FINAL REPORT OF THE CHRISTMAS ISLAND EXPERT WORKING GROUP TO THE MINISTER FOR ENVIRONMENT PROTECTION, HERITAGE AND THE ARTS

Red crabs, Christmas Island – Photo by Max Orchard

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1 April 2010

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

The Christmas Island Expert Working Group (EWG) was formed in February 2009 in response to growing concern about the possibility of extinction of the Christmas Island Pipistrelle (*Pipistrellus murrayi*), the island's only insectivorous bat. The working group quickly recognised that the threat of extinction of this bat was real, and that its status was a symptom of more general ecological management problems of the island as a whole. Following an interim report (Beeton et al., 2009), this view was endorsed by the Minister and the EWG was expanded and re-briefed to include examination of all threats to the island's ecology, biodiversity management and any other issues relating to the conservation management of Christmas Island and its surrounds. This final report reflects that history.

The working group notes that failure to resolve conservation issues on Christmas Island has been an ongoing concern. There have been previous inquiries by the House of Representatives Committee on Environment and Conservation (1974) and the Senate Standing Committee on Science, Technology and the Environment (1983). Concern is also expressed in many published works and internal reports of the Department of the Environment, Water, Heritage and the Arts (DEWHA). The previous inquiries characteristically attempted to balance mining and a specific conservation issue – the conservation of Abbott's Booby – and resulted in the creation of the Christmas Island National Park and enhanced rehabilitation after mining. Current problems arise from invasive species establishing on the island as a whole, not just the national park.

The major difference in focus between previous reviews and this one is that this report seeks to provide a comprehensive review by independent experts of all available information and to address a wide brief that focuses on the conservation of all the Island's unique values.

The Australian Territory of Christmas Island (10° 30' S, 105° 39' E) is a remote tropical oceanic island that covers an area of 135 km^2 and has 73 kilometres of coastline. It lies 360 km to the south of the Indonesian capital of Jakarta in the northern Indian Ocean and is the limestone capped peak of an ancient volcano that rises 5000 m above the sea floor. Surrounding the Island is a coral reef system that abruptly drops off to the abyssal plain.

Christmas Island was settled 120 years ago. Today the Settlement comprises a small community of around 1,300 to 1,500 people. In the past, the phosphate mining enterprise has been the basis of the island's economy. Today the island's economy is being overtaken by the activities of the Australian Government's Immigration Detention Centre (IDC) housing up to 2000 asylum seekers seeking entry to Australia. In the last decade, the Australian Government developed an Immigration Detention Centre (IDC) to house up to 2000 asylum seekers seeking entry to Australia. The Federal Attorney General's Department, DEWHA, the Shire of Christmas Island, and Phosphate Resources Limited all have control over areas on the Island. Around four per cent of the Island is taken up by the Settlement and associated facilities, 14 per cent by phosphate mining activities, 19 per cent is Unallocated Crown Land and 63 per cent is the rainforest-dominated Christmas Island National Park.

The Island has extraordinary terrestrial, subterranean and marine conservation values that are being diminished by management deficiencies and threats that are pervasive, chronic and increasing. Unfortunately, these problems will not have simple solutions.

Christmas Island has already suffered two confirmed extinctions (two native rodent species (*Rattus macleari* and *R. nativitatis*), and two probable extinctions, the Christmas Island Pipistrelle (*Pipistrellus murrayi*) and the Christmas Island Shrew *(Crocidura trichura*). Furthermore, the Island is currently witnessing further rapid declines in other important species. At risk of extinction in the short to medium term are its few remaining endemic reptile species, some of its endemic birds and, quite possibly, a fifth mammal, the Christmas Island Flying Fox (*Pteropus natalis)* which is the only remaining indigenous mammal on the island. It is also probable that seven plant species and several invertebrate species are extinct.

Christmas Island is also undergoing dramatic losses of the Island's endemic Red Crab[1] (*Gecarcoidea natalis)*. The Red Crab is not only the island's most conspicuous and remarkable species, but also the pivot of its unique ecology. The island's crab-dominated rainforests and remarkable ecological structure is of international significance and, along with the other biodiversity attributes of the island, is potentially a major tourist attraction. The EWG also recognised that the status of the Robber Crab (*Birgus latro*) is of concern. This species is the world's largest terrestrial arthropod, once numerous on many other tropical islands, but Christmas Island now has the only remaining significant population. There are also concerns for the island's remarkable stygofauna (fauna of underground water-filled voids).

The EWG recognises the pervasive effects of the many pressures on the Christmas Island ecosystem and the enormous challenges that these pose for implementing appropriate management responses. After an appraisal of several hundred reports, publications and documents relevant to Christmas Island, numerous consultations with experts and a visit to the Island, the EWG has arrived at a series of specific recommendations that are a product its own deliberations. Inevitably, some of the recommendations echo and endorse those made by others, and the EWG acknowledges the significant contributions by many researchers and Parks Australia staff who have made this synthesis possible. Attribution is assigned where appropriate in the report.

The EWG's recommendations set out the long-term and substantial changes that will be required for the successful future management of Christmas Island and its surrounding seas as a single ecological entity. We warn that a 'business as usual' approach in future will mean that management will fail and the extraordinary national asset that is Christmas Island's biodiversity will be replaced by a combination of many introduced and a few resilient native species. That outcome would be a failure in biodiversity conservation and would compromise the potentially secure economic future for the island as a tourist venue.

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 parlous state. The cause is the intrinsic vulnerability of Christmas Island, as an oceanic island, to the direct impact on its biodiversity by a succession of human-related changes to the landscape and by introductions of non-indigenous species. These factors have interacted to erode the ecological equilibrium, structure and functioning of the island, leading to several 'ecological cascades' of biodiversity loss. The fate of the Christmas Island Pipistrelle, which probably became extinct in 2009, is an example of and a symptom of this broad pattern of change and decline.

Recognition of the parlous decline of the Christmas Island Pipistrelle was the catalyst for this inquiry, particularly the report by Lumsden (Lumsden and Schultz 2009). For

[1] This species also occurs on the Cocos Keeling Islands where it may have been introduced from Christmas Island

some species, decline and extinction may be a simple straightforward process, with a readily identified single causal agent. In other cases, decline may be an indirect consequence of a compound of interacting factors, operating with varying intensities across time and space. The fate of the Christmas Island Pipistrelle was likely collateral damage associated with the broad-scale environmental changes triggered by the deliberate or – in most cases – inadvertent introduction of non-indigenous species to Christmas Island. Oceanic islands may be particularly susceptible to such perturbation, and Christmas Island has provided a text book example of 'invasional meltdown' (O'Dowd et al*.,* 2003), the collapse of existing ecological processes and structure, and of inter-specific relationships, because of the impacts of one or more invasive species.

In the case of Christmas Island, this meltdown, or 'ecological cascade' has been particularly potent because so much of the rainforest ecological function, structure and community composition of the Island's rainforest is determined by a single keystone species, the Red Crab, and this species has proven highly susceptible to one particular invasive species, the Yellow Crazy Ant (*Anoplolepis gracilipes*). Although these two species are currently the primary and largely antagonistic major drivers of the ecology of the island, many other species contribute to or are caught up as indirect victims or beneficiaries of the ecological change. Changes in the abundance of these other species may further increase the pace, scale and magnitude of ecosystem-wide change. In particular, introduced scale insects provided the key resource required to allow and maintain the development of supercolonies of Yellow Crazy Ants. Christmas Island has suffered multiple introductions, extending from its first settlement probably to the present day. Some of these introductions had direct or indirect detrimental impacts independent of the meltdown associated with Yellow Crazy Ants. For example, the very early extinction of Christmas Island's two native rodents was a consequence of escape to the island of black rats (*Rattus rattus*) and the novel diseases that accompanied them. The decline and loss of the Christmas Island Pipistrelle fits within the context of the reverberative ecological changes driven by one or more such invasive species. It may be that, ultimately, its loss can be traced back to a single introduced species, but the pathway for the impact may be complex, indirect and multi-pronged.

Here, we provide a speculative scenario that illustrates the network of factors that may have contributed to the Pipistrelle's loss.

1. Christmas Island was settled in the late 19th Century to allow exploitation of its phosphate deposits. Lack of quarantine from the early days of settlement and mining allows introduction and establishment of many non-indigenous species. Among them are many species of ants (including the Yellow Crazy Ant) and the Giant Centipede (*Scolopendra morsitans*).
2. Christmas Island undergoes severe ecological stress from activities associated with mining that has cleared over 25% of the island area at one time or another. This includes a widespread Island 'grid' survey.
3. Several species of scale insects were introduced more recently, perhaps associated with plants (possibly fruit trees) brought to the island. The scale insects established in low numbers on rainforest trees and spread throughout the island, increasing in abundance in the 1980s due to the lack of effective native predators or parasites.

4. Yellow Crazy Ants become the dominant ant species that is attracted to honeydew secreted by scale. The ants 'farm' the scale leading to a gradual increase in their numbers.
5. Excess honeydew from scale allows the extensive growth of sooty mould on the leaves of rainforest trees, stressing them further (stressed plants are more susceptible to insect attack).
6. Between 1984 and 1994, the Christmas Island Pipistrelle starts to decline, perhaps because of an increase in Yellow Crazy Ant numbers before the first supercolonies were noted.
7. Feedback mechanisms cause population explosions in both scale and Yellow Crazy Ants during the late 1990s. Yellow Crazy Ants form supercolonies with multiple queens. Scale and ant outbreaks increase in extent and number.
8. Supercolonies of Yellow Crazy Ants kill significant numbers of Red Crabs, leading to changes in rainforest structure, including understorey and litter characteristics.
9. Either directly (through reduced predation by Red Crabs) or indirectly (because of changed vegetation characteristics due to decline in Red Crabs), some additional introduced invertebrates (such as the Giant Centipede) increase in abundance, while some native invertebrates decreased in abundance (perhaps reducing the potential food supply for the Pipistrelle).
10. Reduced abundance of native invertebrates that provide food for the Pipistrelle leads to lower reproductive success. At roost sites, Pipistrelles are killed or disturbed by the increased abundance of Yellow Crazy Ants and/or Giant Centipedes.

Parts of this chain are speculative, or supported mostly by inference or limited evidence. We present this scenario to emphasise the interactions and multiple, indirect pathways that may lead, unforeseen, from one or more introductions to severe consequences for apparently ecologically distant species. This observation reiterates our principal finding that the conservation of biodiversity on Christmas Island (or any other island) pivots around the prevention of introductions of non-indigenous species and the control and eradication of existing introduced species.

Introductions have been a critical factor at several stages in this and other plausible 'ecological cascades' as well as in direct predatory impacts. Many of the introductions are due to inadequate quarantine and they have had and continue to have severe deleterious environmental effects. It is of great concern that the island still lacks effective quarantine and, unless that is addressed, further introductions are inevitable and will accelerate decline in the Island's biodiversity.

The speculative but quite plausible 'ecological cascade' scenario provided above is a stark example of how apparently small and unrelated events can have unexpected major consequences. It also illustrates the ecological complexity of even the comparatively simple ecosystem of Christmas Island.

For the Christmas Island Pipistrelle, actions over the last 12 months have been too little too late and have failed to save it from extinction, an outcome that is deeply regrettable. Its extinction was predicted several years earlier, and options for its survival were largely foreclosed soon after. Its loss is now a lesson and the EWG has sought in this report to identify changes that must be made to ensure that other extinctions will not follow.

Context of Recommendations

The EWG notes that, by happenstance, this report is contemporaneous with a number of other Christmas Island-related issues that are under consideration. At the time of writing, a decision about the future of mining on the Island is pending, an inter-departmental task force is considering the future management of the island, and large numbers of illegal entries to Australia of people claiming refugee status is occurring, precipitating the rapid expansion of the Immigration Detention Centre. A National Heritage assessment is underway, as is consideration of the recommendation from the EWG's Interim Report to assess the Island and its surrounding seas for listing a threatened ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In addition, a Park Management Plan and a multi-species regional recovery plan are being developed. Faced with this complexity, the EWG has focused entirely on its amended terms of reference.

RECOMMENDATIONS

The recommendations in this report provide strategies that can be followed to greatly improve management of biodiversity on Christmas Island. Both the original and revised terms of reference are reported on, but specific recommendations in the interim report pertaining to the Christmas Island Pipistrelle that have already been acted on now appear as Appendix 1 of this report.

The EWG's recommendations are set in a hierarchy of actions that are essential for achieving appropriate management outcomes. These actions can be categorised as those that

- Protect the integrity of Christmas Island ecosystems from further unwanted introductions, prevent additional detrimental changes to the landscape and establish better environmental governance and management frameworks for the island.
- Manage the island's ecological processes so as to prevent further loss of biodiversity.
- Can be taken immediately to prevent or slow biodiversity loss.

The EWG has given each recommendation a priority ranking. The EWG:

- Used an outcomes model with time lines to set priorities (Appendix 13).
- Stresses that its priority setting is to facilitate effective immediate management.
- Notes that the majority of its recommendations are given a high priority; this is because the island's biodiversity is well down the pathway towards collapse and most recommendations require urgent and immediate action.
- Considers that implementation of all recommendations will be essential in the long term if a satisfactory outcome is to be achieved.
- Recognises that recommendations under the second and third dot points in the categories of actions above will evolve if used in the adaptive management framework that is strongly recommended.

Protect the integrity of Christmas Island ecosystems from further unwanted introductions, prevent additional detrimental changes to the landscape and establish better environmental governance and management frameworks for the island.

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 implementing high quality quarantine, and reforming island governance and the funding systems for conservation.

This requires:

- **Recommendation 1: (High priority)** Biosecurity management on Christmas Island be upgraded urgently to a standard commensurate with the Island biodiversity values using Chevron Australia's Barrow Island Quarantine Management System as a model (see sections 3.3.4, 4.2, 4.5.4 and 4.6).
- **Recommendation 2: (High priority)** The governance of Christmas Island be modified so that environmental governance, including matters of biological protection, conservation management and quarantine, is brought under a single authority with both the power and the resources to be effective (see sections 4.2, 4.3.1 and 4.6).
- **Recommendation 3 (High priority)** The pressures on the environment posed by the increasing use of the Island as an Immigration Detention Centre and the continuation of mining be recognised and minimised or adequately managed through new governance arrangements, with biodiversity conservation being the highest priority. This must include much better management of the roads between the Settlement and the IDC to greatly reduce the high level crab deaths due to vehicles (sections 3.2, 3.3.4, 4.5.7 and 4.11).
- **Recommendation 4: (High priority)** The utilisation and management of surface and subterranean water and coastal marine waters be addressed as part of improved island governance (section 4.5.7).

  In practice this recommendation should include the following:

  1. Urgent completion of a Service Delivery Agreement between the Attorney General's Department and the Western Australian Department of Water so that the water supply on Christmas Island can be properly regulated.
  2. Proclamation of Christmas Island as a water reserve under relevant WA legislation and development of a Water Resource Management Plan ensuring that water allocation is dependent on a licence with suitable conditions issued by the Department of Water in consultation with the authority proposed in Recommendation 2. Water supply to be permitted only where it is sustainable for both human use and environmental needs.
  3. Development of a groundwater model for Christmas Island and installation of new monitoring bores as required to ensure model calibration and the sustainability of water use.
  4. Sharing of costs associated with implementation of the above recommendations between the Commonwealth government and the WA Water Corporation.
- **Recommendation 5: Priority (High priority)** Environmental management of the island, including quarantine, research, restoration, environmental approvals and associated compliance, be improved through a single line budget, an appropriate level of funding and management accountability supported by a scientific advisory system and an appropriate research facility (section 4.3.1, 4.5.3 and section 6).

- **Recommendation 6: Priority (High priority)** Where commercial leases or other commercial regulatory instruments exist or are proposed, their negotiation should include additional resources to research and manage areas or matters of high conservation importance (sections 4.5.6 and section 6 lesson 5).
- **Recommendation 7: (High priority)** A science management strategy be developed for Christmas Island as a whole and the management lessons identified elsewhere in this report become part of this process and a Christmas Island Conservation Research Centre be established (sections 4.3.1, 4.5.3 and 4.13).

Management of the island's ecological processes so as to prevent further loss of biodiversity

The approaches to management on the Island have been partially successful in reducing some ecological impacts and monitoring change, with the Yellow Crazy Ant control program, the Island Wide Survey (IWS) and the current vegetation rehabilitation program being examples.

However, control of the major threat posed by Yellow Crazy Ants through baiting indefinitely with Fipronil is not a satisfactory long-term solution, and there is a need to develop additional approaches. This group of recommendations addresses this and related issues.

The working group recommends that:

- **Recommendation 8: (High priority)** In the absence of any alternative, baiting Yellow Crazy Ant supercolonies with Fipronil continues as a short-term control measure, but with greatly enhanced monitoring of its non-target effects (sections 4.4 and 4.5.3).
- **Recommendation 9: (High priority)** The initial steps taken already to explore biological control of the introduced scale insects be accelerated and biological control trials be started as soon as possible (sections 4.4, 4.5.3, 4.11.1). In addition helicopter bait delivery trials be conducted over larger areas of the island with the aim of preventing rapid re-establishment of Yellow Crazy Ant supercolonies. These and other initiatives should be implemented within an adaptive management and integrated pest control framework (sections 4.4 and 4.11.1).
- **Recommendation 10: (High priority)** Monitoring of biodiversity condition and trends be continued but with a high priority for continuous improvement and adaptive management that is informed by the independent scientific advisory system of Recommendations 5 and 7 (sections 4.3.2, 4.13).
- **Recommendation 11: (Medium to High priority)** Threats to the island's subterranean fauna and marine ecosystems be assessed and appropriate processes developed to address them (section 4.14).
- **Recommendation 12: (High priority)** A comprehensive review that builds on this report be commissioned to determine gaps that must be filled in our understanding of the biology and population ecology of Red Crabs. Subsequently commissioned research needs to focus on informing adaptive management that concentrates on crab population enhancement and reestablishment in areas from which they have been eliminated (sections 4.4, 4.9.2 and 4.11.1).

- **Recommendation 13:** (**Medium priority**) Red Crabs be re-introduced experimentally to ghost forests[2] (section 4.4).
- **Recommendation 14: (High priority)** Robber Crabs be given a high conservation priority and a study of their population ecology and key threats be undertaken as soon as possible (section 4.11.2).
- **Recommendation 15: (High priority)** Eradication of Black Rats and Feral Cats from Christmas Island be carried out as soon as possible in a coordinated project and research into rat eradication commence as soon as possible (sections 4.5.2.2 and 4.9.2).
- **Recommendation 16: (High Priority)** A comprehensive program of invertebrate biodiversity research be undertaken resolved to a high taxonomic level and that the definitive collection of Christmas Island invertebrates be housed in a recognised public fauna collection with only non-critical voucher specimens retained on Christmas Island (section 4.13).
- **Recommendation 17: (Medium priority)** Potential ‘sleeper’ species of both exotic plants and animals be identified and those species identified as being a high threat to the island’s biodiversity be eradicated (section 4.5.1).

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 18: (High priority)** Sampling take place to establish baseline levels of prevalence of pathogens, disease and parasites in selected endemic animals and plants (section 4.5.4).
- **Recommendation 19: (High priority)** Sampling take place to establish 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, Wolf Snakes and Giant African Land Snails) (section 4.5.4).
- **Recommendation 20: (Medium priority)** A program of regular and robust monitoring of these pathogen levels be developed (section 4.5.4).
- **Recommendation 21: (Medium priority)** The development of a response protocol and framework associated with the monitoring program be undertaken (section 4.5.4).

Management actions that can be taken immediately to prevent or slow biodiversity loss

Christmas Island Pipistrelle

Recommendations made in the Interim Report concerning the Christmas Island Pipistrelle are now, with some modification, provided in Appendix 1

- **Recommendation 22 (High priority)** A program for checking for the presence of the Pipistrelle be continued for the next two years, with a response protocol in place for implementation should a detection occur (Section 4.7).

Land clearance for mining and other purposes

- **Recommendation 23 (High priority)** All proposals for land clearance and resource extraction on the island be subject to rigorous assessment and amendment where necessary to prevent significant impact on Island

[2] Ghost forests are forest from which the resident Red Crabs have been eliminated by the direct of indirect impact of Yellow Crazy Ants

biodiversity. Where land clearance and resource extraction is approved associated conditions should be locally monitored and enforced (section 4.5.6).

The Endemic Flying Fox

- **Recommendation 24**: **(High priority)** The costs / benefits and need for a flying fox captive breeding program be considered, for establishment, if recommended, by December 2010 (section 4.10).
- **Recommendation 25**: **(High priority)** Appropriate monitoring and targeted research be conducted to identify major threatening processes for the endemic flying fox (Section 4.10).

Tropicbirds

- **Recommendation 26: (High priority)** Measures be implemented immediately to exclude Cats from Red-tailed Tropicbird nesting areas along the Settlement shoreline (section 4.9.2).

Highly Threatened Endemic Reptiles

- **Recommendation 27: (High priority)** The recently established captive breeding program for the Blue-tailed Skink, Lister's Gecko and Forest Skink be continued (section 4.8).
- **Recommendation 28: (High priority)** Appropriate monitoring and/or targeted research be conducted to identify major threatening processes for endemic reptiles (section 4.8).

The Scale Insect – Yellow Crazy Ant Nexus

- **Recommendation 29: (High priority)** Fundamental investigations continue and be augmented by adaptive management and aspects of Integrated Pest Control experimental work to develop cost-effective methods to break the scale insect - Yellow Crazy Ant mutualistic dependence (sections 4.4 and 4.5.3).

Conserving Christmas Island

- **Recommendation 30: (High priority)** "Christmas Island and its surrounding seas" be considered for listing as a threatened ecological community under the Environment Protection and Biodiversity Conservation Act (section 5.1).

Communicating the Problem and Management Responses

- **Recommendation 31: (High priority)** An appropriate community communications program relating to the recovery of Christmas Island biodiversity and re-establishing key ecological relationships be planned and executed (sections 4.3.1 and 5.2).

Findings with wider applicability

- **Recommendation 32: (High priority for DEWHA as a whole)**

There are important lessons that can be drawn from the current and continuing biodiversity crash on Christmas Island. These have much wider applicability to biodiversity management in Australia and beyond (section 6.0). These lessons highlight the need for:

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 continuity in conservation management, with appropriate monitoring and adaptive capacity.

3. Development and implementation of a management prioritisation framework.
4. More systematic and streamlined processes for identification and review of threatening processes and lists of threatened species, including those in conservation reserves.
5. The application of suitable conditions on developments to create additional resources to manage areas or matters of high biodiversity conservation importance.
6. Development and maintenance of a secure funding stream for the conservation management of all biodiversity aspects of Parks Australia reserves.
7. Development and maintenance of robust, integrated monitoring programs for Parks Australia reserves, including for threatened species, ecosystem health and other matters of particular conservation significance, the provision of annual reports on such monitoring and using monitoring as a basis for ongoing adaptive management.
8. Improved monitoring and 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.
10. Establishment of conservation reserves is a useful step towards biodiversity conservation, but must be accompanied by appropriate management for biodiversity conservation outcomes; this must include direct assessment of threats (especially by introduced biota), biodiversity condition and trends, and of management effectiveness.

1.0 INTRODUCTION

A chronology of events that culminated in this report is set out in Appendix 7. The principal triggering event was recognition of the probable extinction of the Christmas Island Pipistrelle, the island's only insectivorous bat; this has now occurred. This report will demonstrate that its demise reflects the 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 16 February 2009 (Appendix 7). This followed advice provided to the Minister by the Threatened Species Scientific Committee, at the Minister's request, on 3 February 2009 in response to a report by Lumsden and Schulz (2009). The minutes of the committee and the Minister's subsequent press release are provided in Appendix 7.

The EWG provided an interim report to the Minister on 28 June 2009 and the Minister responded on 1 July 2009. The immediate action was an attempt to establish a captive population of the Pipistrelle, an enterprise that failed (see Appendix 1).

The Minister subsequently requested that the EWG complete its report with the addition of two members and with expanded terms of reference. The new members brought marine and invertebrate expertise to the EWG. This report addresses the new terms of reference while retaining relevant comment from the interim report. Some sections of the interim report that are no longer matters for action are referenced in this report and placed in appendices.

All but the amended term of reference 2 are resolved by this report. Amended term of reference 2 will require a term that is greater than the EWG however the processes we propose will ensure its long term resolution.

1.1 INITIAL 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.

1.2 AMENDED MEMBERSHIP AND AMENDED TERMS OF REFERENCE

Members:

Chair –
Associate Professor Beeton (TSSC Chair[3]): Ecology and management
Members -

- Dr Andrew Burbidge (Previous TSSC Chair): Ecology, conservation management and island management
- Prof Gordon Grigg (Previous TSSC Member): Ecology and physiology
- Professor Peter Harrison (Additional member, TSSC Member): Marine ecology and management
- Dr Ric How: Conservation biology and taxonomy
- Dr Bill Humphreys (Additional member, TSSC Member): Invertebrate taxonomy and ecology
- Mr Norm McKenzie: Bat ecology and wildlife ecology
- Dr John Woinarski (TSSC Member):Tropical ecology and birds.

Amended terms of reference:

The expert working group is established by the Minister, and will report to him through the Director of National Parks. The working group will:

1. Review the threats to biodiversity on Christmas Island, including the Christmas Island Pipistrelle.
2. 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.
3. 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.
4. Develop the way forward including identifying all threats, drivers of change and pathways to recovery for biodiversity on the Island.
5. Identify the next steps in understanding ecosystem function.
6. Identify strategies for prioritising management actions.
7. Provide such advice as deemed necessary to improve the development of the regional recovery plan, and the development of a research plan for the Island.

2.0 APPROACH TO ADDRESSING THE TERMS OF REFERENCE

2.1 PHASE 1

The expert working group was established immediately following the Minister's announcement. The Department allocated staff to support the working group and,

[3] TSSC – Threatened Species Scientific Committee established under the *Environment Protection and Biodiversity Conservation Act 1996*

following consultation with the Chair, all relevant information available about Christmas Island was assembled, a process that has been ongoing throughout the EWG's tenure. This material was distributed among members of the working group (see documentation list Appendix 11). 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 and subsequent 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 and circulated to members, 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, 2009. The program of work on the island is presented in Appendix 8. After the island visit the working group met six times by teleconference and developed the interim report, representing progress made up to June 2009. The Interim Report was released on the Department's website on 1 July 2009 at the same time as the Minister's response. See

http://www.environment.gov.au/parks/publications/christmas/interim-report.htmlhttp://www.environment.gov.au/minister/garrett/2009/pubs/mr20090701a.pdf

A number of critical issues remained outstanding and these are incorporated into this final report. In addition, new information was drawn to the EWG's attention through the public and expert responses to the interim report.

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

Outstanding work at the time of writing the interim report is presented in Table 1.

Table 1 Completed and remaining tasks at the times of presentation of the Interim Report (20/6/09) and the Final Report

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 at the time of the interim report and comment on current status :

- 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. Not complete not reported here
- 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. Not done but should be reviewed in the future
- Finalise assessment of Christmas Island Pipistrelle after assays are carried out on museum specimens and live animals to test for disease. Not complete or reported here
- 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. Not complete not reported here

2.2 PHASE 2

The EWG reconvened by teleconference on 27th October 2009 to review the amended terms of reference, review public comments on the Interim Report and plan the finalisation of its report. The remaining tasks (Table 1) were reviewed and additional tasks identified from the amended terms of reference. Subsequent teleconferences were held on 13th November, 27th November, 4th December, 18th December, 18th January 2010, 1st February, 18th February. As previously, all teleconferences were minuted and action items identified and allocated to members. Throughout this phase additional experts were consulted and additional documents identified and reviewed. The complete document list is provided at Appendix 11.

This final report was developed from contributions by all members and finalised on the 25th of March 2010.

3.0 CHRISTMAS ISLAND OVERVIEW

3.1 BACKGROUND INFORMATION

3.1.1 Biophysical

Christmas Island (10° 30' S, 105° 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

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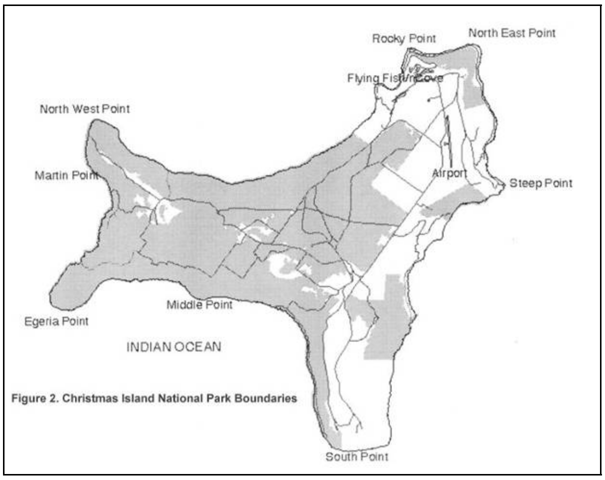

Figure 2 Map of Christmas Island (From Christmas Island Management Plan)

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

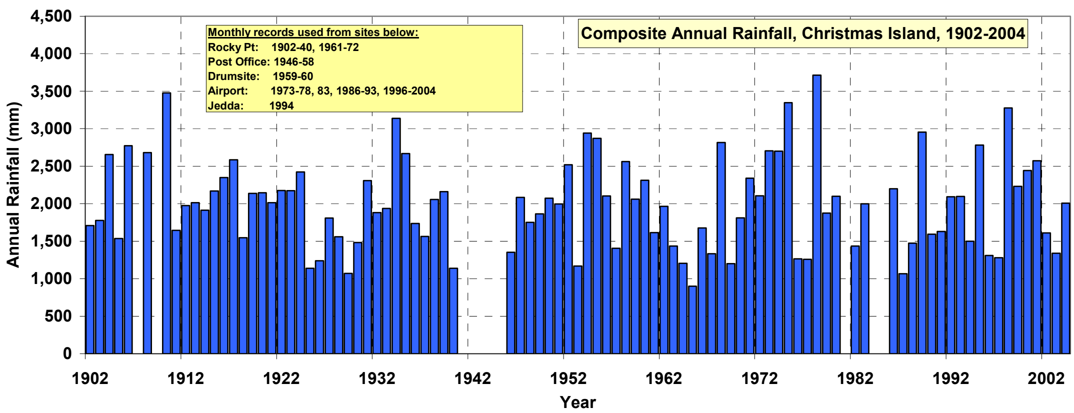

Figure 3 Composite rainfall pattern 1902 to 2004

The island is composed of limestone surrounded by a coral reef on the top of a basaltic volcanic seamount. The island is step terraced, reflecting its origin and changing sea levels (both global and orogenic) over the past several million 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, in The Dales and in places on the island's eastern and northern coastal slopes, basaltic rocks are exposed. These intersections result in springs and so are associated with surface water.

The island is on a tectonic plate moving northwards a few centimetres a year that puts its present location is at least 700 km north of where it first emerged from the sea. Rising to 330 m above sea level, the island is the tip of a 5000 m high seamount that emerged in the late Miocene. Eustatic changes have resulted in the deposition of carbonates, interbedded with volcanics in places, and a sequence of seven carbonate terraces rising to the plateau.

Each terrace was formed by the combined effects of fringing reef development and subsequent erosion of a sea cliff following the next fall of relative sea level. Examples of more recent faulting with undersea lava flows are evident. Caves and sinkholes typical of limestone formations occur at many points on the island and mixing zone karst features typical of carbonate islands, including anchialine cave development, fringe the island at both contemporary and historic sea levels. These form the habitats for the island's troglofauna and stygofauna and other cavernicolous animals such as Christmas Island Glossy Swiftlets (*Collocalia linchi natalis*).

The processes that gave rise to Christmas Island also contributed to the formation of numerous subsea seamounts that remain associated with Christmas Island and the biodiversity values of its surrounding seas.

The phosphorites commonly found on coral islands are now believed to result from lagoonal marine sediments forming during cycles of either uplift and subsidence or sea level change. This appears to be the case for Christmas Island. 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 seasonal upwelling areas that are rich in pelagic fish, including whale sharks (*Rhincodon typus*), and support the island's significant populations of seabirds. The biological values of the nearby seamounts are poorly understood but are likely to be significant.

The single global spawning ground of Southern Bluefin Tuna (*Thunnus maccoyii)* lies between Java and northern Western Australia and includes waters east and north of Christmas Island.

3.2 Social and Economic Matters

Until recently Christmas Island has a resident population of 1,300 – 1,500 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, the detention and processing of asylum seekers, 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 island access and accommodation are extremely limiting at present.

Other than the activities of the Immigration Detention Centre (IDC), the island's longer term economic future will either be a decline and depopulation as phosphate is depleted and ecological collapse occurs, or become supported by biodiversity-based tourism, a future that will be possible only if the island undergoes ecological restoration.

Current events leading to a very rapid expansion of the Immigration Detention Centre (IDC) and associated building programs are of concern to the EWG as they could lead to continuing catastrophic breaches of quarantine. The EWG communicated this concern to the Minister in late December 2009 (**Recommendation 3**).

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 that has resulted in a fragmentation of governance of the island and consequential confusion about responsibilities on matters that 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 (63.0%)
Unallocated Crown Land (UCL)	2670 (19.2%)
Phosphate Resources Limited Mine Lease	1900 (13.7%)
Residential / Industrial / Future Urban zones	300 (2.1%)
Airport	165 (1.2%)
CI Resort	47 (0.3%)
Immigration Detention Centre (IDC)	43 (0.3%)
Golf Course	14 (0.1%)

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, populations on isolated islands 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. In having derived all their flora and fauna by random colonisation, 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 that arrive randomly.

The terrestrial vegetation communities of Christmas Island comprise several types of rainforest, dominated by plants that 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 to the island. Both 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 recorded 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 (Dutson et al., 2009) and BirdLife International have included Christmas Island in their lists of 'Important Bird Areas', partly because of the seabird populations.

The subterranean environment of Christmas Island is diverse and includes freshwater, marine, anchialine (a salinity stratified water body with limited exposure to the surface and having subterranean connection to the ocean) and terrestrial habitats (Humphreys and Eberhard 1998). 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 partly because it supports the only recorded co-occurrence of epicontinental and seamount anchialine faunas (Humphreys and Danielopol, 2006). The cave fauna comprises Christmas Island Glossy Swiftlets, and a diverse assemblage of terrestrial and aquatic invertebrates, including a number of rare and endemic species of high conservation significance (Humphreys and Eberhard, 1998). The aquatic fauna includes a number of remarkable endemic species: a subterranean shrimp (*Procaris noelensis*) of a genus known elsewhere only from three seamounts in the Atlantic and Pacific Oceans (Bruce and Davie, 2006), and the first living examples of a seed shrimp, *Microceratina martensi,* known elsewhere from Late Cretaceous fossils, a so-called living fossil (Namiotko et al., 2004). Notable amongst the troglofauna are terrestrial isopods (Humphreys and Eberhard, 1998), an endemic blind scorpion (*Liocheles polisorum*, one of two blind scorpions in Australia and 20 worldwide, mostly in Mexico), a spider and a new species of cockroach, *Metanocticola christmasensis*, a genus endemic to the island (Roth, 1999).

In the absence of surface runoff, nearly all the water entering the aquifer is discharged as submarine groundwater discharge that will influence the upper 100 m of the marine environment in places. As well as maintaining the dynamics of the anchialine fringe skirting the island, this massive freshwater discharge is likely to locally influence the marine biota on the periphery of the anchialine system through salinity and nutrient effects, and may support novel biota.

The shallow marine environment surrounding Christmas Island is extremely limited due to the steep submarine topography and, this combined with its geographic isolation and small size, limits the diversity of the shallow marine species present. Some 622 marine fish species from 80 families have been recorded around Christmas Island, including four endemic reef fish species and 11 hybrid coral reef fishes (Allen et al*.,* 2007; Hobbs et al*.,* 2009a). This marine hybrid hotspot is highly significant as it represents the greatest number of hybrid fish recorded from any marine location and indicates that Christmas Island and Cocos (Keeling) Islands are the marine equivalent of terrestrial suture zones between different biogeographic provinces (Hobbs et al., 2009a). Whale sharks (*Rhincodon typus*) use the waters around Christmas Island for foraging and as an important juvenile habitat, and feed on Red Crab and other planktonic larvae (Hobbs et al*.,* 2009b).

Small numbers of Vulnerable Green Turtles (*Chelonia mydas*), and more rarely Hawksbill Turtles (*Eretmochelys imbricata*), nest on Christmas Island, and Endangered Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) Turtles are also thought to forage in its marine habitats (Brewer et al., 2009). Short-beaked Common dolphins (*Delphinus delphis*) and Long-snouted Spinner dolphins (*Stenella longirostris*) have been recorded feeding and possibly breeding around Christmas Island, while three (possibly four) species of whales have been sighted infrequently near the island (Brewer et al., 2009). Other cetacean species are likely to use, or occur in, the marine environments around Christmas Island, but there have been no dedicated published surveys to determine cetacean distribution or abundance in this region.

The marine invertebrate fauna recorded around Christmas Island includes at least 89 reef-building scleractinian coral species (Done and Marsh, 2000), more than 200 species of decapod crustaceans, and about 490 mollusc and 90 echinoderm species including some endemic species (summarised in Brewer et al., 2009). Further detailed surveys are needed to document the full extent of marine biodiversity around Christmas Island. Mass coral mortality has periodically reduced the coral fauna and habitats available for other associated reef species, and this is likely to have affected the numbers of species recorded in the previous comprehensive marine survey by the WA Museum in 1987. Up to 75% live coral cover has recently been recorded at some shallow reef sites around Christmas Island, highlighting the resilience of these isolated coral assemblages (Brewer et al., 2009). Future surveys are likely to increase the numbers of species recorded, particularly for reef corals and coral-associated species.

The deeper marine habitats surrounding the Christmas Island and other seamounts in this region are largely unknown, but are considered likely to include a range of unique habitats and diverse marine assemblages supported by seasonally high productivity (Brewer et al., 2009). This high productivity supports seasonal migrations of whale sharks and other large pelagic fish, and may enhance the survival of larvae of the commercially important and possibly threatened Southern Bluefin Tuna.

Threats to marine biota and habitats around Christmas Island include loss of corals and reef organisms from mass coral bleaching, and coral disease (Hobbs and Frisch, 2010) and climate change altering seawater chemistry (ocean 'acidification'), temperature regimes and currents that could affect the recruitment of pelagic species and larvae of Red Crabs and other land crab species. Further development on Christmas Island is likely to increase fishing pressure on pelagic species, increase the risk of eutrophication, and may lead to physical alteration of the coastal environment to accommodate increased vessel activity. In addition, increased vessel traffic increases the risk of marine pollution including the introduction of exotic marine species from release of ballast water, which again highlights the need for enhanced quarantine protection for both marine and terrestrial environments.

Oceanic islands are known to be vulnerable to invasion by introduced plants, animals and microorganisms. Often, 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 and impact 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 some 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 several 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 provided at Appendix 9.

The impact of these animal introductions is reflected in the extinctions of three, probably four, endemic vertebrates on Christmas Island in the last few decades and the imminent extinctions of several more endemic vertebrates that have been in decline over the last two decades. Currently there are 14 species of animals and three species of plants recognised as threatened under the EPBC Act. In addition, the Yellow Crazy Ant and other 'Tramp Ants' on the island are covered by a National listing as a 'Key Threatening Process' under the EPBC Act and a generic Threat Abatement Plan has been prepared.

The EWG is of the view that some Christmas Island species listed as vulnerable should be moved to a higher category of threat and that there are many other species that may warrant listing as threatened. An alternative may be that the entire island is listed as a threatened ecological community and a comprehensive regional recovery plan is funded and implemented.

Additionally, there have been recent sightings or captures of two lizard taxa that were presumed to have become extinct (*Lepidodactylus listeri, Emoia atrocostata*). Neither of these taxa had been listed as threatened species.

Table 3 **Known chronology of some significant animal introductions and jurisdictional governance**

	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 2nd 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 in 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 Christmas Island
2000s	2004 trend of increasing numbers detected					First trials of feral cat bait. Cat management plan drafted	2002 – Christmas Island excised from Australia's migration zone 2005 – construction of detention centre commences

There has been a long history of vegetation clearance and loss of habitat for fauna and flora on the island. This has been followed by limited rehabilitation, both natural and by human intervention. The most notable cause has been 100 years of phosphate mining, which is still continuing and which has directly affected at least 25 per cent of the area of the Island. Clearing reached a peak with the 1969 mining exploration grid line survey that covered most of the island with a cleared rectangular grid pattern, each grid line being up to nine metres wide with lines set between 30-120 metres apart (Corbett et al., 2003). In addition, during the 1970s, the British Phosphate Commission cleared all then existing mining leases completely (see section 4.5.6).

Natural disturbance occurs also, particularly associated with occasional intense storm events. Local islanders reported that the most recent extensive natural vegetation disturbance was 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 Red Crab – rainforest community that is not found anywhere else, the unique stygofauna, a significant number of endemic species including marine fish hybrids, the island's importance as a seabird rookery and as an aggregation site for juvenile threatened whale sharks (Hobbs et al., 2009b). The threat posed by introduced species is indicated by the number of exotic (introduced) species already on the island, recent extinctions and measured ecological change (Table 3).

3.3.3 Ecological uniqueness and ecological shift

The principal ecological shifts that have occurred in recent times on Christmas Island are land clearance, phosphate soils removal, the establishment of Yellow Crazy Ant (*Anoplolepis gracilipes*) supercolonies, and interaction between these ants and scale insects. The extreme abundance of Yellow Crazy Ants, driven by the availability of food (honeydew) from scale insects, has resulted in the loss of land crabs from areas where ant supercolonies have developed. The loss of crabs has led to major changes in forest structure (O'Dowd et al., 1999, 2003). These changes, if not arrested, will lead to the effective destruction of the unique Christmas Island terrestrial and possibly subterranean ecosystems.

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 recognisable forms through the action of Yellow Crazy Ant supercolonies and their ecological effects (Davis et al., 2008). These three forms are:

1. the original, unaltered forest 'gardened' by Red Crabs (Figure 4),
2. forest occupied by supercolonies 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 been extirpated while migrating through ant infested areas (Figure 6).

Consequently Christmas Island is now a complex mosaic of these forest types plus the residual altered landscapes from phosphate mining, which has destroyed significant areas of rainforest. Many of the mined areas remain as almost bare, un-vegetated rock (Figure 7, 9 and Appendix 14).

In the working group's discussion with interested members of the community, there was agreement among those with more than a decade's experience of the island environment that there has been a decline in Red Crab recruitment. These observations are not supported by any quantitative data. However, it is possible that both the Red Crab and the Robber Crab, together with a number of other land crabs, could become threatened through a complex cascade similar to that hypothesised for the Pipistrelle.

Figure 4 Photo of typical Red Crab 'gardened' forest, exhibiting minimal understorey or leaf litter and very few weeds.

Figure 5 Photo of a Yellow Crazy Ant supercolony 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 for much better biosecurity and for high-quality monitoring and ongoing adaptive management strategies.

Notwithstanding these observations, the problem remains that we have little detailed understanding of what has triggered the major ecological changes. In the case of Yellow Crazy Ants, it is likely that the introduction or eruption of one or more species of scale insect and the establishment and spread of strong mutualism between a number of scale insects and Yellow Crazy Ants may have been the trigger (O'Dowd et al., 1999, 2003; Abbott, 2004; Abbott and Green, 2007). 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). This interaction has resulted 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). Similar outbreaks have occurred on Palmyra Atoll and Samoa in the Pacific Ocean and in the Seychelles in the eastern Indian Ocean (Greenslade, 2008). Yellow Crazy Ants have also interacted with scale insects in Java, the Seychelles and Tokelau (Abbott and Green, 2007).

Experience gained from these other outbreaks shows the way ahead for dealing with it on Christmas Island. The ant 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 prey upon the scale insects (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 9. On Hawaii, severe reduction in native invertebrate fauna has occurred due to the lack of co-evolved defences of the endemic terrestrial fauna against exotic ants (Reimer, 1994).

On Christmas Island two spider species common when described in 1900 have not been found during a recent targeted collection. Among ants on Christmas Island, the Fire Ant and Big Headed Ant are considered a serious threat to biodiversity, and *Strumigenys* ants are specialist hunters on springtails (Framenau and Thomas, 2008), typically a principal element of the litter fauna. Greenslade (2008) reviewed ant-scale interactions on Coral Sea sand islets and elsewhere and reported that in some cases there had been a decline of ants and scale without intervention. She suggested climate variability leading to tree stress as being the primary cause and cautioned against using biocontrol measures, as once used they are irreversible. However, the islands discussed in her review are small and have very simple ecosystems, usually with a single species of tree. The EWG's view is that the much larger and more complex Christmas Island is a different case with no evidence of ant decline without intervention and that intervention to control both ants and scale insects is absolutely necessary.

Decomposition of and consumption by crabs of plant material appears to provide the principal nutrient pathway of Christmas Island's rainforest ecosystems (O'Dowd and Lake, 1989, 1990, 1991). The decomposer food chain is dominated, visually, by the breakdown of leaf litter and fruit by the crab community; however, the role of fungi and microorganisms, and of invertebrates such as springtails and woodlice, in facilitating this nutrient cycle has not been investigated. This is a significant knowledge gap and a documentation of the fungal and mycophagous communities, and of invertebrate detritivores, is essential to understanding the rainforest ecosystems and their recovery. This strongly suggests the need for an experimental and adaptive management approach, which will be discussed later.

3.3.4 Biosecurity

Many of the current biodiversity conservation problems on Christmas Island are due to the introduced species of animals, plants and microorganisms that arrived with humans and their equipment and food. While many 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, biosecurity remains inadequate, as detailed below and evidenced by the establishment of the Tree Sparrow in the 1980s and the Wolf Snake as recently as 1987. 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's legislated role under the Quarantine Act 1908 is to apply quarantine measures to protect human, animal and plant health. It is not specifically empowered with a biodiversity protection role. Quarantine arrangements for Christmas Island are in place both to deliver effective protection for human, animal and plant health on Christmas Island, and to ensure that the mainland is protected from pests and diseases present on the Islands but absent from the mainland. AQIS is a fee-for-service organisation. Christmas Island (with the Cocos-Keeling Islands) has no agriculture or other industries to support fees for a quarantine service and is unique in that quarantine of incoming goods and people is required only to protect biodiversity. The Attorney General's Department currently pays AQIS about $140,000 per annum as a contribution towards the cost of quarantine. During 2008-09, AQIS's expenditure on Christmas Island exceeded $500,000. Australian Customs also has a role to play on Christmas Island but this does not include biosecurity. Present quarantine arrangements are entirely unsatisfactory and ineffective through being severely under-resourced.

Significant quantities of materials and food are imported to Christmas Island each year. Much comes from the Australian mainland but some, e.g. vegetables, comes from Asia. Information from May 2009 shows that during a six-week period at the port, about 35 containers can be expected to arrive from Australia and three from Asia. This is beyond what current quarantine staff and facilities can handle. However, there has been a significant increase in shipments since then, associated mainly with the increased number of people in the IDC and the consequent need to expand island accommodation and infrastructure. There has been no increased level of quarantine surveillance associated with this expansion. 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 first arrival was in December 2009.

The number of staff employed in quarantine operations on the Island varies in accordance with demand for services and is appropriate for the workload. However this is a small number with one or two AQIS staff (supported by some casual staff) 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 staff, one may be away or one may be in the process of being replaced, meaning that the full load of inspections often has to be carried by a single person.
- During its visit the EWG was informed that AQIS may be reducing the already small staff resources by 25%, from 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. (These facilities are customarily privately owned and operated through Australia).
- Fumigation and wash down facilities are not available (Again customarily privately owned facilities).
- 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 understood to be frequent.
- Major works, such as the construction of the IDC, have seriously and further overloaded the capacity of the quarantine system, such as it is.
- The large number of illegal arrivals at the island by boat poses a significant quarantine threat and requires specific quarantine protocols. The EWG has not been able to establish whether or not any such protocols exist.
- The importation of large construction equipment, construction materials and entire dwellings significantly increases the probability of quarantine breaches.

Data on organisms detected during inspections are not recorded. We were told that soil, ants, 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 happened on Guam, would have a catastrophic effect on Christmas Island's animals, especially its birds. Two species of toad are potential new arrivals, given the source of material currently being imported, i.e. the Cane Toad (*Bufo marinus*) and the Asian Spiny Toad (*Bufo melanostictus*).

Biosecurity on Christmas Island is in urgent need of improvement. Chevron Australia has recently developed a detailed Quarantine Management System (QMS) for Barrow Island, off the Pilbara coast, and this is considered to be state of the art worldwide. Chevron has offered to make its QMS available so that the development of a better QMS for Christmas Island can be expedited (**Recommendations 1 and 2**).

4.0 SPECIFIC ISSUES CONSIDERED BY THE WORKING GROUP

4.1 NATURAL DYNAMICS OF OCEANIC ISLANDS

As already mentioned, isolated oceanic 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 ecological interactions. 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 can lead to a population crash with little possibility of recovery through re-colonisation.

The periodic massive mortality of reef-building corals recorded previously at Christmas Island is likely to have been ecologically significant because these corals form the primary structure of the shallow-water reef habitats and provide essential habitats for many other coral-associated reef species. The coral assemblages are starting to recover at some sites, but the source of the coral recruits is not known. This highlights the significant problem for marine species and some terrestrial species such as the land crabs that have life histories involving dispersive planktonic larvae. These larvae are likely to be dispersed away from their natal spawning sites by currents that vary in time and space, resulting in highly variable patterns of recruitment success (Davies, 2006). The vagaries of larval recruitment patterns that are primarily controlled by ocean currents mean that recovery of local populations following massive perturbations on small and isolated islands such as Christmas Island is likely to be slower and more variable compared with recovery rates on islands that are larger and closer to sources of regular recruits.

Oceanic islands generally 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 or naturally dispersed disease. 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, swamping adaptive responses of the native biota.

These recent immigrants include many species, such as the Flower-pot Snake, Giant African Land Snail, Giant Centipede and numerous plant species that could never have arrived without human help, and many species from distant biogeographic provinces, including the African Land Snail, New World ants and the Yellow Crazy Ant itself.

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 improved 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 (both terrestrial and marine), are brought under a single authority with both the power and the 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 biosecurity 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.

- **Infection** of goods in the supply chain to the island must be eliminated. This requires goods to be quarantine compliant before leaving the embarkation port and for all vessels, aircraft and people arriving at the island to be quarantine compliant. In the case of vessels this extends to ballast water compliancy. 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 of all freight to ships and aircraft. Detailed pathway analyses for all supplies and people coming to Christmas Island would aid this process.
- **Detection** of new species arrivals needs to be of a very high standard and should occur pre-border (e.g., 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 be the same 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 five 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 (O'Dowd and Lake, 1989, 1990, 1991; Green *et. al.*, 1997), 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. More recently, marine research has revealed that Christmas Island has significant values in terms of marine biodiversity (Berry and Wells, 2000; Hobbs et al*.,* 2009a). As these components intersect; some studies have inevitably addressed more than one of these broad fields. Much of this research work has been of international interest. Some has been continued over decades providing useful long-term data while some has accumulated material and data that remain to be analysed. Some has had direct management relevance, and has been translated directly to management actions. Significant amounts of this research have been commissioned, facilitated or directed by the conservation management agency (now Parks Australia).

It is tragic that, for a place that has attracted so much international interest research effort and management action, the Island's unique ecological character is now in decline. Now the complete detrimental restructuring of the island's ecological communities is possible and a rethinking is required to take advantage of the information base available, and to more strategically focus on whole of Island management.

The principal triggering event for this report was the predicted imminent extinction of the Christmas Island Pipistrelle (Lumsden and Schulz, 2009), a prediction originally made by James (2005) and now confirmed. This species was one of only two native mammals (the conservation status of a third, the Christmas Island Shrew *Crocidura trichura*, is uncertain) extant on the island, and its plight reflects a much deeper malaise. Although this malaise is not subject to a simple diagnostic, it is clearly the result of a complex interaction of isolation, governance, scientific awareness, the management of science, the application of science to management, and resource allocation. As such it provides a case study that is addressed in **Recommendation 32**.

The ecological collapse apparently underway on Christmas Island raises fundamental questions about the management of research and monitoring and their use in management decision making.

4.3.1 Scientific Research Priorities, Quality Assurance and Coordination

The unique ecological character of the island has attracted significant research with more than 100 refereed publications and more than 150 additional published works (see document list Appendix 11). 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; often at the urging of the researchers. In this context he EWG recognises that the Yellow Crazy Ant Advisory Committee has made a significant contribution. However, in review, the working group noted that much research, with the exception of that associated with the Monash / La Trobe group who have been largely funded from external sources, has been short term. Ideally research management should enhance the research effort by focusing on significance, relevance, and application. It should also ensure long term continuity. 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 EWG that Christmas Island would benefit from the development of an improved science management approach that makes better use of the Department's system of independent scientific advice with specialist groups being set up under this umbrella where necessary. This EWG is an example of such a group. Some groups should be task oriented 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 design of monitoring and 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 (**Recommendation 7**).

Conservation problems are island-wide and, accordingly, the management response needs to be island-wide. It is also abundantly clear that the ecological management of Christmas Island is beyond the current resources and jurisdictional span available to Parks Australia. To expect Parks Australia to divert resources to Christmas Island from other areas in Australia would stress the management of those areas. The EWG has concluded that the recovery of Christmas Island ecosystems should have a priority that is given equal weighting with the resolution of the other issues that face the Island. The EWG recommends that a permanent Christmas Island environmental recovery fund, incorporating funds from mining royalties, consolidated revenue and funds leveraged from other sources, should be part of ongoing whole-of-island management **(Recommendations 5 and 6)**. The fund should provide resources for whole-of-Island environmental governance. Immediate actions would be: dramatic quarantine improvement, eradication of Cats and Rats, and the further augmentation of work already under way to control the Yellow Crazy Ants and the scale insects on which they feed.

While our assessment indicated a pattern of decline for many components of Christmas Island biodiversity, and a historic lack of quarantine coupled with ineffective governance as the basal causes, the pathways connecting such decline to these factors may be complex and intricate. The management response accordingly needs to be carefully considered and prioritised, and based on firm evidence. While much good research and management has been undertaken on the Island, we recommend that this research and management be conducted more systematically, strategically and with greater long-term assurance of support. To this end we recommend that a Christmas Island Conservation Research Centre be established rapidly as part of the centrally-funded environmental management regime (**Recommendations 2, 5 and 7**). The Centre should be permanently staffed by at least four post-PhD scientists, externally-funded research students and visiting scientists, plus technical and other support staff. Priorities for research should include maintaining relationships with and facilitating the ongoing work of established Christmas Island researchers, investigating the population dynamics and conservation of the distinctive crab fauna, the conservation biology of rapidly-declining animals and plants and the establishment of rescue populations for those species as may be necessary. Such a Centre would become a valuable national and international base for the management of island biodiversity conservation more generally and, with tourism, could contribute significantly to the island's economic support.

The direct work of the Centre should be in an adaptive management framework with Parks Australia, other DEWHA staff, the Shire Council and the community. To facilitate this, professional communications staff should be attached to the Centre to assist with the management of the Island and its development as a unique tourism destination (**Recommendation 31**).

The working group recommends that a science management strategy be developed for Christmas Island as a whole that incorporates these suggestions. It further recommends that the management lessons identified elsewhere in this report become part of this process **(Recommendation 7)**.

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 provided a base line against which changes can be measured. Murray's concern and prescience were 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. Some 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 two spiders and 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 a 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 staff have established a significant monitoring information system and have made progress in organising all available data of relevance to the management of the island. The ongoing Island Wide Surveys (IWS) 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. This may require more detailed assessment of available literature and unpublished insights by experienced Island researchers as part of a strategic process (**Recommendations 7 and 10**).

There is considerable ongoing survey and monitoring work being undertaken by the staff of Christmas Island National Park, including a biennial Island Wide Survey (IWS). The working group supports this ongoing work and recommends that monitoring continues provided that there is a significant level of independent advice on its design, data management and management utilisation **(Recommendation 10)**. The current status of this work is given in Table 4.

Table 4 **Monitoring of Species and Groups of Species on Christmas Island.**

Species/groups of species	Year survey commenced	Year survey concluded	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 (2009)
Island Wide Survey for Yellow Crazy Ants and Red Crabs and other indicated species	2001	On-going	Yes
Robber Crab	2004	2006	Yes
Land Birds	2001	On-going	Yes
Abbott's Booby	1981	On-going	Yes
Christmas Island Hawk Owl	1988	1989	Last survey was Hill (1996), and 1 out of 4 rounds were replicated in BMP survey 2005. Planned for 2010. Included in IWS 2009.
Christmas Island Goshawk	2004	On-going	Yes
Brown Booby	2007	On-going	
Red-tailed Tropicbird	2004	On-going	
Christmas Island Frigatebird	2004	2004	
Insects and macro invertebrates	2004	2006	
Marine monitoring has recently been established at up to 16 sites for coral and reef fish	2004- 2008		
Whale Shark surveys are opportunistic but a system is being developed			

4.4 Yellow Crazy Ant Management

Over the last eight years the Yellow Crazy Ant management program has, along with mine site rehabilitation, threatened species recovery and weed management, dominated island biodiversity management. The program has been necessary to prevent catastrophic collapse of the island's keystone species (rainforest trees and the Red Crab) with consequential dramatic changes in forest composition and the abundance of a number of significant introduced predators. In the absence of any alternative, baiting Yellow Crazy Ant supercolonies with Fipronil continues as a short-term control measure. The EWG therefore recommends Fipronil baiting continue but with greatly enhanced monitoring of its non-target effects (**Recommendation 8)**.

Further, the working group endorses the conclusion reached already by Parks staff, that indefinite baiting of supercolonies with Fipronil is not a satisfactory long term option and that there is a need for the development of a different approach. Strategies for preventing Yellow Crazy Ants from re-establishing supercolonies by introducing parasitoid wasps and/or predators 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, e.g., via pheromones and growth inhibitors, is also being considered and should also be given a high priority (**Recommendation 9**).

Biological control research is likely to take some years. An alternative shorter term strategy that should be investigated and trialled, with appropriate monitoring, is to heli-bait much larger areas of the island to prevent the establishment of new supercolonies near those that are destroyed. The EWG recognises that Fipronil is a wide spectrum insecticide and that non-target effects may be significant, but the extent of such effects can only be determined with monitored trials in an adaptive management context. If this proved satisfactory, even larger areas could be baited, perhaps eventually the whole island, particularly if a more ant-specific control agent can be developed. In the longer term, this might not only limit the re-establishment of supercolonies but also reduce the overall use of Fipronil **(Recommendation 9)**.

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

Any successful long-term program will likely depend upon the effective and simultaneous control of scale insects and possibly other honeydew producing insects and Yellow Crazy Ant supercolonies **(Recommendation 29)**.

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 supercolonies have been eliminated but in which Red Crab recovery has been limited, and forests in which there have been no Yellow Crazy Ant supercolonies but from which Red Crabs have disappeared due to their death on migration through distant supercolony areas. In ghost forests of both derivations significant changes in vegetation and soil structure are occurring. It may be possible to re-establish Red Crabs in ghost forests by translocating animals with a high density of Red Crabs or by moving crablings. Both approaches are essentially experimental and fit into the overall adaptive management approach recommended by the EWG **(Recommendation 13)**.

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 in different places. 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. These observations remain a matter of speculation. This is discussed in more detail in section 4.11 **(Recommendation 12)**.

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 shifts and associated cascade effects

The sections above have outlined the general pattern of ecological shifts that have occurred on Christmas Island and in Appendix 1 a shift leading to the extinction of the Christmas Island Pipistrelle has been proposed. These shifts are highly significant for a number of reasons. Populations of Giant Centipedes and Giant African Land Snails are reported to increase in numbers in forests that have lost their Red Crabs. This view is contested by some for the Giant Centipede but not for the Giant African Land Snail. This debate raises the immediate question of what else has changed and by what means. To improve understanding of this the EWG recommends that a more comprehensive review of invertebrate information be undertaken particularly to improve inventory and to establish monitoring programs **(Recommendation 16)**. In this context it is probable that other sleeper species may become threats to island biodiversity as the dynamics of these forests transition to new, still unknown, states **(Recommendation 17)**. The EWG recognises that much of this is speculative; however, it is an important topic for ongoing island science management and can only be resolved through clarification (**Recommendations 16 and 17**) and a strategic approach to research and management (**Recommendation 7**).

4.5.2 Predation

4.5.2.1 Cats (feral and domestic)

There are many species for which Feral Cats and Black Rats are a known threatening process. Tidemann (1989) found that Feral Cats were widespread but concentrated around areas that were being mined. His analysis of 92 Feral Cat stomach contents found that their diet was dominated by three vertebrate species—fruit pigeons, Christmas Island Flying-foxes and introduced Black 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) of stomach contents 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 (Ishii, 2006).

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 currently a collaborative project coordinated by the Shire of Christmas Island and financially supported by Christmas Island National Park and Christmas Island Phosphate.

The EWG is of the view that both cats and rats should be eradicated from Christmas Island (**Recommendation 15**), as is now a common goal on oceanic and continental islands. There is an ever growing recognition of and acceptance of this need, and of techniques which work and examples of successful implementation.

In 2008 and 2009 trials of a new Feral Cat bait ('Curiosity feral cat bait') were conducted in selected areas of Christmas Island National Park, unallocated Crown land and mine lease areas (Johnston et al*.,* 2009) The trials are part of a collaborative national project between the Commonwealth Department of the Environment, Water, Heritage and the Arts, the Victorian Department of Sustainability and Environment and the Western Australian Department of Environment and Conservation. While the trials are pointing towards methodology for the successful eradication of cats from Christmas Island, further work is underway on bait formulation and on the delivery capsule for the toxin. Methods for laying baits in areas of the island with no road access will have to be developed **(Recommendation 15)**.

4.5.2.2 Rats

Black Rats (*Rattus rattus*) were introduced to Christmas Island in 1889 from a visiting ship. It is now known that the endemic *Rattus macleari* became extinct very soon afterwards because of the introduction of a disease parasite, a 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 and extensive vegetation damage on islands.

Black Rats have been eradicated from numerous islands throughout the world, particularly in New Zealand, but also in Western Australia (Burbidge and Morris, 2002; Howald et al*.,* 2007). '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 many 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). Feral Cat eradication on Wake Atoll (Pacific Ocean) also led to a rat population explosion (A. Wegmann, pers. comm.). A project to eradicate rabbits, rats and mice on Macquarie Island, now in advanced planning stage, will cost $25 million. The need for an integrated Feral Cat - Black Rat eradication plan on Christmas Island is clear.

The occurrence of multiple introduced animals on Christmas Island that interact with each other to an unknown extent presents special problems for planning eradications. The integrated management of Black Rats and Feral Cats will, if successful, prevent Black Rat numbers increasing well above current levels as would be likely if cat eradication takes place in isolation. However, there are introduced animals that cats and rats prey on that may show a response to a reduction in predation, notably the House Mouse and the Giant Centipede.

As mentioned in section 4.5.2.3, there are no known control or eradication methods available for the Giant Centipede. Eradication of the introduced House Mouse (*Mus musculus* species complex) is highly desirable, as it is doubtless having negative effects on indigenous biodiversity as well as being a nuisance in urban areas. Helicopter baiting with a cereal-based bait containing a second generation rodenticide such as Brodifacoum is also the preferred method of eradicating mice; therefore Black Rats and House Mice can be eradicated in a joint operation. However, experience worldwide is that there is a lower success rate in eradicating mice from islands than is the case for rats. The reasons for this are not clear.

Thus there is a risk that a reduction in predation on mice and centipedes by both cats and rats may lead to an increase in mouse and centipede abundance, with possible deleterious effects on indigenous species such as lizards. A precautionary approach should be taken, where:

i. there is monitoring of both indigenous and introduced animals that might become more abundant after Feral Cat and Black Rat eradication occurs, and

ii. threatened animals such as pigeons and lizards that might be deleteriously affected by the eradication are managed, e.g., via establishment of 'insurance' populations by captive breeding (see also sections 4.8 and 4.9).

In 2009, the Shire of Christmas Island called for expressions of interest to prepare a joint Feral Cat – Black Rat eradication plan. Research into methodology for Feral Cat eradication is underway (section 4.5.2.1) but, as discussed above, possible changes in the abundance of other introduced species, such as the Giant Centipede, have not been investigated.

Successful eradication of Black Rats has mostly occurred in temperate and subantarctic island or on arid tropical islands. Black Rat eradication on tropical rainforested islands with significant populations of land crabs has as yet not been successful (Buckelew et al*.,* 2005; Rodríguez et al*.,* 2006). Research, including eradication trials, by Island Conservation on islands in the Pacific Ocean suggests that Black Rat eradication is possible on tropical rainforested islands, but rodenticide needs to be laid at much higher rates than has been done in the past because land crabs consume much of the bait (land crabs are not affected by second generation anticoagulant rodenticides; Pain et al*.,* 2000) and that there may be issues with rats that live semi-permanently in the canopy (especially in palms) and may not be exposed to rodenticide (Wegmann, 2008; Wegmann et al*.,* 2009). Adding crab deterrent compounds to rodenticide is under discussion and should be followed up (A.Wegmann, pers. comm.).

Another concern at Christmas Island is the occurrence of two species of birds that may consume rodenticide baits, i.e., the Christmas Island Emerald Dove and the Christmas Island Imperial-Pigeon. Birds may be susceptible to rodenticides. Again, it may be possible to add a bird deterrent, such as grape seed extract, to the rodenticide (A.Wegmann, pers. comm.).

All these issues indicate that there needs to be a period of research and planning before a final plan can be prepared for the eradication of Black Rats and possibly House Mice from Christmas Island. Detailed research and planning for rat and mouse eradication will probably need to occur over a period of at least three years. Extensive consultation with Christmas Island residents is also needed. The Draft Lord Howe Island Rodent Eradication Plan (Lord Howe Island Board, 2009) and the recent successful eradication of cats on Ascension Island (Ratcliffe et al*.,* 2009), both of which like Christmas Island are inhabited, are useful models.

The working group recommends that Black Rats and Feral Cats be eradicated from Christmas Island in a coordinated project and that research into rat eradication commence as soon as possible (**Recommendation 15**).

4.5.2.3 Other introduced species

There are introduced species on the island that are already implicated in the decline in biodiversity and others which have potential as 'sleeper' threats and require close monitoring. The development of a strategic approach to science management (**Recommendation 7**), better monitoring (**Recommendation 10**) and an adaptive management framework (several places and **Recommendation 32**) are the key components for understanding, prioritising and resolving these matters. Below the EWG provides a short comment on each of these in the expectation that they will be further considered under a new Island environmental governance arrangement (**Recommendation 2, Recommendations 16 and 17**).

- Ants. At least 50 other ant species occur on Christmas Island, but there has been no comprehensive threat evaluation.
- Giant Centipede. Little is known of this species' ecology or impact. They are killed by commercial snail pellets (metaldehyde).
- Nankeen Kestrel. These are at low abundance and probably could be eradicated by shooting.
- Wolf Snake. Experiments on capture systems should be initiated as part of the proposed adaptive management initiative.
- Asian House (Barking) Gecko and Pacific Gecko. It might be possible to exploit their calls to attract them to traps but experimentation is required.
- Feral fowl. It may be possible to free feed and capture to eliminate.

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 prevent these species being introduced to the island. The following species or groups have a significant potential for invasion:

- snails
- insects
- terrestrial isopods
- spiders
- Brown Tree Snake
- the Cane Toad and Asian Spiny Toad
- Indian Myna (a member of the starling family)
- a range of marine pests, especially those associated with hull fouling and / or ballast water

The potential impacts of the introduction of such species strongly reinforce the necessity for a great improvement in the quarantine regime.

The EWG is of the view that this risk is substantial, and reiterates the recommendations already made with respect to quarantine protocols and the environmental governance of Christmas Island **(Recommendations 1, 2, 11, 17, 30 & 31)**.

4.5.3 Fipronil toxicity

The working group has reviewed the published material on the Yellow Crazy Ant supercolony control program and has held discussions with representatives 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 supercolonies on Christmas Island **(Recommendation 8)**.

Notwithstanding this, the working group remains concerned about the likely impacts of Fipronil. Fipronil can exist in a number of metabolite forms of significant toxicity, has significant residual time, can enter and accumulate up the food chain, can impact on the reproduction of mammals and birds, can neurologically influence animal behaviour and can act systemically in plants. It is also reported as highly toxic to termites, lizards and to marine and freshwater invertebrates. These are all causes of significant concern and the working group has recommended that work be done to explore some of these issues as a matter of urgency (See Appendix 6). Work has now been initiated but the results will not be available until June 2010; consequently this matter becomes a priority for any new management regime.

The EWG recommends that further discussions need to be held with the Yellow Crazy Ant Scientific Advisory Panel to identify alternative and / or complimentary 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 believes that this should be given a very high priority **(Recommendation 9)**.

The breeding and introduction of parasitoid wasps and ladybirds to control scale insects is already underway on Queensland islands and is also used in horticulture; learning from that experience will aid the early implementation of biological control of scale insects on Christmas Island. However, Christmas Island presents a much more complex case than the small cays in Queensland and the Coral Sea as it has 14 species of introduced scale insects, rather than a single dominant scale on the islets. No scale is dominant on Christmas Island; however, one tree canopy species, *Inocarpus fagifer*, is especially impacted on by the lac scale *Tachardina aurantiaca*, with impacts including tree death (Abbott and Green, 2007) and one other scale, the soft scale *Coccus celatus*, is common and widespread. Work to develop simultaneous control of scale and ants should be part of an adaptive management approach that utilises aspects of Integrated Pest Management. Such an approach should include careful consideration (risk-assessment) of possible non-target (i.e. native invertebrate) impacts (**Recommendations 5, 7, 9, 29 and 32**).

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 introduced 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*, which occurred 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*. However, it is only with recent analysis of old DNA from museum specimens 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).

Underwater surveys of reefs at ten sites around Christmas Island in February 2008 revealed that white syndrome coral disease was affecting about 13% of plate *Acropora* corals. The prevalence of white syndrome was greater in shallow water on the northern leeward side of the island than at deeper sites and sites on the more exposed coastal areas (Hobbs and Frisch, 2010). Subsequent surveys revealed that most of the coral affected by disease had died or exhibited partial colony mortality, resulting in a significant loss of coral cover at the more severely impacted reef sites (Hobbs, pers. comm.).

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, apart from the two examples above, there is currently very little 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. For example, *Toxoplasma gondii*, the parasitic protozoan that causes the disease toxoplasmosis, is widespread in cats on Christmas Island and can be transmitted from them to other species such as native mammals and birds, as well as to humans. Research that demonstrates that *Toxoplasma* can infect and kill skinks (Stone and Manwell, 1969) is of concern.

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, the EWG recommends:

1 sampling to establish baseline levels of prevalence of pathogens, disease and parasites in selected endemic animals and plants **(Recommendation 17)**;

2 similar sampling of exotic plants and animals now present on Christmas Island (specifically including Black Rats, domestic and feral cats, dogs, Tree

Sparrows, Java Sparrows, House Geckos, Wolf Snakes and Giant African Land Snails) **(Recommendation 18)**;

3 a program of regular and robust monitoring of these levels be developed **(Recommendation 19)**;

4 a response protocol and framework associated with the monitoring program be developed **(Recommendation 20)**;

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 regarded as an important 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 periods 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 seabird 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).

4.5.6 Land Clearance and Soil Removal

There has been a long history of vegetation clearance and soil removal on Christmas Island, resulting in loss of habitat for fauna and flora. The impact of 125 years of anthropogenic activity, most notably from more than 100 years of phosphate mining (Appendix 14), has had a marked impact on the Island ecosystem and has directly affected at least 25 per cent of the total area of the Island (Figure 7).

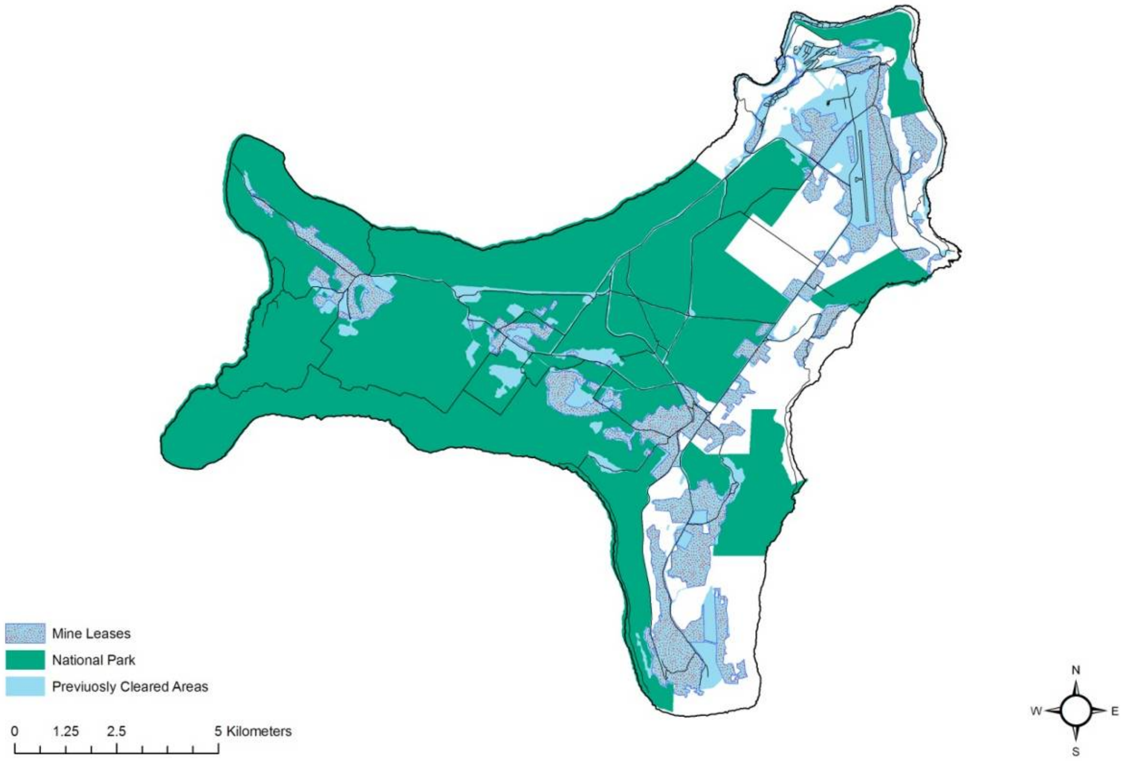

Figure 7 Historic land clearance on Christmas Island (Source CIMFR Annual Report, 2009)

Vegetation clearing reached a peak with the 1969 grid line survey which covered most of the island with a cleared rectangular grid pattern (Figure 8), each grid line was up to nine metres wide with lines set 30 -120 metres apart (Corbett et al*.,* 2003). Additionally, during the 1970s the British Phosphate Commission cleared all existing mining leases completely (Figure 7).

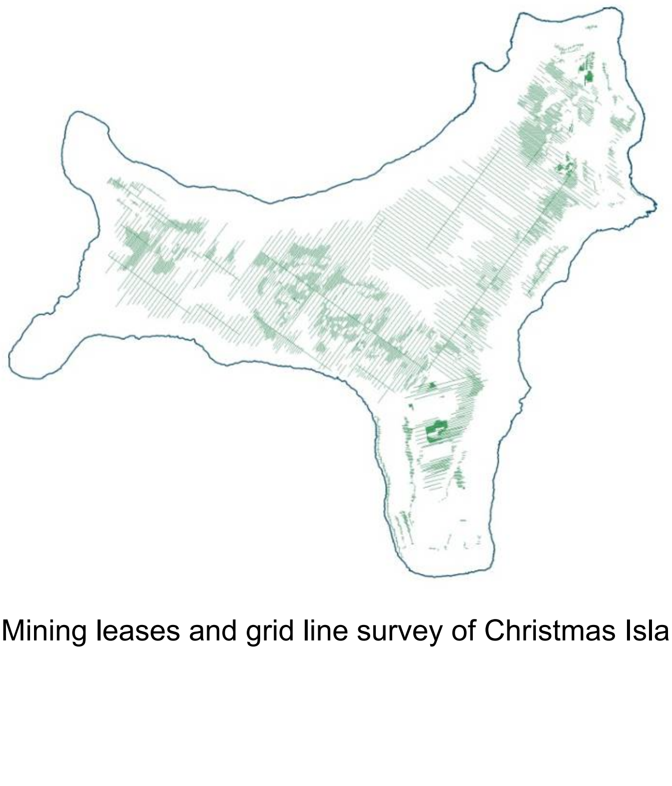

Figure 8 Mining leases and grid line survey of Christmas Island 1969

Removal of soil for phosphate mining has resulted in significant areas of the Island returning to limestone base rock, colonised with small patches of early successional vegetation communities on skeletal soils. This impact has been most notable on the central plateau which covers 6,506 ha. About 40% of the 'deep soil' on the plateau was cleared for mining up to the mid-1980s. Much of this area has subsequently been mined.

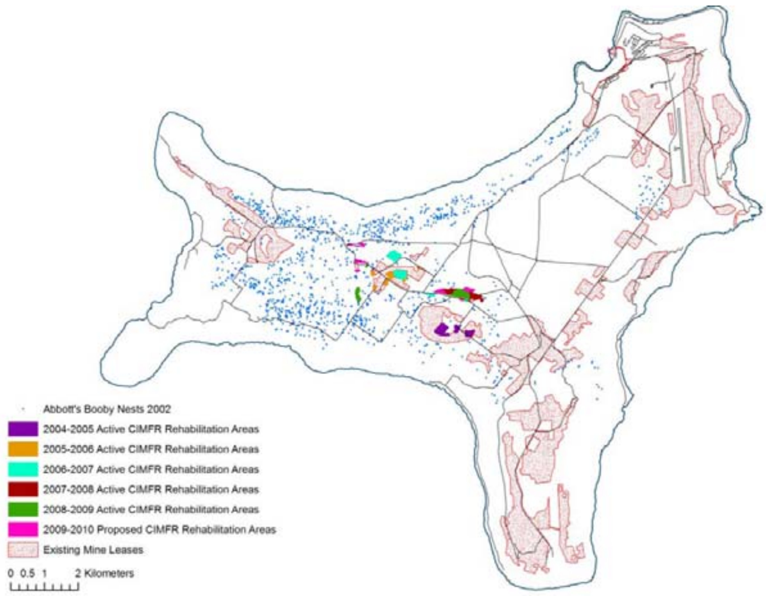

Figure 9 Pattern of Rehabilitation on Christmas Island (Source CIMFR Annual Report 2009)

Vegetation loss and modification together with invasive species, diseases and stochastic events, such as fire and storms, form the principal vectors altering natural ecosystems. The impact of vegetation loss and disturbance on Christmas Island fauna has not been examined or documented in any major published scientific studies of the area and, consequently, there is no information on the impact of mining of soil and vegetation clearance on any of the fauna and micro-organisms that are essential to ecosystem functioning, or on rainfall infiltration to the groundwater.

Modern conservation legislation demands restoration and rehabilitation of mined landscapes, however, there have been only small areas (<7% of mined land) involved in restoration attempts on the Island thus far, and much of the old mined areas remain in either arrested development where no soil was left (Figures 7 and 9) (CIMFR, 2009).or as regrowth in areas where some soil was left. These areas are primarily on the lower terraces and along the grid lines.

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.

However, some of the other concerns may be ameliorated if there is strict regulation of mining operations and appropriate mine site rehabilitation governed by stringent protocols and performance requirements. Such protocols would cover rehabilitation, groundwater impact, dust management and biodiversity impact mitigation. These in turn depend on better island governance.

Where commercial leases or other commercial regulatory instruments exist, their re-negotiation should include, as part of the negotiating brief, the creation of resources to manage areas or matters of high conservation importance, such as restoration of landscapes and investigation of ecosystem processes. Also, conditions associated with approvals should be subject to rigorous monitoring **(Recommendation 6 and 23)**.

Disturbance can also occur naturally on Christmas Island through 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. Such events are natural and stochastic; however their impact is greater where disturbance has already occurred.

4.5.7 Water

The Western Australian Water Corporation is responsible for water supply on Christmas Island, under an arrangement with the Commonwealth Attorney General's Department. The Western Australian Department of Water regulates water extraction in Western Australia, but there is currently no Service Delivery Agreement between the Attorney General's Department and the Department of Water. Christmas Island is not a proclaimed area under relevant WA legislation and consequently there is no water resource management plan and no licence issued that would regulate the Water Corporation's activities.

EWG representatives met with staff from the Attorney General's Department, the WA Department of Water and WA Water Corporation on 27 August 2009. The EWG was advised by the Attorney General's Department that a Service Delivery Agreement with the Department of Water to appoint them as regulators will be put in place but it could not provide a timetable for this. Christmas Island Water Corporation staff advised the EWG that they would welcome proper regulation of their activities.

The Department of Water provided the EWG with a copy of "Water Resource Management Review Indian Ocean Territories (Christmas and Cocos (Keeling) Islands" October 2008. This report makes a series of recommendations 'to address short falls', the first of which is the proclamation and gazettal of water reserves on Christmas Island.

The town, mine and the IDC water supply is sourced from a subterranean stream that traverses both Jedda and Jane-Up Caves on the central plateau, and from springs at Ross Hill Gardens. In the past water has been taken from Waterfall Spring. The Water Corporation is currently constructing a new pump station in the Waterfall area near the resort entrance.

Monitoring bores have been established and are monitored by Ecowise Environmental, Fyshwyck, who report to the Water Corporation. Most monitoring bores are, however, near the coast, not near the water sources being expoited. Monitoring has been aimed at ensuring sustainable flows for human use, not for establishing and monitoring environmental requirements. Department of Water hydrologists consulted by the EWG agreed that information on groundwater on Christmas Island was very limited and that this made it impossible to evaluate the effects of drought and abstraction on the environment.

Groundwater supports significant communities on Christmas Island. The perched mangrove community at Hosnie's Spring, a Ramsar Wetland, and The Dales communities are dependent on spring flows. Stygofauna are dependent on groundwater and anchialine systems depend on the balance between fresh groundwater flow and the underlying intrusion of marine water.

There is no verified groundwater model for Christmas Island and therefore the utility of the present monitoring bores to inform on human impacts on the environment is unknown. With increasing pressure on water resources, owing to the expanding human population (including at the IDC) and through climate change, there is an urgent need for an adequate understanding of the groundwater environment.

The lack of adequate groundwater monitoring and therefore the lack of information on the possible effects of abstraction or drought on the rainforest, stygofauna and wetlands that depend on groundwater are of considerable concern. **Recommendation 4** covers the need for better water management.

4.6 CONSERVATION STATUS OF ENDEMIC SPECIES

The EWG's examination of the ecology of Christmas Island has led to two main conclusions relevant to this issue. Firstly, two extinctions can be attributed to disease. Secondly it can be hypothesised that the decline in other endemic species is related to either disease, predation or 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 2**).

4.7 CHRISTMAS ISLAND PIPISTRELLE

The Christmas Island Pipistrelle is effectively a case study in extinction. The details of the EWG's assessment of its fate and recommendation in the interim report are provided in Appendix 1. Reflecting rapid and permanent loss of recovery options between the Interim Report and this report, those recommendations are now redundant, and this consideration shifts from one of prospective management to retrospective analysis, or inquest. The first at least semi-quantitative assessment of its status was undertaken in 1984; and by the next survey (in 1994) its decline had begun, and continued apparently inexorably until its demise in 2009. Over this period, there was substantial effort made to conserve it. The Christmas Island Pipistrelle was listed as endangered in 2004 and its status up-listed to critically endangered in 2006. A recovery plan was established in 2004 that provided a framework for recovery actions, most of which were funded and undertaken. These actions included those typical of the conservation management arsenal, including ongoing monitoring, assessments of ecological requirements, and the attempted identification and ameliorative management of all possible threats, including predation, disease and habitat modification. Additionally, it was reasonably presumed that the species would benefit from the ongoing island-wide management of one probable threat, the Yellow Crazy Ant. Notwithstanding these considered actions, the species continued to decline, as either its principal threat evaded identification or effective management, or the complex tapestry of multiple threats proved impossible to unravel. The likely extinction of the species was predicted in 2005, and proposals for emergency *ex-situ* (captive) breeding explored from 2007. In hindsight, such proposals, and their progress, developed too slowly, and by the time these actions were recognised as the only immediate option, and approved, it was too late. Table 5 outlines the chronology of the Pipistrelle recovery actions.

Table 5 Christmas Island Pipistrelle chronology

Date	Status
1900	Described by Andrews
1940s	"flourishing during the period of my stay on the island" (Gibson-Hill, 1947)
1976	"in good numbers" (Bell, 1976)
1984	Reported as widespread and common in primary and secondary rainforest, and settlement: first intensive study (Tidemann, 1985)
1994	Re-assessment of status: surveys reported it to be widespread but patchy, and uncommon in NE of island; concluded that the species had declined and contracted since the last sampling (of 1984) (Lumsden and Cherry, 1997)
1998	Further sampling by Lumsden, reporting further decline and contraction. Likely threats identified, and management advice provided, including for establishment of a monitoring program (Lumsden et al., 1999)
1999	Ranked as endangered in Bat Action Plan, based on extent of decline and small population size (Duncan et al., 1999)
2002	Brief study that reported 33% decline since 1998, with further westward contraction (Corbett et al., 2003)
2003-09	Included within Christmas Island biodiversity monitoring program; with this monitoring demonstrating further declines (James and Retallick, 2007)
2004	Listed as Endangered under EPBC Act
2004	Recovery Plan developed, describing priority management actions (Schulz and Lumsden, 2004)
2005	Recovery plan part funded
2005	Review of status, concluding decline of about 75% between 1994 and 2004; prediction of extinction by 2008 (James, 2005)
2006	Radio-telemetry studies identify roost preferences (Hoye, 2006)
2006	Uplisted to Critically Endangered under EPBC Act and TSSC recommended consideration of captive breeding; good data on population decline available
2007	Review of status and threats (James and Retallick, 2007)
2007	Establishment of artificial roost sites, and predator-proofing of some known roost sites
2007	Population estimate of 500 – 1000 individuals
2007	First approaches made to zoos to establish interest in and feasibility of captive breeding
2008-09	Report prepared on options and need for captive breeding; population estimated as possibly less than 20 individuals (Lumsden and Schulz, 2009)
2009	Expert working group established
2009	Unsuccessful capture attempt for captive breeding; presumed extinction

Frustratingly, it may now never be known irrefutably what caused the Pipistrelle's likely extinction. A series of plausible culprits were explored, without conviction or cure; and with numbers rapidly declining, options for investigative study rapidly diminished (Appendix 1).

The late attempt to establish a captive population following a recommendation by Lumsden and Schultz (2009), and endorsed by the EWG in its interim report, failed. The lesson to be learnt is that the early recognition of the rapid change in the Island's ecological function in the mid-1990s (Lumsden and Cherry, 1997; O'Dowd et al., 2003) should have initiated an urgent and comprehensive review followed by management actions. Instead, piecemeal responses that occurred demonstrate that management without sound science-based monitoring and sound scientific interpretation that is acted on will fail.

The situation is similar for all the other vertebrates on the island, and this report therefore recommends science-based management approaches. The EWG is cautiously optimistic that with appropriate change and investment Christmas Island can be returned to one of the World's ecological icons. If so, the Christmas Island Pipistrelle may truly have been the 'canary in the coal mine' – but this is not a desirable management approach.

Notwithstanding thorough attempts to locate persisting Pipistrelles in August-September 2009, some parts of the island are extremely difficult to access and it is possible that a few persist. The working group's Interim Report recommended that "Monitoring 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.". There have been no detections during the subsequent five months of monitoring, so the working group recommends that the drive-around survey be repeated once a year for the next two years and, in case Pipistrelle activity is detected, that an appropriate response protocol be developed which includes a rapid population assessment (**Recommendation 22**).

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; James, 2007a). The endemic species comprise two skinks, two geckos and a blind snake.

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 (*E. navitatus*) and Coastal (*E. atrocostata*) skinks from Christmas Island.

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 (Case and Bolger, 1991; Foufopolous and Ives, 1999). 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).

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). However, there is some disagreement between the findings of Schulz and Lumsden (2008) and those of James (2007a). Using the detailed findings of the Biodiversity Monitoring Program, conducted between December 2003 and April 2007, James (2007a) concluded that the Giant Gecko remained common over a large part of the island and was the most frequently recorded reptile species during the survey. It was the only native reptile known to occur in forests immediately adjacent to the IDC and was shown to co-habit logs with Crazy Ant nests. As the only native reptile taxon in sufficient abundance and widely enough distributed for accurate survey monitoring, a detailed investigation of the species and its physiological tolerances to Fipronil should be undertaken.

Lister's Gecko (*Lepidodactylus listeri*) is listed as Vulnerable under the Commonwealth EPBC Act. The last recorded observation was in 1987 and it was thought to be extinct until an individual was captured in the Egeria Point area in September 2009 and photographed by Parks Australia staff. Despite numerous targeted reptile and Island Wide Surveys over recent years (James, 2007a; Schulz and Lumsden, 2008) this remains the only recent record or observation and indicates that it is a critically endangered species.

The 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 year one of these two remaining populations has become extinct (Retallick, pers. comm.). James (2007a), referring to Rumpff (1992), stated that the decline and disappearance of this species occurred in settled areas around this time and implicated the introduced Wolf Snake (*Lycodon capucinus*) as a prime predator and largely responsible.

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 (James, 2007a) and was not observed by Schulz and Barker in 2008. Although there is photographic evidence of this species as recently as September 2009, the extent of its decline in distribution across Christmas Island would indicate that it is a critically endangered taxon.

The Forest Skink (*Emoia nativitatus*) was abundant in rainforests on all landforms during 1979 (Cogger and Sadlier, 1981) and remained common during the survey in 1998 (Cogger and Sadlier, 1999). However, it declined rapidly during the early years of this century (James, 2007a) 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.). Cats are a major predator of the species with several studies indicating Forest Skink bodies in cat stomach contents, and cats remain a significant threat to the small remaining populations of the skink (James 2007a).

The Christmas Island Blind Snake (*Typhlops exocoeti*) is, like most blind snakes, a poorly known species. Infrequently recorded on the island, an individual was captured in September 2009 (the first record since 1986) and there are occasional unconfirmed sightings of this species (Schulz and Barker, 2008). There has been a comprehensive compilation of the limited records of the Christmas Island Blind Snake (James, 2007a) that provided the best assessment of its status and habitat preferences.

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 Common Wolf Snake. 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

The recording in September 2009 of Lister's Geckos and a Coastal Skink confirmed their status as highly threatened species on Christmas Island, rather than being extinct, and indicates that there is an urgent need to either commence or continue captive breeding efforts for the persistence of all native Christmas Island reptile species. The current situation is that captive Blue-tailed Skinks are successfully breeding in captivity on the Island and Lister's Gecko and Forest Skinks exist in small but vunerable populations.

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 including 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, have been considered to impact on all lizard species. There is now strong observational evidence of lizards being casualties to Yellow Crazy Ants (Abbott, pers. comm., Green, pers. comm.); however, the continued presence of four endemic species of lizard species on Egeria Point (Smith, pers. comm.), an area noted for persistent and dense Yellow Crazy Ant supercolonies, indicates that ants are unlikely to be solely responsible for the demise of lizard populations. Competition between the native geckos and the introduced Asian House Gecko and Pacific Gecko and between the native skinks and the introduced Grass Skink could 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 (Fordham and Brook, 2010) also remain conjectural.

Case and Bolger (1991) investigated the impacts of introduced species on island reptiles and reported three major conclusions. 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 and Lister's Gecko are close to extinction, 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 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 management intervention more native reptiles on Christmas Island will become 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 are endorsed by the EWG namely to;

- Continue Captive Breeding programs **(Recommendation 27)**.
- Prepare nominations for the EPBC Threatened Species Listing **(Recommendation 30)**.
- Conduct an Ecosystem Health Monitoring program to identify major threatening processes **(Recommendation 10)**.

Other 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.

See **Recommendations 7, 10 and 31**.

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 landbirds (three species and four subspecies);
2. breeding seabirds (nine species, including two endemic species and one endemic subspecies);
3. four other resident native landbirds, waterbirds and shorebirds, some of which have colonised the island only in the last few decades;
4. visitors (at least 19 species, and many more occasional vagrants); and
5. introduced species (three species) (Appendix 9).

This bird fauna is of considerable conservation significance, to the extent that Christmas Island is recognised as a globally Important Bird Area by BirdLife International (http://www.birdata.com.au/iba.vm). Six Christmas Island bird taxa (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 Glossy Swiftlet), and terrestrial omnivores (Christmas Island Thrush).

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, and its conservation. For example, Chasen (1933) described concerns by the District Officer in

1904 about an apparent rapid decline of the Christmas Island Imperial-pigeon in the few years following initial settlement, and a report from 1929 that it was "rapidly dying out", in part due to hunting pressure. More recently, concerns about the significant losses of breeding colonies of the endemic Abbott's Booby from forest clearing for mining (particularly in the 1970s) provided 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 seas many hundreds of kilometres distant from Christmas Island).

World-wide, island birds have proven to be especially susceptible to extinction (Blackburn et al., 2004, 2005; Didham et al., 2005; Trevino et al., 2007; Sax and Gaines, 2008). Of 24 Australian bird species or subspecies considered extinct, 21 were restricted to islands. 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 intermittent, and for most species there are neither long-term ongoing monitoring programs nor robust population estimates (indeed, in many cases, there are widely divergent population estimates). Such uncertainty renders management prioritisation difficult, and would hamper initiation of any rapid response to sudden decline.

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 IPRC, 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 Glossy Swiftlet, and 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 from 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 Glossy Swiftlet, Christmas Island Thrush, Christmas Island Emerald Dove, Christmas Island Imperial-pigeon and Golden Bosunbird were widespread and abundant in 2005-06. The sampling and the subsequently established Island Wide Survey program is highly repeatable and provides a robust benchmark from which broad trends can subsequently be discerned.

The prioritisation of conservation management response for birds is made complicated by the current formal conservation status attributed to different taxa. For example, the Christmas Island Thrush (an endemic subspecies) is listed as endangered under the *EPBC Act* but appears to be numerous and stable, whereas the Christmas Island population of the Red-tailed Tropicbird is not listed as threatened, but is undergoing rapid decline at nesting sites due to predation, mostly by cats.

There has been more focused attention on the status of some Christmas Island birds that have been listed as threatened, with recovery plans in existence (and some consequential research and management) 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). Notably, all of these plans are now at the end of their allotted time period, and will be subsumed within a broader regional recovery plan, due for release in 2010.

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-eye, 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 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. To date, such responses do not appear to have caused substantial or significant declines for these bird species.

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.

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 land crabs, presumably because birds on such islands may be 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 further bird declines unless Black Rats and cats are eradicated.

Notwithstanding Atkinson's (1985) general argument, some recent unpublished studies have indicated that nesting success of tropicbirds in the settlement area is currently being markedly reduced through predation of chicks (and, less frequently, adult birds) by cats (especially) and Black Rats; and this threat is currently unabated.

Garnett and Crowley (2000)) ranked several of the Christmas Island endemic and breeding birds as Critically Endangered because of concern that Yellow Crazy Ant supercolonies, at that time occupying 15-18% of the island and expanding, 'would alter the whole ecology of the island by killing the super-numerous Red Crab (*Geocardoidea natalis)* and by farming scale insects, which damage the trees. Flow on effects could include the spread of introduced Black Rats (*Rattus rattus)* into areas formerly occupied by crabs. All endemic birds are threatened by the spread of the ant. Seabirds also face an additional, if unquantified, threat from long-line fishing.' They 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.

The 2000 recommendation to establish secure captive populations of landbirds is noteworthy, given the lack of such comparable timely recommendation for the Christmas Island Pipistrelle. In hindsight, the recommendation would seem to be right in principle, but directed towards the wrong species. Garnett and Crowley (2000) appear to have over-estimated the immediate threat to birds posed directly or indirectly by Yellow Crazy Ants, and may have over-estimated the likelihood and/or severity of decline for Christmas Island birds, at least in the short term.

Although birds comprise a higher proportion of listed threatened species than any other group, the current trends for most birds on Christmas Island are nowhere near as parlous as those for endemic reptiles, or for that shown by the Christmas Island Pipistrelle. Historically, most bird decline has been associated with forest clearing, but this threat is now mostly reduced.

In the following paragraphs we present brief accounts of the status of all listed threatened Christmas Island birds, all endemic birds, and seabirds with important breeding populations on Christmas Island. A collation of the priority management actions is presented in Table 6.

RED-TAILED TROPICBIRD (Silver Bosun) *Phaethon rubricauda*

Population estimates: 10-100 pairs (van Tets, 1975); 1,380 pairs (1984 estimate, in Stokes, 1988).

Endemic status: Nil.

Threatened status: Nil.

Recovery plan: Nil.

Major threats: Predation by cats (especially) and Black Rats of chicks (and adults) at nests for one major colony. The impacts of Yellow Crazy Ant infestations on this species are unknown. 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

Management priorities: Urgent requirement to protect more accessible colonies from cat predation, with medium-term requirement to eradicate cats and rats **(Recommendations 15 and 21)**.

WHITE-TAILED TROPICBIRD (Golden Bosun) *Phaethon lepturus fulvus*

Population estimates: 10-100 pairs (van Tets, 1975); 600 pairs (1984 estimate, in Stokes, 1988); 12,000 -24,000 (Dunlop, 1988); 20,000 (Garnett and Crowley, 2003).

Endemic status: A distinctive subspecies, with breeding restricted to Christmas Island.

Threatened status: Nil. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Nil.

Major threats: Stokes (1988) reported that "many nestlings are taken by goshawks and cats, and rats may rob the nests". The impacts of Yellow Crazy Ant infestations on this species are unknown. 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

Management priorities: Eradication of cats and Black Rat **(Recommendations 15 and 21)**.

CHRISTMAS ISLAND EMERALD DOVE *Chalcophaps indica natalis*

Population estimates: 100-1000 pairs (van Tets, 1975); 5,000 (Garnett and Crowley, 2003); 900-3,500 (Corbett et al*.,* 2003); about 1000 pairs (Johnstone and Darnell, 2004). Regarded as "widespread and common" by Parks Australia (2008).

Endemic status: Endemic subspecies

Threatened status: Endangered.

Recovery plan: Nil.

Major threats: Historically this species was hunted for food. Predation by cats and rats may be having some detrimental impact. Garnett and Crowley (2000) reported that Yellow Crazy Ants had been shown to kill nestlings.

Management priorities: Develop or maintain monitoring programs; eradicate control cats and Black Rats; control Yellow Crazy Ants **(Recommendations 7, 8, 15 and 20)**.

CHRISTMAS ISLAND IMPERIAL-PIGEON *Ducula whartoni*

Population estimates: 10-100 pairs (van Tets, 1975); 1,000 (Garnett and Crowley, 2003); 35,000-66,000 (Corbett et al*.,* 2003); 1,000-10,000 mature individuals (2000-2006: James in http://www.birdata.com.au/iba.vm). Regarded as "abundant" by Parks Australia (2008).

Endemic status: Endemic species.

Threatened status: Nil. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Nil.

Major threats: Historically, subjected to periods of intensive hunting. It has probably also declined more or less proportionally to the extent of clearing.

Management priorities: Develop or maintain monitoring programs **(see Recommendation 10)**

CHRISTMAS ISLAND GLOSSY SWIFTLET *Collocalia linchi natalis*

Population estimates: 100,000 -1,000,000 pairs (van Tets, 1975); 5,000 (Garnett and Crowley, 2000). Regarded as "widespread and abundant" by Parks Australia (2008).

Endemic status: Endemic subspecies. Note that the affinity of this taxon has been contested. It has conventionally been placed within *C. esculenta*, but Christidis and Boles (2008) concluded that it was more closely related to *C. linchi*.

Threatened status: Nil. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Nil.

Major threats: No demonstrated threat. Change in invertebrate composition and/or abundance due to ecological dominance by Yellow Crazy Ants, and to consequential change in forest structure, may affect this species. There is some potential that it may be affected by uptake of Fipronil, but there is no primary evidence for this.

Management priorities: Assess any uptake of Fipronil, or its breakdown products. Develop or maintain monitoring program **(Recommendation 10)**.

GREAT FRIGATEBIRD *Fregata minor*

Population estimates: 100-1,000 pairs (van Tets, 1975); 3,250 pairs (1984 estimate, in Stokes, 1988).

Endemic status: Nil.

Threatened status: Nil.

Recovery plan: Nil.

Major threats: Some breeding colonies were formerly cleared for mining. The impacts of Yellow Crazy Ant infestations on this species are unknown. 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

Management priorities: Develop or maintain monitoring program **(Recommendation 10)**.

CHRISTMAS ISLAND FRIGATEBIRD *Fregata andrewsi*

Population estimates: 100-1,000 pairs (van Tets, 1975); 1,620 pairs (Stokes, 1984), "may be less than 1600 pairs" (Stokes, 1988); 4,500 breeding birds (Garnett and Crowley, 2000); 2,200-3,000 breeding birds (James, 2003); 1,200-2,400 breeding pairs (2003: James in http://www.birdata.com.au/iba.vm); 1,100 pairs (Parks Australia, 2008).

Endemic status: A species that breeds only on Christmas Island.

Threatened status: Vulnerable. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Hill and Dunn (2004).

Major threats: James (2003) considered the population to be undergoing gradual decline. Following historic clearing and other disturbance (notably dust fallout 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. 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).

Management priorities: Maintenance of habitat quality (especially relating to weed control) at nesting colonies; rehabilitation of nearby areas to allow for possible expansion of breeding colonies; off-island management of fisheries. Maintain monitoring program **(Recommendations 5 and 10)**.

ABBOTT'S BOOBY *Papasula abbotti*

Population estimates: 100-1,000 pairs (van Tets, 1975); 6,000 breeding birds (Garnett and Crowley, 2000), 3,000-4,000 breeding birds (Olsen, 2005); 1,500-2,500 breeding pairs (2002: James in http://www.birdata.com.au/iba.vm).

Endemic status: A species that now breeds only on Christmas Island.

Threatened status: Endangered. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Department of the Environment and Heritage (2004).

Major threats: Nesting in loose colonies in emergent and canopy rainforest trees, clearing for mining development led to significant population loss. The impacts of Yellow Crazy Ant infestations on this species are unknown. 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).

Management priorities: Maintain monitoring program. Constrain vegetation clearance. See **(see Recommendations 5 and 10)**.

RED-FOOTED BOOBY *Sula sula*

Population estimates: 100,000-1,000,000 pairs (van Tets, 1975); 12,050 breeding pairs (1984 estimate, in Stokes, 1988).

Endemic status: Nil.

Threatened status: Nil.

Recovery plan: Nil.

Major threats: Previous large breeding colonies were destroyed by clearing for mining, and it was formerly harvested "for food in considerable numbers" (Stokes, 1988). The impacts of Yellow Crazy Ant infestations on this species are unknown. 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.

Management priorities: Develop or maintain monitoring program **(Recommendation 10)**.

BROWN BOOBY *Sula leucogaster*

Population estimates: 10,000-100,000 pairs (van Tets, 1975); 4,910 breeding pairs (1984 estimate, in Stokes, 1988).

Endemic status: Nil. Christmas Island supports one of the world's largest breeding colonies (Parks Australia, 2008).

Threatened status: Nil.

Recovery plan: Nil.

Major threats: Some former breeding areas were destroyed by clearing for mining; it was formerly hunted; and some “chicks are taken by feral cats” (Stokes 1988). The impacts of Yellow Crazy Ant infestations on this species are unknown. 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.

Management priorities: Develop or maintain monitoring program **(Recommendation 10)**.

CHRISTMAS ISLAND GOSHAWK *Accipiter hiogaster natalis*

Population estimates: 10-100 pairs (van Tets, 1975); 150 (Garnett and Crowley, 2003); “as few as 100 adults” (Hill, 2004a); about 250 birds, based on colour-banding studies (Hurley, 2005; Parks Australia, 2008). Parks Australia (2008) noted that it is “considered to be the rarest endemic bird on Christmas Island.”

Endemic status: Endemic subspecies. Note that the affinity of this taxon has been contested. It has conventionally been placed within *A. fasciatus*, but Christidis and Boles (2008) concluded that it was more closely related to *A. hiogaster*, but that further taxonomic analysis may be warranted to examine whether it is specifically distinct.

Threatened status: Endangered. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Hill, 2004a.

Major threats: There has been no conclusive demonstration of threats, but it has probably declined more or less proportionally to the extent of clearing, although Corbett et al*.,* (2003) reported it to use a range of rehabilitation areas. The impacts of Yellow Crazy Ant infestations on this species are unknown. The small population size may particularly pre-dispose this species to novel factors, including disease (e.g. Whiteman et al*.,* 2006).

Management priorities: Maintenance of ongoing monitoring. **(Recommendation 10)**

COMMON NODDY *Anous stolidus*

Population estimates: 10,000-100,000 breeding pairs (van Tets, 1975); 5,390 breeding pairs (1984 estimate, in Stokes, 1988).

Endemic status: Nil.

Threatened status: Nil.

Recovery plan: Nil.

Major threats: Stokes (1988) reported that “their numbers have been adversely affected since settlement by rats, cats, hunting and habitat clearance”, but “they remain common”. The impacts of Yellow Crazy Ant infestations on this species are unknown. 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.

Management priorities: Develop or maintain monitoring program. **(Recommendation 10)**.

CHRISTMAS ISLAND HAWK-OWL *Ninox natalis*

Population estimates: 10-100 pairs (van Tets, 1975); 100 pairs (Stokes, 1988); 820-1,200 birds (Hill and Lill, 1998); 1,200 breeding birds (Garnett and Crowley, 2003); 1,000 individuals (1996: James in http://www.birdata.com.au/iba.vm); about 54 calling birds (survey of 54 sites by Parks staff January-February 2005). Recent anecdotal evidence (N. Hamilton, WA Wildlife Research Centre, pers. comm.) suggests that this species may have declined abruptly over the last few years, although in 2009 Smith (2009) reported it in seven of eight sites sampled.

Endemic status: Endemic species. Previously considered as a subspecies of *N. squamipila*, but recent taxonomic studies have concluded that it is specifically distinct (Christidis and Boles, 2008).

Threatened status: Vulnerable. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Hill (2004b).

Major threats: There has been no conclusive demonstration of threats, but a limiting factor may be the abundance (or availability) of hollows in large rainforest trees. Because of the requirement for hollows for breeding, it has probably declined more or less proportionally to the extent of clearing. The impacts of Yellow Crazy Ant infestations on this species are unknown. Change in invertebrate composition and/or abundance due to ecological dominance by Yellow Crazy Ants, and to consequential change in forest structure, may affect this species. There is some potential that it may be affected by uptake of Fipronil, but there is no primary evidence for this.

Management priorities: We rate it a high priority to monitor this species and undertake rapid management responses if such monitoring indicates decline. Assessment of breeding success is also urgent as, if it is in rapid decline, this is possibly due to breeding failure. Assess any uptake of Fipronil, or its breakdown products **(Recommendations 7, 10 and 20)**.

CHRISTMAS ISLAND WHITE-EYE *Zosterops natalis*

Population estimates: 100,000-1,000,000 pairs (van Tets, 1975); 20,000 (Garnett and Crowley, 2003); 80,000-170,000 (Corbett et al*.,* 2003); 20,000 individuals (2004-2006: James in http://www.birdata.com.au/iba.vm).

Endemic status: Endemic species.

Threatened status: Nil. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Nil.

Major threats: Not clearly demonstrated, but probably predation by cats and Black Rat, and potentially reductions in reproductive success and/or invertebrate abundance and foraging effectiveness, due to Yellow Crazy Ants. There is some potential that it may be affected by uptake of Fipronil, but there is no primary evidence for this.

Management priorities: Maintain monitoring program. Assess any uptake of Fipronil, or its breakdown products. Eradicate cats and Black Rat **(Recommendation 15)**.

CHRISTMAS ISLAND THRUSH *Turdus poliocephalus erythropleurus*

Population estimates: 100,000-1,000,000 pairs (van Tets, 1975); 4,000 (Garnett and Crowley, 2003); 20,000-50,000 (Corbett et al*.,* 2003).

Endemic status: Endemic subspecies.

Threatened status: Endangered. [Considered to be critically endangered by Garnett and Crowley (2000)].

Recovery plan: Nil.

Major threats: Not clearly demonstrated, but probably predation by cats and Black Rat, and potentially reductions in reproductive success and/or invertebrate abundance and foraging effectiveness, due to Yellow Crazy Ants. There is some potential that it may be affected by uptake of Fipronil, but there is no primary evidence for this.

Management priorities: Maintain monitoring program. Assess any uptake of Fipronil, or its breakdown products. Eradicate cats and Black Rat. **(Recommendation 15)**

Table 6 **A framework for assessing conservation priorities for Christmas Island birds. Note that for some particular actions below, prioritisation may differ when viewed from the perspective of conservation for components of biodiversity other than birds.**

Research and Management Theme	**Priority**	**Time Frame**		
		Immediate (1-2 year)	**Medium** (2-5 years)	**Long-term** (>5 years)
non-native animals	high	develop procedures to reduce predation on nesting seabirds (particularly red-tailed tropicbirds) by cats and black rats	eradicate cats and black rats from the island	
	medium	assess impacts of Yellow Crazy Ants infestations on forest birds and breeding seabirds assess Fipronil uptake (and impact) on insectivorous birds		control Yellow Crazy Ants
	medium		assess disease and parasite status of native and non-native birds	eradicate non-native birds

non-native plants	medium		control those weed species affecting habitat quality for breeding seabirds	
clearing & vegetation management	high	constrain further clearing	rehabilitate previously cleared lands, especially in areas adjacent to significant Christmas Island Frigatebird nesting areas	
monitoring & research	high	develop and implement robust monitoring program for hawk-owl. if monitoring indicates recent decline, undertake research to identify limiting factors and principal threats, and determine and implement appropriate management response	develop, implement and maintain robust monitoring programs, for other threatened and endemic birds, and breeding seabirds	develop thresholds and protocols for interventionist responses for rapid decline of any endemic bird or breeding seabird
	medium		assess impacts upon population viability of off-island threats to seabirds	
governance	high	implement appropriate quarantine		

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 endemic (Eldridge et al., 2009) Christmas Island Shrew (*Crocidura trichura*) and the presently documented likely extinction of the Christmas Island Pipistrelle promotes the Christmas Island Flying-fox (*Pteropus natalis*) to the last remaining endemic mammal species on Christmas Island.

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, both processes that foster successional changes in woody plants and maintain ecosystem processes in the tropics (Shilton et al*.,* 1999; Ingle, 2003; Fleming et al*.*,, 2009).

To quote from James (2007a): "The Christmas Island Flying-fox, *Pteropus natalis*, is restricted to Christmas Island. It has undergone declines of about 75% in the last 22 years (from about 6000 in 1984 to about 1500 in 2006)." James also showed that Flying-fox camps had declined from six to three in this period and, despite a lack of detailed understanding for the reasons for the decline, he attempted to summarise all available information on *P. natalis* in order to facilitate efforts for a recovery of the species.

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. James et al*.,* (2007) provided 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 emerged on the major causal agent but ranking high on their list of 'plausibility' were disease and multi-factor causes.

The EWG 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 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 supercolonies of the ants. Given that 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 cannot be overestimated and this taxon remains an important 'keystone' species.

The Threatened Species Scientific Committee (TSSC, 2008) examined all available evidence for the magnitude of the decline but recommended against listing the sub-species [*Pteropus melanotus natalis*] 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.

The demise of bats on islands has been highlighted in Helgen et al*.,* (2009) with at least ten species, particularly in the flying-fox genus *Pteropus,* becoming extinct over the past two centuries. However, they further indicate that little is known from the literature of 'patterns, processes and drivers' for these island extinctions.

The evidence available to the EWG of a marked population decline in the Christmas Island Flying-fox represents an unfortunate parallel with the recently extinct Christmas

Island Pipistrelle. To avoid a repeat of the Pipistrelle extinction for the island's remaining native mammal, it is imperative that a recognisable 'trigger point' be established that facilitates immediate management interventions. These should include the commencement of active demographic monitoring, a screening of blood for assessment of pesticide residues and potential antibodies to diseases, and a captive breeding program as insurance against probable extinction. Specifically, there is now an urgent need to:

1 Re-assess the structure of the remaining population of flying foxes, in particular their age-class sex ratios, recruitment success and the pattern of mortality.

2 Identify current food plants throughout the year, and determine their distribution, condition, abundance and phenology (geographical as well as seasonal patterns).

3 Carry out or update previous assessments of other potential causes of decline, including interactions with Yellow Crazy Ants, introduced predators/humans, food-tree contamination and diseases/parasites/toxin loads.

4 One week on the island by two bat ecologists is required in mid-2010 to provide a context on the species foraging capabilities, specifically to determine the species' flight speeds and airframe characteristics (maximum commuting range, daily metabolic requirements and energy-cost of lactation).

5 At least until the taxonomic species-level issue and pathogen/parasite questions are resolved, take 15 to 20 individuals into captive breeding while the extant population (circa. 1500 individuals) can sustain such a removal. Being essentially fruigivores, the captive population could be held on the island relatively cheaply pending confirmation of an ongoing need.

Some relevant data exist on (1) and (2), but most of it was collected in 1984, before the population was considered to be threatened. The flying fox project needs to commence immediately and to be well advanced before the next birthing season (December 2010-March 2011) (**Recommendations 24 and 25)**.

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 10), 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, *Gecarcoidea natalis*

Figure 10 Photo of a Red Crab, an iconic species with a very unfortunate recent history and an uncertain future

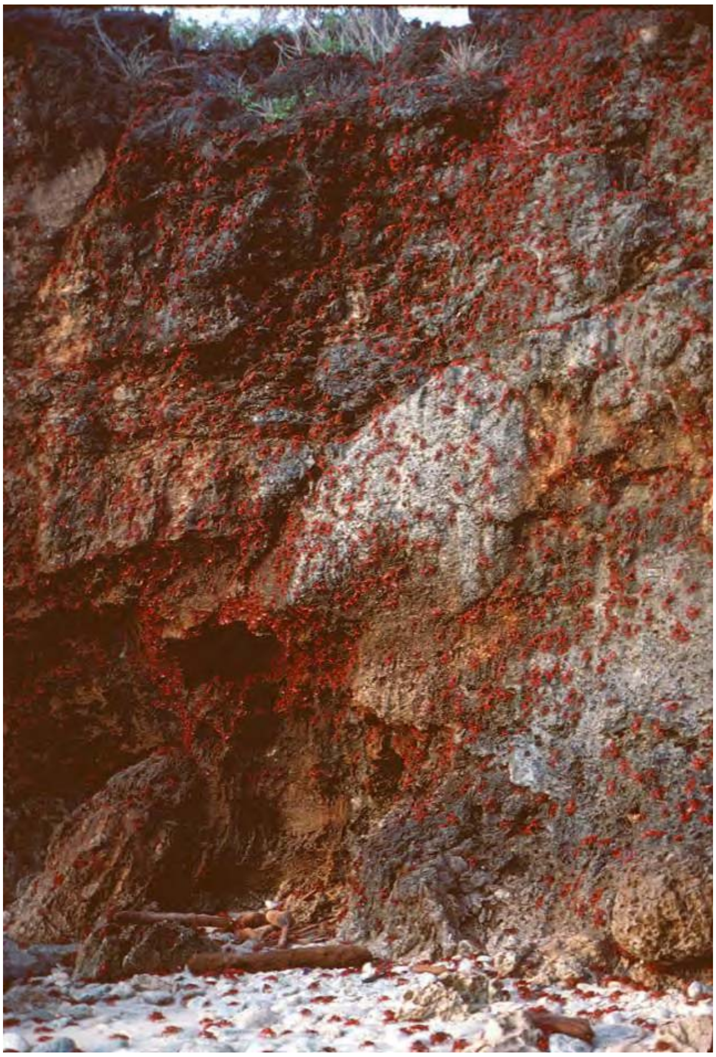

Figure 11 Photo of Red Crab annual migration down to the sea to release eggs. Migrations have become less spectacular since the outbreak of the Yellow Crazy Ant supercolonies.

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 shore in tens of millions to mate and then deposit their eggs in the sea (Figure 11). 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 five 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. By digging burrows, they turn over and aerate the soil and promote water absorption. In the wet season, many 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.

The migrations were studied in 1993-1995 by radiotracking and marking individuals with paint (Adamczewska and Morris, 2001). They estimated an island-wide population of 43.7 million crabs. They reported directions and distances travelled, and the dependence of a high humidity (>85%) before daily travel would occur. They drew attention to the importance of the annual monsoon to stimulate migration. Crab movements tended to be in straight lines rather than 'flowing downhill', and there was a focus on travelling to the north west coast, rather than to whichever coast was nearest. This coast may be most favourable for successful return of crablings, being calmer, which may have resulted in an imprinting on crablings during their first climb up into the forest, which they play out subsequently in mating migrations. This pattern may be reinforced if younger crabs are influenced by travel of more experienced individuals.

The dependence of crab migration on high humidity and monsoonal activity as a trigger implies that their migration and thus their survival could be vulnerable to a change to a drier climate, should that occur.

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 'supercolonies', colonies with multiple queens and ant densities of thousands per square metre. 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 supercolony 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 supercolonies covered 25 per cent of the rain forest on the island (O'Dowd et al., 2003) (Figure 12).

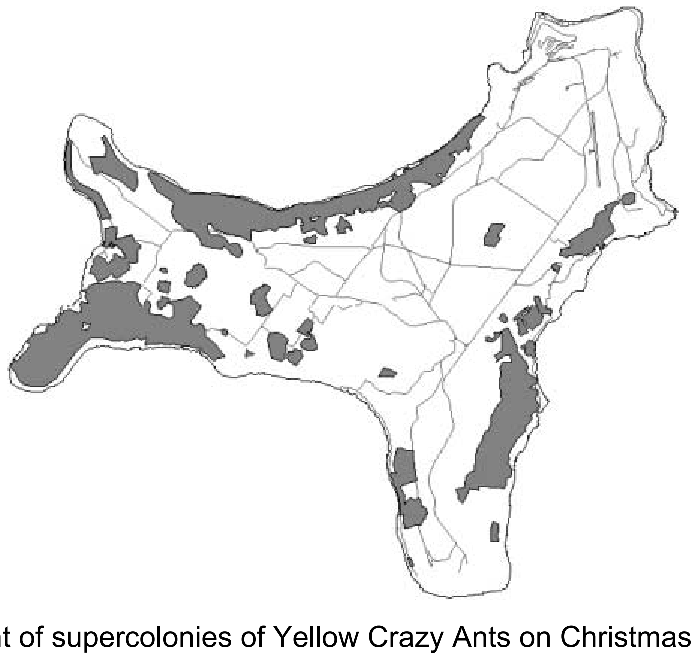

Figure 12 Extent of supercolonies of Yellow Crazy Ants on Christmas Island to 2002 (Abbott, 2007)

The rise of the supercolonies is associated with high densities of two exotic insects, the lac scale**,** *Tachardina aurantiaca* (Kerriidae), and the soft scale *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 honeydew 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 13). 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 honeydew 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 to the Minister they 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 by the TSSC supporting the recommendation can be found at:

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

Figure 13 Photo: Scale insects

Figure 14 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 supercolonies 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 supercolonies. O'Dowd et al. (2003) estimated that one quarter to one third of the Red Crabs had been killed during the late 1990s (Figure 14). 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 supercolonies of Red Crabs was to implement island wide control of Yellow Crazy Ant supercolonies. 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, 2007 and in late 2009. The purpose of the surveys has been to establish the geographic extent of the supercolonies and assess the population of Red Crabs by burrow counts, before and after Yellow Crazy Ant 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 and 2009) and, because of the cost of getting a helicopter to the island, by targeted hand application in other years. The extent of baiting has varied from year to year. The 2002 helicopter baiting covered 2366 ha, while the total area baited between 2002 and 2008 by hand baiting was 1712 ha. Helicopter baiting in 2009 covered an area of 784 ha. The use of Fipronil and the issues that arise from that are discussed elsewhere in this report (Section 4.4).

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 decline in Red Crab numbers appears to have slowed. O'Dowd et al. (2003) estimated that 25-33% of the Red Crabs had been killed by Yellow Crazy Ants. Smith et al. (in prep.) report a statistically significant decline in burrow counts, as a proxy for abundance, of 18% over nine years, to 2009. This accords with the lack of observed mass mortalities of Red Crabs since the baiting commenced.

There has been concern about an apparent lack of significant recruitment events. Anecdotal evidence from long term Parks staff and other residents when the EWG visited the island was that there had not been a significant recruitment event since the late 1980s. This is about when the first YCA supercolonies were noticed. However, just as the mass migrations of Red Crabs to the sea were a much remarked upon spectacle, the locals note 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 for crabling recruitment and recollection has it that the last recognisable event was about nine years ago, so another one was due in late 2009 or early 2010. As it happened, there was a good but not spectacular return of crablings in January 2010, from a substantial crab migration in December 2009 (Orchard, pers. comm.).

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, today 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.

Without adequate recruitment, Red Crabs are likely to decline to extinction. The management goal of 'restoring Red Crab numbers to pre-ant supercolony levels' is appropriate, because that would re-establish the spectacle of the huge reproductive migrations that 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 on their capacity to remove the developing understorey and re-establish the 'bare forest floor' structure which pre-dated the emergence of the ant supercolonies. 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 with certainty. However, in the longer term mature tree mortality and seedling predation by the restored crab populations would be expected to re-establish a new, not necessarily the same, equilibrium forest structure. This can only be resolved experimentally (**Recommendation 13**).

James (2007a) reported that Red Crabs prey on Giant African land Snails, implying that although the snails co-exist with ants, ants in supercolonies and crabs cannot co-exist, and neither can snails and crabs.

James (2007a) collected population statistics on Red Crabs, measuring and sexing nearly 4000 in February – May 2004. He found that sex ratios and size distributions were different at different parts of the island, with males outnumbering females 2:1 on the coastal terraces. Larger individuals of both sexes tended to be found high on the island, farthest from the water. Males were on average slightly larger than females. Small crabs were rare in his samples, implying poor recruitment, at least in that and previous seasons. This study was undertaken after the rise of supercolonies of YCA so, as noted by James, the extent to which it is representative of unaffected populations is unknown.

James (2007a) also reported mortality of crabs due to road traffic. With so much focus on the YCA it is easy to downplay the significance of road mortality of Red Crabs during the seasonal migration. However, James counted 34,000 dead Red Crabs killed on the 14 sections of roads he surveyed in 2005-2006, which extrapolated to an estimate of 425,000 Red Crab deaths from traffic during that migration. This can be compared with an estimate of about 40 million Red Crabs on Christmas Island in the mid-1990s (Adamczewska and Morris, 2001), with a loss of one quarter to one third from YCA by the late 1990s (O'Dowd et al., 2003) and further losses between then and 2005-2006 at the time of James' study. Clearly the loss to traffic is not trivial. Substantial efforts are made annually by Parks Australia Christmas Island staff to reduce mortality through road closures and installation of crab-friendly crossing points, and James reported fewer deaths where crossing were in place. There was a direct relationship between traffic and deaths and James recorded that traffic related to the construction of the IDC apparently accounted for large numbers of crab deaths in the central and western parts of the island. He also reported mortalities of Robber Crabs (see section 4.11.2).

James (2007a) made a number of recommendations that should be given serious consideration in developing ongoing Red Crab management programs. These include a suite of suggestions aimed at reducing mortalities due to traffic, systematic monitoring of wildlife traffic deaths and a study of Red Crab (and Robber Crab) population ecology.

The EWG 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 **(Recommendations 8, 9, 10, 12 and 14)**.

4.11.2 Robber Crabs, *Birgus latro*

Figure 15 Photo of a robber crab.

Robber Crabs (Coconut Crabs) (Figure 15) 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 Indo-Pacific Oceanic islands as well, but throughout their range they are in serious decline. They are omnivorous and feed on coconuts and other fruits, as well as smaller crabs. Their diet on Christmas Island was studied by Rumpff (1986). The island has few natural occurrences of coconut trees, however, they eat a wide variety of fruit, particularly that of the Arenga palm (endemic sago palm, *Arenga listeri*). They also 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. They are also carrion feeders and will cluster around bodies of other crabs killed by road traffic (Rumpff, 1986).

Reproduction involves mating on land and females retain the fertile eggs under their abdomen for several months. Once they are hatched, females deposit 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 their abdomen hardens. They mature in four to eight years, which is a long time for a crustacean.

The status of Robber Crabs on Christmas Island is uncertain. They are facing many threats and there are no reliable estimates of the population or population trends. James (2007b) refers to a 1933 report that they 'were spread over the entire island, often at a 1 m^{-1}'interval. Hicks et al. (1999) reported densities that would imply an estimate of 1-2.3 million, but James (2007b) explained why he thought that could be ‘a substantial over estimate’. Rumpff (1979, referred to in James, 2007b) considered Robber Crabs had declined from estimates made by Harms (1933) and Gibson-Hill (1947). This was, of course, long before the formation of supercolonies by Yellow Crazy Ants.

An English translation of a substantial unpublished PhD thesis on their population ecology and feeding biology by Holger Rumpff has recently become available (Rumpff, 1986), but it provided no definitive data on total populations, or trends. Rumpff counted Robber Crabs along transects utilising the cleared drill lines and estimated population densities at different locations. He also measured body sizes. The population was strongly male biased, and males grow much larger than females. He found the highest densities of Robber Crabs in undisturbed forests towards the north-west, about 160 individuals per hectare. In areas mined previously densities were much lower and in the clear cut areas they were not to be found.

Although adequate data are lacking, anecdotal reports assert that Robber Crabs are in decline and, indeed, they could be seriously at risk from the combination of loss of habitat, traffic mortality, Yellow Crazy Ants and Fipronil. Like Red Crabs, Robber Crabs are killed by Yellow Crazy Ants and they are sensitive to Fipronil (Green et al., 2002), the insecticide used to control Yellow Crazy Ants. Steps are taken during the baiting to minimise this, with anecdotally good results, however the long-term effectiveness is unknown. Many are killed by traffic on the roads both during feeding and during their breeding migration. During the 2005-2006 migration, James (2007b) counted Robber Crabs killed by traffic in the 14 sections of road totalling 50.5 km that he had under surveillance. Three surveys were conducted, one each in October, November and December 2005. Respectively 31, 49 and 27 Robber crabs were killed, a total of 107. Making some reasonable assumptions, this was translated to approximately 1,200 killed during the migration. James (2007b) reported a strong correlation between crab mortality and traffic numbers. With higher vehicle densities than ever before on Christmas island now, because of the expansion of the IDC, mortality from traffic can be expected to rise. The assertion is brought out by recent observations. Prompted in late 2009 by subjective impressions by Christmas Island community members that there was an increase in the numbers of Robber Crabs being killed by traffic, Parks Australia staff in the course of their normal travels began logging dead crabs and painting them pink, to draw attention to these mortalities. They also logged locations and, between 1 January and 19 February 2010, counted and plotted 125 Robber Crab deaths. As seen on the map (Figure 16), most Robber Crab kills have been found along the main access road to the Immigration Detention Centre. Such mortality rates are likely to be unsustainable.

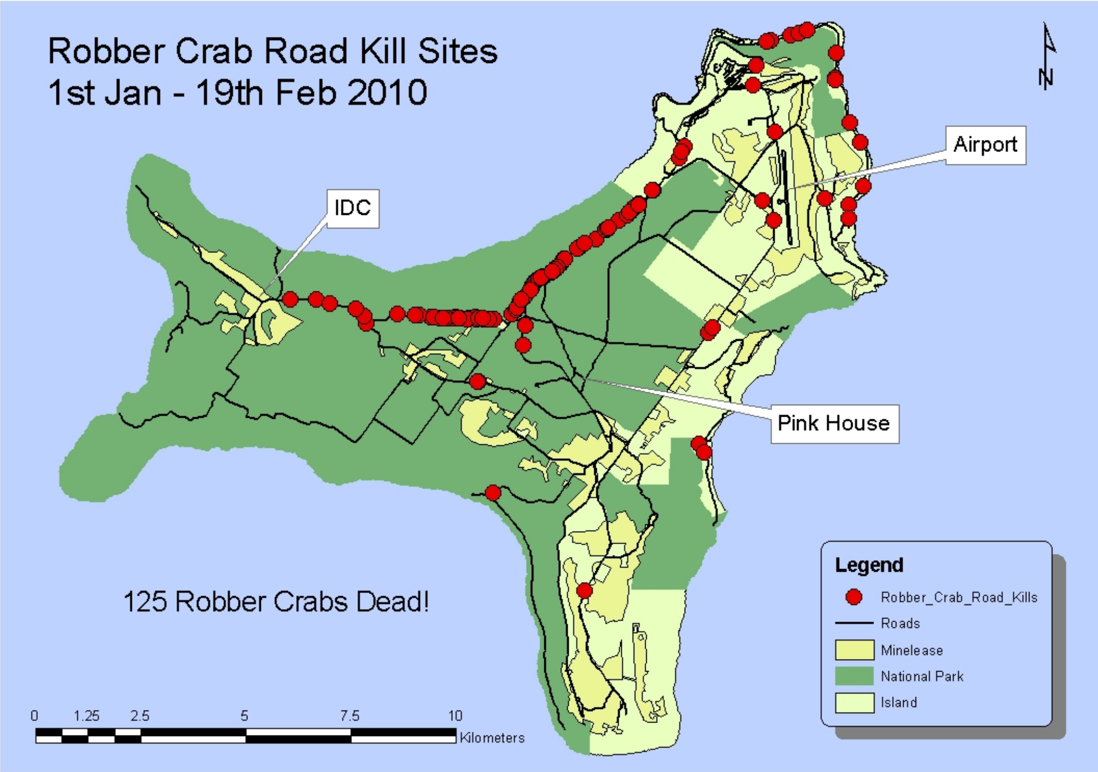

Figure 16 Robber Crab Road Kills January to February 19th 2010

It is noteworthy that the crab crossings installed at many places to reduce mortality to Red Crabs are ineffective in directing Robber Crabs to safe conduits; Robber Crabs are too good at climbing.

Parks Australia staff are at present increasing their community education actions in support of more crab-friendly driving. This includes publicity for more responsible driving through the local newspaper, posters, road signage, Australian Federal Police targeting speeding, and information sessions given for Department of Immigration and IDC staff.

Some Robber Crab mortality results also from their use as human food, including some illegal poaching.

Only limited information is available about the population ecology of Robber Crabs. Most of it is about population structure, with little or no information on longevity. James (2007b) sexed and measured 538 individuals and found a highly skewed sex ratio, 2.36:1 in favour of males, more male biased than values reported by Rumpff (1986) (1.69:1 total, 1.24:1 over the size range common to both sexes). It would be interesting to know whether this difference over about two decades represents an island-wide change or is a sampling artefact. James also found that males are much larger than females. As for the Red Crabs, he found small Robber Crabs to be rare, raising concerns about recruitment. Whereas Rumpff (1986) reported many crabs with carapace widths below 50 mm, to about 30mm, James (2007b) reported only one below 50 mm. This could be the result of poor recruitment years, or it could be indicative of something more serious. James did not have the Rumpff thesis available so was not able to discuss these interesting comparisons with the earlier study.

No population studies provide information about longevity, and this is urgently needed. The numbers of Robber Crabs that are killed annually by traffic on Christmas Island is much lower than for Red Crabs. However, there are far fewer Robber Crabs, and they certainly live longer, perhaps very much longer. Good data on longevity are lacking from elsewhere too, but Schiller (1992) found in a study of Coconut Crabs on Nuie that a viable population depended upon a female having five successful spawnings. On top of their six years to maturity, a viable population depends therefore upon females living to 11 years. Schiller (1992) showed that the population ecology of *Birgus latro* makes it particularly vulnerable to harvesting for food, and the Niue population was in a parlous state, with a preponderance of small animals.

What is known or can be inferred from studies elsewhere suggests that Robber Crabs on Christmas Island may be in serious decline or even at risk of extinction. They are suffering habitat loss, traffic mortality, attack by Yellow Crazy Ants, poisoning by Fipronil, and some limited poaching. Fewer crabs in smaller size classes than reported previously could be a consequence of chance low recent recruitment, or perhaps they provide a more disconcerting signal. More information is needed. In the short term, steps could be taken to reduce traffic mortality. In the medium term, phasing out the use of Fipronil is desirable and, urgently, the EWG recommends monitoring Robber Crabs and embarking on a study of their population ecology and also their ecological roles (predation on Red Crabs, fruit dispersal etc.) **(Recommendation 14)**.

4.12 Flora and Vegetation

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.

However, two highly localised vegetation communities on Christmas Island have been listed as Wetlands of International Importance 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 25 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.

Island management would benefit from the development of a 'synthetic' mappable vegetation classification as part of ongoing biodiversity monitoring (**Recommendation 10**).

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. A longer term Memorandum of Understanding between the Attorney General's Department and Parks Australia is currently being finalised that should to some extent reduce this funding uncertainty. (**Recommendations 5, 6, 7 and 10**).

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 Malaysian 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 10).

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 more than 100 years.

There is little long-term monitoring programs for 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. The EWG 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 9) 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 (Table 7) 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.

Table 7 Asplenium Recovery Plan Actions

No.	Action	Suggested timing
Objective 1:	**To abate and avert threats to the species**	
1.1	Keep locations of populations confidential	Continuing
1.2	Monitor visitor pressure and impact on Gannet Hill population	Continuing
1.3	Ensure inclusion of *Asplenium listeri* in all guidelines and specifications for environmental assessment and standards, particularly along the east coast	Continuing
1.4	Pursue national park status for the Ross Hill Gardens area and around South Point, and other areas related to populations of *Asplenium listeri* that are located within the term of this plan	continuing
1.5	Consider need for listing on the EPBC Register of Critical Habitat to strengthen legal protection, with update as new populations are located	Being considered – potential listing of CI ecosystem
1.6	Expand content about *Asplenium listeri* (and other listed plant species) in future national park management plans with specific reference to recovery plans and relevant threat abatement plans (keeping precise locations confidential)	Next revision - 09/10; consider in CI Regional Recovery Plan (currently being drafted)
1.7	For the population at The Dales, and if a population is located at Hosnie's Spring, update the relevant Ramsar Information Sheet and description of ecological character to ensure the most robust protective framework under the EPBC Act	ECD project underway
Objective 2:	**To improve knowledge of factors in the restricted distribution of the species**	
2.1	Survey all known occurrences of *Asplenium listeri* to compile a comprehensive list of environmental factors (physical and biological) and base data (including photographic) for population monitoring	Planning underway for possible survey 2010
2.2	Consider use of the above to develop predictive models to assist location of additional populations	2011
Objective 3:	**To increase the number of known occurrences**	
3.1	Survey potential habitat for more populations, with focus on the east coast, including Hosnie's Spring (following a wet season)	By Year 2 not completed
3.2	Examine the need for and potential of ex situ cultivation	Year 2 not completed
3.3	Examine potential for (re)introduction of *Asplenium listeri* into additional east coast terrace cliff-tops	By Year 5 for review of this plan Not completed

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	

4.13 OTHER TAXA

The high rate of endemism amongst the vertebrates is also reflected in a high level of endemism amongst several groups of invertebrates on the island (James and Milly, 2005). In a detailed search of the literature on Christmas Island biota, as part of the Biodiversity Monitoring Program, a specific Inventory of endemic forms was compiled that documented over 250 endemic species and a further 165 that occurred nowhere else on Australian territory. Several taxonomic groups were identified as poorly known (fungi, nematodes and taxa in the plankton complex) and in need of further documentation (James, pers. comm.).

Kessner (pers. comm.) documented the land snails and land slugs of Christmas Island in 2006 and concluded that of the 40 species documented, nine were presumed endemics, three were natives, 23 were introduced and 5 species were of uncertain origin (i.e., cryptogenic species). Framenau and Thomas (2008) considered that none of the 52 ant species recorded by them were endemic to the Island (Appendix 9).). Likewise, Abbott (2004), in her doctoral thesis, determined that none of the 14 species of scale insects on the Island (some now with revised taxonomic identity (Abbott, pers. comm.)) were endemic and that most had the potential to be significant pests. The latter two invasive insect groups, with their generally mutualistic associations, have proven to be the major driver behind ecological meltdown in many island ecosystems.

It is essential that the comprehensive documentation of species endemic to Christmas Island be maintained as they are essential component of the Island's biodiversity and to the management of the Island's unique ecology **(Recommendations 5, 7 and 10)**.

These concerns are reinforced by the fact that the primary driver of the ecological state of Christmas Island is invertebrates, but knowledge of invertebrate biodiversity on the island is fragmentary and uncoordinated. A number of studies have made significant general collections of terrestrial invertebrates but most have been discontinued following only elementary identification that is inadequate to inform on endemic biodiversity. The level of taxonomic expertise sought on specific issues is sometimes inadequate to the task and can potentially result in serious delays and misdirected allocation of funding. Furthermore, the material collected and stored on the island is inadequately housed and curated to provide the sustainable permanent collection required to assess the nature of and trends in Christmas Island biodiversity, or to recognise newly arrived species by-passing quarantine **(Recommendation 16)**.

4.14 MARINE ENVIRONMENT

The working group initially 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 seabirds 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 recognised and that 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 either nest on the island or use marine habitats around the island, all of which are listed as threatened, spend nearly their entire life-cycle in the ocean. Green Turtles, and more rarely Hawksbill Turtles, have been recorded nesting on Dolly Beach on the small area of sand above the high tide level, and occasionally attempt to nest on Greta Beach, but this beach is small and can be inundated by high tide, which reduces the likelihood of successful nesting (Brewer et al., 2009). The nesting area on Dolly Beach is used as a campsite by locals, and some people are known to poach the turtle eggs (Brewer et al., 2009).

The marine biodiversity of Christmas Island has been documented by Berry and Wells (2000) - and references therein, and more recently reviewed by Brewer et al., (2009).

Surveys of the marine fauna indicate that Christmas Island has a relatively low biodiversity when compared to other islands, reefs and atolls in the Indian Ocean. This can be partly attributed to the small size of the island, its isolation from regular sources of planktonic larvae, and the extensive mortality of corals that occurred several years prior to the comprehensive survey by the WA Museum in February 1987, and more recently in 2008 (Hobbs, pers. comm.). Recent studies have shown that Christmas Island forms a globally significant marine suture zone characterised by a relatively large number of hybrid fishes that result from interbreeding between Pacific Ocean and Indian Ocean species that coexist at the island (Hobbs et al*.,* 2009a). In addition, Christmas Island is now recognised as a significant location for migrating whale sharks and an aggregation site for juvenile whale sharks (Hobbs et al*.,* 2009b). Marine scientists from James Cook University are currently investigating the impacts of coral disease (Hobbs and Frisch, 2010) and other disturbances on the shallow coral reef systems directly surrounding Christmas Island.

Clearly, it is essential to better understand the marine environment surrounding Christmas Island and the interaction between its oceanic and terrestrial ecosystems **(Recommendation 4, 7 and 10)**.

4.15 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 are endemic to Christmas Island (Namiotko et al*.,* 2004; Bruce and Davie, 2006), while others, such as the shrimp *Macrobrachium lar* that is found in anchialine waters and freshwater springs (Humphreys and Eberhard, 1998), are closely related to populations in the Pacific (A. Duffy, pers. comm., 2005 in Humphreys and Danielopol, 2006)

Christmas Island has an anchialine community of the Procaridid-type which are restricted to isolated seamounts (known elsewhere from Bermuda, Ascension Island and Hawaii: Bruce & Davie, 2006; Humphreys and Danielopol, 2006). Remarkably, the Christmas Island anchialine system also has the thaumatocyprid ostracod genus *Danielopolina* (Kornicker et al*.,* 2006; Humphreys et al*.,* 2009), a genus typical of a second type of anchialine community, the Remiped-type, elsewhere restricted to epicontinental areas; Christmas Island is the only known location, globally, where representatives of both types of anchialine community co-occur (Humphreys and Danielopol, 2006). *Danielopolina baltanasi* of Christmas Island belongs to a different subgenus from the only other Indian Ocean (and Australian) member of the genus, *D. kornickeri*, the latter being known only sympatrically with *Lasionectes exleyi*, an EPBC Act-listed species found in Bundera Sinkhole, alongside Ningaloo Reef. The general composition of both types of anchialine community is predictable, even to the generic level, however far apart in the world they occur.

Of particular significance is that the only living member of the ostracod genus *Microceratina*, a genus with a long, well-established fossil history to the Late Cretaceous and a true 'living-fossil' (Namiotko et al*.,* 2004), is recorded only 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 11)**.

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 clearly shown that these are of National and International significance. Succinctly these values include the unique ecological character of the crab – forest community that is not found anywhere else, the unique stygofauna, a significant number of endemic species of plants and animals and its importance as a seabird rookery and marine suture zone. It is almost certain that other undiscovered values will be found, including those in the surrounding marine ecosystems and the interaction between these and the Island ecosystems.

The EWG, while recognising the extreme threats to the integrity of Christmas Island as an ecological entity, recommends that consideration be given to listing "Christmas Island and its surrounding seas" as a threatened ecological community under the EPBC Act **(Recommendation 30).**

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 of system' focus.

5.2 COMMUNICATING CHRISTMAS ISLAND'S VALUES

Implementation of the recommendations made in this report is dependent on public understanding on Christmas Island, amongst the Island's resident community and intermittent visitors from Australia and across the World. This cannot be achieved without a properly designed and executed communications plan **(Recommendation 31)**.

6.0 FINDINGS WITH WIDER APPLICABILITY

Effective management of threatened species is not easy, straightforward or inexpensive. But the presumed extinction of the Christmas Island Pipistrelle, 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. In addition, many of the Island species are subject to formal recovery plans and many of the declining species have been the subject of sustained, intensive and good scientific research. Collective these actions mean that considerable resources have been invested in conservation management on Christmas Island over this period. So 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. We recommend that the lessons learned be considered by DEWHA as a whole **(Recommendation 32)**:

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, many of which have extraordinary conservation values and high susceptibility to biodiversity loss; with concomitant resourcing for substantial management needs. The recent move to form a national island rescue foundation following the 'Island Arks' Symposium in Queensland in December, 2009, should be supported.

2. The conservation management of the island was overwhelmed by the crisis of dealing with Yellow Crazy Ants. 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 supercolonies 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 Crazy Ants (or their control) on many of the island's endemic invertebrates.

   It is also understandable that any strategic research and management focus may have been blurred or interrupted by the unanticipated imposition of the detention facility (IDC) 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 island-wide multi-species recovery plan.

3. A management prioritisation process was lacking. The large number of threatened and endemic species on Christmas Island is a significant

management 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.

Lesson: Develop and implement a management prioritisation framework.

4. Legislative conservation listing does not necessarily equate to conservation needs or the allocation of resources. 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 status. 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 and streamlined processes for identification and review of threatening processes and lists of threatened species, including those in conservation reserves.

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. Many of the threats now operating on Christmas Island are the indirect, rather than the direct effects of mining, so that it is debatable whether or not rehabilitation of the more visible effects of mining should be the paramount conservation concern on the island. Rehabilitation of land made inhospitable for vegetation by mining may not be the most effective use of the conservation levy.

   Lesson: Where commercial leases or other commercial regulatory instruments exist or are proposed, their re-negotiation or negotiation should have, as part of the negotiating brief, the application of suitable conditions to create additional resources to manage areas or matters of high biodiversity conservation importance.

6. Resourcing insufficiency and insecurity. The conservation of threatened species and ecosystems usually requires 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: Development and maintenance of a secure funding stream for the conservation management of all biodiversity aspects of Parks Australia reserves.

7. Improved monitoring. A robust monitoring program is an essential foundation for the conservation and management of biodiversity. Without one, there is no way to know with certainty whether or not a problem is looming, and whether or not implemented management actions are working. For most endemic and threatened species on Christmas Island, there is no ongoing monitoring program capable of detecting undesired population trends in a timely fashion, of assessing the effectiveness of management, or to provide the evidence needed for rational prioritisation of management actions.

   Lesson: Development and maintenance of robust, integrated monitoring programs for Parks Australia reserves; this should include the early identification of potentially threatened species, ecosystem health and other matters of particular conservation significance. The provision of annual reports setting out the results of such monitoring would form the 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 did not address the issue of captive breeding; it did not initiate a belated program to monitor population recruitment and made no mention of what is now seen as one likely 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.

   Although researchers worked mostly comprehensively and innovatively to the Plan, in hindsight the plan was flawed by the absence of adaptive management processes and clear trigger points.

   Lesson: Incorporate adaptive management more strongly into Recovery Plans.

9. Lack of an 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 of 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 had captive breeding commenced. 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. The assumption that national parks are adequate as a standalone conservation measure.

    Lesson: Establishment of conservation reserves is a useful step towards biodiversity conservation, but must be accompanied by appropriate management for biodiversity outcomes; this must include direct assessment of threats (especially by introduced biota), biodiversity condition and trends, and of management effectiveness.

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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: habitats comprising bodies of inland waters under marine tidal influence, usually salinity stratified waters with restricted exposure to the open air and with extensive connections with subterranean waters showing marine and terrestrial influences. They typically occur in limestone or volcanic coasts.

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 is 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 and recover from 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 permanently 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 can recover from change).

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.

APPENDIX 1 CHRISTMAS ISLAND PIPISTRELLE

Recommendation 19 in the interim report of the EWG was

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

Given the latest taxonomic data the working group recommends:

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.

4.7.1 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. The IUCN (2008) also lists it as a distinct species.

Clearly, it was important to resolve the taxonomic status of the Christmas Island Pipistrelle to define an appropriate course of action for the population remaining on Christmas Island. Accordingly, a study of the taxonomic status of the Christmas Island

Pipistrelle was commissioned by the Australian Biological Resources Study of the Department of the Environment, Water, Heritage and the Arts (Helgen et al*.,* , 2009).

The detailed examination of the morphological and molecular status of *P. murrayi* by Helgen et al*.,* (2009) resolved, unequivocally, that the species is a discrete taxon that can be differentiated from close relatives in the nearby Indonesian archipelago on the basis of morphological as well as both mitochondrial and nuclear DNA criteria. It is endemic to Christmas Island.

The working group accepts the conclusion of Helgen et al (2009) and treats *P. murrayi* as an endemic species.

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 5 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 supercolonies, 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 1). 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,' one of the least cleared parts of the island until the detention centre was built but one of the first places that Yellow Crazy Ant supercolonies were found.

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 have exacerbated the subsequent decline and extinction(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.

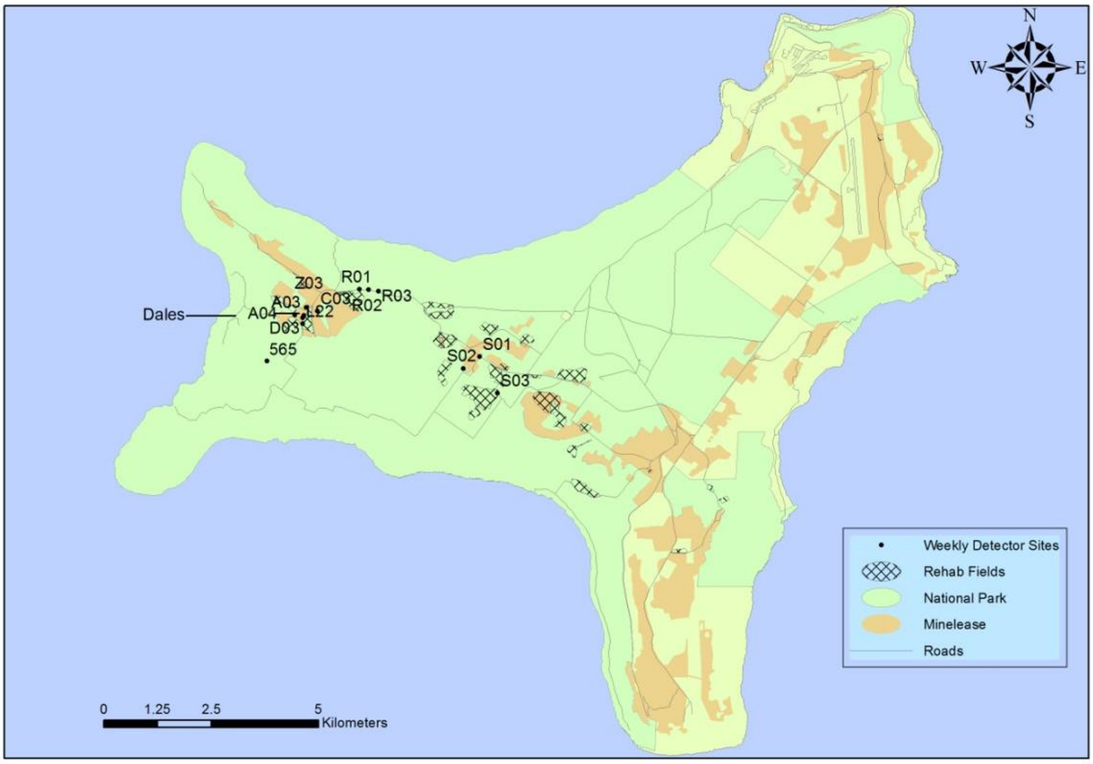


Figure 1   Key monitoring sites for the Christmas Island Pipistrelle.

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. The only recent known roost is under exfoliating bark on a dead tree, six to eight metres above ground. However, over the last decade the Christmas Island Pipistrelle has been recorded as roosting among twisted roots of live fig trees, in a hollow in a live tree, in dead hollow palms and in palm and pandanus foliage. Observations are too few to conclude that there has been any change in roost selection.

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 (Bullen and McKenzie, 2001; 2009a) 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, 2009) 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 (Bullen and McKenzie, 2004; 2009b), 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 2. The results show that the Christmas Island Pipistrelle is a moderately agile air superiority strategist[4] 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.

[4] 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.

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.

For microbats, flight-time and population recruitment are both energetically expensive. The eco-physiology data (Appendix 2) 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 2). 'Successful foraging' means that a female captures one appropriately-sized insect every 64 seconds. To achieve this level of efficiency, species echolocation is finely optimised; Triblehorn & Yager (2005) showed that the sensitivity of hearing in microbat species is narrowly tuned to a particular prey-size. Given its airframe design, usual foraging microhabitat and echolocation call characteristics, *Pipistrellus murrayi's* optimum prey are near-canopy, nocturnal, flying moths and beetles about 7 mm long. Population recruitment will be vulnerable to a prolonged reduction in the abundance of these insects that could have resulted from the many changes happening in the island's rainforest community. To assess this, the Malaise trap insect samples collected between 2000 to 2004 as part of the pre- and post-Fipronil application program (2002 – 2004) would need to be reassessed to see if they show the continued high abundance of nocturnal volant insects that James argues for in his submission to the working group and in James and Retallic (2007, Appendix G). A further program of light trap sampling would indicate current abundance of insects and, although the pipistrell is now considered to be extinct, and baseline data for the previous decade is absent, this might still have value for the Hawk Owl and other endemic insectivores.

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

Figures 16 to 18 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.

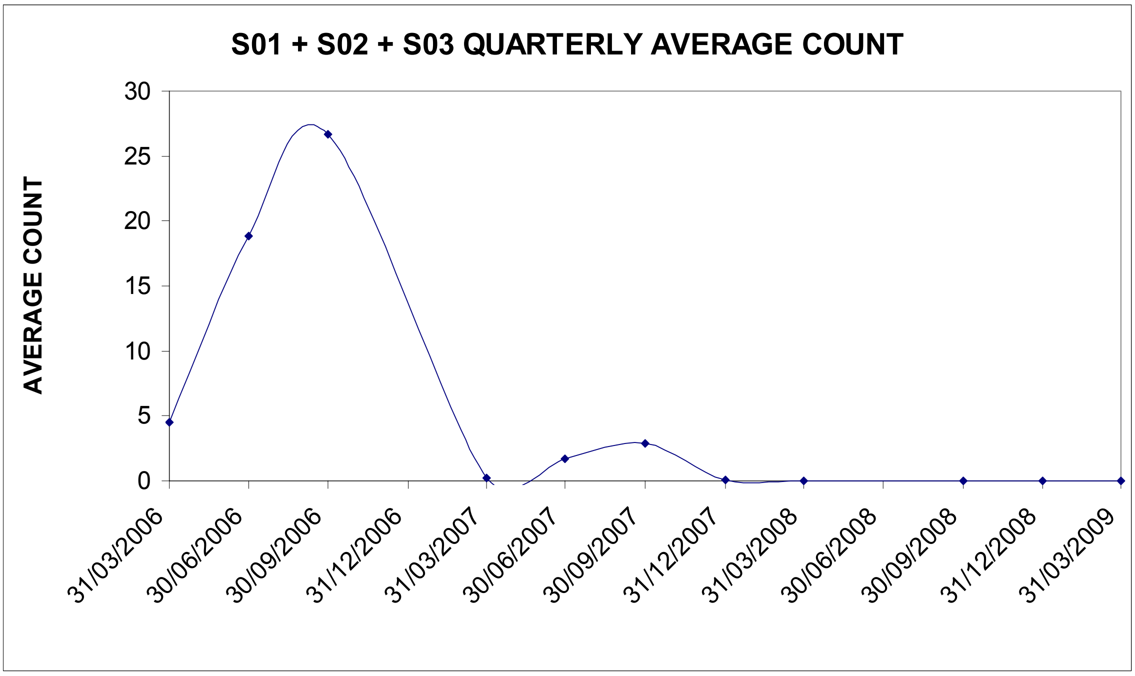


Figure 2 Christmas Island Pipistrelle quarterly counts at S01+S02+S03, three adjacent foraging sites in the island's central-west, about 5 km east of The Dales

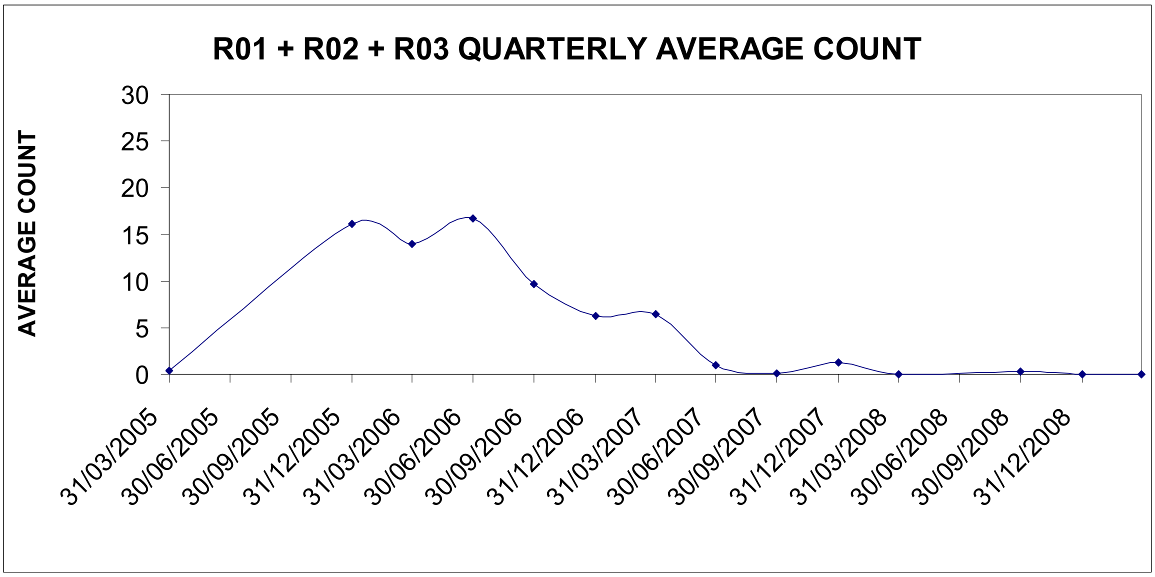


Figure 3 Christmas Island Pipistrelle quarterly counts at R01+R02+R03, three adjacent foraging sites a few kilometres closer to The Dales

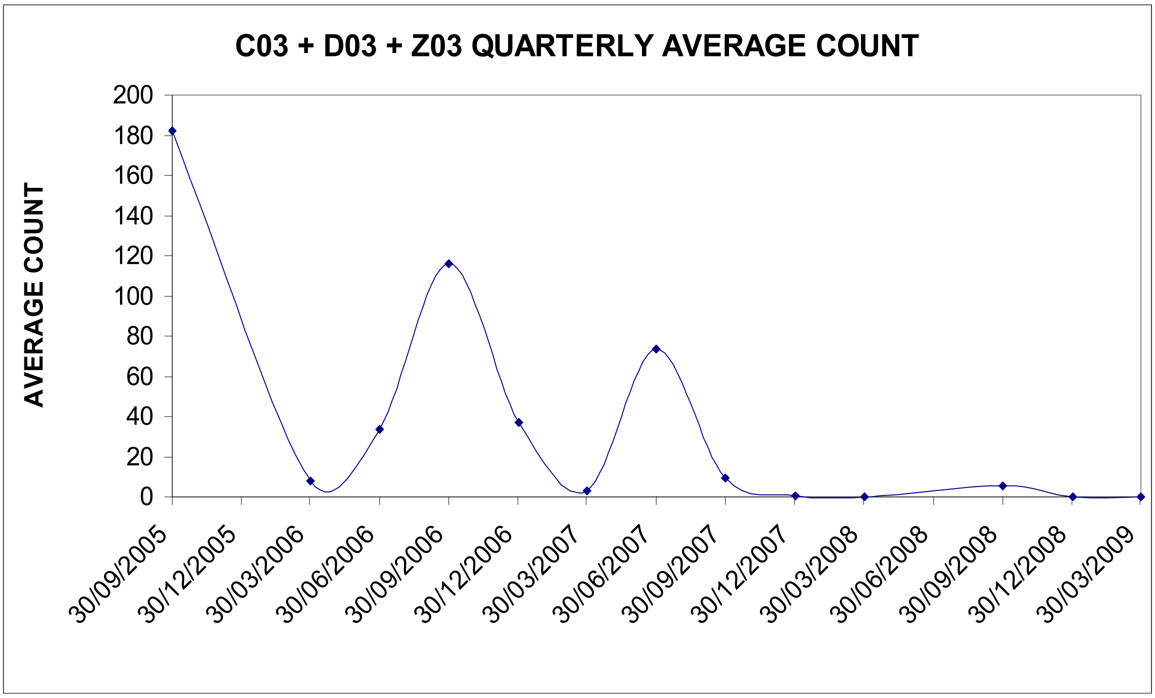


Figure 4 Christmas Island Pipistrelle quarterly counts in the Dales, close to the western end of the island, at three sites immediately peripheral to the species core foraging area: C03+D03+Z03.

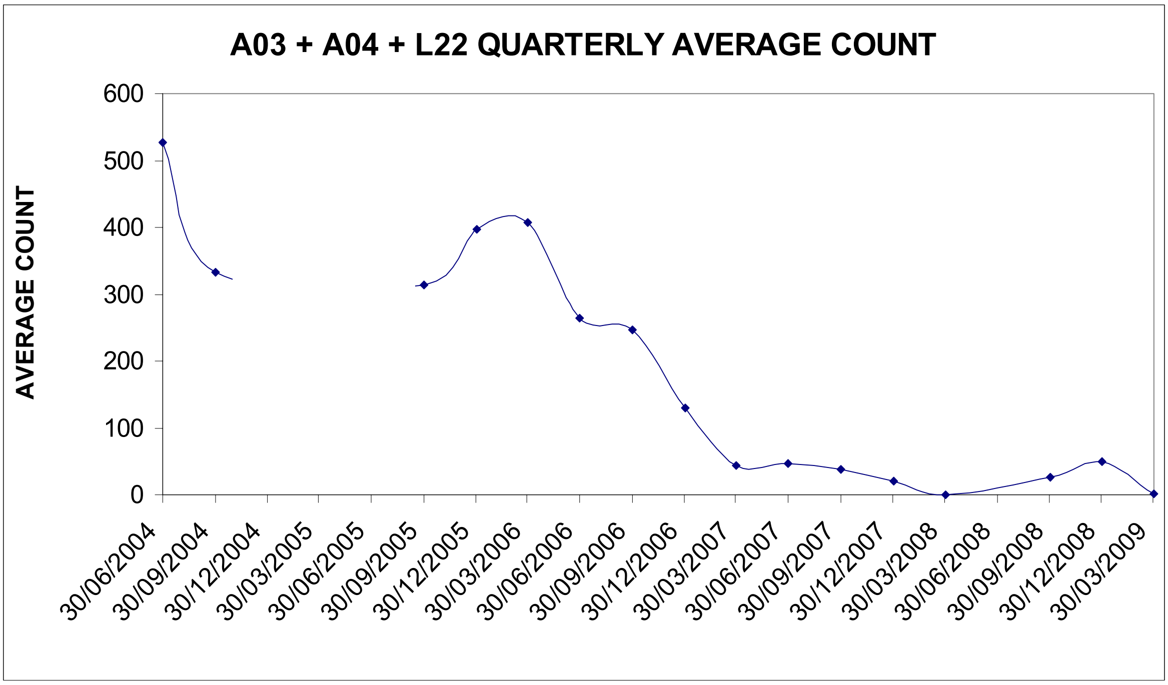


Figure 5 Christmas Island Pipistrelle quarterly counts in the Dales, close to the western end of the island, at three sites in the core foraging area where the species showed the highest level of activity post-2005: L22+A03+A04 (James, 2005; James et al.**, , 2007).**

Figures 2 to 5 all show a clear decline in recorded sequences with time. Activity declined substantially in the peripheral areas during late 2006 and early 2007. There was continuous decline in the core foraging area until mid-2008 at least , but from a much higher level (Figure 5).

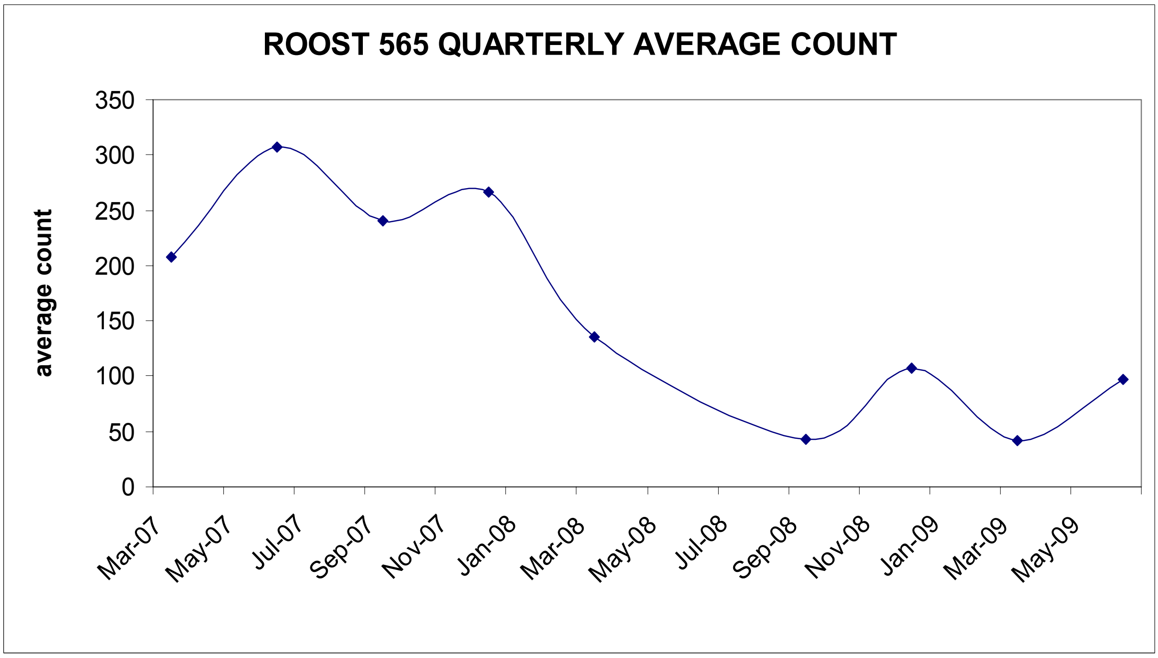


Figure 6 Quarterly average counts of Christmas Island Pipistrelle at roost-site 565

Figure 6 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”) during 2009. Activity at this roost declined until late 2008 after which it appears to have fluctuated at a level suggesting few individuals.

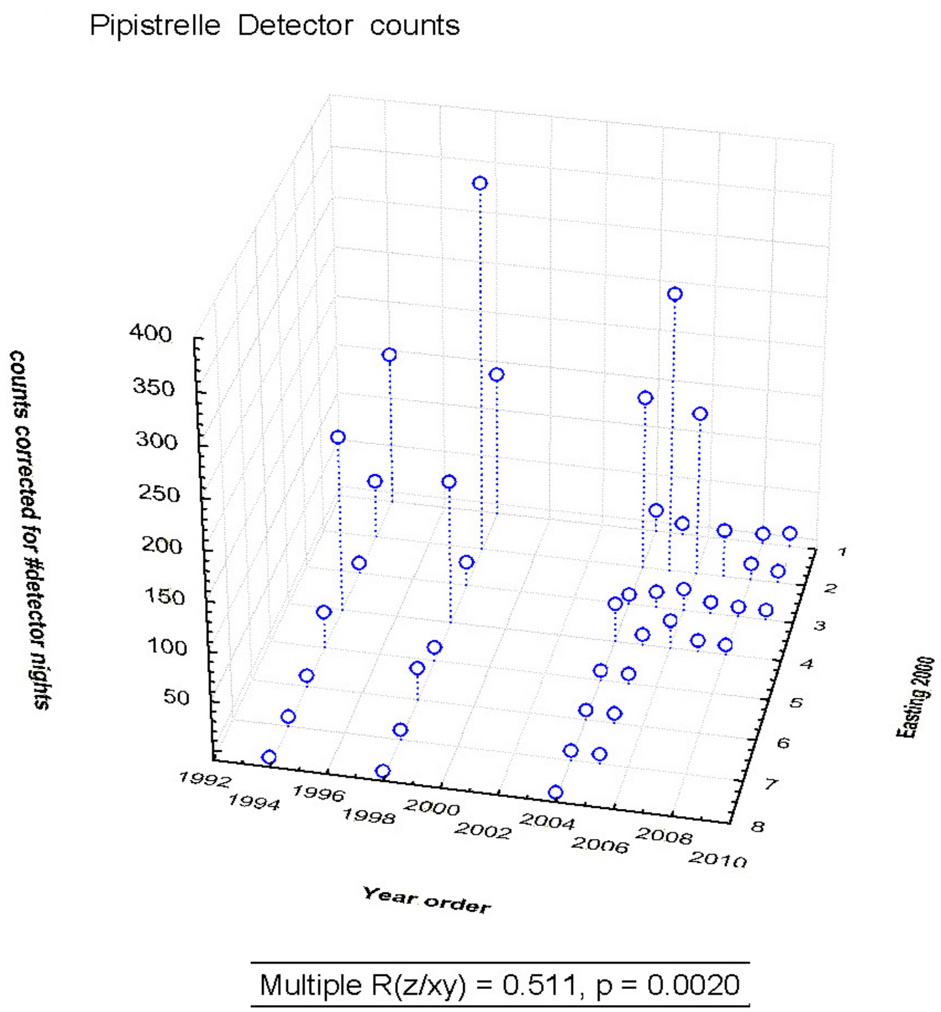


Figure 7 Christmas Island Pipistrelle counts: corrected ground-static detection (excluding roosts). The figure is a three dimensional image of 'total counts' versus year versus *'easting'*

Figure 7 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 2004 – 2008 'drive around' survey result was reliable for all parts of the island, including the inaccessible terraces. According to the Park's data-base (Appendix 3), this method detected Christmas Island Pipistrelles up until 2008. Nearly all of these detections were made during Lumsden's 2004 survey and, except for two passes recorded in the island's eastern side (on 8 March 2004 at site DS12), they were virtually confined to the island's western parts. The only others were two single passes recorded in July 2008, again in western parts of the island. In general then, the drive around survey results were consistent with the ground static monitoring results. The removal of ground-static monitoring sites from the islands centre and east after 2005 is the only constraint on fully resolving the question of a contemporary east-west difference.

In combination, the fixed station data and the 'drive around' survey confirmed 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.

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 actually increased after 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.

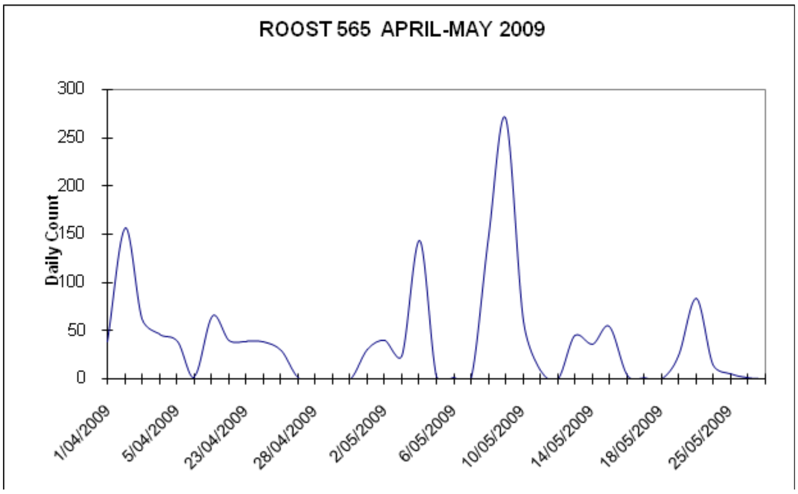


Figure 8 'Roost 565 April-May 2009'

A rescue effort to capture and breed the remaining Christmas Island Pipistrelles commenced on 8 August 2009 in response to the working group's interim report confirming recent population trend analyses (e.g. Figure 6 in James and Retallick 2007; Figure 1 in Lumsden & Schultz 2009). Only one bat was heard (using the Anabat detectors) and observed in the first week of the rescue attempt. It was encountered near the last known roost tree (site 565, in the Dales) and along the foraging area on the Winifred Beach track. Despite strenuous efforts over the subsequent three weeks using a variety of methods, the team of bat specialists was unable to capture this individual, and no other Pipistrelles were detected when their systematic survey was expanded to cover other remote areas on the island. During the final week (ending on 4 September 2009), no bats were detected at all Campbell 2009, Lumsden 2009b.

4.7.6 Causes of Christmas Island Pipistrelle decline

James (2005), reviewing the available data, predicted the extinction of the Pipistrelle in 2008. It proved to be a sadly accurate prediction. By the end of 2008 there were only a few left (Lumsden and Schultz 2009) and none has been heard since August 2009.

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 and Cherry (1997), James (2005), Lumsden et al*.,* (2007) and Lumsden and Schultz (2009) reviewed aspects of Christmas Island Pipistrelle biology and discussed processes that are potentially threatening to its population numbers. These authors identified and assessed a range of potential threats, including disease, roost site condition and availability, a variety of introduced predators, Yellow Crazy Ants, Fipronil and a decline in prey (food) availability (see Lumsden et al*.,* 2007, p. 62). We have incorporated their data and deductions into the text below.

4.7.6.1 Predation

Lumsden and others identified the following possible candidates: Nankeen Kestrels, Wolf Snakes, Black Rats, feral cats and Giant Centipedes. They also identify Yellow Crazy Ant supercolonies 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.

4.7.6.2 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 used infrequently 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. James (2005, p. 14) recognised the good temporal correlation but poor geographical correlation between the “explosion of Crazy Ants and the decline of Pipistrelles”. The working group noted that this pipistrelle forages at around 14 kph (Appendix 2), so individuals could cross half of the island in 30 minutes, feeding along the way, which may account for the absence of a geographical correlation at local scales.

4.7.6.3 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).

4.7.6.4 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. At least two Black Rats were photographed on the trunks of Pipistrelle roost trees in 2006: four times on roost tree 17 and twice on roost tree 21 (James and Retallick 2007). No pipistrelles were detected in a sample of 114 cat stomachs and 95 scats collected between 1981 and 2004. 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.

4.7.6.5 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.

4.7.6.6 Giant Centipede

In published reports (Parks Australia, 2008; Lumsden and Schulz, 2009 and earlier papers such as James 2005), 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 three species of bats in South America (Molinari 2005).

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 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 has a debilitating if not lethal bite for pipistrelle-sized vertebrates (e.g. James 2005, p. 13). These centipedes have been photographed on Christmas Island Pipistrelle roost trees by remote cameras. Their habit of taking refuge under loose bark would be likely to bring them into direct contact with roosting pipistrelles.

A link between the reduction of Red Crabs by Yellow Crazy Ants (following their formation of supercolonies) and the increase in Giant Centipedes was suggested in the Issues paper (Parks Australia 2008c). We take the connection further by hypothesising that Giant Centipede numbers are usually restrained by Red Crabs, both indirectly through prevention of a leaf litter habitat forming and perhaps directly through predation (see below). The removal/reduction of Red Crabs by supercolonies of Yellow Crazy Ants has led to an increase in the amount of leaf litter habitat available for Giant 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 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 and expose the centipedes to increased predation so their numbers could be reduced severely, leading to an ecological regime in which the 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 crablings during their migration onto and across the terraces.

Under this putative explanatory scenario, Giant 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 and extinction of the 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 is no evidence demonstrating predation, there is no information about population structure and hence recruitment success during the decline, 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 more timely and effective intervention. 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.

4.7.6.7 Fipronil toxicity

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

The working group is concerned about the non-target impact of Fipronil on the Christmas Island Pipistrelle (Appendix 6 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. The high food intake required by lactating females (Appendix 2) would focus the effect of an otherwise sub-lethal toxin load on the juvenile age class, i.e. impair recruitment. In such a scenario, the > 7 year longevity of adult Pipistrelles would mask an abrupt temporal correlation with overall population numbers. Frustratingly, there are no data on population structure during the annual period of population recruitment (December to March) when juvenile and sub-adult age classes are apparent.

4.7.6.8 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 (Anabat II detector zero crossing analysis interface module output) (see Table 16 in Corbett et al*.,* 2003). Although stridulating insects are a very small subset of nocturnal insects and do not feature highly in the diet of pipistrelles, the data does suggest that there has been at least some insect response.

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). As discussed above, the lactating females would be the most affected.

It may be possible to assess food availability by counting the number of bat ultrasound feeding 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. Some pre-processing of Lumsden's pre-2004 recordings to cassette tape would be required. This work could not be done in the time available.

In the context of the potential collapse of the bat's food base, the Pipistrelle is likely to be quite specific in its prey-size requirement. Members of the working group did not accept the argument that the persistence of insectivorous birds is convincing evidence against food shortage (James 2005), particularly during the period when the female bats are lactating. Given that adults may live for >10 years in the wild, the correlation between bat counts and ant patterns of persistence across the island /local population-trends would be poor if the smaller metabolic requirement by non-lactating adults was still being met but bat recruitment was failing. A re-analysis that interacted several of the supposed threats (ant, clearing, centipede etc) against the bat decline might be instructive. An even better test of the relevant null hypothesis would have been possible if data had been collected on population age stucture over the monitoring period (but see section 7.2 in James 2005).

The working group considered the age/reproductive data that have been collected from captured *P. murrayi*. Bat age classes are assessed by inspecting wing bones, which progressively ossify for 3 months from birth. In June and July 1994 Lumsden and Cherry (1997) captured 10 females and 12 males (1:1 ratio), but no sub-adults, pregnant or lactating bats were encountered. Similarly, Lumsden et al*.* (1999, p. 71) captured 61 males and 65 females (1:1 ratio) between 10 May & 20 June 1998, but again no sub-adults, pregnant or lactating bats were encountered. Unfortunately, both samples were taken more than 3 months after the end of the period when females were likely to be lactating. The same problem besets Tideman's 1988 collection; his 21 individuals (all males) were taken between June and mid-August, so all were adult. Of the 26 individuals he captured in 1985 (15 males & 11 females), nine (3 males and 6 females) were taken in March, but all were adult and none were pregnant or lactating (Tidemann 1985), although he did find a higher proportion of bats with little or no tooth wear in March than in September.

Incidentally, Christmas Island Pipistrelles used to forage at dusk, but recently only foraged at night. While it is tempting to speculate that these were the lactating females and/or the sub-adults, no explanation can be made for this observation, which is made even more puzzling because swiftlet abundance remains high, suggesting that at least some components of the diurnal insect biomass have 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 since 2007. Bat detectors have been placed around the perimeter fence but did not detected any bats flying through the light column (Richards, 2008).

4.7.6.9 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 6 sets out the logic for this conclusion.

Table 1. 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

4.7.6.10 Changes to surface water

There is some evidence that there has been a change in surface water availability on the island, although there was little surface water to begin with. 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.

4.7.6.11 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 primary 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 purely structural reason why it should still not continue to be so, at least in the areas that still have primary forest. This said, current detection and detection history is biased towards gaps in the forest created by roads, and the effective range of the 'ground-static' monitoring detectors is less than canopy height in remaining areas of primary forest. [The working group has subsequently been made aware of recordings from a detector hauled approximately 10m up a tree at site L22, with a control at ground level.]

4.7.6.12 Low genetic variability does the data from the taxonomic investigation help with this

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. However, the limited samples of *P. murrayi* available to Helgen et al. (2009)

did not indicate any major decline in heterozygosity, in either nuclear or mitochondrial DNA, when contrasted to congeneric populations in adjacent parts of Indonesia.

4.7.7 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 and a real indication of population status, as subsequent events have shown;

ii 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;

iii 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;

iv the monitoring data 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;

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

Although monitoring has increasingly involved "hunting" remaining populations, the population viability and persistence predictions reported in James & Retallick (2007) and Lumsden and Schultz (2009) have been realised.

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

The parlous decline of the Christmas Island Pipistrelle was the catalyst for this inquiry. For some species, decline and extinction may be a simple straightforward process, with a readily identified single causal agent. In other cases, decline may be an indirect consequence of a compound of interacting factors, operating with varying intensities across time and space. The fate of the Christmas Island Pipistrelle was likely collateral damage to the broad-scale environmental changes triggered by the deliberate or – in most cases – inadvertent introduction of non-indigenous species to Christmas Island. Oceanic islands may be particularly susceptible to such perturbation, and Christmas Island has provided a text book example of "invasional meltdown" (O'Dowd et al*.,* 2003), the collapse of existing ecological processes and structure, and of inter-specific relationships, because of the impacts of one or more invasive species.

In the case of Christmas Island, this meltdown, or "trophic cascade" has been particularly potent because so much of the rainforest ecological function, structure and community composition of the island is determined by a single keystone species, the Red Crab, and this species has proven highly susceptible to one particular invasive species, the Yellow Crazy Ant. Although these two species are the primary and largely antagonistic drivers of the ecology of the island, many other species contribute to or are caught up as indirect victims or beneficiaries of the ecological change, and changes in the abundance of these species may further ratchet up the pace, scale and magnitude of ecosystem-wide change. In particular, introduced scale insects probably provided the key resource required to allow and maintain the development of supercolonies of Yellow Crazy Ants. But Christmas Island suffered multiple introductions, extending from its first settlement probably to the present day. Some of these introductions had direct or indirect detrimental impacts independent of the meltdown associated with Yellow Crazy Ants – for example, the very early extinction of Christmas Island's two native rodents were a consequence of escape to the island of black rats (*Rattus rattus*) and the novel diseases that accompanied them. The decline and loss of the Christmas Island Pipistrelle fits within the context of the reverberative ecological changes driven by one or more such invasive species. It may be that ultimately its loss can be traced back to a single introduced species, but the pathway for the impact may be complex, indirect and multi-pronged.

Here, we provide a speculative sketch that illustrates the network of factors that may have contributed the Pipistrelle's loss.

1. Christmas Island is settled in the late 19th Century to allow exploitation of its phosphate deposits. Lack of quarantine from the early days of settlement and mining allows introduction and establishment of many non-indigenous species. Among them are many species of ants (including the Yellow Crazy Ant) and the Giant Centipede.
2. Christmas Island undergoes several severe ecological stress from activities associated with mining that has cleared over 25% of the island area at one time or another. This includes an Island "grid" survey.
3. Several species of scale insects were introduced more recently, perhaps associated with plants (possibly fruit trees) brought to the island. The scale insects established in low numbers on rainforest trees and spread throughout the island, increasing in abundance in the 1980s due to the lack of effective native predators or parasites or because ants started removing excess honeydew, which can suffocate scale insects.
4. Yellow Crazy Ants become the dominant ant species that is attracted to honeydew secreted by scale. The ants 'farm' the scale leading to a gradual increase in their numbers.
5. Excess honeydew from scale allows the extensive growth of sooty mould on the leaves of rainforest trees, stressing them further (stressed plants are more susceptible to insect attack).
6. Between 1984 and 1994, the Christmas Island Pipistrelle starts to decline, perhaps because of an increase in Yellow Crazy Ant numbers before the first supercolonies were noted.
7. Feedback mechanisms cause population explosions in both scale and Yellow Crazy Ants during the late1990s. Yellow Crazy Ants form supercolonies with multiple queens. Scale and ant outbreaks increase in extent and number.
8. Supercolonies of Yellow Crazy Ants kill significant numbers of Red Crabs, leading to changes in rainforest structure and understorey and litter characteristics.

9. Either directly (through reduced predation by Red Crabs) or indirectly (because of changed vegetation characteristics due to decline in Red Crabs), some additional introduced invertebrates (such as the Giant Centipede) increase in abundance whereas some native invertebrates decreased in abundance (perhaps reducing the potential food supply for the Pipistrelle).
10. Reduced abundance of native invertebrates that provide food for Pipistrelle leads to lower reproductive success. At roost sites, Pipistrelle are killed or disturbed by the increased abundance of Yellow Crazy Ants and/or centipedes.

Parts of this chain are speculative, or supported mostly by inference or limited evidence. We present this scenario to emphasise the interactions and multiple, indirect pathways that may lead, unforeseen, from one or more introductions to consequences for apparently ecologically distant species. This observation reiterates our principal finding that the conservation of biodiversity on Christmas Island (or any other island) pivots around the prevention of introductions and the control and eradication of existing introduced species.

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. This is but one hypothesis, another is that the Pipistrelle (like the endemic Christmas Island rat) was the victim of an unknown disease. This possibility is consistent with the low white cell counts detected in their blood (Lumsden 2009) and some circumstantial evidence reviewed by James (2005). Other factors that may have exacerbated the Pipistrelle decline were reviewed earlier, including Giant Centipedes and Fiprinol.

4.7.9 Options for management action considered by the working group before the apparent demise of the Pipistrelle.

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 was relatively low, with more than 30 species of pipistrelle currently recognised worldwide, and its close molecular and morphological relationship with species in the nearby Indonesian archipelago (Helgen et al*.,* 2009).. The working group accepts *P. murrayi* as taxonomically distinctive and that 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 no longer had a major role in the ecology of Christmas Island. If population size could have been 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 might have corroded this valuation.

The likelihood of success of the management.

This issue is dealt with more fully below. Its key components were 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.

The urgency.

In this case, there was 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 might have had some collateral benefits to other Christmas Island species on the brink of extinction, and/or might ultimately have helped identify the factor(s) that most threaten Christmas Island endemic species.

Where resources are finite, assessment against these criteria needed to 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 was to leave the Pipistrelle unmanaged. This option would result, almost certainly, in its extinction, probably within less than a year. This option would involve no financial cost.
2. Leave the 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 had 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 was possible that the measures undertaken may have forestalled extinction. There are limits to how much further such actions could be taken, no evidence to suggest that these actions were necessarily preventing the most profound of the threatening factors; and no evidence to suggest that the actions taken had resulting in population increase for Pipistrelle. This option required relatively modest financial investment (about $10,000 per year).
3. Establishment of a captive breeding population on Christmas Island. This option would require capture of sufficient Christmas Island Pipistrelle individuals from the wild to found a captive breeding colony. It would require 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 would be some possibility that a Christmas Island captive breeding colony would still be exposed to the factor(s) that most caused the decline of the wild population. There would be 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 have reduced establishment costs, and may more firmly have removed the captive animals from the threats operating on Christmas Island. However, there may have been 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 have been some risks to the bats in the long transportation required. As with option 3, there was considerable risk of failure, and the option would require considerable expense.

The working group noted that successful establishment of a captive breeding colony may have opened opportunities for out-breeding with closely related species, which would be lost if the species became extinct in the wild and none were held in captivity.

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

The working group acknowledged that there were 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 had suggested that this species may be especially challenging to maintain. However, it was recognised that husbandry techniques had improved significantly since Dr Tidemann's work, and survival of captive individuals was more likely. There are always some risks of injury or death to individual bats in all aspects of any capture program, but previous experience of captures by bat experts suggested that risks of harm to bats during capture and short-term housing are low (Appendix 4).

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 was 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. The utility of the program was constrained by unanticipated difficulties experienced in capturing Northern Territory pipistrelles. However, one individual female pipistrelle was maintained in captivity for several months with ongoing good health, although this individual aborted foetal material after around one month. Given these difficulties, the working group agreed that the analogue program on *P. westralis* should be discontinued.

The working group recognised that all the possible choices were problematic and risky, in part because the choices had to be made too late in the process of decline of the species. The working group considered that option 1 (do nothing) was inappropriate while there was a slim chance that future management of threats and, thus, reintroduction was a possibility, so this was not recommended. The working group considered that option 2 would be window-dressing and would not succeed in its objective. Accordingly, the working group acknowledged that the only possibility for the continued existence of this species would be through a captive breeding program. However, the working group considered that such a program would have a high likelihood of failure, and any implementation of such a program must acknowledge this high risk at the outset. The working group acknowledged that knowledge gained from the analogue (Northern Territory) program had 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 considered that resourcing the Christmas Island Pipistrelle breeding program should be circumscribed. The working group was 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 were difficult, because the amount of time required to capture the few remaining wild Pipistrelles could be unbounded. The probability of capturing these individuals at any time would be low, but could be expected to be increased with more personnel and traps, and more time; but any ongoing investment could reap diminishing returns.

The working group recognised 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 would clearly be dependent entirely upon the success of the former.

With respect to the captive breeding stage, while all relevant information was not then available, option 3 (on-island captive breeding) was judged to be 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 existed which would lead to the extinction of the Christmas Island Pipistrelle.

In coming to its recommendation, the working group was influenced by the possibility that management actions on the island could make the ecosystem once more favourable for Christmas Island Pipistrelles 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 recommended: (see section 4.7.1)

1. That Christmas Island Pipistrelles be captured from the wild as soon as practicable, as founders of a captive breeding colony.
2. That there be 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 be 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.

4.7.10 The framework in which the Interim Report's Recommendation 19 was originally considered

Although the working group had concluded that without captive breeding the Christmas Island Pipistrelle was unlikely to survive, it recognised that the Christmas Island Pipistrelle decision would have to be made in the wider context of conservation priorities for the Island and Australia. The working group had 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 was a generalised decision tree (Figure 9), the second was a descriptive model specific to the Christmas Island Pipistrelle (Figure 10) and the third a model of the recovery scenarios for a captive breeding population of Christmas Island Pipistrelles (Table 2).

These tools were based on the best information available to the working group and needed to be considered against other evaluations of probability and cost that might have been forthcoming on the release of this report.

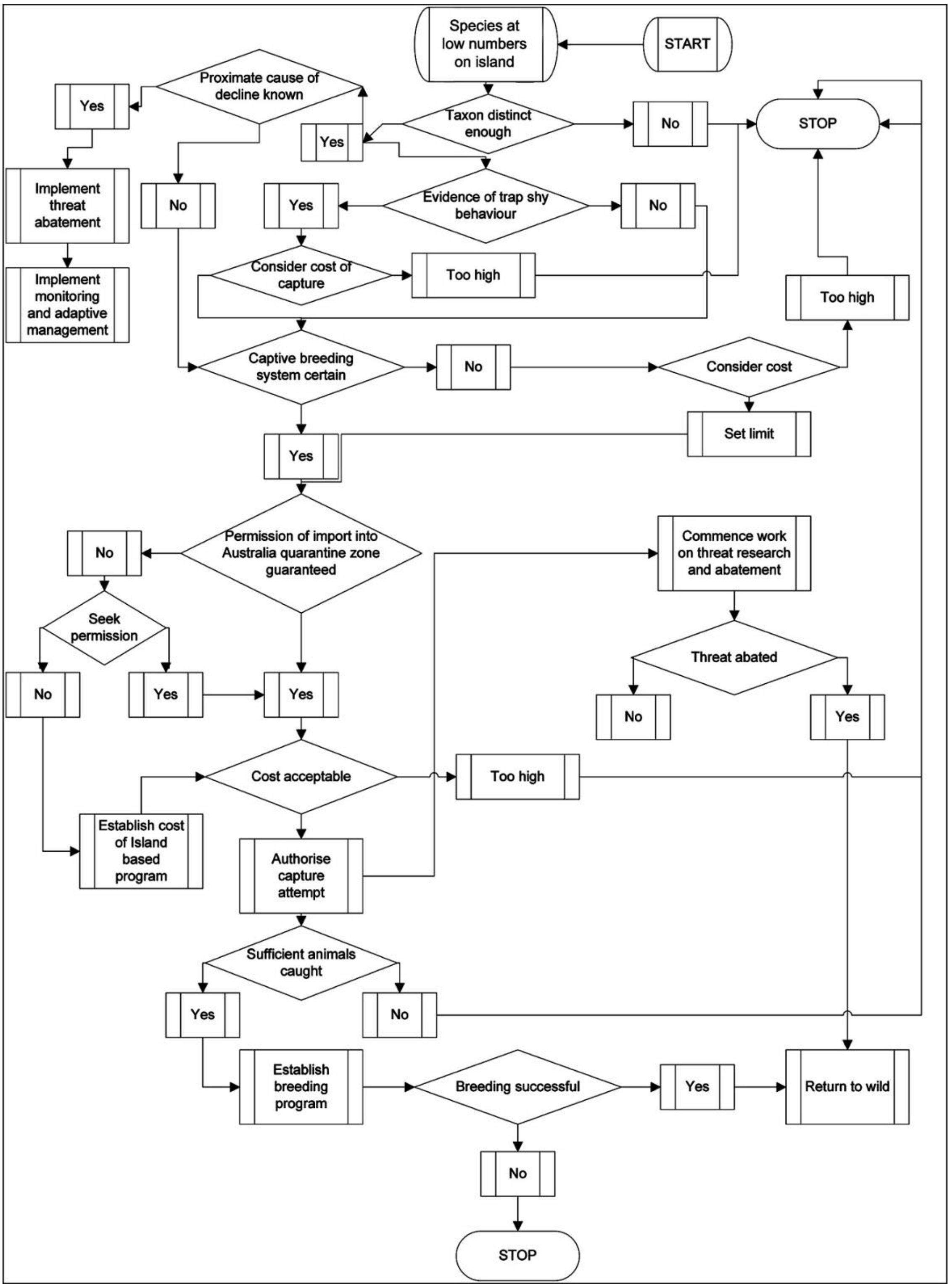
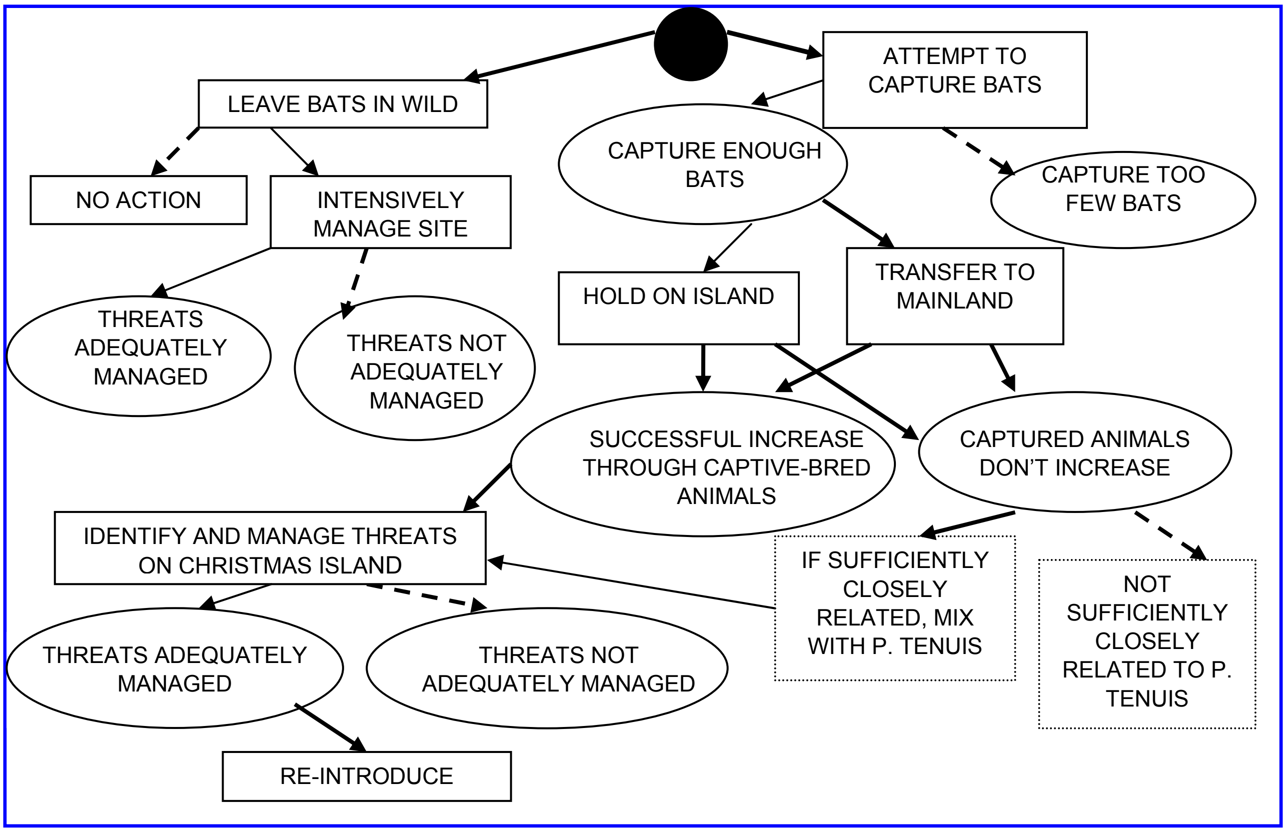
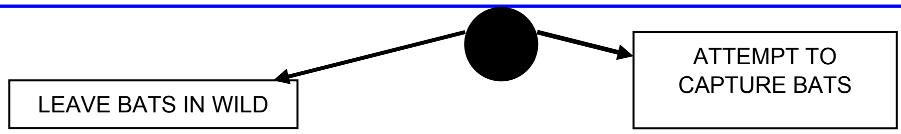


Figure 9 A generalised decision tree for use in considering decisions for threatened species.

Figure 10 Decision tree used for 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

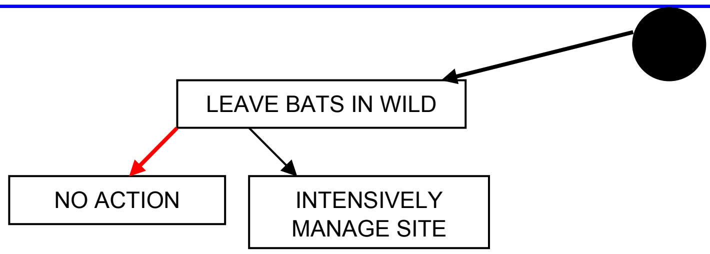


CHOICE: This is the fundamental choice for decision-making. On current trends, leaving bats in the wild will result in almost certain extinction, probably within one year. There will be little or no financial cost in this action.

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.

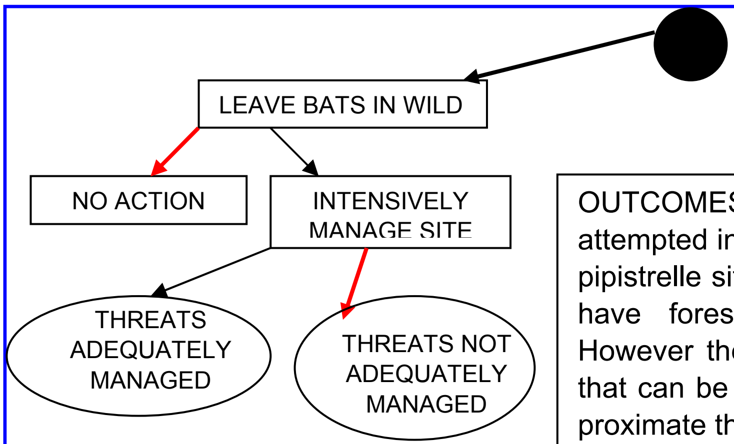
The working group recommends an initial allocation of $100,000 for capture and temporary care with a review after three months.

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.

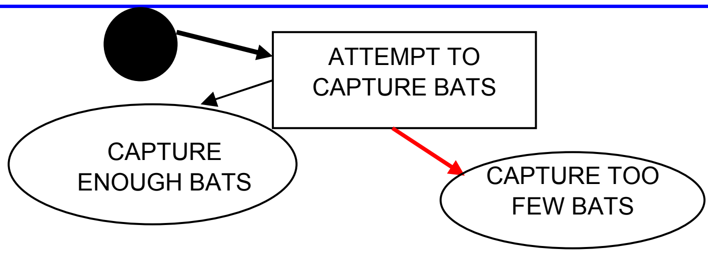
Decision point three



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.

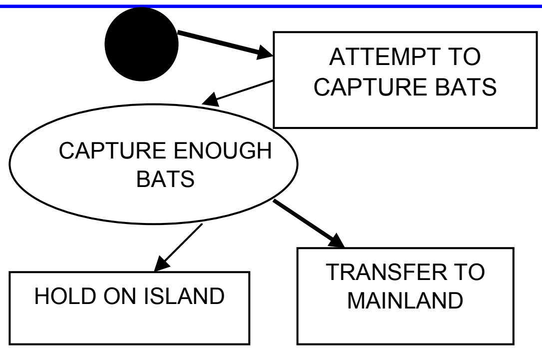
Decision point four



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



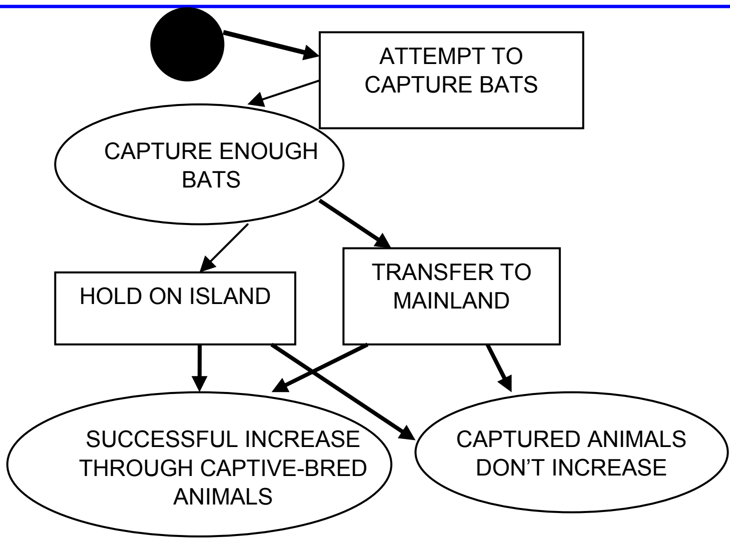
CHOICE: Assuming sufficient bats are captured and held temporarily on Christmas Island, a choice is then required on whether to set up the captive breeding program on the island or at an existing mainland institution. At the present time due to the quarantine status of Christmas Island, only on-island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

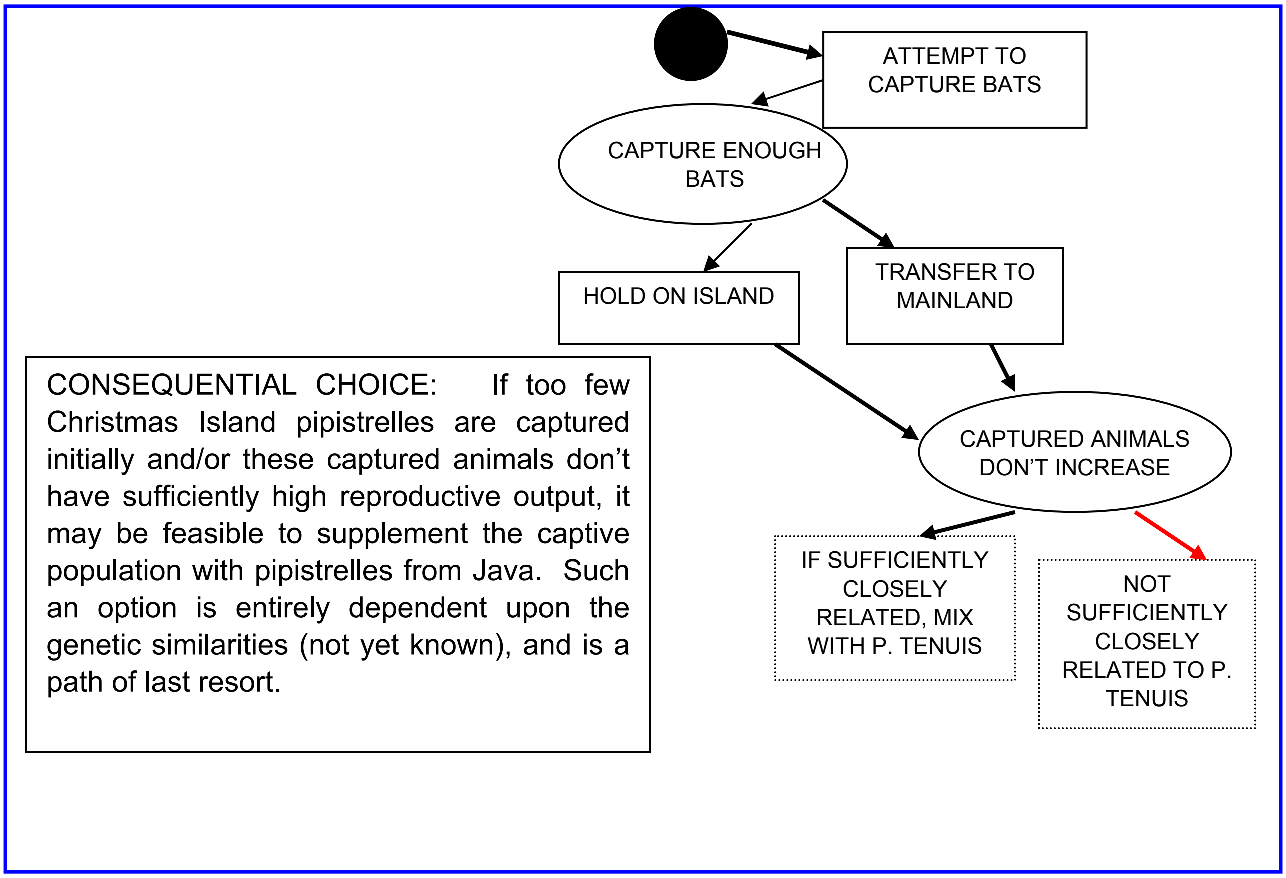
Decision point six



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).

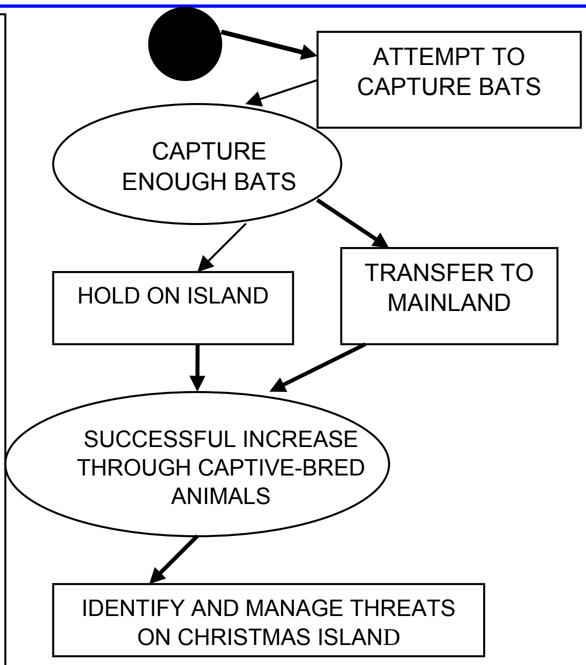
Decision point seven



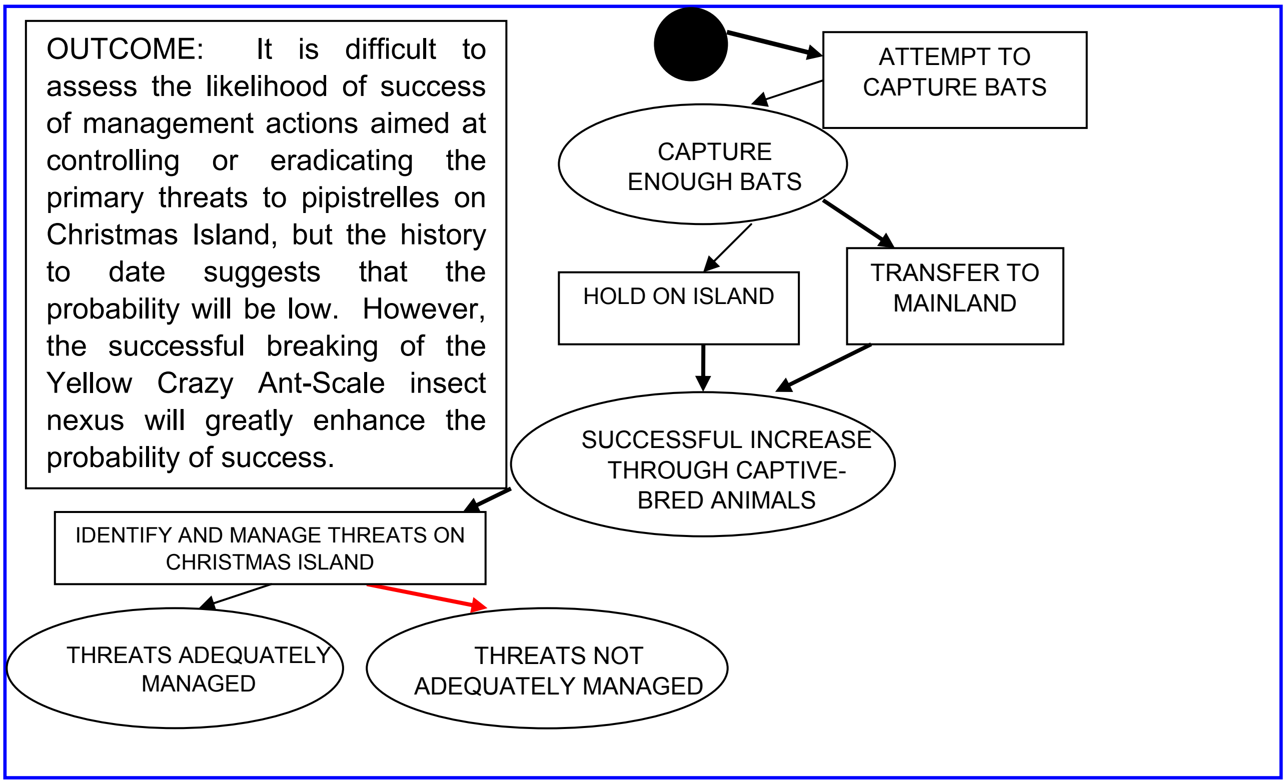
Decision point eight

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.

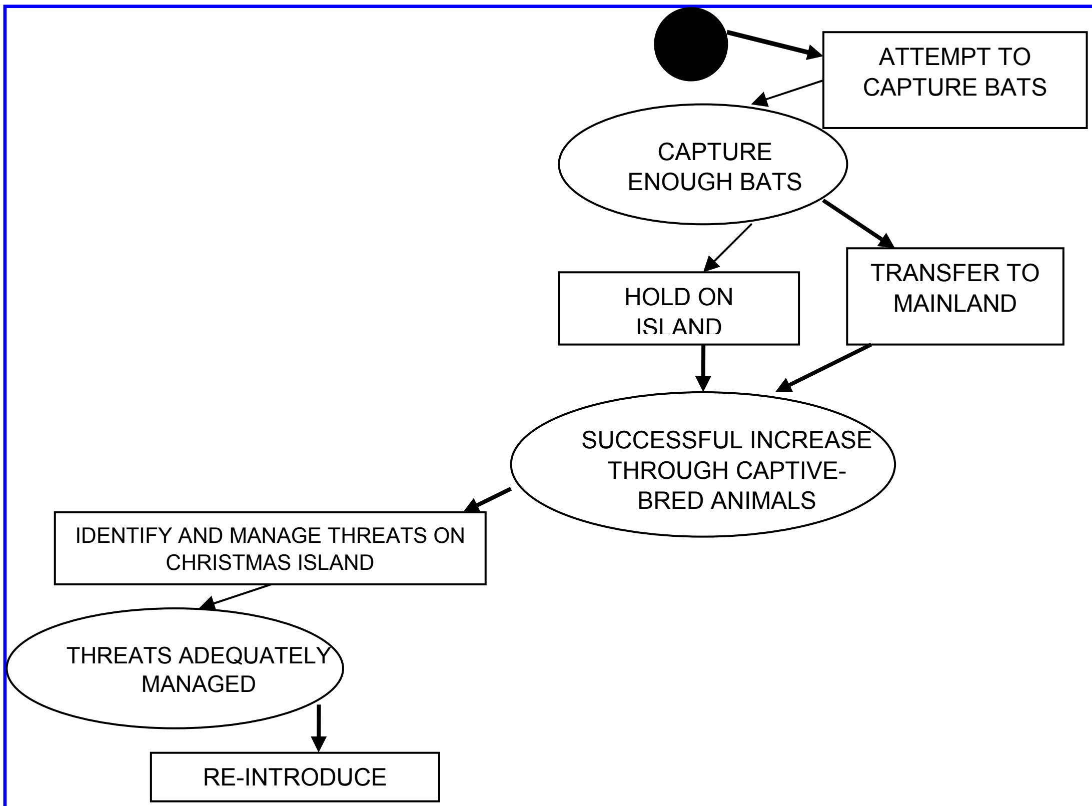
In considering this cost, it should be noted that there would likely be very significant collateral benefits to other Christmas Island species.



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.

Model output for different captive breeding scenarios

This initial model is used to provide some indication of the length of time that may have been 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 assumed (i) all mature females would have become pregnant and produced one young per year: (ii) the sex ratio at birth = 1:1: (iii) once mature, annual survival (p) would be within the range 0.8-0.98: (iv) survival from birth to one year old was 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

APPENDIX 2 ECOPHYSIOLOGY OF *PIPISTRELLUS MURRAYI*

Airframe parameters, flight muscle-mass and heart-mass fractions, and field metabolic requirements of *Pipistrellus murrayi* (Pm) compared to other small tropical bats of similar design, [P. westralis,(Pw) *Vespedalus caurinus* (Vc)], and known foraging ecology (N.McKenzie & R.Bullen measurements and modelling).

--	relevance	Pm	Pw	Vc	Kimberley fauna
Aspect Ratio		6.24	6.08	6.29	5.8 – 8.4
Wing Loading (g/cm^2)		3.83	3.77	3.96	4.0 – 11.5
TEAR	agility	13.3	13.6	15.0	2.8 – 41.8
Flight muscle ratio (%)	flight cost	10.1	10.1	14.3	10 – 22
Heart mass ratio (%)	aerobic	0.98	0.98	0.72	
F_{peakC} (kHz)	optimum prey length	48.5*	46.0	62.0	
Model Results:					
Max aerobic flight speed (cruising, kph)	foraging	14.0	14.5	14.7	13 – 29
Max sustainable anerobic speed (max cruise, kph)	maximum commuting (marathon)	23	23.9	25.8	
Optimum prey-length or -wingspan (mm)		7.0	7.4	5.5	
Assumed prey capture rate		1 per 64 sec	1 per 70 sec	1 per 32 sec	
FMR (lactating, pre-weaning) ($kJ\ day^{-1}$)		25.4	27.5	24	

* measured 1 April 2009

Daily time-energy budget to meet metabolic requirement

Pm, Pw & Vc same

Reproductive condition	normal	early preg	lactating
Day roosting inactive hrs	12	12	9.5
Day roost active hrs	8.5	8.5	8
Night roosts	1	1	0.5
Time commuting (hrs)	0.5	0.5	0.5
Time foraging (hrs)	2	2	5.5

APPENDIX 3 PIPISTRELLE DETECTOR DATABASE RECORDS

The working group interrogated pipistrelle data collected on acoustic bat detectors that have been deployed around Christmas Island over recent years. This is in the form of a large spreadsheet of 3972 datapoints and is available on request.

APPENDIX 4 COMMENTS ON CAPTIVE BREEDING OF PIPISTRELLUS MURRAYI

Bat scientist supportive of captive breeding

The EWG received advice from Dr Dedee Woodside who introduced bat husbandry and bat breeding to the zoo community in Australia. This has included insectivorous bats of 4 species that are now to F3 with two re-introduction programs for *Nyctophilus gouldi* and *Macroderma gigas* now about F5 or F6). Dr Woodside wrote many bat husbandry protocols, and offered to arrange for Australian zoos to assist with captive breeding for *P. murrayi*. She also suggested that some genetic material should be stored in the wildlife registry in case of surrogate breeding opportunities, and as part of an insurance strategy while working on protecting habitat and augmenting the in-situ population. Recommendation: genetic material should be collected and stored.

Bat scientist not supportive of captive breeding

Dr Chris Tidemann, in an email to the working group, reported that he had considerable difficulty hand-feeding P. murrayi during his visit to the island during the 1980s, when he held individuals in captivity. He commented that, weighing barely 3 g, P. murrayi is minute, with extremely fine teeth that are well-suited to a diet of soft-bodied insects, like mosquitoes, but unsuited to dealing with hard-bodied insects, such as mealworms.

Working group's consideration

The working group considers that advice received from the Australasian Bat Society bears on this issue. Dietary studies on this species have revealed 26% of their diet is beetles, with mosquitoes representing only 0.1% (Table 1). The exoskeleton of beetles is considerably harder than the exoskeleton of mealworms, and so as long as relatively small mealworms are used (as recommended by Lumsden and Schulz 2009), the Christmas Island Pipistrelle should be able to readily consume mealworms. Other similar sized species of pipistrelles (P. westralis and P. adamsi) also consume a substantial proportion (approximately 50%) of hard-bodied insects such as beetles, bugs and cockroaches (see below). There are no physical issues that would prevent the mastication of mealworms by P. murrayi

Summary of available dietary information for the Christmas Island Pipistrelle. 1984 data is from Tidemann (1985); 1994 is from Lumsden and Cherry (1997); and 2004 is from DNP unpublished data. (From Lumsden & Schulz 2009).

Prey type	1984	1994	2004
Moths (Lepidoptera)	Present	51.5%	Present
Beetles (Coleoptera)	Present	25.8%	Present
Flying ants (Hymenoptera)	–	21.5%	–
Bugs (Hemiptera)	–	1.1%	Present
Flies (Diptera)	Present	0.1%	Present

Micro-wasps (Hymenoptera)	Present	0	–
Thrips (Thysanoptera)	Present	0	–
Bark lice (Psocoptera)	–	0	Present

APPENDIX 5 CHRONOLOGY OF PIPISTRELLE BAT MANAGEMENT ACTIONS AND OUTCOMES

Date	Action	Outcome
1984	First study by Tidemann	Was widespread and common in primary and secondary rainforest. Common in settlement.
1994	Surveys- Dr Lindy Lumsden	42 sites sampled Species present at 31% of sites Widespread but patchy in distribution and low numbers Uncommon in NE Indicated that species had declined and contracted
1998	Surveys- Dr Lindy Lumsden	Anabat ultrasonic bat detectors used to assess distribution and relative abundance along driven transects. 84 sites sampled Further decline and westward range contraction Disappeared from NE Uncommon in centre of the island Indicated that species had declined and contracted
2002	Christmas Island Phosphate surveys.	Corbett, L, Crome F and Richards G. 2003. Fuana survey of mine lease applications and national park reference areas, Christmas Island, August 2002. Appendix G in CIP (ed). *Drafty Environmental Impact Statement for the Proposed Christmas Island Phosphate mines (9 sites),* Christmas Island Phosphates, Perth. Undertook a brief study with detectors at 22 sites. They found a further westward contraction of the range and 33% decline since 1998.
2003- 2007	Christmas Island Biodiversity Monitoring Program Funded by the Department of Finance and Deregulation and implemented by Parks Australia.	A summary report (with a series of reports on individual species, a species inventory, databases and GIS maps). 2004- 97 fixed stations sampled (44 previously used by Lumsden and 53 new stations) and driving transect largely repeated. Decline in relative

		abundance.
2004	A national recovery plan for the Christmas Island Pipistrelle was made under the EPBC Act	The primary objectives of the Recovery Plan are: a) determine the threatening processes responsible for the decline in the species b) maximise the opportunity for the viability of the species in the wild c) clarify its taxonomic status.
2004-2009	Monitoring- Stationary detectors	Stationary detector monitoring undertaken to assess changes in relative abundance at prime foraging areas. This sampling has been critical in improving understanding of the continuing decline. 2006 Re-sampled 44 of the 1998 sites Recorded at 8 sites Disappeared from >80% of the former range Common in only one area
2005	The Australian Mammal Society and the Australasian Bat Society wrote to the Minister raising concerns about the decline of the Pipistrelle bat and implementation of the recovery plan.	Response by Minister Campbell *"The cause of the rapid decline of the Pipistrelle is not well understood. To reverse the trend requires identification of the actual threat(s) so that mitigating actions can be implemented. Funding was recently allocated under the Natural Heritage Trust to the Arthur Rylah Institute so that research can be carried out into the Pipistrelle's decline. That research will be commencing in December 2005. Ongoing monitoring will also continue as part of the Biodiversity Monitoring Programme together with ongoing implementation of the National Recovery Plan"*
2005	$100,000 Funding has been allocated from the Natural Heritage Trust to researchers at the Arthur Rylah Institute in Victoria to investigate the Pipistrelle's decline.	
2005	*"An interim assessment of the Conservation status and threats of the Pipistrelle"*- one of the internal species reports that fed into the summary report of the Biodiversity Monitoring Report.	It declined in abundance and range by about 75% between 1994 and 2004, and if those trends continue it will be extinct by 2008. The cause(s) of the decline are not known. The BMP has been mapping the distribution and relative abundance of Christmas Island Pipistrelle using bat detectors placed at fixed stations overnight.

		It appears that the Pipistrelle has declined further since 2004 and is now restricted to the western 10-15% of Christmas Island.. The only significant population of Pipistrelles located during 2005 is an area little over 1 km^{-2}, centred on the top of Winifred Beach Track within the National Park boundary (the Winifred Gate). The main feeding area is in secondary growth on old mine stockpiles, in mine leases. This area is known as ML 140 and/or field 26.
2005	Test for presence of disease and parasite loading.	A very low white blood cell count was recorded, but the significance of this is not yet understood. Otherwise the population was found to be healthy and free of disease and parasites.
2005-06	Monitoring	9 roosts with 30-40 individuals in each
2005	Meeting between IDC Project Manager (Department of Finance and Administration) and Department of Immigration and Multicultural and Indigenous Affairs (DIMIA) over potential threats to the Pipistrelle bat and concerns arising from the supply of soil from stockpiles in the area currently used by the bat for feeding (mining leases 138-140).	95% of the remaining population feeds in a small area which is centred on ML 140 and adjacent sections of National Park, and extends to parts of ML139 and eastern edge of ML138.
2006	Fly By Night Bat Surveys contracted by David James to undertake radiotelemetry surveys.	Trapping undertaking at 3 sites. A total of 14 individuals were captured 2males and 12 females. Transmitters were attached to 6 females. 4 of the females tracked to diurnal roosts all under decorticating bark on dead stags. Trees were all located in Sydney Dale.
2006	The Christmas Island Pipistrelle was upgraded from 'Endangered' to 'Critically Endangered'.	
2006	Remote cameras were established on roost trees to look for potential predators.	Up to four infra-red cameras have been used on roost trees in the Sydney Dale areas- shifted in early 2008. By April 2006, only three roost sites at two locations remained.

		Cameras identified giant centipede (3 occasions) and black rat (1 occasion) scaling roost trees in April-May 2006.
2006	Population monitoring using bat detectors continues. The design has been changed in order to set a baseline and monitor trends on finer spatial and temporal scales.	
May 2006	Installation of roost boxes	PA Christmas Island have experimentally installed 14 bat roost boxes at 7 locations near known roost trees and former roost trees in the Sydney Dale area.
2007	Arthur Rylah Institute studies	• Total estimated population of the Pipistrelle was only 500 to1,000 individuals. • The Pipistrelle was found likely to become extinct in several years if current population decline trends continued. • Seven maternity roosts were located, all under loose bark on dead trees. 17 months after they were located, five of the roost trees had collapsed and one had lost its bark. • Only one former maternity roost tree is still inhabited. • Blood tests showed no indication of disease, but further studies are required.
2007	Predator proof known roosts	Protective sleeves were fitted around the remaining roost trees and their adjoining trees and saplings. Infrared cameras were stationed at some of these trees for extended periods. Predator cameras detected three potential predators on roost trees: Black Rats, Giant Centipedes and a Wolf Snake. The sleeves significantly reduced access by potential predators
2007	Investigation into captive breeding	Parks staff contacted Singapore Zoo and Territory Wildlife Park (Darwin) to make initial investigations into the feasibility and facilities/expertise required for a captive breeding program
2008	Captive breeding investigations	Parks staff member visited Singapore for further discussions on captive breeding, further advice received from Territory Wildlife Park. As a result of initial discussions, it was determined further information was required on captive breeding options, including quarantine, transport and husbandry issues. Dr Lindy Lumsden from the Arthur Rylah Institute was commissioned to provide detailed

		advice on captive breeding options and in-situ management of the bats.
2008	additional monitoring and survey work was undertaken to determine if the Pipistrelles may have moved elsewhere on the Island (every track checked by parks staff)	It was found that the population has contracted to the north western end. 1 detector pass/site/night 99% decline in 14 years.
May 2008	Dr Lumsden of the Arthur Rylah Institute, was contracted to provide advice on captive breeding and in-situ management of the bats.	Report received January 19, 2009 Given the extremely low numbers of Pipistrelle bat now thought to be in existence (less than 20), Dr Lumsden has recommended that a emergency response plan be initiated to capture remaining bats if possible, and initiate a 10 year captive breeding program on Christmas Island. Estimated cost of such a program is $4.9m.
June 2008	Driving detector monitoring	Martin Shultz sampled a total of 66 person hours over 3 nights across the whole island driving every accessible track at <20km/hr. No Pipistrelle were recorded.
July 2008	Driving detector monitoring	Targeted driving and walking surveys were undertaken over 3 nights in the west of the island to focus on areas where the species has been recorded in recent years. A total of 52 person hours and 91km covered by either foot or car. Only 2 Pipistrelle calls were recorded- one pass at the Sydney Dale car park and one within 50m of the Winifred Beach Track gate.
September 2008	Island Wide Survey	84 stationary sites sampled (driver detector sampling). No Pipistrelles were recorded.
2008	PRL engaged Dr Greg Richards who has been working closely with Dr Lumsden, to develop a collaborative approach to accelerate efforts to save the Pipistrelle.	
2008	Application for Caring for Country funding	Unsuccessful.
January 2009	PRL funded Dr Lumsden's field trip to Christmas Island with Dr Richards	
January 2009	Surveys	Bat detectors set at 2 apparently abandoned roosts to determine if they were being re-used. No calls were recorded.

		Likely that the population comprises less than 20 individuals.
January 2009	Report received on captive breeding options	Dr Lumsden provided her report

WHAT ARE WE DOING NOW?

Contracted bat scientists to advise on how to manage the Pipistrelle.

Considering Dr Lindy Lumsden's proposal to establish a captive breeding facility on-island.

Continuing to undertake regular management activities under the advice of Dr Lumsden.

PRL has in the past cleared land where the bats were known to forage. The bats were known to forage in secondary regrowth on mine lease areas and the company now wants to clear new sites close to the last remaining roost habitat DEWHA is providing advice to the Attorney-General's Department about habitat areas critical to the Pipistrelle bat (AG's are responsible for deciding if land can be cleared outside the National Park) PRL has also been critical that not enough is being done to stop the Pipistrelle bat from becoming extinct.

Dr Lumsden and Dr Richards have recommended that tracks be re-instated in mine lease areas with secondary regrowth occurs, to emulate conditions that were current where bats were known to forage as recently as 2007. The tracks may facilitate access to foraging areas, and may provide an opportunity to trap bats (bats were trapped there before). This action will be undertaken only if AG's agree, and if CIP are willing to reinstate tracks on mine leases (approx 200m of track a bob-cat blade wide)

Current management activities are:

Management action	**Activity**	**Purpose**
Monitoring		
	Driver detector monitoring	to document changes in the distribution of the species throughout the island.
	Monitoring occupancy and numbers of bats in remaining roosts	to document the usage of known roosts by regularly monitoring how frequently the roost is occupied using a bat detector set below the roost and occasional emergence checks
	Monitoring potential predators using infra-red cameras	undertaken to continue the protection all known roosts of the Christmas

		Island Pipistrelle.
Managing roosts		
	Location of potential roost sites	to locate potential roost trees within the Winifred Beach Track/Sydney Dales/Dales/Martin Point Track area to document the availability of suitable roost trees, determine locations at which to set bat detectors in an attempt to locate used roosts, and identify potential trees on which to install protective barriers. 130 potential tress have been identified in the area, and 16 potential roosts and surrounding encroaching trees are about to be protected with barriers by CINP staff (Dr Richards had proposed that CIP undertake this work)
	Artificial roosts	Due to the concern over the rapidly collapsing roost trees, artificial roosts were established to provide additional roosting habitat that could be kept predator-free.
Managing potential threats from predators		
	Predator-proof known roosts	to continue the protection all known roosts of the Christmas Island Pipistrelle
	Yellow Crazy Ant control	undertaken to reduce potential impacts on the species by the Yellow Crazy Ant (although the impact of Yellow Crazy Ants is not clearly understood)
	Feral Cat control trial	undertaken to reduce potentially adverse impacts of key Feral Cat prey species that are likely to increase in numbers following the Feral Cat control trial . The feral cat control trial has specifically been excluded from the NW area of CI, as it is not known if control of feral cats may result in an increase of rats, a potential predator of the bats.
Managing habitat		
	Protect and enhance foraging	undertaken to protect and enhance key foraging habitat of the Christmas Island

habitat	Pipistrelle outside the Christmas Island National Park, through management of clearing permit applications and rehabilitation of former mine site areas

APPENDIX 6 ADDITIONAL INFORMATION ON FIPRONIL

Fipronil is in a new phenylpyrazole class of neurotoxic insecticides, and disrupts normal nerve function by targeting the γ-aminobutyric acid type A (GABA) receptor system of animals, particularly invertebrates (Kidd and James 1991). It is registered for use in Australia, and the fish-meal bait formulation is permitted for use on Christmas Island by Parks Australia under emergency permit PER 4091 issued by the Australian Pesticides and Veterinary Medicines Authority.

Fipronil is used to control ants on Christmas Island. Some toxins can concentrate through food chain effects to kill individuals, reduce reproductive success and/or impair sensory system. Following hand-dispersal of baits in 1999-2001, it was found that Fipronil was extremely effective at killing crazy ants; a knock-down effect of at least 99% mortality in forager ants is achieved within a matter of days, and queens begin dying one to two weeks after application. "Super colonies have not re-formed in any areas where the entire infestation was baited, including those baited in October 2000, some 18 months after treatment. However, there are signs of super colony re-formation in some infestations that were only partly baited – crazy ants have reinvaded these sites from adjacent, unbaited areas."

Consequently, a widespread program of delivery by helicopter was undertaken in Sept 2002, along with plot surveys for subsequent monitoring (aerial drops of a fish-meal based bait over two weeks, with Fipronil at 0.1g / kg as the active ingredient, and commercially named Presto 01®, was broadcast to cover infested areas of forest. In addition the trial tested the use of an ultra-low concentration bait formulation with a view to using it in the future, particularly in areas where ant densities are low). The aim of the trial was to establish that the technique is effective at killing greater than 95% of ants. Presto® 01 Ant Bait is a small, uniform pellet (2 mm x 2 mm x 6 mm).

According to 'Christmas Island Aerial Baiting Assessment' (2002), most vertebrates are not affected by Fipronil (Rhône-Poulenc 1996), and the compound is classed as a WHO Class II moderately hazardous pesticide (WHO, 1998-1999). Fipronil degrades (without volatility) in the environment in four ways; reduction in the soil produces a sulphide, hydrolysis in soil or water produces an amide, oxidation in the soil produces a sulfone, and direct sunlight slowly degrades Fipronil into a desulfinyl photodegradate in either water or soil (Bobe et al. 1998a, Belayneh 1998). The photodegradate is about 10 times more toxic than Fipronil itself (U.S. EPA 1998), and reputedly longer lived in the environment. The sulfide, sulfone and desulfinyl photodegradate are known to act at the GABA receptor site and are biologically active, but the amide elicits no reaction at the GABA receptor site and is not considered to be a biologically active metabolite (Dange 1993).

Peveling (2000a) found severe non-target impacts of Fipronil against several species of spiders, bugs, ants, termites, beetles, crickets and grasshoppers. The same study also found severe non-target impacts on a skink (Mabuya elegans) and an iguana (Chalarodon madagascariensis), and it concluded that these impacts were indirect, being the result of a treatment-induced population reduction in termites and other invertebrates, the principal food of these reptiles. The non-target impacts were considered so severe that Peveling (2000a) recommended against the widespread use of Fipronil for controlling locusts in Madagascar. The potential impact of the proposed baiting operation on reptiles, both through direct ingestion and indirectly through impacts on their invertebrate prey, is of considerable concern and the feasibility of assessing the impact of the aerial baiting operation on terrestrial reptiles is being considered (Christmas Island Aerial Baiting Assessment 2002).

Fipronil applied as a spray for locust control in Madagascar (at 7.5 g/l) had no impact on the mammal Geogale aurita (a tenrec), but did have an adverse impact on another tenrec Echinops telfairi due to food chain links (Peveling 2000a).

Toxin load from YC Ant control: "…the chemical option remains controversial in natural areas because of potential persistence in the environment and non-target impacts. This is of special concern on islands that have many endemic species with high conservation value." (O'Dowd, et al., 1999).

"Toxic bait was used to exclude A. gracilipes from large (9-35 ha) forest patches [on CI]. Within 11 weeks, ant activity on the ground and on trunks had been reduced by 98-100%, while activity on control plots remained unchanged" (Abbott and Green 2007).

"Assuming an application rate of 6 kg/ha of high concentration bait over all infested forest (c. 2500 ha), then 1.5 kg of Fipronil will be dispersed over sections of the Christmas Island National Park and adjacent vacant crown land ..." (Aerial baiting Referral Document 2002). At no time was the bait be dispersed over forest less than 1 km from the nearest residential dwellings. The work was supervised by a steering committee. Following the baiting trials, a Steering Committee that included the CRC Tropical Rainforest team including Nigel Stork & chaired by CSIRO's Alan Anderson met by teleconference to review progress.

This was followed by plot-monitoring in April 2003 to assess collateral affects on abundance of sub-canopy arthropods (by family) and a sub-set of 5 vertebrate species (2 diurnal fruigivore birds, 2 diurnal mainly insectivorous birds and the Christmas Island gecko) (see Stork et al. 2002). The overall plot sample numbers were relatively small; only the Christmas Island Imperial Pigeon showed any reduction in numbers at treated vs control plots. Acute Fipronil toxicity has been extensively studied in a number of avian species, and so far, only certain groups of gallinaceous birds (pheasants, partridges and quails) have proved to be susceptible to Fipronil. The direct risk of the proposed aerial baiting operation to the land-bird community on Christmas Island is rated as extremely low – none are gallinaceous, and all are unlikely to ingest the bait (Aerial baiting Referral Document 2002). In the decade prior to the baiting, the Christmas Island Pipistrelle, which was previously common and widespread on the island, had declined markedly in distribution and abundance, and by 2002 had been classified as Endangered. It was not fully understood what has caused this rapid decline.

Although Stork et al. were aware that there might be immediate (behavioural) or "substantially delayed (via food chain)" effects from insecticides such as Fipronil, neither vertebrate nor invertebrate tissues have been assessed for Fipronil concentrations since the baiting.

Appendix 7 Original Documentation for TSSC and Minutes of TSSC including Recommendation to Minister

Chronology of actions for the Christmas Island Pipistrelle (*Pipistrellus murrayi*)

Background

- The Christmas Island Pipistrelle (*Pipistrellus murrayi*) is a small (weight 3-4.5g) insectivorous bat that is endemic to Christmas Island. The Pipistrelle was common on Christmas Island in the 1980s but has continued to decline over the last 14 years. The known population of bats has contracted to the North West end of the island.
- The remaining population is located in a small area in the NW part of the National Park, and may forage in an adjacent mine lease area
- Parks Australia has made significant efforts to research the Pipistrelle in order to determine causes of decline and prevent this from continuing including an ongoing monitoring program, DOFA Biodiversity Monitoring Program undertaken by DNP, and research commissioned through the Arthur Rylah Institute.
- Despite our best efforts, research efforts have not been able to determine the causes of decline. Our research advisers suspect that multiple factors are almost certainly involved. Contributing factors may be:
- habitat loss
- climatic conditions
- introduced predators and pests (eg the Wolf Snake (Lycodon aulicus), Black Rat (Rattus rattus) and Giant Centipede (Scolopendra morsitans) and supercolonies of invasive Yellow Crazy Ants
- Disturbance at roost sites is probably important (Lumsden et al*.,* 2007).
- Neither habitat loss nor reduction in prey items appears to be a cause.
- There is little evidence for disease as a cause but it cannot be ruled out (Lumsden et al*.,* 2007).
- Without certainty regarding the cause of decline, our management strategies have focused on:
- continuing research to improve our understanding of the decline; and
- Implementing mitigation measures against some potential causes of the decline (i.e. protection of roosts from predators).
- Options for captive breeding have been considered in the past. However with such little knowledge about this species and potential risks involved, this has not been attempted in the past.

What have we done?

Summary

- Prepared recovery plans and implemented management actions in accordance with the recovery plan
- Contracted bat scientists Dr Lindy Lumsden and Dr Martin Schultz to advise on how to manage the Pipistrelle
- Undertaken numerous, extensive, island-wide surveys to gain understanding of bat distribution and abundance, habitat preferences, foraging habitats, roosting preferences.
- Undertaken research into potential causes of decline, including potential predators, disease, habitat changes (including mine lease), loss of roost trees.
- Undertaken management actions to prevent further decline, including installation of roosting boxes, predator proofings roost trees, identifying potential/possible predators through infra-red cameras
- Investigated options for captive breeding.

Pipistrelle Management actions.

- A national recovery plan for the Christmas Island Pipistrelle was made under the EPBC Act in 2004. The Christmas Island Pipistrelle was upgraded from 'Endangered' to 'Critically Endangered' in 2006.
- A National Recovery Plan has been adopted. Recovery Plan Actions that have been implemented include:
    - installation of roosting boxes
    - predator guards around the remaining known roost tree
    - automatic cameras to monitor potential predators
    - control main potential predators including invasive ants, centipedes, rats and snakes and interaction between potential predators and bats.
    - monitoring of the bat's population and distribution– ultrasonic detectors, remote cameras, harp trapping, radio-transmitter installation and tracking, and roost surveillance.
    - Members of the Natural Resource Management team on Christmas Island have continued to monitor bat call detection, movements and distribution, predation/possible predators on roost trees and artificial roosts.
- In early 2007, Parks Australia's contractors, the Arthur Rylah Institute (the biodiversity research base for the Department of Sustainability and Environment in the Victorian Government) found:
    - Total estimated population of the Pipistrelle was only 500 to1,000 individuals.
    - The Pipistrelle was found likely to become extinct in several years if current population decline trends continued.
    - Seven maternity roosts were located, all under loose bark on dead trees.
    - Blood tests showed no indication of disease, but further studies are required.
    - Predator cameras detected three potential predators on roost trees: Black Rats, Giant Centipedes and a Wolf Snake (though there was no evidence of any direct impact on the Pipistrelle). Ants and spiders may also have the potential to disrupt the roost.
- Seventeen months after the seven maternity roosts were located, five of the trees had collapsed and one had lost its bark. Only one former maternity roost tree is still inhabited.
- In 2008, additional monitoring and survey work was undertaken to determine if the Pipistrelles may have moved elsewhere on the Island, however it was found that the population has contracted to the north western end.
- In May 2008, Dr Lumsden of the Arthur Rylah Institute, was contracted to provide advice on captive breeding and in-situ management of the bats.

- In a Draft Report on the captive breeding and future in-situ management of the Christmas Island Pipistrelle (January 2009), Dr Lumsden reported that there were extremely low numbers of Pipistrelle bat.
- Parks Australia is considering her recommendation for a captive breeding program.
- PRL has engaged a bat expert, Dr Greg Richards, who is working closely with Dr Lumsden to develop a collaborative approach to accelerate efforts to save the pipistrelle.

Additional potential roost trees have been identified by parks staff and researchers, and work is underway to secure these as possible habitat for the remaining bats.

THREATENED SPECIES SCIENTIFIC COMMITTEE, OUT-OF-SESSION PAPER 30 JANUARY 2009

Christmas Island Pipistrelle Bat - advice on conservation

Background

1. The endemic Christmas Island Pipistrelle bat (P*ipistrellus murrayi*) is listed as 'critically endangered' under the EPBC Act. A national recovery plan is in place and is being implemented. The bat has been in serious decline over the last 14 years. Parks Australia has made significant efforts to undertake and support research into possible causes of decline and prevent this trend from continuing (Attachment 1). Despite best efforts, there are no clear causes of decline, and multiple factors are thought to be involved. A survey in January 2009 indicated there are possibly less than 20 bats remaining.

2. In May 2008, Dr Lindsay Lumsden of the Rylah Institute, was contracted to provide advice on captive breeding and in situ management of the bats. A draft report was provided to Parks Australia in January 2009 (Attachment 2). Given the extremely low numbers of Pipistrelle bat now thought to be in existence, Dr Lumsden has recommended that an emergency response plan be initiated to capture remaining bats if possible, and initiate a ten-year captive breeding program on Christmas Island. The estimated cost of such a program is $4.9 million.

Issues

3. Options for captive breeding have been considered in the past. However with little knowledge about the species and the potential risks involved, particularly given the small remaining population, Parks Australia on behalf of the Minister is seeking further advice about this option, as well as other recommendations for conservation measures for the Pipistrelle.

4. Biodiversity generally on Christmas Island is facing several challenges. There are other species under pressure, besides the Pipistrelle, and in this context a landscape wide approach to biodiversity loss is essential. A Regional Recovery Plan will shortly be developed for the island. An issues paper (Attachment 3) was prepared as part of the development of the draft plan, and this provides an overview of the island species, the existing and potential threats to biodiversity, and management actions.

5. A Christmas Island Biodiversity Monitoring Program, funded by the Department of Finance and Deregulation, was implemented by Parks Australia between 2003 and 2007. Its primary purpose was to monitor the effects of the construction of the IDC on Christmas Island, and it generated additional baseline biodiversity data for the island.

6. Prior to this it was widely thought that there were less than 50 endemic species of plants and animals on Christmas Island, but the figure is now estimated to be in excess of 250. The program also found a worrying loss of biodiversity. The program was unable to fully explore the causes of decline for particular species. The summary report (Attachment 4) found that attention needs to focus on addressing the root causes of biodiversity loss on Christmas Island. These causes are: invasive species that have entered the island due to poor quarantine procedures; poor land management practices that are historical and widespread which have allowed the spread of weeds and invasive animals; and global factors such as climate change.

7. As a matter of urgency the Minister is seeking advice from the Committee on the advisability and feasibility of undertaking ex-situ management of the species and any associated risks. Following discussion the Committee may wish to set up a small sub-committee to facilitate provision of this advice.

8. The Committee is also invited to provide expert participation in a broader dialogue on threats to biodiversity on Christmas Island.

Recommendation

That the Committee **agrees**:

1. To consider ongoing threats to the pipistrelle bat and provide urgent advice on the feasibility of a captive breeding program and any other appropriate conservation actions for the Pipistrelle bat;

2. To participate in and nominate representatives for an expert committee to consider threats to biodiversity on Christmas Island within the context of developing the Regional Recovery Plan and guiding conservation priorities.

Attachments

1. Chronology of research and actions for the Christmas Island Pipistrelle
2. "Captive breeding and future in situ management of the Christmas Island Pipistrelle *Pipistrellus murrayi*" Lindsay Lumsden and Martin Schulz 2009, Arthur Rylah Institute for Environmental Research
3. Issues paper - Conservation status and threats to the flora and fauna of the Christmas Island Region - May 2008 (prepared for be development of a draft Regional Recovery Plan for Christmas Island)
4. " Christmas Island Biodiversity Monitoring Program: December 2003 to April 2007" report to the Department of Finance and Deregulation from the Director of National Parks, September 2008

SUPPLEMENTARY PAPER PREPARED FOR THE DELIBERATIONS OF THE TSSC

Bob Beeton Chair

I apologise if this is a rather hasty document so please regard it as a first draft that members might improve when we meet by teleconference next week.

The Christmas Island Pipistrelle has been considered by the Committee on four occasions. It was listed as endangered at the fifth meeting, a recovery plan was approved at the 18th meeting (2004), a report was received on the recovery plan and action was commenced on up listing at the 26th meeting. At the 28th meeting the species was recommended for up listing to its current status.

Below is an extract from the minutes of the 28th meeting and members will note that there were significant concerns expressed by the Committee about the possible fate of species. Additional conservation advice was offered especially with respect to priorities.

In the papers that have been provided for us by the Department we are requested to provide urgent advice for the Department and Minister on actions that should now be taken. Specifically the Department is requesting that we consider the following two recommendations for the Minister.

Recommendation

*That the Committee **agrees**:*

1. *To consider ongoing threats to the pipistrelle bat and provide urgent advice on the feasibility of a captive breeding program and any other appropriate conservation actions for the Pipistrelle bat;*

2. *To participate in and nominate representatives for an expert committee to consider threats to biodiversity on Christmas Island within the context of developing the Regional Recovery Plan and guiding conservation priorities.*

This advice would formerly be offered to the Minister who would then direct the Department in its actions. I understand that the Minister has requested such advice.

A careful reading of all the documentation provided and the comments made by the Committee at the 28th meeting lead me to the conclusion that treating the symptoms, namely the decline in the Pipistrelle, is unlikely to reverse either the dramatic decline in biodiversity on Christmas Island in general and Pipistrelle in particular. I would be interested in the opinion of members on the threat to the Pipistrelle of trying to implement what could only be described as a highly experimental capture of wild animals followed by a captive breeding program. We do have to make a recommendation on this and what the conservation outcome might be of a multi-million-dollar exercise.

I ask members to focus particularly on the second recommendation and consider the following.

Would the expert committee achieve anything?

If yes then what terms of reference should be recommended for the operation of the expert committee?.

My first reaction is that it should:

- be given a very short time to report,
- have access to all available material,
- get on the ground,
- consist of people who are expert in the recovery of declining islands and with a practical understanding of on ground management,
- be small
- be directed towards the recommendation of very specific and immediately implementable actions in addition to longer term actions and
- be asked to continue to serve as an oversight committee for what I see as the first action.

The first action should be the establishment of rigorous monitoring with an appropriate system for evaluating its results on short and long time cycles.

Overview

Our consideration of this matter should be considered as strategic as well as immediate and tactical. I believe the time has arrived where we have to seriously consider whether spending large amounts of money on highly targeted single species recovery is an appropriate use of resources when clearly it is system decline that is driving the process.

If members are of this view then we should regard our recommendation to the Minister as contextualising the way these matters should be dealt with in the future. This would be consistent with our recommendation to the Hawk review of the necessity to focus more on threats and ecological communities and less on species after the damage has been done. This would also be consistent with the Committee's long held view about the need for multi-threat, multi-species, multi-community planning in the regional context.

Extract from the minutes of the 28th meeting of TSSC September 2006

7.1 *Pipistrellus murrayi* (Christmas Island Pipistrelle)

The Committee **requested** that the following amendments be made to the draft listing advice:

- The following additional sentence be included under criterion 3: 'These results, in addition to data from capture numbers and detector passes, suggest that an estimate of the total population may be in the order of 500-1000 individuals (L. Lumsden 2006, pers.comm.).'

- The discussion under criterion 3 be amended to reflect the fact that of the seven roost trees recorded, four have since fallen and are therefore lost as roost sites.
- The last sentence of the second paragraph in the conclusion on page 5, be replaced with: 'Indicative modelling suggests that if the current rate of decline continues, the Christmas Island Pipistrelle will become extinct in the near future.'

The Committee discussed population size in the context of the decline predicted by the graph on page 23, and whether the species might be considered critically endangered under criterion 3. The committee **noted** that only estimates of relative abundance were available and therefore **agreed** that the species remains eligible for listing as endangered under criterion 3.

The Committee **noted** that it would be useful to have an aerial photograph of the location where the species occurs on the island.

The Committee **agreed** to recommend to the Minister that *Pipistrellus murrayi* (Christmas Island Pipistrelle) is eligible for transferring from the endangered category to the critically endangered category of the threatened species list.

The Committee **agreed** not to provide advice to the Minister on Critical Habitat for the species at this time.

The Committee **noted** that whilst the 2004 recovery plan had identified key threats for the species, it had not yet succeeded in determining the cause of, or arresting the population decline of the species.

The Committee discussed whether exotic animal reduction on the island had been successful under the 2004 recovery plan. The Committee **noted** that a regional recovery plan for Christmas Island (currently in preparation) would provide an opportunity to revisit such species recovery actions.

The Committee **requested** that the following amendments be made to the draft conservation advice:

- The following sentence be added to the disclaimer note: 'The Threatened Species Scientific Committee recognises that a Recovery Plan exists for the species under its previous conservation status. Given the change in conservation status for the species to critically endangered the Committee provides the following conservation advice'.
- Under priority recovery and threat abatement actions:
  - that the fifth dot point 'eradicate exotic animals' become the first action.
  - the now second dot point be amended to 'monitor known sites to identify key threats'.
  - the third dot point be amended to 'monitor known sites to identify any amendments in indicators used to estimate relative abundance'.

- the fifth dot point be amended to 'ensure any amendments in land use do not have direct adverse impacts on known sites important to the species or indirect impacts on the species in other ways'.

- Under regional priority recovery and threat abatement actions:
    - that the third dot point ' Develop a management plan for the control and eradication of introduced species such as the Common Wolfsnake and feral cat in the local region' become the first action.
    - the last sentence be amended to 'Priority for the development of recovery plan: 'The Committee recognises that Christmas Island has a number of threatened species requiring recovery actions and continues its support for multi-species plans. The priority for a multi-species recovery plan for Christmas Island is high. For this species the Committee believes that resources should initially be directed towards Action One of the current recovery plan, namely determining or arresting the cause of population decline. The Committee believes that if necessary, the development of radical conservation action may be required. Radical conservation action could include translocation, captive breeding, habitat sterilization, and reintroduction or population supplementation by means yet to be determined'.

In considering the conservation advice the Committee **noted** that given the history of species extinction on Christmas Island, the futility of existing measures may need to be recognised and *ex situ* conservation measures may need to be considered.

The Committee **approved** the amended conservation advice for *Pipistrellus murrayi* (Christmas Island Pipistrelle).

THREATENED SPECIES SCIENTIFIC COMMITTEE - MINUTES

Extraordinary Meeting on Christmas Island Pipistrelle

Teleconference – 3 February 2009

Present

Threatened Species Scientific Committee

Associate Professor Bob Beeton (Chair)

Dr Guy Fitzhardinge

Dr Gordon Guymer

Professor Peter Harrison

Dr Bill Humphreys

Dr Rosemary Purdie

Dr John Woinarski

Associate Professor Keith Walker

Department of the Environment, Water, Heritage and the Arts

Ms Kerry Smith

Mr Mark Flanigan

Mr Peter Latch

Mr Saravan Peacock

Mr Matthew White

Ms Meryl Triggs

Ms Anne Marie Delahunt

Mrs Leanne O'Donohue

Apologies

Dr Andrea Taylor

Dr Tony Lewis

Agenda Item 1

WELCOME

The Chair welcomed Committee members and Departmental officers to the teleconference.

Agenda Item 2

Christmas Island PIPISTRELLE

- The Chair noted the attachments sent to the Committee and asked for preliminary comments from the members on the Supplementary Paper prepared by the Chair, Associate Professor Bob Beeton.
- A summary of the comments from members are as follows:
- There are a variety of concerns for biodiversity in general on Christmas Island
- There are some questions about the taxonomic status of the Christmas Island Pipistrelle, and its distinctiveness from other similar bats
- The reasons for the decline of the Christmas Island Pipistrelle are unknown
- A captive breeding program may be an option
- There are risks involved in a captive breeding program
- A mainland captive breeding program could be used to test a Christmas Island Pipistrelle program
- Funding could be usefully directed to conserving Christmas Island biodiversity in general rather than a large investment in just one species
- Anne Marie Delahunt introduced the Departmental Paper and discussed the following issues:
- Decline in biodiversity on Christmas Island
- There are a variety of threat abatement, recovery and management programs already operating on Christmas Island eg to abate threats from Yellow Crazy Ants
- Dealing with existing and historical mining impacts on the Island
- Christmas Island is outside the Australian quarantine zone, so moving bats to the mainland is difficult
- Singapore Zoo is not currently interested in a breeding program for the Christmas Island Pipistrelle

The Committee then discussed the following:

- Mining dust and the effects on the species
- Impacts of Detention Centre lighting on food sources (insects) for the Christmas Island Pipistrelle
- Survey efforts in areas other than known sites
- Questions about reliability of population data

- Questions on the methodology of surveys
- Analysis of old roost sites for possible reasons for decline
- Need to determine more about the generation time of the species
- Captive breeding facility on Christmas Island may be an opportunity to benefit other species
- There seem to be a low number of pipistrelles for a captive breeding program and there are potential capture risks associated with such a program
- Although there are some captive micro-bats knowledge of husbandry is seems to be insufficient to base a captive breeding program of such sensitivity on
- The use of baiting for Crazy Ants and the effects of this on other species
- Other invasive species on Christmas Island
- Reduction of available options due to small numbers left
- Mortality issues and possibility of gaining more information via autopsies/droppings before anything else is done
- Possibility of having a dedicated Biologist on Christmas Island
- Make-up of Expert Committee

Conclusion

The Committee **assessed** the information provided on the condition of biodiversity on Christmas Island, including the Christmas Island Pipistrelle, and formed the opinion that there is no realistic chance, in the timeframe available, that management of the Christmas Island environment will improve the chances of survival of the Christmas Island Pipistrelle in the wild. Consequently, extinction in the wild of the Christmas Island Pipistrelle is almost inevitable.

The Committee **discussed** the options for the Christmas Island Pipistrelle and concluded that there were two options, either to allow the current trend to continue, probably to extinction, or consider a captive breeding program which, of itself, may not prevent extinction.

The Committee **assessed** the proposed captive breeding program based on all the information provided to it. The Committee was concerned about the risk of failure of a highly experimental program in the absence of key information. An additional concern was the likely small founder population that would be involved.

The Committee **discussed** a five stage process which would address the continued decline of Christmas Island biodiversity in general and minimize the risks associated with an immediate Christmas Island Pipistrelle captive breeding program and increase the probability of success of such a program if undertaken.

The Committee **recommends**:

1. An immediate review by an expert committee of threats to biodiversity on Christmas Island, including the Christmas Island Pipistrelle, and the development of priority setting protocols by the expert committee. This should inform the development of the Regional Recovery Plan currently under way.
2. An intensification of threat identification and abatement for all island biodiversity based on priorities identified by the expert committee at its first meeting.
3. The immediate implementation of a test captive breeding program on *Pipistrellus westralis* on the mainland. This is an abundant and secure mainland species closely related to the Christmas Island Pipistrelle and occupying similar habitat. The objectives, within three months, should be to prove that the safe capture of individuals is possible and to identify optimal husbandry requirements for the species. Subsequently, captive breeding should be tested, along with other relevant threat management strategies.
4. The immediate intensification of survey work on the island under rigorous protocols which minimise the threats of this work to the Christmas Island Pipistrelle and other threatened species. This should be oversighted by the expert committee referred to above.
5. The immediate commencement of preparations for a possible Christmas Island Pipistrelle captive breeding program on Christmas Island with a decision on whether to proceed being dependent on the outcomes of the mainland proof of concept study and the results of further survey work on Christmas Island. This decision should be recommended to the Minister by the Department following an appropriate risk assessment.

The Committee agreed **that the advice would be checked by the Department and sent to the Minister.**

Agenda Item 3

Brief update on submission to EPBC Act review

The Committee agreed **to discuss the EPBC Act Review at the 38th TSSC meeting.**

Close of Meeting

The Chair thanked Committee members and Departmental staff for a successful teleconference.

I declare, on behalf of the Committee, that these Minutes are a true and accurate record of the teleconference.

Associate Professor Bob Beeton *AM FEIANZ*

Chair

MINISTERIAL PRESS RELEASE

MEDIA RELEASE

The Hon Peter Garrett MP

Minister for the Environment, Heritage and the Arts

PG /211 16 February 2009

MINISTER TAKES FURTHER ACTION ON PIPISTRELLE DECLINE

Environment Minister Peter Garrett has accepted the recommendations of Australia's leading threatened species experts - the Threatened Species Scientific Committee (TSSC) – for further urgent action on the Christmas Island pipistrelle bat.

The Committee has recommended actions to address the continued decline of Christmas Island biodiversity and to minimise the risks associated with a captive breeding program for the pipistrelle. "Sadly, the Committee has confirmed what we feared, that the pipistrelle is in severe decline and that extinction in the wild is almost inevitable," Mr Garrett said.

"We are now at a critical stage. Despite some $470,000 spent over the last five years under the recovery plan and around $4 million spent slashing the numbers of yellow crazy ants which are the biggest threat to biodiversity on the island, combined with the huge efforts by park managers and independent scientists, these actions have so far failed to reverse its rapid decline.

"Unfortunately, the Threatened Species Scientific Committee has also advised me that there is a high risk associated with a proposed captive breeding program for the pipistrelle with so few left on the island. The bats are also very difficult to catch and no-one knows how to keep them alive for breeding.

"The Committee have informed me that they are aware of no captive breeding program for microbats undertaken anywhere in the world – we are on new ground here.

"I therefore accept that there are unacceptably high risks involved in embarking on an immediate captive breeding program .

"However, on the Committee's recommendation, a trial program on a closely related species, *Pipistrellus westralis*, will begin as soon as possible. This bat is abundant and secure in the top end of the Northern Territory and I am pleased the Northern Territory Government will work with us on this project.

"The objective, within three months, is to demonstrate safe capture methods and to identify optimal husbandry requirements of the species.

"At the same time, the Director of National Parks is preparing for a potential captive breeding program on Christmas Island, in the event that the mainland trial is successful."

Mr Garrett said TSSC chair Associate Professor Bob Beeton had agreed to chair an experts group, which will meet on island within the next few weeks to review the threats to biodiversity across the entire of Christmas Island.

“These experts will identify priorities to protect all the island’s biodiversity, so that actions to intensify threat identification and abatement feed into the Regional Recovery Plan that is currently under development.

”We will do whatever is practical and feasible to save the pipistrelle, even though it is the case that bat numbers on the island have been in rapid decline for around 14 years now for reasons that are not clear. I am deeply concerned by the fact that its prospects do not appear bright on the basis of our current understanding of the situation.”

Media contact: Ben Pratt 0419 968 734

APPENDIX 8 EXPERT WORKING GROUP – PROGRAM OF ON-ISLAND MEETING MARCH 30TH – APRIL 3RD 2009

Date	Time	Venue	Item	
Mon 30th March	2.30 *P.murrayi*	-	Flights arrive from Perth	Marjorie Gant, Park Manager
	3.30 *P.murrayi* to 5.30 *P.murrayi*		Orientation drive around island Landscape scale overview including Margaret Knoll, Blowholes, DIAC lookout, North East Point, South point and mined sites. Pipistrelle site area (start of Winfred Track)	Parks staff to guide
	6.30 *P.murrayi*		Working Dinner - EWG (Rumah Tingi)	EWG and relevant Park staff
Tues 31st March	8.30 – 9.30 am	Recreation Centre	Staff meeting and discussion Introduction of EWG to park staff EWG meeting aims & anticipated outcomes Brief overview of Park (e.g. native and invasive species, YCA, CIMFR, Tourism, marine areas, GIS, management arrangements)	Relevant Park staff
	9.30am – 9.45 am	Recreation Centre	Morning Tea	
	9.45-12.30 pm	Field Trip	Crazy ant supercolony site visits and discussions IWS methodology YCA program	Relevant Park staff.
	12.30-1.30 pm	Recreation Centre	Working Lunch	
Tues 31st March	1.30–4.30	Recreation Centre	EWG meeting Threats to Biodiversity discussion of data, and theories	Relevant Park staff.
	4.30-9.00 pm	Field Trip Picnic dinner provided	*P. murrayi* roost from 1745 to 1900 *P. murrayi* foraging area 1915 to 2100 hrs *Nocturnal search for geckos and centipedes*	Norm, Andrew & others with relevant Park staff

Date	Time	Venue	Item	
Wed 1 April	3.30-7.00 Am	Field Trip	*P.murrayi* roost and foraging area Predawn head torching	Norm, Gordon and Ric
	8.30 - 10.30	Shire training room	EWG meeting General discussion with staff about threats to biodiversity on island	Relevant Park staff
	10.30 am - 11.00 am	Shire training room	Morning Tea	
	1.30–4.30		Pipistrelle	Relevant Park staff
	4.30-9.00 pm	Field Trip Picnic dinner provided	Pipistrelle	Relevant Park staff
Thursday 2 April	8.30am – 12.30 am	Recreation Centre	With Staff key issues	Relevant Park staff
	1300 to 4.00		Island Ecology	Relevant Park staff then EWG
	4:00 6:00		Community meeting	
	4.30-9.00 pm	Field Trip Picnic dinner provided	Pipistrelle	Relevant Park staff
Friday	8:30 12:00	Recreation centre	Discussion of issues and report framework	EWG

APPENDIX 9 INTRODUCED BIOTA OF CHRISTMAS ISLAND

The following tables list many of the non-Indigenous animals and plants recorded from Christmas Islands. These lists are comprehensive for some taxonomic groups, but indicative only for other taxonomic groups (especially some invertebrates).

Introduced fauna found on Christmas Island

Species name	Common name or family	Comments
MAMMALS		
Rattus rattus	Black rat	arrived 1899
Mus domesticus	House mouse	probably arrived with settlement
Felis catus	Feral cat	widespread
Canis familiaris	Dog (feral and domestic)	few remaining around settlement
REPTILES		
Hemidactylus frenatus	Asian House gecko	first mentioned 1931-41
Gehyra mutilata	Pacific gecko	first recorded 1979
Lycodon aulicus capucinus	Common wolf snake	arrived ~1987
Ramphotyphlops braminus	Flowerpot Snake	first recorded 1940
Lygosoma bowringii	Grass skink	arrived sometime in 1960s
	terrapins ? species	in the tank at Ross Hill Gardens
BIRDS		
Gallus gallus	Domestic fowl	
Anas platyrhynchos	Domestic duck	
Meleagris gallopavo	Domestic turkey	
Padda oryzivora	Java sparrow	arrived 1908-1923
Passer montanus	Tree sparrow	arrived 1980s
FRESHWATER FISH		
Scleropages formosus	Asian bony tongue	IUCN Endangered A1cd+2cd ; SE Asia

Eleotris fusca	Brown gudgeon	Native: Oceania
Oreochromis sp.	Tilapia	East Africa
Poecilia reticulata	Guppy	Americas
Gambusia holbrooki	Mosquito fish	North America
Xiphophorus maculatus	Swordtail	Central America
ARTHROPODS		
ANTS – from Framenau & Thomas (2008) None of the ants occurring on Christmas Island are considered to be endemic; however, the island may fall within the native range of a few species.		
Amblyopone zwaluwenburgi	Amblyoponinae	tramp
Cerapachys biroi	Cerapachyinae	tramp
C. longitarsus	Cerapachyinae	widespread in the Indo-Australian region
Ochetellus sp.	Dolichoderinae	tramp
Tapinoma melanocephalum	Dolichoderinae	tramp
Tapinoma sp.	Dolichoderinae	widespread in the Indo-Australian region
Technomyrmex vitiensis	Dolichoderinae	tramp
Anoplolepis gracilipes Yellow Crazy Ant	Formicinae	considered one of the most ecologically damaging introduced ants
Camponotus sp. (2 spp)	Formicinae	widespread in the Indo-Australian region
C. melichloros	Formicinae	widespread in the Indo-Australian region
Paratrechina bourbonica	Formicinae	tramp
P. longicornis	Formicinae	tramp
Paratrechina sp (2 spp)	Formicinae	tramp
P. vividula	Formicinae	tramp
Plagiolepis alluaudi	Formicinae	tramp
P. exigua	Formicinae	
Leptanilla sp	Leptanillinae	
Cardiocondyla kagutsuchi	Myrmicinae	widespread in the Indo-Australian region
C. wroughtonii	Myrmicinae	tramp
Monomorium destructor	Myrmicinae	tramp

M. floricola	Myrmicinae	tramp
M. latinode	Myrmicinae	
M. orientale	Myrmicinae	
M. pharaonis	Myrmicinae	tramp
M. cf. subcoecum	Myrmicinae	
Pheidole megacephala African big-headed Ant	Myrmicinae	considered one of the most ecologically damaging introduced ants
Pheidole sp. (*variabilis* group)	Myrmicinae	widespread in the Indo-Australian region
Pheidole sp.	Myrmicinae	widespread in the Indo-Australian region
Pyramica membranifera	Myrmicinae	tramp
Solenopsis geminate Tropical Fire Ant	Myrmicinae	considered one of the most ecologically damaging introduced ants
Strumigenys emmae	Myrmicinae	tramp
S. godeffroyi	Myrmicinae	tramp
Tetramorium bicarinatum	Myrmicinae	tramp has formed supercolonies elsewhere
T. insolens	Myrmicinae	tramp
T. lanuginosum	Myrmicinae	tramp
T. pacificum	Myrmicinae	tramp; widespread in the Indo-Australian region
T. simillimum	Myrmicinae	tramp
T. cf simillium	Myrmicinae	
T. smithi	Myrmicinae	
T. walshi	Myrmicinae	
Anochetus sp.	Ponerinae	tramp; widespread in the Indo-Australian region
Hypoponera confinis	Ponerinae	widespread in the Indo-Australian region
H. opaciceps	Ponerinae	tramp
H. punctatissima	Ponerinae	tramp
Leptogenys falcigera	Ponerinae	tramp

L. harmsi	Ponerinae	widespread in the Indo-Australian region
Odontomachus simillimus	Ponerinae	widespread in the Indo-Australian region
Pachycondyla (*Brachyponera*) *christmasi*	Ponerinae	widespread in the Indo-Australian region
Pachycondyla (*Trachymesopus*) *darwinii*	Ponerinae	widespread in the Indo-Australian region
Platythyrea sp.	Ponerinae	widespread in the Indo-Australian region
Ponera swezeyi	Ponerinae	tramp
HEMIPTERA – search for Christmas Island on ScaleNet at: http://www.sel.barc.usda.gov/SCALENET/SCALENET.HTM (P. Gullan, pers. comm.2010 UC Davis)		
Species	**Family**	Origin (Abbot 2004)
Ceroplastes ceriferus (Fabricius)	**Coccidae**	native to South America
Ceroplastes destructor Newstead	**Coccidae**	native to Africa
Coccus celatus De Lotto	**Coccidae**	native to Africa
Coccus hesperidum hesperidum Linnaeus	**Coccidae**	native to ?South Africa
Milviscutulus mangiferae (Green)	**Coccidae**	
Saissetia coffeae (Walker)	**Coccidae**	native to Africa
Saissetia oleae oleae (Olivier)	**Coccidae**	native to Africa
Odonaspis ruthae Kotinsky	**Diaspididae**	
Pinnaspis strachani (Cooley)	**Diaspididae**	
Paratachardina lobata lobata (Chamberlin) [now *Paratachardina silvestri* (Mahdihassan) by synonymy]	**Kerriidae**	native to India and Sri Lanka Specimens attributed to this species have subsequently been identified as a new species, *Paratachardina pseudolobata* (Kondo & Gullan 2007), a widespread and serious pest species identified as one of several

		polyphagous scale insect species causing canopy die-back on Christmas Island although not identified in any of the published papers on the subject and the error was reported as early as 2006. The recent appearance of this scale as a pest in Florida (USA), Bahamas, and Christmas Island indicated that the species is introduced but the native range is unknown (Schroer et al. 2008).
Tachardina aurantiaca (Cockerell)	**Kerriidae**	Southeast Asia?
Icerya purchasi purchasi Maskell	**Margarodidae**	native to Australia
Planococcus minor (Maskell)_	**Pseudococcidae**	
In addition Abbott (2004) reported the following taxa (after recent name changes are taken into account).		
Aspidiotus destructor	Coconut scale [Diaspididae]	unknown
Pseudaulacaspis pentagona	White peach scale [Diaspididae]	native to China
Hemiberlesia palmae	Tropical palm scale [Diaspididae]	
Lindingaspis sp.	soft scale [Diaspididae]	
OTHER INSECTS		
Apis mellifera	honeybee	
Periplaneta americana	cockroach	
	termites (2 species)	
	fruit fly (4 species)	
MYRIAPODS		
Scolopendra morsitans	giant centipede	

Asiomorpha coarctata	a millipede	
Prosopodesmus jacobsoni	a millipede	
Cylindrodesmus hirsutus	a millipede	
Solaenaulus butteli	a millipede	
Leptogoniulus sorornus	a millipede	
Trigoniulus corallinus	a millipede	
Hypocambala exocoeti	a millipede	
ARACHNIDS after Framenau Waldock and Harvey, (pers.comm.)		
Scytodes venusta	Scytodidae	Sri Lanka-Java
Scytodes velutina	Scytodidae	Mediterranean
Scytodes longipes	Scytodidae	pantropical
Oecobius navus	wall spider	
Artema atlanta	Pholcidae	pantropical
Crossopriza lyoni	Pholcidae	cosmopolitan
Pholcus gracillimus	Pholcidae	Sumatra Java
Smeringopus pallidus	Pholcidae	cosmopolitan
Opopaea lena	Oonopidae	Hawaii, Seychelles Thailand
Oecobius navus	Oecobiidae	cosmopolitan
Hersiliola versicolor	Hersiliidae	Cape Verde
Zosis (Uloborus) genticulata	Uloboridae	pantropical
Philoponella sp.	Uloboridae	?
Heteropoda venatoria	Sparassidae	circumtropical
Achaearanea tepidariorum	Theridiidae	cosmopolitan
Argyrodes argentatus	Theridiidae	China, India, Hawaii
Tetragnatha mandibulata	Tetragnathidae	West Africa, SE Asia, Australia
Nephila antipodiana	Nephilidae	?
Nephila pilipes	Nephilidae	Oriental
Argiope modesta	Araneidae	Borneo-Australia
Argiope reinwardti	Araneidae	Asia
Clycosa bifida	Araneidae	?
Cyclosa mulmeinesis	Araneidae	Africa-Japan, Philippines
Cyclosa insulana	Araneidae	Mediterranean-Philippines
Cyclosa VWF sp.791	Araneidae	?

Cryptophora unicolor	Araneidae	Sri Lanka-Philippines, Australia
Gasteracantha kuhli	Araneidae	India-Japan
Neoscona theisi	Araneidae	India, China, Pacific
Neoscona nautica	Araneidae	cosmotropical
Neoscona punctigera	Araneidae	?
Hohna crispipes	Lycosidae	Australasia and Pacific
Agelena sp.	Oxyopidae	?
Clubiona sp.	Clubionidae	?
Corinomuna moerens	Corinnidae	Sumatra
Oedignatha scrobriculata	Corinnidae	India Seychelles-Philippines
Cytea sp.	Salticidae	?
Hasarius adansoni	Salticidae	cosmopolitan
Menemerus bivittatus	Salticidae	pantropical
Plexippus paykulli	Salticidae	cosmopolitan
Simaethula (Homalattus) aurata	Salticidae	Queensland
Latrodectus geometricus	Brown widow spider	
Schizomus lunatus	a schizomid	Indian & Pacific Ocean regions
MOLLUSCS from Kessner (pers. comm. 2010)		
Achatina fulica	Giant African snail Achatinidae	introduced
Bradybaena similaris	Asian tramp snail Bradybaenidae	introduced
Cecilioides sp.	Ferussaciidae	unknown
Charopa sp.	Charopidae	unknown
Discocharopa cf. *aperta*	Charopidae	introduced
Elasmias manilensis	Achatinellidae	introduced
Georissa williamsi	Hydrocenidae	introduced
Gastrocopta servilis	Pupillidae	introduced
Georissa sp.	Hydrocenidae	unknown
Georissa aff. *Williamsi* (subrecent)	Hydrocenidae	unknown – presumed extinct
Gulella (*Huttonella*) *bicolor*	Streptaxidae	introduced
Kaliella cruda	Helicarionidae	unknown

Lamellaxis gracilis	Subulinidae	introduced
Liardetia (*Belopygmaeus*) *doliolum*	Helicarionidae	introduced
Liardetia (*Liardetia*) *scandens*	Helicarionidae	introduced
Melampus castaneus	Ellobiidae	introduced
Melampus fasciatus	Ellobiidae	introduced
Melampus luteus	Ellobiidae	introduced
Microcystis sp.	Helicarionidae	introduced
Opeas pumilum	Subulinidae	introduced
Paropea achatinaceum	Subulinidae	introduced
Pupisoma orcula	Pupillidae	introduced
Pupisoma sp.	Pupillidae	introduced
Rhachis punctata	Cerastidae	introduced
Semperula sp.	Veronicellidae	introduced
Subulina octona	Subulinidae	introduced
Succinea solidula	Succineidae	introduced
Tornatellinops sp.	Achatinellidae	introduced

Introduced plants of Christmas Island

Weeds grouped as trees, shrubs, vines and herbs, and ranked in 3 classes of risk (where 1 is the highest) for each of 3 vegetation types on Christmas Island. The shaded species are those that are high risk in undisturbed areas (from CINP Draft Weed Strategy) .

Species & Life-form	**Risk Rating**		
Trees	**Tall Evergreen forest**	**Semi-deciduous forest & deciduous scrub**	**Disturbed/regenerating areas**
Adenanthera pavonia	1	1	1
Aleurites moluccana	1	1	1
Barringtonia asiatica	2	1	1
Castilla elastica	1	1	1
Ceiba pentandra	2	1	1
Clausena excavata	1	1	1
Delonix regia	1	1	1
Ficus elastica	2	2	2
Hevea brasiliensis	1	1	1
Jatropha curcas	2	2	1
Leucaena leucocephala	2	1	1
Manihot glazvoii	2	1	1
Melia azaderach	1	1	1
Muntingia calabura	2	2	1
Piper aduncum	2	1	1
Pithocellobium dulce	2	2	1
Psidium spp.	1	1	1
Pterocarpus indicus	1	1	1
Senna sulphurea	3	2	1
Spathodea campanulata	1	1	1
Syzygium spp.	1	1	1
Shrubs			
Cordia curassavica	2	1	1
Hyptis capitata	3	1	1
Tecoma stans	2	1	1

Tithonia diversifolia	2	1	1
Pluchea indica	3	2	1
Vines			
Antigonon leptopus	1	1	1
Calopogonium spp.	3	2	1
Centrosema pubescens	2	1	1
Ipomoea cairica	3	2	1
Ipomoea nil	3	2	1
Macroptilium atropurpureum	2	1	1
Mikania micrantha	2	2	1
Mucuna albertisii	1	1	1
Paederia foetida	2	2	1
Herbs			
Parthenium hysterophorus	3	1	1
Cenchrus echinatus	3	1	1
Mimosa spp.	3	2	1

APPENDIX 10 NATIVE BIOTA OF CHRISTMAS ISLAND

The following tables list, for some vertebrate and invertebrate groups, native species recorded from Christmas Island. The listing is comprehensive for some groups, but indicative and incomplete for others, in part reflecting carrying levels of inventory.

Native and endemic fauna found on Christmas Island

Species Name	Common Name	Status	Abundance
RESIDENT LAND, FRESHWATER AND SHOREBIRDS			
Accipiter hiogaster natalis	Christmas Island Goshawk	endemic	uncommon
Amaurornis phoenicurus	White-breasted Water-hen	self-introduced	uncommon
Chalcophaps indica natalis	Emerald Dove (Christmas Island)	endemic	common
Collocalia linchi natalis	Christmas Island Swiftlet	endemic	abundant
Ducula whartoni	Christmas Island Imperial Pigeon	endemic	common
Egretta novaehollandiae	White-faced Heron	self-introduced	rare
Egretta sacra	Eastern Reef Egret	native	rare
Falco cenchroides	Australian Kestrel	self-introduced	common
Gallus gallus	Feral Fowl	introduced	common
Ninox natalis	Christmas Island Hawk-owl	endemic	uncommon
Passer montanus	Tree Sparrow	self-introduced	common
Turdus poliocephalus erythropleurus	Christmas Island Thrush	endemic	common
Zosterops natalis	Christmas Island White-eye	endemic	abundant
BREEDING SEABIRDS			
Anous stolidus	Common Noddy	native	common
Fregata andrewsi	Christmas Island Frigatebird	endemic	uncommon
Fregata ariel	Least Frigatebird	native	rare
Fregata minor	Great Frigatebird	native	common
Papasula abbotti	Abbott's Booby	endemic	uncommon
Phaethon lepturus fulvus	Golden Bosun	endemic	common
Phaethon rubricauda	Silver Bosun	native	common

Sula leucogaster	Brown Booby	native	common
Sula sula	Red-footed Booby	native	common
REGULAR MIGRANTS AND OCCASIONAL VISITORS (note that there are many other infrequent visitors)			
Actitis hypoleucos	Common Sandpiper	regular migrant	
Apus pacificus	Fork-tailed Swiflet	regular visitor	
Ardea alba	Great Egret	occasional visitor	
Arenaria interpres	Ruddy Turnstone	regular migrant	
Bulweria bulwerii	Bulwer's Petrel	occasional visitor	
Charadrius leschenaultii	Greater Sand Plover	rare migrant	
Charadrius veredus	Oriental Plover	rare migrant	
Chlidonias hybrida	Whiskered Tern	occasional visitor	
Cuculus saturatus	Oriental Cuckoo	rare migrant	
Gallinago stenura	Pin-tailed Snipe	occasional visitor	
Glareola maldivarum	Oriental Pratincole	rare migrant	
Gorsachius melanolophus	Malay Night-heron	occasional visitor	
Hirundo rustica	Barn Swallow	common migrant	
Motacilla cinerea	Grey Wagtail	common migrant	
Motacilla flava	Yellow Wagtail	common migrant	
Pluvialis fulva	Pacific Golden Plover	regular migrant	
Stiltia isabella	Australian Pratincole	occasional visitor	
Tringa glareola	Wood Sandpiper	rare migrant	
Tringa nebularia	Greenshank	rare migrant	

Species Name	Common Name	Status	Abundance
MAMMALS			
Crocidura trichura	Christmas Island Shrew	endemic	rare, possibly extinct

Pipistrellus murrayi	Christmas Island Pipistrelle	endemic	probably extinct
Pteropus melanotus natalis	Christmas Island Flying-fox	endemic	uncommon
Rattus macleari	Maclear's Rat	endemic	extinct
Rattus nativitatis	Bulldog Rat	endemic	extinct
REPTILES			
Chelonia mydas	Green Turtle	native	uncommon
Cryptoblepharus egeriae	Blue-tailed Skink	endemic	rare, declining
Cyrtodactylus sadleiri	Giant Gecko	endemic	uncommon, declining
Emoia atrocostata	Foreshore Skink	native	rare, declining
Emoia nativitatis	Forest Skink	endemic	rare, declining
Eretmochelys imbricata	Hawksbill Turtle	native	rare
Lepidodactylus listeri	Tree Gecko	endemic	rare, declining
Typhlops exocoeti	Pink Blind Snake	endemic	rare, declining

Species Name	**Common Name**	**Status**	**Abundance and Distribution**
LAND AND SHORELINE CRABS			
Birgus latro	Robber Crab	native	uncommon, widespread, arboreal
Chiroantes obtusifrons	Yellow-eyed Crab	native	common, crevices high in seacliffs beyond tidal or salt spray, around coast
Coenobita brevimanus	Purple Hermit Crab	native	common, beaches and shore terraces
Coenobita perlatus	Red Hermit Crab	native	common, rubble beaches
Coenobita rugosus	Tawny Hermit Crab	native	common, beaches and shore terraces
Cyclograpsus integer	Sandy Rubble Crab	native	rare, restricted to rubble buried in sand at Greta and Ethel beaches
Discoplax hirtipes	Blue Crab	native	uncommon, moist areas with water seepages
Epigrapsus politus	Brown Crab	native	rare, beach sand/rubble boundary on forest soil, usually under rocks
Gecarcoidea lalandii	Purple Crab	native	rare, distributed island-wide

Gecarcoidea natalis	Red Crab	endemic	abundant, distributed island-wide
Geograpsus crinipes	Yellow Nipper	native	uncommon, lower terraces, seacliff and beaches
Geograpsus grayi	Little Nipper	native	common, distributed from shore terrace to plateau
Geograpsus stormi	Red Nipper	native	rare, under shoreline rocks and in crevices on the seacliff near water
Grapsus tenuicrustatus	Grapsus Crab	native	common all round coastline
Labuanium rotundatum	White-striped Crab	native	uncommon, terraces above Greta Beach, the Dales and West White Beach
Metasesarma rousseauxi	Mottled Crab	native	rare, leaf litter above beaches
Ocypode ceratophthalma	Horn-eyed Ghost Crab	native	common, sandy beaches
Ocypode cordimanus	Smooth-handed Ghost Crab	native	common, sandy beaches
Ptychognathus pusillus	Freshwater Crab	native	uncommon, restricted to fresh running water
Sesarmoides jacksoni	Jackson's Crab	endemic	rare, cool moist areas on lower terraces, in caves

Species Name	**Status**	**Abundance and Distribution**
TERRESTRIAL SNAILS		
Assiminea andrewsiana	endemic	uncommon, isolated small colonies near coast
Assiminea sp.	endemic	associated with permanent springs
Charopa sp.	endemic?	rare
Georissa aff. *williamsi*	unknown	presumed extinct
Georissa sp.	unknown	common in rainforest on plateau, partly arboreal
Japonia wallacei	native	common in central plateau and upper terraces, on palms, pandanus and trees with smooth bark
Kaliella cruda	native?	unknown

Lamprocystis mabelae	endemic?	unknown
Lamprocystis mildredae	endemic	restricted distribution, common in primary rainforest, leaf litter and under logs
Lamprocystis normani	endemic	restricted distribution, rare in primary rainforest, leaf litter and under logs
Nesopupa proscripta	endemic	common, partly arboreal, on trees with smooth bark
Pythia scarabaeus	native?	common in moist leaf litter near the coast and springs
Succinea solidula	endemic	common in rainforest on central plateau and upper terraces
Succinea solitaria	endemic	rare, limestone boulders and cliffs in open or partially shades on lower eastern slopes
Truncatella guerinii	native	abundant in gravel and leaf litter

Plant species that are endemic to Christmas Island, listed as threatened under the EPBC Act, and/or are considered to be of concern

Species Name	Common Name	Endemic	Conservation status	Threats
Abelmoschus manihot var. *pungens*	a shrub			weeds
Abutilon listeri	Lantern Flower	endemic		
Amaracarpus pubescens	a shrub			none known
Arenga listeri	Christmas Island Palm	endemic	not of concern	
Asplenium listeri	Christmas Island Spleenwort	endemic	CR	disturbance (mining)
Asystasia alba	a herb	endemic		predation by crabs; weeds
Balanophora abbreviata	a herb			none known
Blumea balsamifera	Camphor Bush			
Blumea lanceolaria	a herb			predation by crabs; weeds
Brachypeza archytas	an epiphytic orchid	endemic	not of concern	
Bryobium pubescens	an epiphytic herb			
Cinnamomum iners	Wild Cinnamon			
Cleome gynandra	an annual herb			
Colubrina pedunculata	a shrub	endemic		none known
Commicarpus chinensis ssp. *chinensis*	a subshrub			
Cycas rumphii	Cycad			weeds
Cynometra ramiflora	Wrinklepod Mangrove			stress during dry periods
Dendrocnide peltata	Stinging Tree	endemic		none

var. *murrayana*				known
Dicliptera maclearii	a herb	endemic		predation by crabs; weeds
Didymoplexis pallens	an orchid		possibly extinct	
Ficus saxophila	a fig tree			
Flickingeria nativitatis	an epiphytic orchid	endemic		
Grewia insularis	a tree	endemic		none known
Hibiscus vitifolius	a herb		possibly extinct	
Hoya aldrichii	Hoya Vine	endemic	not of concern	
Huperzia phlegmaria	Common Tassel Fern			none known
Illigera elegans	a vine	endemic		none known
Ischaemum nativitatis	Christmas Island Duck-beak	endemic		none known
Jacquemontia paniculata	a twining herb			
Leptochilus decurrens	a fern			none known
Leucas zeylandica	a herb			none known
Lycianthes biflora	a herb			
Meullerargia timorensis	a climber			none known
Momordica charantia	an annual climber			
Mucuna pruriens	Velvet Bean			
Pandanus christmatensis	Pandanus, Screw-pine	endemic	not of concern	
Pandanus elatus	Pandanus, Screw-pine	endemic	not of concern	
Peperomia laevifolia	an epiphytic herb			
Peperomia rossii	an epiphytic herb	endemic	possibly extinct	
Phreatia listeri	an epiphytic orchid	endemic		

Pneumatopteris truncata	a fern		CR	predation by crabs
Pteridrys syrmatica	a fern			
Remusatia vivipara	an epiphytic herb		possibly extinct	
Selaginella alutacia	a fern-ally		possibly extinct	
Setaria clivalis	a grass		possibly extinct	
Spermacoce mauritana	an annual herb			
Spondias cytherea	Great Hog Plum			predation by crabs
Strongylodon lucidus	a climbing shrub			none known
Taeniophyllum hasseltii	an epiphytic orchid			none known
Tectaria devexa var. *minor*	a fern		EN	disturbance (mining); weeds
Tectaria dissecta	a fern			
Tectaria sp.	a fern			
Thelasis capitata	an epiphytic orchid			none known
Thrixspermum carinatifolium	an epiphytic orchid			
Triphasia trifolia	Limeberry			none known
Triumfetta suffruticosa	a shrub			
Vitis flexuosa	a climber			weeds
Zehneria alba	a vine	endemic		
Zeuxine exilis	a terrestrial orchid	endemic	possibly extinct	

Conservation status: CR=listed as Critically Endangered; EN=Endangered; possibly extinct=not recorded on Christmas Island for >100 years.

Threats: modified from Parks Australia (2008). Where no threat is given, no account of the species was presented in Parks Australia (2008).

APPENDIX 11 DOCUMENTATION LIST

This list contains all documents considered by the EWG in the preparation of the report the cited references are in the References list

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Full document list in management system used in preparing the report						
Circulat'n date	**Author/s**	**Year publ.**	**Title**	**Format**	**Status**	**Notes**
4/03/2009	Director of National Parks	2008	Regional Recovery Plan Issues Paper - Conservation status and threats to the flora and fauna of the Christmas Island Region. Unpublished Draft report. Commonwealth of Australia.	Recovery Documents Zip file	Background document	
4/03/2009	Cogger, H	2006	National Recovery Plan for Lister's Gecko Lepidodactylus listeri and the Christmas Island Blind Snake Typhlops exocoeti. Department of the Environment and Heritage, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Butz, M.	2005	National Recovery Plan for Tectaria devexa. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Cogger, H	2005	Background Information on Lister's Gecko Lepidodactylus listeri and the Christmas Island Blind Snake Typhlops exocoeti. Department of the Environment and Heritage, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Department of the Environment and Heritage	2005	Whale Shark (Rhincodon typus) Recovery Plan Issues Paper. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Department of the Environment and Heritage	2005	Whale Shark (Rhincodon typus) Recovery Plan 2005-2010. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Olsen, P	2005	National Recovery Plan for the Abbott's Booby Papasula abbotti. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	

4/03/2009	Butz, M	2004	National Recovery Plan for the Christmas Island Spleenwort: Asplenium listeri. Commonwealth of Australia, Canberra	Recovery Documents Zip file	Background document	
4/03/2009	Hill, R	2004	National Recovery Plan for the Christmas Christmas Island Hawk-Owl Ninox natalis. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Hill, R	2004	National Recovery Plan for the Christmas Island Goshawk Accipiter fasciatus natalis. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Hill, R, Dunn A	2004	National Recovery Plan for the Christmas Island Frigate Fregata andrewsi. Commonwealth of Australia, Canberra	Recovery Documents Zip file	Background document	
4/03/2009	Schultz, M and Lumsden, L F	2004	National Recovery Plan for the Christmas Island Pipistrelle Pipistrellus murrayii. Commonwealth of Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Environment Australia	2003	Recovery Plan for Marine Turtles in Australia. Environment Australia, Canberra.	Recovery Documents Zip file	Background document	
4/03/2009	Bullen, RD and McKenzie, NL	2007	Bat wing airfoil and planform structures relating to aerodynamic cleanliness. Unpublished.	McKenzie and Possingham Zip File	Suggested by McKenzie	
4/03/2009	McKenzie, NL, Start, AN and Bullen, RD	2002	Foraging ecology and organisation of a desert bat fauna. Aust Journal of Zoology, Vol 50	McKenzie and Possingham Zip File		Suggested by McKenzie
4/03/2009	Bullen, RD and McKenzie, NL	2001	Bat airframe design: flight performance, stability and control in relation to foraging ecology. Aust Journal of Zoology, Vol49	McKenzie and Possingham Zip File		Suggested by McKenzie
4/03/2009	Bottrill, MC et al		Is conservation triage just smart decision-making? Unpublished.	McKenzie and Possingha	Suggested by Possingha	In press (2009)

				m Zip File	m	
4/03/2009	Joseph, LN, Maloney, RF and Possingham, HP		Optimal allocation of resources among threatened species: a project prioritization protocol. Unpublished.	McKenzie and Possingham Zip File	Suggested by Possingham	
4/03/2009	*Minutes of the Threatened Species Scientific Committee.*	2009	Extra-ordinary meeting on the Christmas Island Pipistrelle, 3 February 2009	Agenda and Further information email		Minutes are confidential
4/03/2009	*Terms of Reference for the Expert Working Group*	2009		Agenda and Further information email		
4/03/2009	Parks Australia		General and historical description of the island, its ecology and threats (general overview of ecology)	Agenda and Further information email	Working document.	
4/03/2009	Parks Australia		Christmas Island - governance, tenure and stakeholders (overview of governance on the island)	Agenda and Further information email	Working document	
5/03/2009	Lumsden, L. and Schulz, M.	2009	Captive breeding and future in-situ management of the Christmas Island Pipistrelle Pipistrellus murrayi. Unpublished draft report. Arthur Rylah Institute. Department of Sustainability and Environment, Heidelberg, Victoria.	Pipistrelle related docs Zip file.	Critical document	Dr Lumsden is completing a final version of this report.

5/03/2009	Lumsden L, Silins J and Schulz M	1999	'Population dynamics and ecology of the Christmas Island pipistrelle, Pipistrellus murrayi on Christmas Island', Arthur Rylah Institute for Environmental Research. Unpublished report to Parks Australia North, Christmas Island.	Pipistrelle related docs Zip file.	Critical document	
5/03/2009	O'Dowd, D.J., Green, P.T., and Lake, P.S.	1999	Status, impact and recommendations for research and management of exotic invasive ants in Christmas Island National Park. Report to Environment Australia, Monash University. Melbourne. 60 pp.	Pipistrelle related docs Zip file.	Critical document	
5/03/2009	Lumsden L and Cherry K 1997,	1997	Report on a preliminary investigation of the Christmas Island pipistrelle, *Pipistrellus murrayi*, in June-July 1994', Arthur Rylah Institute for Environmental Research. Unpublished report to Parks Australia North, Christmas Island.	Pipistrelle related docs Zip file.	Critical document	
5/03/2009	Parks		Annotated Bibliography: Christmas Island Pipistrelle bat (Pipistrellus murrayi)	Pipistrelle related docs Zip file.	Background	
5/03/2009	Summary of studies - 1985 to 2009			Pipistrelle related docs Zip file.	Background	
5/03/2009	Director of National Parks	2006	Christmas Island Biodiversity Monitoring Program: Forest Birds of Christmas Island. Unpublished internal report	BMP part 3 Zip file		Note: unpublishe d internal report. Referencin g on document is incorrect

5/03/2009	Director of National Parks	2006	Christmas Island Biodiversity Monitoring Program: Population structure and road mortality in Red Crabs and Robber Crabs. Unpublished internal report	BMP part 3 Zip file		Note: unpublished internal report. Referencing on document is incorrect
5/03/2009	Director of National Parks	2005	Species inventory. Unpublished internal report	BMP part 3 Zip file, also part 2 Zip file		Note: unpublished internal report. Referencing on document is incorrect
5/03/2009	Director of National Parks	2006	Christmas Island Biodiversity Monitoring Program: A Biodiversity Inventory Database for Christmas Island National Park. Unpublished internal report	BMP part 2 Zip File		Note: unpublished internal report. Referencing on document is incorrect
5/03/2009	Director of National Parks	2005	Species inventory. Unpublished internal report	BMP part 2 Zip File		Note: unpublished internal report. Referencing on document is incorrect

5/03/2009	Director of National Parks	2007	Christmas Island Biodiversity Monitoring Program: Research into the Conservation Status and Threats of the Christmas Island Pipistrelle (pipistrellus murrayii). Unpublished internal report	BMP part 1 Zip file		Note: unpublished internal report. Referencing on document is incorrect
5/03/2009	Director of National Parks	2007	Christmas Island Biodiversity Monitoring Program: Asian House Gecko, . Unpublished internal report	BMP part 1 Zip file		Note: unpublished internal report. Referencing on document is incorrect
6/03/2009	Woinarski		Flowchart of possibly pathways to connect Darwin Captive breeding trial to CI	Woinarski email	Working document	
6/03/2009	McKenzie		Norm McK - notes on Xmas island	McKenzie email	Background	McKenzie's notes on CI issues
6/03/2009	Document status – first version			AMD email	Working document	
6/03/2009	Parks		Bibliography of Christmas Island biodiversity	AMD email	Working document:	
8/03/2009	Burbidge/IUCN		Extinct bats and captive breeding	Burbidge email	Background	Burbidge's notes on IUCN status and other captive breeding programs

10/03/2009	Stork et al	2003	Impact of aerial baiting for control of crazy ants on the vertebrates and canop-dwelling arthropods of Christmas Island	Rea email	Background	Suggested by McKenzie
10/03/2009	CINP staff		Yellow Crazy Ants - distribution threats and management of YCA	Rea email	Working document	
10/03/2009	CINP staff		Yellow Crazy Ants - conservation management	Rea email	Working document	
10/03/2009	CINP staff		Christmas Island - overview of staff activities to manage the CI Pipistrelle	Rea email	Working document	
12/03/2009	Approvals and Wildlife Div, DEWHA		Christmas Island 2002 - Aerial Baiting Approval	Rea email	Background	
12/03/2009	Green, P, Slip, D, Comport, S		Christmas Island 2002 - Aerial Baiting Assessment	Rea email	Background	
12/03/2009	Parks Australia		Christmas Island 2002 - Aerial Baiting Referral	Rea email	Background	
12/03/2009	Parks Australia		On Island Meeting Agenda/Program	Rea email	Working document	
13/09/2009	McKenzie		Norm McK - notes on Xmas island, updated	McKenzie email	Background	McKenzie's notes on CI issues (update of doc no 37)
16/03/2009	WA Museum		List of CI specimens held at WAM	How email		
17/03/2009	CINP staff		Map of tracks covered in June 2008 pipistrelle drive survey	Cameron email	Background	
17/03/2009	CINP staff		Report from June 2008 pipistrelle drive survey	Cameron email	Background	
17/03/2009	CINP staff		Instructions for June 2008 pipistrelle drive survey	Cameron email	Background	
17/03/2009	Geoscience Australia		Christmas Island Geographic Information System - System Documentation	Cameron email	Background	

17/03/2009	CINP staff		CINP Data management paper	Cameron email	Background	
17/03/2009	CINP staff		CINP Screen dump of data folders	Cameron email	Background	
18/03/2009	CINP staff		Maps of pipistrelle calls overlaid with crazy any baiting history (7 maps in total)	Cameron emails (1 of 2 & 2 of 2)	Background	
19/03/2009	McInnes et al (CSIRO)	2008 (still unpubl.)	Recent and future climate conditions for Christmas and Cocos islands	Cameron email - weather	Background	
19/03/2009	Green	1997	Red crabs in rain forest on Christmas Island, Indian Ocean: activity patterns, density, biomass.	Cameron email - articles on CI crabs	Background	
19/03/2009	Green et al	1997	Control of Seedling Recruitment by Land Crabs in Rain Forest on a Remote Oceanic Island	Cameron email - articles on CI crabs	Background	
19/03/2009	Green	1998	Litterfall in Rain Forest on Christmas Island, Indian Ocean: Quantity, Seasonality, and Composition	Cameron email - articles on CI crabs	Background	
19/03/2009	Green	2004	Filed observations of moulting and loult increment in the red land crab on Christmas Island	Cameron email - articles on CI crabs	Background	
19/03/2009	Green et al	2004	Resistance of island rainforest to invasion by alien plants:influence of microhabitat and herbivory on seedling performance	Cameron email - articles on CI crabs	Background	
19/03/2009	Green	1999	Greta's Garbo: stranded seeds and fruits from Greta Beach, Christmas Island, Indian Ocean	Cameron email - articles on CI crabs	Background	

19/03/2009	Green	2004	Burrow dynamics of the red land crab in rain forest on CI	Cameron email - articles on CI crabs	Background	
19/03/2009	Green	1996	Canopy Gaps in Rain Forest on Christmas Island, Indian Ocean: Size Distribution and Methods of Measurement	Cameron email - articles on CI crabs	Background	
19/03/2009	O'Dowd & Lake	1990	Red Crabs in Rain Forest, Christmas Island: Differential Herbivory of Seedlings	Cameron email - crabs and ants	Background	
19/03/2009	Lake & O'Dowd	1991	Red Crabs in Rain Forest, Christmas Island: Biotic Resistance to Invasion by an Exotic Snail	Cameron email - crabs and ants	Background	
19/03/2009	O'Dowd et al	2003	Invasional 'meltdown' on an oceanic island	Cameron email - crabs and ants	Background	
19/03/2009	O'Dowd & Green	in press	Invasional meltdown: do invasive ants facilitate secondary invasions?	Cameron email - crabs and ants	Background	
19/03/2009	O'Dowd & Lake	1989	Red Crabs in Rain Forest, Christmas Island: Removal and Relocation of Leaf- Fall	Cameron email - crabs and ants	Background	
19/03/2009	O'Dowd & Lake	1991	Red Crabs in Rain Forest, Christmas Island: Removal and Fate of Fruits and Seeds	Cameron email - crabs and ants	Background	
19/03/2009a gain on 20/3 2009	Green & O'Dowd	in press	Management of invasive invertebrates: lessons from the management of an invasive alien ant	Cameron email - ants, booby,	Background	Chapter 11 in forthcoming book (?) by

				archive		Clout
19/03/2009again on 20/3 2009	Reaser et al	2007	Ecological and socioeconomic impacts of invasive alien species	Cameron email - ants, booby, archive	Background	
19/03/2009again on 20/3 2009	Yorkston & Green	1996	The breeding distribution and status of Abbott's Booby on Christmas Island, Indian Ocean	Cameron email - ants, booby, archive	Background	
19/03/2009again on 20/3 2009	O'Dowd		Draft Archive of files related to research and management of the yellow crazy ant (Anoplolepis gracilipes) on Christmas Island, Indian Ocean, 1998-present.	Cameron email - ants, booby, archive	Background	Currently stored on O'Dowd's Monash computer
19/03/2009	Johnston, Algar & O'Donoghue	2008	Field efficacy trial of the Curiosity® Feral Cat bait on Christmas Island	Cameron cat email	Background	
19/03/2009	CINP staff		Feral Cats on Christmas Island - overview by staff	Cameron cat email	Background	
19/03/2009	CINP staff		Island Wide Survey Report 2007	Cameron email	Background	
20/03/2009	CINP staff		Pipistrelle Detector Database 1994-2009	Cameron email	Background	All pipistrelle records from CI
20/03/2009	Davis, O'Dowd, MacNally & Green	2009 (in review)	Mutualism between invasive ants and scale insects disrupts frugivory by endemic island birds	Cameron email - Davis, Abbott, Green articles	Background	

20/03/2009	Abbott	2006	Spatial dynamics of supercolonies of the invasive yellow crazy ant, Anoplolepis gracilipes, on Christmas Island, Indian Ocean	Cameron email - Davis, Abbott, Green articles	Background	
20/03/2009	Abbott & Green	2007	Collapse of an ant-scale mutualism in a rainforest on Christmas Island	Cameron email - Davis, Abbott, Green articles	Background	
20/03/2009	Abbott	2005	Supercolonies of the invasive yellow crazy ant, Anoplolepis gracilipes, on an oceanic island: Forager activity patterns, density and biomass	Cameron email - Davis, Abbott, Green articles	Background	
20/03/2009	Davis, O'Dowd, Green & MacNally	2008	Effects of an Alien Ant Invasion on Abundance, Behavior, and Reproductive Success of Endemic Island Birds	Cameron email - Davis, Abbott, Green articles	Background	Not sure if this published yet, please treat as confidential.
20/03/2009	Green, O'Dowd & Lake	2008	Recruitment dynamics in a rainforest seedling community: context-independent impact of a keystone consumer	Cameron email - Davis, Abbott, Green articles	Background	
20/03/2009	Green, Lake & O'Dowd	1999	Monopolization of Litter Processing by a Dominant Land Crab on a Tropical Oceanic Island	Cameron email - Davis, Abbott, Green articles	Background	

20/03/2009	CINP staff		Maps of YCA baiting 2000-2004	Cameron email - YCA baiting 2000-2004	Background	
20/03/2009	CINP staff		Maps of YCA baiting 2005-2009	Cameron email - YCA baiting 2005-2009	Background	
20/03/2009	Bergstrom et al	2009	Indirect effects of invasive species removal devastate World Heritage Island	Cameron email - Bergstrom, Kurle Wyatt articles	Background	
20/03/2009	Kurle, Croll & Tershy	2008	Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated	Cameron email - Bergstrom, Kurle Wyatt articles	Background	
20/03/2009	Wyatt et al	2008	Historical Mammal Extinction on Christmas Island (Indian Ocean) Correlates with Introduced Infectious Disease	Cameron email - Bergstrom, Kurle Wyatt articles	Background	
20/03/2009	CINP staff		Updated Pip Detector Database	Cameron email	Background	With improved date information
20/03/2009	Burbidge		Exotic Animals on Christmas Island	Burbidge email	Background	
23/03/2009	Thomas	2006 (internal PA doc)	Ants of Christmas Island - Part 2 Identification and distribution (Part 1)	Cameron email - Ants on CI	Background	
23/03/2009	Thomas	2006 (internal PA doc)	Ants of Christmas Island - Part 2 Identification and distribution (Part 2)	Cameron email - Ants on CI	Background	

23/03/2009	Thomas	2006 (internal PA doc)	Ants of Christmas Island - Part 2 Identification and distribution (Part 3)	Cameron email - Ants on CI	Background	
23/03/2009	Marr, O'Dowd & Green	2003 (internal PA doc)	Assessment of non-target impacts of Presto®01 ant bait on litter invertebrates in Christmas Island National Park, Indian Ocean	Cameron email - 2002 Fipronil assessment	Background	3 Word files containing the text, figures and tables of the report.
23/03/2009	Fraumenau & Thomas	2008	Ants (Hymenoptera: Formicidae) of Christmas Island (Indian Ocean): identification and distribution	How email - Ants on CI	Background	Updated paper following Doc nos: 95-97
23/03/2009	DEWHA Chemicals Branch		Information on Fipronil - confidential	AMD email	Background	
20/03/2009	Abbott	2004	http://arrow.monash.edu.au/vital/access/manager/Repository/monash:6496?query=Abbott	Cameron email - ants, booby, archive	Background	Link to Abbott's PhD thesis
19/03/2009	Beeton		Record of meetings in Melbourne with Dr O'Dowd and Dr Lumsden	Cameron email - minutes from telecon 2 and Melbourne meetings		
20/03/2009	McKenzie		Norm McK - notes on Xmas island, updated	McKenzie email		McKenzie's notes on CI issues (update of doc no 49)

20/03/2009	Kitchener	1986	Revision of Australo-Papuan Pipistrellus	McKenzie email	Background	Extract supplied by McKenzie
26/03/2009	ABRS		Update on DNA assessment of pipistrelles	Cameron email		Update supplied by Cameron Slatyer
26/03/2009	How		CI specimens in Australian museum collections	How email		Embedded in rsponse to email titled 'Update on DNA work'
27/03/2009	Jachowski & Kesler	2009	Allowing extinction: should we let species go?	How email - letters on triage	Background	
27/03/2009	Parr et al	2009	Why we should aim for zero extinction	How email - letters on triage	Background	
27/03/2009	Faith	2009	Phylogenetic triage, efficiency and risk aversion	How email - letters on triage	Background	
27/03/2009	Bottrill, MC et al	2009	Finite conservation funds means triage is unavoidable	How email - letters on triage	Background	
6/04/2009	Hoffman & Kay	2008	Pisonia grandis monocultures limit the spread of an invasive ant - a case of carbohydrate equality?	Burbidge email - ants and scale on other islands	Background	Preview
6/04/2009	Greenslade	2008	Climate variability, biological control and an insect pest outbreak on Australia's Coral Sea islets: lessons for invertebrate conservation	Burbidge email - ants and scale on other islands	Background	Preview

6/04/2009	QldParks & Wildlife Service	2007	Managing scale insect outbreaks in the Capricornia Cays	Burbidge email - ants and scale on other islands	Background	
6/04/2009	Smith & Papacek	2001	Report of the levels of the scale insect Pulvinaria urbicola and its natural enemies on Pisonia grandis in the Coringa-Herald national nature reserve	Burbidge email - ants and scale on other islands	Background	
6/04/2009	McKenzie		CI geology	McKenzie email		Norm's notes from discussion with friend and research
8/04/2009	CINP (Mike Smith)		Blue-tailed skink data	How email - From CI		
8/04/2009	CINP (Mike Smith)		Management of the red crab (*Gecarcoidea natalis*) on Christmas Island, Indian Ocean: the efficacy of a Yellow Crazy Ant (*Anoplolepis gracilipes*) baiting program	How email - From CI		
8/04/2009	McKenzie		Updated bat notes, including text to be extracted for EWG report	McKenzie email		
8/04/2009	CINP		Jedda flow data (from Jedda Cave Weir)	Cameron email - additional CI water reports	Background	
8/04/2009	CINP		CI Rainfall updated Sept 2005	Cameron email - additional CI water reports	Background	

8/04/2009	Falkland	2003	Christmas Island Water Monitoring Visit June 2003	Cameron email - additional CI water reports	Background	
8/04/2009	CINP		Flows at weirs 1965 – 1974	Cameron email - additional CI water reports	Background	
9/04/2009	TSSC		TSSC style guide	Cameron email - TSSC style guide	Background	
9/04/2009	DEWHA Chemicals Branch		Published Fipronil papers	AMD email		List of refs complied by DEWHA Chemicals Branch
13/04/2009	Beeton		Notes from phone discussion with Dr Paul Story	Beeton email		Discussion on Fipronil
14/04/2009	CINP		Draft CI Weed Management Strategy 2010 - 2015	Cameron email		
14/04/2009	CINP		Invasive Weed Management Program 2007-08	Cameron email		Preliminary report
15/04/2009	Standing Committee on Environment and Conservatio n	1974	Conservation of Endangered Species on CI	Cameron email		House of Reps Standing Committee report
15/04/2009	Connelly	2001	Environmental fate of Fipronil	Rotumah email - Fipronil		

				papers		
15/04/2009	Gunasekara et al	2007	Environmental fate and toxicology of Fipronil	Rotumah email - Fipronil papers		
15/04/2009	Volz & Chandler	2003	An enzyme-linked immunosorbent assay for lipovittelin quantification in copepods: a screening tool for endocrine toxicity	Rotumah email - Fipronil papers		
15/04/2009	Konwick et al		Bioaccumulation and enantioselective biotransformation of Fipronil by Rainbow Trout	Rotumah email - Fipronil papers		8th fish symposium
15/04/2009	EU Commission	2007	EU Commission Directive 2007/52/EC to include ethoprophos, pirimiphos-methyl and fipronil as active substances	Rotumah email - Fipronil papers		
15/04/2009	Peveling	2001	Environmental conservation and locust control — possible conflicts and solutions	Rotumah email - Fipronil papers		
15/04/2009	Pesticides News	2000	Poisoning an Island? Locust control in Madagascar	Rotumah email - Fipronil papers		
15/04/2009	SA Govt	2001	Assessment of the impact of insecticide spraying of Australian plague locusts	Rotumah email - Fipronil papers		
15/04/2009	San Miguel et al	2008	Phenylpyrazoles impact on Folsomia candida (Collembola)	Rotumah email - Fipronil papers		

15/04/2009	Smith & Lockwood	2002	Horizontal and Trophic Transfer of Diflubenzuron and Fipronil Among Grasshoppers and between Grasshoppers and Darkling Beetles	Rotumah email - Fipronil papers		
15/04/2009	Story et al	2005	A Case Study of the Australian Plague Locust Commission and Environmental Due Diligence: Why Mere Legislative Compliance Is No Longer Sufficient for Environmentally Responsible Locust Control in Australia	Rotumah email - Fipronil papers		
15/04/2009	Konwick et al	2006	Bioaccumulation, biomagnification and metabolite formation of fipronil and chiral legacy pesticides in rainbow trout	Rotumah email - Fipronil documents 1		
15/04/2009	Le Patourel	1999	Secondary transmission of fipronil toxicity between Oriental cockroaches	Rotumah email - Fipronil documents 1		
15/04/2009	Balanca & de Visscher	1997	Impacts on non-target insects of a new insecticide compound used against the desert locust	Rotumah email - Fipronil documents 2		
15/04/2009	Gibson-Hill	1947	Field notes on the Terrestrial Crabs	Rotumah email - Fipronil documents 2	Not a fipronil doc, just caught up with others	In "Christmas Island - Terrestial Crabs"
15/04/2009	Peveling & Demba	2002	Toxicity and pathogenicity of … and Fipronil to the Fringe-toed Lizard	Rotumah email - Fipronil documents 3		

15/04/2009	Walse et al	2003	The fate of Fipronil in modular estuarine mesocosms	Rotumah email - Fipronil documents 3		
16/04/2009	Pennay		Australasian Bat Society response to Tidemann criticism	McKenzie email		
20/04/2009	Cox	2005	Insecticide Factsheet - Fipronil	Cameron email - more on Fipronil		
20/04/2009	Various	2004	European press clips on Fipronil	Cameron email - more on Fipronil		
20/04/2009	Stanton	2008?	National Toxics Network submission to APVMA on Fipronil	Cameron email - more on Fipronil		
20/04/2009	Ying & Kookana	2002	Laboratory and field studies on the degradation of fipronil in a soil	Cameron email - more on Fipronil	Abstract only	
21/04/2009	Tidemann		Brief notes on keeping pipistrelles	Cameron email		Email from Tidemann describing keeping pips in 1985
21/04/2009	Lawrence et al	1990	CSIRO Entomological Survey of Christmas Island	Cameron email		ANPWS consultancy report
21/04/2009	Vice et al	2005	A comparison of three trap designs for capturing brown tree snakes on Guam	Cameron email - 3 snakes on islands		

				articles		
21/04/2009	Rodda et al	2002	Practical concerns in the eradication of island snakes	Cameron email - 3 snakes on islands articles		In: Veitch & Clout (eds) Turning the tide: the eradication of invasive species IUCN SSC
21/04/2009	SPREP	2000	Invasive Species in the Pacific: A technical review and draft regional strategy	Cameron email - 3 snakes on islands articles		
21/04/2009	Falkland	1999	Groundwater Investigations and Monitoring report - Main report	Cameron email - CI groundwater - text & annexes		Internal report prepared for GHD and CI Administration
21/04/2009	Falkland	1999	Groundwater Investigations and Monitoring report - Annexes A – O	Cameron email - CI groundwater - text & annexes		Internal report prepared for GHD and CI Administration
21/04/2009	Falkland	1999	Groundwater Investigations and Monitoring report - Annexes P - S	Cameron email - CI groundwater - text & annexes		Internal report prepared for GHD and CI Administrati

						on
21/04/2009	Falkland	1999	Groundwater Investigations and Monitoring report - Figures 1 – 5	Cameron email - CI groundwater - figures		Figures provided separately due to large size
21/04/2009	Falkland	1999	Groundwater Investigations and Monitoring report - Figures 13 & 14	Cameron email - CI groundwater - figures		Figures provided separately due to large size
6/04/2009	Schulz & Barker	2008	Terrestrial Reptile Survey of Christmas Island, May-June 2008	How email		A report to Parks Australia North, CI
6/04/2009	Thomas et al	2009	Super colony mosaics: two different invasions by the yellow crazy ant on Christmas Island	How email		Manuscript draft
23/04/2009	Holmes & Holmes	2002	Conservation Status of the Flora of Christmas Island, Indian Ocean	Cameron email - report on CI flora		A report to Parks Australia North
23/04/2009	Richards	2008	Status of the CI pipistrelle on the mining leases and environs in the north west of CI	Cameron email - Richards pip report to CIP		A report to Christmas Island Phosphates
24/04/2009	CINP		Centipede data	Cameron email - centipede survey data		Raw data collected by CINP in April 2009 during surveys of

						skink sites
24/04/2009	Smith & Firth	2009	Current state of Christmas Island Fauna	Cameron email - draft 2009 fauna survey for mine EIS		Draft report for Phosphate Resources Limited
24/04/2009	Corbett et al	2003	Fauna survey of mine lease applications and NP reference areas, CI August 2002	Cameron email - 2003 fauna survey for moine EIS Part 1 & 2		Report for Phosphate Resources Limited, split over two emails
24/04/2009	Cameron		Minutes of on-island meetings	Cameron email - minutes		
28/04/2009	Tidemann	1985	A study of the status, habitat requirements and management of the two species of bat on CI	Cameron email - 1985 Tidemann bat report		Sent in two parts in two emails due to size of the file.
28/04/2009	Tidemann	1989	Survey of the terrestrial mammals on CI	Cameron email - 1989 Tidemann mammal report		Sent in two parts in two emails due to size of the file.
28/04/2009	Australian Museum	2009	Taxonomy of the CI shrew Crocidura attenuata trichura	Cameron email - taxonomy of CI shrew		
29/04/2009	**Territory Wildlife Park**		**P. adamsi data sheet**	**Cameron email - P.adamsi keeping**		

				notes		
Stage 2	Zimmerman	2009	Biologists struggle to solve bat deaths	Email PDF		
Stage 2	Director of National Parks	2009	Draft Christmas Island National Park Management Plan	Email word doc		
Stage 2	Director of National Parks	2009	Annual report on the CI minesite to forest rehabilitation program	Email PDF		
Stage 2	CSIRO	2009	Conservation values in Commonwealth waters of the Christmas and Cocos (Keeling) Island remote Australian territories	CD PDF		
Stage 2	How/Burbidge	2009	Notes at AGD's from meeting on CI groundwater	Email word doc		
Stage 2	Govt of WA	2008	Water resource management review	Email - PDF report		
Stage 2	Galmore Water Research Lab	2009	Memo - Review of CI reports on surface & groundwater hydrology	Email - PDF report		
Stage 2	Zalucki et al	2009	The future of IPM-whither or wither?	E-mail-PDF journal article		
Stage 2	Schroer et al	2008	The genetic diversity, relationships and potential for biological control of the lobate lac scale, Paratachardine pseudolobata	E-mail - PDF journal article		
Stage 2	Director Of National Parks	2009	Contract for Fipronil research with CESAR	E-mail - PDF		

Stage 2	Director of National Parks	2008	contract proposal with Latrobe Uni - Research and development biological control of scale insects: indirect control of the yellow crazy ant	E-mail - word doc		
Stage 2	DEWHA	2006	EPBC act nomination to list in the vulnerable category Pteropus melanotis natalis (christmas island flying fox)	E-mail - word doc		
Stage 2	Director of National Parks	2008	4 Papers prepared for CASAP on research on growth regulators for yellow crazy ants	E-mail - word docs		
Stage 2	Hamilton & Schedvin	2009	Christmas Island Hawk Owl (*Ninox natalis)* notes from observations during field trip and map	E-mail - word doc & map		
Stage 2	Helgen et al	2009	Taxonomic status of the Christmas Island Pipistrelle	E-mail - word doc		
Stage 2	James et al	2007	Christmas Island flying fox-an assessment of conservation status and threats	E-mail - PDF		Internal report to DNP
Stage 2	James	2004	Biodiversity Monitoring Program quarterly report October to December 2004	E-mail - PDF		Internal report to DNP
Stage 2	James	2005	Christmas island Pipistrelle-an interim assessment of conservation status and threats	E-mail - PDF		Internal report to DNP
Stage 2	Abbott	2009	Crazy ants and water stress as facilitators of scale insect outbreaks on Christmas island	E-mail - word doc		Chapter 7 of thesis
Stage 2	DEWHA	2006	Threat abatement plan to reduce the impacts of tramp ants on biodiversity in Australia and its Territories	E-mail - PDF		
Stage 2	DEWHA	2006	Species information sheet-Christmas Island flying fox	E-mail - word doc		

Stage 2	Hobbs & Salmond	2008	Cohabitation of Indian and Pacific ocean species at Christmas and Cocos (Keeling) Islands	E-mail - PDF journal article		Submitted with comments on the interim report
Stage 2	Hobbs et al	2009	Marine hybrid hotspot at Indo-Pacific biogeographic border	E-mail - PDF journal article		As above
Stage 2	James	2009	Comments on the EWG interim report	E-mail - word doc		
Stage 2	Abbott	2009	Comments on the EWG interim report	E-mail - word doc		
Stage 2	Harrison	2009	Comments on the EWG interim report	E-mail - word doc		
Stage 2	Newman	2009	Email to Norm McKenzie about orchids as ecosystem health indicators.	E-mail		
Stage 2	CINP	2009	CASAP membership list	E-mail - word doc		
Stage 2	Director of National Parks	2009	Request for quotation-assessment of reptile and mammal disease prevalence and potential vectors on Christmas Island	Email - word doc		
Stage 2	Abbott KL.	unpublished.	Crazy ants and water stress as facilitators of scale insect outbreaks on Christmas Island.	E-mail - word doc		
Stage 2	Allen GR, Steene RC and Orchard M	2007	Fishes of Christmas Island. 2nd Edition. Christmas Island Natural History Association, Christmas Island, Australia, 284 pp.	Hardcopy book		
Stage 2	Adamczewska A and Morris S	2001	Ecology and Behaviour of Gecarcoidea natalis, the Christmas Island Red Crab, During the Annual Breeding Migration. Biol. Bull. 200: 305–320.	E-mail-PDF journal article		

Stage 2	Australian Quarantine and Inspection Service.	2007	Australian quarantine guidelines for cruise vessel agents and operators. Effective October 2007.	E-mail - word doc		
	Beeton B, Burbidge A, Grigg G, How R, McKenzie N, Woinarski J	2009	Revised Interim Report, Christmas Island Expert Working Group to Minister for the Environment, Heritage and the Arts, 28 June 2009.	E-mail-PDF report		
Stage 2	Biber, E	2002	Patterns of endemic extinctions among island bird species. Ecography 25: 661–676	E-mail-PDF journal article		
Stage 2	Brewer DT, Potter A, Skewes TD, Lyne V, Andersen J, Davies C, Taranto T, Heap AD, Murphy NE, Rochester WA, Fuller M and Donovan A	2009	Conservation values in Commonwealth waters of the Christmas and Cocos (Keeling) Islands remote Australian Territories. Report to Department of Environment, Water, Heritage and the Arts. CSIRO, Cleveland. 216 pp.	E-mail-PDF report		
Stage 2	Campbell, S	2009	The last of its kind? Australasian Bat Society Newsletter No. 33, 28-32.	E-mail-PDF newletter article		
Stage 2	Christmas Island National Park	2009	Annual Report on the AGD-DEWHA Christmas Island Minesite to Forest Rehabilitation (CIMFR) Program. July 2008 - June 2009	E-mail-PDF internal report		

Stage 2	Department of the Environment and Heritage	2006	Threat Abatement Plan. To reduce the impacts of tramp ants on biodiversity in Australia and its territories. Department of the Environment and Heritage, Canberra.	E-mail-PDF plan		
Stage 2	Department of the Environment, Water, Heritage and the Arts	2010	Mining on Christmas Island.	E-mail-summary paper		
Stage 2	Dick CW and Patterson BD	2006	Bat flies - obligate ectoparasites of bats. Micromammals and Macroparasites from Evolutionary Ecology to Management. S. Morand, B.R. Krasnov, R. Poulin (Eds.) 181-194	E-mail-PDF journal article		
Stage 2	Dubey JP	2002	A review of toxoplasmosis in wild birds. Veterinary Parasitology 106: 121–153	E-mail-PDF journal article		
Stage 2	Hill M, Holm K, Vel T, Shah M and Matyot P	2003	Impact of the introduced yellow crazy ant Anoplolepis gracilipes on Bird Island, Seychelles. Biodiversity and Conservation 12: 1969–1984.	E-mail-PDF journal article		
Stage 2	Hobbs JPA, Frisch AJ, Allen GA and Van Herweerden L	2009	Marine hybrid hotspot at Indo-Pacific biogeographic border. Biology Letters 2009 5 258-261.	E-mail-PDF journal article		
Stage 2	Hobbs JPA, Frisch AJ, Hamanaka T, McDonald CA, Gilligan JJ and Neilson J	2009	Seasonal aggregation of whale sharks (Rhincodon typus) at Christmas Island, Indian Ocean. Coral Reefs 28 577	E-mail-PDF journal article		

Stage 2	Hobbs JPA, Jones GP and Munday PL	2010	Rarity and extinction risk in coral reef angelfishes on isolated islands: interrelationships among abundance, geographic range size and specialisation. Coral Reefs 29:1–11	E-mail-PDF journal article		
Stage 2	Kadmon R and Benjamini Y	2006	Notes and Comments: Effects of Productivity and Disturbance on Species Richness: A Neutral Model. The American Naturalist vol: 167, no. 6.	E-mail-PDF journal article		
Stage 2	Kadmon R and Allouche O	2007	Integrating the Effects of Area, Isolation, and Habitat Heterogeneity on Species Diversity: A Unification of Island Biogeography and Niche Theory. The American Naturalist vol: 170, no. 3.	E-mail-PDF journal article		
Stage 2	Kiera G, Krefta H, Tien Ming L, Jetzb W, Ibischc PL, Nowickic C, Mutkea J, Barthlotta W	2008	A global assessment of endemism and species richness across island and mainland regions. Edited by Peter R. Crane, University of Chicago, Chicago, IL, and approved April 14, 2009 (received for review October 13, 2008)	E-mail-PDF journal article		
Stage 2	Kondo T and Gullan P	2007	Taxonomic review of the lac insect genus Paratachardina Balachowsky (Hemiptera: Coccoidea: Kerriidae), with a revised key to gen era of Kerriidae and description of two new species. Zootaxa 1617: 1–41	E-mail-PDF journal article		
Stage 2	Lumsden, L	2009	The extinction of the Christmas Island Pipistrelle. Australasian Bat Society Newsletter No. 33, 21-25.	E-mail-PDF newletter article		

Stage 2	Morris, S. & Adamczewska, A.M.	no date (c. 1996).	Christmas Island Red Crabs and Town Development. School of Biological Sciences, University of Sydney: unpubl. rep. to Australian Nature Conservation Agency, Christmas Island and Canberra; vi + 53 pp.	E-mail-PDF report		
Stage 2	Morris S, UtePoste, Webster S	2009	The climate for migration by Christmas Island red crabs: A dangerous dependence on December downpours? Abstracts / Comparative Biochemistry and Physiology, Part A 153: S56–S63.	E-mail-PDF journal article		
Stage 2	Norton DA, et al	2009	Species Invasions and the Limits to Restoration: Learning from the New Zealand Experience Science 325, 569.	E-mail-PDF journal article		
Stage 2	Rumpff, H	1986	Ethology, Ecology and Population biology field studies of the Coconut Crab, Birgus latro L. (Paguridea, Crustacea, Decapoda), on Christmas Island (Indian Ocean). PhD-thesis in Natural sciences, Biology, presented at the Faculty of Mathematics and Science at Westfälischen Wilhelms-Universität in Münster, Germany.	E-mail-PDF translated thesis		
Stage 2	Schiller, C.B.	1988	Spawning and Larval Recruitment in the Coconut Crab (Birgus Latro) on Christmas Island, Indian Ocean. Consultancy report prepared for the Australian National Parks and Wildlife Service (ANPWS). Unpublished. 33p.	E-mail-PDF report		
Stage 2	S. Schroer, R.W. Pemberton, L.G. Cook, T. Kondo, P.J. Gullan	2008	The genetic diversity, relationships, and potential for biological control of the lobate lac scale, Paratachardina pseudolobata Kondo & Gullan (Hemiptera: Coccoidea: Kerriidae). Biological Control 46: 256–266.	E-mail-PDF journal article		

Stage 2	Smith M. and Boland C.	2010	Management of the red crab (Gecarcoidea natalis) on Christmas Island, Indian Ocean: the efficacy of a yellow crazy ant (Anoplolepis gracilipes) baiting program. Island Invasives: Eradication and Management Conference NZ.	E-mail-PDFconference paper		
Stage 2	Whittaker RJ, Triantis KA and Ladl RJ	2008	A general dynamic theory of oceanic island biogeography Journal of Biogeography (J. Biogeogr.)	E-mail-PDF journal article		
Stage 2	Vaughan, V	2010	Christmas Island crabs make waves - Singapore scientists discover new species in trip to 'crab capital'. 6 February, 8.	E-mail-PDF newspaper article		
Stage 2	Van Driesche, R.G. et al	In press	Classical Biological Control for the Protection of Natural Ecosystems: Past Achievements and Current Efforts. Biological Control *in press*.	E-mail-PDF journal article		
Stage 2	Zalucki MP, Adamson D and Furlong MJ	2009	The future of IPM: whither or wither? Australian Journal of Entomology 48: 85–96.	E-mail-PDF journal article		
Stage 2	Tigga Kingston	2010	Research priorities for bat conservation in Southeast Asia: a consensus approach Biodivers Conserv 19:471–484	E-mail-PDF journal article		
Stage 2	Richard T. Corlett	2010	Invasive aliens on tropical East Asian islands Biodivers Conserv 19:411–423	E-mail-PDF journal article		
Stage 2	Damien A. Fordham · Barry W. Brook	2010	Why tropical island endemics are acutely susceptible to global change Biodivers Conserv 19:329–342	E-mail-PDF journal article		
Stage 2	Nigel E. Stork	2010	Re-assessing current extinction rates Biodivers Conserv 19:357–371	E-mail-PDF journal article		

Stage 2	Michael J. Samways · Peter M. Hitchins ·Orty Bourquin · Jock Henwood	2010	Restoration of a tropical island: Cousine Island,Seychelles Biodivers Conserv 19:425–434	E-mail-PDF journal article		
Stage 2	David J. W. Lane	2010	Tropical islands biodiversity crisisBiodivers Conserv 19:313–316	E-mail-PDF journal article		
Stage 2	Done TJ and Marsh L	2000	Reef-building corals of Christmas Island. Records of the Western Australian Museum. Supplement no. 59: 79-81.			
Stage 2	Eldridge, MDB Johnson RN and Meek PD.	2009	The taxonomy of the Christmas Island Shrew *Crocidura, attenuata trichura*. Australian Museum Report to the Department of Environment, Heritage, Water and the Arts. 11pp.			
Stage 2			Endangered Species Handbook 2000. http://www.endangeredspecieshandbook.org/pdfslive/esh_chapter2.pdf			
Stage 2	Gibbons, J.W., Scott, D.E., Ryan, T.J., Buhlmann, K.A., Tuberville, T.D., Metts, B.S., Greene, J.L., Mills, T., Leiden, Y., Poppy, S.	2000	The global decline of reptiles, déjà vu amphibians. Bioscience 50: 653-666.	E-mail-PDF journal article		

	and Winne, C.T.					
Stage 2	Roth, L.M.	1999	New cockroach species, redescriptions, and records, mostly from Australia, and a description of *Metanocticola christmasensis* gen. nov., sp. nov., from Christmas Island (Blattaria). *Records of the Western Australian Museum* 19: 327-364.			
Stage 2	Smith M et al	2009 in preparation	Management of the Red Crab (*Gecarcoidea natalis*) on Christmas Island: the efficacy of a Yellow Crazy Ant (*Anoplolepis gracilipes*) baiting program.			
Stage 2	Smith M, Boland C, Retallick K, Maple D, Reeves R, Tiernan B, Barr R, Humphries C, Napier F and R Taylor.	Manuscript in preparation	The Christmas Island Red Crab (*Gecarcoidea natalis*): Temporal and spatial patterns in burrow counts.			

Stage 2	Smith, D., D. Papacek, M. Hallam, and J. Smith.	2004	Biological control of *Pulvinaria urbicola* (Cockerell) (Homoptera: Coccidae) in a *Pisonia grandis* forest on North-East Herald Cay in the Coral Sea. *Gen. Appl. Entomol.* 33:61–68.	E-mail-PDF journal article		

723

APPENDIX 12 SUMMARY OF RECOVERY PLAN ACTIONS

Summary table of main recovery plan actions for all Christmas Island species with current recovery plans (noting that most such plans are now in their final year). Costs are given where readily identified in the recovery plan. Priorities (P) given to particular actions were explicitly given only in the Abbott's booby recovery plan. Our retrospective assessment of whether or not the action was successfully undertaken are indicated by shading (red= undertaken as planned; green=not undertaken as planned; no colour=unknown).

	CI hawk-owl	**Abbott's booby**	**CI frigatebird**	**CI goshawk**	**CI shrew**	**Lister's gecko & CI blind snake**	**CI spleenwort**	**Tectaria devexa**	**CI pipistrelle**
	2004-09	2004-09	2004-09	2004-09	2004-09	2006-11	2004-09	2005-10	2004-09
taxonomy									
				clarify taxonomic status [$6,000]	clarify taxonomic status [$10,000]				clarify taxonomic status (2009-10)
survey and monitoring									
monitor		develop and trial monitoring techniques [$15,000] **P: high**.	develop techniques to monitor total breeding population [$45,900]						establish and conduct monitoring program; investigate westward contraction
	monitor every 2 years [$17,500 in 1st year, then $9,500/2 years]	implement monitoring [$40,000] **P: high**	monitor total breeding population [$126,500]	implement monitoring [$11,000/yr + $7500/5 yr]		survey and monitor		quantify and monitor populations	
		monitor					monitor visitor		

	CI hawk-owl	Abbott's booby	CI frigatebird	CI goshawk	CI shrew	Lister's gecko & CI blind snake	CI spleenwort	Tectaria devexa	CI pipistrelle
		fisheries [$5,000 +AFMA] **P: low**					pressure and impact		
define distribution		accurately map critical breeding habitat [$15,000] **P: low (inside Park) – high (outside Park)**			investigate current status and distribution [$58,000/yr]; identify critical habitat [$58,000]	undertake annual searches	use predictive modelling to guide searches for new populations;	undertake annual searches	assess population and distribution
		satellite tracking [$120,000] **P: high**							
		upgrade historical database [$2000] **P: medium**							establish and maintain database
primary ecological studies									
investigate ecology						conduct autecological studies to inform recovery priorities			determine roost requirements; trial artificial roosts; assess

	CI hawk-owl	Abbott's booby	CI frigatebird	CI goshawk	CI shrew	Lister's gecko & CI blind snake	CI spleenwort	Tectaria devexa	CI pipistrelle
									primary foraging sites; investigate diet
off-reserve management									
manage areas outside Park	develop & implement wildlife management plan for areas outside park [$10,000 in 1st year then $5,000/yr]		develop & implement wildlife management plan for areas outside park [$10,000 in 1st year then $5,000/yr]	develop & implement wildlife management plan for areas outside park [$10,000 in 1st year then $5,000/yr]	develop & implement wildlife management plan for areas outside park [uncosted – assumed PA]				increase protection of known and potential habitat outside Park
	ensure protection of critical habitat outside park [$2,000/yr]		ensure protection of critical habitat outside park [$2,000/yr]	ensure protection of critical habitat outside park [$2,000/yr]			attempt to expand Park to include off-park populations		
			monitor & assist recovery of dryer's breeding colony [$10,000]						
		supervise construction of IDC facility and associated roadworks							

	CI hawk-owl	Abbott's booby	CI frigatebird	CI goshawk	CI shrew	Lister's gecko & CI blind snake	CI spleenwort	Tectaria devexa	CI pipistrelle
		[$40,000 in 1st year] **P: high** monitor impact of IDC [not costed] **P: medium-high**							
							ensure locations of this species are appropriately recognised in planning, impact assessment and management	ensure locations of this species are appropriately recognised in planning, impact assessment and management	
rehabilitation of degraded areas									
rehab	continue an effective and long-term rainforest rehabilitation program [$750,000/yr]	continue an effective and long-term rainforest rehabilitation program [$750,000/yr] **P: high**		continue an effective and long-term rainforest rehabilitation program [$750,000/yr]					
		manage removal of						assess relevance of	assess impact of phosphate

	CI hawk-owl	Abbott's booby	CI frigatebird	CI goshawk	CI shrew	Lister's gecko & CI blind snake	CI spleenwort	Tectaria devexa	CI pipistrelle
		phosphate stockpiles [$5,000/yr] **P: high**						canopy gaps	stockpile removal
		assess rehab effectiveness via wind model [$15,000] **P: high**							
manage threats									
weed management		implement CI weed management strategy. [uncosted – within PA budget] **P: medium**							
crazy ants	implement YCA action plan [$475,000 in 2002/03 then $100,000/yr]	implement YCA action plan [uncosted – within PA budget] **P: high**	implement YCA action plan [$475,000 in 2002/03 then $100,000/yr]	implement YCA action plan [$475,000 in 2002/03 then $100,000/yr]	implement YCA action plan [uncosted – within PA budget]	review and maintain existing control actions for YCA			continue active management for the control of YCA
identify threatening processes					identify threatening processes	identify role of Wolf snake; identify role of			assess impact of YCA on activity levels;

	CI hawk-owl	Abbott's booby	CI frigatebird	CI goshawk	CI shrew	Lister's gecko & CI blind snake	CI spleenwort	Tectaria devexa	CI pipistrelle
					[$30,000]	cats and rats			assess impact of YCA on roost requirements; assess impacts of wolf snake; assess impacts of kestrel
					manage areas of remnant popn [$10,000/yr]				establish and implement guidelines to reduce vehicle impact (especially relating to IDC)
quarantine	maintain and review quarantine barrier [$2,000/yr]		maintain and review quarantine barrier [$2,000/yr]	maintain and review quarantine barrier [$2,000/yr]		review quarantine protocols			
communication, education and community involvement									
community education	increase profile in local community [$2,000/yr]		increase profile in local community [$2,000/yr]	increase profile in local community [$2,000/yr]	implement community awareness program [$4,000]		keep locations confidential	keep locations confidential	
recovery administration									

	CI hawk-owl	Abbott's booby	CI frigatebird	CI goshawk	CI shrew	Lister's gecko & CI blind snake	CI spleenwort	Tectaria devexa	CI pipistrelle
recovery team	establish a recovery team [$2,000/yr]	establish a recovery team [$5,000/yr] **P: low**	establish a recovery team [$2,000/yr]	establish a recovery team [$2,000/yr]					
maintenance		manage day-to-day operations [$5,000/yr] **P: high**							
review plan	review recovery plan [$2,500]	re-evaluate conservation status [$1,000] **P: low**	review recovery plan [$2,500]	review recovery plan [$2,500]		re-assess conservation sttatus	annual evaluation by recovery team		review conservation status
captive breeding									
establish captive breeding					if found, establish captive breeding population [$50,000 in yr 1; then $30,000/yr]		examine need for and potential for ex situ cultivation; examine potential for re-introduction	examine need for and potential for ex situ cultivation;	

APPENDIX 13 MODEL USED FOR PRIORITY SETTING

The model contextualises existing threats by their reverse statement as a management outcome. .

Table 12.1. A threat-based framework for prioritising the recommendations in this report.

Each cell contains an outcome to be achieved by the elimination of a threat where arrows are used they indicate that the outcome below is dependent on the outcome to the left. Collectively these represent the outcomes of research and management necessary if Christmas Island is to be restored. Each recommendation has been considered using this table as a guide.

Priority for the Outcome	Time frame for the Outcome		
	Short (Now)	**Medium (1 to 5 years)**	**Long (3 to 10 years)**
High	Island governance arrangements are reformed	↓	↓
	Further introductions are prevented	Environmental management of Island as a whole is practiced	New environmental management system has proven to be enduring
	An effective independent scientific advisory committee for the island is established	An enduring adaptive environmental management regime for the entire island is developed and implemented	An independent system for measuring environmental change is delivering measured outcomes
	Further loss of crab-structured forests is halted by continuing and improving current control of Yellow Crazy Ants until a better approach is available. Land clearance is minimised	Ghost forests are recolonised with Red Crabs	Ecological resilience and resistance of island ecosystems is measurably enhanced
	Procedures to reduce or eliminate introduced animal impacts are planned and implemented using a transparent system of priority setting	Acceptable control of Yellow Crazy Ants and other threats have been introduced across the island using an adaptive management and integrated pest management framework	↓
	Research on biological control agents for scale insects and Yellow Crazy Ants has occurred and biological control trials are planned and implemented	Understanding of the effects of Fipronil on Christmas Island ecosystems and species is achieved	Integrated control of Yellow Crazy Ants and scale insects has been achieved
	A secure and sufficient long-term funding arrangement for biodiversity	↓	↓

	conservation priorities on Christmas Island is in place.		
	Existing management infrastructure is improved	Appropriate infrastructure to achieve all priority outcomes is constructed and staffed.	↓
	Identification and control of high-threat weed species has occurred	Adaptive management systems for weed control are under way	Control of low threat weed species is underway
Medium	Robust terrestrial, groundwater and marine monitoring programs are developed, implemented and response protocols are in place	Monitoring protocols are enhanced. A groundwater model has been developed and a Water Resource Management Plan guides water utilisation	Enhanced long term monitoring programs are continued and evaluated annually
	The process' for building on this report using peer reviewed assessments of research priorities and management actions is in place.	Intervention protocols and responses for rapid decline of any island endemic species are in place	Based on emerging science, regular reviews and adaptation of protocols for intervention responses are undertaken.
		Identification and assessment of possible impacts on species viability from off shore threats is routine	↓
		Rehabilitation of cleared lands has been accelerated using strict restoration protocols	The elimination or reduction in numbers of "non-threatening" exotic animals and plants is planned and under way
Low			World Heritage listing of a recovered and secured island is considered and the island is managed for the benefit of nature and people who choose to live there.

APPENDIX 14 MINING AND REHABILITATION ON CHRISTMAS ISLAND

Mining and rehabilitation figures from DEWHA, 2010.

Mining on Christmas Island

- Mining started on Christmas Island in 1899. It was initially restricted to Dogs Head in the North East and South Point in the South East until the mid-1960s.
- In the twenty years since the mid-1960s clearing for mining tripled. It extended north-south from Dogs Head to South Point, and through the east-west spine of the island. The rate of extraction of the phosphate resource also increased significantly with the use of new technology – bulldozers and extraction equipment. (Most of the earlier mining was done by hand.)
- Up to the mid-1980s about 24% of the island was cleared for mining, although not all of the cleared areas were mined. The phosphate resource extracted was the higher grade ore and the lower grade ore was left in stockpiles.
- In 1998 a 21 year lease was given to PRL which initially encompassed over 2,000ha (covering 15% of the island). The new lease only included areas previously cleared for mining (within the 24% of the island previously cleared), although some edges within the current mining lease may not have been cleared.
- PRL has relinquished 204ha of that lease over the last 10 years, so approximately 1,829ha remains (13.5% of Christmas Island landmass).
- PRL removes 'stockpiles' of phosphate that were previously considered uneconomic, as well as undertaking in situ mining.
- Christmas Island has an area of 13,584ha. The plateau covers 6,506ha, of which 2,136ha [32.8%] has been cleared. Approximately 3,099ha of the plateau has 'deep soil' (over 2m to limestone), of which 1,199ha [38.7%] has been cleared. About 40% of the 'deep soil' on the plateau was cleared for mining up to the mid-1980s. Much of which was been extensively mined.

Rehabilitation on Christmas Island

- Of the approximately 3,000ha [22.1% of island] of previously disturbed mined land (most of which was originally primary rainforest) approximately 220ha [7% of previously disturbed] has been rehabilitated by Parks Australia since 1990, and a further 150ha was taken over by PA following various former rehabilitation exercises not designed to replace rainforest.
- Of this 370ha total, 210ha is targeted for progression to rainforest, 140ha needs further inputs, and 20ha has failed.
- Based on estimates of potential stockpiles of 'soil' and a two-metre requirement as the depth of the root zone for the target rainforest ecosystem, current projections are that only about 400ha of the remaining 2,780ha will be able to be rehabilitated back to rainforest. The remainder (2,380ha) of the disturbed land will have an end land-use other than that of primary rainforest.

APPENDIX 15 THE EXPERT WORKING GROUP

Associate Professor R.J.S. (Bob) Beeton is employed by the University of Queensland where he teaches environmental problem solving. He was Acting Head and Head of the Department of Management Studies from 1992 to 1997. From 1998 to 2002 he was foundation Head of the School of Natural and Rural Systems Management. Bob has held many University positions in addition to Australian and State Government appointments. Currently he is Chair of the Australian Threatened Species Scientific Committee. Bob has supervised 47 higher degrees and he and his student's current research interests are environmental problem solving, and sustainability issues associated with both natural and rural systems and regional communities. He has published 124 scholarly works and numerous reports to government.

Bob has received a 1988 Australian Bicentennial award; the 1994 University of Queensland Excellence in Teaching Award; the 2000 University of Queensland Affirmative Action Commendation; in 2000 he was elected a Fellow of the Environmental Institute of Australia and New Zealand; in 2009 appointed a Member of the Order of Australia for his contribution to environmental and natural resource management and in 2009 was named one of 15 Lockyer Legends his for service to the community.

Dr Andrew A Burbidge is a consultant conservation biologist and Honorary Research Associate with the Western Australian Department of Environment and Conservation. Prior to retirement from the WA Public Service, he held senior positions in science and administration in State conservation agencies. He has wide research and management interests, which include island biodiversity management, and he has been leader of several successful eradications of invasive animals on islands, including black rats, rabbits, goats and feral cats. He has published more than 200 scientific papers, government reports and educational articles.

Andrew was chair of the Commonwealth government's Endangered Species Advisory Committee and Endangered Species Scientific Subcommittee from 1992 to 1998 and has been chair of the Western Australian Threatened Species Scientific Committee for many years. He is a co-author of the recent book *Australia's Biodiversity and Climate Change*, a member of the Gorgon Project Quarantine Expert Panel and a member of the Board of Directors of WWF-Australia.

Professor Emeritus Gordon Grigg retired in 2007 from the University of Queensland where he was Professor of Zoology from 1989 and Head of the Department of Zoology for ten years until 1998. Prior to that, from 1968 he was at the School of Biological Sciences at The University of Sydney, including two years on a Queen Elizabeth Postdoctoral Fellowship. His PhD was at the University of Oregon, following Bachelors and Honour degrees at The University of Queensland. He also has a DSc from the University of Sydney. Gordon has supervised more than 50 Honours students and 30 MSc and PhD students and has authored or co-authored about 180 peer-reviewed research publications.

Gordon is a physiological ecologist with wide-ranging interests and experience in vertebrate biology, particularly their thermal relations, salt and water balance and metabolic, respiratory and cardiovascular physiology. He has had a parallel career in kangaroo population ecology and is an advocate for achieving positive conservation outcomes through the sustainable commercial use of wildlife. Much of his research has been on crocodiles, echidnas, kangaroos and camels, and he is a strong supporter of the need to study animals in their natural situations through field work.

Professor Peter L Harrison is the Director of Marine Studies at Southern Cross University and a marine specialist on the Australian Threatened Species Scientific Committee. He has been awarded multiple prizes for excellence in science research and University teaching including a Eureka Prize for Environmental Research, and a 2009 Australian Learning and Teaching Council citation for outstanding University Teaching. Peter has been actively researching and teaching aspects of marine science and management for 30 years and has been awarded more than $4.5 million in research grants and consultancies - the majority from national and international competitive research grants. He has successfully supervised 35 Postgraduate and Honours research students and published more than 100 scientific research papers, books, invited major review chapters and major reports, which have been cited more than 2,200 times.

Dr Ric How is a Senior Curator at the Western Australian Museum and an Adjunct Professor at the University of Western Australia. He has published over 100 scientific papers and 80 reports covering biodiversity survey and monitoring, biogeography, taxonomy, ecology, wildlife management and conservation reproduction and molecular variation in vertebrate species from arid, temperate and tropical ecosystems throughout Western Australia and adjacent areas of south-eastern Indonesia, Sri Lanka and southern China. He recently worked as a contracted specialist for the Sri Lankan Government on the Biodiversity Baseline Survey of Sri Lanka. He has supervised several postgraduate students, been the recipient of over 20 competitive grants and has sat on several Western Australian Government Committees reviewing environmental issues and appeals.

Dr William (Bill) F. Humphreys, has held University appointments in Australia and England and is now Senior Curator Terrestrial Zoology at the Western Australian Museum. His focus is on all aspects of the subterranean biology of aquatic and terrestrial fauna following a background of ecology and physiology of terrestrial and aquatic invertebrates and mammals. He is Adjunct Professor, School of Animal Biology, University of Western Australia and Adjunct Associate Professor, School of Earth and Environmental Sciences, University of Adelaide.

He has published 150 scholarly works and 40 other publications, has undertaken consultancies for a wide range of government agencies and mining houses, and prepared numerous reports to government. He has convened several international scientific meetings in Australia and Europe and has an active editorial role in several scientific journals. He is a member of the Commonwealth Threatened Species Scientific Committee and the Scientific Advisory Committee for Threatened Ecological Communities, Western Australia. In 2008 he was awarded the *Eureka Prize: Excellence in Taxonomic Research.*

N.L. (Norm) McKenzie was awarded a MSc in Zoology by Monash University 1976 and is employed by the Western Australian Department of Environment and Conservation to design and carry out broad-scale ecological surveys for nature conservation. He led the State's biodiversity survey program from 1977 until 2007, and has published 79 papers in refereed journals in a range of fields, including biogeography, community ecology, reserve system design, mammal conservation and bat ecology. He has also published numerous conservation policy reviews and reports to government and contributed 15 species accounts to editions of "Mammals of Australia".

Dr John Woinarski is the Director of Biodiversity Conservation for the Northern Territory Department of Natural Resources Environment The Arts and Sport, and an Adjunct Professorial Fellow at Charles Darwin University. He is a member of the Threatened Species Scientific Committee, and of the Taskforce for Australia's National Biodiversity Strategy. He has published about 200 scientific articles and books, on a wide variety of topics including island biogeography and conservation, forest ecology, conservation reserve planning and management, monitoring, threatened species, endemism, environmental history, plants, invertebrates, herpetofauna, mammals and birds.

John has been awarded a Eureka Prize for biodiversity research, a Serventy Medal for lifetime contribution to Australian ornithology, and the Northern Territory Chief Minister's Award for Research and Innovation.