Recovery plan for the northern bettong *Bettongia tropica* 2000–2004

Prepared by Dr Andrew Dennis with the Northern Bettong Recovery Team

Northern bettong. Photo by Andrew Dennis

Queensland Government
Environmental Protection Agency
Queensland Parks and Wildlife Service

Natural Heritage Trust
Helping Communities Helping Australia

Recovery plan for the northern bettong *Bettongia tropica* 2000–2004

Prepared by: Dr Andrew Dennis with the Northern Bettong Recovery Team

Copies may be obtained from the:
Executive Director
Queensland Parks and Wildlife Service
PO Box 155
Brisbane Albert St Qld 4002

Disclaimer:
The Queensland Parks and Wildlife Service publishes recovery plans to detail the actions needed for the conservation of threatened native wildlife.

The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved, and may also be constrained by the need to address other conservation priorities. Approved recovery plans may be subject to modification due to changes in knowledge and changes in conservation status.

Publication reference:
Dennis, A.J. 2001. Recovery plan for the northern bettong, *Bettongia tropica* 2000–2004. Report to Environment Australia, Canberra. Queensland Parks and Wildlife Service, Brisbane.

This recovery plan was preceded by a draft Interim recovery plan for the northern bettong (1993–1994) and a research plan for the northern bettong (1993–1998). The results of the management actions and research completed through the interim plan have led to the next phase in the recovery process - the recovery plan with a five year cycle of management actions, research and public involvement. The recovery process was formally reviewed in late 1997 and the results were included in the development of the current plan.

This plan has included significant public input through the representatives on the recovery team.

Recovery plan for the northern bettong *Bettongia tropica* 2000–2004

Contents

Summary

Current species status
Northern bettongs are listed as endangered under the Queensland *Nature Conservation (Wildlife) Regulation* 1994 and under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Its listing conforms to the criteria of endangered under IUCN Red List categories (IUCN SSC 1994), Category B1,2c (extent of occurrence <5,000 km^2, occurs at <5 localities, decline in the quality and extent of habitat).

Habitat requirements and limiting factors
Northern bettongs appear to be entirely reliant on a range of tall and medium sclerophyll habitats in the uplands of the Wet Tropics biogeographic region (Winter 1997). These habitat types occur as a narrow fragmented strip along the western edge of wet tropical rainforests. The tall eucalypt components are at risk from the invasion of rainforest. Up to 70% of tall forest types may have undergone sufficient alteration, due to rainforest invasion in the last 200 years, to make them unsuitable (or marginal) habitat for northern bettongs (Harrington and Sanderson 1994).

Northern bettong distribution appears to be limited by the availability (including total abundance, diversity and seasonality) of hypogeal sporocarps from ectomycorrhizal fungi and potentially, cockatoo grass, *Alloteropsis semialata,* and lilies, *Hypoxis* spp., all of which are critical food resources. The distribution of these resources appears to be limited by vegetation associations which are controlled by fire. Areas that remain unburnt in the tall, wet sclerophyll forest component of northern bettong habitat soon lose some or all of these resources.

Recovery Objectives
Overall objective
To significantly improve the conservation status of the northern bettong by maintaining or expanding existing wild populations, and establishing new wild populations.

Specific objectives
- To manage the habitat of known populations of northern bettongs.
- To develop public support for the recovery program and increase community involvement in bettong recovery.
- To reduce the impact of introduced predators and competitors.
- To increase the number of wild populations of northern bettongs.
- To support the recovery process

Recovery Criterion
Populations of northern bettongs occupy five suitable areas of habitat and populations remain stable in the long term.

Recovery actions
- Manage the habitat of the four known populations of northern bettongs for their conservation.
- Encourage community participation in the recovery process.
- Monitor and control exotic predators and competitors.
- Re-introduce northern bettongs into their former range.
- Administer the operation of the recovery team and review the recovery process.

Progress criteria
(criteria for progress against specific objectives)

Progress criterion 1.1

- The production of GIS layers detailing:
  - sites where northern bettong populations occur and their relative population densities (actions 1.1.1 and 1.1.3);
  - areas of “degraded” habitat based on measures of rainforest invasion (action 1.1.1);
  - areas of potentially suitable habitat based on habitat parameters and truffle abundance, diversity and seasonality (actions 1.1.1 - 2, 4); and
  - areas of highest suitability for re-introductions based on truffle abundance, diversity and seasonality (action 1.1.4).
- The development of a predictive model describing the potential distribution of northern bettongs.

Progress criterion 1.2

- Memorandum of understanding is in place between DNR Resource Management and QPWS to protect and manage areas of State Forest for the benefit of northern bettongs.
- Regulatory and interpretive signs are in place at Lamb Range, Paluma, Windsor Tableland and Carbine Tableland.
- Prescribed burning practices are managed to suit the needs of northern bettongs as far as they are understood.

Progress criterion 1.3

- Appropriate fire management regimes are under development.
- Inappropriate fire management regimes have ceased.
- Monitoring sites for examining the long-term effects of fire on northern bettongs, vegetation and truffles are established and being used.

Progress criterion 1.4

- The size and rate of change of northern bettong populations at the Lamb Range, Carbine Tableland, Windsor Tableland and Paluma are known.

Progress criterion 2.1

- A core of volunteers is established such that the number of committed volunteer days matches or exceeds the requirement for assistance in the field.
- Three media releases are used by local media in each year of the plan.
- Pamphlets are produced and disseminated.
- Four public talks are delivered in each year of the plan.
- One article is published in each year of the plan.

Progress criterion 2.2

- A survey establishing the level of public awareness of northern bettongs is undertaken early in the plan.
- A measure of the change in level of awareness of northern bettongs is taken late in the life of this plan.

Progress criterion 3.1

- Continuous monitoring of foxes is established as a community concern.
- Biennial monitoring using an activity index is carried out.
- The effect of baiting on non-target species is known.
- A fox control plan is ready to be enacted if foxes become a problem.

Progress criterion 3.2

- The overlap in diet between feral pigs and northern bettongs is quantified.

- The overlap in foraging ranges between feral pigs and northern bettongs is quantified.
- The effects of pig control measures on northern bettongs and other non-target species is fully understood.
- The most effective control method is implemented when necessary.

Progress criterion 4.1

- At least one captive colony and stud book is maintained and includes twelve available breeding adults.
- At least two locations are selected as having the highest potential for re-introductions.
- Rehabilitation and habitat maintenance are undertaken in the re-introduction sites.
- A population is established and monitored at one of the sites.

Progress criterion 5.1

- There is continued functioning of a recovery team to direct the recovery process.
- A major review is undertaken of the recovery process.
- A new recovery plan is prepared at the end of the life of this plan.

Figure 1. Chart outlining the specific objectives (S.O.), progress criteria (C) and actions (A) relating to the overall objective of downlisting northern bettongs Bettongia tropica to vulnerable within 15 years. To facilitate clarity, links and overlaps between actions have not been included here but they are noted under each action description.

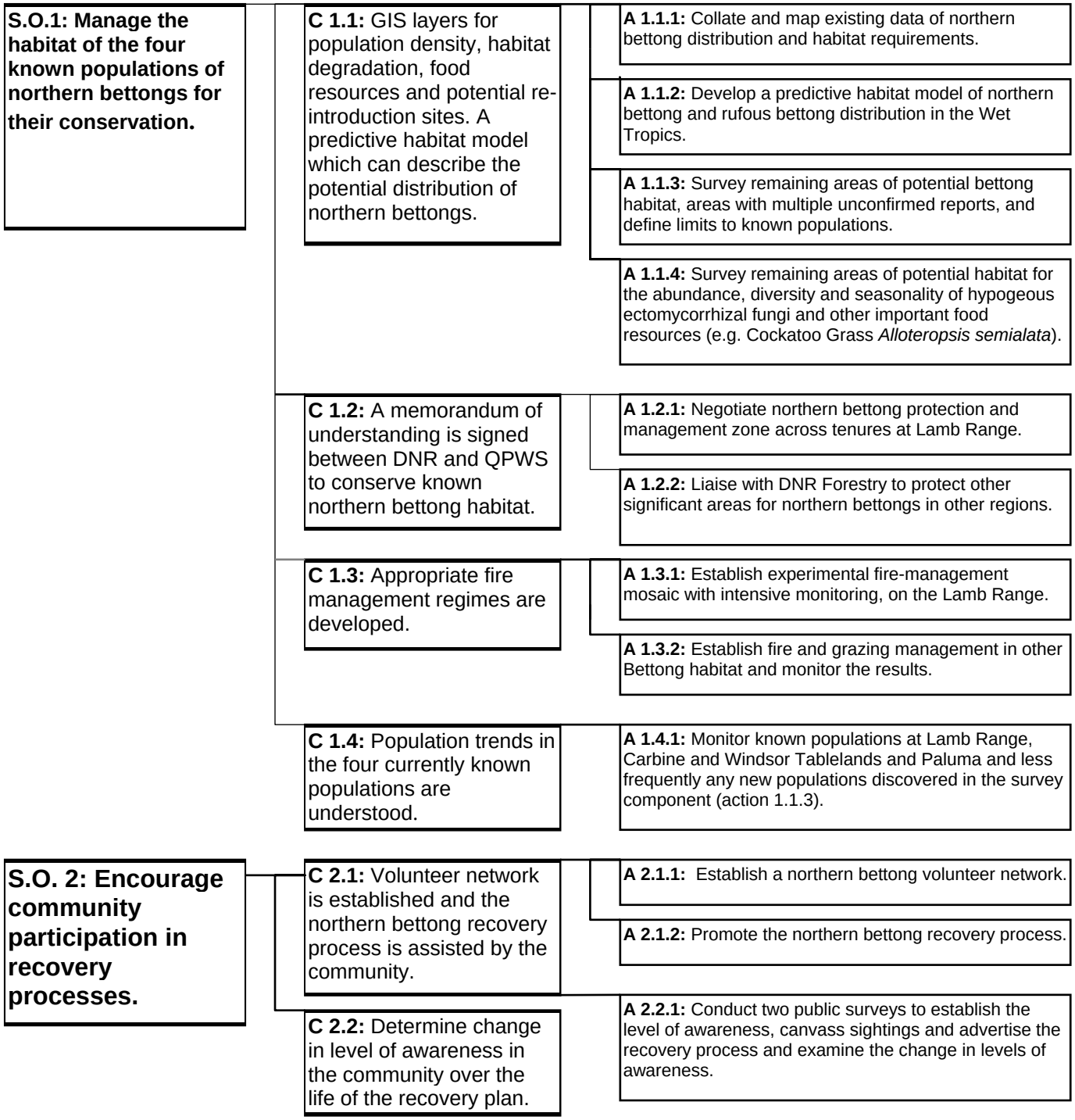


Figure 1. *(cont.)*

S.O. 3: Reduce the impacts of introduced predators and competitors.	**C 3.1:** Fox numbers are monitored and control measures are ready to be implemented.	**A 3.1.1:** Develop and implement method of monitoring the presence of foxes in low densities.
		A 3.1.2: Prepare fox control contingency plan and implement when necessary.
	C 3.2: The effects of pigs on northern bettongs are understood and control measures are ready to be implemented.	**A 3.2.1:** Quantify pig diet in bettong habitat.
		A 3.2.2: Compare pig habitat use and foraging sites to bettong habitat use and foraging sites.
		A 3.2.3: Develop and implement management strategies for the control of pigs in bettong habitat if this is determined necessary in actions 3.2.1 and 3.2.2.
S.O. 4: Increase the number of wild populations of northern bettongs.	**C 4.1:** A captive colony is maintained and northern bettongs are re-established at one site from which they had previously declined.	**A 4.1.1:** Maintain captive colony of northern bettongs.
		A 4.1.2: Identify appropriate re-introduction site from actions 1.1.1 - 4 and by consulting with community members in potential areas.
		A 4.1.3: Return degraded habitat into sclerophyll structure using appropriate fire regime.
		A 4.1.4 Re-introduce into trial area and continue long-term monitoring and management of the new population
S.O. 5: Support recovery process.	**C 5.1:** Continued functioning of a recovery team to direct the recovery process, a major review and a new Recovery Plan.	**A 5.1.1:** Support non-government organisation attendance at meetings.
		A 5.1.2: Conduct a major review of the recovery process.
		A 5.1.3: Rewrite the recovery plan at the end of five years.

Biodiversity benefits

The conservation of the northern bettong is an important national, state and regional priority and focuses attention on a range of other regional conservation and land use issues. Protection and management of northern bettong habitat will assist the protection of ecological communities of conservation concern, such as the tall eucalypt forests on the western fringe of the rain forest belt. Some of these forests have the highest arboreal mammal diversity in Australia, contain many endemic and dependant species or represent the northern most population isolates of predominantly southern fauna and flora. An overlap between dry woodland fauna, rainforest fauna and habitat specific endemics makes these forests highly biodiverse. Threatened species and regional ecosystems of conservation concern that could benefit from habitat protection and management are listed in Tables 1 and 2. In addition the northern quoll *Dasyurus hallucatus*, a species experiencing declining populations (Braithwaite and Griffiths 1994), and a newly discovered population of the northern population of the southern brown bandicoot *Isoodon obesulus peninsulae* on the Lamb Range (Pope *et al*. in press) will also benefit.

Table 1. *Rare and threatened species associated with northern bettong habitat. - Australian and New Zealand Environment and Conservation Council (ANZECC) (2000); Environment Projection and Biodiversity Conservation Act 1999 (EPBC); E = endangered; V = vulnerable.*

Common Name	Scientific Name	Status		Notes
		ANZECC	EPBC	
Mammals				
Yellow-bellied glider	*Petaurus australis* (Wet Tropics)	V		
Ghost bat	*Macroderma gigas*	V		
Birds				
Southern cassowary	*Casuarius casuarius*	E	E	edge of range
Red goshawk	*Erythrotriorchis radiatus*	V	V	
Buff-breasted button-quail	*Turnix olivii*	V		
Frogs				
Waterfall frog	*Litoria nannotus*		E	
Magnificent broodfrog	*Pseudophryne covacevichae*	V	V	Ravenshoe area

Table 2. *Regional ecosystems of conservation concern that will be managed as part of the northern bettong recovery process (from Sattler and Williams 1999).*

Regional Ecosystem	Description	Status
7.12.21	Rosegum forest on granite and rhyolite uplands	of concern
7.12.22	Red mahogany forest on granite and rhyolite uplands	of concern
7.12.23	Pink bloodwood woodland on granite and rhyolite uplands	of concern

Introduction

Description

Northern bettongs, *Bettongia tropica*, are small potoroids (Macropodoidea) with an adult weight of about 1.2 kg and a soft grey pelage, which is darker above and paler below. Their most distinctive features, apart from their small size, include: a short black crest of fur on the upper-distal part of the tail; very short fore-limbs which are held close to the body while moving; long nails on the hands (used for digging); delicate hind legs; and a rounded back and low head while hopping. Sexes are similar.

Northern bettongs are similar in appearance and genetics to woylies, *Bettongia penicillata*, from Western Australia. The relative taxonomic status of the two species has undergone several changes. Currently they are considered two distinct species (Winter 1997) but they may again be reviewed. Even if they are reviewed and are re-described as a single taxon this should make no difference to their conservation status or management. The north-eastern Australian population is sufficiently isolated in distance and time from other populations to warrant treating it as a separate entity for management purposes.

Distribution

Extant populations

Northern bettongs are known to currently occur at three locations (Figure 2). Only one of which, the Lamb Range, appears to contain a substantial number of animals over a broad area. Locations with extant populations include:

1. Mt Carbine Tableland: A very small, restricted and low density population at a site known as the NW Glider Shelf. Two individuals, caught within 200m of one another, were trapped during 559 trap nights covering 102ha in 1996 (Dennis 1997, trap rate = 1%; Winter 1997).
2. Lamb Range: Includes Davies Creek, Emu Creek and Tinaroo sub-populations which are genetically distinct but geographically close (Pope 2000a, trap rate Davies Ck = 14%, Emu Ck = 4%; Winter 1997).
3. Coane Range (Paluma): A recently discovered population in which eight individuals were trapped during 378 trap nights in November 1997 over an area of approximately 350ha (trap rate = 2%, McIlwee and Freeman 1998). The low trap success compared to Davies Ck again suggests a small, low density population.

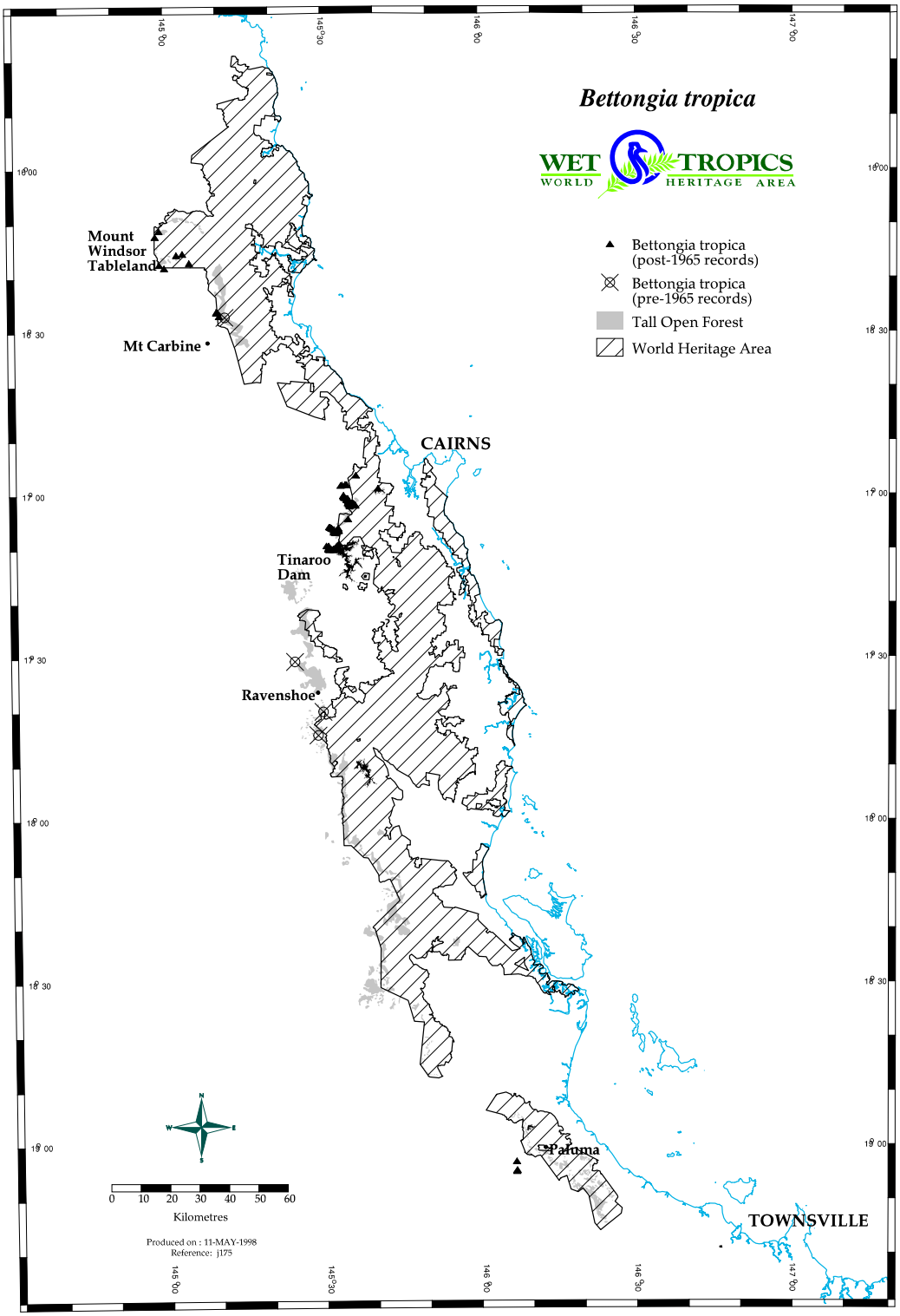
Probable extant populations

One location, Mt Windsor Tableland, was known to have an extant population as recently as January 1989. However, despite considerable effort (520 trap nights; 44 hours of spotlighting; digging transects; Winter 1992), no northern bettongs have been seen since this time. Winter (1992) suggested that the lack of success was due to the low density of the population.

"Extinct" populations

Northern bettongs once occurred in the "greater Ravenshoe area", an area at least as large as the current Lamb Range populations (Winter 1997). None have been seen since the 1920's, although a single, unconfirmed sighting by reliable witnesses was made at Red Road, the southern limit of the historical distribution for this region (Winter 1997). Despite considerable search effort (2120 trap nights, D. Storch pers. comm. April 1998, Winter 1997), no northern bettongs have been captured in recent times.

Figure 2. Known distribution of northern bettongs, Bettongia tropica.



The first recorded northern bettong specimen was from the Dawson Valley near Rockhampton. None have been seen in this region since, nor have any been seen in the country between the Dawson Valley and the Wet Tropics (Winter 1997).

Habitat

Extant populations of northern bettongs occur in a range of eucalypt forest types associated with the western edge of the rainforests in the Wet Tropics bioregion and the eastern edge of the open eucalypt woodlands in the Einasleigh Upland bioregion. This narrow band of habitats consists of a cline of eucalypt forest types from very tall and wet *Eucalyptus grandis* dominated forests through tall *E. resinifera-Syncarpia glomulifera* dominated forests to medium height and drier *E. citriodora* or *E. platyphylla* dominated forests. The cline represents a change in floristic and structural composition of habitats brought about by a decrease in annual rainfall and an increase in rainfall seasonality as one moves west from the rainforest edge. Sporadic sightings in rainforest have also been noted but these are probably due to occasional forays by individuals into this habitat from adjacent eucalypt woodlands.

Johnson and McIlwee (1997), suggest that the most critical habitat feature limiting their distribution may be the presence of hypogeal sporocarps of ectomycorrhizal fungi (truffles) in sufficient diversity and abundance and low seasonality. While not a directly measurable habitat feature, truffles may be associated with other measurable features of the habitat, such as floristic composition and diversity or structure. All of these features may be further inter-correlated with climatic variables. A greater understanding of truffle associations with various plants and communities is necessary before this can be further defined. Northern bettongs show no clear association with soil type and are found in forests growing on basalt, granite, metamorphic and alluvial derived soils (Laurance 1996, Winter 1997, D. Storch pers. comm. March 1998).

Winter (1997) developed a habitat model using the occurrence of rufous bettongs, *Aepyprymnus rufescens,* as a counterpoint to help define the limits and habitat requirements of northern bettongs. Northern and rufous bettongs have a contiguous distribution, a narrow zone of overlap or a disjunct distribution in different areas. This lead to the conclusion that northern bettongs were restricted to the moist or wet eucalypt forests which had a generally dense canopy, a well developed woody understorey and a sparse ground layer. Rufous bettongs occurred in moist to dry eucalypt forests of short to medium stature with a dense ground layer and few woody understorey plants. Winter (1997) suggested that this model could be better and further developed to give a more accurate picture of the requirements of northern bettongs as opposed to rufous bettongs. He further suggested that the latter species may be responding to habitat changes and moving into areas from which the northern bettong has declined. The habitat types described by Winter (1997) probably correspond to those described as types 1, 4, 6 and 7 by Harrington and Sanderson (1994).

Life history and ecology

Northern bettongs produce a single young, which attaches to one of only two teats and remains in the pouch for about 100 days. Young are produced throughout the year with no discernible seasonal trend (Vernes 1998). Their rate of reproduction is high when compared to other members of the Macropodoidea, being able to produce up to three young per year if conditions remain optimal. However, studies in the wild suggest that sub-adult recruitment rates are probably low (Vernes 1998).

Like many other Potoroids, northern bettongs are heavily reliant on truffles as a food resource. Studies by McIlwee (1994) and Johnson and McIlwee (1997) demonstrate that truffles, belonging to about 36 species of fungus, generally comprise about 45% of their diet. This proportion varies between location and season from 30% to 70%. Roots and tubers are also important food items particularly in the early dry season. However, the consumption rate

of roots and tubers changes with different habitats, being lower in wetter habitats. Grasses, particularly the subterranean stem bases from cockatoo grass, *Alloteropsis semialata,* and lilies *Hypoxis* spp. are also consumed in significant quantities (10 - 35% of the diet). In addition, northern bettongs eat herbs, invertebrates and seeds but only in small quantities (10% of diet all results combined, McIlwee 1994, Johnson and McIlwee 1997).

Vernes (1998) found that male northern bettongs have a larger range of movements than female bettongs, 72 $\pm$ 10.9ha versus 49 $\pm$ 8.4ha. However, both genders had a high mean rate of movement while foraging. Ranges overlapped for individuals, both between and within sexes. Fire has no impact on the location or use of individuals' home ranges. Both during and after a fire, individuals remain within the limits of their movements prior to a fire. There is no direct or indirect mortality of bettongs associated with fire (Vernes 1998). Despite the lack of broad scale changes to movements associated with fire, there were clear changes in the fine scale movements and foraging patterns of bettongs immediately after a fire. Search effort for truffles becomes focussed, the level of foraging success is higher and the foraging path more sinuous in recently burnt areas compared to unburnt areas (Vernes 1998). This is probably due to ease of movement and detection of previously un-located truffle clusters, and an increase in productivity of a few species of truffle immediately after a fire (Christensen 1980, Taylor 1991, Johnson 1995, Vernes 1998).

Reasons for listing

Northern bettongs have undergone a large range contraction. They have disappeared completely from two of their previously known locations, Dawson Valley and greater Ravenshoe area, and are now restricted to only three (possibly four) disjunct populations. The greater Ravenshoe area contained what was possibly the most geographically widespread population. Of the four remaining (possible) sites: two (Mt Carbine and Paluma) are extremely small with only three to eight individuals known and insufficient data to be able to estimate a total population; at one (Mt Windsor) no evidence of their presence has been found since early 1989; and one (Lamb Range) appears well populated. The small size and isolated nature of the remaining populations and the limited geographical extent of the species make them extremely susceptible to stochastic extinction events, inbreeding depression or predation from a few individual introduced predators. In addition, the sclerophyll forests at the wetter end of their habitat range are undergoing dramatic structural and floristic changes in many areas. These changes are being caused by the lack of fire and the subsequent invasion of rainforest species and are leading to a cumulative loss of habitat in some of the remaining population areas.

Listing of the bettong conforms to the criteria of Endangered under IUCN Red List categories (IUCN SSC 1994), Category B1,2c (extent of occurrence <5,000 km^2, population fragmented and occurs at no more than five locations, decline in the quality and extent of habitat). For example, on the Lamb Range up to 53% of very tall and wet, and tall eucalypt forest has been lost to rainforest invasion which represents 29% of available habitat for the northern bettong (G. Harrington pers. comm. February 1998) .

Existing conservation measures

Recent conservation actions, including research with conservation directed goals, include:

1. Surveys to determine distribution, relative population abundances and habitat associations.
2. Research into the fire related ecology of northern bettongs.
3. Research into population genetics and mating systems.
4. Surveys of fox distribution and abundance and the partial development of a fox control plan.
5. Liaison with Department of Natural Resoures (DNR) - Resource Management to manage State Forests containing bettong populations for their conservation.

6. Partially completed development of interpretive signs for Davies Creek National Park and Lamb Range State Forest.

Recovery actions

Strategy for recovery

The strategy for recovery is most clearly outlined in Figure 1. Each of the actions, their linkages with other actions, progress criteria and specific objectives are outlined in detail in the following section. The budget for each action is summarised in Appendix 2.

Action 1. Manage the habitat of the four known populations of northern bettongs for their conservation

Action 1.1.1 Collate and map existing data on northern bettong distribution and habitat requirements

(Determines priorities for actions 1.1.2 - 4; links with action 5.1.2.)

Responsibility: CSIRO Tropical Forest Research.

Community involvement: Distribution and habitat information disseminated to community.

Background: An accurate and complete knowledge of bettong distribution is a pre-requisite for re-assessing their conservation status, prioritising sites for management and determining sites at which replicates can be established for the research components of the plan. Existing data on locations where northern bettongs occur and where they are thought to be absent are contained in two major and several smaller reports (Winter 1992, Grant and Naylor 1993, McIlwee 1994, Laurance 1996, Winter 1997, Dennis 1997, McIlwee and Freeman 1998) and Queensland Parks and Wildlife Service electronic data bases. Habitat information is also available in Laurance (1996) and Winter (1997).

Tasks:
(a) Compile all current presence and absence survey records into a single data base for inclusion in Wildnet.

(b) Overlay these records on to detailed sclerophyll vegetation maps, which include a classification of sclerophyll sub-communities (including rainforest invaded sclerophyll), and land tenure maps.

(c) Produce a reference map of the current knowledge of the distribution and habitat requirements of northern bettongs. In combination with recent records this map will assist in identifying sites in need of further surveys.

(d) Determine the usefulness of pursuing the development of a habitat model. The model would re-analyse the existing data from Laurance (1996) and augment it where necessary (see action 1.1.2).

Action 1.1.2 Develop a predictive habitat model of northern bettong and rufous bettong distribution in the Wet Tropics

(Partially dependent on the results of action 1.1.1; part (a). Helps define survey areas for action 1.1.3; some data collection can be done during actions 1.4.1 and 1.1.3; links with actions 1.2.1, 1.2.2 and 5.1.2.)

Responsibility: QPWS, CSIRO

Community involvement: Volunteers needed for the rufous bettong component.

Background: Although some data is already available on the habitat variables associated with areas in which northern bettongs have been caught (Laurance 1996, Winter 1997), it is worthwhile re-analysing this data and augmenting it where necessary to give a clearer understanding of which habitat variables or plant resources limit their distribution. Development of a predictive habitat model for the northern bettong and closely related rufous bettong will help to define the limits for each, give a stronger indication of whether the two species compete and help to identify appropriate sites for re-introduction.

Tasks:
(a) Re-analyse existing data and augment it where necessary based on the results of action 1.1.1, which will help to determine the value of the existing data.

(b) Collect habitat and resource data, which is associated with trapping results for both northern and rufous bettongs in the Wet Tropics region and appropriate areas of the adjoining Einasleigh Uplands.

(c) Develop a predictive habitat model for each species using both similarities and differences between them to help define their respective requirements.

Action 1.1.3 Survey remaining areas of potential northern bettong habitat.
(Search areas partially defined by actions 1.1.1, 1.1.2; may link with action 1.2.2, 1.3.2, 1.4.1; Camera traps also useful to action 3.1.2.)

Responsibility: QPWS

Community involvement: Volunteers needed for surveys, particularly in remote areas. Information on new locality records disseminated to the community.

Background: Current knowledge of the distribution and habitat requirements of northern bettongs is still incomplete despite two previous surveys of broad geographical reach (Laurance 1996, Winter 1997). For example, a population previously unsurveyed was discovered by McIlwee (McIlwee and Freeman 1997) in the same general region surveyed by Winter eight years earlier. In addition, there are several areas in which unconfirmed sightings have been recorded by reliable observers.

It is also important to understand the distribution of northern bettongs on a finer scale. Understanding the limits to a population's local distribution and identifying local discontinuities is important for effective management of each population. For example, the Lamb Range was generally considered to support a "single" population of northern bettongs. However, Lisa Pope's (2000a) recent genetic studies on the Lamb Range have shown that northern bettongs are in effect three separate populations, one at Tinaroo, one at Emu Ck and one at Davies Ck.

Because many of the areas in which potential northern bettong habitat occurs are difficult to access, the first stage of these surveys would involve the use of easily portable digital "camera-traps". They have several advantages over cage traps; they are small, light and each camera is capable of making multiple "captures". Their disadvantages include lack of opportunity to mark individual animals and greater expense.

Tasks:
(a) Conduct camera-trap and/or cage-trap surveys in areas with sightings (>90% confidence) made by reliable observers. To date, these include: P.E.I. Rd, Butchers Ck and nearby sclerophyll forest on "the Old Cairns Track"; Mt Pandanus, near Ravenshoe; Red Road, near Ravenshoe; James Cook University field station, Kirrama.

(b) Conduct camera-trap and/or cage-trap surveys in areas identified as potential northern bettong habitat from actions 1.1.1 and 1.1.2.

(c) Conduct camera-trap surveys to determine the full extent of distribution within populations.

Action 1.1.4 Survey potential habitat for the abundance, diversity and seasonality of northern bettong food resources
(Extremely important to action 5.1.3.)

Responsibility: QPWS

Community involvement: Information disseminated to the community. May be opportunity for volunteer involvement in field work. The use of sniffer dogs may provide positive publicity reaching a wide audience for Quarantine Service, Department of Natural Resources, Queensland Parks and Wildlife Service, researchers and northern bettongs.

Background: It is likely that food resources, including the hypogeal sporocarps of numerous species of ectomycorrhizal fungi (truffles), cockatoo grass *Alloteropsis semialata* and lilies *Hypoxis* spp., are critical determinants of the distribution of northern bettongs (Johnson and McIlwee 1997; see also Seebeck *et al.* 1989 for accounts of other Potoroid's dependence on fungal resources). Further, Johnson and McIlwee (1997) suggest the seasonal changes in abundance and diversity of truffles in particular, is the limiting factor to bettong distribution. Therefore, a study to determine the geographical extent of areas of suitable habitat is essential to: (i) identify the factors the limit the distribution of northern bettongs; (ii) determine sites with large enough areas of suitable food resources (available through all seasons) that would give re-introduced northern bettongs long term prospects for survival. This also links to habitat suitability determined in actions 1.1.1 and 1.1.2.

Truffles are extremely difficult to detect (K. Vernes pers. comm. January 1998). This poses significant problems for measuring their seasonality and diversity. The method with the greatest degree of certainty, is to train and employ sniffer dogs to detect truffles. Dogs are currently used in Tasmania on commercial truffle farms (Steve Austin, pers. comm. February 1998). The most efficient approach would be to contract a dog handler with a trained dog to find truffles, while a biologist controls the sampling design and collects the samples. In addition, trained dogs could be used in studies to determine the responses of truffles to different fire management regimes (action 1.3.1) and the data be collected in such a way as to determine the response of truffles to various environmental events (rain, dry periods, fire). Sniffer dogs need from three to six months training to become fully field proficient (Steve Austin of Detectadog, the firm that trains and handles sniffer dogs, pers. comm. February 1998).

Because of the likelihood that truffles are the most critical determinant of northern bettong distribution and the health and longevity of populations, this action is considered one of the most critical in the plan (Northern Bettong Recovery Team, March 1998). By using dogs it should be possible to determine truffle associations with different species of tree and develop a sampling method based on truffle-tree associations. This would allow determination of suitable bettong habitat and the testing of the hypothesis that current populations of bettongs are fragmented because critical food resources are disjunct (action 1.1.4).

Tasks:
(a) Trial and develop a method to use sniffer dogs to sample truffle abundance and diversity across a range of habitat types.

(b) Depending on the success of the first task, determine the extent of suitable habitat for bettongs based on resource availability by:

- Conducting systematic, monthly surveys of truffle abundance and diversity over samples of all habitats identified as suitable (in actions 1.1.1-3), continuing into adjacent "unsuitable" habitat. This will define the limits to potential habitat and may explain the fragmented nature of current populations if resources prove to be currently distributed as a series of disjunct "islands".

- Quantifying the availability of other resources (e.g. cockatoo grass and *Hypoxis* Lilies) simultaneous to, and using the same sampling design as above.

(c) Add data to a GIS database combining information from actions 1.1.1-3 and calculate the areas of suitable habitat compartments to determine which ones have the most potential for the long term persistence of a re-introduced population.

Progress Criterion 1.1: The success of actions 1.1.1-4 will be measured by:
(a) The production of GIS layers detailing
- sites where northern bettong populations occur and their relative population densities (actions 1.1.1 and 1.1.3);
- areas of "degraded" habitat based on measures of rainforest invasion (action 1.1.1);
- areas of potentially suitable habitat based on habitat parameters and truffle abundance, diversity and seasonality (actions 1.1.1 - 2, 4);
- areas of highest suitability for re-introductions based on truffle abundance, diversity and seasonality (action 1.1.4).

(b) The development of a predictive model describing the potential distribution of northern bettongs.

Action 1.2.1 Negotiate northern bettong protection across tenures at Lamb Range
(Extent of area to be protected determined in actions 1.1.1 - 4; forms basis for action 1.2.2; strong links to action 1.3.1.)

Responsibility: QPWS, DNR, Community

Community involvement: Will require extensive liaison with and support from local community groups (including indigenous groups), landholders and Councils. It will therefore provide opportunities for community and government to work together and widely publicise northern bettongs in the local area.

Background: Very little of the range of northern bettongs is in National Park, although much of it occurs in State Forest and/or in the Wet Tropics World Heritage Area, managed by the Department of Natural Resources. State Forest is often managed as a multi-use area which can include timber extraction, cattle grazing, water catchment protection, tourism and recreational camping. Standard management practices and/or problems associated with these uses may be detrimental to northern bettongs. For example, dogs accompanying campers are known to kill bettongs (Dennis pers. obs. 1983), the synergistic effects of grazing and fire may be detrimental to truffles and fire strategies may allow the invasion of bettong habitat by rainforest. In addition, various of the actions outlined in this recovery plan will include extensive work in State Forests (actions 1.1.1 - 4) and intensive, direct management in some cases (actions 1.3.1 - 2, Specific Objectives 3, 4 and 5). It is essential, therefore, that agreements are reached with the Department of Natural Resources to manage State Forest containing northern bettong habitats for the benefit of bettongs.

The Lamb Range contains the largest and most geographically extensive populations of northern bettongs. Because of this it is the most critical area to be protected and managed

specifically for bettongs. It is surrounded on all sides by either privately owned land, rainforest or Tinaroo Falls Reservoir. For effective management a memorandum of understanding should be entered into so that the State Forest, World Heritage Area and National Park are managed specifically with northern bettongs in mind. In addition, surrounding land holders could be encouraged to enter into Voluntary Conservation Agreements.

Tasks:
(a) Define a zone on the Lamb Range within which management actions will be directed specifically toward the long-term protection of northern bettongs. Management actions could include dog control measures, removal of grazing leases, population and vegetation monitoring, instigation of action 1.3.1.

(b) Encourage surrounding landholders to enter into Voluntary Conservation Agreements, which will be managed for private use but with the long-term protection of northern bettongs as a secondary aim.

(c) Encourage cooperative management between the Department of Natural Resources and Queensland Parks and Wildlife Service, local land holders, researchers, Councils and the Wet Tropics Management Authority.

(d) Provide quality on-site interpretation of northern bettong ecology, management and research, and explanations of any restrictions placed on the public use of the area (e.g. restriction on access for dogs).

Action 1.2.2 Protect and manage other significant areas for northern bettongs
(Significant areas defined in actions 1.1.1-4; management will depend on results of actions 1.3.1, 1.4.1, 3.1.1-3.2.3.)

Responsibility: DNR, QPWS

Community involvement: Liaise with grazing lessees about northern bettongs and their requirements; ensure general community in each area is aware of northern bettongs and management intents aimed at their recovery (local community groups may be able to undertake the local awareness campaigns).

Background: Once the Lamb Range, Northern Bettong Management Zone is established and management practices are refined it is important to extend these efforts to other key habitat areas so that more than one population is secured. Other key areas include Coane Range, Carbine Tableland, Windsor Tableland and the Ravenshoe area. In the interim, certain measures can be taken to facilitate the protection of bettongs. For example, signs can be erected to make people aware they are in a northern bettong habitat and should control their dogs. Grazing lessees should be made aware of the importance of notifying DNR when they undertake management burns so that follow up monitoring can be scheduled.

Tasks:
(a) Ensure that district rangers are aware that northern bettongs are in their area and outline what management measures might need to be undertaken.

(b) Seek agreement from DNR to manage areas (including Paluma, Carbine Tableland and Windsor Tableland initially) to meet the needs of northern bettongs.

Progress criterion 1.2: Measures to determine the success of actions 1.2.1-2:
(a) A memorandum of understanding is in place between DNR Resource Management and QPWS to protect and manage areas in State Forest for the benefit of northern bettongs.

(b) Regulatory and interpretive signs are in place at Lamb Range, Paluma, Windsor Tableland and Carbine Tableland.
(c) Prescribed burning practices are managed to suit the needs of northern bettongs as far as they are understood.

Action 1.3.1 Establish an experimental fire management mosaic with intensive monitoring
(This will provide information for actions 1.2.1-2, 4.1.1, 5.1.3; will depend on agreement being reached in action 1.2.1; could link to the Rural Fire Division of Queensland Fire Board's NHT Project: "Monitoring the effects of fire on native vegetation")

Responsibility: Consultant, QPWS, DNR

Community involvement: Intent and reasons for fire management explained to community (including indigenous groups) and neighbouring landholders; local rural fire board and tradional owner representatives can be invited to assist; northern bettong volunteers may be able to assist with follow up monitoring.

Background: This is an extremely important action, which must be conducted as a substantial, well focussed, scientific study. It combines both management actions and monitoring of their effects and should be in the form of an experimental design with manipulated treatments and controls.

One of the key management requirements for the maintenance of sclerophyll forests is periodic burning. This is particularly important in wet sclerophyll forests which are rapidly being invaded by rainforest (Harrington and Sanderson 1994). It is also an important factor determining the vegetation structure of drier medium sclerophyll forests and woodlands, particularly the structure of the understorey vegetation through the effects on grasses and woody plants.

Grazing can also have significant impacts on fire intensity and vegetation structure and floristics. Therefore, if grazing continues on the Lamb Range, its impacts should also be taken into consideration when designing, collecting and analysing the fire management experiment.

Karl Vernes (1998, 2000), in his study on the effects of fire on northern bettongs, has provided important baseline information and the first insights into the effects of fire on bettongs. Some important results are that: (i) no mortality of northern bettongs occurred as a direct result of fire; (ii) fire had no discernible effect on population size or structure; (iii) fire did not affect broad-scale habitat use; (iv) certain species of truffle responded by producing a greater biomass of fruit shortly after a fire; (v) foraging success for bettongs increased immediately after a fire and (vi) foraging paths were more sinuous on burnt ground. Similar studies in Western Australia showed that subsequent to a fire, the population of woylies *Bettongia penicillata* declined (Christensen and Maisey 1987). This was attributed to increased predation by foxes and cats due to the lack of cover. These results indicate that fire is not a threatening process to northern bettongs but its management requires refinement to enhance the production of truffles.

Johnson and McIlwee (1997) found that the seasonality of truffle production became more pronounced on the western limits of the distribution of northern bettongs - possibly related to a decrease in rainfall.

The use of fire as a management tool is controversial in the local community (pers. obs.). Therefore, it is important that a clear scientific understanding of the use of fire is developed

and that management burns are implemented in stages with unburnt controls being left in all regions.

Tasks:
(a) Design and implement a rigorous set of protocols for measuring fire intensity and environmental conditions prior to a burn (e.g. soil moisture, humidity, fuel loads, fuel moisture, fire history).

(b) Establish a mosaic of fire regime treatments in the form of a replicated experimental design with unburnt controls.

(c) Management agencies responsible for burns liaise with a consultant who conducts the measurements, monitoring and analysis of data associated with the burns.

Action 1.3.2 Establish and monitor fire and grazing management in other bettong habitats
(Timing of fires and nature of monitoring determined in action 1.3.1; links to actions 4.1.1 and 5.1.3; could link to the Rural Fire Division of Queensland Fire Board's NHT Project: "Monitoring the effects of fire on native vegetation".)

Responsibility: DNR, QPWS

Community involvement: Local Rural Fire division, land holders, indigenous groups and graziers advised of and consulted about management burns.

Background: To maintain appropriate vegetation structure and truffle abundance, fires are a necessary management tool. Action 1.3.1 will give us a greater understanding of the effects of fire on essential bettong resources. This knowledge can then be used to adjust existing fire management practices in areas with northern bettong populations.

Tasks:
(a) Develop and implement a fire management protocol based on results of action 1.3.1, which can be used in areas occupied by northern bettongs.

(b) Develop and implement a simplified monitoring protocol based on what are shown to be the most effective measures from the more detailed monitoring in action 1.3.1 (should include monitoring fire intensity in association with subsequent vegetation parameters and if feasible truffle availability).

Progress Criterion 1.3: Measures to determine the success of actions 1.3.1-2:
(a) Appropriate fire management regimes are under development.
(b) Inappropriate fire management regimes have ceased.
(c) Monitoring sites for examining the long-term effects of fire on northern bettongs, vegetation and truffles are established and being used.

Action 1.4.1 Monitor known, and newly discovered, populations of northern bettongs
(Important assessment tool to partially determine the overall success of the recovery plan; new populations determined in action 1.1.3; separate to the monitoring involved in actions 1.3.1 and 5.1.3.)

Responsibility: QPWS

Community involvement: Opportunity for volunteers to assist. Information disseminated to community.

Background: To measure and re-assess the status of northern bettongs it is essential to know how many populations are extant, the population size in each area and the extent of those populations. In addition, it is important to understand population trends. Annual samples will be taken for each population so that long term trends can be established. This monitoring should be done separately, but may complement monitoring associated with other actions. In addition to monitoring population size at sample sites, measures of vegetation structure and floristics and other environmental variables should be taken concurrently so that any trends relating population size or structure to other variables, can be investigated.

Tasks:
(a) Establish a series of paired sites in wet and dry sclerophyll forests at each of the following populations:

- Tinaroo (Lamb Range)
- Tinaroo Ck Road (Lamb Range)
- Davies Ck (Lamb Range)
- Glider Shelf (Carbine Tableland)
- Mt Windsor sclerophyll belt - Bettong Creek
- Mt Windsor sclerophyll belt - Piccaninny Creek
- Coane Range (Paluma)
- Any new populations identified in action 1.1.3 (biennially)

(b) Conduct mark-recapture and vegetation monitoring at each site.

Progress Criterion 1.4: Measures to determine the success of actions 1.4.1:
The size and rate of change of northern bettong populations at the Lamb Range, Carbine Tableland, Windsor Tableland, and Paluma are known.

Action 2. Encourage community participation in the recovery process

Special Note: Most actions under this objective will require the time and skills of one person to coordinate, and in some cases implement, the actions (interpretive officer part-time). These human resources are currently not available through QPWS. A person could be employed by either QPWS or a community group.

Action 2.1.1 Establish a northern bettong volunteer network.

(Links to actions 1.1.3, 1.3.1, 1.3.2, 1.4.1, 2.2.3, 3.1.1, 4.1.2, 5.1.3.)

Responsibility: Community, QPWS

Background: Promoting an attitude of responsibility and involvement with endangered species is an important aspect of the recovery process. Many of the actions in this plan will be partially reliant on volunteers for assistance in the field and for disseminating information. These volunteers may be drawn from existing bodies, including Tableland Volunteers, natural history and conservation oriented groups as well as from members of the community not associated with groups.

Tasks:
(a) Establish a list of potential volunteers for field work and information dissemination.

(b) Draw up a roster from the relevant actions and coordinate the filling of positions on that roster.

Action 2.1.2 Promote northern bettong recovery

(Links to action 2.1.1, 2.1.3; Disseminates information from most other actions.)

Responsibility: Community, QPWS

Background: The northern bettong is a significant species in the north Queensland and reaches its highest density on the Lamb Range near the towns of Kuranda, Mareeba, Yungaburra and Atherton. It is important therefore that local communities are fully aware of their presence and threats to their survival (particularly from foxes), and are involved in their recovery. Talks to community groups and schools, information pamphlets, articles in the print media and items on radio and television raise public awareness of the northern bettong recovery efforts and how they can become involved. Talks can be given by both QPWS staff and interested volunteers.

Tasks:
(a) Identify potential community groups and schools at which talks should be given throughout the range of northern bettongs. Draw up a roster of speakers and venues and present talks at each.

(b) Ensure that information on significant events in the northern bettong recovery process is provided to local print, radio and television media establishments.

(c) Produce two pamphlets, one for consumption at school level and one for interested adults and landholders.

(d) Identify targets for the dissemination of pamphlets, including schools, organisations and individuals (particularly landholders adjoining northern bettong habitats).

(e) Ensure that at least one publication is produced in the popular literature in each year of the recovery plan.

Progress criterion 2.1: Measures to determine the success of actions 2.1.1-3:
(a) A core of volunteers is established such that the number of committed volunteer days matches or exceeds the requirement for assistance in the field.
(b) Three media releases are used by local media in each year of the plan.
(c) Pamphlets are produced and disseminated.
(d) Four public talks are held in each year of the plan.
(e) One article is published in each year of the plan.

Action 2.2.1 Conduct a public survey to advertise northern bettongs, canvass sightings and assess the level of awareness of them
(Links to actions 2.1.1 - 2.2.2.)

Responsibility: Consultant

Background: To measure the success of the public outreach, awareness and education components of this recovery plan it is necessary to measure the level of awareness and depth of knowledge directly. This can be done using a public survey specifically designed for this purpose and taking samples at local and regional scales. It is necessary to establish a baseline measure of awareness early in the plan's life and then re-assess awareness levels at a later date to measure the change. The same survey will also be useful in raising awareness of northern bettongs and will assist in collecting further reports of bettongs in the region.

Tasks:
(a) Undertake surveys early and late during the recovery plan to determine the level of awareness of northern bettongs in the community, canvass sightings and provide avenues for further information.

(b) Collate and analyse responses, and report to recovery team and funding sources.

Progress criterion 2.2: Measures to determine the success of actions 2.2.1-2:
(a) A survey establishing the level of public awareness of northern bettongs is undertaken early in the plan.
(b) A measure of the change in level of awareness of northern bettongs is taken late in the life of this plan.

Action 3. Monitor and control exotic predators and competitors

Action 3.1.1 Develop and implement protocols for detection of the presence of foxes in low densities

(Critical to success of action 5.1.3; links to actions 1.2.1-2, 2.1.1-3, 2.2.2-3.)

Responsibility: DNR, QPWS

Community involvement: Northern bettong volunteers and other community members can be encouraged to remain vigilant and report sightings of foxes (including road kills). In addition, volunteers can assist in fox monitoring.

Background: Foxes have caused the decline of native species of similar size to northern bettongs (Kinnear *et al.* 1988, Friend 1990, Short *et al.* 1992) and therefore represent a significant threat. The success of conservation and re-introduction efforts for threatened wildlife in southern and western Australia has often been contingent on the control of foxes (Saunders *et al.* 1995, Copley P. pers. comm. February 1998).

Recent sightings and a survey has confirmed the presence of the fox on the Atherton Tablelands in low numbers, adjacent to northern bettong populations (Mason 1996a, 1996b). Mason (1996b) has suggested refinements of methods he used for detecting foxes in sparse populations and recommended involving the general community in maintaining fox surveillance.

Tasks:
(a) Develop community surveillance procedures for reporting fox sightings in the region.

(b) Develop and implement fox activity indices and community network to monitor for the presence of foxes in northern bettong areas.

(c) Trial the monitoring in sample bettong populations (e.g. Paluma and Lamb Range).

Action 3.1.2 Prepare fox control contingency plan and implement when necessary

(Critical to success of action 5.1.3; links to actions 1.2.1-2, 2.1.1-3, 2.2.2-3.)

Responsibility: QPWS, DNR

Community involvement: Landholders adjacent to northern bettong populations could be encouraged to trap or bait foxes if their numbers increase to significant levels.

Background: (See action 3.1.1 above). If foxes appear in areas occupied by northern bettongs rapid action is required. In Western Australia, the decline of many native mammals has been attributed to fox predation. The subsequent recovery of some of those species is directly linked to fox control (Bailey 1996, Start *et al.* 1996). The use of poison (1080) baits has proven to be the most successful method of fox control throughout Australia. It is particularly good because many native animals are highly resistant to the toxin, sodium fluoroacetate (Saunders *et al.* 1995). However, Mason (1996) suggested that tiger and

northern quolls (*Dasyurus maculatus gracilis* and *D. hallucatus*) may be at risk from a baiting program. Therefore, further trials using different types of (unpoisoned) bait should be conducted before a poisonous baiting program is initiated. These tests will assess the risk to non-target species caused by the baiting of foxes. It is important that the risks to non-target species be assessed well before foxes become a problem so that rapid action can be taken if foxes do become a problem.

Tasks:
(a) Prepare a fox control contingency plan by determining which baits pose least risk to non-target species in a poisonous bait program. This should include an estimate of the number of individuals of each target species likely to be affected.

(b) Implement control measures when and where it is deemed necessary from action 3.1.1. This should be done using traps until the risk to non-target species from the use of baits is assessed.

Progress criterion 3.1: Measures to determine the success of actions 3.1.1-2:
(a) Continuous monitoring of foxes is established as a community concern.
(b) Biennial monitoring using an activity index is carried out.
(c) The effect of baiting on non-target species is known.
(d) A fox control plan is ready to be enacted if foxes become a problem.

Action 3.2.1 Quantify pig diet in northern bettong habitat
(Links to actions 1.2.1-2, 5.1.3.)

Responsibility: Consultant, QPWS

Community involvement: Volunteers may assist.

Background: Laurance (1996) and Laurance and Harrington (1997) have shown that a large proportion (up to 47.4%) of sites in bettong habitat has been affected by pig rooting activity. They suggest that pigs may represent a significant threat to northern bettongs, probably as a contributing factor to declines in concert with other threatening processes. However, there is insufficient data to determine this. Therefore, it is necessary to establish if pigs are consuming truffles and thus competing with bettongs for food.

Tasks:
(a) Assess the diet of pigs during times of peak and trough abundance of truffles. Ensure data is collected in such a way that habitat use and foraging sites can also be examined.

(b) Make recommendations for future management or research based on findings from this study.

Action 3.2.2 Compare pig habitat use and foraging sites to northern bettong habitat use and foraging sites
(Depends on results of action 3.2.1; requirement for this action should be determined by the recovery team at the appropriate time.)

Responsibility: Consultant

Community involvement: Volunteers may assist.

Background: If action 3.2.1 indicates that the diets of pigs and bettongs have significant overlap, particularly during the trough in abundance of truffles, then an analysis of overlap in foraging sites is necessary to further define the threat. This may be possible using data from

Vernes (2000) and action 3.2.1. If the available data is sufficient, then the action can be completed in a short time within QPWS. If not, then a six month contract to augment existing data and combine and analyse it may be required.

Task:
(a) Determine to what degree pig and northern bettong foraging ranges overlap and therefore determine the level of threat posed by pigs to northern bettongs.

Action 3.2.3 Implement an experimental pig control program and monitor the response of northern bettongs
(Dependent on results from 3.2.1, 3.2.2; Links to 1.2.1-2, 5.1.3; necessity to be determined by northern bettong recovery team at an appropriate time.)

Responsibility: Consultant, DNR, QPWS

Community involvement: None

Background: If it is found that pigs pose a significant threat to northern bettongs (actions 3.2.1-2) then control measures will need to be implemented to reduce pig numbers. The method used will need to be tested for its risk to northern bettongs and other non-target species. Several methods are available for controlling pigs, including: trapping; poison baiting (with Warfarin and fermented grain); and hunting (QPWS Pig Workshop 1998). Hunting is seen as an inappropriate method in northern bettong habitat because of the use of dogs. Trapping may be suitable in many areas as road access is available and the risk to non-target species is probably low. However, the use of poisonous baits is probably cheaper and needs to be assessed as the most viable option depending on the risks to northern bettongs and other non-target species.

Tasks:
(a) Determine which methods of pig control are most suitable for wet sclerophyll habitats. This will be done by assessing the extent of habitat able to be reached by use of traps and by completing a risk assessment for poisoning based on the impacts of pigs on bettongs and the risk to non-target animals.

(b) Implement the most effective method as a long-term (indefinitely) management strategy. Includes monitoring pig numbers to determine when control is needed.

Progress criterion 3.2: Measures to determine the success of actions 3.2.1-3:
(a) The overlap in diet between feral pigs and northern bettongs is quantified.
(b) The overlap in foraging ranges between feral pigs and northern bettongs is quantified.
(c) The effects of pig control measures on northern bettongs and other non-target species are fully understood.
(d) The most effective control method is implemented when necessary.

Action 4. Re-introduce northern bettongs into their former range

Action 4.1.1 Maintain a captive colony of northern bettongs
(Links to action 4.1.4; important to overall objective.)

Responsibility: QPWS

Community involvement: Status of captive colony communicated to community.

Background: Northern bettongs have disappeared from areas previously occupied and not contiguous with known existing populations (Winter 1997). To re-establish populations in

these areas probably requires re-introductions of the bettong. Therefore, a captive colony needs to be maintained in order to have animals available for re-introduction. Although recent work suggests that re-introductions using wild caught animals are more successful, there are advantages to using captive stock in addition to wild stock. Benefits include: (i) extra genetic variation; (ii) a more readily accessible source of animals; (iii) reduced interference with wild populations; and (iv) captive bred animals are more adaptable to supplementary feeding, handling and temporary housing during initial phases of release. A captive colony currently maintained by QPWS in Townsville is providing basic reproductive data and can serve as a source for future re-introductions.

Task:
(a) Maintain a captive breeding stock of northern bettongs and collect reproductive and genetic information.

Action 4.1.2 Identify appropriate re-introduction sites
(Links to actions 1.1.1 - 4, 3.1.1-2, 4.1.1, 4.1.3-4.)

Responsibility: QPWS

Community involvement: Assistance with selecting areas and monitoring re-introductions.

Background: Before re-introductions can occur, suitable sites containing appropriate habitat and ample food resources (both in space and time) need to be identified or re-habilitated. Historical occurrence information is outlined in Winter (1997). Site identification will be carried out using the historical data and in actions 1.1.1-4. Rehabilitation of appropriate sites will be carried out in actions 4.1.3. This process will lead to the identification of a limited number of sites able to support northern bettongs in the long-term. The next step, and the main function of this action, is to determine which of the available sites should be chosen for a first stage re-introduction. This requires knowledge of: (i) threats to re-introduced animals in the area (e.g. dogs, foxes); (ii) level of community support (for control of threats and help in monitoring); and (iii) ease of accessibility for monitoring and management requirements.

Task:
(a) Develop a list of potential re-introduction sites based on information from actions 1.1.1-4, 3.1.1-2. Select the most suitable site based on consultation with the communities and indigenous people around each site and the appropriate land managers (e.g. DNR).

Action 4.1.3 Return degraded northern bettong habitat to appropriate sclerophyll structure using the appropriate fire regime
(Fire regime determined in action 1.3.1; links to 4.1.4.)

Responsibility: DNR, QPWS

Community involvement: Rural fire division, local indigenous groups and landholders may assist in burning.

Background: A significant proportion of habitat suitable for northern bettongs has been degraded by the invasion of rainforest vegetation (Harrington and Sanderson 1994). If the extent of occurrence and population size of bettongs is to be increased, then at least some degraded habitat needs to be returned to the appropriate structure and floristics. This may be essential for establishing viable re-introduction sites (see also background for action 1.3.1).

Monitoring vegetation changes following burning is necessary to determine whether structural changes will benefit the bettongs. In addition, monitoring is required to ensure that

northern bettongs are not present so that the area is suitable for the re-introduction of captive bred animals.

Tasks:
(a) Select appropriate areas (from actions 1.1.1-4) and implement prescribed burning schedules (based on action 1.3.1) to rehabilitate degraded habitat which was once known to support northern bettongs.

(b) Undertake appropriate measurements prior to and during prescribed burns as a baseline to further monitoring in this action.

(c) Monitor the change in vegetation structure following the prescribed burns. Monitoring should be based on the simplified tool developed in action 1.3.1 and where possible should include an assessment of the availability of truffles.

(d) Monitor the presence of northern bettongs in the area in case a previously unnoticed population exists. It is important to determine that bettongs are absent before reintroductions are attempted.

Action 4.1.4 Re-introduce northern bettongs into trial area and continue long-term monitoring and management of the new population
(Links to actions 1.1.1 - 4, 3.1.1-2, 4.1.1-3; important to overall objective.)

Community involvement: Cooperation of local people needed to ensure protection of area. Volunteers may assist in follow up monitoring.

Background: After site selection and maintaining a captive colony the next step is to conduct a re-introduction. This step will draw on the experience of other re-introduction programs, such as for bilbies *Macrotis lagotis* in the Northern Territory and woylies *Bettongia penicillata* in South Australia. The re-introduction should be done as a staged release with large outdoor enclosures and supplementary feeding as the first stage. Intensive monitoring of the health of individuals and the population and any threats affecting them should be implemented immediately upon stage one of the release. Animals to be released should include both wild-caught and captive bred individuals. The wild-caught individuals could be introduced to the staged release program just prior to allowing the captive animals to go free of the enclosure.

Tasks:
(a) Conduct a staged release program at a suitable location (e.g. Tumoulin) using both wild caught and captive reared individuals.

(b) Intensively monitor the new population and manage its environment according to the requirements outlined from the results of actions 1.3.1-2, 3.1.1, 3.2.1-3 and 4.1.3.

Progress criterion 4.1: Measures to determine the success of actions 4.1.1-4:
(a) At least one captive colony and stud book is maintained and includes twelve available breeding adults.
(b) At least two locations have been selected as having the highest potential for re-introductions.
(c) Rehabilitation and habitat maintenance are undertaken in the re-introduction sites.
(d) A population is established and monitored at one of the sites.

Action 5: Administer the operation of the recovery team and review the recovery process

Action 5.1.1 Support non-government organisation attendance at meetings

(Links to management and refining of all actions.)

Responsibility: QPWS

Community involvement: Community representatives on recovery team.

Background: For the recovery team to function effectively, representatives from a range of backgrounds will be required to attend meetings to discuss relevant issues. These representatives may include both members and invited associate members or stakeholders relevant to a particular topic being discussed at a meeting. Some of these people will require support to ensure their ability to attend - sitting fees, fares and accommodation.

Tasks:
(a) Provide financial support for recovery team members and invited stakeholders or experts to attend relevant recovery team meetings.

Action 5.1.2 Conduct a major review of the recovery process

Community involvement: None.

Responsibility: Consultant, QPWS

Background: A major review is a requirement of the recovery process to assess the progress made toward meeting the recovery plan objectives. It should include input from people not involved in the recovery plan and may require contracting a university consultant scientist.

Task :
(a) Conduct a major review of the progress made toward meeting recovery plan objectives.

Action 5.1.3 Rewrite recovery plan at end of five years
(Links to all actions)

Responsibility: QPWS

Community involvement: Community response to various actions will be taken into consideration in re-writing the plan.

Background: As information is gathered and management actions are implemented the actions in the recovery plan will need to be reviewed and new actions (if any) identified. This process will continue throughout the life of this recovery plan. At the end of the life of this recovery plan we will be dealing with a different situation as many actions will be completed, new information gained and management actions taken. Therefore, a new recovery plan will need to be written.

Task:
(a) Write a new recovery plan based on the advances made during the life of this plan.

Progress criterion 5.1: The success of actions 5.1.1-3 will be measured by:
(a) The continued functioning of a recovery team to direct the recovery process.
(b) A major review of the recovery process.
(c) The preparation of a new recovery plan at the end of the life of this plan.

References

Bailey, C. 1996. Western shield: bringing wildlife back from the brink of extinction. *Landscope* Winter 1996. Department of Conservation and Land Management.

Braithwaite, R.W. and Griffiths, A.D. 1994. Demographic variation and range contraction in the northern quoll *Dasyurus hallucatus* (Marsupialia: Dasyuridae). *Wildlife Research* 21, 203-217.

Christensen, P.E.S. 1980. The biology of *Bettongia penicillata*, (Gray 1837), and *Macropus eugenii*, (Desmarest 1817) in relation to fire. *Forest Department of Western Australia Bulletin* 91, 1-90.

Christensen, P. and Maisey, K. 1987. The use of fire as a management tool in fauna conservation reserves. In Saunders, D.A., Arnold, G.W., Burbidge, A.A. and Hopkins, A.J.M. (eds) *Nature Conservation: the Role of Remnants of Native Vegetation*. Surrey Beatty and Sons, Sydney.

Dennis, A. 1997. *Re-survey of Northern Bettong,* Bettongia tropica*, populations on the Carbine and Windsor Tablelands*. Report to Environment Australia, Endangered Species Program.

Department of Environment 1998. *Feral Pig Workshop for Reserve Managers.* 25-26 February 1998, DNR/DPI South Johnson Research Station.

Friend, J.A. 1990. The Numbat (Mymecobiidae): History of decline and potential for recovery. *Proceedings of the Ecological Society of Australia* 16, 369-377.

Grant, J.D. and Naylor, L.M. 1993. *Surveys for the northern brush-tailed bettong Bettongia tropica on the Mount Carbine Tableland and Mount Lewis, north-east Queensland*. Report to the Queensland Department of Environment and Heritage, Far Northern Regional Centre.

Harrington, G.N. and Sanderson, K.D. 1994. Recent contraction of wet sclerophyll forest in the wet tropics of Queensland due to invasion by rainforest. *Pacific Conservation Biology* 1, 319-327.

IUCN Species Survival Commission. 1994 *IUCN Red List Categories*. IUCN, Gland.

Johnson, C.N. 1995. Relationship between fire, mycophagous mammals and dispersal of ectomycorrhizal fungi in *Eucalyptus* forests. *Oecologia* 104, 467-475.

Johnson, C.N. 1997. Fire and habitat management for a mycophagous marsupial, the Tasmanian bettong *Bettongia gaimardi*. *Australian Journal of Ecology* 22, 101-105.

Johnson, C.N. and McIlwee A.P. 1997. Ecology of the Northern Bettong, *Bettongia tropica*, a tropical mycophagist. *Wildlife Research* 24, 549-559.

Kinnear, J. E., Onus, M.L. and Bromilow, R. N. 1988. Fox control and rock wallaby population dynamics. *Australian Wildlife Research* 12: 435-450.

Laurance, W. F. 1996. *A distributional survey and habitat model for the endangered northern bettong (*Bettongia tropica*) in tropical Queensland*. Report to the Department of Environment, March 1996.

Laurance, W.F. and Harrington, G.N. 1997. Ecological associations of feeding sites of feral pigs in the Queensland Wet Tropics. *Australian Wildlife Research* 24, 579-590

McIlwee, A.P. 1994. *The dietary ecology of three mycophagous marsupials in north-eastern Queensland.* Honours Thesis. Department of Zoology and Tropical Ecology, James Cook University of North Queensland, Townsville.

McIlwee, A.P. and Freeman, A. 1998. *The discovery of Northern Bettongs (*Bettongia tropica*) at Paluma, North Queensland.* Report to the Department of Environment.

Mason, S.G. 1996a. *Evaluating the presence of the European Red Fox (*Vulpes vulpes*) on the Atherton Tablelands: Public Survey.* Report to the Conservation Strategy Branch of the Department of Environment.

Mason, S.G. 1996b. *Evaluating the presence of the European Red Fox (*Vulpes vulpes*) on the Atherton Tablelands: Field Survey and Management Recommendations.* Report to the Conservation Strategy Branch of the Department of Environment.

Pope, L. 2000a. Final report on the conservation genetics of the northern bettong, *Bettongia tropica.* Report to the Department of Environment and Heritage.

Pope, L. 2000b. *Population structure of the northern bettong*. PhD Thesis. Department of Zoology, University of Queensland.

Pope, L., Storch, D., Adams, M., Moritz, C. and Gordon, G. (in press). A phylogeny for the genus *Isoodon* and a range extension for *I. obesulus peninsulae* based on mtDNA control region and morphology. *Australian Journal of Zoology*.

Sattler P. and Williams, R. (eds) 1999. *The conservation status of Queensland's bioregional ecosystems*. Environmental Protection Agency.

Saunders, G., Coman, B., Kinnear, J. and Braysher, M. 1995. *Managing vertebrate pests: Foxes.* Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Seebeck, J.H., Bennett, A.F. and Scott, D.J. 1989. Ecology of the Potoroidae. In Grigg, G., Jarman, P. and Hume I *(eds) Kangaroos, Wallabies and Rat-kangaroos.* Surrey Beatty and Sons. Chipping Norton.

Short, J., Bradshaw, S.D., Giles, J., Prince, R.I.T. and Wilson, G.R. 1992. Re - introduction of macropods (Marsupialia; Macropodia) in Australia - a review. *Biological Conservation* 62, 189-204.

Start, T., Courtneay, J. and Morris, K. 1996. Its Back: The return of the Woylie. *Landscope* Autumn 1996.

Taylor, R.J. 1991. Plants, fungi and bettongs: a fire-dependent co-evolutionary relationship. *Australian Journal of Ecology* 6, 409-411.

Vernes, K. 1998. *Ecology of the Northern Bettong (*Bettongia tropica*) in relation to fire*. Report to Conservation Strategy Branch of the Department of Environment.

Vernes, K. 2000. Ecology of the northern bettong in fire prone wet sclerophyll forest. PhD Thesis in the Department of Zoology and Tropical Ecology, James Cook University of North Queensland, Townsville.

Williams, S. E., Pearson, R. G. and Walsh, P. J. 1996. Distributions and biodiversity of the terrestrial vertebrates of Australia's Wet Tropics: A review of current knowledge*. Pacific Conservaton Biology* 2, 327-362.

Winter, J. W. 1992. *Population assessment of the northern brush-tailed bettong on the Mt Windsor Tableland, north-eastern Queensland.* Report to Conservation Strategy Branch of the Department of Environment.

Winter, J. W. 1997. *Distribution of the northern bettong,* Bettongia tropica, *in north-eastern Australia.* Report to the World Wide Fund for Nature, Australia.

Appendices

Appendix 1. Recovery team structure and representation

Stakeholders	Status
Queensland Parks and Wildlife Service	Lead agency
Environment Australia	Active members
Queensland Department of Natural Resources	Active members
Researchers	Active members
Indigenous interests	not yet joined
Interested public	Active members
Conservation groups	Active members
Shire councils	Active members
Wet Tropics Management Authority	Active members

Groups kept informed, consulted or otherwise involved. Where these are the same as those listed above they represent other sections or specific contacts within the group.

Stakeholders
Environmental Protection Agency
Department of Natural Resources
Department of Primary industries
Researchers
Conservation groups
Developers
Landholders
Traditional owners
Shire councils
Grazing interests
Tourism interests

Appendix 2. Estimated costs of recovery ($000's)

Implementation Schedule										
Task	**Task Description**	**Priority**	**Feasibility**	**Responsible Party**						
					Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
A1.1.1	Collate and map existing data	1	100%	CSIRO	4.05	0.00	0.00	0.00	0.00	4.05
A1.1.2	Develop a predictive habitat	1	90%	QPWS/CSIRO						
	model for Tropical and Rufous				27.59	5.41	5.41	5.41	0.00	43.82
A1.1.3	Survey remaining areas of	1	95%	QPWS						
	potential bettong habitat				15.48	11.88	10.08	0.00	0.00	37.44
A1.1.4	Survey for Tropical Bettong	1	100%	Consultant						
	food resources									
					0.00	139.75	119.75	117.75	0.00	377.25
A1.2.1	Negotiate Tropical Bettong	1	90%	DoE/DNR						
	protection accross tenures at			Community						
	Lamb Range				18.74	13.74	18.74	13.74	13.74	78.70
A1.2.2	Protect and manage other	1	100	DNR/QPWS						
	significant forestry areas				0.00	14.28	9.28	9.28	9.28	42.12
A1.3.1	Establish an experimental	1	95%	Consultant/QPWS						
	fire management mosaic			DNR	0.00	86.28	81.28	81.28	0.00	248.84
A1.3.2	Conduct fire and grazing	1	100%	QPWS/DNR						
	management in other areas				0.00	0.00	0.00	10.10	9.10	19.20
A1.4.1	Monitor Tropical Bettong	1	100%	QPWS						
	populations				14.81	14.81	14.81	14.81	14.81	74.05
A2.1.1	Establish volunteer network	1	100%	community/QPWS						
					8.20	8.20	8.20	8.20	8.20	41.00
A2.1.2	Promote Tropical Bettong	1	100%	community/QPWS						
	recovery				15.21	13.21	13.21	13.21	13.21	68.05
A2.2.1	Conduct a public survey	3	100%	consultant	16.00	0.00	0.00	0.00	16.00	32.00
A3.1.1	Monitor foxes	1	100%	community/DNR/						
				QPWS	0.00	5.14	5.14	5.14	5.14	20.56
A3.1.2	Control foxes when necessary	1	80%	DNR/QPWS	0.00	24.70	3.70	3.70	3.70	35.80
A3.2.1	Quantify pig diet in Tropical	2	95%	consultant						
	Bettong habitat				0.00	0.00	59.60	0.00	0.00	59.60
A3.2.2	Compare foraging sites of pigs	3	95%	consultant						
	and Tropical Bettongs				0.00	0.00	0.00	30.58	0.00	30.58
A3.2.3	Control pigs if necessary	3	75%	consultant/DNR/						
				QPWS	0.00	0.00	0.00	64.40	18.17	82.57
A4.1.1	Maintain captive colony	1	100%	QPWS	30.44	30.44	30.44	30.44	30.44	152.20
A4.1.2	Identify appropriate	1	100%	QPWS						
	re-introduction site				0.00	0.00	0.00	6.85	0.00	6.85
A4.1.3	Rehabilitate degraded habitat	2	80%	DNR/QPWS	0.00	0.00	0.00	5.92	5.92	11.84
A4.1.4	Re-introduce and monitor	1	100%	QPWS/DNR	0.00	0.00	0.00	55.53	10.42	65.95
A5.1.1	Support NGO attendence	2	100%	NGO	3.00	3.00	3.00	3.00	3.00	15.00
A5.1.2	Conduct major review	1	100%	consultant	0.00	0.00	0.00	0.00	9.00	9.00
A5.1.3	Rewrite recovery plan	1	100%	QPWS	0.00	0.00	0.00	0.00	5.00	5.00
	Total/year (000's)				153.52	370.84	382.64	479.34	175.13	1561.47