Revised Interim Report
Christmas Island Expert Working Group
to
Minister for the Environment, Heritage and the Arts

Red crabs, Christmas Island – Photo by Max Orchard

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Executive Summary

Introduction

The Expert Working Group was formed in February 2009 in response to growing concern about the decline of the Christmas Island Pipistrelle (the island's only insectivorous bat) and, in particular, the report to DEWHA by Lumsden and Schulz (2009). The working group came quickly to the realisation that, to meet its brief, its focus would have to be both wide and deep, encompassing the ecology of the whole island and its surrounds. This report reflects that approach.

The working group notes that resolution of biodiversity conservation issues on Christmas Island has been an ongoing concern, expressed previously by Inquiries by the House of Representatives Committee on Environment and Conservation (1974) and the Senate Committee of Science, Technology and the Environment (1983).

There is a major difference in focus between previous reviews and ours. The earlier reviews sought resolution of classical but simple conflicts between resource utilisation (specifically, phosphate mining) and biodiversity conservation (specifically, the breeding sites of seabirds) through the judicious allocation of lands, either to National Parks or to mining.

We realised that this approach has been inadequate: the conservation problems on Christmas Island are pervasive, chronic and increasing and, unfortunately, will not have simple solutions.

Despite the majority of its land being in a national park, Christmas Island has suffered extinctions of three vertebrate species and is witnessing rapid decline to probable extinction of its few remaining endemic reptile species and its only insectivorous bat. It is also probable that seven plant species may be extinct.

In addition Christmas Island is suffering dramatic losses of the Red Crab. The Red Crab is not only its most conspicuous and remarkable species, but also the pivot of the island's unique ecology, which is of international significance. There are also concerns for the island's remarkable stygofauna. These facts imply a deep ecological malaise.

Our assessment reflects recognition of the more pervasive effects of the many pressures on the Christmas Island ecosystem, and the enormous challenge that these pose for implementing appropriate management responses on the island.

Our conclusion is that long-term and substantial changes will be required in the management of Christmas Island and its surrounding seas as a single ecological entity. Otherwise management will fail.

The working group's recommendations include some which are broad-ranging and long-term. We are recommending changes that will reduce the probability of further extinctions and reverse the decline in the island's endemic species and ecological processes. We are recommending changes that must be maintained to ensure the future of the extraordinary national asset that is Christmas Island's biodiversity.

Recognising that the need for some actions is very urgent, we present this report, grounded in the terms of reference provided by the Minister on 16 February 2009. The report will be refined over the coming months as there are a number of outstanding assessments that require time. The most significant of these are the possible disease loads of the Christmas Island Pipistrelles and the ecological impact of Fipronil. Findings in these areas could influence our final recommendations and future management.

What has happened on Christmas Island?

The principal finding of the working group is that the extremely high biodiversity values of Christmas Island are in a perilous state. The cause is the intrinsic vulnerability of Christmas Island as an oceanic island to the direct threats posed to biodiversity by a succession of human-related introductions of non-indigenous species and their ecological consequences. It is of concern that the lack of effective quarantine to prevent further introductions may exacerbate the decline in the future.

The fate of the Christmas Island Pipistrelle, now facing imminent extinction, is a symptom of this broad pattern of change and decline. There are many interacting factors and processes that could have led to the demise of the pipistrelle, but the complexity of these interactions may best be illustrated by considering the following scenario which, though just one of several potential pathways leading to the near extinction of the species, is the working group's most favoured hypothesis at this stage:

1. Lack of quarantine from the early days of settlement allows introduction and establishment of many non-indigenous species. Among them are ants (including the Yellow Crazy Ant) and the Giant Centipede.
2. At some time, perhaps more recently, species of scale insect are introduced on plants (possibly fruit trees) brought to the island. The scale insects establish in low numbers on rainforest trees and spread throughout the island.
3. Between 1984 and 1994, the Christmas Island Pipistrelle starts to decline, perhaps because of an increase in Yellow Crazy Ant numbers before the first super colonies were noted, perhaps because of reduced nocturnal insect numbers due to scale and ants competing with and eliminating the herbivorous larvae of moths, beetles and other insects.
4. In the 1980s rainforest trees became stressed, possibly because of lower water tables as a result of drought and/or water extraction for human use. Scale numbers increase on rainforest trees. (It is known that insects attack stressed plants more readily than healthy ones.) Alternatively, because the introduced scale insects had ineffective natural predators and parasites, they gradually proliferated.

5. Yellow Crazy Ants are attracted to honeydew secreted by scale. The ants ‘farm’ the scale and prevent predators and parasites, such as ladybirds and parasitoid wasps, from attacking them and constraining their numbers.
6. Excess honeydew from scale allows the extensive growth of sooty mould on the leaves of rainforest trees, stressing them further.
7. Feedback mechanisms cause population explosions in both scale and Yellow Crazy Ants. Yellow Crazy Ants form super colonies with multiple queens. Scale and ant outbreaks increase in extent and number.
8. Yellow Crazy Ants kill Red Crabs, leading to changes in rainforest structure. Red Crab recruitment is low due to unknown factors in the ocean and/or the crablings that do emerge from the ocean are killed by Yellow Crazy Ants as they move upslope.
9. Yellow Crazy Ants attack Christmas Island Pipistrelles while they are roosting in live trees. Pipistrelles become limited to roosting in dead trees (this interaction could have started earlier but we cannot know this).
10. Reduction in the numbers of Red Crabs leads to an increase in the numbers of Giant Centipedes due to an increase in leaf litter on the forest floor, increasing their habitat contemporaneously with a reduction in predation by crabs.
11. Giant Centipedes expand their foraging range and kill Christmas Island Pipistrelles while they are roosting under bark in dead trees. They possibly also kill a number of small island reptiles which are now highly threatened.
12. Yellow Crazy Ant super colony control by Fipronil possibly leads to additional stress on insectivorous fauna (currently speculative).

This plausible ‘ecological cascade’ provides a stark example of how apparently trivial events can have unexpected consequences, and illustrates the ecological complexity of even this comparatively simple ecosystem.

Recommendations

The recommendations in this report suggest strategies that can be followed to develop better management of biodiversity on Christmas Island.

As called for in Term of Reference 2, our findings propose a hierarchy of actions that are necessary. The first level is protecting the integrity of the ecosystems from further unwanted introductions and establishing better environmental governance of the island. The second level is the management of the island’s ecological processes so as to prevent further loss of biodiversity. The third level comprises management actions which can be taken immediately to prevent or slow biodiversity loss.

We present our recommendations in this summary. Each recommendation is grounded in the report and appears in it at the section indicated. The recommendations cover all of the terms of reference which are also indicated as appropriate. The order of the recommendations reflects the hierarchy of actions we have proposed. In addition, as called for in Term of Reference 1, we have given each recommendation a priority ranking using Table ES1 that contextualises existing threats by the reverse statement of a management outcome. The working group stresses that priority setting is to facilitate management and all recommendations are essential in the long term.

Table ES1. A threat-based framework for prioritising the recommendations in this report. The cells are outcomes to be achieved by management, each recommendation has been considered using this table as a guide this addresses ToR 1 in part.

Priority for the Recommendation	**Time frame for the Recommendation**		
	Short	**Medium**	**Long**
High	Prevent further introductions	Improve environmental management of Island as a whole	Establish an enduring adaptive management regime
	Prevent further loss of crab-structured forests by continuing current control of Yellow Crazy Ants until a better approach is available	Re-colonise ghost forests with Red Crabs	Have a secure island with ecological resilience and resistance
	Develop procedures to reduce predation impacts	Acceptable control of Yellow Crazy Ants and other threats introduced across the island	
	Accelerate research on biological control agents on scale insects and Yellow Crazy Ants and implement biological control trials as soon as possible	Accelerate understanding of Fipronil in the Christmas Island ecosystems	Implement integrated control of Yellow Crazy Ants and scale insects
	Develop secure and sufficient long-term funding arrangements for biodiversity conservation priorities on Christmas Island.		
Medium	Develop and implement robust monitoring programs and develop response protocols	Enhance monitoring protocols	Continue enhanced monitoring programs
	Build on this report using peer reviewed assessment of Christmas Island ecology and the immediate (10 - 20 years maximum) threats to its survival	Develop protocols for interventionist responses for rapid decline of any island endemic	Based on emerging science regularly review protocols for interventionist responses for rapid decline of any island endemic
	Control high-threat weed species	Identify and assess impacts on species viability from off shore threats	Control low threat weed species
Low	Rehabilitate cleared lands	Eliminate “non-threatening” exotic animals	Consider World Heritage listing of a secured island and manage it for the benefit of nature and people who choose to live there.

Recommendations Level 1: Protecting the integrity of the island and better environmental governance

The highest priority for the management of biodiversity on Christmas Island is the preservation of the functional ecology of the island and surrounding seas. This depends on reforming island governance and the funding systems for conservation. Consequently there needs to be an appropriately coordinated regime of management, with responsibility to maintain the island's unique biodiversity.

This requires:

- **Recommendation 1: Priority High** That quarantine management on Christmas Island be upgraded urgently to a standard commensurate with the Island biodiversity values (see sections 4.2, 4.5.4, 4.6).
- **Recommendation 2: Priority High** The governance of Christmas Island be modified so that environmental governance, including matters of biological protection and quarantine, is brought under a single authority with both the power and the resources to be effective (see sections 4.2, 4.6).
- **Recommendation 3: Priority Medium** That environmental management of the island should no longer be program-based, but have a single line budget with an appropriate level of funding and management accountability (see section 6).
- **Recommendation 4: Priority Medium** That a science management strategy be developed for Christmas Island as a whole. The working group further recommends that the management lessons identified elsewhere in this report become part of this process (see sections 4.3.1, 4.13).

Recommendations Level 2: Management of the island's ecological processes so as to prevent further loss of biodiversity

Control of Yellow Crazy Ants by baiting indefinitely with Fipronil is not a satisfactory long-term solution and there is a need for the development of a different approach. The working group recommends that:

- **Recommendation 5: Priority High - with ongoing monitoring** In the absence of any alternative, baiting Yellow Crazy Ants with Fipronil continues as a short-term control measure, but with greatly enhanced monitoring of its non-target effects (see sections 4.4, 4.5.3).
- **Recommendation 6: Priority High** The initial steps taken already to explore biological control of the scale insects be accelerated and biological control trials be started as soon as possible (see sections 4.4, 4.5.3, 4.11.1).

- **Recommendation 7: Priority High** There be aggressive maintenance of migration routes to and from the ocean for the remaining Red Crab populations, both adults and crablings (see sections 4.4, 4.9.2).
- **Recommendation 8: Priority High** Monitoring of biodiversity condition and trends be continued but with a high priority for continuous improvement and adaptive management that is informed by independent scientific advice. (see sections 4.3.2, 4.13).
- **Recommendation 9: Priority Medium** Threats to the island's subterranean fauna and marine ecosystems be assessed and appropriate processes developed to address them (see section 4.14).
- **Recommendation 10: Priority High** More information be acquired on the biology and population ecology of Red Crabs, particularly on ways to enhance recruitment (see sections 4.4, 4.9.2, 4.11.1).
- **Recommendation 11: Priority Medium** Potential sleeper species of both exotic plants and animals be identified and eradication be conducted for those identified as having high threat to the island's biodiversity (see section 4.5.1).
- **Recommendation 12: Priority Medium to High** Robber Crabs be investigated and expressions of interest called for a study of their population ecology (see section 4.11.2).
- **Recommendation 13: Priority Medium** The eradication of Black Rats and feral cats from Christmas Island be carried out in a coordinated project (see sections 4.5.2.2, 4.9.2).
- **Recommendation 14: Priority Low** Steps be taken to assess the threat, and plan for the suppression, of fire (see section 4.5.5).

Disease is likely to be an ongoing concern for all endemic Christmas Island plant and animal species (see section 4.5.4). The working group recommends:

- **Recommendation 15: Priority High** Sampling to establish baseline levels of prevalence of pathogens, disease and parasites in selected endemic animals and plants (see section 4.5.4).
- **Recommendation 16: Priority High** Sampling of disease (including parasite) levels in exotic plants and animals now present on Christmas Island (specifically including Black Rats, feral cats, dogs, Tree Sparrows, Java Sparrows, House Geckos and Wolf Snakes) (see section 4.5.4).
- **Recommendation 17: Priority Medium** A program of regular and robust monitoring of these pathogen levels (see section 4.5.4).
- **Recommendation 18: Priority Medium** The development of a response protocol and framework associated with the monitoring program (see section 4.5.4).

Recommendations Level 3: Management actions which can be taken to prevent immediate biodiversity loss

Under this heading there are recommendations regarding issues that require immediate action.

Christmas Island Pipistrelle

It is apparent that the Christmas Island Pipistrelle is genetically and morphologically very similar to some pipistrelle species in the Indonesian archipelago including the islands of Java, Flores and Sumbawa. These populations are the likely original source of the Christmas Island Pipistrelle. The report on the Christmas Island Pipistrelle's taxonomic status received on June 20 confirms *P. murrayi* as taxonomically distinctive. The working group considers it should be treated as an endemic species for management purposes.

In addition, ongoing monitoring efforts of the Christmas Island Pipistrelle on Christmas Island confirm that it continues to persist.

- **Recommendation 19: Priority High** Christmas Island Pipistrelle *Pipistrellus murrayi*: (Terms of reference 3 and 4)

Given the latest taxonomic data the working group recommends: (see section 4.7)

1. That Christmas Island Pipistrelles are captured from the wild as soon as practicable, as founders of a captive breeding colony.
2. That there is an initial allocation of $100,000 for the capture and temporary care phase, with a review by the working group in three months;
3. That Government funding be allocated immediately for this purpose;
4. That tenders are sought expeditiously from suitable experts to undertake the capture and care;
5. That funding partnerships with non-government organisations be encouraged;
6. That the program and any future funding (relating particularly to captive breeding) be reviewed in September 2009 on the basis of (i) the success or otherwise to date, (ii) assessments of the feasibility and costs of tenders for captive breeding (see below); and (iii) any additional information relating to the resolution of the taxonomic status of the species;
7. That immediate calls be made inviting expressions of interest (with indicative quotes) from zoos accredited as Quarantine Approved Premises on the Australian mainland for establishing and maintaining a quarantined breeding colony of Christmas Island Pipistrelles; and

8. That monitoring of Christmas Island Pipistrelles in the wild continues until no more passes are recorded for 26 weeks, at which time the monitoring program should be reviewed. This should include the re-establishment of some fixed-stations in the northern and eastern parts of the island.
9. That the trial captive breeding program on an analogue species in the Northern Territory be concluded.

Tropicbirds

- **Recommendation 20: Priority Medium** Measures be implemented to exclude cats from Red-tailed and White-tailed Tropicbird nesting areas along the Settlement's shore line (see section 4.9.2).

Highly Threatened Endemic Reptiles (see section 4.8.4)

- **Recommendation 21: Priority High** A captive breeding program be commenced immediately for the Blue-tailed Skink and Forest Skink (see section 4.8).
- **Recommendation 22: Priority High** That relevant species be nominated for the EPBC Act list of threatened species, unless the entire island is nominated for listing as a threatened ecological community (see section 4.8).
- **Recommendation 23: Priority High** That appropriate monitoring and/or targeted research be conducted to identify major threatening processes (see section 4.8).

Giant Centipedes and African Land Snails

- **Recommendation 24: Priority High** Development of methodologies to achieve reduction in Giant Centipede numbers and possibly African Land Snails in key areas be instigated immediately. In the longer term, this will presumably require the breaking of the scale insect - Yellow Crazy Ant nexus (see section 4.7.5.6).

Scale Insect – Yellow Crazy Ant Nexus

- **Recommendation 25: Priority High** Continue investigations on methods to break the scale insect - Yellow Crazy Ant mutualistic dependence (see section 4.4).

Conserving Christmas Island as an Entity

- **Recommendation 26: Priority High to Medium** That "The Christmas Island Sea Mount including its terrestrial and marine components and the surrounding seas" be considered for listing as a threatened ecological community under the Environment Protection and Biodiversity Conservation Act (see section 5.1).

Communicating the Problem and Management Responses

- **Recommendation 27: Priority High** That an appropriate community communications program relating to the recovery of Christmas Island biodiversity and re-establishing key ecological relationships be planned and executed (see section 5.2).

Findings with wider applicability

- **Recommendation 28: Priority High for DEWHA a whole**

There are lessons that can be drawn from the actual and impending biodiversity crash on Christmas Island. These have much wider applicability to biodiversity management in Australia and beyond. The lessons suggest that there should be:

1. National recognition (and concomitant resourcing) of Australia's iconic islands, many of which have extraordinary conservation values and a high susceptibility to biodiversity loss.
2. Long-term strategic continuity in conservation management, balanced by appropriate flexibility and adaptive capacity.
3. Development and implementation of a management prioritisation framework.
4. More systematic streamlining process for development and review of threatening processes and lists of threatened species, including those in conservation reserves.
5. Where commercial leases or other commercial regulatory instruments exist their re-negotiation should have, as part of the negotiating brief, the creation of resources to manage areas or matters of highest conservation importance.
6. Development and maintenance of a secure funding stream for the conservation management of threatened species and for dealing with other matters of conservation significance in Parks Australia reserves.
7. Development and maintenance of robust, integrated monitoring programs for threatened species and other matters of conservation significance
8. Stronger incorporation of adaptive management into Recovery Plans.
9. Development of explicit response protocols for intervention in recovery planning, including the option of precautionary establishment of captive breeding populations.

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1.0 Introduction

A chronology of events that culminated in this report is set out in Appendix 1. The principal triggering event was the probable imminent extinction of the Christmas Island Pipistrelle, the island's only insectivorous bat. The species is one of only two native mammals now extant on the island and this report will demonstrate that its plight reflects much more complex ecological problems on Christmas Island.

This report has been prepared by a working group whose formation was announced by the Minister for the Environment, Heritage and the Arts on 16th February 2009 (Appendix 1). This followed advice provided to the Minister by the Threatened Species Scientific Committee at the Minister's request on 3rd February 2009 in response to a report by Lumsden and Schulz (2009). The minutes of the committee and the Minister's consequent press release are also provided in Appendix 1.

1.1 Terms of Reference of the working group

1. Review the threats to biodiversity on Christmas Island, including the Christmas Island Pipistrelle, and develop appropriate priority setting protocols.
2. Prioritise and recommend threat identification and abatement for all Christmas Island biodiversity.
3. Oversee the development of rigorous protocols for survey work on the Christmas Island Pipistrelle and other threatened species which minimise the threats of this work.
4. Provide advice on captive breeding of the Christmas Island Pipistrelle, following a review of the outcomes of the mainland proof of concept study, and the results of further survey work on the Christmas Island Pipistrelle.
5. Provide such advice as deemed necessary to improve the development of the regional recovery plan, currently underway.

2.0 Methodology

The expert working group was established immediately following the Minister's announcement. The Department allocated staff to support the working group and, following consultation with the Chair, all relevant information available on Christmas Island was assembled. This material was distributed to members of the working group (see documentation list). The working group met by teleconference on March 6, 13, 20 and 27 before its visit to the island. From the commencement of its work the group developed a working paper that recorded its meetings and allocated tasks to be undertaken by members and by support staff. In addition, the Chair and Ms Anne-Marie Delahunt visited Melbourne to liaise with Dr Denis

O'Dowd, on behalf of the Crazy Ant Scientific Advisory Panel, and Dr Lindy Lumsden, whose actions in January 2009 (with Martin Schulz) led to the formation of the working group and, ultimately, this report. Records of these meetings provide part of the documentation list of the working group. In addition Dr O'Dowd provided his complete body of literature on Christmas Island issues. Literature available from Dr Lumsden was already held by the working group. All members sought additional reference material and obtained, in confidence, relevant information from their networks. Other consultations by the Chair and Ms Delahunt were held with Dr Andrew Keats and Dr Paul Story concerning the properties of Fipronil.

During the course of its teleconferences the working group developed a program of investigations to be carried out on Christmas Island by the group and also by the staff of Christmas Island National Park. The working group and its support staff visited Christmas Island from March 30 to April 3. The program of work on the island is presented in Appendix 2. Since the island visit the working group has met six times by teleconference and this report represents the progress that the working group has made. A number of critical issues remain outstanding and will be incorporated into this report when information becomes available (see Table 1).

Apart from the island visit, the working group has conducted its business entirely by e-mail and teleconference.

Outstanding work is presented in Table 1 which details tasks completed and tasks that remain to be completed before a final report can be presented.

Table 1 Completed and remaining tasks

Completed tasks:
• General assessment of the status of Christmas Island's biodiversity. • Identification of the major threats to biodiversity • Assessment of quarantine management • Develop framework of conservation priorities for the island • Identification of lessons learned from Christmas Island that could be applied to biodiversity management on other Australian islands • Review of relevant literature and biodiversity monitoring data • Review of management actions • Review of decline of Christmas Island Pipistrelles • Review of declines in other endemic (and other significant native) species
Remaining tasks:
• Finalise assessment of possible Fipronil impact on non-target species by assaying biological samples to determine possible systemic uptake and bioaccumulation. Expert advice is that this would be best done in conjunction with the next aerial baiting in October, 2009. • Review data on changes to background insect noise for the period where recordings are available, to assess whether a possible reduction in available prey may be a factor that has contributed to the decline of Christmas Island Pipistrelles. • Finalise assessment of Christmas Island Pipistrelle after assays are carried out on museum specimens and live animals to test for disease. • Review additional information on possible changes to groundwater levels due to drought and abstraction. • Review information concerning high cadmium content in Christmas Island phosphates and possible effects on native mammals, especially flying foxes.

3.0 Christmas Island Overview

3.1 Background information

3.1.1 Biophysical

Christmas Island (10^0 $30^{'}$ S 105^0 $39^{'}$ E) is a tropical oceanic island covering an area of 135 square kilometres with 73 kilometres of coastline (Figures 1 and 2).

Figure 1 Map of location of Christmas Island within the Indo-Australian region.

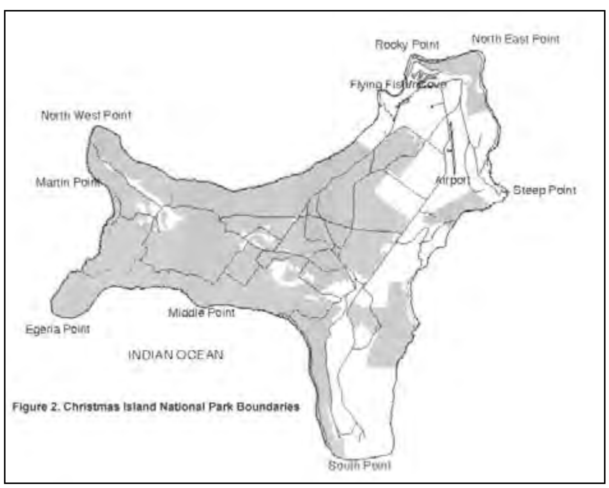

Figure 2. Christmas Island National Park Boundaries

Figure 2 Map of Christmas Island (From Christmas Island Management Plan)

Christmas Island has an equitable climate of 27-29^o C during the day – 24^o C at night, uniform year round. The island experiences high humidity in the 'wet' from mid-November – early April. Mean annual rainfall is approx. 2000 mm +/- approx. 630 mm, as demonstrated in Figure 3.

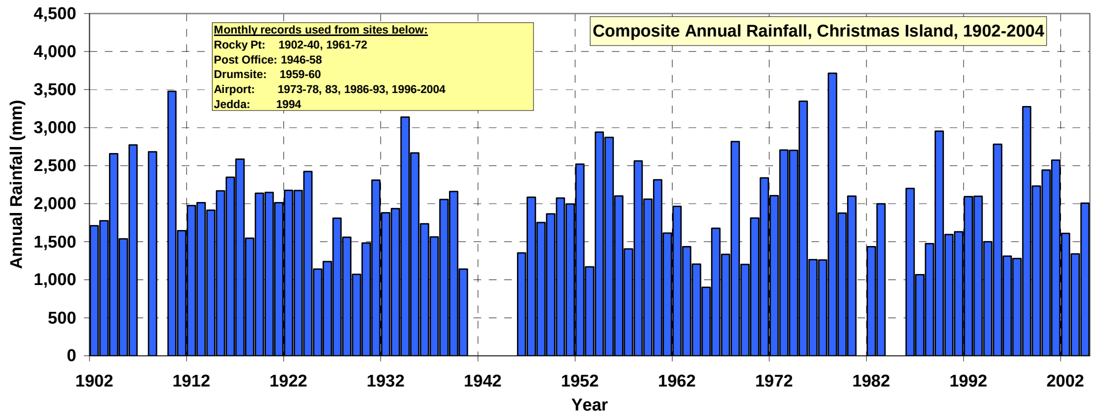

Figure 3 Composite rainfall pattern 1902 to 2004

The island is composed of limestone surrounded by a coral reef on the top of a basaltic volcanic sea mount. The island is step terraced, reflecting its origin and changing sea levels (both global and orogenic) over the last 250,000 years.

There are three main limestone sequences on Christmas Island and two of them have extensive cave networks. In a few places on the side of Murray Hill, 2 km east of 'The Dales', basaltic rocks are exposed. At this site phosphate has reacted with the iron in the area to produce a bright blue mineral known as 'Vivianite'. Basalt is also exposed in The Dales and in places on the island's eastern and northern coastal slopes. These intersections are associated with surface water.

The island is on a tectonic plate moving northwards a few centimetres a year that puts its present location some 700 km, or about 15 degrees of latitude, north of where it first emerged from the sea. About 60 million years ago an undersea volcano rose to the surface and a coral atoll formed. Some 20 million years ago, the atoll began to subside and limestone accumulated as the corals sank. About 10 million years ago the subsidence reversed and the island emerged in a series of uplifts that, together with sea level changes, give it a stepped appearance. Each terrace was formed by the combined effects of fringing reef development and erosion of the sea cliff before the next uplift or sea level change occurred. Examples of more recent faulting with under sea lava flows are evident. Caves and sinkholes typical of limestone formations occur at many points on the island. These form the habitats for the island's troglofauna and stygofauna.

The phosphorites commonly found on coral islands are now believed to result from lagoonal marine sediments on Christmas Island, although the chemistry of their formation is unclear. The soils of Christmas Island are derived from two sources - limestone (terra rossa soils) or basalt (krasnozem soils) (Parks Australia, 2008a).

The reef systems that surround the island drop rapidly from close inshore for several thousand metres. The surrounding seas have a number of nutrient-rich upwelling areas that are rich in pelagic fish and support the island’s significant populations of seabirds. The single global spawning ground of Southern Bluefin Tuna (*Thunnus maccoyii)* that lies between Java and northern Western Australia includes waters surrounding Christmas Island.

3.2 Social Economic

Christmas Island has a resident population of around 1300 people from a variety of ethnic backgrounds, reflecting the island’s diverse economic and cultural history. The main industries on the island relate to mining, government services and tourism. Mining involves the removal and export of high-phosphate soil for use in south-east Asian plantations. Tourism is a small but prospective industry, however, transport costs are extremely limiting.

In the long term the island’s economic future will either be a decline and depopulation as phosphate is depleted and ecological collapse occurs, or the island could undergo restoration with biodiversity-based tourism probably being its main industry.

3.2.1 Island Tenure and Governance

Christmas Island is an external territory of the Commonwealth of Australia and has been so since its transfer from British jurisdiction in 1958. The island is administered as a Commonwealth territory. In recent years a process of “normalisation” has been carried out which has resulted in a fragmentation of governance of the island and consequential confusion about responsibilities on matters which are key issues for maintaining the island’s biological integrity.

The tenure system on Christmas Island is set out in Table 2. The governance of the island is split between a number of Australian Government departments. In addition a number of Western Australian Government departments and corporations are involved in the contracting out of “governance”, as is a local government Shire Council. There is no coordinated environmental management save that which is derived from the individual actions of departmental managers cooperating outside of any formalised framework.

Table 2 Land tenures and their Area on Christmas Island.

Land tenure	**Area (ha) (% of Island)**
National Park	8760 (63%)
Unallocated Crown Land (UCL)	2670 (19%)
Phosphate Resources Limited Mine Lease	1900 (14%)
Residential / Industrial / Future Urban zones	300 (2%)
Airport	165
CI Resort	47
Immigration Reception and Processing Centre (IRPC)	43
Golf Course	14

3.3 Biological

3.3.1 Introduction

Christmas Island, like all emergent oceanic islands, is occupied by a suite of species that are derivatives of colonisers from distant land masses having arrived serendipitously by air or ocean currents. Because of small founder numbers, island populations usually have little genetic heterogeneity and limited ecological resistance to perturbations. These processes consequently lead to the formation of unique ecological communities, and Christmas Island provides a striking example of this. In having derived all their flora and fauna by random colonisation events emergent oceanic islands differ from continental (or land-bridge) islands, which retain many of the biotic elements of their continental parents and/or adjacent larger land masses, plus those which arrive randomly.

The terrestrial vegetation communities of Christmas Island comprise several types of rainforest dominated by plants which are pan-tropical tramp species, mostly probably of South East Asian origin. The role of land crabs in shaping the forest floor and lower forest strata is a unique feature of the island and is of international significance.

In common with many oceanic islands, Christmas Island is also of international significance as a seabird rookery. Abbott's Booby, *Papasula abbotti,* now occurs only on Christmas Island, having formerly bred on other Indian Ocean islands, while the Christmas Island Frigatebird, *Fregata andrewsi,* is endemic. Both species are listed as threatened species under the Commonwealth *Environmental Protection Biodiversity Conservation Act 1999* (EPBC Act). Other breeding seabirds are Red-tailed Tropicbird, *Phaethon rubricauda*, White-tailed Tropicbird, *Phaethon lepturus* (as a golden-tinted subspecies, known locally as the Golden Bosunbird, which is known only from Christmas Island), Red-footed Booby, *Sula sula*, Brown Booby, *Sula leucogaster*, Great Frigatebird, *Fregata minor*, Lesser Frigatebird, *Fregata ariel*, and Common Noddy, *Anous stolidus*. Birds Australia has included Christmas Island in its list of 'Important Bird Areas', partly because of the seabird populations.

The subterranean environment of Christmas Island is diverse and includes freshwater, marine, anchialine (a land locked water body with a subterranean connection to the ocean) and terrestrial habitats. Although still poorly known, the cave fauna is a significant component of the island's biodiversity. Subterranean fauna are found in air-filled (troglofauna) and water-filled (stygofauna) voids. With at least 12 endemic species, Christmas Island is a significant cave fauna province in an international context. The cave fauna comprises Christmas Island Swiftlets, and a diverse assemblage of terrestrial and aquatic invertebrates, including a number of rare and endemic species of high conservation significance. Notable amongst the troglofauna are terrestrial isopods, a blind scorpion and new genus of cockroach.

Oceanic islands are known to be vulnerable to invasion by introduced plants, animals and microorganisms. Typically, these introductions lead to extinctions and a significant proportion of world vertebrate extinctions have occurred in this manner. While the recent introductions on Christmas Island and their consequent events could be seen as an extension of such natural processes, the rate of introductions of damaging non-indigenous species has been greatly increased by human activity and many of the recently-introduced species could not have arrived without human assistance.

A chronology of the arrival of significant introduced fauna species on Christmas Island since settlement is set out in Table 3. This table does not include scale insect invasions that have possibly occurred four times and numerous species of other insects, any number of which could be significant in the future. The table includes a parallel chronology of jurisdictional arrangements and relevant historical events. An inventory of known recently introduced species is at Appendix 3.

The impact of these animal introductions is reflected in the imminent extinction of three endemic vertebrates on Christmas Island following declines over the last two decades. This follows the probable extinctions of two, probably three, other endemic vertebrates in the previous few decades. The ongoing process of change is reflected in Appendix 4 which identifies the number of currently listed threatened species and those that the working group believes should be considered as threatened. In addition there are several plant species that are considered threatened (Appendix 4). Currently there are 14 species of animals and three species of plants recognised as threatened under the EPBC Act, and in addition, the Yellow Crazy Ant is listed as a Key Threatening Process. The working group is of the view that there are many other species which would warrant listing as threatened.

Table 3 Chronology of significant animal introductions other than the Yellow Crazy Ant and jurisdictional governance

	Fire Ant	**Big-Headed Ant**	**Giant Centipede**	**Kestrel**	**Black (Ship) Rat**	**Wolf Snake**	**Giant African Snail**	**Domestic feral cat**	**Governance and relevant historical events**
1890s					1899 - First Arrival				Governor of the Straits Settlements (Britain)
1900s			Abundant By 1907					Established by 1904	Incorporated into the Settlement of Singapore
1910s									
1920s									
1930s			Island-Wide By 1939						
1940s							Probably introduced in 2^{nd} WW (Sproul 1983)		Occupied by Japan 1942-1945. From 1946, a British Colony under the Colony of Singapore
1950s				Self-Introduction					1958 - made an Aust territory, but Singapore laws still apply
1960s				Probably At Low Abundance					Christmas and Cocos Islands become Aust

									Indian Ocean Territories
1970s				Probably At Low Abundance					1977 – govt Conservator from Aust Nat Parks and Wildlife Service appointed
1980s				Became More Abundant Late 1980s		First Record (1987/1983??)		Study showed that cats widespread on island	1980-89 – Nat Park declared and extended
1990s								Cats implicated in reptile and bird decline. Cat trapping implemented at settlement.	Many asylum seekers arrive on CI
2000s	2005 – Mostly Open Areas (Not Suited To Rainforest)	2005 – Limited distribution, Mostly In Disturbed Areas						First trials of feral cat bait. Cat management plan drafted	2002 – CI excised from Australia's migration zone 2005 – construction of detention centre commences

There has been a long history of vegetation disturbance on the island. The most notable of these is 100 years of phosphate mining (directly affecting about 25 per cent of the area of the Island). In addition the 1969 grid line survey covered the island in a cleared rectangular grid pattern, each grid line was up to nine metres wide with lines set between 30-120 metres apart (Corbett et. al., 2003). A map of the coverage of these gridlines is provided at Appendix 5. In the 1970s the British Phosphate Commission cleared all existing mining leases completely.

Natural disturbance occurs also, particularly associated with occasional intense storm events with local islanders reporting the most recent extensive natural vegetation disturbance as being in 1988 from a storm associated with the tail of a cyclone.

3.3.2 Biodiversity Values

The critical biodiversity values of the island are its unique ecological character particularly the crab – forest community that is not found anywhere else, the unique stygofauna, a significant number of endemic species (Appendix 4) and its importance as a seabird rookery. The threat posed by introduced species is indicated by the number of exotic species already on the island (Table 3, Appendix 3).

3.3.3 Ecological uniqueness and ecological shift

The principal ecological shifts that have occurred on Christmas Island are now represented by the Yellow Crazy Ant, *Anoplolepis gracilipes,* and scale insect interaction. This results in the loss of land crabs and major changes in forest structure. These changes, if not arrested, will lead to the effective destruction of the unique Christmas Island ecosystem.

The original principal vegetation type of the island is rainforest of which there are floristic and structural variations relating mostly to soil depth and other surface features. All these types are now expressed in three recognizable forms through the action of Yellow Crazy Ant super colonies and their ecological effects. These three forms are:

1) the original, unaltered forest 'gardened' by Red Crabs (Figure 4),
2) forest occupied by super colonies of Yellow Crazy Ants that is devoid of Red Crabs and their ecological contribution (Figure 5), and
3) 'ghost' forests where ants have been eliminated (or have never colonised) but Red Crabs have either not recolonised the area or have indirectly been extirpated by migrating through anted areas (Figure 6).

Consequently Christmas Island is now a complex mosaic of these forest types and the residual altered landscapes from phosphate mining.

In the working group's discussion with interested members of the community it was apparent that all those with more than a decade's experience of the island environment expressed the view that there had been a decline in Red Crab recruitment. These observations are supported by the data. It is possible that both the Red Crab and the Robber Crab, together with a number of other land crabs, could become endangered.

Figure 4 Photo of typical Red Crab ‘gardened’ forest, exhibiting minimal understorey and very few weeds.

Figure 5   Photo of a Yellow Crazy Ant super colony area, exhibiting dense understorey growth in the absence of Red Crabs.

Figure 6 Photo of ‘ghost’ forest, with neither ants or crabs and increasing density of understorey and weeds.

Even if these changes are arrested there is no guarantee of the island's long term ecological integrity. There are many exotic species already established on the island and, while not all present a problem at this time, the fact that the Yellow Crazy Ant was on the island for at least 60 years before it became a significant problem illustrates the potential of "sleeper species" to alter major island ecological processes. This reinforces the necessity of high-quality, ongoing and adaptive management strategies.

Notwithstanding these observations, the problem remains that we have little understanding of what triggers major ecological changes. In the case of Yellow Crazy Ants it is likely that the introduction of one or more species of scale insect, either alone or in conjunction with moisture stress of the forest trees (either by drought or the depletion of groundwater) may have been the trigger. This cannot be substantiated at this time, but no alternative potential trigger mechanism has yet been identified.

The importance of this observation is reinforced by the fact that the explosion in numbers of an invasive ant on an island is not unique to Christmas Island. The African Big-headed Ant or Coastal Brown Ant (*Pheidole megacephala*) has interacted with scale insects on Tryon and Wreck Islands in the Capricornia Cays National Park in the southern Great Barrier Reef (Freebairn, 2006a) and another ant *Tetramorium bicarinatum* has interacted with scale on Coringa South West Islet Island in the Coringa-Herald National Nature Reserve in the Coral Sea (Smith and Papacek, 2001; Freebairn, 2006b, 2007), resulting in the complete loss of the *Pisonia grandis* forest on Tryon Island and extensive damage to vegetation on other islands (Kay et al., 2003; Hoffman et al., 2004; Freebairn, 2006a, b). The outbreaks in the Capricorn Cays National Park have been actively and successfully managed by the Queensland Parks and Wildlife Service through the poisoning of attendant ants and the introduction of biological control agents, such as ladybirds and parasitoid wasps, that predate the scale insects (Greenslade, 2008, Smith et al., 2004, Olds, 2006; Freebairn, 2006a). As with Christmas Island, it is considered that the ant outbreak on these islands is a secondary result of the scale outbreak. The Big-headed Ant is one of more than 50 non-native ant species that now occur on Christmas Island (Framenau and Thomas, 2008). These non-native ant species are listed in Appendix 3.

Decomposition of plant material appears to provide the principal nutrient pathway of Christmas Island's rainforest ecosystems. The decomposer food chain is dominated, visually, by the breakdown of litter and fruit by the crab community, however, the role of fungi and microorganisms in facilitating this nutrient cycle has not been investigated. This is a significant knowledge gap and a documentation of the fungal and mycophagous communities is essential to understanding the rainforest ecosystems.

3.3.4 Biosecurity (Background)

Many of the current biodiversity conservation problems on Christmas Island are due to the presence of introduced species of animals, plants and microorganisms that arrived with humans and their equipment and food. Most of these organisms arrived on the island before it became an Australian external territory and before there were any quarantine provisions or inspections in place. History tells us that new invasive species will continue to arrive on Christmas Island, with ensuing detrimental, perhaps even catastrophic, effects on the island's biodiversity, unless an effective quarantine management system is in place.

Quarantine at Christmas Island is the responsibility of the Australian Quarantine Inspection Service (AQIS). AQIS is a fee-for-service organisation and Christmas Island (with the Cocos-Keeling Islands) is unique in that quarantine of incoming goods and people is required entirely to protect biodiversity, rather than agriculture and other industries, and in that there are no industry fees. The Attorney General's Department currently pays AQIS about $140,000 per annum as a contribution towards the cost of quarantine. Australian Customs also has a role to play on Christmas Island but this does not include biosecurity.

Significant quantities of materials and food are imported to Christmas Island each year. Much comes from the Australian mainland but some, e.g. fresh food and vegetables, comes from Asia. At the port, during a six-week period, about 35 containers would arrive from Australia and three from Asia. Many aircraft arrive from the Australian mainland and from Asia. About 50 to 70 privately-owned yachts arrive at Christmas Island each year and large cruise liners are adding Christmas Island to their itinerary.

The two AQIS staff at Christmas Island are responsible not only for inspecting incoming goods etc., but also for minimising the chance of infected goods being transported from Christmas Island to the Australian mainland. They are able to meet and inspect incoming aircraft and ships, but their effectiveness is hampered by a number of factors.

- Of the current two staff, one may be away or one may be in the process of being replaced, meaning that a single person often has to carry the full load of inspections.
- AQIS may be reducing the already small staff resources of two full time equivalent personnel to 1.5.
- The lack of quarantine-approved premises to de-stuff containers or inspect other goods means that inspections occur in an environment where, once container doors or packages are opened, any mobile organisms can escape.
- Fumigation and wash down facilities are not available.
- Inspections are visual only, thus animals such as small insects or spiders in fruit and vegetables are unlikely to be detected.
- Customs operates X-Ray equipment at the airport, but AQIS staff do not necessarily have access to it.
- AQIS staff do not have a suitable vessel from which to inspect visiting yachts, meaning that yachts and their hulls are not inspected. Alternative control methods to boarding include documentation that must be provided by visiting yachts on bio-fouling etc before they can moor

offshore, but this is not as robust as an inspection by trained quarantine officers.

- Some island inhabitants have a negative attitude to quarantine and object to their luggage and other imports being inspected, particularly by officers who are, in such a small community, familiar to residents. Attempts to smuggle garden plants onto the island are not infrequent.
- Major works, such as the construction of the Immigration Detention Centre, have seriously overloaded the capacity of the system.

Data on organisms detected during inspections are not recorded. We were told that soil, spiders and nests (including birds' nests) have been found in incoming goods recently, as well as whole plants and seeds.

Elements of Christmas Island's biodiversity have declined and are currently in severe decline because of introduced species and diseases. The addition of more invasive species to the already high load can only make matters worse. For example, the introduction and establishment of the Brown Tree Snake (*Boiga irregularis*), as has happened on Guam, would have a catastrophic effect on Christmas Island's animals, especially its birds. Two species of toad are potential new arrivals, the Cane Toad (*Rhinella marina*) and the Asian Spiny Toad (*Bufo melanostictus*).

4.0 Specific Issues Considered by the Working Group

4.1 Natural Dynamics of Oceanic Islands

As already mentioned, island biotas typically form naturally-simple systems that can be subject to significant perturbations in short time frames. These perturbations can be natural events, exotic species invasions or more complex interactions of an ecological nature. In addition, anthropogenic actions that change the vegetation or alter groundwater levels of the island can lead to unforeseen consequences.

A particular feature of oceanic islands is that few, if any, geographic refuges are available to species and as a consequence a major natural perturbation or significant threat is likely to lead to a population crash with little possibility of recovery through re-colonisation.

Oceanic islands have natural but low species turnover rates. New species arrive from distant land masses and existing species may die out naturally due, for example, to small population size or to interactions with newly-arrived species. However, the rate of arrival and establishment of new species on Christmas Island since human settlement has been several orders of magnitude higher than the natural background rate. Furthermore, the recent immigrants include species that could never have arrived without human help.

4.2 Securing Christmas Island against further invasions

4.2.1 Governance and Quarantine

It is quite clear to the working group that significant expenditure on the implementation of biodiversity management on the island will be useless without a concurrent implementation of a strong system of environmental governance. The working group strongly recommends that the governance of Christmas Island be reviewed so that environmental governance, including matters of biological conservation and quarantine, are brought under a single authority with both the power and resources to be effective. These changes should include an adequate single line budget driven by priorities (long term) for biodiversity conservation rather than programmatic funding which, of its nature, prevents good management decisions being made. **(Recommendation 2)** This would ensure that the island is managed as a whole and that strict quarantine procedures are put in place and staffed appropriately **(Recommendation 1)**.

An effective quarantine management system for Christmas Island should include a coordinated analysis of and response to infection, detection and eradication.

- <u>Infection</u> of goods in the supply chain to the island must be eliminated. This requires goods to be quarantine compliant before leaving the embarkation port. Quarantine provisions need to be written into contracts for goods being supplied to the island, perhaps by making a single logistics company responsible for consolidation, container stuffing and delivery to ships and aircraft. Detailed pathway analyses for all supplies and people coming to Christmas Island would aid this process.

- Detection needs to be of a very high standard and should occur pre-border (eg, at embarkation, in quarantine-approved premises on the island or at sea). Additional detection surveillance should occur post border on the island near the airport and sea port.
- Eradication plans must be in place, with all necessary pre-approvals. Eradication equipment must be stored on the island for all high-risk groups of organisms and staff trained in its use to allow rapid response. The organisation responsible for quarantine and the organisation responsible for biodiversity conservation on the island should either be the same or work very closely together to maximise the probability of any organisms that get through quarantine barriers being eradicated before they establish, breed and expand their range.

4.3 Christmas Island research and monitoring

Initially stimulated largely by concerns about the destructive impacts upon nesting seabirds of phosphate mining, a modern phase of research on the island's threatened species and ecology has extended from the 1970s to the present day. There have been four broad themes of this modern phase of research – assessment of the complex ecological relationships and dynamics of the island (focusing particularly on the ecology and ecological role of the Red Crab), assessment of the status of some threatened species, assessment of some non-native pest species and their control, and inventory studies that have assessed the impacts of current or proposed developments. As these components intersect, some studies have inevitably addressed more than one of these broad fields. Some of this research work has been of international interest and standard. Some has been continued over decades. Some has had direct management relevance, and has been translated directly to management actions. Much of the research has been commissioned or directed by the conservation management agency (now Parks Australia).

It is tragic that for a place that has attracted so much international interest and research effort the Island's unique ecological character is threatened and without heroic management actions, the complete restructuring of the island's ecological communities is likely.

The principal triggering event for this report was the predicted imminent extinction of the Christmas Island Pipistrelle (Lumsden and Schulz, 2009). This species is one of only two native mammals (the conservation status of the other, the Christmas Island shrew, *Crocidura attenuate trichura*, is uncertain) now extant on the island, and its plight reflects a much deeper malaise.

These observations raise fundamental questions about the management of research and monitoring and their use in management decision making.

4.3.1 Research Management

The unique ecological character of the island has attracted significant research with over 100 refereed publications and over 150 additional published works (see document list Appendix 6). The working group recognised the high quality of much of this research, and the extent to which many results of this research were collated and used in management. However, in review, the working group noted that better research management could enhance the research effort, by focusing on significance, relevance, and application. The fact that non-peer reviewed reports of science conducted on Christmas Island significantly outnumber peer reviewed reports strongly suggests to the working group that a peer review process for Christmas Island science, and for that matter all park management science, would greatly improve its usefulness.

It is the view of the working group that Christmas Island would benefit from the development of a better science management approach that made better use of the Department's system of independent scientific advice with specialist groups being set up under this umbrella where necessary. This Expert Working Group is an example of such a group. Some groups should be task orientated while some need to be standing groups with a longer life. In every case the work should be independent, expert and outcome directed in an adaptive management context. This would extend from the interpretation of data through to the identification of data gaps. The establishment of mechanisms for addressing these gaps would support an adaptive management approach.

The working group recommends that a science management strategy be developed for Christmas Island as a whole. It further recommends that the management lessons identified elsewhere in this report become part of this process. **(Recommendation 4)**

4.3.2 Biodiversity Monitoring on Christmas Island

There has been an unusually detailed body of research undertaken on Christmas Island. Fortunately, and almost uniquely, this includes a remarkably comprehensive baseline account of biodiversity compiled within a decade of the island's initial settlement (Andrews, 1900). Sir John Murray recognised this opportunity in 1900:

> "*It has not hitherto been possible to watch carefully the immediate effects produced by the immigration of civilized man and the animals and plants which follow in his wake upon the physical conditions and upon the indigenous fauna and flora of an isolated oceanic island*" (Sir John Murray, 1900, quoted in Stokes, 1988)

This initial assessment has provides a base line against which changes could be measured. Murray's concern and prescience was remarkable, as a continuous stream of non-native plants, animals and micro-organisms since introduced (deliberately or inadvertently) to the island have had devastating impacts upon much of the island's original biodiversity. Biological changes came quickly, and others with more delay. Rapid change, including the extinction of the two native rodent species, was documented within 10 years of the original baseline (Andrews, 1900). Many other species (including seven native plants) have not been recorded on Christmas Island since these initial studies.

Unfortunately, far less attention was paid to the fate of Christmas Island biodiversity in the following decades. The next landmark, and far less comprehensive, account was by Gibson-Hill (1947), and there was then a further hiatus until about the 1970s. Trends in the native plants and animals, and in the arrival, spread and impact of non-native species, over this period are largely unknown.

Today Christmas Island National Park has established a significant monitoring information system and has made progress in organising all available data of relevance to the management of the island. The ongoing island wide surveys will further advance this knowledge base. Island managers need to integrate and interpret currently-available data, the scientific and grey literature and the observations of staff and consultants.

There is considerable ongoing survey work being undertaken by the staff of Christmas Island National Park, including a bi-annual island wide survey (IWS). The working group supports this ongoing work and recommends that monitoring continues provided there is a significant level of independent advice on its design, data management and management utilisation **(Recommendation 8)**. The current status of this work is given in Table 4.

Table 4 Surveys of Species and Groups of Species on Christmas Island.

Species/groups of species	Year survey commenced	Year survey concluded	For inclusion in 2009 IWS
Christmas Island Pipistrelle (visual and acoustic monitoring of roosting and foraging habitat)	1998	On-going	
Christmas Island Flying Fox	1986	On-going	Yes
Reptiles	1978	On-going	Skinks and Barking Gecko
Island Wide Survey for Yellow Crazy Ants and Red Crabs and other indicated species	2001	On-going	Yes
Robber Crabs	2004	2006	Yes
Land Birds	2001	On-going	Yes
Abbot’s Booby	1981	On-going	Yes
Hawk Owl	1988	1989	Yes
Goshawk	2004	On-going	Yes
Brown Booby	2007	On-going	
Red-tailed Tropicbirds	2004	On-going	
Christmas Island Frigatebird	2004	2004	
Insects and macro invertebrates	2004	2006	

4.4 Yellow Crazy Ant Management

Over the last eight years the Yellow Crazy Ant management program has dominated island biodiversity management[1]. The program has been necessary to prevent catastrophic collapse of the island's keystone species (the Red Crab) with consequential dramatic changes in forest composition and the abundance of a number of significant introduced predators **(Recommendation 5)**.

As discussed in detail elsewhere it is unlikely that the current Yellow Crazy Ant management program, which relies entirely on Fipronil bait, is not a long term solution (**Recommendation 6)**. It is highly likely that any successful long-term program will depend upon the effective and simultaneous control of scale insects and Yellow Crazy Ant super colonies **(Recommendation 25)**.

In the meantime ghost forests of two types will remain a feature of the island. These ghost forests are those from which Yellow Crazy Ant super colonies have been eliminated but in which Red Crab recovery has been limited, or forests in which there have been no Yellow Crazy Ant super colonies but from which Red Crabs have disappeared due to their death on migration through distant super colony areas **(Recommendation 7)**. In ghost forests of both derivations significant changes in forest and soil structure are occurring.

During the working group's time on the island it was suggested that there is a demonstrable difference in the size, distribution and therefore probably age classes of Red Crabs. Two mechanisms were suggested. The first is the direct effect of Yellow Crazy Ants and the second is some other unknown marine influence on Red Crab recruitment. The latter remains a matter of speculation. This is discussed in more detail in the Red Crab section **(Recommendation 10)**.

4.5 General threats to endemic and other native species

There are a number of actual and potential threats to biodiversity on Christmas Island that may be affecting multiple endemic species. These are discussed in general terms below, with more detailed discussion of their effect on individual species later in the report.

4.5.1 Ecological shift and associated cascade effects

The section above outlines the pattern of ecological shifts that have occurred on Christmas Island. These shifts are highly significant for a number of reasons. The shifts have already seen established populations of Giant Centipedes and African Land Snails are reported to increase in numbers in forests that have lost their Red Crabs. It is probable that other sleeper species may become threats to island biodiversity as these forests undergo unknown transitions **(Recommendation 11)**. The working group recognises this is speculative; however, it is an important topic for ongoing island science management.

[1] Other significant programs of mine site rehabilitation, threatened species recovery and weed management have also occurred in this period. These will be further developed in the final report.

4.5.2 Predation

4.5.2.1 Cats

There are seven species for which feral cats and Black Rats are a threatening process, namely the Emerald Dove, Hawk-owl, Thrush, Tree Gecko, Red Tailed Tropicbird, White Tailed Tropicbird and Pink Blind Snake. Another species, Lister's gecko, has not been seen since the 1980s and may already be extinct; cats and Black Rats may be a possible contributor. Tidemann (1989) found that feral cats were widespread but concentrated around areas that were being mined. An analysis of 92 feral cat stomach contents found that their diet was dominated by three vertebrate species—fruit pigeons, Flying-foxes and introduced rats.

In 1996 a study on the status of feral cats and their prospects for control on Christmas Island recorded cats at 0.19/km (van der Lee, 1997). An analysis of 19 cat stomachs from this study found that a significant proportion (30-40 per cent) consisted of the native Giant Gecko, Forest Skink and Blue-tailed Skink. Two recent unpublished studies of breeding colonies of Red-tailed Tropicbirds in the Settlement area found 100 per cent and 96 per cent chick mortality rates due to cat predation**.**

The Shire of Christmas Island has introduced local cat management laws (*Shire of Christmas Island Local Law for the Keeping and Control of Cats 2004*) under the *Local Government Act 1995 (WA) (CI)* with the aim of limiting cat ownership to two cats per house and requiring residents to register and neuter (de-sex) their cats. The de-sexing program is a collaborative project coordinated by the Shire of Christmas Island and financially supported by Christmas Island National Park and Christmas Island Phosphates.

In 2008 a trial of a new feral cat bait ('Curiosity feral cat bait') was conducted in selected areas of Christmas Island National Park, unallocated Crown land and mine lease areas. Further bait trials will be conducted in 2009. The trial(s) are part of a collaborative national project between the Commonwealth Department of Environment, Water, Heritage and the Arts, the Victorian Department of Sustainability and Environment and the Western Australian Department of Environment and Conservation.

4.5.2.2 Rats

Black Rats (*Rattus rattus*) were introduced to Christmas Island in 1889 from a ship. It is now known that the endemic *Rattus macleari* become extinct because of the introduction of a disease parasite, murid trypanosome, brought in by Black Rats and transmitted by fleas (Wyatt et al., 2008). Another endemic rat, *Rattus navitatis*, also became extinct at the same time, almost certainly from the same cause. Elsewhere, introduced rats have been the cause of numerous bird and other animal extinctions on islands.

Black Rats have been eradicated from numerous islands throughout the world, particularly in New Zealand and Western Australia. 'Predation by exotic rats on

Australian offshore islands of less than 1000 km^2 (100,000 ha)’ is listed as a Key Threatening Process under the EPBC Act. Feral cats have also been eradicated from islands, including three in Western Australia. Eradication of feral cats from Macquarie Island led to introduced rats and rabbits becoming superabundant, with the latter causing massive vegetation loss and erosion (Bergstrom et al., 2009).

The working group recommends that Black Rats and feral cats be eradicated from Christmas Island, in a coordinated project **(Recommendation 13)**.

4.5.2.3 Other introduced species

There is already a number of species on the island some of which are already implicated in the decline in biodiversity**.** Others have potential as “sleeper” threats and require close monitoring. These species include:

- at least 50 other ant species
- Giant Centipede
- Nankeen Kestrel
- Wolf Snake
- House Mouse
- Asian House (Barking) Gecko
- Pacific Gecko
- feral fowl
- white line disease in coral

4.5.2.4 Potential Introductions

In addition there are a number of species that have invaded other islands that represent potential threats to Christmas Island biodiversity. Measures are needed to address the prevention of these species being introduced to the island. The following species or groups have a significant potential for invasion:

- snails
- spiders
- Brown Tree Snake
- the Cane Toad and Asian Spiny Toad
- Indian Myna
- a range of marine pests especially associated with hull fouling

These facts strongly reinforce the necessity of a great improvement in the quarantine regime.

The working group is of the view that these threats are real and the only approach to their alleviation is the recommendations already made with respect to quarantine and environmental governance of Christmas Island **(Recommendations 1, 9, 11 & 24)**.

4.5.3 Fipronil toxicity

The working group has reviewed the published material on the Yellow Crazy Ant super colony control program and has held discussions with the representative of the Crazy Ant Scientific Advisory Panel. The working group accepts the argument that Fipronil is probably the only agent currently available to control Yellow Crazy Ant super colonies on Christmas Island **(Recommendation 5)**.

Notwithstanding this, the working group remains concerned about the likely impacts of Fipronil. It has established that Fipronil can exist in a number of metabolite forms of significant toxicity, has significant residual time, can enter the food chain, can impact on the reproduction of mammals and birds, can neurologically influence animal behaviour and can act systemically in plants. These are all causes of significant concern and the working group has requested that work be done to explore some of these issues as a matter of urgency. The interpretation of this work will be reported in the working group's final report. Further discussion of the possible impact of Fipronil on endemic Christmas Island species is found elsewhere in this report.

The working group recommends that further discussions need to be held with the Yellow Crazy Ant Scientific Advisory Panel to further identify alternative actions and lines of research that can be pursued as a matter of urgency. The working group is aware that initial steps have been taken to explore biological control of the scale insects and believe that this should be given a very high priority **(Recommendation 6)**. The breeding and introduction of parasitoid wasps and ladybirds to control scale insects is already underway on Queensland islands and learning from that experience will aid the early implementation of biological control of scale insects on Christmas Island.

4.5.4 Disease

In a recent broad ranging review of the role of disease in biological conservation, Smith et al. (2006) concluded that "while infectious diseases as a driver of species extinction may have been historically overlooked, contemporary extinctions, due in part to pathogens – are becoming increasingly documented and are likely to play a significant role in future species endangerment".

It is likely that many extinctions caused by disease have not been recognised as such. However, some extinctions caused by disease have been notable. For example, the loss of most species of the rich Hawaiian endemic passerine bird fauna (with the most recent extinction in 2004) was due primarily to the inadvertent introduction to the island of avian malaria. Island species may be particularly susceptible to novel pathogens because they typically have small total population size, relatively low genetic diversity, limited immunity, and no refuge.

The two earliest recorded extinctions on Christmas Island were of its two native rodent species, *Rattus macleari* and *R. nativitatis*, between their original discovery (in 1887 and 1889 respectively) and 1904. This rapid extinction has long been known to coincide with the arrival on the island of the exotic Black (Ship) Rat *R. rattus*, but it is only with recent analysis of ancient DNA that the cause of the extinction has been unequivocally shown to be infectious disease

(Trypanosomiasis), spread to the native rats from infected fleas on the invading Black Rats (Wyatt et al., 2008).

Given the wide range of exotic plants and animals that have been deliberately or inadvertently introduced to Christmas Island since its settlement, it is highly likely that many additional pathogens, parasites and diseases have been introduced, that many of these have spread to native species, and that this spread has contributed to the decline of those native species. However, currently there is no evidence for (or against) such introduction, spread and impact. This makes assessment of the role of disease in the decline of the Christmas Island biota highly conjectural, and hence difficult to manage.

Disease is likely to be an ongoing concern for all endemic Christmas Island plant and animal species, and incidentally (although presumably with less impact, more rapid detection and more likelihood of determined response) to the human population of Christmas Island. To appropriately recognise and prepare for this contingency, working group recommend:

(1) sampling to establish baseline levels of prevalence of pathogens, disease and parasites in selected endemic animals and plants **(Recommendation 15)**;

(2) similar sampling of exotic plants and animals now present on Christmas Island (specifically including Black Rats, feral cats, dogs, Tree Sparrows, Java Sparrows, House Geckos and Wolf Snakes) **(Recommendation 16)**;

(3) a program of regular and robust monitoring of these levels **(Recommendation 17)**;

(4) the development of a response protocol and framework associated with the monitoring program **(Recommendation 18)**;

(5) increase in the effectiveness of quarantine procedures (**Recommendation 1**).

Disease also has the management complication that it may thwart, handicap or make more expensive any captive breeding (or ex situ cultivation) program on the island, and demand substantial quarantine hurdles for any captive breeding program off the island.

4.5.5 Fire

Fire is not currently seen as an issue on Christmas Island (Claussen *pers. comm*; Retallick *pers. comm.*), however it is noted that a fire did occur in the terrace rainforests during the long dry of 1994 and again in September 1997 (GHD 2002a). If dry seasons become more severe, more frequent, or forest vulnerability increases because of increased forest complexity and fuel loads through Red Crab removal, then impact from fires may become an issue for many species that are not adapted to such events (Butz, 2004). The limited area of some sea bird nesting colonies makes them especially vulnerable to fire. The Cemetery and Golf Course nesting colonies are close to human activity, which substantially increases the risk of wildfire in those areas (Hill and Dunn, 2004) **(Recommendation 14)**.

4.5.6 Land Clearance

More than one hundred years of mining has resulted in vegetation disturbance on approximately 25 per cent of the island. Some of this area has revegetated naturally, some has been restored and the reminder is old or current mining sites. The current area of mining leases comprise 14 per cent of the island's area.

The concerns expressed elsewhere in this report about the future of biodiversity on the island will be aggravated by any further fragmentation of the island and the destruction of corridors of forest. However some of the other concerns will be ameliorated if there is strict regulation of mining operations and appropriate mine site rehabilitation. These in turn depend on better island governance.

4.5.7 Water use

Governance arrangements regarding the utilisation of the island's available groundwater are complex. The major water resources are located in the approximate centre of the island near Jedda Cave and Jane-up, however most of the monitoring of water quality and extraction occurs at outflows closer to the coast. Monitoring of the groundwater is focussed on ensuring water supply demand can be met. There are no environmental conditions imposed on the extraction of water on the island, and therefore no formal consideration of the broader impact that groundwater extraction may have on the surrounding island ecosystems.

4.6 Conservation status of endemic species

The working group's examination of the ecology of Christmas Island has led to two conclusions. Firstly some extinctions can be attributed to either disease or predation. Secondly it can be hypothesised that the decline in other endemic species is related to the ecological shift that the island has undergone, which in turn can lead to increased predation, physiological disruption, habitat change or changes in food availability. The working group has also formed the opinion that endemic population collapses will continue either as a result of single introductions or resulting from an ecological cascade unless the principal driving forces are abated. To achieve the recommendations elsewhere in this report, those relating to the ecological governance and quarantine of the island are critical (**Recommendation 1 and Recommendation 2**).

4.7 Christmas Island Pipistrelle

4.7.1 Taxonomic Status

It was acknowledged by Schulz and Lumsden (2004) that "there are differing opinions regarding the taxonomic status of the Christmas Island Pipistrelle *Pipistrellus murrayi* and taxonomic clarification is required".

First described by Andrews (1900), principally on the basis of its size and pelage, the Christmas Island Pipistrelle has been the subject of conflicting reviews by Koopman (1973; 1993), Kitchener et al., (1986) and Hill and Harrison (1987). The most recent Australian Bat Action Plan (Duncan et al., 1999) follows the taxonomy of Kitchener et al., (1986) and considers the taxon endemic to Christmas Island. On this basis, the species has been listed under the EPBC Act and its closest relative, on morphological grounds, is considered to be the *P. tenuis* complex from Java and islands to the east.

Clearly, it was important to resolve the taxonomic status of the Christmas Island Pipistrelle. If, for example, it were shown that it was taxonomically the same as one of the Indonesian species of pipistrelle, that would likely lead to a different recommendation about an appropriate course of action, as it would not be endemic to Christmas Island.

Accordingly, a study of the taxonomic status of the Christmas Island Pipistrelle has been undertaken. Analysis of the morphological and molecular structure of the Christmas Island Pipistrelle has clarified the taxonomic status of the Christmas Island Pipistrelle and its systematic relationships with other Indo-Australian *Pipistrellus* species (Donnellan and Helgen, 2009). The conclusion of this study is that the Christmas Island Pipistrelle is taxonomically distinctive, though closely related to species of pipistrelles in Indonesia.

The working group accepts this conclusion and agrees that the *P. murrayi* should be treated as an endemic species for management purposes.

4.7.2 Christmas Island Pipistrelle conservation status

In 1888 Christmas Island Pipistrelle was discovered and described as abundant across the entire island. Lumsden and Cherry (1997) reviewed the scant early observations on the species' distribution and abundance. Briefly, Andrews (1900) reported it as common; Gibson-Hill (1947) reported it 'in good numbers', and Tidemann (1985) reported it as 'well distributed over the island and is common' in 1984, and that 'overall its status is secure'. Clearly, the situation had changed by 1994 when Lumsden and Cherry carried out a systematic survey of the island's pipistrelles using harp traps and an echolocation detector. Appendix 10 provides a chronology of Christmas Island Pipistrelle management actions between 1984 and 2009.

By the mid-1990s, before the Yellow Crazy Ant population dramatically increased to form super colonies, the range of Christmas Island Pipistrelle had contracted to the western half of the island. Subsequent quantitative survey data show that its population has declined catastrophically over the last decade, and it is now detected only in a small area of 'The Dales' at the western end of the island (Lumsden and Schulz, 2009) (Figure 7). The overall pattern of decline has been a westward contraction in the species' geographical range, away from the more settled and cleared parts of the island, followed by local contraction and decline in abundance in the 'The Dales,' which was the least disturbed part of the island until the detention centre was built and Yellow Crazy Ants entered part of the area.

It is important to note that the Christmas Island Pipistrelle's population had already suffered a massive population decline and range-contraction before 2002, when the program of extensive Yellow Crazy Ant baiting commenced. Although a bio-accumulated toxin load could be exacerbating the subsequent decline (see Fipronil toxicity), there are no post-2002 Christmas Island Pipistrelle tissue-specimens available for assay.

When Dr Lumsden assessed the population in December 2008, she reported that Christmas Island Pipistrelle activity was virtually restricted to one known foraging area (L22), one known roost tree (site 565) and one alternate roost site still to be located. Her night-scope observations in December 2008 (during the breeding season) at roost 565, which previously had a colony of 40 plus individuals, revealed that "there maybe only 4 individuals now".

Foraging area L22 was virtually the only other place where activity was being detected via ultrasonic detector equipment in December 2008, with 20-30 passes/night. When activity was recorded at L22, none was recorded at the roost area and visa versa. Occasional passes detected elsewhere may have been other individuals. Dr. Lumsden has provided her data from hundreds of nights of recordings for many other sites to demonstrate decline.

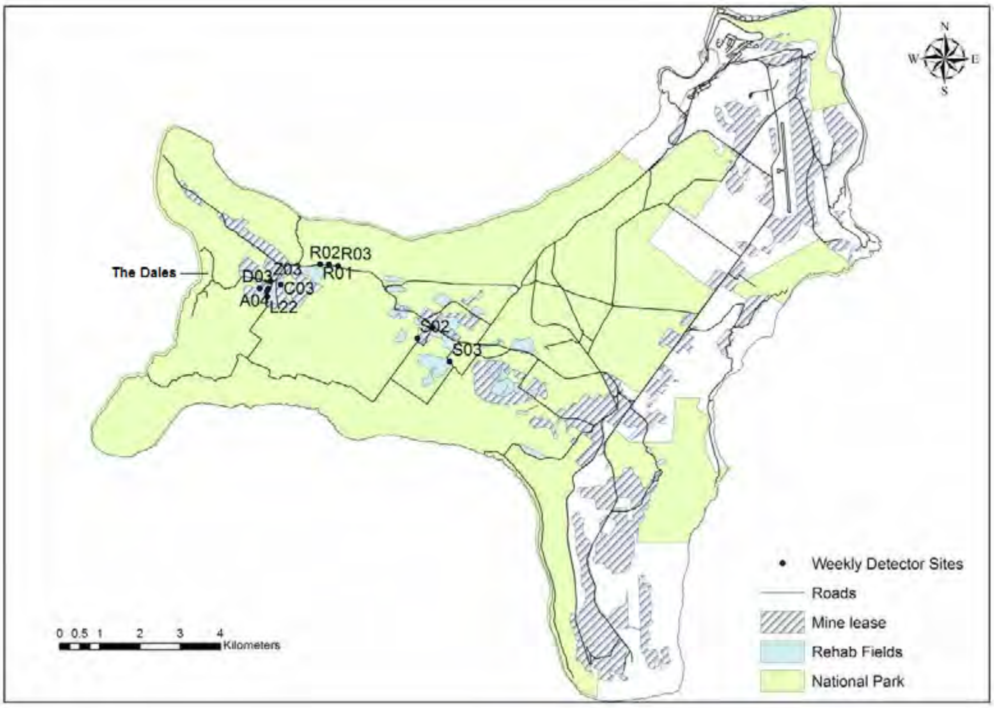

Figure 7 Key monitoring sites for the Christmas Island Pipistrelle.

4.7.3 Christmas Island Pipistrelle biology

An understanding of the biology of the Christmas Island Pipistrelle is important in trying to come to grips with the cause of their decline.

The Christmas Island Pipistrelle is a bat that takes its airborne, nocturnal, insect prey in-flight from 'edge' microhabitats. Its search-mode echolocation call frequency (F_{min}) averages 46 kHz. Like many small bats in the family Vespertilionidae, the Christmas Island Pipistrelle conserves energy by becoming torpid in its day-roost. In this condition individuals are vulnerable to Giant Centipedes, Wolf Snakes or Black Rat predation and ant disturbance or death due to being sprayed with formic acid by Yellow Crazy Ants. In addition young Christmas Island Pipistrelles are particularly vulnerable to predation and disturbance because they are left alone in the roost or at a different temporary roost at night while adults forage.

Christmas Island Pipistrelles roost in trees rather than caves. All recent known roosts are under exfoliating bark on dead trees usually six to eight metres above ground with a few being higher. Previously the Christmas Island Pipistrelle has been recorded as roosting under bark on live trees as well as in palms and pandanus foliage. This shift in roosting could be due to Yellow Crazy Ant activity which would not necessarily involve super colonies or the presence of other predators.

Like other small pipistrelles and other vespertilionids, the Christmas Island Pipistrelle has relatively low fecundity (one young per female per year; most females breed every year). Its longevity is unknown, but is probably seven years in the wild if it survives infancy. Related species of bats have lived for 15 years in captivity. Based on its ability for female sperm storage and its close phylogenetic relationship to other small vespertilionid species, it has been predicted that Christmas Island Pipistrelle will breed in captivity (Lumsden, 2009; Woodside pers. comm., 2009; Australasian Bat Society, 2009). This opinion has been challenged by Tidemann (pers. comm., 2009), who suggested that it will be difficult to keep and breed pipistrelles in captivity.

During the breeding season, females usually roost separately from males. Lumsden (2009) suggests that females formed colonies of 20-30 individuals, males in colonies of one to six. A similar pattern was apparent during the dry season. However, differences in observed dry season sex ratios at different times using different methods may indicate that males and females differ in their foraging behaviours.

Recent observations in “The Dales” show that Christmas Island Pipistrelles depart their roost immediately after dark but return regularly to spend a considerable time circling and approaching the roost before actually landing. This wary behaviour is unusual for a micro-bat.

4.7.4 Eco-physiology of Christmas Island Pipistrelle

The working group sought to expand/confirm its understanding of the species’ foraging ecology in order to make better informed biological judgement about possible causes of decline.

This understanding was improved through:

1. Undertaking an airframe analysis on adult male and female museum specimens to assess the agility/manoeuvrability, optimum foraging microhabitat, foraging strategy and flight speeds of Christmas Island Pipistrelle.
2. Recording Christmas Island Pipistrelle echolocation sequences during the working group’s visit to the island in April 2009 and then analysing

the spectral characteristics of its search-mode echolocation (Q6dB and F_{peakC}) (McKenzie and Bullen, 2003) to confirm its foraging microhabitat and strategy, and to determine its optimum prey-size.

3. Dissecting museum specimens to determine the species' flight-muscle and heart mass ratios, then combining these with the airframe data to develop a time-energy budget that includes estimates of the insect mass required per day, commuting distance and daily foraging time requirements compared to other vespertilionids of similar size.

The results of this work are described in Appendix 7. The results show that the Christmas Island Pipistrelle is a moderately agile air superiority strategist[2] that hunts in semi-cluttered airspaces such as those found along tracks and roads and within a few metres of the forest canopy - the animal simply outflies its prey. Its foraging ecology is indistinguishable from the Australian mainland species *P. westralis*, but it is not as agile as *Vespedalus caurinus*. The species has a viable commuting range that is as large as the island, suggesting that foraging habitat is not limiting. Typical commuting range for the predicted time-energy budget is 3.5 km away from the roost, assuming the species does not feed while commuting.

Pre-settlement, the island was covered entirely with rainforests and bats were believed to have been abundant in the early days. It may be that fresh growth in disturbed areas such as L22 causes insect biomass to increase locally, but otherwise there is no obvious reason why the uneven nature of semi-cluttered airspaces immediately above the island's rainforest canopy is not good foraging habitat.

The monitoring program, and therefore the detection history, has tended to focus on ground-level monitoring in forest gaps and along tracks. Given the canopy height of the primary forest (30 m+), the bat echolocation detector's ability to detect the 48 kHz (F_{peakC}) ultrasound calls of Christmas Island Pipistrelle at ranges greater than 25 m might be an issue. A test of this during the island visit in April by using a cherry picker to get above the canopy at the L22 foraging area revealed only one echolocation sequence during the 2.5 hour sampling period. However, this does not constitute a comprehensive above-canopy test for additional foraging areas.

The eco-physiology data (Appendix 7) indicates that females are most vulnerable to food shortages when lactating (December to March). At this time they need 5.5 hours of successful foraging per night to meet their daily energy requirements (Appendix 7). Population recruitment will be vulnerable to a prolonged reduction in the abundance of nocturnal insect prey in their optimal size-range (moths and beetles about 7 mm long) that could have resulted from the many changes happening in the island's rainforest community.

4.7.5 Analysis of Christmas Island Pipistrelle Monitoring Data

To provide a robust assessment of Christmas Island Pipistrelle status, Parks Australia's fixed station (ground-static) echolocation monitoring data from June

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[2] Insectivorous bats have three hunting strategies; they can intercept an insect in direct flight, out manoeuvre the insect in what amounts to a "dog-fight" (air superiority) or take an insect off a perch or the ground.

1994 to 2 April 2009 was standardised for differences in effort between stations (number of detector nights) and for their irregular geographical dispersal.

Figures 8 to 10 summarise the species' activity levels in its known foraging areas. Each area represents a cluster of adjacent foraging sites (within approximately 1 km of each other) that were sampled using the 'ground-static' ultrasound detectors mounted on tripods for (usually) four to five sequential nights. We averaged the number of ultrasound sequences recorded per detector-night in each three-month period of each year, and displayed the result as a smoothed line chart (quarterly average counts). The four quarters were January to March, April to June, July to September, and October to December.

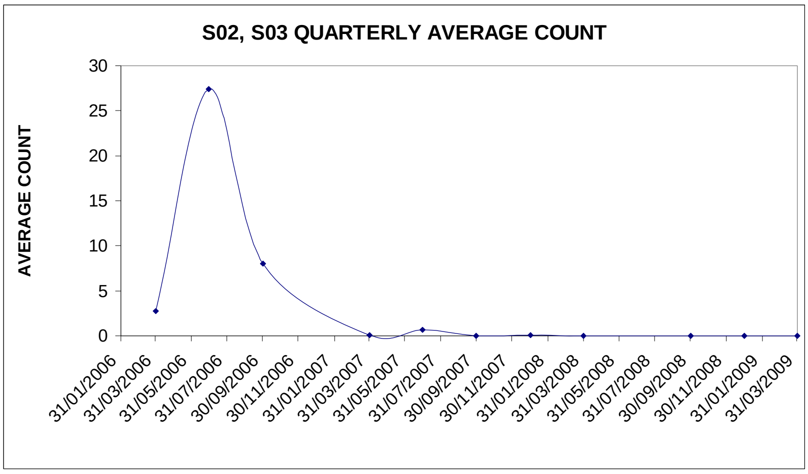


Figure 8 Christmas Island Pipistrelle quarterly counts at S02+S03 two adjacent foraging sites in the island's central-west, about 5 km east of The Dales

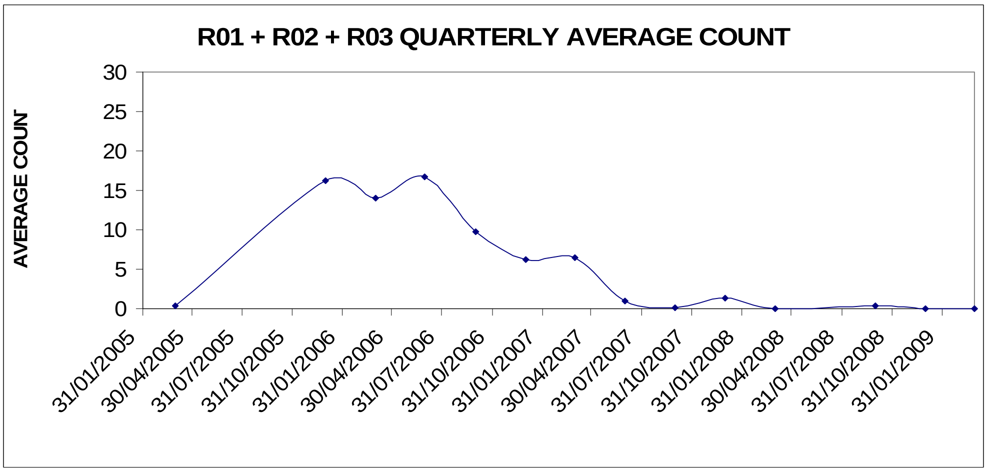


Figure 9 Christmas Island Pipistrelle quarterly counts at R01+R02+R03 three adjacent foraging sites a few kilometres closer to The Dales

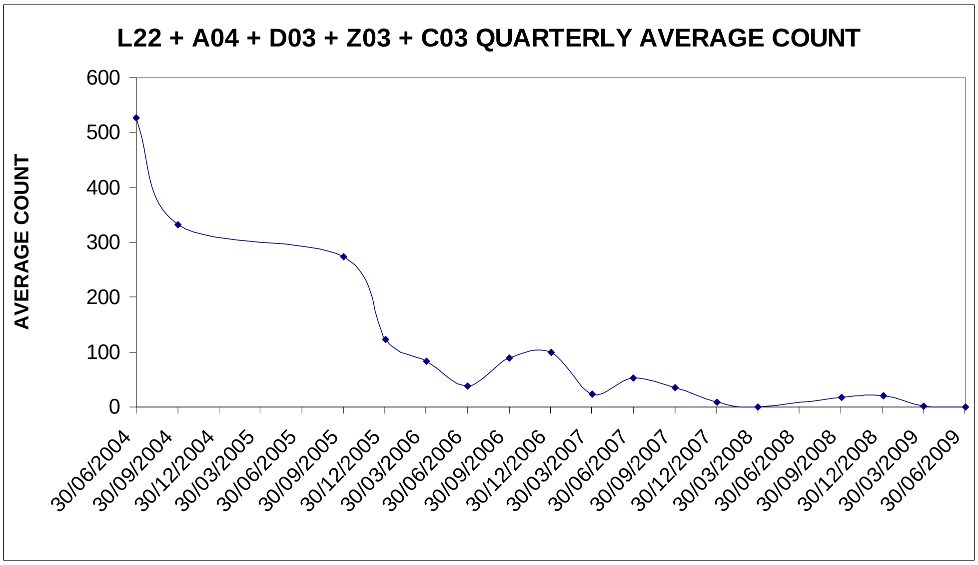


Figure 10 Christmas Island Pipistrelle quarterly counts at L22+A04+D03+C03 adjacent foraging sites in The Dales, close to the western end of the island.

Figures 9 to 10 show a clear decline in recorded sequences with time. The decline in activity at the RO1 and SO2 foraging areas happened during 2006 and 2007, and in the L22 area throughout the whole monitoring period (2004 to 2009) but from a much higher level.

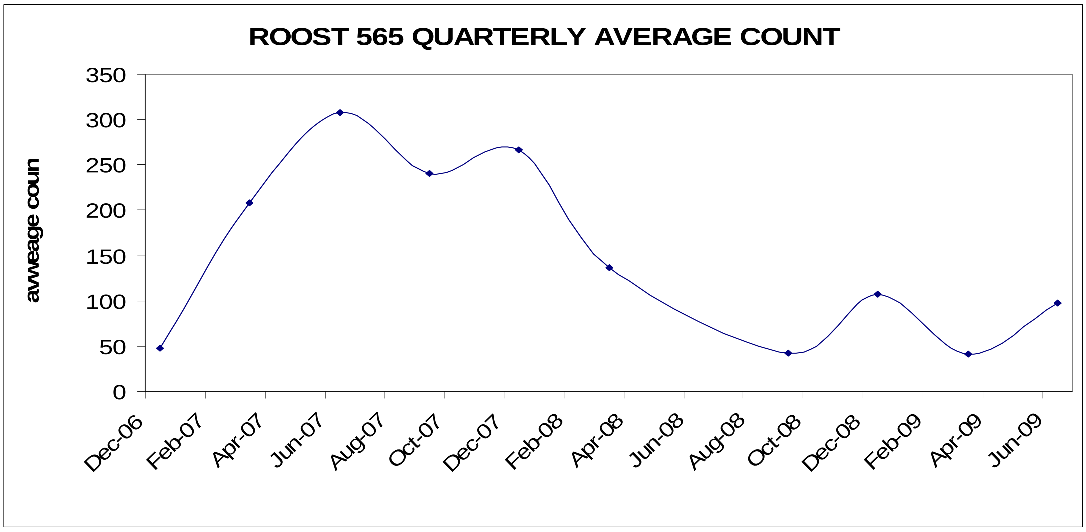


Figure 11 Quarterly average counts of Christmas Island Pipistrelle at roost-site 565

Figure 11 displays an equivalent graph of data from 'ground-static' monitoring stations at the only roost still known to be frequented by Christmas Island Pipistrelle (Roost 565 in "The Dales"). Activity at this roost increased during the first half of 2007, then declined until late 2008 after which it appears to have fluctuated at a level suggesting few individuals.

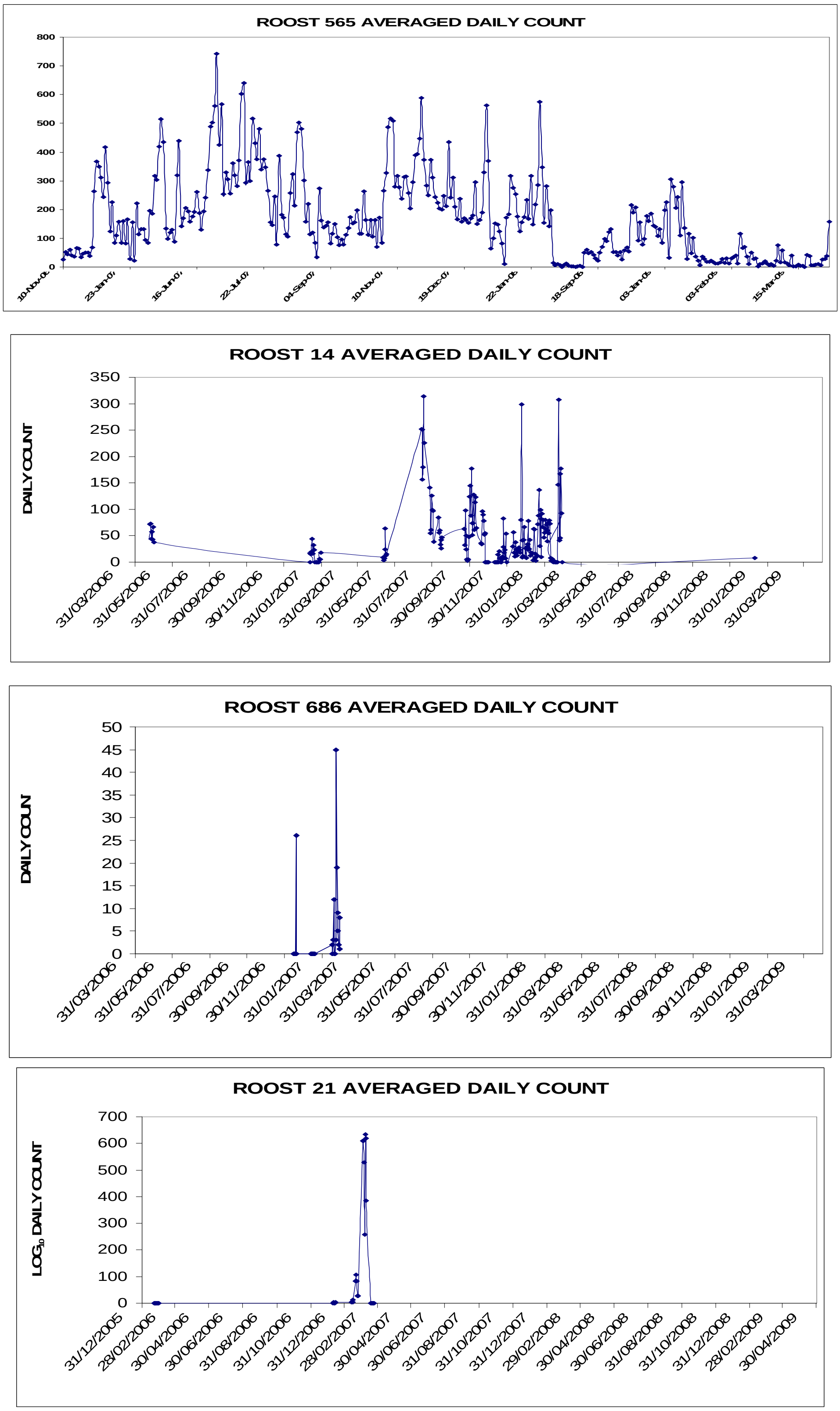


Figure 12 Average daily (detector-night) counts Christmas Island Pipistrelle at four ‘known or presumed’ roosts in the western parts of the island. Note that these are daily rather than quarterly averages.

Figure 12 displays counts from several roost-sites, including roost 565. Variation dominates roost 686, while roost 14 showed great variation in activity interspersed with periods of little activity; gaps in monitoring make the pattern hard to interpret. The peak of activity at roost 21 corresponds to the breeding season, when females need to spend 5.5 hours successfully foraging per night, instead of the normal 2 hours. Roost 565 has been monitored for the longest period of any roost-site, and this plot is provided for comparison with the quarterly averages discussed above for this roost site. Its daily plot clearly demonstrates that night-to-night, as well as quarter-to-quarter, variation dominates the mean values, which suggests intermittent and/or transitory use of the roost over the last few years, although overall average use has become less since mid-2008.

All four graphs in Figure 11 show reasonable activity-levels, but variation between nights is so large that it is hard to be sure that the roost had actually been abandoned when monitoring ceased at roosts 686, 14 and 21, although these roosts may have been on dead trees that fell down in the period between December 2005 and September 2006 (Lumsden et al., 2007).

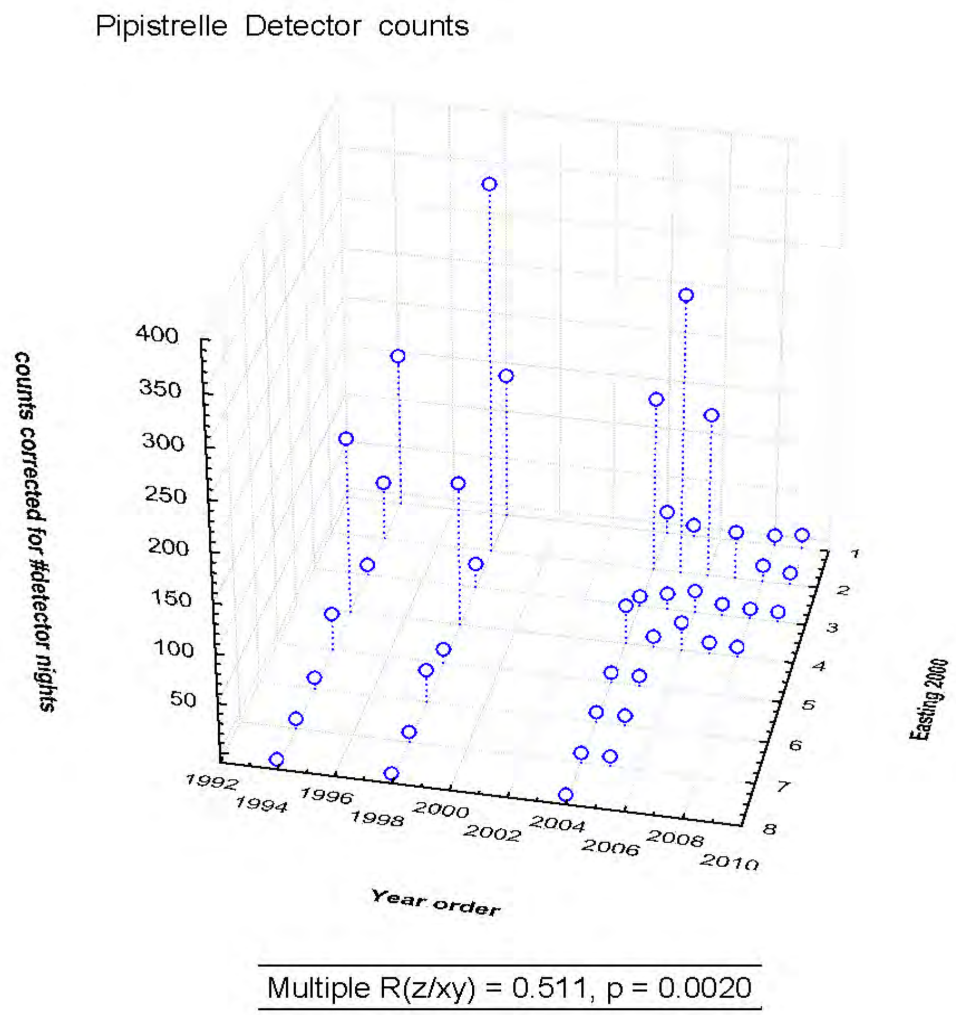
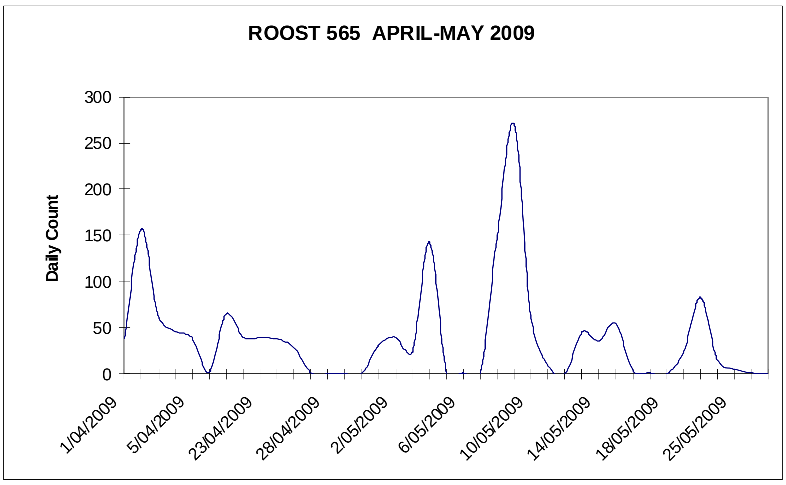


Figure 13 Christmas Island Pipistrelle counts: corrected ground-static detection (excluding roosts). The figure is a three dimensional image of 'total counts' versus year versus 'easting'

Figure 13 is a three dimensional plot of ‘total counts’ versus year versus ‘easting’. It was produced by dividing the island into 8 longitudinal strips of equal width (ca. 2 km). It includes all of the ground-static monitoring detector data available from the 340 sites (excluding roost sites) that have been sampled on the island since 1994, but the counts have been corrected for sampling effort by averaging the individual detector-night counts for each strip in each year. In some years there was no ground-static monitoring in the eastern parts of the island (2006-2009), and in other years there was none anywhere (1995-1997 and 1999-2003), hence the absence of points in the plot. The graph shows that there has been more activity in the island’s western parts over the entire monitoring period, even in 1994, and less overall activity recently. This said, the lack of recent monitoring data from the eastern parts of Christmas Island presents problems in drawing definitive conclusions.

The working group considered whether the ‘drive around’ survey result was reliable for all parts of the island, including the inaccessible terraces. According to the Park’s data-base (Appendix 7), this method has only detected Christmas Island Pipistrelles in the western part of the island, but in all but two cases, these counts were made during Lumsden’s 2004 survey which was confined to the island’s western parts. The other two were single passes recorded in July 2008. In the absence of ground-static monitoring sites in the east, there are insufficient recent counts from this method to fully resolve the question of an east-west difference.

Monitoring data collected during April and May 2009 was provided to the working group on 5 June. It shows that the Christmas Island Pipistrelle continued to be detected at the known roost site and at a nearby site. Numbers of detections had increased since the working group’s visit to the island, possibly because of advice given about use of the detectors, but almost all records came from Roost 565. Limited searches at sites elsewhere on the island have failed to detect any bats.



In combination, the fixed station data and the ‘drive around’ survey confirm that Christmas Island Pipistrelle declines exceed the proportional loss of rainforest area on the island, and the working group is convinced that the species is in severe decline. This said, current detection and monitoring has focussed on forest gaps such roads and mining lease regrowth areas rather than the air space immediately above the primary forest’s canopy.

4.7.5 Causes of Christmas Island Pipistrelle decline

Many factors may contribute independently, serially or synergistically to the decline of a species and, in some cases, it may be difficult to tease apart a particular factor that is most pivotal in that decline without experimental evidence. Also, the factor that causes the final extinction of a species may be different from the factor that caused the decline.

Lumsden & Cherry (1997), Lumsden et al. (2007) and Lumsden (2009) have reviewed aspects of Christmas Island Pipistrelle biology and discussed processes that are potentially threatening to its population numbers. Lumsden et al., (2007) further identified and reviewed a range of potential threats to the bat’s population, including disease, roost site condition and availability, a range of introduced predators, Yellow Crazy Ants, Fipronil and decline in prey (food) availability (see Lumsden et al. 2007, p. 62). We have incorporated their data and deductions into the text below.

4.7.5.1 Predation

Lumsden and Schulz (2009) identified predation as a likely cause of the decline in Christmas Island Pipistrelles. In this and previous reports, Lumsden and co-authors identified the following possible candidates: Nankeen Kestrels, Wolf Snakes, Black Rats, feral cats and Giant Centipedes. They also identify Yellow Crazy Ant super colonies as having an impact on the Christmas Island Pipistrelle. Generally speaking, a severe reduction in numbers of a prey species by predation is more likely when the predator has other food sources as well. All of these species have a diverse array of prey and could feed opportunistically on Christmas Island Pipistrelle while relying mainly on other prey.

4.7.5.2 Yellow Crazy Ants

The decline in Christmas Island Pipistrelles may have been driven initially directly by Yellow Crazy Ants. The bats may have had to shift from their preferred roost sites (hollows in live trees, fronds of pandanus, etc.) because Yellow Crazy Ants foraged extensively in such live trees. The remaining Christmas Island Pipistrelles would then have shifted roosts to loose bark on dead trees (which are not much used by Yellow Crazy Ants, because there are no scale insects on them). For the Christmas Island Pipistrelle, such sites are “predator traps” and/or likely to be highly susceptible to collapse. Yellow Crazy Ants may also have directly led to a significantly reduction in the number and variety of prey insects available to the pipistrelles.

4.7.5.3 Wolf Snakes

The main argument suggesting a role for Wolf Snakes is the approximate synchrony in the apparent arrival date and spread of the Wolf Snake with the timing and spatial pattern of decline in Christmas Island Pipistrelle. However, there seems to be no direct evidence to implicate them as significant predators on Christmas Island Pipistrelle. They feed primarily on lizards, are said to have limited climbing ability (although there is a remotely-triggered photo of a Wolf Snake at moderate height on a roost tree; Lumsden and Schulz 2009) and are uncommon in the forested areas (though becoming more common). Christmas Island Pipistrelles have not been found in Wolf Snake gut contents (Parks Australia unpub. data).

4.7.5.4 Rats and Cats

Exotic rats and feral cats have been on Christmas Island for at least 100 years, and there is no direct evidence to suggest that either has increased in abundance or distribution over the period of the decline of Christmas Island Pipistrelles (although it could be conjectured that rats may have increased with the decline in Red Crabs). Black Rats are capable climbers and their diet could include pipistrelles, but there is no direct evidence of predation. Feral cats and Black Rats are more common in the settled area and, without either direct or circumstantial evidence, can probably be discounted as the cause of the decline in Christmas Island Pipistrelle.

4.7.5.5 Nankeen Kestrels

These have been on the island for more than 60 years, are seen commonly around the settled areas but clearly their mobility gives them the capability to forage anywhere on the island. Their diet includes Swiftlets which, like Christmas Island Pipistrelle, hawk flying insects, but they do so in daylight (Parks Australia, 2008). Lumsden and Schulz (2009) referred to the possibility that the Christmas Island Pipistrelle shifted its foraging time from late afternoon and dusk to the hours of darkness in order to avoid Nankeen Kestrels. Significantly, Nankeen Kestrels were well established well before the Christmas Island Pipistrelle decline was apparent. Their present foraging time combined with the other considerations imply that they were and are not significant in the decline in Christmas Island Pipistrelle.

4.7.5.6 Giant Centipede

In published reports (Parks Australia, 2008; Lumsden and Schulz, 2009 and earlier papers), attention has been drawn to the Giant Centipede as a possible culprit of Christmas Island Pipistrelle decline. Large centipedes are aggressive predators and have been reported taking microbats in South America (Lumsden et al. 2007).

Trends in the abundance and distribution of the introduced Giant Centipede, *Scolopendra morsitans*, on Christmas Island are difficult to detail with precision. Perhaps unexpectedly, they were reported to be abundant by 1907 and by 1939 they were reported to be island-wide, suggesting that Christmas Island

Pipistrelles may have long persisted with them. Interviews with Parks staff revealed that the Giant Centipede was noticed to be increasing in numbers by about 2004, and that the upward trend is continuing, such that the species is now highly apparent in all habitats on the island, including primary rainforest; and that it forages extensively on tree trunks. A number of island residents also reported a substantial increase in the abundance of centipedes over the last 10-20 years.

The Giant Centipede climbs trees readily, and centipedes have been photographed on Christmas Island Pipistrelle roost trees by remote cameras. The habit Giant Centipedes have of taking refuge under loose bark would be likely to bring them into direct contact with roosting Christmas Island Pipistrelles.

A link between the reduction of Red Crabs by Yellow Crazy Ants (following their formation of super colonies) and the increase in Giant Centipedes was suggested in the Issues paper (Parks Australia 2008). We take the connection further by hypothesising that centipede numbers are usually restrained by Red Crabs, both directly through predation and through prevention of a leaf litter habitat forming (see below). The removal/reduction of red crabs by super colonies of Yellow Crazy Ants has led to an increase in the amount of leaf litter habitat available for centipedes and, simultaneously, a release of the crab predation pressure, leading to a substantial increase in their numbers. Under this proposed scenario, we envisage that centipede populations have expanded to such an extent that they forage beyond the opportunities provided in the leaf litter and have included the trunks of trees with their loose bark refuges as part of their habitat. In doing so, they have opportunities to prey on Christmas Island Pipistrelles.

It might be argued that control of Yellow Crazy Ants will lead to a recovery in Red Crab numbers to the extent that the forest floor is again free of a significant leaf litter layer. This is presumably a high predation regime for Giant Centipedes, so their numbers could be reduced severely, leading to an ecological regime in which the Christmas Island Pipistrelle could again survive. It was this last consideration which had some influence on the working group’s recommendation in favour of a (modest) effort to establish a breeding colony of Christmas Island Pipistrelles in captivity.

Unfortunately, however, it is not yet known at this stage whether the control of Yellow Crazy Ants will lead to re-establishment of the original high densities of Red Crabs and the removal of leaf litter (Smith et al. in prep). Early indications are that recruitment by the immature, juvenile crabs (crablings) may be insufficient to maintain increase of Red Crab populations because of depredations by Yellow Crazy Ants on their migration onto and across the terraces.

Under this putative explanatory scenario, centipede densities should now be high in forest in which Yellow Crazy Ants have removed Red Crabs, lower in ‘pristine’ forest unaffected by Yellow Crazy Ants and low (again) in forest into which Red Crabs have recolonised following Yellow Crazy Ant control programs. To this end, the working group suggested that a short, sharp survey be conducted, as a pilot study, in the hope that early results might be informative. Christmas Island National Park staff have initiated this survey but early results were inconclusive.

The working group formed the view that Giant Centipedes could well be a significant causal agent in the decline of Christmas Island Pipistrelle **(Recommendation 24)**.

We note that the argument presented above about predation is frustratingly conjectural. It is difficult to deduce the factor(s) causing the decline of Christmas Island Pipistrelles. There has been no evidence demonstrating predation, there is little quantitative information on trends in the abundance or distribution of potential predators, and little quantitative information about the relative abundance of potential predators in areas differentially affected by Yellow Crazy Ants. Such information would have provided far more clarity in ascribing causes, and would have allowed for far more timely and effective responsive actions. In this context, it is interesting that the factor suggested above to be the most likely proximal cause of decline, predation by Giant Centipedes, was not considered as a possibility in the 2004-09 Recovery Plan for the Christmas Island Pipistrelle (Schulz and Lumsden, 2004), and no actions were proposed to address it.

4.7.5.7 Fipronil toxicity

The use of Fipronil to control Yellow Crazy Ants may pose a risk to Christmas Island Pipistrelles, given that the species is insectivorous and may ingest Fipronil secondarily by consuming poisoned invertebrates. A possible additional impact is through a reduction in their invertebrate prey and therefore a reduction in food availability for Christmas Island Pipistrelles.

The working group is concerned about the non-target impact of Fipronil on the Christmas Island Pipistrelle and will investigate this further, with evaluation of available evidence and discussion in the final report (Appendix 11 provides additional information).

Figures 7 to 12 all show a pronounced decrease in average Christmas Island Pipistrelle activity since 2004 that may correlate with the September 2001 to 2004 Fipronil program.

4.7.5.8 Food availability and population changes in prey items

Corbett et al., (2003) suggested that there may be an indirect impact whereby pipistrelles are forced to vacate roosting and/or foraging areas because Yellow Crazy Ants have caused large declines in bat prey (mostly moths and beetles, Churchill 1998). This evidence was based on the negative correlations observed between insect calls and Yellow Crazy Ant abundance ($r = -0.87$, $p. = 0.02$), and between bat calls and Yellow Crazy Ant abundance ($r = -0.64$, $p. = 0.0$) as recorded by CF-Zcaim detectors (see Table 16 in Corbett et al., 2003).

If food has become less abundant, the Christmas Island Pipistrelle would need to spend more time foraging, so recorded activity levels might hold or even increase until catch-success falls below this high-energy species' time-energy budget threshold (see time-energy budget above).

It may be possible to assess food availability by counting the number of ultrasound intercept buzzes per unit time during the 10-year period that these call sequences have been recorded during monitoring work at foraging sites such as L22, to see if averages have declined. This work remains to be done.

In addition Christmas Island Pipistrelles used to forage at dusk, but now only forage at night. No explanation can be made for this and this is made more puzzling because swiftlet abundance remains high, suggesting that diurnal insect biomass has not declined markedly (see above under Nankeen Kestrel).

The construction of the detention centre on Christmas Island has resulted in a significant change in lighting regime on the island. Bat detectors have been placed around the perimeter fence and have not detected any bats flying through the light column (Richards, 2008). While it is possible that the lights might have been a huge insect trap over the first few years the centre was operating lack of data means that no conclusion can be drawn with respect to changes in insect or bat abundance.

4.7.5.9 Disease

Tests for diseases, included blood assessment (taken from lateral vein in tail membrane) and respiratory opening swabs, showed no detectable disease load. However, white-cell counts were low compared to similar species. Such leukopenia has been associated with a range of diseases including infectious diseases and with toxic insults (Lumsden, 2009). Again, the chronology of the declines apparent in Figures 7 to 12 for the post-Fipronil period since 2004 corresponds with the period when low white-cell counts were detected in the Christmas Island Pipistrelle. Dr Lumsden checked for external parasites and found none, while faeces showed no evidence of internal parasites (Lumsden, 2007).

With respect to the decline of Christmas Island Pipistrelle, there is no substantial evidence for or against the role of disease, Table 5 sets out the logic for this conclusion.

Table 5 Testing for evidence of decline of Christmas Island Pipistrelles via disease

Characteristic of disease cause	**Evidence for Christmas Island Pipistrelle**
Decline may be rapid, with incremental spatial spread	Consistent with disease
Some sick animals may be detected	No sick animals detected, but such instances would be unlikely given small size of the pipistrelle and likely rapid consumption of sick or dead animals by crabs or ants

Most likely introduced through recent invasion of a taxonomically related vector	None

4.7.5.10 Changes to surface water

There is some evidence that there has been a change in surface water availability on the island. The most likely explanation to this is water abstraction through a series of bores. Again the working group is reduced to speculation on this matter; however it is notable that the area where the bats currently occur is the only part of the island where there is regular surface water.

4.7.5.11 Structural vegetation change

As discussed previously the vegetation on Christmas Island has been significantly fragmented by at least three relatively recent events: the 1960s grid surveys, the 1970 clearance of all mining leases and the 1988 storm. While these vegetation changes fragmented the forest they may also have improved foraging habitat for Christmas Island Pipistrelles. This is entirely speculative but it may be that bat populations were advantaged despite this disruption. However this does not constitute an explanation in itself because the pre-settlement condition was an island covered entirely with rainforests and in which the bats were present and apparently abundant. In these circumstances it is highly likely that the rainforest canopy was the major feeding site at that time and there is no reason why it should still not continue to be so. This said, current detection and detection history tends to focus on gaps in the forest created by roads.

4.7.5.12 Low genetic variability

Low genetic variability of Christmas Island Pipistrelle due to a small founder number could lead to a natural crash and an increased vulnerability to disease. Such an event has happed previously on Christmas Island, where a Trypanosome has been linked to Christmas Island rodent extinctions (Wyatt et al., 2008). A narrow genetic base could also increase a species' vulnerability to other challenges such a tissue-toxin load from ant poison.

4.7.6 Working group's conclusions on the Christmas Island Pipistrelle

The working group closely scrutinised the reported data describing decline in the Christmas Island Pipistrelle and carried out the investigations reported above. The group concluded that:

(i) the reported data provided a generally robust assessment of trends in relative abundance (but no precise estimate of actual population size);

(ii) the actual rate of decline in total population size may have been even more dramatic than that depicted, because the set of bat detectors used for population estimate became increasingly focused on the dwindling residual population on the west of the island (i.e. monitoring increasingly involved "hunting" remaining populations);

(iii) different or innovative search and monitoring practices (e.g. use of detectors above the forest canopy, detectors focused around water sources) failed to reveal new information;

(iv) as reported in Lumsden and Schulz (2009), this species is now restricted to a very small number of individuals in a very restricted area; and with a rapid rate of population decline;

(v) further survey work is most unlikely to identify any additional populations or to change the prognosis.

The monitoring data reviewed in Lumsden and Schulz (2009), and analysed by the working group, provide an unusual demonstration of the rapid decline and possible extinction of an animal species. On current trends, the Christmas Island Pipistrelle will probably become extinct in a short time frame.

4.7.7 Speculative scenario which may account for the Christmas Island Pipistrelle decline; a knock-on from Yellow Crazy Any impact on Red Crabs?

The fate of the Christmas Island Pipistrelle, now facing imminent extinction, is a symptom of a broader pattern of change and decline on the island. There are many interacting factors and processes that could have led to the demise of the Christmas Island Pipistrelle, but the complexity of these interactions may best be illustrated by considering the following scenario, which is the working group's most favoured hypothesis at this stage:

1. Lack of quarantine from the early days of settlement allows introduction and establishment of many non-indigenous species. Among them are ants (including the Yellow Crazy Ant) and the Giant Centipede.
2. At some time, perhaps more recently, species of scale insect are introduced on plants (possibly fruit trees) brought to the island. The scale insects establish in low numbers on rainforest trees and spread throughout the island.
3. Between 1984 and 1994, the Christmas Island Pipistrelle starts to decline, perhaps because of an increase in Yellow Crazy Ant numbers before the first super colonies were noted, perhaps because of reduced nocturnal insect numbers due to scale and ants competing with and eliminating the herbivorous larvae of moths, beetles and other insects.
4. In the 1980s rainforest trees become stressed, possibly because of lower water tables as a result of drought and/or ground water abstraction for human use. Scale numbers increase on rainforest trees. (It is known that insects attack stressed plants more readily than healthy ones.) Alternatively, because the introduced scale insects had ineffective natural predators and parasites, they gradually proliferated.
5. Yellow Crazy Ants are attracted to honeydew secreted by scale. The ants 'farm' the scale and prevent predators and parasites, such as ladybirds and parasitoid wasps, from attacking them and constraining their numbers.
6. Excess honeydew from scale allows the extensive growth of sooty mould on the leaves of rainforest trees, stressing them further.

7. Feedback mechanisms cause population explosions in both scale and Yellow Crazy Ants. Yellow Crazy Ants form super colonies with multiple queens. Scale and ant outbreaks increase in extent and number.
8. Yellow Crazy Ants kill Red Crabs, leading to changes in rainforest structure. Red Crab recruitment is low due to unknown factors in the ocean and/or the crablings that do emerge from the ocean are killed by Yellow Crazy Ants as they move upslope.
9. Yellow Crazy Ants attack Christmas Island Pipistrelles while they are roosting in live trees. Pipistrelles become limited to roosting in dead trees (this interaction could have started earlier but we cannot know this).
10. Reduction in the numbers of Red Crabs leads to an increase in the numbers of Giant Centipedes due to an increase in leaf litter on the forest floor, increasing their habitat contemporaneously with a reduction in predation by crabs.
11. Giant Centipedes become more abundant, expand their foraging range and kill Christmas Island Pipistrelles while they are roosting under bark in dead trees. They possibly also kill a number of small island reptiles which are now highly threatened.
12. Yellow Crazy Ant super colony control by Fipronil possibly leads to additional stress on insectivorous fauna (currently speculative).

This plausible ‘ecological cascade’ provides a stark example of how apparently trivial events can have unexpected consequences and illustrates the ecological complexity of even this comparatively simple ecosystem.

4.7.8 Options for management action

Given world-wide increases in the number of threatened species, and competing demands for management responses, increasingly rigorous frameworks have been developed for the assessment of options for the management of threatened species. These typically use a triage approach (e.g. Bottrill et al., 2008; Joseph et al., 2008), with resource allocation and prioritisation influenced by:

The phylogenetic distinctiveness of the taxon.

The phylogenetic distinctiveness of the Christmas Island Pipistrelle is relatively low, with more than 30 species of pipistrelle currently recognised worldwide. Mitochondrial DNA evidence suggests that the closest relative of the Christmas Island Pipistrelle is the wide-spread and variable *P. tenuis*, found on the nearby islands of the Indonesian archipelago. However, the taxonomic investigation report provided to us confirms *P. murrayi* as taxonomically distinctive. The working group considers it should be treated as an endemic species for management purposes.

The ecological significance of the species.

In this case, with such low population size, the Christmas Island Pipistrelle now has no major role in the ecology of Christmas Island. If population size could be recovered, it would be the major predator of nocturnal flying insects on Christmas Island once again, a substantial ecological role.

The social value of the species.

Christmas Island is celebrated for its uniqueness and biodiversity, and the further loss of an endemic species may corrode this valuation.

The likelihood of success of the management.

This issue is dealt with more fully below. Its key components are the likelihood of successful capture of sufficient male and female bats to found a captive breeding colony; the ability to maintain this colony in an appropriate holding facility and to achieve reproductive success and colony population increase; and, ultimately, the ability to manage threats sufficiently to release captive-bred animals back to the wild (in this case, this may relate particularly to the feasibility of control of Yellow Crazy Ants and Giant Centipedes).

The urgency.

In this case, there is no option to delay response until some more opportune time in the future **(Recommendation 19)**.

The extent of collateral benefits.

In this case, captive breeding of Christmas Island Pipistrelles may have some collateral benefits to other Christmas Island species on the brink of extinction, and/or may ultimately help identify the factor(s) that most threaten Christmas Island endemic species.

Where resources are finite, assessment against these criteria should be related to other competing cases (in this case, the many other threatened species on Christmas Island, post-mining rehabilitation, Yellow Crazy Ant control, etc.)

The working group considered four options for the conservation management of the Christmas Island Pipistrelle. These options are briefly introduced below. In part, these arguments have been presented previously in Lumsden and Schulz (2009).

1. Do nothing. This option is to leave the Christmas Island Pipistrelle unmanaged. This option will result, almost certainly, in its extinction, probably within less than a year. The option comes at no financial cost.
2. Leave the Christmas Island Pipistrelle in the wild, but manage the site of the remnant population more intensively. In the last few years a range of more intensive management initiatives have been attempted at the site(s) of remnant populations, including collaring of known and potential roost trees (to diminish risks of predation), installation of artificial roost sites, and intensive baiting of Yellow Crazy Ants. It is possible that the measures undertaken may have forestalled extinction. There are limits to how much further such actions can be taken; no evidence to suggest that these actions are necessarily preventing the most profound of the threatening factors; and no evidence to suggest that the actions taken to date are resulting in population increase for Christmas Island Pipistrelle.

This option requires relatively modest financial investment (about $10,000 per year).

3. Establishment of a captive breeding population on Christmas Island. This option requires capture of sufficient Christmas Island Pipistrelle individuals from the wild to found a captive breeding colony. It requires the installation of a suitable facility on the island, with suitably qualified staff, and a commitment extending over at least a five-year period. Unlike option 4, there is some possibility that a Christmas Island captive breeding colony would still be exposed to the factor(s) that most cause the decline of the wild population. There is considerable risk of failure, and the option would require considerable expense.
4. Establishment of a captive breeding population off Christmas Island. As for option 3, but the captive breeding population would be based in an already established facility off the island (e.g. at an Australian zoo). This option may reduce establishment costs, and may more firmly remove the captive animals from the threats operating on Christmas Island. However, there may be substantial quarantine issues (e.g. if the captured Christmas Island Pipistrelles had diseases that were not already present on the Australian mainland), and there may be some risks to the bats in the long transportation required. As with option 3, there is considerable risk of failure, and the option would require considerable expense.

The working group notes that successful establishment of a captive breeding colony may open opportunities for out-breeding with closely related species, which would be lost if the species becomes extinct in the wild and none are held in captivity.

The working group considered the practicality of options three and four. There may already be too few individuals (and of both sexes) still alive to provide a viable founding population. The capture of those few remaining bats will be extremely challenging, noting that no bats were caught in the most recent (limited) attempts at capture.

The working group acknowledges that there are many precedents for the successful maintenance of small insectivorous bats in captivity (Lumsden and Schulz, 2009), and some but fewer precedents for successful captive breeding (as opposed to simply maintenance of wild-caught individuals) of small insectivorous bats. Further, the only previous attempt to maintain captive Christmas Island Pipistrelles by Dr C. Tidemann, over a limited time has suggested that this species may be especially challenging to maintain. However, it is recognised that husbandry techniques have improved significantly since Dr Tidemann’s work, and survival of captive individuals is more likely. There are some risks of injury or death to individual bats in all aspects of any capture program, but previous experience of captures by bat experts suggest that risks of harm to bats during capture and short-term housing are low (Appendix 9).

As a means of identifying (and minimising) risks to a captive breeding program for Christmas Island pipistrelles, an analogue program was established in the Northern Territory for the closely related species *Pipistrellus westralis* and *P. adamsi.* This program has been designed to investigate optimal husbandry (e.g. diet, housing conditions, causes of mortality in captive populations, preferred social arrangements) in similar species to the Christmas Island Pipistrelle. To date the utility of the program has been constrained by the unanticipated difficulties experienced in capturing Northern Territory pipistrelles. However, one individual female pipistrelle has now been maintained in captivity since mid-March with ongoing good health, although this individual aborted foetal material after around one month and will therefore not be reproducing this season. Given these difficulties, the working group has agreed that the analogue program on *P. westralis* should be discontinued.

The working group recognises that all the possible choices are problematic and risky, in part because the choices must now be made too late in the process of decline in this species. The working group considers that option 1 (do nothing) is inappropriate while there is a slim chance that future management of threats and, thus, reintroduction is a possibility and is not recommended. The working group considers that option 2 is window-dressing and will not succeed in its objective. Accordingly, the working group acknowledges that the only possibility for the continued existence of this species is through a captive breeding program. However, the working group considers that such a program has a high likelihood of failure, and any implementation of such a program must acknowledge this high risk at the outset. The working group acknowledges that knowledge gained from the analogue (Northern Territory) program has some potential to reduce those risks.

Given a reasonably high likelihood of failure of a captive breeding program for Christmas Island Pipistrelles (see section 4.7.9), and given the many other priorities for biodiversity conservation on Christmas Island (most with higher probability of delivering successful conservation outcomes), the working group considers that resourcing the Christmas Island Pipistrelle breeding program should be circumscribed. The working group has been made aware of a range of budgets proposed for such a program (e.g. Lumsden and Schulz, 2009; Australasian Bat Society, 2009) and sought advice from the Department.

Funding estimates are difficult, because the amount of time required to capture the few remaining wild pipistrelles may be unbounded. The probability of capturing these individuals at any time is low, but could be expected to be increased with more personnel and traps, and more time; but any ongoing investment may reap diminishing returns.

The working group recognises that a captive breeding program comprises two main components – the capture from the wild of a sufficient founder stock, and the subsequent husbandry and breeding from that stock. The latter is clearly entirely dependent upon the success of the former.

With respect to the captive breeding stage, while all relevant information is not yet available, option 3 (on-island captive breeding) is the only realistic short to medium term option, given the quarantine status of Christmas Island. The working group considered the decision-making framework (section 4.7.9) and recognised that a number of stopping points exist which will lead to the extinction of the Christmas Island Pipistrelle.

In coming to its recommendation, the working group has been influenced by the possibility that management actions on the island could make the ecosystem once more favourable for Christmas Island Pipistrelle and, if that were the case, then a successful reintroduction could occur only if individuals from a captive breeding colony were available.

Recommendation 19:

Given the latest taxonomic data the working group recommends: (see section 4.7)

1. That Christmas Island Pipistrelles are captured from the wild as soon as practicable, as founders of a captive breeding colony.
2. That there is an initial allocation of $100,000 for the capture and temporary care phase, with a review by the working group in three months;
3. That Government funding be allocated immediately for this purpose;
4. That tenders are sought expeditiously from suitable experts to undertake the capture and care;
5. That funding partnerships with non-government organisations be encouraged;
6. That the program and any future funding (relating particularly to captive breeding) be reviewed in September 2009 on the basis of (i) the success or otherwise to date, (ii) assessments of the feasibility and costs of tenders for captive breeding (see below); and (iii) any additional information relating to the resolution of the taxonomic status of the species;
7. That immediate calls be made inviting expressions of interest (with indicative quotes) from zoos accredited as Quarantine Approved Premises on the Australian mainland for establishing and maintaining a quarantined breeding colony of Christmas Island Pipistrelles; and
8. That monitoring of Christmas Island Pipistrelles in the wild continues until no more passes are recorded for 26 weeks, at which time the monitoring program should be reviewed. This should include the re-establishment of some fixed-stations in the northern and eastern parts of the island.
9. That the trial captive breeding program on an analogue species in the Northern Territory be concluded.

4.7.9 A framework for considering Recommendation 19

Although the working group has concluded that without captive breeding the Christmas Island Pipistrelle is unlikely to survive, it has recognised that the Christmas Island Pipistrelle decision will have to be made in the wider context of conservation priorities for the Island and Australia. The working group has developed three tools for decision makers to use in considering the recommendation to attempt to implement a captive breeding rescue of the Christmas Island Pipistrelle. The first is a generalised decision tree (Figure 14), the second is a descriptive model specific to the Christmas Island Pipistrelle (Figure 15) and the third a model of the recovery scenarios for a captive breeding population of Christmas Island Pipistrelles (Table 6).

These tools are based on the best information available to the working group and should be considered against other evaluations of probability and cost that may be forthcoming on the release of this report.

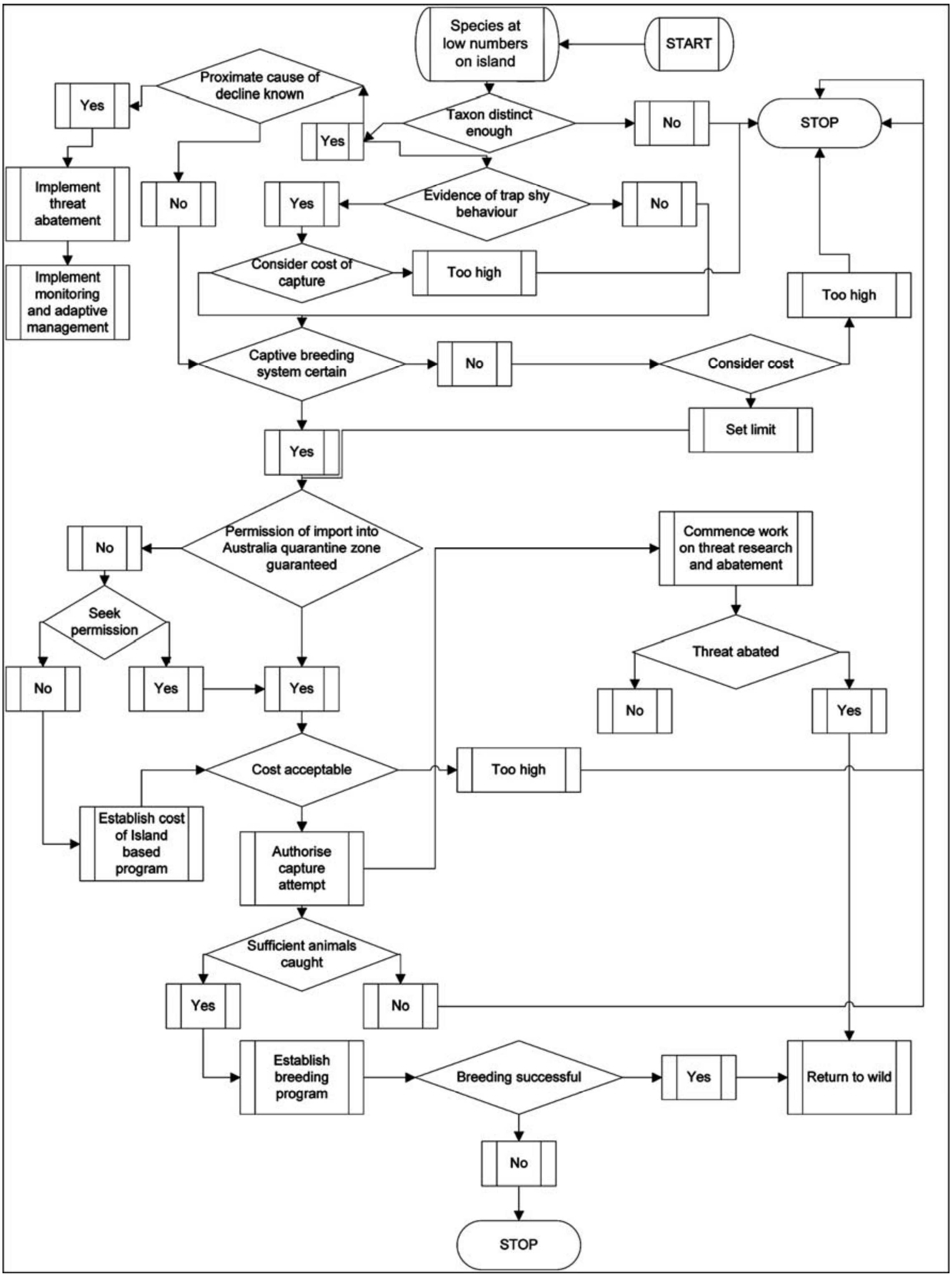
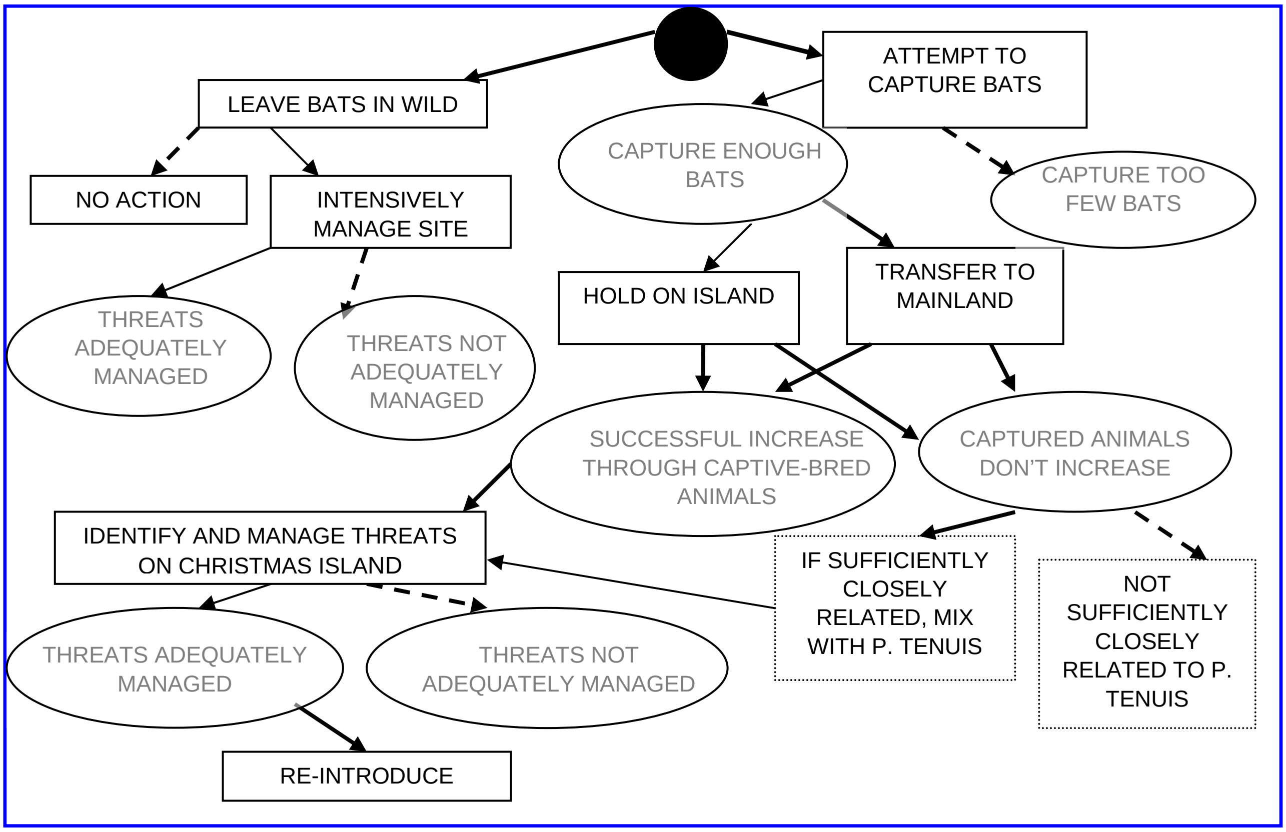
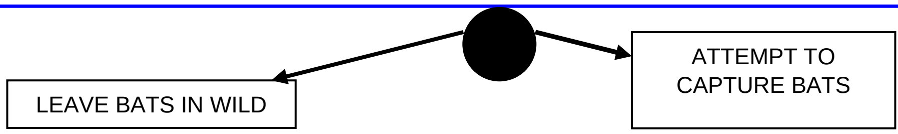


Figure 14 A generalised decision tree for use in considering decisions for threatened species.

Figure 15 Decision tree for Christmas Island Pipistrelles, dotted arrows indicate stop points and the cost estimates are in addition to current base funding for Christmas Island National Park.



Decision point one

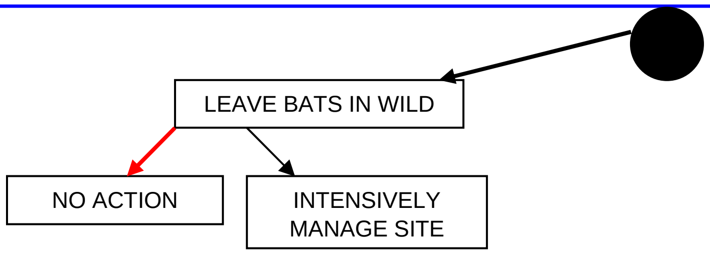


CHOICE: This is the fundamental choice for decision-making. On current trends, leaving bats in the wild will result in almost certain extinction, probably within one year. There will be little or no financial cost in this action.

The alternative is to attempt a more active intervention to seek to establish a captive breeding program. This may be expensive and have a low probability of an ultimately successful outcome.

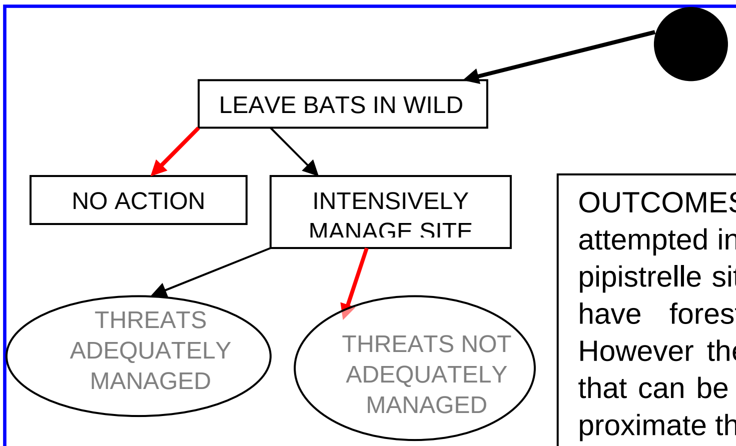
The working group recommends an initial allocation of $100,000 for capture and temporary care with a review after three months.

Decision point two



CHOICE: Following the non-recommended choice above, if bats are left in the wild, they can either be unmanaged (with no cost and almost certain rapid extinction), or they (and their location) can be managed more intensively (e.g. through predator-proofing of roost trees), with costs of ca. $10,000.

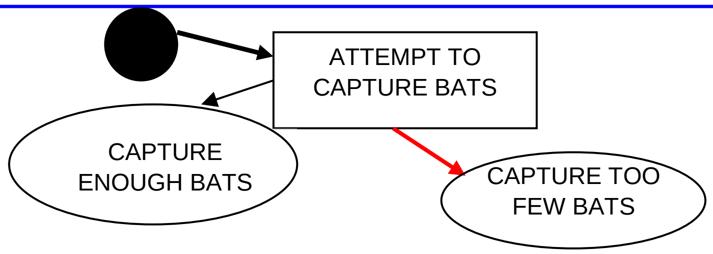
Decision point three



OUTCOMES: Parks staff and others have attempted intensive management of the remaining pipistrelle site(s) over the last few years, and may have forestalled extinction by such actions. However there are no obvious additional actions that can be considered and uncertainty about the proximate threat renders such actions imprecise.

The working group considers that it will not be practical to manage existing threats in situ with sufficient time and success to ward off extinction.

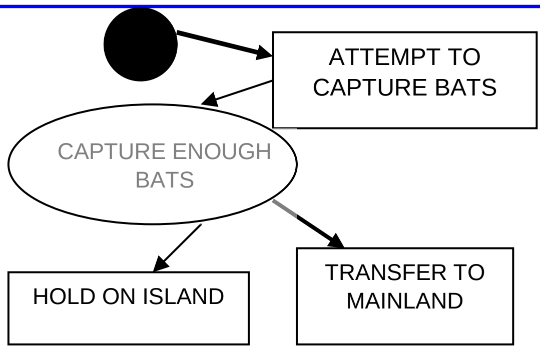
Decision point four



OUTCOMES: There may now be so few bats left in the wild that (i) it will be highly unlikely that they can be caught, and (ii) even if all were caught, this would be insufficient to provide enough founders to establish a captive breeding program. The likelihood of catching enough bats may be increased by increasing the amount of people, traps and time, but such expenditure may rapidly provide diminishing returns. The likelihood of successful captive breeding will be increased with more founder stock, but other than the obvious Noah's Ark number there is no absolute minimum. This species has low reproductive output (one offspring per female per year), so build-up of any captive breeding colony will inevitably be slow, and likely to be fatally compromised by a high proportion of mortalities in founder stock.

The working group would consider that a target of at least three females and two males should be required to justify any subsequent Government investment in a captive breeding program.

Decision point five



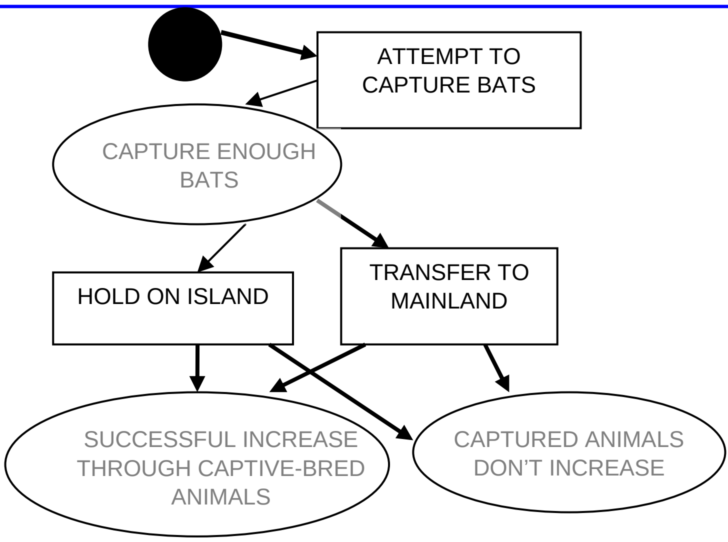
CHOICE: Assuming sufficient bats are captured and held temporarily on Christmas Island, a choice is then required on whether to set up the captive breeding program on the island or at an existing mainland institution. At the present time due to the quarantine status of Christmas Island, only on-island conservation is the only realistic short to medium term option.

The Christmas Island choice would require establishment of a suitable facility and provision of appropriately skilled staff (e.g. vets), capacity to provide adequate food and dietary supplements, and may not secure bats from the threat operating on the island.

The mainland choice would require quarantining approvals and protocols, and may be difficult to match climate.

The department has estimated the cost of the island option as infrastructure costs of between $1.1 and $2 million over the first two years, with annual costs, including two staff and four veterinary visits of between $401,000 and $475,000 annually.

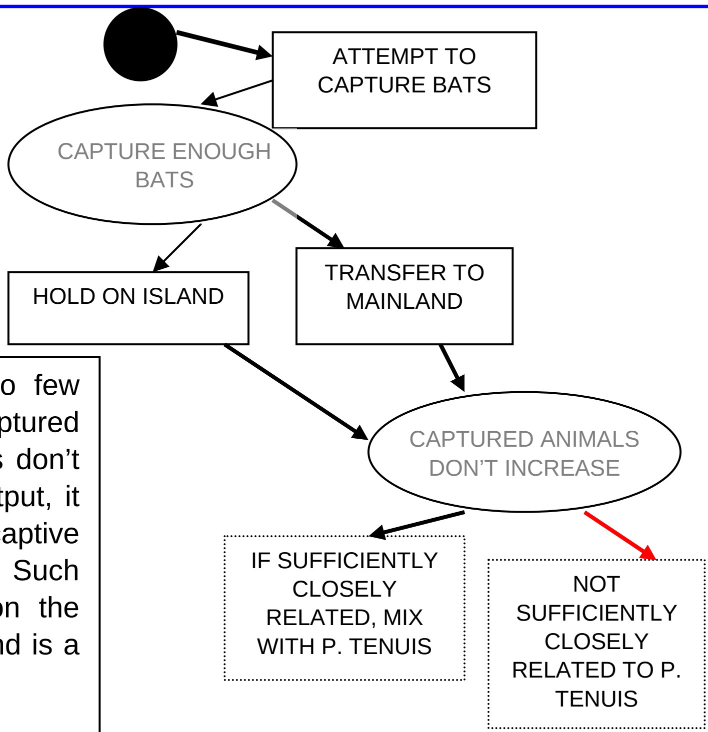
Decision point six



OUTCOMES: Given the likely small founder population, the slow natural rate of increase and relatively limited previous history of building up substantial captive-bred populations of related species, it will be challenging to develop a captive-bred population of pipistrelles that is sufficiently large to consider for possible re-introduction.

The probability of developing a captive population of say 10 bats after 10 years will be dependent upon the founder population size (see Table 6).

Decision point seven

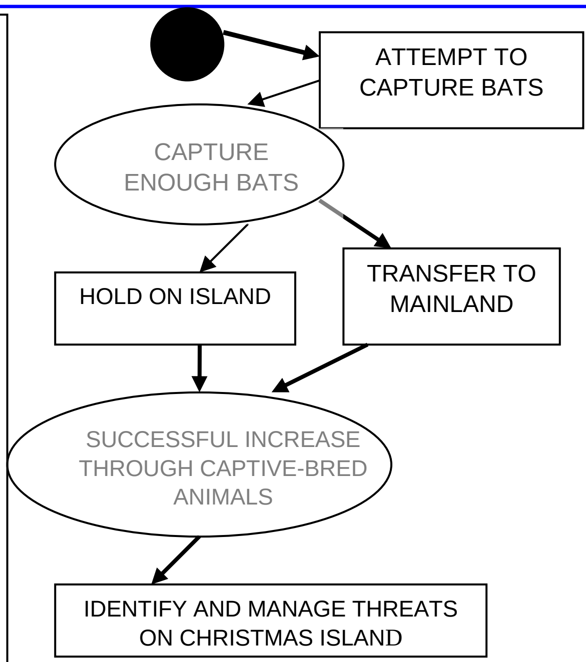


CONSEQUENTIAL CHOICE: If too few Christmas Island pipistrelles are captured initially and/or these captured animals don't have sufficiently high reproductive output, it may be feasible to supplement the captive population with pipistrelles from Java. Such an option is entirely dependent upon the genetic similarities (not yet known), and is a path of last resort.

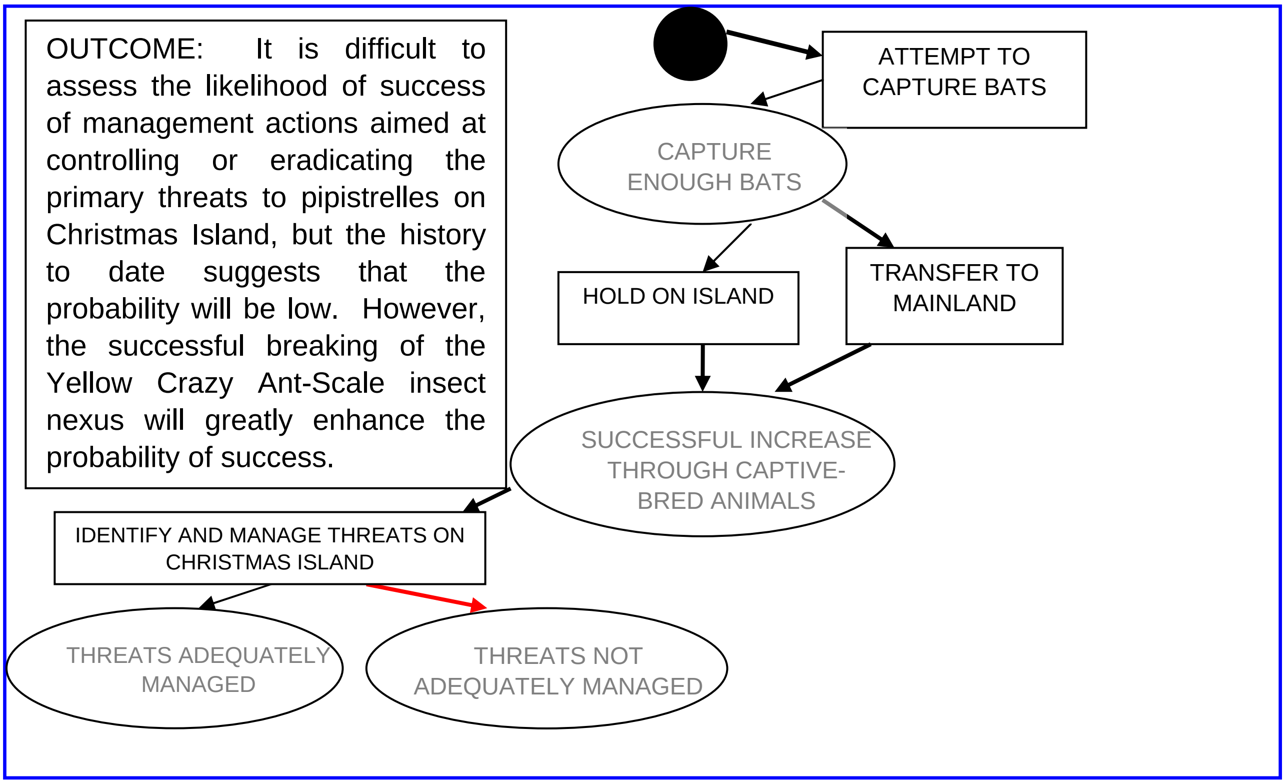
Decision point eight

FIXED CHOICE: There is little conservation gain in simply maintaining a captive colony of pipistrelles. Rather, the ultimate conservation outcome is in re-introducing the pipistrelles to Christmas Island. This will be an entirely forlorn exercise if the threats that led to decline are still uncontrolled. Hence, before reintroduction can be undertaken, the original causal factors should be (i) identified and (ii) controlled. Both of these steps are challenging. At this stage it is very difficult to assess likely costs, but a plausible estimate of threat management would be ca. $500,000 pa.

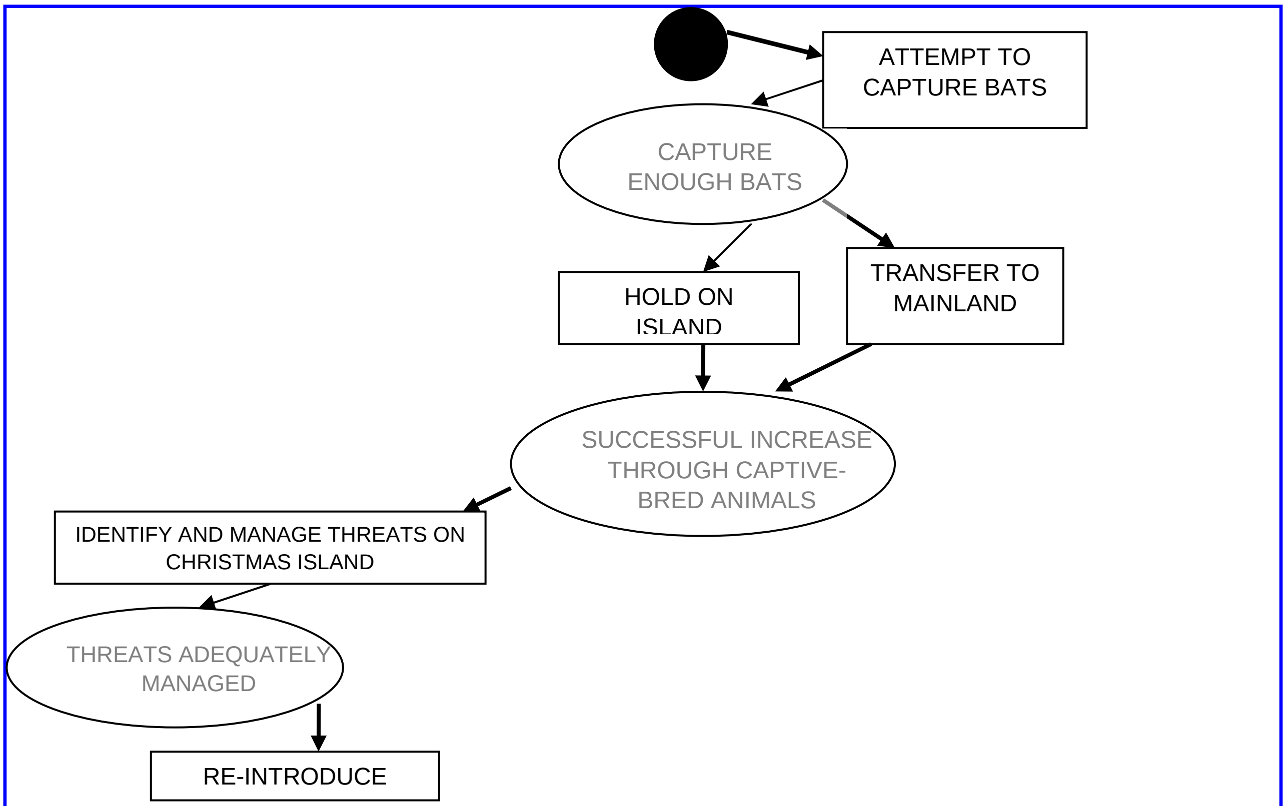
In considering this cost, it should be noted that there would likely be very significant collateral benefits to other Christmas Island species.



Decision point nine



Decision point ten



OUTCOME: Even if the primary threat to the pipistrelle on Christmas Island is successfully controlled, the reintroduction may still be challenging (e.g. because of loss of genetic heterogeneity, loss of nous in captive populations, etc.), and there may be some issues related to quarantine and risks of spread of new pathogens to Christmas Island. Assuming that the threats can be controlled, the cost of simply the re-introduction exercise is estimated at about $50,000.

TOTAL PATHWAY COSTS:

With the caveat that all estimates for costs and likelihood of success are best guesses, thus, the total cost from today until reintroduction (without taking into account threat abatement which should be part of Island management) is $5,610,000 to $6,900,000.

Table 6 Model output for different captive breeding scenarios

This initial model is used to provide some indication of the length of time that may be required for a captive breeding colony to build up sufficient animals for a re-introduction and to help provide bounds for assessment of total project costs.

For this model, we assume (i) all mature females will become pregnant and produce one young per year: (ii) the sex ratio at birth = 1:1: (iii) once mature, annual survival (p) is within the range 0.8-0.98: (iv) survival from birth to one year old is in the range 0.6-0.8.

A Survival estimates

The probability of a captive individual bat surviving over 1-7 years, depending upon annual survival probability (p).							
years	**1**	**2**	**3**	**4**	**5**	**6**	**7**
survival p.	**0.8**	0.6	0.5	0.4	0.3	0.3	0.2
survival p.	**0.9**	0.8	0.7	0.7	0.6	0.5	0.5
survival p.	**0.95**	0.9	0.9	0.8	0.8	0.7	0.7

Model output showing the number of females in a captive population, related to adult survival rates, first-year survival rates and duration of captive-breeding program. A copy of the model is available as an excel spreadsheet

Adult Survival		**0.8**	**0.9**	**0.9**
Probability of a newborn surviving in its first year		**0.6**	**0.6**	**0.8**
Enter start number females		2	2	2
Year	**1**	2.2	2.4	2.6
	2	2.4	2.9	3.4
	3	2.7	3.5	4.4
	4	2.9	4.1	5.7
	5	3.2	5.0	7.4
	6	3.5	6.0	9.7
	7	3.9	7.2	12.5
	8	4.3	8.6	16.3
	9	4.7	10.3	21.2
	10	5.2	12.4	27.6

4.8 Reptiles

4.8.1 Introduction

The Christmas Island reptile assemblage consists of five endemic species plus a wide-ranging skink found on many other oceanic islands, together with five introduced species (Schulz and Barker, 2008). The endemic species comprise two skinks, two geckos and a blind snake.

In their detailed recent summary of the reptile populations on Christmas Island, Schulz and Barker (2008) noted that all native species have shown recent rapid declines in abundance and distribution and strongly recommended that the highest priority be given to establishing captive breeding populations to “insure against the potential disappearance of these species on the island”.

Many reptile and amphibian populations are in decline in ecosystems across the world (Gibbons et al., 2000), particularly on islands (Foufopolous and Ives, 1999; Case and Bolger, 1991). The most dramatic extinction of island reptile assemblages has occurred on the Mascarene Islands in the Indian Ocean where thirteen species have become extinct, while on Guam, a Pacific Ocean island, reptile extinctions have been caused by the introduction of the Brown Tree Snake, *Boiga irregularis*, a novel and effective predator (Fritts and Rodda, 1998). An examination of the 28 recorded reptile extinctions in the *2000 IUCN Red List of Threatened Species* indicated that the majority of extinctions were of island species and, although the immediate causes were often not specifically apparent, interactions with invasive biota associated with anthropogenic colonisation, modification or visitation was responsible for nearly all documented cases (Nilson, 2000).

The taxonomic integrity of the Blue-tailed Skink has been verified recently using both morphological and molecular techniques (Horner and Adams, 2007) while molecular work has commenced on a global examination of *Emoia* species (Fisher *pers. comm*.) with material being sought for both the Forest and Coastal skinks from Christmas Island.

4.8.2 Population Declines in Native Reptile Species

There are well compiled histories of the distribution and abundance of both native and introduced reptiles on Christmas Island and these demonstrate a dramatic recent decline in all native species and a concomitant increase in invasive species. These changes have been collated and synthesised by Schulz and Barker (2008) in their report from the last extensive reptile survey and review during May and June 2008. Their findings are briefly summarised below.

The Giant Gecko (*Cyrtodactylus sadlieri*) is uncommon and declining, despite remaining the most abundant native reptile species, particularly in the primary rainforest of the central plateau. Its decline has been most marked since the 1998 survey) when it was abundant and widespread (Cogger and Sadlier, 1999), a status retained from previous reptile surveys (Cogger and Sadlier, 1981).

Lister's Gecko (*Lepidodactylus listeri*) is now extinct. The last recorded observation was in 1987 and, despite numerous targeted reptile and Island Wide Surveys during the intervening years, there has been no recent record or observation.

Blue-tailed Skink (*Cryptoblepharus egeriae*) was widespread and common in numerous habitats during 1979 (Cogger and Sadlier, 1981) but by the 1990s it had declined noticeably (Cogger and Sadlier, 1999) and by 2008 (Schulz and Barker, 2008) it had become restricted to just two locations on the western end of the island. In the last three months one of these two remaining populations has become extinct (Retallick *pers comm.*).

The Coastal Skink (*Emoia atrocostata*) occupies the rocky coastal intertidal zone and adjacent fringing limestone rock outcrops. It is a species known to occur on many islands through the Pacific and Indian Oceans and it has one of the widest distributions of any reptile taxon. Recorded as widespread but patchily distributed on Christmas Island during the 1979 survey (Cogger and Sadlier, 1981) it had declined by 1998, was last recorded in 2004 (Director of National Parks, 2007) and has not been observed since (Schulz and Barker, 2008).

The Forest Skink (*Emoia nativitatus*) was abundant in rainforests on all landforms during 1979 (Cogger and Sadlier, 1981) and remained common during their survey in 1998 (Cogger and Sadlier, 1999). However, it declined rapidly during the early years of this century (Director of National Parks, 2007) and became confined to scattered populations on remote coastal terraces, having disappeared from its preferred inland rainforests, and it is now almost impossible to find (Retallick *pers. comm*.).

The Christmas Island Blind Snake (*Typhlops exocoeti*) is, like most blind snakes, a poorly known species. Infrequently recorded on the island it was last collected in 1986 but there remain occasional unconfirmed sightings of this species on the island (Schulz and Barker, 2008).

The five introduced species of reptile are the Asian (or Barking) House Gecko (*Hemidactylus frenatus*), the Pacific Gecko (*Gehyra mutilata*), the Grass Skink (*Lygosoma bowringii*), the Flowerpot Snake (*Ramphotyphlops braminus*) and the Wolf Snake (*Lycodon capucinus*). All these invasive species, except the Flowerpot Snake, have widespread, abundant and expanding populations on Christmas Island that have the potential to be key threatening processes for the survival of the native species.

In summarising the recent situation for native reptiles Schulz and Barker (2008) assigned them into three status categories:

Group A. Not seen for varying periods of time; a high potential of no longer being present:

- Lister’s Gecko (not seen since 1987)
- Coastal Skink (not seen since 2004)

Group B. No confirmed records for several decades, but may still be present as readily overlooked due to its cryptic habits:

- Christmas Island Blind Snake

Group C. Common in recent decades, but undergoing current rapid decline:

- Blue-tailed Skink
- Forest Skink
- Giant Gecko

4.8.3 Likely causes of decline

Schulz and Barker (2008) list 15 threats to the reptile populations that may account, in part, for the rapid decline in abundances and distributions. Factors such as habitat loss, impact of Yellow Crazy Ant populations or their control measures, predation by introduced invertebrates, such as the Giant Centipedes, or vertebrates, such as Nankeen Kestrels, feral cats, Wolf Snakes, Black Rats or Jungle fowl, can be considered to impact on all species while competition between the native Geckos and the introduced Asian House Gecko and Pacific Gecko and between the native skinks and the introduced Grass Skink may also account for declines in native species. It is also possible that there are different factors operating on nocturnally and diurnally active native species, while the role of disease and impacts of unknown stochastic events and climate change remain conjectural.

Case and Bolger (1991) investigated the impacts of introduced species on island reptiles and recorded three major results. Firstly, introduced predators caused severe reductions in the abundance and extinctions of native and introduced reptiles but their effect on the ‘predator-naïve’ native species was more severe; secondly, species-rich communities were more resistant to the invasion of introduced lizards than were species-poor communities and; thirdly, competition between introduced species was more severe than competition between introduced and native species. Smith et al., (2006) summarised the impact of disease on population extinctions in birds, mammals and amphibians and, although there is no compelling extinction evidence for reptiles, stated “epidemiological theory predicts that infectious diseases should only drive species to extinction under specific circumstances – most commonly where pre-epidemic population size is small, reservoir hosts are available, or when the infectious agent can survive in the abiotic environment”. These findings have significance for future adaptive management of the lizard fauna of Christmas Island.

4.8.4 Conclusions

The situation for native reptile populations on Christmas Island is parlous. The Coastal Skink may have joined Lister’s Gecko in being extinct, while the Blind Snake and Forest Skink are exceedingly difficult to find and the Blue-tailed

Skink is known from only one population. The Giant Gecko has now also commenced a dramatic population decline. The causes for decline in populations in four, possibly all five, remaining native reptiles of Christmas Island are not well understood and may be attributable to either single or, more likely, multiple causes; a situation that reflects the working group's interpretation of the decline in the pipistrelle.

What is conclusive is that without dramatic intervention management more native reptiles on Christmas Island will go extinct. This cascade to extinction was recognised by Schulz and Barker (2008) and they proposed 19 recommendations for reptile conservation and management on the Island.

Their Highest Priority recommendations were to;

- Commence Captive Breeding programs **(Recommendation 21)**.
- Prepare nominations for the EPBC Threatened Species Listing **(Recommendation 22)**.
- Conduct an Ecosystem Health Monitoring program to identify major threatening processes **(Recommendation 23)**.

Very High Priority recommendations were to:

- Continue with Reptile Monitoring Plots.
- Establish a Scientific Advisory Committee to advise Parks Australia and Christmas Island National Park
- Actively encourage community involvement.
- Prepare a brochure on the Christmas Island Blind Snake.
- Update reptile information on the Issues Paper of the Christmas Island National Park.

The working group committee endorses these priority recommendations **(Recommendations 21, 22 & 23)**.

4.9 Conservation of Christmas Island birds

4.9.1 Introduction

Christmas Island has a distinctive but species-poor bird fauna, comprising five main groups:

1. endemic land birds (three species and four subspecies) (Appendix 4),
2. nesting sea birds (nine species, including two endemic species and one endemic subspecies) (Appendix),
3. four other resident native land birds, waterbirds and shorebirds (Appendix),
4. visitors (at least 19 species, and many more occasional vagrants), and
5. introduced species (three species) (Appendix 3)

This bird fauna is of considerable conservation significance, and is recognised as an Important Bird Area by Birdlife International (Birds Australia in press). Six of these birds (all endemic to Christmas Island) are listed as threatened under the EPBC Act. The endemic taxa include a broad range of ecological groups, including frugivores (e.g. Christmas Island Imperial Pigeon), carnivores

(Christmas Island Goshawk), aerial insectivores (Christmas Island Swiftlet), and terrestrial omnivores (Christmas Island Thrush). Notably, the endemic birds present some parallels in ecological roles with the Christmas Island Pipistrelle (i.e. Christmas Island Swiftlet forages exclusively on small flying insects, and the Christmas Island Hawk-owl may forage largely on nocturnal moths) and with the Christmas Island Flying-fox (Christmas Island Imperial Pigeon), such that trends in the status of these birds may provide insight into causes of decline in the bat fauna.

Christmas Island has been a refuge for some bird species that have disappeared elsewhere. For example, until the early 1900s, Abbott's Booby bred on many islands of the Pacific and Indian Ocean, but all other breeding populations have now been extirpated.

There has been a long-standing interest in the bird fauna of Christmas Island, with concerns about the significant losses of breeding colonies of the endemic Abbott's booby from forest clearing for mining (particularly in the 1970s) being one of the major drivers for tighter regulation of mining and the establishment of a national park in 1980.

Along with its highly conspicuous and significant crab fauna, the natural environment of Christmas Island is most characterised by its bird fauna, with tropicbirds, frigatebirds and/or Abbott's Booby particularly featuring on the island's flag, logos, tourism material and iconography. Bird-watchers, attracted by the endemic bird species, now form a major component of the island's tourism market.

The ecology and conservation of seabirds is of particular interest as they depend upon both the resources of Christmas Island and its surrounding marine areas. Further, unlike most other Christmas Island species, their conservation status may reflect and be particularly affected by actions distant from the island (e.g. much of the mortality of Christmas Island Frigatebirds may be due to direct or indirect impacts of fishing in Indonesia).

World-wide, island birds have proven to be especially susceptible to extinction. Of 24 Australian bird species or subspecies considered extinct, 21 were restricted to islands (Appendix 4). Given this obvious vulnerability of island birds, it is perhaps surprising that the birds of Christmas Island have persisted so well, especially as the Christmas Island endemics include birds whose close relatives have become extinct on other islands (Christmas Island White-eye, Christmas Island Thrush and Christmas Island Hawk-owl). (It is notable that many of these bird extinctions on other Australian islands are most likely attributable to predation by introduced rats.)

4.9.2 Status, trends, threats and management priorities

Assessment of the status of most Christmas Island birds has been episodic, and for most species there are neither robust population estimates nor ongoing monitoring programs. Such uncertainty renders management prioritisation difficult, and would hamper initiation of any rapid response to sudden decline. As evidence of this uncertainty, the most recent assessment of status of Christmas Island forest birds (Director of National Parks, 2007) provides a tabulation of all previous population estimates for seven bird species (Appendix 4). These different sources provide notably very disparate assessments of population size and, in the case of the Swiftlet, are not consistent with the working group's own observations which would place this species as abundant.

In response to the lack of any established monitoring programs for most Christmas Island birds, and to provide context for assessment of the impacts of the Christmas Island detention facility, Parks Australia (Director of National Parks, 2007) instituted a broad-based survey, as baseline for a proposed ongoing monitoring program, for eight Christmas Island bird species, namely Golden Bosunbird, Christmas Island Goshawk, Nankeen Kestrel, Christmas Island Imperial Pigeon, Christmas Island Emerald Dove, Christmas Island Thrush, Christmas Island Swiftlet, Christmas Island White-eye, with sampling occurring at 128 sites at four intervals over the period 2005-06, and with sites stratified by broad vegetation type. These are evergreen rainforest, semi-deciduous rainforest, disturbed areas which includes cleared and/or rehabilitating areas and ecotones. This monitoring provided indices of abundance rather than absolute population estimates. The sampling used sites different to the island-wide monitoring program and did not explicitly consider the impacts of Yellow Crazy Ant occurrence or control, and has not been repeated.

Notwithstanding such shortcomings, the survey was useful in demonstrating that at least Christmas Island White-eye, Christmas Island Swiftlet, Christmas Island Thrush, Christmas Island Emerald Dove, Christmas Island Imperial Pigeon and Golden Bosunbird were widespread and abundant in 2005-06, and the sampling is highly repeatable, and provides a robust benchmark from which broad trends can subsequently be discerned.

There has been more focused attention on the status of Christmas Island birds that have been listed as threatened, with recovery plans in existence for Abbott's Booby (Department of the Environment and Heritage, 2004), Christmas Island Frigatebird (Hill and Dunn, 2004), Christmas Island Goshawk (Hill, 2004a), and Christmas Island Hawk-owl (Hill, 2004b).

For Abbott's Booby, trends are difficult to assess because annual monitoring ceased in 1994 (Department of the Environment and Heritage, 2004). The most recent population estimates include 2500 pairs (a 1991 estimate, cited in Department of the Environment and Heritage, 2004), 6000 breeding birds (Garnett and Crowley, 2000), and 3,000 to 4,000 breeding birds (Olsen, 2005). Comparison of estimates made during helicopter sampling in 2002 with previous estimates indicates that the population may be stable (Olsen, 2005). The most persistent threat to the status of Abbott's Booby on Christmas Island has been clearing (mostly for mining) of breeding sites in the canopies of tall trees in primary rainforest: some breeding colonies are outside the national park and may be affected by ongoing habitat destruction. The impacts of Yellow Crazy Ant infestations on this species are unknown.

For the Christmas Island Frigatebird, trends are difficult to assess because there has been no regular population monitoring. Relatively recent estimates include 1620 pairs (Stokes, 1984), 4500 breeding birds, and stable (Garnett and Crowley, 2000), and 2,200 to 3,000 breeding birds (James 2003). James (2003) considered the population to be undergoing gradual decline. Following historic clearing and other disturbance (notably dust fall out from phosphate driers), there are now only three, relatively restricted (total area ca. 170 ha) breeding colonies, in large trees of terrace rainforests. These colonies are only partly included within the National Park. The major threat to this species on Christmas Island is degradation (through weed infestation or other disturbance) of nesting habitat. The impacts of Yellow Crazy Ant infestations on this species are unknown. As with Abbott's Booby, this species may also be affected by factors (particularly impacts of, and interactions with, fishing) in its foraging range remote from its Christmas Island breeding sites (Parks Australia, 2008).

For the Christmas Island Goshawk, trends are difficult to assess because there has been no regular population monitoring. Hill (2004a) suggested that the total population size may be "as few as 100 adults", and Garnett and Crowley (2000) estimated 150 breeding birds, with low reliability. A more recent estimate based on banding suggested that the total population may be about 250 birds (Parks Australia, 2008). There has been no conclusive demonstration of threats. The impacts of Yellow Crazy Ant infestations on this species are unknown.

For the Christmas Island Hawk-owl, trends are difficult to assess because there has been no regular population monitoring. Some relatively coarse estimates of population size included 10-100 pairs (van Tets, 1975) and 100 pairs (Stokes, 1988); but a more systematic survey in 1995-96 suggested that the population size was 820-1200 birds (Hill and Lill, 1998). Garnett and Crowley (2000) estimated 1200 breeding birds, and decreasing, with high reliability. There has been no conclusive demonstration of threats, but a limiting factor may be the abundance of hollows in large rainforest trees. The impacts of Yellow Crazy Ant infestations on this species are unknown.

There are population estimates for some other breeding seabirds, including 2800 Red-tailed Tropicbirds (1984 estimate, in Stokes, 1988), 12,000 to 24,000 White-tailed Tropicbirds (1988 estimate, Dunlop, 1988), 25,000 Red-footed Booby (1984 estimate, in Stokes, 1988), 10,000 Brown Booby (1984 estimate, in Stokes, 1988), and 6,500 Great Frigatebird (1984 estimate, in Stokes, 1988) [Birds Australia in press]. The working group established that both tropicbirds are suffering nesting failures from cat predation at the nest and recommend that this issue be addressed immediately **(Recommendation 20)**.

For a few species, recent intensive studies have provided information relevant to conservation management. Davis et al. (2008) assessed the abundance, behaviour and reproductive success of Christmas Island White-eyes, Christmas Island Thrush and Christmas Island Emerald Dove in forested areas with and without Yellow Crazy Ants and in ghosted forest (areas in which Red Crabs were now absent because Yellow Crazy Ants elsewhere had prevented crab immigration). The ground-feeding Christmas Island Emerald Dove was significantly less common in areas with Yellow Crazy Ants, whereas the White-eye was more common in areas without crabs (presumably because this species is favoured by a denser understorey). The Christmas Island Thrush had significantly reduced reproductive success in forests with ants.

Some recent unpublished studies have indicated that nesting success of tropicbirds in the settlement area is markedly reduced through predation of chicks by cats (especially) and Black Rats; and this threat is currently unabated.

Garnett and Crowley (2000) provided an integrated series of management recommendations for birds on Christmas Island, comprising:

1. develop techniques for controlling Yellow Crazy Ants;
2. control abundance and spread of the Yellow Crazy Ant;
3. pending control, establish captive populations of at least the land birds with the aim of reintroduction once ant control has been achieved;
4. negotiate with all landowners to ensure protection of primary forests outside the national park;
5. review the Christmas Island Quarantine Service;
6. continue rainforest rehabilitation of priority minefields;
7. assess impacts of long-line fishing on endemic seabirds;
8. form an Island Recovery Team, and develop and implement island-wide conservation management and recovery plans.

Although birds comprise a higher proportion of listed threatened species than any other group, the current trends for birds on Christmas Island are nowhere near as parlous as those for endemic reptiles or for the Christmas Island Pipistrelle. Historically, most bird decline has been associated with forest clearing, but this threat is now mostly reduced. The impact of Yellow Crazy Ants (and consequential broad-scale changes to the island's ecology) on birds has been only sketchily documented. Yellow Crazy Ant infestations may directly cause reductions in some forest birds (notably the Christmas Island Thrush and Christmas Island Emerald Dove while Davis et al (2009) also implicate ants as important agents in impacting on frugivory of Christmas Island birds). More speculatively, Yellow Crazy Ant infestations may reduce habitat quality for nesting seabirds through decline in the health of canopy trees. Yellow Crazy Ant infestations may also lead to an increased predation rate on many bird species by feral cats and Black Rats (if these introduced mammals increase in areas without crabs), and such predation has been the primary cause of bird extinctions on many islands elsewhere. More immediately, the current rates of predation (especially by cats) upon ground-nesting seabirds will lead to substantial decline. Consequently, improved control of cats (in tandem with control of Black Rats) should be an immediate short-term priority with the longer-term priority being eradication of both **(Recommendation 13)**. Table 7 summarises our assessment of short, medium and long term priorities for the conservation of Christmas Island's birds.

Extinctions of island birds elsewhere have often been associated with Black Rats (e.g., Lord Howe Island, Norfolk Island). Atkinson (1985) reviewed island extinctions worldwide and found that extinctions due to rats were less likely on islands that had a land crabs, presumably because they are pre-adapted to predation. Therefore, the maintenance of high density Red Crab populations on Christmas Island may also be beneficial to its birds and a continuing reduction in Red Crab numbers may lead to bird declines unless Black Rats and cats are eradicated **(Recommendations 7 & 10)**.

Table 7 A framework for assessing conservation priorities for Christmas Island birds

Priority	**Time frame**		
	Short	**Medium**	**Long**
High	Develop procedures to reduce predation on nesting seabirds by cats and Black Rats	Eradicate cats and Black Rats from the island	Control Yellow Crazy Ants
	Limit extent of Yellow Crazy Ants	Implement appropriate quarantine	
Medium	Develop and implement robust monitoring programs	Assess Fipronil uptake (and impact) on insectivorous birds	Implement and maintain monitoring programs for all endemic birds and breeding seabirds
	Assess impacts of Yellow Crazy Ants infestations on forest birds and breeding seabirds	Rehabilitate cleared lands	Develop protocols for interventionist responses for rapid decline of any endemic bird or breeding seabird
		Control those weed species affecting habitat quality for breeding seabirds	
		Assess impacts upon population viability of off-island threats to seabirds	
Low	Rehabilitate cleared lands	Eliminate exotic birds	

4.10 Christmas Island Flying-Fox

The extinction of Maclear's Rat (*Rattus macleari*) and the Bulldog Rat (*Rattus nativitatis*) over 100 years ago, the possible recent extinction of the Christmas Island Shrew (*Crocidura trichura*) and the current dramatic decline in the abundance and distribution of Christmas Island Pipistrelle promotes the Christmas Island Flying-fox (*Pteropus natalis*) to the last remaining endemic mammal species on Christmas Island with viable populations.

Studies have shown that fruit bats, rather than birds, play the dominant role in seed dispersal in tropical forests as well as an essential role in pollination, processes that foster successional changes in woody plants and maintain ecosystem processes in the tropics (Shilton et al., 1999; Ingle, 2003).

The recent report on the endemic Christmas Island Flying-fox (James *et al.* 2007), the only fruit bat on Christmas Island, provides some information that this species is also in decline. The Threatened Species Scientific Committee (TSSC, 2008) examined all available evidence for the magnitude of the decline but recommended against listing the species as a threatened taxon because previous estimates of colonies numbers, social dispersion and population abundance were not comparable as estimates had been made using different protocols and in different seasons. As with most other vertebrate species on Christmas Island the causes for this decline remain uncertain, however, a large number of individuals appear to have disappeared after the major storm event of March 27th 1988. The report of the Biodiversity Monitoring Program (Director of National Parks, 2007) provides detailed discussion on the likely threats to this species that include predation by numerous introduced carnivores, interference by Yellow Crazy Ant, loss of habitat and the potential impacts of Fipronil poisoning and disease and parasites. No conclusive pattern emerges on the major causal agent but ranking high on their list of 'plausibility' are disease and multi-factor causes.

The working group were informed at the community meeting on the island that the Christmas Island Flying-fox was more numerous 25 years ago, at a time when planting fruit trees was practised in mining areas, and that many Flying-foxes were hunted for food by local workers. This is also noted by James et al. (2007) as a potentially important regulating factor, but hunting has now ceased.

No direct studies on the impact of the Yellow Crazy Ant on the Flying-fox have been undertaken, however, Davis et al. (2009) showed that frugivory in birds was impacted by super colonies of the ants. Given the Flying-fox is an obligate frugivore, it is reasonable to assume that there may also be negative interactions between the Flying fox and Yellow Crazy Ants. The significance of the endemic Christmas Island Flying-fox in maintaining key ecosystem processes in the rainforest of Christmas Island can not be underestimated and this taxon remains an important 'keystone' species.

A minor concern of the working group is the possible long term impact of the robber crabs on fruit tree recruitment. This concern is speculative but supports work on this species.

4.11 Christmas Island land crabs

Nowhere on earth is there a more diverse land crab fauna than on Christmas Island. Among 20 species two are very conspicuous, the very numerous Red Crab (Figure 16), famous for its spectacular migrations and, among the five species of hermit crabs, the gigantic and colourful Robber Crab, known elsewhere as the Coconut Crab.

4.11.1 Red Crabs, Gecaroidea natalis

Figure 16 Photo of a Red Crab, an iconic species with a very unfortunate recent history and an uncertain future

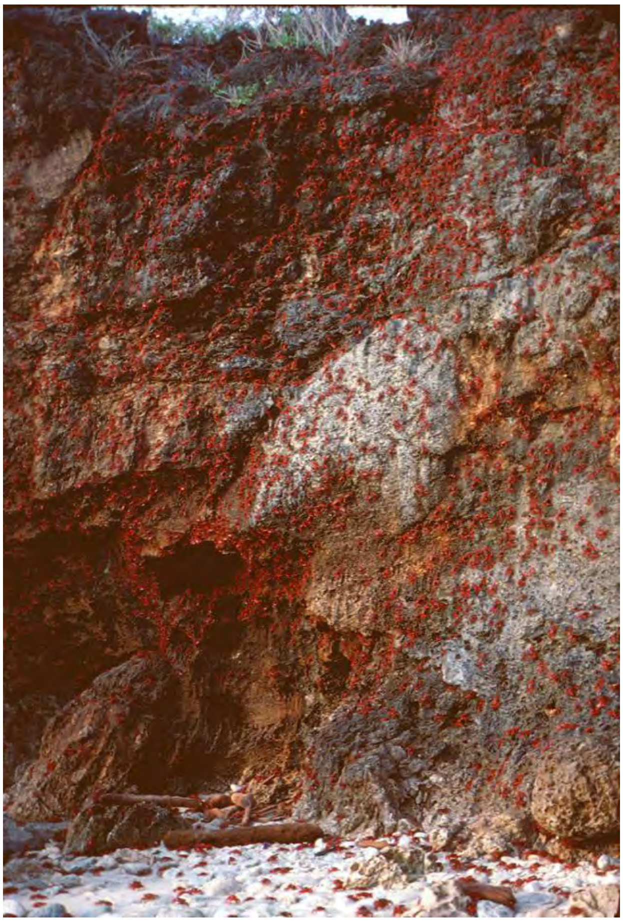


Figure 17 Photo of Red Crab annual migration down to the sea to release eggs. Migrations have become less spectacular since the outbreak of the Yellow Crazy Ant super colonies.

No element of the Christmas Island fauna has attracted more public attention than the Red Crabs (*Gecarcoidea natalis*) and their spectacular seasonal migrations to the sea in hundreds of millions to deposit their eggs (Figure 17). Perhaps surprisingly, there has been comparatively little research on their population ecology. Until Hicks (1985) described their breeding behaviour and migrations, most of the information was semi-popular or anecdotal in nature (reviewed by him). The next focus was about 5 years later when the role of the crabs in shaping forest structure was being elucidated (O'Dowd and Lake 1989, 1990, 1991; Green et al., 1997). Essentially, red crabs are the dominant forest floor consumer, clearing the forest floor of leaf litter and consuming most seeds and seedlings before they can become established. In the wet season, millions and millions of crabs migrate to and from the coast, where they mate in burrows close to the ocean and, subsequently, the females deposit fertile eggs in the ocean before returning to the forest floor. These migrations have made Christmas Island famous and have come to be regarded as one of the wonders of the biological world.

In the mid 1990s, Yellow Crazy Ants, which were introduced accidentally between 1915 and 1934 (O'Dowd et al., 1999), were recognised as an emerging and serious problem. There is an excellent review of the early stages of their recognition as a pest on Christmas Island, a description of their biology and recommendations for management in a report to Environment Australia (now DEWHA) (O'Dowd et al., 1999). The report was a study apparently stimulated by a realisation that there were some areas of very heavy infestation and the formation of 'super colonies', colonies with multiple queens and ant densities of thousands per square meter. The ants had been present in very low numbers for more than 60 years and were thought not to be a problem. In 1989 the first super colony was identified. In December 1998 O'Dowd and co-workers estimated that 2-3 per cent of the island's intact rainforest was infested. This percentage increased dramatically soon afterwards, with an estimate that by 2001 super colonies covered 25 per cent of the rain forested areas on the island (O'Dowd et al., 2003). (Figure 18).

Figure 18 Extent of super colonies of Yellow Crazy Ants on Christmas Island to 2002. (Abbott, 2007)

The rise of the super colonies is associated with high densities of two exotic insects, the lac scale**,** *Tachardina aurantiaca* (Kerriidae), and *Coccus celatus* (Coccidae) (Hemiptera, Homoptera, Coccoidea). Yellow Crazy Ants, like other 'tramp' ant species, form mutualistic associations with scale insects which suck sap from the trees and secrete carbohydrate rich honey dew on which the ants feed. The ants tend and protect the scale insects from parasitoids, parasites and predators and they attain very dense populations on leaves and stems high in the canopy (Figure 19). This has both direct and indirect negative effects on the trees; direct through removal of large quantities of sap and indirectly through the accumulation of excess honey dew on the leaves plus the photosynthesis-reducing sooty mould that results**.** Thus, the trees become very stressed. In extreme cases, without intervention a forest may be at risk of destruction (Smith et al., 2001). In 2005, the TSSC recommended successfully to the Minister that he list as a Key Threatening Process **"**Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean**".** The comprehensive paper supporting the recommendation can be found at:

http://www.environment.gov.au/biodiversity/threatened/ktp/christmas-island-crazy-ants.html

Figure 19 Photo: Scale insects

Figure 20 Photo: A dead Red Crab, killed by Yellow Crazy Ants

The effect of Yellow Crazy Ants on the numbers of Red Crabs following the outbreak of super colonies was dramatic. Yellow Crazy Ants kill, through formic acid attack, and eat Red Crabs and overwhelm them by sheer numbers, to the extent that the crabs are extirpated from the areas of the super colonies. O'Dowd et al. (2003) estimated that one quarter to one third of the Red Crabs had been killed during the late 1990s (Figure 20). The subsequent effect on the forest was equally dramatic. Leaf litter, usually consumed by the crabs, was able to accumulate in most parts of the forest, seeds germinated and a lush understorey developed, changing the character of the forest completely.

The response by Parks Australia to the recognition of the dire threat posed by the super colonies of Red Crabs was to implement island wide control of Yellow Crazy Ants. This followed the first island-wide survey in 2001, undertaken to assess the extent of the invasion. There have been subsequent surveys in 2003, 2005 and 2007, with another soon to be conducted this year. The purpose of the surveys was to establish the geographic extent of the super colonies and assess the population of Red Crabs by burrow counts, before and after Yellow Crazy Ants control measures. Control has been implemented using Fipronil, an insecticide delivered in a fish-meal matrix originally sold as AntOff®, now sold as Presto®. Delivery has been by helicopter (2002, over 2800 hectares) and, because of the cost of getting a helicopter to the island, by targeted hand application. The use of Fipronil and the issues that arise from that are discussed elsewhere in this report.

The most recent source of information post 2000 is a paper now in preparation (Smith et al. in prep) which reviews the results of the four island-wide surveys and assesses the effectiveness of baiting with Fipronil and its subsequent effect on Red Crab numbers.

There is no doubt that baiting with Fipronil has proven extremely effective in reducing Yellow Crazy Ants, and the good news is that the decline in Red Crab numbers has apparently been halted; there has been no statistically significant downward trend in Red Crab numbers over the six years straddled by of the surveys. This accords with the lack of observed of mass mortalities of Red Crabs since the baiting commenced.

The bad news is that neither has there been any sign of an increase in Red Crab numbers since the baiting and, further, there have not been any significant recruitment events. Anecdotal evidence, from long term Parks staff and other residents, is that there has not been a significant recruitment event since the late 1980s, which is about when the first super colonies were noticed. However, just as the mass migrations of Red Crabs to the sea were a much remarked upon spectacle, the locals noted well the return of millions of 'crablings' as well, and these returns *en masse* have never been regarded as an annual event. Hicks (1985) reported that Gibson-Hill (1947) observed no baby crabs emerging in seven out of 21 years (1919 to 1939). Additionally, no baby crabs were seen in two of the four years of Hicks' own study, and he attributed these lean recruitment years to events in the ocean. He was even able to record a personal observation by 'Harvey' that a whale shark was observed in the Cove, apparently feeding on swarms of recently released crab larvae in the November of one of these lean years, 1982. Local opinion is that maybe only one year in ten is a good one and recollection has it that the last recognisable event was about nine years ago so another one is due.

However, although oceanic events undoubtedly have an influence on the number of crablings that complete their development to the point of emerging from the ocean to seek the forest floor of the Central Plateau, these days to get there they need to survive crossing the terraces where Yellow Crazy Ants are likely to be in high enough numbers to intercept and kill them.

As Smith et al. (in prep) write, without adequate recruitment the Red Crabs are likely to decline to extinction. The management goal they identify, 'restoring Red Crab numbers to pre-ant super-colony levels' seems appropriate, because that would re-establish the spectacle of the huge reproductive migrations which have come to be regarded as the signature of Christmas Island.

Whether or not this goal could be achieved is unknown, and many questions need answering. It is not known, for example, to what extent increasing populations of Red Crabs, re-occupying areas after the removal of Yellow Crazy Ants, will have the capacity to remove the developing understory and re-establish the 'bare forest floor' structure which pre-dated the emergence of the ant super-colonies and their removal of the crabs. On the face of it, some of the understorey now present in some of these areas may already be beyond a stage that removal by the crabs could be predicted.

The working group came to the view that much more information is needed about the biology and population ecology of Red Crabs, in particular to explore ways to enhance recruitment prospects. The situation on the island now offers a diversity of 'natural' experiments, with known histories of ant density, treatments, crab densities etc., and analysis of this could be supplemented by long term monitoring of population structures in different areas and, quite possibly, experimental treatments **(Recommendation 10)**.

The other recommendation is that the working group endorses the conclusion reached already by Parks staff, that indefinite baiting by Fipronil is not a satisfactory long term option and that there is a need for the development of a different approach. The idea of preventing Yellow Crazy Ants from re-establishing super colonies by introducing a parasitoid wasp or other parasitoids such as ladybirds to attack the mutualistic scale insects would seem to hold particular promise and this should be pursued with expedience. Research into biological control of the ants, eg via pheromones, is also being considered and should be given a high priority **(Recommendation 6)**.

The urgency of controlling the ant-scale insect mutualism is emphasised by recent work on Christmas Island by Davis et al. (2008) which shows that the high densities of Yellow Crazy Ants and their associated scale insects are affecting the abundance, behaviour, and reproductive success of forest birds.

4.11.2 Robber Crabs

Figure 21 Photo of a robber crab.

Robber Crabs (Coconut Crabs) *Birgis latro* (Figure 21) are the world's largest terrestrial arthropod and Christmas Island has the world's largest population. They are not endemic to Christmas Island, indeed they have a wide distribution across many Pacific Oceanic islands as well, but in most of their range they are in serious decline. They are omnivorous and feed on coconuts and other fruits, as well as smaller crabs. They are known to feed on Red Crabs, and whereas Red Crabs apparently obtain their sodium by 'dipping' in the ocean on their migration, Greenaway (2001), in a study of the salt and water balance of Robber Crabs, concluded that they depend on animal tissue for sodium.

Reproduction involves mating on land and females retain the fertile eggs under their abdomen for several months. Once they are hatched, she deposits them in the ocean. After about two months during which they undergo their zoea and megalopa stages and metamorphose into their immature form as a hermit crab, they emerge onto the shore for increasing lengths of time, housed in a sea shell of appropriate size. As they grow they inhabit progressively larger shells until above a certain size they abandon that habit and the abdomen hardens. They mature in four to eight years, a long time for a crustacean.

The status of Robber Crabs on Christmas Island is uncertain. They too suffer from Yellow Crazy Ants and also getting skittled on the roads during their breeding migration. Some mortality results also from their use as food and they are highly susceptible to Fipronil, the insecticide used to control ants. Island wide sampling in 2004-2006 found the sex ratio to be skewed towards males and that small crabs were rare, raising concerns about recruitment and whether the population is ageing (Parks Australia, 2008).

What little is known about their population ecology, and with a similar life cycle to Red Crabs, suggests that Robber Crabs too may be at serious risk of extinction unless control of Yellow Crazy Ants is implemented successfully.

The working group recommends monitoring of Robber Crabs and a study of their population ecology **(Recommendation 12)**.

4.12 Threatened plants

4.12.1 Vegetation communities

The status of vegetation communities on Christmas Island has not been formally assessed against criteria for listing as threatened under the EPBC Act.

Two highly localised vegetation communities on Christmas Island have been listed as wetlands of International significance under the Ramsar Convention. These comprise the small (0.33 ha) patch of isolated upland mangroves (*Bruguiera gymnorhiza* and *B. sexangula*) at Hosnie's Spring, and the system of permanent springs, seepages and streams supporting distinctive wetland and moisture-loving vegetation around The Dales. Both communities may be threatened by changes in hydrology, weed infestations or ecological changes associated with Yellow Crazy Ants and other exotic invertebrates.

The main vegetation communities of the island have been exposed to more than a hundred years of disturbance from mining, with about 20 per cent of the island's vegetation previously cleared and/or mined, and highly variable success in rehabilitation.

The dominant vegetation type of the island, primary rainforest, is subject to pervasive threats arising from changes to its main ecosystem drivers, from Red Crabs to Yellow Crazy Ants. The distinctive forest and forest floor structure has been largely determined by the impacts of high densities of terrestrial Red Crabs consuming much of the ground-level vegetation and detritus. With replacement of Red Crabs by Yellow Crazy Ants, a far higher proportion of seeds germinate and seedlings reach the mid-storey, radically changing the forest structure, floristic composition and dynamics. Further, the Yellow Crazy Ant supercolonies help develop or maintain heavy infestations of scale insects on foliage, with consequential increases in mortality of trees of some species. Infestations of Yellow Crazy Ants (or loss of Red Crabs) may also favour some other exotic pests (such as the giant African snail), with compounded impacts on floristics and vegetation dynamics.

On terraces and cliffs with skeletal soils, semi-deciduous vine forests and deciduous vine thickets may also be affected by replacement of Red Crabs with Yellow Crazy Ants, with impacts similar to those in primary rainforests. These lower and more open vegetation types may also be more prone to invasion by weeds, and have been affected by fires in unusually dry periods.

4.12.2 Weeds

About 175 exotic plant species (42 per cent of the island's flora) have become naturalised on Christmas Island, with about 80 of these now considered to be noxious weeds (Christmas Island Plan of Management). Many of these plants were deliberately introduced, including many for post-mining rehabilitation. Weeds are now particularly prevalent in highly disturbed areas, including rainforest margins; but a few weed species particularly threaten primary rainforests, semi-deciduous and deciduous thickets; and there is recent evidence that some "sleeper" weeds may now be becoming far more invasive (Claussen *pers. comm.).*

A management plan guides the response to weeds, particularly in National Park areas, but the implementation of this plan has typically been dependent upon short-term funding opportunities.

4.12.3 Native plant species of conservation concern

The Christmas Island flora comprises about 240 native vascular plant species, of which 19 species are endemic to Christmas Island, a further 125 species are known in Australia only from Christmas Island (but occur elsewhere in the Indo-Malayan or Malesian regions) and three are listed as threatened under the EPBC Act (Parks Australia, 2008). The high number of endemic plants on Christmas Island is a notable conservation feature of the island.

The most comprehensive assessment of the status of Christmas Island's flora (Holmes and Holmes, 2002) considered 53 species to be of conservation concern, including many species that were considered to meet listing criteria but have not been listed as threatened (Appendix 4).

Many of the species considered to be of conservation concern are known from only one or few sites with a small number of individuals, and hence may be particularly susceptible to a range of stochastic or other disturbance factors. Seven species (including two endemic species) in the list above have not been recorded for >100 years.

To our knowledge, there are no long-term monitoring programs for any of the plant species of conservation concern, few targeted surveys for plants of conservation significance (Du Puy, 1988; Holmes and Holmes, 2002), and relatively little assessment of threats or management requirements. We have found little information on the response of these plant species to Yellow Crazy Ant infestations or control procedures.

Some of the plant species considered to be of conservation concern are pioneer, edge or disturbance specialists that may have always had a precarious foothold in the ecology of this island, but are now likely to be outcompeted by the many more vigorous exotic plants that are also disturbance specialists. Weeds (Appendix 14) may also be the main threat for some plants of conservation concern in primary rainforests.

There are existing recovery plans for two of the three plant species listed as threatened under the EPBC Act (*Asplenium listeri* and *Tectaria devexa*), but it is not clear that the actions described in these plans have been implemented. Both plans consider options for ex situ cultivation. Such a management response may be appropriate for many more of the Christmas Island plants of conservation concern.

4.12.4 Priorities for conservation of plants and vegetation communities.

The conservation of Christmas Island's vegetation communities and their associated plants is a critical basal condition for the survival of the island as an internationally important biodiversity site. Table 8 sets out a methodology for allocating conservation priorities for the management of the island's vegetation and plants.

Table 8 Conservation priorities for Christmas Island plants and Vegetation Communities

Priority	**Time frame**		
	Short	**Medium**	**Long**
High	Establish ongoing robust monitoring program for highest priority native plant species	Integrate weed control off- and on-park	Control the exotic plant species of greatest concern
	Assess direct and indirect impacts of Yellow Crazy Ants, and their control mechanisms, on native plant species of conservation concern		Increase quarantine effectiveness to prevent introductions of new invasive plants
Medium	More intensively assess threats for plant species of conservation concern	Establish ex situ populations of native plant species of most conservation concern.	Rehabilitate disturbed areas
		Rationalise threatened species listings for Christmas Island plants	
		Broad-scale surveys to re-assess distribution and status of Christmas Island native plant species	
Low			

4.13 Other taxa

Given the high rate of endemism in the higher taxa it is highly probable that there is a high level of endemism amongst the lower taxa on the island. This represents a gap in knowledge that could be significant in the management of the island's unique ecology and the addressing of this represents a priority **(Recommendations 4 & 8)**.

4.14 Other matters

4.14.1 Marine environment

The working group focused its attention on the terrestrial environments of Christmas Island as the Terms of Reference dictated that the species and processes most in need of conservation consideration occurred in those ecosystems. However, on Christmas Island, as with all islands, the surrounding ocean exerts a strong influence on the climate as well as the structure and function of the composite terrestrial ecosystems. The relatively recent description and research on the Dipole Mode Index across the tropical Indian Ocean (Indian Ocean Dipole Index) has shown changes in it to be correlated with far-reaching temporal variation in climates across the Indian Ocean and on bordering continents. The significance of these variations on ocean conditions around Christmas Island has yet to be determined.

The marine ecosystems surrounding Christmas Island are known to provide critical resources and processes for many terrestrial species that occur on the island. All sea birds on Christmas Island, either breeding, migratory or transient, are dependent on the surrounding ocean for their dietary needs. All species of terrestrial crabs, for which Christmas Island is internationally recognized and which perform major ecosystem functions, must migrate to the ocean to spawn and the marine environment supports their early life stages. The marine turtle species that nest on the island, all of which are listed as threatened, spend the nearly their entire life-cycle in the ocean.

The marine biodiversity of Christmas Island has been documented by Berry and Wells (2000) - and references therein. Their survey of the marine fauna indicated that Christmas Island had a relatively low biodiversity when compared to other islands, reefs and atolls in the Indian Ocean, and they attributed this to the small size of the island, its isolation from sources of planktonic larvae and the extensive die-off of corals that had occurred several years prior to their survey in February 1987. Marine scientists from James Cook University are currently investigating apparent recent increases in coral disease in the waters directly surrounding Christmas Island.

There is a necessity to better understand the marine environment surrounding Christmas Island and the interaction between its oceanic and terrestrial ecosystems **(Recommendation 9)**.

4.14.2 Subterranean Fauna

The Christmas Island seamount is of global significance for the subterranean fauna that occurs there. Preliminary studies by Humphreys and colleagues have documented a diverse and zoogeographically important fauna.

The troglobitic fauna contains an array of cave-dwelling species (Harvey and West, 1998) and one of only two known blind scorpions in Australia, a group of arachnids that is focused in Mexico with outliers in Ecuador, Sarawak and Christmas Island (Volschenk et al., 2001). However, the troglobitic fauna remains relatively poorly known and surveyed; a situation that also exists with the stygofauna (subterranean fauna living in freshwater-filled voids) and anchialine fauna (subterranean fauna occurring in a water body with connections to the ocean). Some aquatic taxa (Short & Meek, 2000) are closely related to populations in the Pacific (A. Duffy, pers. comm., 2005 in Humphreys & Danielopol, 2006)

Christmas Island has a dominant anchialine community of the Procaridid-type which are restricted to isolated seamounts (Bermuda, Ascension Island and Hawaii: Bruce & Davie, 2006; Humphreys & Danielopol, 2006). However, Christmas Island also has a second anchialine community of the Remiped-type and is the only known location, globally, where representatives of both communities co-occur. Remiped-type epicontinental anchialine communities are characterized by the presence of the thaumatocyprid ostracod genus *Danielopolina* (Humphreys & Danielopol, 2006; Kornicker et al., 2006; Humphreys et al., 2009). The differences between these two community types in the higher taxonomic composition of their faunas remain constant, irrespective of how far apart in the world they occur (Humphreys & Danielopol, 2006).

Of particular significance is that the only living member of the ostracod genus *Microceratina*, a genus with a long well established fossil history and a true 'living-fossil' (Namiotko et al., 2004), is recorded from Christmas Island.

The high degree of endemicity of the documented subterranean fauna of Christmas Island and the ancient lineages of several taxa indicate its global biogeographic significance. There is a pressing need to further document this component of the island's biodiversity and better understand the processes likely to impact on it **(Recommendation 9).**

5.0 Consideration of Christmas Island as a Conservation Entity

5.1 Recognition of a unique place

At many places throughout this report the point has been made that Christmas Island has unique biological and ecological values and hence biodiversity values. In addition it has been pointed out that these are of National and International significance. Succinctly these values are the unique ecological character of the crab – forest community that is not found anywhere else, the unique stygofauna, a significant number of endemic species and its importance as a seabird rookery. It is almost certain that other undiscovered values will be found in the surrounding marine ecosystems and the interaction between these and the Island ecosystems.

The working group, while recognising the extreme threats to the integrity of Christmas Island as an ecological entity, recommends that consideration be given to listing “The Christmas Island Sea Mount including its terrestrial and marine components and the surrounding seas” as a threatened ecological community under the EPBC Act. **(Recommendation 26).**

The effect of such a listing would be to strengthen many of the recommendations made in this report and consolidate all recovery planning into a single document with a whole system focus.

5.2 Communicating Christmas Island’s Values

The recommendations made in this report are dependent on public understanding on Christmas Island, in Australia and across the World. This cannot be achieved without a properly designed and executed communications plan. **(Recommendation 27).**

6.0 Findings with wider applicability

Effective management of threatened species is not necessarily easy, straightforward or inexpensive. But the crash to imminent extinction of three endemic vertebrates on Christmas Island over the last two decades (following probable extinction of two other endemic vertebrates in the previous few decades), and ongoing rapid decline in many other native and endemic species, represents an unusually conspicuous failure. This failure may be seen to be especially vexing, given that Christmas Island is a relatively small area; is mostly national park; that many of the species are subject to formal recovery plans; that many of the declining species have been the subject of sustained, intensive and good scientific research; and that considerable resources have been invested in conservation management on Christmas Island over this period. How did it go so badly wrong?

Here, we list a series of factors that have contributed to the failure. We readily acknowledge that such assessment is far easier to make in retrospect; and we stress that we are not seeking to ascribe incompetence or neglect to those involved in the management of this island.

1. The dynamics supporting island ecosystems, particularly oceanic islands, are particularly susceptible to change. Islands typically support relatively few species that may have evolved intricate ecological inter-relationships. Where the isolation of the island is broken down and many non-native species colonise, these underlying inter-relationships are readily decoupled, and island-wide broad-scale ecological change is likely, leading to collapse of the island's biotic communities. In the case of Christmas Island, the ecological equilibrium of the island pivots around the Red Crab, and invasions that reduce Red Crab numbers will have a vast range of indirect consequences that may be rapidly or sequentially apparent.

Lesson: There should be national recognition of the set of Australia's iconic islands - those that have extraordinary conservation values and susceptibility; with concomitant resourcing for substantial management needs.

2. The conservation management of the island was overwhelmed by the crisis of dealing with Yellow Crazy Ants. Given the argument in the paragraph above, it is entirely understandable that much of the attention of the island's conservation managers was directed at an emergency response to the real threat posed by the development of super colonies of Yellow Crazy Ants; and the relative success of such intervention has been justifiably recognised. However, the process of dealing with this threat has probably led to reduced focus on immediate actions needed for other acute conservation problems. Further, we note that the management of Yellow Crazy Ants has left some substantial questions unconsidered or unresolved: there is little or no evidence available on the fate of Fipronil in the island's ecological system, or on the impacts of Yellow Yellow Crazy Ants (or their control) on many of the island's endemic invertebrates.

Relatedly, it is understandable that any strategic research and management focus may have been blurred or interrupted by the unanticipated imposition of the detention facility (IRPC) and its consequential and unique demands for environmental assessment.

Lesson: There is a need for long-term strategic continuity in conservation management, balanced by appropriate flexibility and adaptive capacity. In the case of Christmas Island, this may be best set in the Christmas Island National Park Plan of Management, and/or a regional multi-species recovery plan.

3. A management prioritisation process was lacking. The large number of threatened and endemic species on Christmas Island is both a virtue and a problem. There are many potentially competing demands for conservation attention; but no clear mechanism for rational allocation of management resourcing and actions, tactically and strategically across short, medium and long time frames. For Christmas Island, we suspect that the prioritisation process may have been driven partly by the interests and persistence of individual externally-based researchers.

Lesson: Develop and implement a management prioritisation framework

4. Legislative conservation listing does not necessarily equate to conservation needs. In this case, the prioritisation has probably been confounded by the inexact matching of listed threatened species with actual conservation status, and the consequential, somewhat ad hoc, development and implementation of recovery plans. For example, neither of the two reptile species in imminent threat of extinction is listed as threatened under the EPBC Act; many plant species of obvious conservation concern are not listed; and the Christmas Island birds listed (and the status ascribed them) is a poor match for their current conservation concern. For some species, listing (and consequential management resourcing) has been based on historical issues and/or chronic threats now largely moderated; whereas the conservation response system responds slowly to species suffering very rapid decline from acute and novel threats.

Lesson: More systematic streamlining process for development and review of lists of threatened species.

5. Resourcing inertia. Historically, the main conservation issue on Christmas Island has been rainforest clearing and habitat degradation due to mining. This continues to be a main focus of management attention, and rehabilitation post-mining is the sole beneficiary of the conservation levy regulated under the mining agreement. It is no longer the case that rehabilitation of the mined legacy is the paramount conservation concern on the island, and it is no longer appropriate that the conservation levy should be so directed.

Lesson: Where commercial leases or other commercial regulatory instruments exist their re-negotiation should have as part of the negotiating brief the creation of resources to manage areas or matters of highest conservation importance.

6. Resourcing insufficiency and insecurity. The conservation of threatened species may require substantial funds, secured for many years. This requirement may be magnified substantially when many threatened species are coincident, and when very substantial interventions may be required. Our understanding is that there has been no secure substantial funding for threatened species management on Christmas Island.

Lesson: Develop and maintain a secure funding component for the conservation management of threatened species and other matters of conservation significance on Christmas Island (and other Parks Australia reserves).

7. Improved monitoring. A robust monitoring program is an essential foundation for the conservation and management of biodiversity. For most endemic and threatened species on Christmas Island, there is no ongoing monitoring program, capable of detecting undesired trends in a timely fashion, for assessing the effectiveness of management, or for providing the evidence needed for rational prioritisation of management actions.

Lesson: Develop and maintain a robust integrated monitoring program for threatened species and other matters of conservation significance on Christmas Island (and other Parks Australia reserves); provide annual reports on such monitoring; and use this as a basis for ongoing adaptive management.

8. Inadequacies in the Christmas Island Pipistrelle Recovery Plan. In hindsight, it is apparent that the 2004-09 recovery plan for the Christmas Island Pipistrelle had some notable shortcomings. It does not address the issue of captive breeding, and makes no mention of what is now seen as a likely proximate cause of decline, predation by Giant Centipedes. It reflected the knowledge base at the time, and the optimism that management would ameliorate the presumed threats. It did not provide for an adaptive management process, whereby newly acquired knowledge (e.g. of population trends) would result in consequential changes in management priorities and the recovery plan.

Nonetheless, we credit the researchers and managers of the Christmas Island Pipistrelle program for undertaking the monitoring that has now been instrumental in proving the decline, for accumulating evidence that has helped eliminate some potential causes and narrow the list of suspects, and for their commitment and innovative management responses.

Lesson: Incorporate adaptive management more strongly into Recovery Plans.

9. Lack of explicit trigger for heroic intervention. With ongoing threats, species may decline, with that decline leading inexorably to extinction. There is a time when it may be too late in that decline for any realistic hope of preventing extinction in the wild, or anywhere: they are living dead. In the case of the Christmas Island Pipistrelle, the chances of success in a captive breeding program would have been far higher 10 or 5 or even 2 years ago; and investments made then would have been far more cost-effective than investments now needed. Few, if any, recovery plans or other conservation

management initiatives have explicit triggers or thresholds for initiation of captive breeding or other heroic intervention.

Lesson: Develop an explicit trigger point for all recovery planning that provides for a precautionary establishment of captive breeding populations.

10. Inadequate quarantine. The extremely large number of non-indigenous species of plants and animals now present on Christmas Island reflects a lack of quarantine in the past. Our examination of current quarantine practices by AQIS shows that they are not world's best practice for such an important biodiversity conservation site and suggest that further invasive species may establish on the Island unless quarantine is improved.

Lesson: Develop and find a new upgraded quarantine management system for Christmas Island. This could be based on the system developed for Barrow Island by Chevron Australia.

7.0 Acknowledgements

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9.0 Glossary

Adaptive management: Management practices that accommodate and respond to uncertain future events. A structured, iterative process (repetition of a process) of optimal decision-making in the face of uncertainty, with an aim of reducing uncertainty over time via monitoring. In this way, decision-making simultaneously maximises one or more resource management objectives and, either passively or actively, accrues information needed to improve future management. It is often characterised as ‘learning by doing’.

Anchialine: Coastal salt-water habitats having no surface connection to the sea.

Atoll: An island of coral that encircles a lagoon partially or completely.

Basalt: A common extrusive volcanic rock, usually grey to black and fine-grained due to rapid cooling of lava at the surface of a planet.

Biodiversity: A neologism derived from **biological diversity**. The variety of all life forms: the different plants, animals and microorganisms, their genes and the communities and ecosystems of which they are part. Biodiversity is usually recognised at three levels: genetic diversity, species diversity and ecosystem diversity.

Biological control (biocontrol): A method of controlling pests (including insects, weeds and plant diseases) that relies on predation, parasitism, herbivory or other natural mechanisms.

Community / **Ecological Community**: A naturally co-occurring biological assemblage of species that occurs in a particular type of habitat.

Ecological cascade: A chain, or cascade, of effects in an ecological community initiated by the removal of a species or addition of a new species, eg, a series of secondary extinctions that is triggered by the primary extinction of a keystone species in an ecosystem. The primary extinction may be due to an invasive species.

F_{min}: Call minimum frequency.

F_{peakC} : Call peak frequency, relates the bat’s optimum prey-size.

Ghost forest: Rainforest on Christmas Island where there are now no red crabs.

Mycophagous: Feeding on fungi.

Out breeding (outcrossing**)**: The practice of introducing unrelated genetic material into a breeding line. It increases genetic diversity, thus reducing the probability of all individuals being subject to disease or reducing genetic abnormalities.

Pathogen: A biological agent that causes disease or illness to its host.

Resilience: The capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity. The more resilient a system, the larger the disturbance it can absorb without shifting into an alternate state.

Resistance: The degree to which a system does not respond to a shock (as opposed to resilience which describes the extent to which it changes).

Phosphorite (phosphate rock): A sedimentary rock that contains high amounts of phosphate bearing minerals.

Stygofauna: Animals that live within groundwater systems, such as caves and aquifers; usually they are small aquatic invertebrates, although stygofaunal vertebrates are known. Stygofauna can live within freshwater, brackish or saline aquifers and within the pore spaces of limestone, calcrete or laterite, and are also found in marine caves and wells along coasts.

Troglofauna: Subterranean animals that live only in the air spaces in caves and rock cavities. Most troglofauna have lost their body pigmentation. Usually they are small invertebrates including spiders, cockroaches, scorpions and terrestrial isopods.