biocontrol (with a 50 - 60% chance it will be applied within the 20 year time frame) and alternative chemical baiting of YCA super-colonies. The cost of a BAU strategy over a 20 year time horizon was estimated at $2.53M.

ii. **Cadmium mitigation**

A cadmium regulation strategy would address concerns about cadmium poisoning due to mining on the island. Management would consist of the following actions: cadmium regulation, dust control plus additional controls plus enforcement of these regulations. For this strategy a captive breeding program (with diagnostic testing for disease) could be established with the aim of supplementing populations (approximately 20 - 25 individuals). If practical, drinking water provisions could be established to mitigate exposure to cadmium through water sources. The cost of this strategy over a 20 year time horizon was estimated at $4.17M.

iii. **Food**

This management scenario was developed to address concern about food availability. Supplementary feeding of trace elements and carbohydrates will occur at food stations positioned around the island. These two actions were later merged into one action, supplementary feeding. Tube stock planting will occur to provide new sources of plants. Because YCA indirectly effect the plant composition of the rain forest, YCA biocontrol and alternative YCA chemicals are used in this strategy. Rehabilitation of mine sites and habitat restoration were also included as actions in this strategy. The cost of implementing this strategy over a 20 year time horizon was estimated at $1.285M.

iv. **Protection of roost sites**

This strategy would focus on protecting known roost sites through cat eradication and high intensity YCA baiting. To further protect roost sites from YCA, trees would be banded. Drinking water at roost sites could be established, if practical. Control of centipedes was discussed but experts could not identify a feasible management strategy for this threat. The cost of this strategy over a 20 year time horizon was estimated at $22.84M.

v. **Food and captive breeding**

In this strategy, approximately 20 – 25 individuals would be bred in captivity (with diagnostic testing for disease) over the 20 year time horizon and supplemented into the wild population. While this captive breeding program is taking place food resources on the island would be improved through targeted tube stock planting and rehabilitation of mine sites. Rat populations would also be controlled. The cost of the strategy was estimated at $4.34M over the 20 year time frame.

vi. Disease

In this strategy, captive breeding is conducted at medium intensity with the aim of testing individuals for disease and parasites. A captive breeding facility would be established on the island as moving a captive population to another location is not feasible. Increased quarantine and border protection controls would be implemented through DAFF Biosecurity . This strategy was estimated to cost $11.2M over a 20 year time horizon. However, experts acknowledged that management for diseases really depends on the type and nature of the disease. Disease risk to humans should also be considered. The effectiveness of captive breeding depends on the type, rate and severity of diseases.

Under each scenario and for each of the eight short-listed hypotheses, experts collectively provided nominal estimates and plausible bounds for the probability of extinction over a 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.

3.0 RESULTS

Aggregate risk of extinction under each scenario is shown in Figure 3. Under business as usual, the probability of extinction of CIFF is 0.82[1] over the next 20 years, with plausible bounds of [0.43, 1.00]. The constituent threat specific probabilities that contribute to aggregate estimates of extinction are shown graphically in Figure 4 and tabulated at Appendix 6.

Nominal estimates for the reduction in risk under alternative management scenarios are modest. The greatest expected reduction is associated with the strategy of *cadmium mitigation*, with a probability of extinction of 0.68. The next best option (*Disease)* has a nominal estimate of 0.72. The worst option is *Food*, 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 (see Figure 4).

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.

[1] This estimate is broadly consistent with a geometric model parameterized using the inferred decline of 35% from detection surveys conducted in 2006 and 2012 (see Figure 1). 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 $1 - (1 - 0.35)^{3.33} = 0.76$.

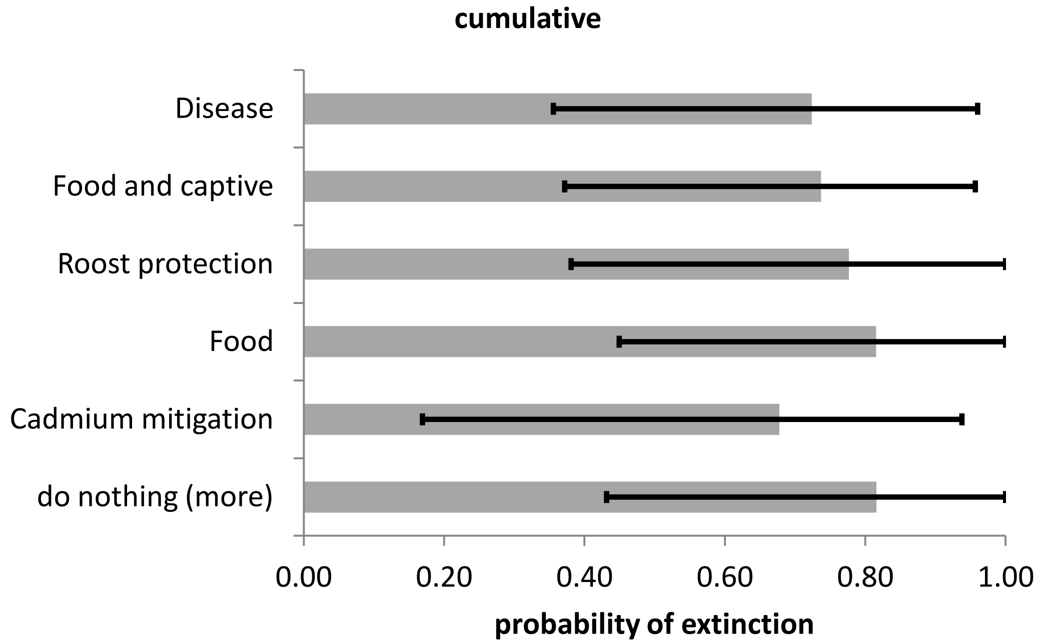
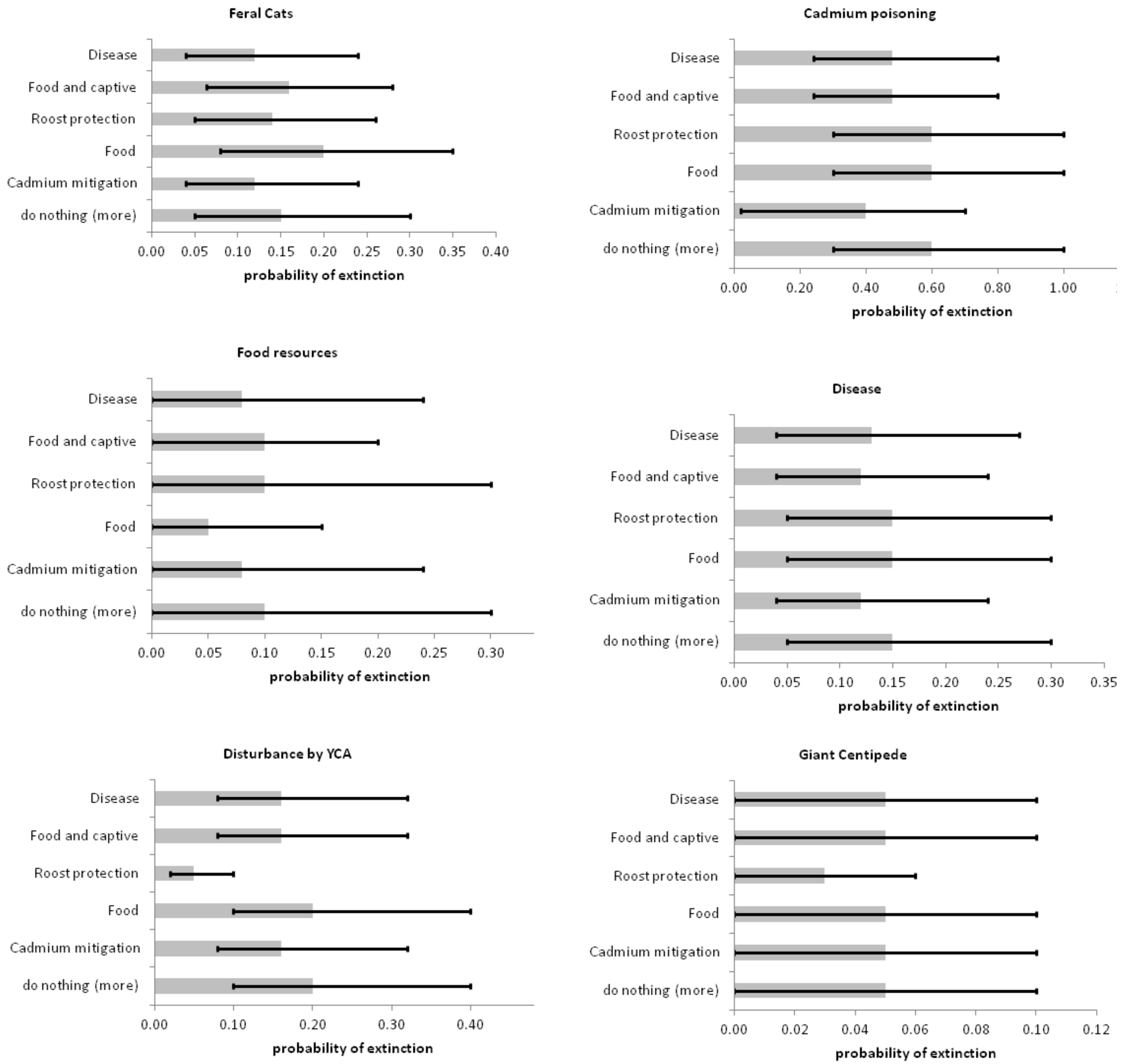


Figure 3. Risk of extinction aggregated over eight threats for each of six management scenarios. Grey bars show nominal best estimates. Error bars report plausible bounds.



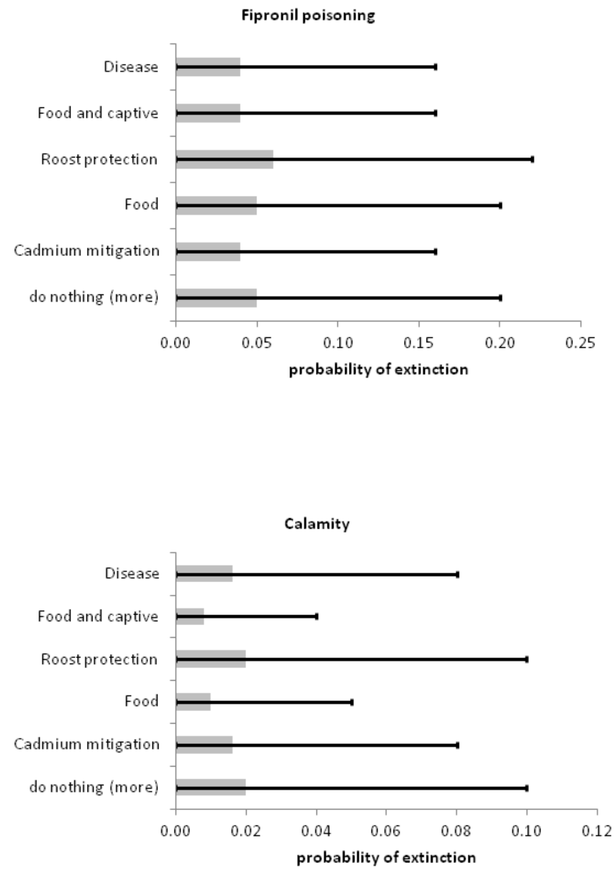


Figure 4. Risk of extinction posed by each shortlisted threat under each management scenario. Grey bars show nominal best estimates. Error bars report plausible bounds.

4.0 DISCUSSION

4.1 Risk evaluation

Cost-effectiveness
It is important when evaluating the merit of candidate management strategies that the costs of implementation are considered as well as the benefits of action (e.g. change in risk of extinction given action) (Joseph et al. 2009). A simple cost-effectiveness analysis allows the unit increase in what we care about (e.g. probability of extinction of CIFF) to be assessed against the cost of each strategy under consideration. The cost of management of Christmas Island is inflated due to its isolated location, personnel constraints and due to the rugged terrain of much of the island meaning that implementation is time consuming. On the basis of nominal best estimates, all strategies are estimated to result in only modest reductions in extinction risk. Before proceeding with the recommendations described below, Parks Australia may consider the costs of investment in mitigation of risks posed to CIFF in the broader context of the cost-effectiveness of actions for other species on Christmas Island and in other reserves.

Based on the nominal best estimates of extinction and the change in this value from the BAU strategy, cadmium mitigation is the most cost-effective strategy (Figure 5). Further to this cadmium mitigation offers the best chance of a 'windfall' outcome with a lower/optimistic bound on probability of extinction in the next 20 years of 0.17, well below the lower bound of any of the other strategies.

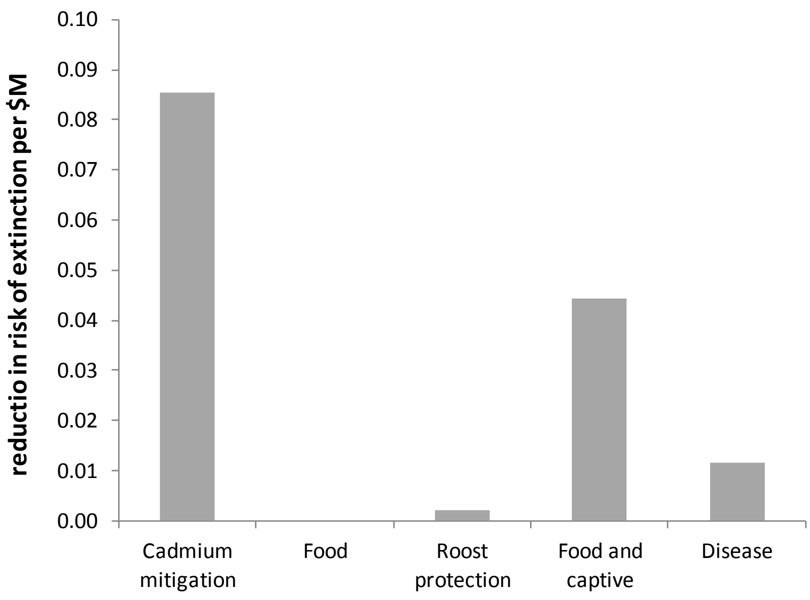


Figure 5. Cost-effectiveness of alternative strategies, relative to the base case of business as usual (BAU). For each strategy *i* the reduction in risk of extinction was calculated as

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

Limitations of approach

We used a standard risk-based approach in this workshop. This approach involved the elicitation of probabilities of extinction of the CIFF over the next 20 years based on different management scenarios from experts. An alternative approach is to predict the impact of management alternatives on extinction risk using a population viability analysis (PVA). However, this approach is much more time consuming and requires additional information, most of which will be highly uncertain. Further the analysis of the utility and effectiveness of alternative strategies for managing the CIFF hinges on the specification of these alternative management strategies. We have bundled management actions (e.g. cat control) into strategies (e.g. Roost protection) to allow a more realistic representation of management and to reduce the elicitation burden. The downside to bundling is loss of visibility of the effectiveness of individual actions. The coarse estimates of cost-effectiveness for each strategy presented in Figure 5 may conceal some highly effective actions that are bundled with poor-performing actions. We note that the results presented in Figure 4 allow some insights into the merit of individual actions that comprise the candidate strategies.

When developing a captive breeding program it is essential to consider a number of factors. Firstly we must define the purpose of the captive breeding colony so that, for example, the appropriate sized colony can be established and meet its purpose. A captive breeding colony may be used to supplement the population or to maintain a wild population of CIFF for future release. If the goal of management is to maintain a wild population of flying foxes then captive breeding is only useful if the threat driving the population is absent when individuals are released back into the population and the likelihood of significantly reducing a threat must be considered when evaluating the benefits of captive breeding. Further captive breeding facilities require a number of start-up and fixed costs and must contain a number of separate enclosures used for example for breeding, raising young and preparing individuals for release back into the wild. When designing a captive breeding facility it would be essential to consult further with experts on captive breeding of flying foxes.

4.2 Recommendations

The main outcome of the risk analysis presented above was the identification of potential windfall outcomes from the management of cadmium on CIFF. Based on these insights, the decision tree shown in Figure 6 was developed to assist planning for recovery of the CIFF. The main steps in the decision tree are to first assess the potential impact of cadmium and the timeframe over which this impact might operate. The first recommendation is to prioritize the testing of CIFF to determine Cd levels. This could be done by sampling several male CIFF individuals from several sites across the Island and assess if Cd levels are lethal or sub-level. Another option is to sample non-destructively using urine collection at roost sites and assess if Cd is present at lethal or sub-lethal levels. This non-destructive option is preferred if a method exists to sample in this manner. If lethal or sub-lethal levels are detected it must be assessed whether these levels would have serious impacts on the population dynamics of the species, through either reduced survivorship of individuals or through reduced fecundity of the population. IF Cd levels are high then it is suggested that further testing take place around the island on:

- the Cd levels in food plant tissues (native and introduced)
- the Cd levels in water sources used by CIFF and estimates of intake rate of contaminated water by CIFF
- modelling of dust plumes (using collated data from ambient measurements), and
- the Cd levels in other species and other media (soil, water, food) with a view to assessing the potential health implications of Cd on Christmas Island to the local human population.

If tissue concentrations of Cd are deemed to be potentially toxic, further modelling work is also required to estimate the population-level implications of elevated exposure to cadmium for the CIFF and an assessment made on the rate of decline. If a precipitous decline is expected in the near term, a captive breeding program may be warranted. However, it is important that the cost-effectiveness of any captive breeding program be established before implementation with the help of captive breeding experts and that the most cost effective approach be utilised. If the population modelling suggests a gradual decline, in-situ cadmium mitigation measures may be sufficient for material improvement in the viability of the species.

We note that if, on the basis of eco-toxicological testing, cadmium is found to be a significant factor, then the benefits of mitigation will likely extend to improved viability for other species on Christmas Island. Further we note that if cadmium doses were found to be contributing to suppressed fecundity and survivorship, extensive negotiation with the mining industry will be required for successful mitigation.

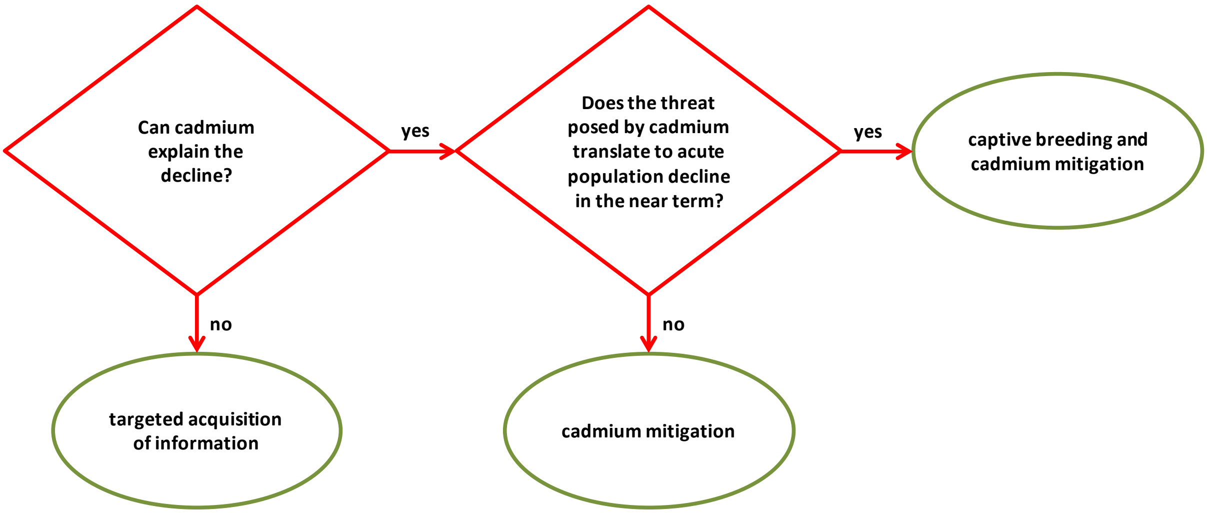


Figure 6. Decision tree for management of the Christmas Island Flying Fox

If testing of Cd levels in CIFF indicates benign exposure then we recommend targeted acquisition of information to improve our understanding of threats to the CIFF and inform management actions. On the basis of judgments presented in Figures 3 and 4, pertinent questions include:

- Can we establish acute temporal bottlenecks in food resources?
- Can we get a better understanding of the dynamic interactions of cats, rats and bats?
- Can we establish whether tree banding successfully mitigates risks posed by YCA in roost trees, or do the ants gain access to roost sites through canopy-level contact between trees?

- Can we determine if disease, parasites, other heavy metals, genetics issues or fipronil are affecting CIFF by taking appropriate samples from CIFF sampled for Cd testing?

During the workshop further suggestions were made about modelling and data collection that might aid our knowledge of CIFF:

- Given weak evidence to support a spatial trend in population declines with fewer individuals being detected in some parts of the island, such as along major roads, it was suggested that analysis of the spatial trends amongst other populations of declining species on the island might help distinguish between competing hypotheses about threats on the island.
- Flying foxes have been shown to be highly mobile species when in search of food and resources. Individuals move regularly between camps and forage throughout the whole island, suggesting a single population exists (Tidemann 1985). This makes interpretation of spatial and temporal data on the CIFF decline difficult. Experts suggested there were other data sources to support the belief that populations are declining, however further analysis of these datasets may be needed to support evidence of temporal and spatial changes in the CIFF population.
- Flying fox energetic requirements for flight have been investigated in the past by looking at aerodynamics and morphological measurements of flying foxes. It was suggested that using simple radar measurements of CIFF and through morphological investigation of museum samples of CIFF collected by Tidemann the energetic requirements of CIFF could be assessed.
- Further analysis was suggested of Tidemann's data from the 1980's to provide more information than currently presented in this work.
- Further analysis of CIFF monitoring data was suggested to look at occupancy to estimate population size and decline.

The merit of pursuing each line of inquiry presented above is not self-evident. It is crucial when considering investigative work to consider the value of this information for informing future management decisions and for improving our ability to reach our objective of population viability for the CIFF. In other words we must consider the benefits of information to management relative to the costs of collecting such information (McDonald-Madden et al 2010). When dealing with threatened species it is also important to note that these costs are not just in dollars but can manifest in the time taken to collate or collect information and the risk of inappropriate or lack of action during this time. The trade-offs that need to made here are not always easy, but there is qualitative guidance (McDonald-Madden et al. 2010) and quantitative approaches (Expected Value of Information Analysis, Runge et al. 2011) to assist evaluation.

Acknowledgements

We thank workshop participants for their time and thoughtful contributions. We are especially grateful to John Woinarski, who compiled the information shown at Appendix 2 prior to the workshop for distribution to all participants.

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Appendix 1 – Workshop participants

Participants - Please insert whatever attribution you wish to have here.

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Appendix 2 – Initial 12 hypotheses

HYPOTHESIS 1. **Hunting**

Description: Historically, the species was subjected to a high rate of hunting, extending to at least the 1980s when Tidemann (1985) noted that "catches of 200 at a time may not be uncommon. But it is unknown how frequently hunting is indulged in nor by how many". It is now illegal, although is known to still occur, but probably at very small scale.

supporting evidence for	Much evidence of substantial previous hunting since the Island's settlement in the 1880s. Anecdotal reports of some ongoing take. Hunting may have impacts beyond immediate number of individuals removed, if it leads to disturbance at maternity roosts.
evidence against	No indication of substantial current take. Islanders now far less dependent upon "wild food".
definitive test	(i) broad-scale community survey; (ii) remote cameras at roosts
feasibility of definitive testing	(i) reasonably high, but illegality of take may subvert open answers to any community survey; (ii) low
costs of definitive testing	(i) c $10k; (ii) c $20-50k
impacts of current management	Most roosts are in areas with relatively limited access. However there is little or no surveillance of roosts by managers. Regulation has probably caused substantial decline in threat.
management response if proven	increased surveillance; more community consultation and awareness of conservation concern
feasibility of management to control	reasonable likelihood of effectiveness (70-80%) to levels where threat has no impact on viability
costs of targeted management	c. $50 k/yr
collateral benefits of targeted management	limited but pervasive increased appreciation by community of conservation issues
collateral detriment of targeted management	nil
linkages to other hypotheses	no obvious linkage

HYPOTHESIS 2. **Predation by feral cats**

Description: There is a high density of feral cats on Christmas Island and flying-foxes have been reported as a major prey item. Flying-foxes may be especially vulnerable when foraging near ground in the exotic shrub *Muntingia*.

supporting evidence for	Tidemann *et al*. (1994) reported that Christmas Island flying-foxes were present in 10% of a large sample of cat guts. Assuming that prey items may remain in cat guts for 3 days, and that the population of cats on Christmas Island is at least 1000 individuals (probably conservative given about 150 domestic cats, and the high abundance (no./km of transect) of feral cats reported: Algar *et* al. 2011), the Tidemann *et al*. (1994) incidence of flying-foxes translates as an annual mortality of at least 1200 flying-foxes.
evidence against	Inspection of a substantial number of cat guts since Tidemann's study has failed to detect such high rates (indeed, any) flying-foxes. Cats have been on CI since about 1903, so unlikely to be new impetus for recent CIFF decline.
definitive test	(i) extermination or very substantial and sustained reduction in cat population; (ii) continuing assessment of cat diet; (iii) radio-telemetry studies of CIFF (to identify causes of mortality)
feasibility of definitive testing	(i) low to medium; (ii) relatively straightforward and achievable; (iii) low to medium
costs of definitive testing	(i) ?c. $2-5 m; (ii) c. $100k/yr; (iii) c $50-100k
impacts of current management	localised cat control over recent years has led to some decreases in cat populations, which may have had some minor benefit to flying-fox.
management response if proven	(i) eliminate cats (nb circular if this is the proof required for the hypothesis). (ii) captive breeding.
feasibility of management to control	if cats are the primary driver of decline in flying-fox and cats are eliminated, then such control is highly likely to provide a sustained benefit. feasibility of cat control is marginal (50%)
costs of targeted management	?c. $2-5m
collateral benefits of targeted management	if cats are eliminated, likely to provide very substantial benefit to many other native species (unless cat elimination leads to increase in Black Rats)
collateral detriment of targeted management	any increase in Black Rats will be likely to have substantial detrimental impacts on many native species
linkages to other hypotheses	10. Predation by wolf snake

HYPOTHESIS 3. **Decline in food resources (or their temporal connectivity)**

Description: Flower or fruit resources may have declined (with particular impact from any decline or changed phenological patterning of any plant species that provided resources at periods of landscape-scale shortage of resources) due to cumulative clearing impacts (to 25-30% of Island area), selective mortality of tree species associated with Yellow Crazy Ant ("YCA") supercolonies, changed phenological patterns (or productivity) associated with YCAs, and decrease (eradication) of some non-native plant species due to deliberate management control. It is possible that changed climatic conditions (or periods of unusually wet or dry seasons) may have had long-term (or short-term) impacts on food availability.

supporting evidence for	Over the last decade, management has reduced the abundance of the introduced *Schefflera actinophylla*, and post-mine rehabilitation no longer uses the exotic Jamaican cherry, and its abundance along roadsides had been reduced. The diet of the CIFF now includes a considerable proportion of introduced species. Such food sources may provide less nutrition than the native species that they have replaced (as has been reported for Pacific Island flying-foxes: Nelson *et al*. 2000): some non-native species may have toxic or other impacts on CIFF. YCA super-colonies (or the high densities of scale insects associated with them) result in reduced viability (?and reduced productivity) or death of some tree species (selectively), and at periods over last decade have extended to >20% of forest area.
evidence against	Considerable spread and "duplication" of fruiting and flowering periods of tree species known to be included in CIFF diet (i.e. no prima facie evidence of one or few tree species pivotal in diet because they are the only species providing resource at any particular time of year). CIFF population could be expected to stabilise to new lower levels of food availability. No evidence of decline in other Island frugivore (CI Imperial-pigeon). No evidence of increase in CIFF associated with periods of YCA control.
definitive test	(i) assessment of condition of CIFF over the course of a year; (ii) seasonal monitoring of tree phenology and food resource abundance (and cf. of this with historic (Green) records); (iii) modelling of floristic changes associated with YCA; (iv) assess reproductive output/success (it may be lower than "expected" if food resources low before birth and during nursery stage); (v) radio-telemetry studies to follow nightly foraging beats of CIFF. [skewed sex/age structure may indicate food-related reproductive failures]
feasibility of definitive testing	(i) reasonably feasible (c 80%) [constrained by catchability]; (ii) feasible (90%), but not necessarily definitive (and may require several years to indicate general trends); (iii) feasible (90%) but not necessarily definitive; (iv) feasible (70%); (v) low (30-50%)
costs of definitive testing	(i) c$50-100k; (ii) c$50-100k; (ii) c$10k; (iv) c$30-50k; (v) c$50-100k
impacts of current management	YCA control may provide some temporary benefit (but not demonstrated). Control of some fruit- or flowering-producing "weeds" may have some detrimental impacts.
management response if proven	(i) Increased use of important plant species in rehabilitation, or deliberate "orchard" plantings of CIFF-

	important plant species. Note that these will have no short-term benefit. (ii) Supplementary feeding of wild populations during periods of food shortages. (iii) Captive-breeding.
feasibility of management to control	YCA control achievable in short-term by broad-scale intermittent baiting. Selective planting feasible (but may take decades to provide benefit). Supplementary feeding is probably feasible (c70%). Captive-breeding is probably feasible but may not resolve the threat.
costs of targeted management	
collateral benefits of targeted management	minor
collateral detriment of targeted management	minor
linkages to other hypotheses	4. YCA-disturbance at roost sites 6. Diseases and parasites (reduced nutrition status may increase susceptibility to, or impacts of, disease) 8. Habitat loss

HYPOTHESIS 4. **Disturbance at roost sites by YCA**

Description: YCA forage in very large numbers in tree canopies. In such situations, they may encounter CIFF and swarm over them in large numbers. This may cause CIFFs to move frequently when resting during the day, increase stress levels, and reduce breeding output.

supporting evidence for	broad temporal coincidence between onset of YCA supercolonies and recent decline of CIFF
evidence against	YCA super-colonies covered no more than 25% of forest; little or no indication of YCA super-colonies at important CIFF roosts; no apparent positive response of CIFF to YCA control
definitive test	(i) monitoring of CIFF roosts for YCAs; if any with YCAs observe responses of CIFFs; (ii) retrospectively assess incidence of YCAs around known roosts and relate to changes in roost CIFF populations. (There are unethical procedures for more rigorous testing) (iii) assess reproductive output. [skewed age/sex structure may indicate problem is at maternity roosts]
feasibility of definitive testing	moderate (75%)
costs of definitive testing	c. $20k
impacts of current management	current management (episodic YCA baiting) would be expected to provide significant benefit
management response if proven	high intensity YCA baiting around in and around important roost sites (noting fipronil can't be used at the most important site, because of its aquatic setting)
feasibility of management to control	high (80%) to hold YCAs to low levels at important roost sites; but probably no long-term eradication
costs of targeted management	c$50k /yr for intensive baiting at roost sites
collateral benefits of targeted management	localised benefit to some other threatened and significant plant and animal species
collateral detriment of targeted management	more frequent and intensive localised baiting may lead to increased tolerance of YCA to pesticides
linkages to other hypotheses	3. Decline in fruit/flower resources (through YCA) 6. Diseases and parasites (increased stress at roost sites may increase susceptibility to, or impacts of, disease)

HYPOTHESIS 5. **Cadmium poisoning**

Description: Cadmium occurs at high concentration on CI, typically associated with phosphate; it is highly likely that it is present in the phosphate dust that is widespread around tracks, at mining areas and around loading. CIFFs may be exposed to lethal or sub-lethal doses through ingesting when foraging on fruit/flowers, when cleaning fur, and when drinking at temporary ponds in scrapes around mined areas. Cd has population-level impacts on many wildlife species, where exposure rates are high

supporting evidence for	demonstration of Cd as causal agent of decline in many locations elsewhere (e.g. Rocky Mountain birds); high levels of Cd in liver of the only CIFF tested (higher than any individuals across a wide range of animal species tested in a European study); desertion or loss of one CIFF colony from area where highly exposed to dust
evidence against	while high, the Cd level in the only CIFF tested was well below lethal concentration; no evidence that CIFF drinks at temporary pools
definitive test	(i) the most definitive is to test Cd levels in CIFFs, but this may require killing them; (ii) testing of Cd levels in temporary pools and at "dust-covered" flowers/fruits; (iii) seeking non-lethal tests for Cd concentrations in CIFF
feasibility of definitive testing	(i) unethical, but any CIFFs found dead/dying should be tested; (ii) feasible, but interpretation may be challenging; (iii) uncertain
costs of definitive testing	(i) n/a; (ii) c $30k; (iii) uncertain
impacts of current management	no current management addresses this factor
management response if proven	(i) tighter regulation relating to emissions and dust suppression; (ii) provision of "clean" drinking water sources; (iii) captive breeding
feasibility of management to control	mine closure in 2019 should eliminate the problem; interim measures to reduce emissions may be of low-medium feasibility
costs of targeted management	uncertain
collateral benefits of targeted management	human health benefit; benefit to other wildlife species drinking at temporary water sources
collateral detriment of targeted management	nil
linkages to other hypotheses	6. Diseases and parasites (Cd poisoning may lead to increased morbidity and hence more susceptibility to some diseases). [Post-mortem testing for Cd can provide evidence about disease.] 12. Poisoning by fipronil

HYPOTHESIS 6. **Disease and parasites**

Description: A novel disease has led to increase in CIFF morbidity and mortality.

supporting evidence for	Some inconclusive evidence from recent sampling*. Other examples of disease driving decline in CI endemic mammals. Other examples of disease or parasites driving decline in flying-foxes (e.g. paralysis tick). [One recent case of CIFF found on forest floor apparently uninjured but dying,]
evidence against	Recent sampling inconclusive.
definitive test	More comprehensive sampling of health status
feasibility of definitive testing	Variable, depending upon disease agent
costs of definitive testing	Variable, depending upon disease agent
impacts of current management	Nil
management response if proven	Variable, depending upon disease agent and its mode of transmission. (i) captive breeding
feasibility of management to control	Likely to be low (25%)
costs of targeted management	uncertain, may be very high
collateral benefits of targeted management	probably limited
collateral detriment of targeted management	probably nil
linkages to other hypotheses	probably limited

* Hall *et al*. (2011) recorded coccidia in 4 of 16 faecal samples, and a single incidence of "Ascarid-like ova". "This result is very interesting, as internal parasites from this species have not been reported before despite Tidemann performing thorough examinations of the gut of over 100 individuals [in 1984]." "Infection with this parasite rarely causes clinical disease in adult *Pteropus* bats, however upper airway obstruction, ill thrift demeanour and morbidity have been recorded in grey-headed flying-fox and variable flying-fox pups." Hall *et al*. (2011) also reported that the levels of Alkaline Phosphatase, Amylase and Lipase were considerably higher, and Urea (Blood Urea Nitrogen) considerably lower, in their samples (N=28) of Christmas Island flying-fox compared to six other flying-fox species for which this information was available. These parameters are consistent with some reduced functionality of liver or pancreas. They also reported no sign of Hendra virus.

HYPOTHESIS 7. **Stochastic calamity**

Description: A near-cyclonic strength storm in March 1988 knocked over many trees and may have killed or blown away much of the population. It hasn't recovered.

supporting evidence for	1988 storm was highly destructive. Cyclones are implicated in the decline and extinction of some other island flying-foxes. Timing broadly consistent with first recognition of modern decline of CIFF.
evidence against	CIFFs have continued to decline since storm
definitive test	none
feasibility of definitive testing	n/a
costs of definitive testing	n/a
impacts of current management	some post-mining rehabilitation may lead to gradual increases in forest area
management response if proven	nil
feasibility of management to control	nil
costs of targeted management	n/a
collateral benefits of targeted management	n/a
collateral detriment of targeted management	n/a
linkages to other hypotheses	8. Habitat loss 9. Loss of genetic heterogeneity (small population concerns)

HYPOTHESIS 8. **Habitat loss**

Description: 25-30% of CI has been cleared (mostly for mining), with high rates of clearing in the 1960s and 1970s, hence not long preceding the probable onset of the recent decline of CIFF. This clearing may have eliminated some traditional maternity (and other) roost sites, and reduced Island-wide resource availability, possibly exceeding some threshold in minimum forested area for population viability.

supporting evidence for	Forest clearance has been a major factor in the decline and extinction of other island flying-fox species.
evidence against	75% of the Island's forests have remained uncleared. No roosts are known to have been destroyed.
definitive test	no definitive tests, but (i) evaluation of minimum island size supporting contained populations of flying-foxes elsewhere may be broadly indicative of minimum area to sustain viable flying-fox populations; and (ii) gradual rehabilitation may lead to increases in forest area and hence restoration of population viability
feasibility of definitive testing	(i) feasible (80%), but may be challenging to interpret; (ii) non-feasible in short-term
costs of definitive testing	(i) $10k
impacts of current management	no (well, little) clearing of primary rainforest now allowed. this may lead to population stabilisation. the current (limited) rehabilitation program may eventually lead to population recovery
management response if proven	the driver has already stopped and the issue is now largely a legacy of previous clearing. (i) increased rate of rehabilitation of cleared areas; (ii) no clearing of vegetation recovering from previous mining; (iii) captive breeding. .
feasibility of management to control	(i) low (50%); (ii) low (20%); (iii) medium (70%)
costs of targeted management	(i) c $200-500k/yr; (iii) uncertain; (iii) ?c$200k in yr 1, $100k/yr subsequently
collateral benefits of targeted management	medium-high, restoration of greater forest extent will have marginal benefits for many native species
collateral detriment of targeted management	nil
linkages to other hypotheses	3. decline in food resources 7. stochastic calamity

HYPOTHESIS 9. **Loss of genetic heterogeneity (small population troubles)**

Description: Species with small population size face a range of conservation challenges, including some demographic aberrations (e.g. colony size becomes too small to function effectively) and loss of genetic diversity, and consequential reduced fitness, adaptability and/or reproductive success.

supporting evidence for	broad theoretical support, but more acute with even lower population size
evidence against	nil
definitive test	no definitive test, but extent of genetic variability can be sampled
feasibility of definitive testing	medium-high (70%)
costs of definitive testing	c. $20k
impacts of current management	nil
management response if proven	probably nil
feasibility of management to control	
costs of targeted management	
collateral benefits of targeted management	
collateral detriment of targeted management	
linkages to other hypotheses	links to most other hypotheses which may have led to low population size.

HYPOTHESIS 10. **Predation by wolf snake**

Description: The Asian wolf snake was introduced (accidentally) to CI in the 1980s and has subsequently spread across the entire Island, reaching high densities in some areas. It grows to c. 1.5-2 m and large specimens may consume unguarded young CIFFs, thereby reducing reproductive success.

supporting evidence for	Correlation of timing of snake's arrival with presumed onset of CIFF's recent decline. Wolf snake is partly arboreal. Parallels with brown tree snake on Guam.
evidence against	Most wolf snakes are far too small to consume CIFFs, even new-born. Many snakes dissected, but no CIFF in stomach contents. Although wolf snake may be partly arboreal, most hunting is on ground.
definitive test	(i) assessment of snake abundance and behaviour at CIFF roost sites; (ii) continuing assessment of snake diet; (iii) radio-telemetry studies of CIFF (to identify causes of mortality)
feasibility of definitive testing	(i) feasible (75%); (ii) feasible (75%); (iii) maybe (50%)
costs of definitive testing	(i) c$20k; (ii) $10k; (iii) $50-100k
impacts of current management	nil. no management of wolf snakes
management response if proven	(i) localised intensive trapping of wolf snakes around flying-fox roosts; (ii) captive breeding
feasibility of management to control	(i) localised population reduction of wolf snakes may be feasible (75%)
costs of targeted management	c$30k/yr
collateral benefits of targeted management	limited
collateral detriment of targeted management	nil
linkages to other hypotheses	2. Predation by cats 4. Disturbance at roost sites by YCA

HYPOTHESIS 11. **Giant Centipede**

Description: Although present on CI since at least the 1890s, the non-native Giant Centipede has probably increased in abundance over the last 2-3 decades (probably because of YCA). It is large, has a venomous bite, is aggressive, is partly arboreal and very abundant. When interacting with CIFF at roosting or foraging sites, giant centipede bites may paralyse or kill CIFFs.

supporting evidence for	convincing anecdotal evidence for increase in centipedes over same time period as establishment of YCA super-colonies. one recent (2012) record of a CIFF found alive but partly immobilised on forest floor.
evidence against	centipedes have been on island since 1890s; incidence of CIFF/centipede interactions (e.g. on terminal branches of trees) may be of very low frequency
definitive test	possibly no ethical definitive test, but (i) radio-telemetry of CIFF to identify cause of death; (ii) assessment of abundance of centipedes in foliage and around fruit/flowers
feasibility of definitive testing	(i) reasonable (50%); (ii) low (30-50%)
costs of definitive testing	(i) c $50-100k; (ii) c$10k
impacts of current management	episodic baiting of YCA may result in decrease of giant centipedes (after red crabs return to de-anted areas)
management response if proven	(i) intensive control attempts of giant centipedes at roost sites; (ii) ongoing control of YCA until red crab population increases substantially; (iii) captive breeding
feasibility of management to control	(i) low (20%) (partly because CIFF-centipede interactions may be in the more diffuse foraging areas); (ii) low-medium (30-50%), and benefits may be realised only in long-term rather than short-term
costs of targeted management	(i) c$20-50k; (ii) c$300k/yr
collateral benefits of targeted management	(i) some but low, because localised; (ii) substantial for many species
collateral detriment of targeted management	(i) low probability of collateral detriment, but depends on the mechanism used to attempt to control centipedes; (ii) some, but outweighed by benefits
linkages to other hypotheses	4. Disturbance by YCA 6. Disease and parasites

HYPOTHESIS 12. **Poisoning by the insecticide Fipronil**

Description: The potent insecticide fipronil has been applied aerially (in pellet form) across large parts of the Island on at least three occasions. CIFFs may have ingested this directly when foraging, or when fur-grooming.

supporting evidence for	fipronil is highly toxic and large amounts were applied
evidence against	decline of CIFF preceded first aerial application; unlikely that CIFFs would have accessed the baits; most (or all) CIFF roosts were not baited; impacts would have been episodic only (i.e. at 3 application years)
definitive test	no real ethical definitive test (mainland flying-foxes could be tested for sensitivity); (i) CIFFs could be monitored intensively before during and after the next round of aerial application; (ii) post-mortems of any dead/dying bats around time of aerial application
feasibility of definitive testing	(i) low (30%); (ii) very low (10%)
costs of definitive testing	(ii) c$10k; (c $10k
impacts of current management	current management uses fipronil, so if this is the causal factor, then current management is contributing to decline
management response if proven	alternative chemicals or other control agents for YCA
feasibility of management to control	high (cease baiting)
costs of targeted management	little or no economic cost of stopping baiting, but costs of alternatives to fipronil may be higher than for fipronil (say $200k/yr)
collateral benefits of targeted management	other control agents may have less non-target impacts than fipronil, so possibly some benefit
collateral detriment of targeted management	firponil remains the most effective and practical control measure against YCAs, so if its use was constrained then there would be substantial biodiversity detriments
linkages to other hypotheses	4. Disturbance at roost sites by YCA 5. Cadmium poisoning 6. Disease and parasites

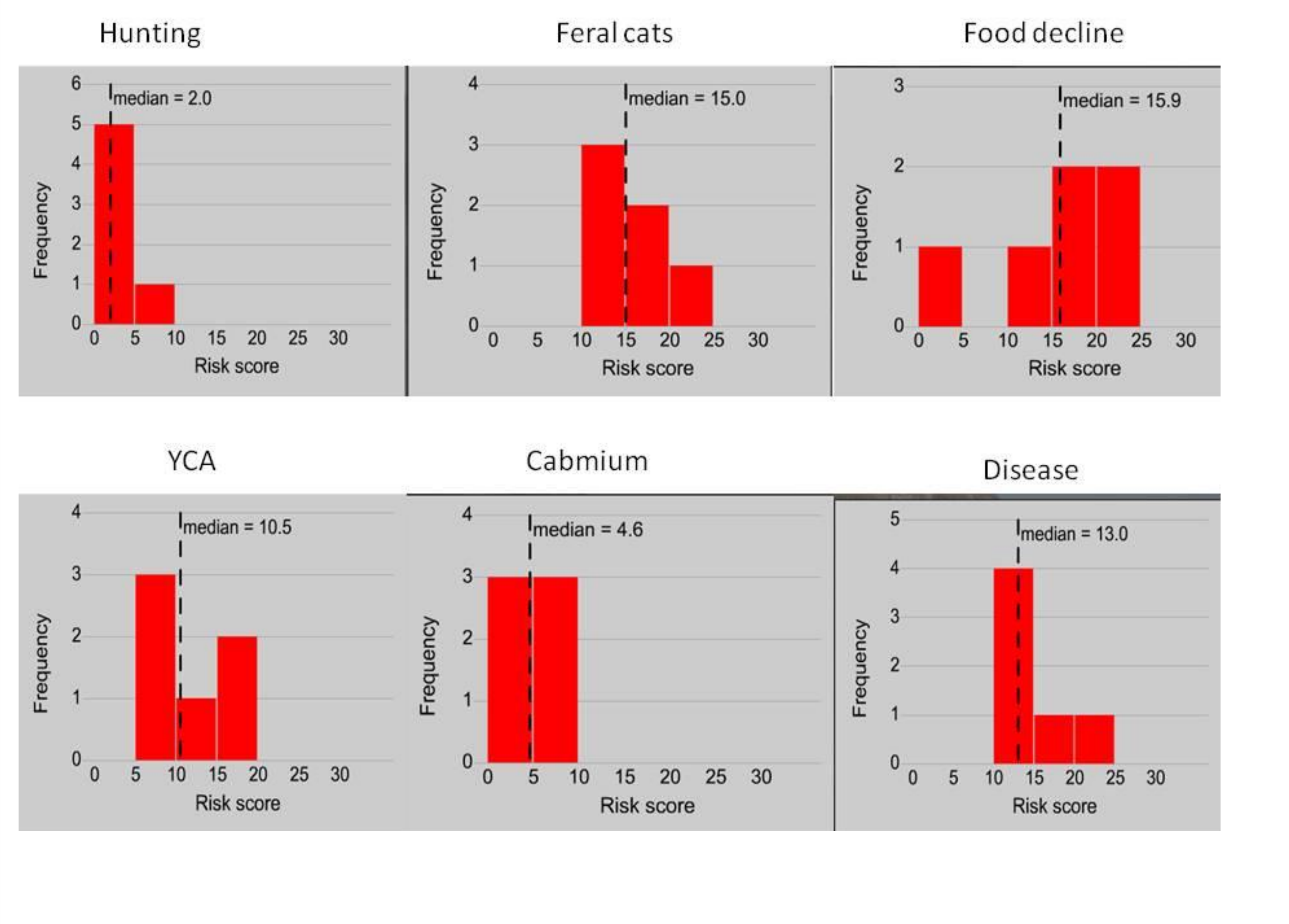
Appendix 3 - Risk Analysis matrix

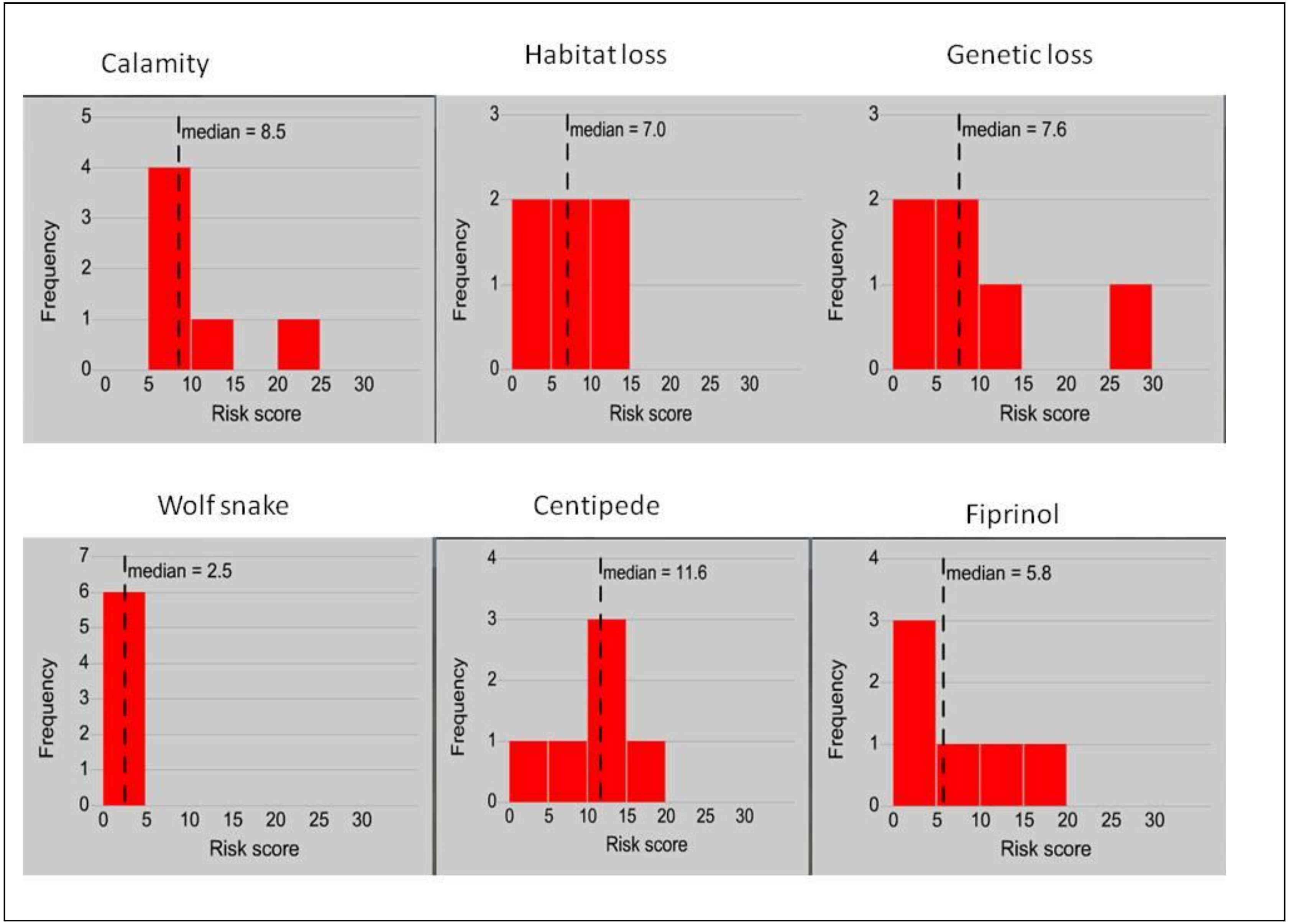
		Consequence				
Likelihood		Insignificant	Minor	Moderate	Major	Catastrophic
		(1)	**(2)**	**(3)**	**(4)**	**(5)**
Almost certain	**(5)**	5	10	15	20	25
Likely	**(4)**	4	8	12	16	20
Moderately likely	**(3)**	3	6	9	12	15
Unlikely	**(2)**	2	4	6	8	10
Rare	**(1)**	1	2	3	4	5

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

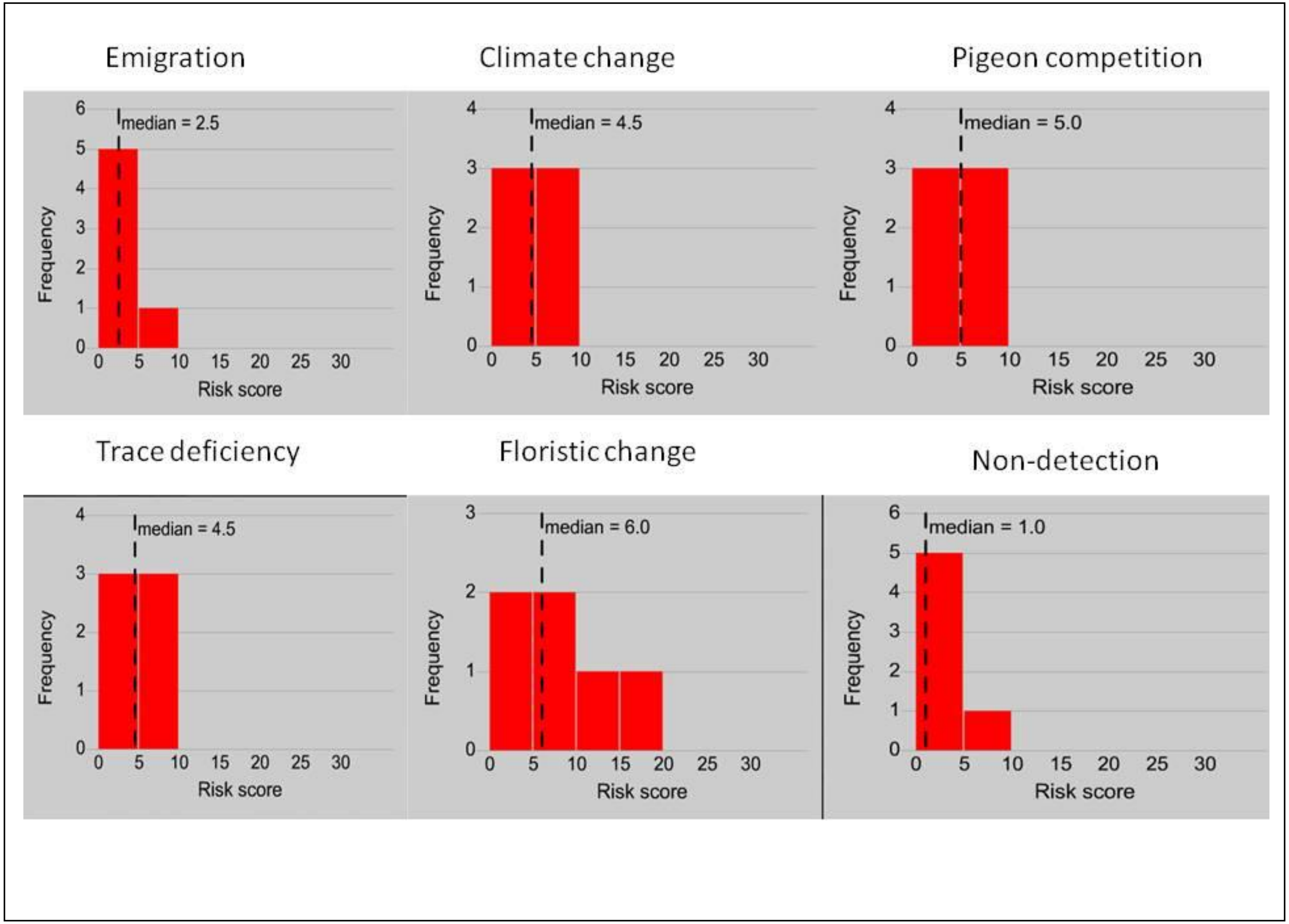
Consequence (Ecological Risk)
1 no decline
2 < 5% decline
3 5 – 10% decline
4 10 – 50% decline
5 >50% decline

Appendix 4 – Risk score histograms, reporting the midpoints of six independent assessments.



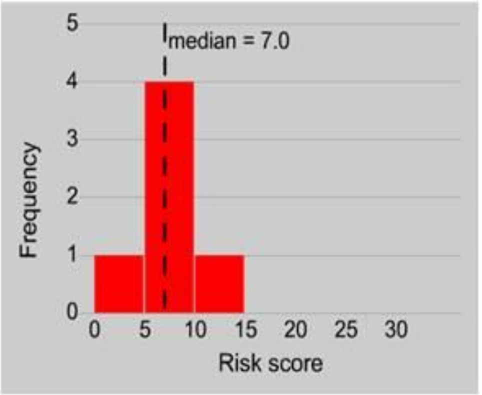


Calamity
Habitat loss
Genetic loss
Wolf snake
Centipede
Fiprinol
median = 8.5
median = 7.0
median = 7.6
median = 2.5
median = 11.6
median = 5.8
Frequency
Risk score
0
5
10
15
20
25
30



Emigration
median = 2.5
Frequency
Risk score
Climate change
median = 4.5
Frequency
Risk score
Pigeon competition
median = 5.0
Frequency
Risk score
Trace deficiency
median = 4.5
Frequency
Risk score
Floristic change
median = 6.0
Frequency
Risk score
Non-detection
median = 1.0
Frequency
Risk score

Heavy metals



Appendix 5 – Management scenarios

Business as usual

Activity	Strategy	Cost
YCA baiting	non CIFF targeted YCA control of super-colonies (5% of 20M for CIFF over 20yrs)	1M
Rehab of mine sites	10 ha per year (implying small annual net loss) 1.5M per yr over 20 yrs (only 5% on CIFF)	1.5M
YCA biocontrol	R&D leading to successful control agent (net cost as no longer implementing fipronil baiting) (5% rule)	30K
		$2.53M

Cadmium mitigation

Activity	Strategy	Cost
Captive breeding and subsequent supplementation	25 individuals and diagnostics (500k setup, $50k and 120K per yr for 20 yrs)	4M
Cadmium regulation	dust control - additional controls + enforcement (50k staff to negotiate over 6 mths, 20k per year 20yrs for enforcement, 5% rule)	70K
Drinking water provision	cover half dozen water points , install other water points (20k per yr for 20 yrs)	100k
		$4.17M

Food

Activity	Strategy	Cost
Supplementary feeding (food stations)	food stations at critical times of year (3mths per yr, 30k food per yr, 60k per year labor, 40k set up cost, 10 yrs)	940k
Plant food resource trees	Targeted (phenology) tube stock planting (cost per yr for flying fox 30k per yr over 10 yrs)	300k
Rehab of mine sites	change spp mix of current rehab program (10 ha per year - cost neutral as just change in species)	0
Rat Control	yes (45k per yr over 20 yrs, 5% rule)	45k

$1.285M

Protect roost sites

Activity	Strategy	Cost
Cat eradication at roosts	at roost sites (1% of 2/3 of 2.8 x2 intensity / yr for 20 yrs)	750k
YCA baiting at roost sites	high intensity (10k per ha on foot , 100 ha, per yr for 20 yrs)	20M
Predator proof roost trees	high intensity (85k pr yr for 20 yrs)	1.7M
Rat Control	yes - (1% of 1/3 of 2.8 x 2 intensity / yr for 20 yrs)	375k

$22.835M

Food and captive breeding

Activity	Strategy	Cost
Captive breeding and subsequent supplementation	25 individuals and diagnostics (500k setup, $50k and 120K per yr for 20 yrs)	4M
Plant food resource trees	Targeted (phenology) tube stock planting (cost per yr for flying fox 30k per yr over 10 yrs)	300k
Rehab of mine sites	change spp mix of current rehab program (10 ha per year - cost neutral as just change in species)	0
Rat Control	yes (45k per yr over 20 yrs, 5% rule)	45k
		$4.345M

Disease

Activity	Strategy	Cost
Captive breeding and subsequent supplementation	25 individuals and diagnostics (500k setup, $50k and 120K per yr for 20 yrs, +200k for extra vet care etc)	4.2M
Quarantine controls	Increased (350 k per yr over 20 yrs to border control)	7M
		$11.2M

Appendix 6 – Risk of extinction posed by each shortlisted threat under each management scenario

do nothing (more)	**nominal**	**lower**	**upper**
Feral Cats	0.15	0.05	0.30
Food resources	0.10	0.00	0.30
Disturbance by YCA	0.20	0.10	0.40
Cadmium poisoning	0.60	0.30	1.00
Disease	0.15	0.05	0.30
Giant Centipede	0.05	0.00	0.10
Fipronil poisoning	0.05	0.00	0.20
Calamity	0.02	0.00	0.10

Cadmium mitigation	**nominal**	**lower**	**upper**
Feral Cats	0.12	0.04	0.24
Food resources	0.08	0.00	0.24
Disturbance by YCA	0.16	0.08	0.32
Cadmium poisoning	0.40	0.02	0.70
Disease	0.12	0.04	0.24
Giant Centipede	0.05	0.00	0.10
Fipronil poisoning	0.04	0.00	0.16
Calamity	0.02	0.00	0.08

Food	**nominal**	**lower**	**upper**
Feral Cats	0.20	0.08	0.35
Food resources	0.05	0.00	0.15
Disturbance by YCA	0.20	0.10	0.40
Cadmium poisoning	0.60	0.30	1.00
Disease	0.15	0.05	0.30
Giant Centipede	0.05	0.00	0.10
Fipronil poisoning	0.05	0.00	0.20
Calamity	0.01	0.00	0.05

Roost protection	nominal	lower	upper
Feral Cats	0.14	0.05	0.26
Food resources	0.10	0.00	0.30
Disturbance by YCA	0.05	0.02	0.10
Cadmium poisoning	0.60	0.30	1.00
Disease	0.15	0.05	0.30
Giant Centipede	0.03	0.00	0.06
Fipronil poisoning	0.06	0.00	0.22
Calamity	0.02	0.00	0.10

Food and captive	nominal	lower	upper
Feral Cats	0.16	0.06	0.28
Food resources	0.10	0.00	0.20
Disturbance by YCA	0.16	0.08	0.32
Cadmium poisoning	0.48	0.24	0.80
Disease	0.12	0.04	0.24
Giant Centipede	0.05	0.00	0.10
Fipronil poisoning	0.04	0.00	0.16
Calamity	0.01	0.00	0.04

Disease	nominal	lower	upper
Feral Cats	0.12	0.04	0.24
Food resources	0.08	0.00	0.24
Disturbance by YCA	0.16	0.08	0.32
Cadmium poisoning	0.48	0.24	0.80
Disease	0.13	0.04	0.27
Giant Centipede	0.05	0.00	0.10
Fipronil poisoning	0.04	0.00	0.16
Calamity	0.02	0.00	0.08