Australian Government

Department of the Environment and Heritage

BACKGROUND INFORMATION
FOR THE

Abbott's Booby

Papsasula abbotti
RECOVERY PLAN

Department of the Environment and Heritage

Based on a document prepared by Penny Olsen (2001)

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http://www.deh.gov.au/biodiversity/threatened/recovery/list-common.html
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Community Information Unit
Department of the Environment and Heritage
GPO Box 787
Canberra ACT 2601
Ph: 1800 803 772

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http://www.deh.gov.au/biodiversity/threatened/recovery/list-common.html
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Species Information

Conservation status

Abbott's booby is listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

In recent years, the species has been uplisted internationally from Endangered to Critically Endangered (BirdLife International 2000; Hilton-Taylor 2000; IUCN 2001), based largely on the Action Plan for Australian Birds (Garnett and Crowley 2000), due to change in assessment procedures rather than a deterioration of the situation. It meets 1994 IUCN Red List (IUCN 1994) Criteria A2c,e and B1+2b,c,e:

> A2 c and e the population is projected to suffer an 80% population reduction over the next three generations (in this case, c. 90-120 years) based on a decline in (c) the area of occupancy, extent of occurrence and/or quality of habitat; and (e) the effects of introduced taxa, in this case, crazy ants.
>
> B1 + 2 b, c and e the extent of occurrence is estimated to be less than 100 km^2 or the area of occupancy is estimated at less than 10 km^2 and the species is known to exist at only 1 location and a continuing decline is inferred or projected in the following: (b) area of occupancy; (c) area, extent and/or quality of habitat; and (e) the number of mature individuals.

Under the revised IUCN criteria (2001) this is equivalent to A2c,e and B1+2a,bii,iii,v, with identical definitions.

Description and taxonomy

Abbott's booby *Papasula abbotti* is a large, long-lived seabird, with the only known extant nesting colony on Christmas Island. It is an unusual black and white, large-headed, tree-nesting booby, with a distinctive hooked bill. Originally described, as *Sula abbotti* (Ramsay 1893), from a specimen collected northwest of Madagascar in 1892, it is one of the largest of the seven species in the family Sulidae, the gannets and boobies. More recently it has been recognised as unique among sulids in osteology (Olson and Warheit 1988), breeding biology and behaviour (Nelson 1971), and lack of distinctive juvenile plumage (Carboneras 1992), and placed in its own genus (Olson and Warheit 1988; Christidis and Boles 1994). It is thought to be the most primitive Sulidae, a family that belongs to one of the most ancient bird orders, probably originating in the late Cretaceous, more than 60 million years ago (Carboneras 1992).

Previous Distribution

Abbott's booby was described from a specimen allegedly collected from Assumption Is., northwest of Madagascar, by the American naturalist W.L. Abbott in 1892. There has been some debate as to whether the specimen was collected from Assumption Is or nearby Glorioso Is (Gibson-Hill 1950; Nelson 1974, 1978; Stoddart 1981). Regardless, all known breeding populations in the western Indian Ocean, near Madagascar, had disappeared by 1926-30 (Vesey-Fitzgerald 1941; Stoddard 1981; Carboneras 1992). This was generally attributed to forest clearance (Nelson 1978; Steadman *et al.* 1988), although harvesting by humans (Steadman *et al.* 1988) may have contributed. Fossil remains were recently found in the Solomon Is, in the western Pacific Ocean, and a proposed subspecies identified from the Tahuata and Hiva Islands in the Marquesa Group (Steadman *et al.* 1988), indicating a wider prehistoric range.

Life history and ecology

Its habit of roosting and nesting high in tall rainforest trees and foraging far out to sea has made study of Abbott's booby difficult. Two reports summarise most of the life history information:

Nelson and Powell (1986) analysed results of extensive field studies on breeding biology between the mid 1970s and 1982; and Reville *et al.* (1990a) summarised results of an intensive study of breeding biology and population dynamics between 1983 and 1989. Most information is from unmarked individuals and, except at the nest site, it is difficult to distinguish between free-flying immatures and adults.

Breeding biology

Abbott's booby is presumed to form long-term pair bonds and return to the same nest site for each breeding attempt, as in other sulids. It is less gregarious than other members of the family, nesting in loose colonies with a maximum recorded density of 20 pairs/ha, occasionally several pairs to a tree, but typically less than 5 pairs/ha, each in their own tree (Marchant and Higgins 1990).

The breeding season commences in March, when established pairs begin returning to nest sites and start collecting nest material (Nelson and Powell 1986; Reville *et al.* 1987). Egg-laying may occur any time between April and October, but most pairs lay between mid-May and mid-July (Nelson and Powell 1986). Although there is a regular annual breeding season, most pairs can only breed biennially due to the long period of dependence. About 5% of pairs succeed in raising successful fledglings from eggs laid in consecutive years, but only if the young of the previous year becomes independent in June or July.

Pairs build a substantial stick nest, lined with green-leaved twigs, 10-40m from the ground, in an open-crowned, emergent tree. The pair moves nest site only if they have been repeatedly unsuccessful or the site has been destroyed. When displaced they probably move a short distance (Nelson and Powell 1986; Reville *et al.* 1990b). Therefore, it takes a pair many years to move away from an area of disturbance.

Egg-laying may occur as early as 2-3 weeks after return to the nest site, but pre-laying activities usually last about 2 months. Both parents share incubation of a single, thick-shelled egg, which is incubated with the webs of the feet. The eggs are the largest and heaviest, and the c. 56 day incubation is by far the longest within the *Sulidae* (Nelson 1971).

Most young hatch between June and November (Reville *et al.* 1987), are brooded on top of the webs of the feet and feed directly from their parent's mouth or throat. Naked at hatching, by 6-7 weeks they have a thick white down. They spend 5 months in the nest or, if it has disintegrated, at the site, and another 7.5 months in post-fledging dependency. Dependent fledglings return to the nest to be fed once or twice a week by both parents. A slow growth rate may adapt the chicks to extended periods without food (Nelson 1978). The mean period from hatching to fledging is 151 days (range 140-175, n=11); free-flying juveniles remain dependent on their parents for a further 230 days (162-280); and the total time from hatching to independence is, on average, 363 days (314-418, n=22)(Nelson and Powell 1986). Hence, the complete cycle from laying to fledging can take between 486 and 504 days.

Foraging and movements

Abbott's booby is a highly aerial, pelagic feeder, often spending long periods at sea, several hundred kilometres from land. Although little is known about feeding habits it appears to hunt by plunge diving, mainly for squid and fish, including flying fish (Nelson and Powell 1986; Reville *et al.* 1988). It has an unusual serrated bill with slightly hooked tip.

When breeding, the booby departs the island on long fishing trips (Nelson 1971, 1972) and is suggested to travel as far as 400km to feeding grounds (Becking 1976), but few have been seen at sea and the location of fishing areas is not confirmed. Christmas Island is relatively close to cold water upwelling(s) south of Java (e.g., Wyrtki 1962) which are thought to provide abundant seasonal food, increasing about the time of hatching of eggs. In addition, strong El Niño events in the Pacific Ocean may result in lower sea temperatures in the Indonesian area, and a number of seabirds may benefit from the resultant increased feeding opportunities (Quinn *et al.* 1978; Rasmusson and Carpenter 1982; Carboneras 1992). Reville *et al.* (1987) reported a significant correlation between breeding success and sea-surface temperature in the shallow seas of the Indonesian archipelago: breeding success was reduced in years with short periods of cool water upwelling.

Although they make extended foraging trips, breeding adults are largely sedentary. Independent young and non-breeders live away from the island and may travel large distances, dispersing across tropical waters to areas food is available: several individuals have been recorded near the Chagos Archipelago, some 4000km west of Christmas Island (Hirons *et al.* 1976), and in the Banda Sea, about 2000km northeast of the island (van Balen 1996).

Breeding success and age at maturity

Breeding success is low (Carboneras 1992); less than 50% of pairs that attempt to breed are successful in fledging a youngster (Reville *et al.* 1987). Twenty-five percent of nestlings die, most in the first four weeks after hatching, lost to starvation and predation during periods when they are unattended (Reville *et al.* 1987; Marchant and Higgins 1990). Cyclones have been recorded to kill up to 20% of nearly fledged and free-flying young (Marchant and Higgins 1990). Pairs are estimated to rear an average of 2 offspring every 9.5 years (Reville *et al.* 1987). Age of first breeding is uncertain, but Reville *et al.* (1990a) had some evidence that it was at about eight years. Other sulids mature earlier, between 3 and 6 years depending on the species (Carboneras 1992).

Adult mortality and life expectancy

Results from monitoring indicated adult mortality rate between 1983 and 1988 averaged 4.5% (Reville *et al.* 1990a), not atypical for sulids (Caboneras 1992). Adult mortality rate was influenced by the proximity of the roost or nest site to clearings: in areas unaffected by clearings 3.2%, downwind of clearings 5.4%. Downwind of clearings, wind turbulence in the canopy is increased, leading Reville *et al.* (1990a) to suggest two reasons for increased adult mortality:

- difficulty in landing in the increased turbulence. If an adult misses its footing and falls to the forest floor it will starve unless it can climb through hanging vegetation to the canopy. Adults cannot take off from the ground except in very open areas (Meek 1997); and
- stress brought about by more frequent nesting attempts. Nests failed more often downwind of clearings; to produce the same output of chicks, pairs in these areas were laying three eggs to every two for pairs upwind of clearings.

Starvation, bad weather, and accidents, often in concert, are probably the most common cause of death (Nelson 1980). Accidents at breeding colonies, particularly landing accidents, are a common cause of adult mortality among seabirds. Reville *et al.* (1990a) suggested that the average life span of Abbott’s booby could be about 40 years, which is typical for sulids (Carboneras 1992).

Demography

Using estimates of breeding success and pre-breeding mortality, Nelson and Powell (1986) calculated it would take 24 years for a breeding pair to replace itself. Reville *et al.* (1990a) used different information and concluded that it takes between 25 and 31 years for parents to produce their replacements.

Nelson and Powell (1986) calculated that for the population to remain stable the annual mortality rate must be 4% or less, or the survival rate between independence and breeding age must be greater than that for other sulids. Evidence from a number of sources suggests that in other sulids, 40% of independent young reach breeding age (Nelson and Powell 1986). Reville *et al*.’s (1990a) annual adult mortality rate of 4.5% together with their estimate that between 28 and 35% of fledglings survive from independence to breeding age, indicate that the Abbott’s booby population may not meet these expectations.

However, these figures average the different mortality rates for disturbed (breeding areas affected by wind turbulence) and undisturbed nest areas. If the whole population resided in undisturbed areas then according to Nelson and Powell’s (1986) model, the mortality rate of 3.2% would permit sufficient recruitment to maintain a stable population. In 1986/87, 42.6% of the known population of breeding pairs were nesting within 305m of clearings (Reville *et al.* 1990b). The surveys of 1991 found that 36% of the population were in areas affected by clearings (Yorkston and Green, 1997). Adjusting for these figures, the adult mortality rate for the total population is 4%, which may be adequate for recruitment.

A more recent demographic model (simplified life table, see Attachment 1) for Abbott’s booby was developed by Dr Greg Hood (Meek 1997) to model the effect of clearing on the finite rate of population change, and to examine whether rehabilitation of disturbed areas increases the rate of change. The model shows that population growth is most sensitive to adult survival, with age at first breeding, juvenile and immature survival being much less important; it also highlights the importance of habitat, particularly good quality habitat, to population change.

Threats and issues

Identification of threats

Modification and destruction of breeding habitat

Abbott’s booby nests in tall rainforest trees, mostly in uneven canopy containing emergent trees. Nesting density is highest along crests of gullies and slopes that can easily be approached from the northwest (Nelson and Powell, 1986). Since the turn of the twentieth century mining for phosphate has been an important part of the island’s economy. Yet before 1970 over 90% of the island was still forested. As a result of continued mining, almost 24% of the island’s vegetation has been cleared, including one-third of the plateau forest used by Abbott’s booby for nesting. Loss of habitat to clearance for mining ceased in 1987 but the open minefields continue to cause a number of adverse effects on survival of adults and breeding success (Reville *et al.* 1990b), and on breeding habitat. Together these losses have probably constituted the greatest threat the survival of the species.

Currently, most remaining Abbott's booby habitat is protected within Christmas Island National Park. The Park was declared in 1980 to provide protection for some Abbott's booby nesting areas. To encompass most of the remaining habitat, in 1986, two extensions were added and, in 1989, further extensions increased the park to approximately 63% of the island (Environment Australia 2002). There are now only a few relatively small areas used by Abbott's booby for nesting outside the park.

Despite this protection, Abbott's booby breeding habitat is still threatened by a range of processes. These include further mining operations, proximity of existing breeding sites to old mining fields, introduced weeds, introduced pest animals and other anthropogenic threats which could impede/delay vegetation restoration. There is also a proposal to clear and mine nine new sites, which may impact on Abbott's booby habitat.

Mining and removal of stockpiles

Phosphate was first discovered on Christmas Island in 1887. The British government annexed the island for the purposes of phosphate mining and began settlement in 1888. For almost 100 years, mining has provided the main source of employment. The first shipment of phosphate left the island in 1895. Australia and New Zealand purchased the lease and assets of the island in 1948, and sovereignty was passed to the Australian Government in 1958. Phosphate mining increased in the 1960s and reached peak production in 1973-74. The opening of new mining sites and the associated clearance of rainforest ceased in 1987.

In 1990 a lease providing for limited phosphate mining was signed between the Australian Government and a private company, Phosphate Resources Limited (PRL). A subsequent lease was signed in 1997, came into effect in February 1998, and is in place until 2019. The Mining Schedule was suspended in 1999, reinstated in principle in July 2002 and is being renegotiated as part of a limited review of the Mining Lease. This operation has been limited to previously mined areas, and a condition of the lease is that no primary rainforest be cleared and a conservation levy is paid to the Australian Government (Environment Australia 2002). The levy was formerly administered by Parks Australia North (PAN) towards implementing the Christmas Island Rainforest Rehabilitation Program (CIRRP), but is now collected and administered by the Department of Transport and Regional Services (DOTARS). A MOU between PAN and DOTARS was signed in February 2004 to allow PAN to continue the CIRRP within Christmas Island National Park.

Whilst mining is not permitted in the park, some stockpiles of topsoil or phosphate material inside the park or which straddle the park boundaries may be considered for removal (Environment Australia 2002). PRL is required, through the Environmental Management Plan required under their lease, to provide notice to Parks Australia of intention to remove vegetation. This is the first step in removing stockpiles which have rainforest regrowth. Some of this type of regrowth is many years old. The Christmas Island National Park Management Plan (Prescription 7.3 g) requires that stockpiles may be removed provided the activity benefits the management of the park, and does not have a significant environmental impact on the Park. Further, if removal is a 'mining operation' within s355 of the EPBC Act, approval of the Governor-General will be required.

Removal of stockpiles which are extensively covered by regrowth will create further openings within the forest, and may result in increased wind turbulence downwind of the sites. The impact of these activities on the breeding habitat of Abbott's booby will depend on the proximity and direction of the stockpiles from breeding sites. Sites which are particularly important in this regard are those at the top of the list in Table 1. Regard should also be given to the effect of removal of the stockpiles themselves on wind patterns, to ensure that wind turbulence problems for nesting Abbott's boobies are not exacerbated by the removal. In places where it is advantageous to have stockpiles removed, sufficient should be left to backfill minefields and support revegetation.

*Table 1. Priorities for rehabilitation of Christmas Island mining fields (Environment Australia 2002, p. 94). Mine fields of relevance to Abbott's booby are bolded. *Sites partly taken by Immigration Reception and Processing Centre*

Mining field	Land tenure	Mine lease (ML)	Priority
Field 20 West	Mine lease	ML 110	1
Field 20 East	Mine lease	ML 109	2
Field 18D	Mine lease	ML 108	3
Field 27*	Mine lease	ML 138	4
500 foot quarry	Mine lease	ML 136	5
Field 23	National Park/Mine lease	ML 116, 117	6
Field 23A	National Park		7
Completion of Field 21	National Park/Mine lease	ML111, 112, 113	8
Field 18 North	Mine lease	ML 105	9
Field 18 South	Mine lease	ML 106 (part only)	10
Field 25 South	National Park/Mine lease	ML 139	11
ML 107	Mine lease	ML 107	12
Field 17 North	National Park/Mine lease	ML 101	13
LB7 North	Mine lease	ML 132	14
Field 26	National Park/Mine lease	ML 140	15
LB1	Mine lease	ML 123	16
LB2A	Mine lease/Crown land	ML 130	17
RH1 and RH2	Mine lease	Ml 121 and 124	18

Open mined areas and wind turbulence

Mining operations have resulted in approximately 70 clearings across the island, covering about 3,300ha or 24% of the island (Carew-Reid 1987; Environment Australia 2002). Where these areas are adjacent to Abbott's booby nesting sites, they pose a threat to breeding success and survival of adults (Fig. 1). Forested areas up to 300m downwind of cleared areas suffer much greater wind turbulence in the canopy than other forested areas (Brett 1989; Reville *et al.* 1990b). Abbott's boobies nesting downwind of clearings have lower breeding success than those upwind of clearings. Furthermore, experienced breeders move nest sites more often and there is a higher proportion of consistently unsuccessful sites downwind of clearings compared with pairs nesting upwind of clearings (Reville *et al.* 1990b). Since forest clearing, there has been a slow shift of nest sites away from cleared areas to areas that were previously little used. These newer areas are more remote from clearings, but breeding success is lower than that upwind of clearings (Reville *et al.* 1990b). The edge of the forest downwind of clearings also shows signs of dieback due to increased wind exposure. Targeted re-afforestation of cleared areas has been recommended to reduce wind turbulence downwind (Reville *et al.* 1990b).

Carew-Reid suggested that 832ha or 26% of the area cleared for mining needed to be rehabilitated as a priority for Abbott's booby conservation, and ranked clearings in order of importance (Carew-Reid 1987). The Christmas Island Rainforest Rehabilitation Program (CIRRP) commenced in 1989 following the recommendations of Carew-Reid (1987). The aim was to revegetate clearings in areas adjacent Abbott's booby nesting habitat in an attempt to reduce the wind turbulence created by the clearings. The planting program used both fast-growing pioneer species and slower-growing forest species.

Approximately 200ha have been rehabilitated, some with revegetation 22 years old, with varying levels of success (Environment Australia 2002)(Fig. 2). However, the effectiveness in improving breeding success and survival of Abbott's booby has not been assessed. Reviews of the CIRRP (Hopkins *et al.* 1996; Centre for Mined Land Rehabilitation 2000, cited in Environment Australia 2002) were critical of the program and recommended major changes. As a result of these reviews, in 2000 new rehabilitation methods were developed and subsequently adopted (Environment Australia 2002).

How long it takes before the effects of rehabilitation plantings benefit Abbott's booby is still unknown. Hopkins *et al.* (1996) criticised the absence of monitoring to examine the impact of the CIRRP on Abbott's booby breeding success. Rehabilitation probably begins to reduce wind velocity in the clearings once the plants form an almost continuous canopy over the clearing, and this occurs about three to four years after planting (M. Jeffery, pers. comm. 2002), but it will probably take at least ten years before rehabilitation has an effect on the wind turbulence in the canopy (see Brett 1989). Wind tunnel experiments (Brett 1989) demonstrated that turbulence in the canopy was relatively gustier near mined areas, especially downwind, and informed understanding of impacts on the boobies (Yorkston & Green 1997). Developing a refined model could guide rehabilitation, by predicting wind turbulence effects of various rehabilitation procedures, levels of growth, stockpile removal, orientation and other interacting factors.

Prioritisation of sites to be rehabilitated by the CIRRP is based largely on areas where there are high densities of nesting Abbott's booby. Areas requiring rehabilitation and the current priorities for this work are summarised in Table 1. Rehabilitation of these areas is a prescribed management action (Action 7.3 a) in the Christmas Island National Park Management Plan. Funding for the CIRRP has been provided from a levy paid to the Australian Government by the holder of the mining lease, PRL. Previously, the levy was administered by PAN, it is now collected and administered by the Department of Transport and Regional Services (DOTARS). A MOU between PAN and DOTARS was signed in February 2004 to allow PAN to continue the CIRRP within Christmas Island National Park. The mining lease schedule was suspended in June 1999, while phosphate removal was focused away from the Park on preparation of the Asia Pacific Space Centre site. The lease schedule is being renegotiated.

Weeds

Many exotic trees, shrubs and vines are established in disturbed areas throughout the island. So far, most intact rainforest has not been invaded. Many old mining sites were planted with exotics under previous rehabilitation programs and will require years of weed suppression before exotic populations are under control. Whilst weeds remain in these areas, they may pose a risk to adjacent rainforest, much of which is important breeding habitat for Abbott's booby.

A weed management strategy for Christmas Island has been prepared (Hart 1998), and weed control commenced in 1999. Most work currently takes place in old mine fields about to be rehabilitated, or areas that have been rehabilitated (Environment Australia 2002). Information on weed species and management is in the Park Management Plan (Environment Australia 2002).

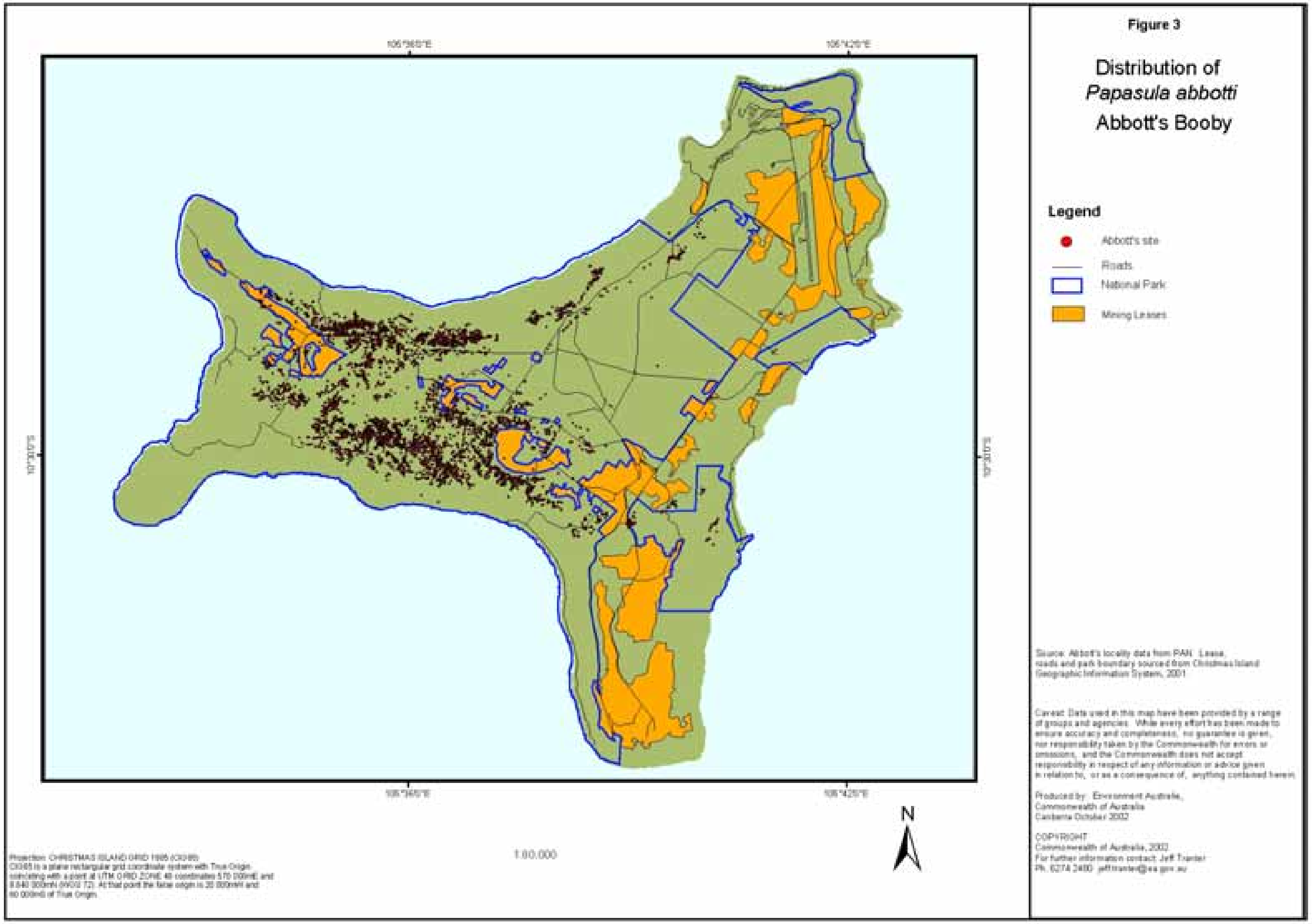

Figure 1. Location of mining fields in relation to traditional Abbott's booby nest sites and Christmas Island National Park boundary

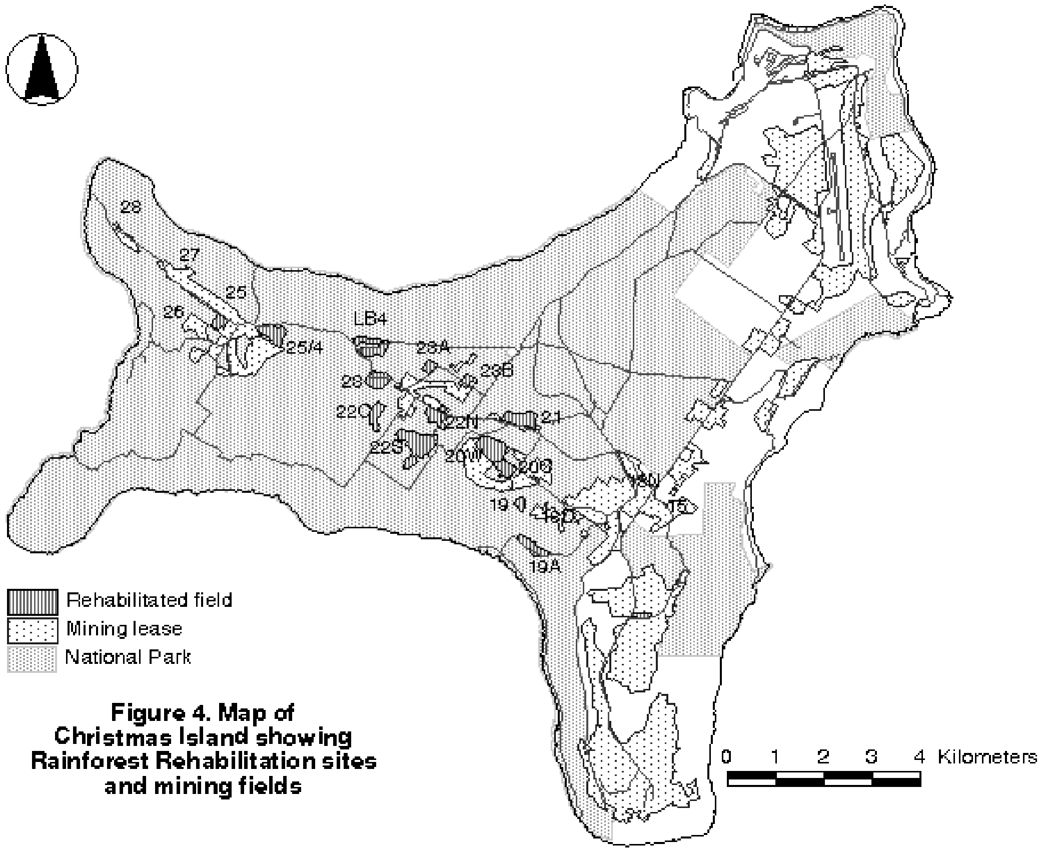

Figure 2. Mining field identification numbers

Yellow crazy ant

Originally from Africa, the Yellow crazy ant *Anoplolepsis gracileps* has been spread through South-east Asia and the Pacific. In Australia, it is also found in the northern gulf area of the Northern Territory and on Christmas Island. The ant was accidentally introduced to Christmas Island more than 70 years ago (Clark 1941). In recent years, it began to form high density, multi-queened super-colonies (first noticed in 1989) and spread rapidly to infest an estimated 24% of the island's natural forest area by 2001 (Environment Australia 2002). By killing Red Crabs *Gecaroidea natalis* and farming scale insects which damage the trees (O'Dowd *et al.* 1999), the ants are devastating the island's ecosystem (Environment Australia 2002). In infested areas, elimination of Red Crabs has a marked effect on forest composition and structure, and litter dynamics. Further, the feeding activities of the ants and their mutualistic scale insects can fatally stress large trees and cause widespread canopy dieback in areas of high infestation. These threats are particularly severe where the ant forms super-colonies.

The ant forages and nests from ground level to well into the canopy (Greenslade 1972), where it may attack nestlings (A. Andersen, in Garnett and Crowley 2000). However, such an interaction has not been observed. The recent the helicopter survey (Attachment 2) did not indicate a change in nest activity around crazy ant distributions.

Crazy ants are regarded as the most serious threat to the conservation of biodiversity on Christmas Island (Environment Australia 2002). As a consequence, management and research on crazy ants has been given immediate and high priority. The National Park Management Plan (Environment Australia 2002) has prescribed the maintenance of the existing control program as a high priority (Prescription 8.3i). Particular care must be taken with control operations taken where ant infestations are closest to booby nest trees (Fig. 3).

In September 2002 aerial baiting was undertaken, with all know supercolonies treated. Results indicate the program was successful in controlling supercolonies over 2500ha of Christmas Island. Crazy ants are still present in low densities on Christmas Island, so further high densities of crazy ants may establish in the terrace forests without warning. PAN staff will continue to monitor any new supercolony formation and treat by hand baiting over the next few years.

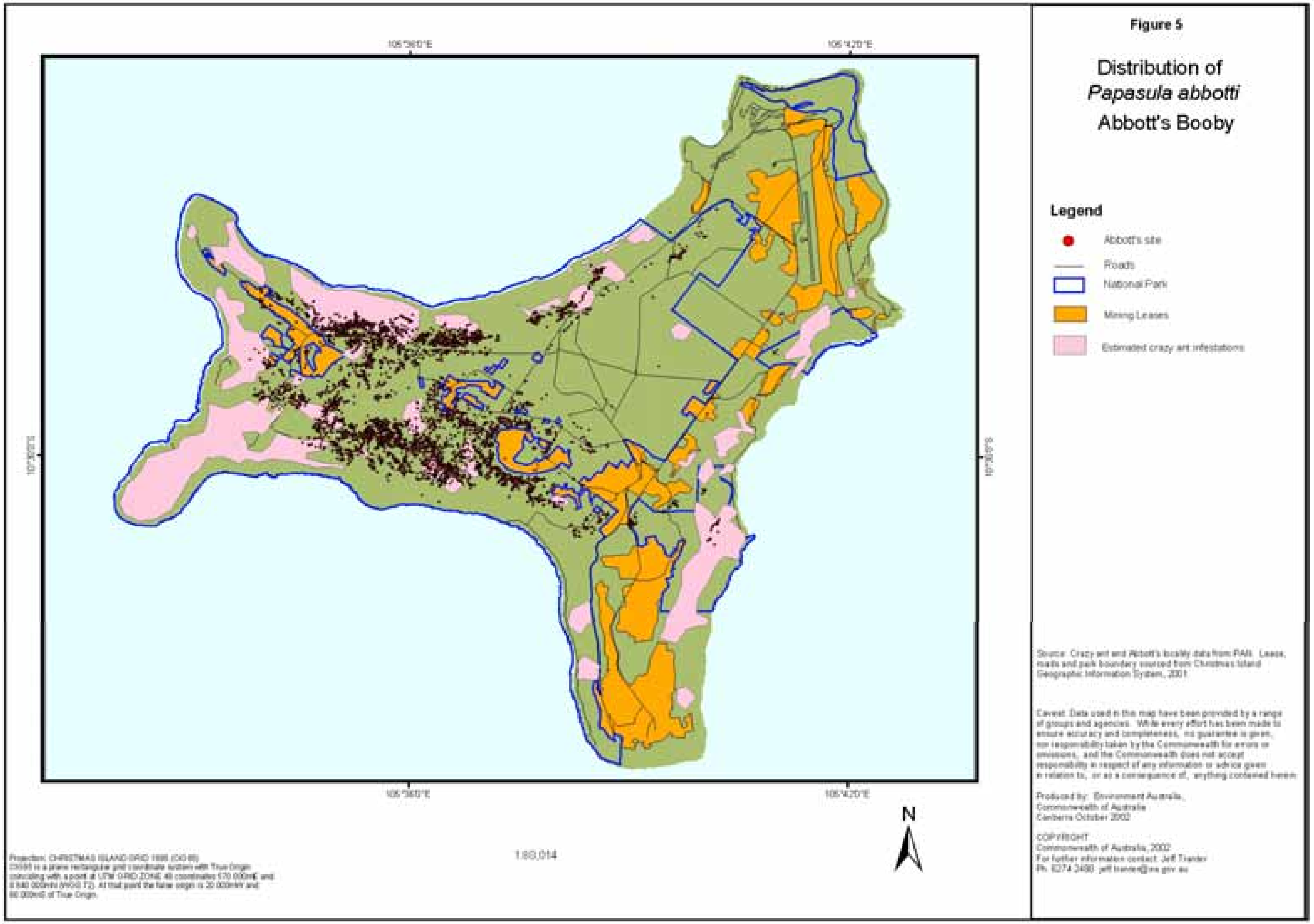

Figure 3. Yellow crazy ant infestations (estimated by Environment Australia mid-2002) in relation to traditional Abbott's booby nest sites

Immigration Reception and Processing Centre

One mining field at northwest point (ML 138), scheduled for rehabilitation at priority 4, is the site for the construction of an Immigration Reception and Processing Centre (IRPC) (Fig. 4). Some rainforest clearing may be required to upgrade the road and permit installation of services, although there is no intention to install any further services other than a buried sewage rising main that will be within the existing road reserve. Any upgrade to the road will be designed to best practice parameters to reduce overall environmental impact of both construction and operation. The road traverses 10 km of rainforest used extensively by nesting Abbott's boobies. There is potential for the destruction of Abbott's booby nesting trees when any upgrading work is carried out and any removal of trees may create gaps in the canopy, increasing wind shear turbulence which could result in reduced breeding success for nests downwind. However, there is no current intention to remove mature trees. Any rehabilitation of the area surrounding the IRPC will be in accordance with the CIRRP.

In addition, it is anticipated that there will be an increase in road traffic as a result of the IRPC. Considerable dust is likely to be created by the increased traffic, which may negatively impact on the boobies and vegetation downwind, although this is expected to be mitigated by the wet season suppressing the dust and the intermittent occupancy of the facility. Sealing of the perimeter road is proposed due to the larger volume of traffic. This will minimise both dust and disturbance of boobies and vegetation by maintenance activities, although the access road is expected to remain unsealed.

Construction of the facility will mean that the site can only be partially rehabilitated and may lead to continued wind-shear effects on adjacent Abbott's booby nests. The Department of Finance and Administration has signed an MOU with the Director of National Parks that provides for $813,000 to be spent over 3 years designing and executing a biodiversity monitoring programme. The object is to monitor the effects of the IRPC on biodiversity (with particular reference to Abbott's booby) and recommend and mitigating measures that may need to be implemented as a result of the construction and operation of the facility.

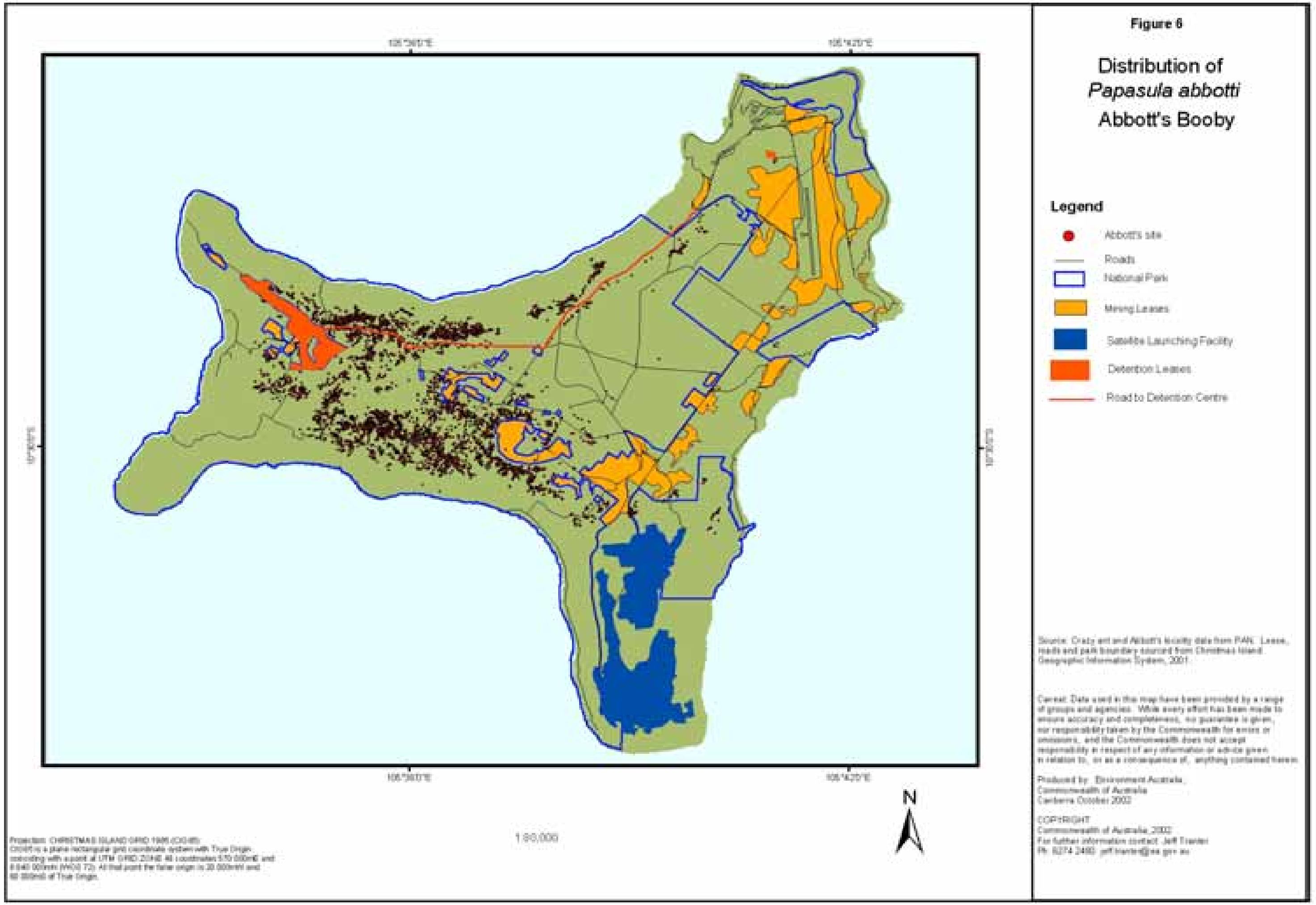

Figure 4. Location of Immigration Reception and Processing Centre and access road, and Australia Pacific Space Facility, in relation traditional Abbott's booby nest sites.

Asia Pacific Space Centre
In January 1998, Asia Pacific Space Centre Pty Ltd (APSC) proposed development of a communications satellite launching facility on Christmas Island, to offer launch facilities for a range of commercial non-military users. The facility is to be located at South Point, some 5 km away from the nearest known Abbott's booby breeding site.

At South Point, APSC will occupy a total of 85ha, on which approximately 30% will be built - a Technical Complex, Launch Complex and Mission Control (Fig. 4). Housing for 250-300 workers will be provided through a mix of on-site construction camps and new housing proposed to be built adjacent to the airport (Anon. 2000; http://www.dotrs.gov.au/terr/xmas/xmas2.htm). In 2001, the Commonwealth committed $100 million in support of the proposal, including $68 million for Common Use Infrastructure improvements, which include an extension of the existing airport runway to handle wide-bodied aircraft, constructing an additional seaport on the East coast and an upgrade of the existing Linkwater Road from the port.

The expected lifespan of the APSC is 15-20 years with ongoing prospects dependent on market forces. Site preparation and commissioning of facilities commenced in 2002. During the environmental assessment of the project, which involved a public comment phase, concerns were raised about the impact of construction and operational activities (including noise and burnt and unburnt fuel) on seabird colonies. Other concerns included the impact of fire on rainforest and terrace forest, vegetation clearance associated with the facility, and long term effects on bird breeding.

Given that the site for the satellite launching facility is some distance from Abbott's booby breeding sites (closest is a small group that nests c. 5 km away), and that satellites will be launched over the sea in easterly and southerly directions (http://www.space-technology.com/projects/christmas/index.html), there would seem little likelihood of direct impact on this species. Nevertheless, there is a chance that falling debris, chemicals or fire from wayward or failed launches may destroy booby habitat (other than nesting sites) or kill birds. In addition, the Draft EIS, under the *Environment Protection (Impact of Proposals) Act 1974*, recognised the possibility that launch noise may have some impact on the fauna on South Point and provided a contour map of the noise levels estimated from a rocket at 50m in height. At 8km from the launch, sound levels are predicted to be 86dBA, for up to 45 seconds (with a gradual build-up). Asia Pacific plans to be launching 10-12 satellites per year. It is not known what impact these sudden bursts of noise will have on nesting Abbott's boobies or other wildlife.

Potentially, launch activity sound could affect seabird colonies in the following ways:

- individual nests deserted temporarily, leaving chicks or eggs exposed to weather and/or predators;
- individual nests permanently abandoned causing loss of chicks or eggs;
- egg breakage, or injury or death of juveniles or adults, as a result of startle responses (Greater Frigatebirds or Abbott's boobies that fall to the ground are often unable to become airborne again and die unless given human assistance);
- abandonment of nesting colony by one or more species.

Seabirds are generally more sensitive to disturbance in the early parts of the breeding cycle (Stokes *et al.* 1996; WBM Oceanics/GBRMPA 1997). Identifying periods of particular sensitivity may enable withholding launches at that time to avoid impacts. However, this is not possible for Abbott's booby, which has an extensive breeding season and is only one of several species potentially impacted.

In assessing the development proposal the Minister for the Environment and Heritage advised there was no environmental reason why the project should not proceed provided the proponent accepted the stringent environmental conditions set out in the Environment Australia (now the Department of the Environment and Heritage) recommendations. These recommendations formed the basis of development conditions. The conditions included that APSC shall, in consultation with Environment Australia and others, develop an Environmental Management Plan to be approved by the Minister for the Environment and Heritage, and that compliance with the agreed EMP is a condition of launch permits. Another condition includes that as part of the EMP, APSC shall:

a) develop and undertake a seabird monitoring program including collection of baseline data for at least 3 years …;
c) identify a range of possible responses and appropriate trigger criteria to ensure that the seabird population and biodiversity of Christmas Island are not significantly affected by the construction and operation of the satellite launching facility at South Point;
d) monitor the effect of the construction and operation noise on bird life at the South Point site … ;
f) develop an adaptive response management regime to the approval of DEH …;
g) where an impact is considered a significant impact by the Minister for Environment and Heritage, further launches must be suspended while possible causes are investigated by a panel of experts …No further launches will occur until such a time that the Minister for Environment and Heritage in consultation with relevant Ministers has determined that further launches are possible without bringing about further decline, or would not prevent the recovery of the seabird population.
h) the EMP must identify threshold(s) of significant impact upon the seabird colony, for approval by the Minister for the Environment and Heritage.

These conditions have been agreed to by APSC, and the EMP is being developed.

Inadequate knowledge of population trends

Accurate estimates of the size and reproductive success of the breeding population are essential, both to gauge the status of the species and to guide habitat restoration and the control of threats. Rugged terrain, the difficulties inherent in locating breeding sites high in the canopy, the absence of a variable proportion of the breeding population each year, and time constraints, combine to make it difficult to obtain precise and accurate population estimates (Yorkston and Green 1997).

Despite these difficulties, estimating population size has been attempted on a number of occasions, with varying degrees of success. The history of these studies and the methods employed are summarised in Yorkston and Green (1997), Reville *et al.* (1990a), Dunn and Hill (1998) and at Attachment 3. Because of the inherent difficulties in detecting and counting Abbott’s boobies, population estimation and monitoring is resource-intensive. For example, the Abbott’s Booby Monitoring Program, from 1983 to 1989, employed three full-time staff for the duration of the study. A reduced program between 1989 and 1992 had a permanent staff of one, with additional staff to assist field surveys. After 1992 the program underwent a further reduction, and by 1994 all monitoring ceased. Until an aerial survey of nest sites was undertaken in September 2002, no population monitoring had been undertaken since 1994.

Dunn and Hill (1998) believed monitoring that had been carried out since the conclusion of the 1989 Monitoring Program was insufficient to meet the objectives of the initial draft Recovery Plan (Dunn and Hill 1995). A review of the Program, and subsequent monitoring efforts, by an expert panel reached a similar conclusion and recommended a new program be developed (Meek 1997). They also recommended expert statistical advice be sought in developing monitoring methods.

Before developing a method it is necessary to define the objective, to determine if (1) an estimate of population size in a given year with an estimate of precision is required, or if (2) detection of population change is sufficient for management. The survey method may be different to achieve these aims. For example, if estimating the number of breeding pairs, it is necessary to predict populations or the number of nests in areas not sampled for a given habitat type or strata. On the other hand, if quantifying change with high precision, then the important design consideration is to essentially re-sample or re-count the same transects/quadrats/core sites from one period of interest (year) to another. Re-sampling a set of quadrats increases precision of estimates when birds show high site fidelity, which is a reasonable assumption for Abbott's booby as birds apparently re-use the same nesting sites from year to year and there are few other options available on Christmas Island to support the current breeding population.

To measure recovery and the impact of conservation management actions such as rehabilitation of mining fields, Meek (1997) concluded it is more important to track changes in population size from year to year than to measure total population size. As a consequence, future monitoring should probably focus primarily on monitoring change, requiring establishment of a relatively small set of foundation sites. If carefully designed, such a program should also permit estimation of annual population size for Christmas Island, although confidence intervals for such an extrapolation would be large. This approach will provide both cost and efficiency benefits over broad-scale or island-wide census.

Nevertheless, the apparent success of the recent helicopter survey in monitoring nests (Attachment 2) indicates this technique should be considered as a potential option for future monitoring. If a helicopter becomes available, whole-of-island monitoring of the population is a practical possibility.

If possible, it would be desirable for the monitoring program to incorporate some or all of the core sites used previously. Monitoring also needs to allow assessment of rates of change in areas both adjacent to and removed from former mining sites, and of breeding success, to provide answers on the effectiveness of rehabilitation practices (Hopkins *et al.* 1996). Measures of breeding success in both these strata would also be used to improve understanding of the effects of climatic events on foraging. To improve understanding of the affect of sea surface temperatures on breeding success, as reported by Reville *et al.* (1990a), and to help separate local impacts from at sea factors, data on the Southern Oscillation Index can be readily accessed on the web. As much as possible the program should also accommodate monitoring needs of APSC and IRPC, to provide comparable and scientifically meaningful data to all parties.

Global warming and other impacts

Sea Surface Temperature Conditions

Abbott's booby probably rely on a seasonal increase in fish numbers associated with cold water upwellings to raise their young (Nelson 1980; Reville *et al.* 1990a). Low sea surface temperatures and rich feeding opportunities result from periodic, strong El Niño events (Quinn *et al.* 1978; Rasmusson and Carpenter 1982; Carboneras 1992). Reville *et al.* (1990a) showed that sea-surface temperature data from satellites strongly correlated with average annual breeding success. Hence, if sea-surface temperatures increase or El Niño events are compromised due to global warming, breeding success could be lower.

"Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases" is a listed Key Threatening Process under the EPBC Act. It is described as reductions in the bioclimatic range within which a species or ecological community exists due to emissions induced by human activities of greenhouse gases (TSSC 2001), and the distribution is continental. Non-biological components include: temperature rise; changes in rainfall patterns; changes to the El Niño Southern

Oscillation; and sea level rise. Reducing greenhouse gas emissions requires an internationally-coordinated effort. Australia is a signatory to the relevant international agreements, and has made a commitment to limit greenhouse gas emissions. In addition, the States and Territories are pursuing additional opportunities to abate emissions in a cost-effective and environmentally sensitive manner.

The National Greenhouse Strategy (NGS) for Australia has the goals: "to limit net greenhouse gas emissions, in particular to meet international commitments; to foster knowledge and understanding of greenhouse issues; and to lay the foundation for adaptation to climate change". The Strategy provides a broad range of actions some of which will be implemented by governments acting individually, some by joint intergovernmental initiatives and some through partnerships between government, stakeholders and the community. To date, the NGS emphasis has been on emission reduction, but the long-term strategy will also address adaptation actions. These include developing a "framework for progressing adaptation planning for biodiversity conservation, … providing for more detailed plans targeted towards components of biodiversity of conservation significance", including: endangered and vulnerable species and communities; assessment of the capacity of protected areas to sustain biodiversity in the event of climate change; identification of altitudinal and latitudinal buffers; and adaptation requirements of species and communities that are likely to be subject to a change in conservation status as a result of climate change (TSSC 2001).

Storms

A severe storm in March 1988 damaged significant areas of rainforest. It felled approximately one third of the nest sites monitored in the Abbott’s Booby Monitoring Program and killed one third of the monitored fledglings (Reville *et al.* 1990a), but the affect on adult mortality is unknown. In 1988 and 1989, numbers of adults attempting to nest were significantly lower than in previous years (Reville *et al.* 1990a, Yorkston 1992), but in 1991 there was no evidence of a decline in adults and some indication adults had shifted from severely storm damaged areas to nest in adjacent forest (Yorkston 1992; Yorkston and Green 1997).

It should be recognised that small populations will always be susceptible to stochastic events, and there is little that can be done to manage this. Establishing additional breeding colonies via translocation may provide insurance against catastrophic loss (Meek 1997), but would require complete understanding of biological processes to maximise success, together with suitable translocation sites. Such an approach is not feasible for the Abbott’s booby at this stage.

Anthropogenic impacts in feeding areas

Until the distribution at sea is determined, it is not possible to understand the potential impacts Abbott’s booby face in the marine environment. Previous recovery plans have raised the need to prescribe actions to investigate at-sea distribution through satellite telemetry. This need still exists and is a high priority.

Satellite telemetry has added much to knowledge of the at-sea movements of other large, far ranging seabirds such as albatrosses (e.g., Jouventin and Weimerskirch 1990; Prince *et al.* 1992; Weimerskirch *et al.* 1993; Brothers *et al.* 1998). The extreme distances mean satellite transmitters need to send powerful signals and, hence, are often relatively heavy units. It is essential that the well-being of the birds being studied is held in the highest regard. Satellite-tracking studies should use minimal-weight equipment and attachment methods that do not rely on harnesses (Barry Baker, pers. comm.). They should also account for Abbott’s booby possibly plunge diving to 30m or more (predicted by Nelson 1978). Satellite tracking studies also need to encompass the potential for foraging strategies to vary by sex, age class and season, as has been observed for albatrosses and petrels (review for Australian species in Baker *et al.* 2002). Whilst attaching weighty transmitters may have been seen as impediment to conducting satellite tracking studies in the past, increasing miniaturisation of transmitters and the targeting of birds which breed at low sites mean that the task is not impossible (Jeff Tranter, pers. comm.)

Abbott’s booby is thought to feed in warm waters of low salinity on squid and fish (Pocklington 1979), but currently there is little information on foraging distribution. It is unknown whether feeding areas are protected from anthropogenic influences, or whether threats such as competition for prey (over-fishing), or indigenous hunting, as occurs with other booby species, are a problem. Abbott's boobies have been sighted off the coast of Java (Becking 1976) and if they regularly feed close to the Java coast there is the potential for interaction with Indonesian or Taiwanese fishermen.

Meek (1997) and Dunn and Hill (1998) raised the potential for Abbott’s booby to be caught incidentally in longline fisheries, but noted that there was no evidence of this. They have not been recorded as bycatch in any Australian longline fisheries observer program, and sulids in general are rarely impacted by this process (Environment Australia 1998; Barry Baker, pers. comm.). A developmental longline fishery was established in the waters around Christmas Island in 1998, but closed after 12 months following limited fishing effort (one cruise). The spawning grounds for southern bluefin tuna are near Christmas Island and there is potential for future fisheries to open. Based on knowledge of conventional gear configurations, bycatch is not likely at this stage. However, any future fishery development should include precautionary measures such as high observer coverage to identify whether bycatch of Abbott’s booby is occurring, thus permitting identification of appropriate measures to eliminate the problem.

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Attachment 1 – Demographic Model (from Meek 1997)

Detailed explanation of the development of an appropriate Demographic Model for Abbott's booby
Prepared by Dr Greg Hood

For a population vulnerable to extinction, it is important that the finite rate of change, λ, is greater than one (this is equivalent to saying that the intrinsic rate of increase, *r*, should be greater than zero). If the population at this year is N_t, and the population last year is N_{t-1}, the finite change is simply the number λ which satisfies the equation:

$$N_t = \lambda N_{t-1}.$$

The population of Abbott's booby on Christmas Island has a low finite rate of change because successful breeding by a pair of boobies, i.e. the whole process of laying an egg and rearing the chick to independence at about 16 months of age, can in general occur only once every two years.

The main process threatening the *breeding* population is habitat destruction (and alteration) caused by the mining operations. Leaving aside off-island processes, it is important to determine the effect of altered habitat on the viability of the population as measured by the finite rate of change. I think two questions need addressing: (1) What effect does clearing for the mining operations, or other disturbances, have on the finite rate of change? and (2) Can rehabilitation of disturbed areas produce a worthwhile change in the finite rate of change? Although much of the hard work designed to answer these questions has been done, the difficulties working with Abbott's booby mean we may never have definitive answers, and we have to make do with the best data available.

To answer the two questions, we need to use life-tables or some kind of demographic model. Clearly, we have insufficient information to construct realistic life-tables. The demographic models developed below are essentially simplified life-tables that contract some parts of the life cycle into a single stage, or contract a large number of vital rates (for example, survival probabilities) into a single parameter. Appropriate "contractions" of the life table are best made by the people who study the birds and know the data. All I try to do here is give some idea how such models are developed and what insights they can provide.

The first demographic model for Abbott's booby looks like Figure 1. This model (Model I) assumes: that the sex ratio is 1:1, that females first breed at eight years of age, and that all birds over two years of age have the same survival rate, *s*. An alternative formulation (Model II), in which the survival probability from age one to eight is different to that of adults.

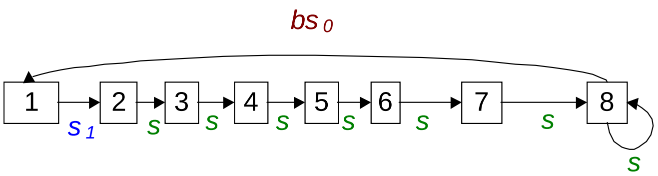


Figure 1. Life cycle graph for female Abbott's boobies (Model I). The boxes represent age classes (in years) and there are four parameters: b is the probability that a female lays an egg in any one year, s_0 is the probability that an egg survives from hatching, s_1 is a chick survives from year 1 to year 2, and s is the "adult" annual survival probability. The diagram uses the formalism for a pre-breeding census from Caswell (1989).

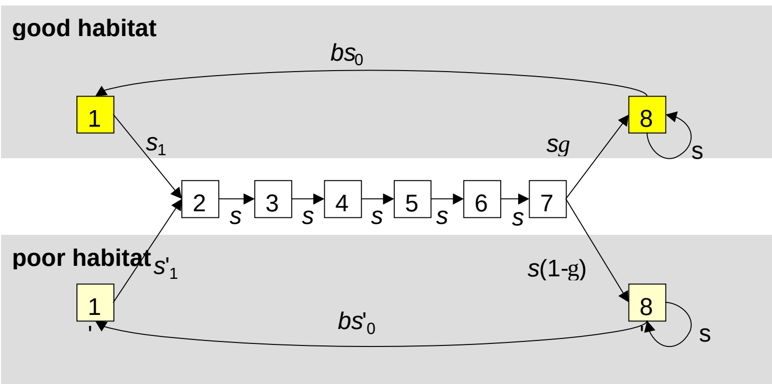
Models such as this are a tool for evaluating the effect of each vital rate on the population's rate of change. The approach is widely recognised in the ecological literature (see for example Lande (1988) and Caswell's (1989) book). To evaluate the importance of the parameters (b, s_0, s_1 and s) we can calculate the *sensitivity* of the finite rate of change, λ, to each of the parameters. To do so, a population projection matrix is constructed. For the life-cycle graph shown in Figure 1, an appropriate matrix is:

$$\begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & bs_0 \\ s_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & S & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & s & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & s & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & s & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & s & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & s & s \end{vmatrix}$$

Methods to evaluate the sensitivity of the finite rate of increase to the demographic parameters are outlined in Caswell's (1989) book. In mathematical terms, we calculate the partial derivative of the dominant eigenvalue of this matrix (= λ) with respect to each parameter.

Using the parameters on the booby collated by Dunn and Hill (1995), I calculate that the finite rate of change, λ, is most sensitive to adult survival, with the remaining parameters being roughly equal in importance. Interestingly, λ is insensitive to the age at first breeding, probably because the older birds contribute so much to the population growth rate. If we take one parameter to represent the survival rate from year 1 to breeding age, as in Model II, then the importance of that parameter, of course, increases.

To answer the two question posed at the outset, we need an extension of the life cycle graph to include different habitats. If we classify breeding habitat as good (non-turbulent) and poor (turbulent), an appropriate life cycle graph can be constructed as shown in Figure 2.



$$
\begin{vmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & bs_0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & bs'_0 \\
s_1 & s'_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & s & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & s & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & s & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & s & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & s & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & sg & s & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & s(1-g) & 0 & s
\end{vmatrix}
$$

Figure 2. Life cycle graph for female Abbott's boobies in two different habitats and the associated projection matrix. The life cycle is the same as Figure 1 except that unique parameters characterise the survival rate in year 0-1 (s'_0) and year 1-2 (s'_1) in the poor habitat. (Note that by setting $g = 1$, we recover the life cycle graph shown in Figure 1). The parameter g represents the proportion of females that are able to select a nest site in the "good" habitat. Age classes and vital rates applicable in the poor habitat are indicated by a prime superscript (eg, the survival rate in year 0-1 in the poor habitat is s'_0, rather than s_0).

This extension of the original model requires three extra parameters: the two survival parameters for poor habitat, s'_0, s'_1, and the parameter g which could be estimated as the proportion of all nesting sites which are in good habitat (perhaps by using Keith Porritt's spatial database). It is quite simple to extend this approach to more than two habitats, but I doubt that enough demographic data could be collected to adequately validate the resulting model.

We can now provide a preliminary answer to our first question by calculating the sensitivity of the growth rate to g, the proportion of the habitat classified as good. Figure 3 shows the finite rate of increase as a function of g, under the assumption that survival probabilities for the chicks in poor habitat are half those of chicks in the good habitat (i.e, $s'_0 = s_0/2$ and $s'_1 = s_1/2$). The population goes into decline ($\lambda < 1$) when about half of the habitat is classified as poor ($g < 0.45$). Given the fact that the population grows very slowly, $\lambda \approx 1$, even in good habitat, this finding is hardly surprising. It emphasises the fact that the population is indeed vulnerable to clearing for mining operations.

The answer to the second question can only be answered by further study, but the sensitivity of the growth rate to habitat clearing does show that it is an important question.

There are some caveats to this analysis. First, I have assumed that all of the demographic parameters are independent of density. If density-dependence is important (for example, if there is strong competition for nest sites), the population will show different behaviour when perturbed from current densities. Unfortunately, it will be difficult to get enough demographic information to test for density-dependence. Second, I have also ignored stochastic variation in the vital rates because the adults are so long-lived that, in a single-species population model, such variation is unlikely to significantly affect λ. It is possible, however, to analyse the sensitivity of the stochastic growth rate as a function of the vital rates using Monte Carlo methods or using an analytical approximation. Note that even if stochastic events do not affect λ—which is essentially a long-term characteristic of the population—catastrophes can obviously affect the viability of the population in the short-term. For example, the population would be vulnerable to small perturbations or a sequence of catastrophes if 90% of the adults were wiped out by a cyclone, even if the finite rate of change after the cyclone was greater than unity. A final caveat is that the model assumes that good and poor habitats are equally accessible.

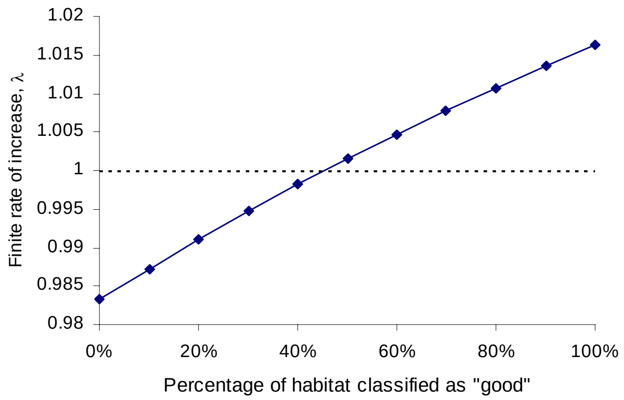


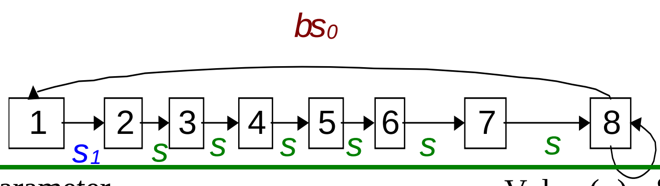
Figure 3. The finite rate of increase, λ, as a function of the percentage of habitat classified as good, g. The dotted line is the threshold for persistence of the population (λ = 1). The sensitivity of λ to g is simply the slope of the line shown in the plot.

Demographic models can also be used to identify which bits of information are required to make better population projections. A preliminary analysis (not shown) suggests that we really need to get a handle on two vital rates: adult survival (s), and survival from year 1 to breeding age (s_1). We already know a fair bit about egg production (b) and survival during the first year (s_0).

Determination of the age-at-first-breeding seems to be relatively unimportant, because of the longevity of the adults once they start breeding. All of these findings seem reasonably robust because they apply in both models.

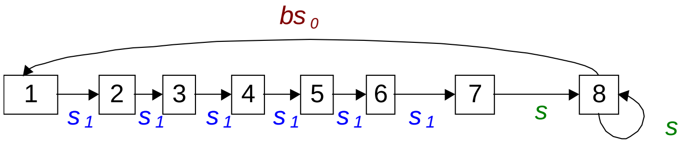
Data Analysis
Sensitivity analyses are shown below for two models. Model I assumes that the adult survival probability prevails from year 2; Model II assumes a "juvenile" survival rate from year 2-7. The parameter s_1 has been adjusted so that the finite rate of increase for each model is the same as that which I calculated based on Dunn and Hill's (1995) PVA. To interpret the tables, note that for both models the sensitivity for s_0 is listed as 0.073. This means that every unit change in s_0 produces a change of 0.073 in the finite rate of change, λ. The conclusions from the models differ slightly. Population growth is most sensitive to adult survival in both models, but there is a difference in importance of the parameter s_1, which simply reflects the number of times it appears in Model II.

Model I



Parameter		Value (π)	Sensitivity ($\partial\lambda / \partial\pi$)
Probability survival first yr	s_0	0.50	0.073
Probability survival during second year	s_1	0.83	0.095
Adult survival	s	0.968	0.975
Age at first breeding	α	8	-0.007
Probability of survival to breeding age	l_α	0.156	
Females produced per breeding female	b	0.346	0.105
Geometric growth rate	λ	1.016	
Generation time	T	28.0	

Model II



Parameter		Value (π)	Sensitivity ($\partial\lambda / \partial\pi$)
Probability survival first yr	s_0	0.50	0.073
Annual probability survival year 2-7	s_1	0.382	0.263
Adult survival	s	0.968	0.788
Age at first breeding	α	8	-0.002
Probability of survival to breeding age	l_α	0.157	
Females produced per breeding female	b	0.345	0.105
Geometric growth rate	λ	1.016	
Generation time	T	28.0	

Attachment 2 – Helicopter survey of active booby nests, September 2002

On 23-24th September 23, 2002, an island-wide transect survey of active Abbott's booby nests was undertaken in a small Bell 47 with a turbine engine, brought to the island to distribute bait for crazy ant control. The technique proved successful in that birds at nests rarely reacted and when they did it was simply to look up. If a suitable helicopter is available, this would be a time-efficient, if not cost-efficient, means of future monitoring and the September survey can act as a baseline.

Some 1500 nests were identified, however, ground-truthing is yet to be conducted and corrections made for possible double-counting and inclusion of advanced nestlings from the previous year (Fig. 5). The results compare favourably with the earlier ground surveys (Figs. 1, 5). There was no indication of crazy ant impact on boobies.

To the north of the IRPC, there is a considerable density of nesting boobies that should be considered in any activity that might cause their disturbance.

A significant cluster of sites of about 30 active nests was identified west and north west of the airport runway and outside the Park. A few nests were known from past surveys but the extent of the cluster was previously undiscovered. This area should be considered habitat critical to survival of the Abbott's booby and action taken to protect it or even incorporate it into the Park.

The preliminary results also indicate that boobies are again nesting to the north-west of some of the mining fields (e.g., Fields 22C and 23B), where regrowth/revegetation is approaching 20 years old. Removal of any phosphate stockpiles at these sites could seriously compromise the nesting of boobies downwind (northwest) of these sites and be contrary to the objectives of the *Abbott's Booby Recovery Plan*.

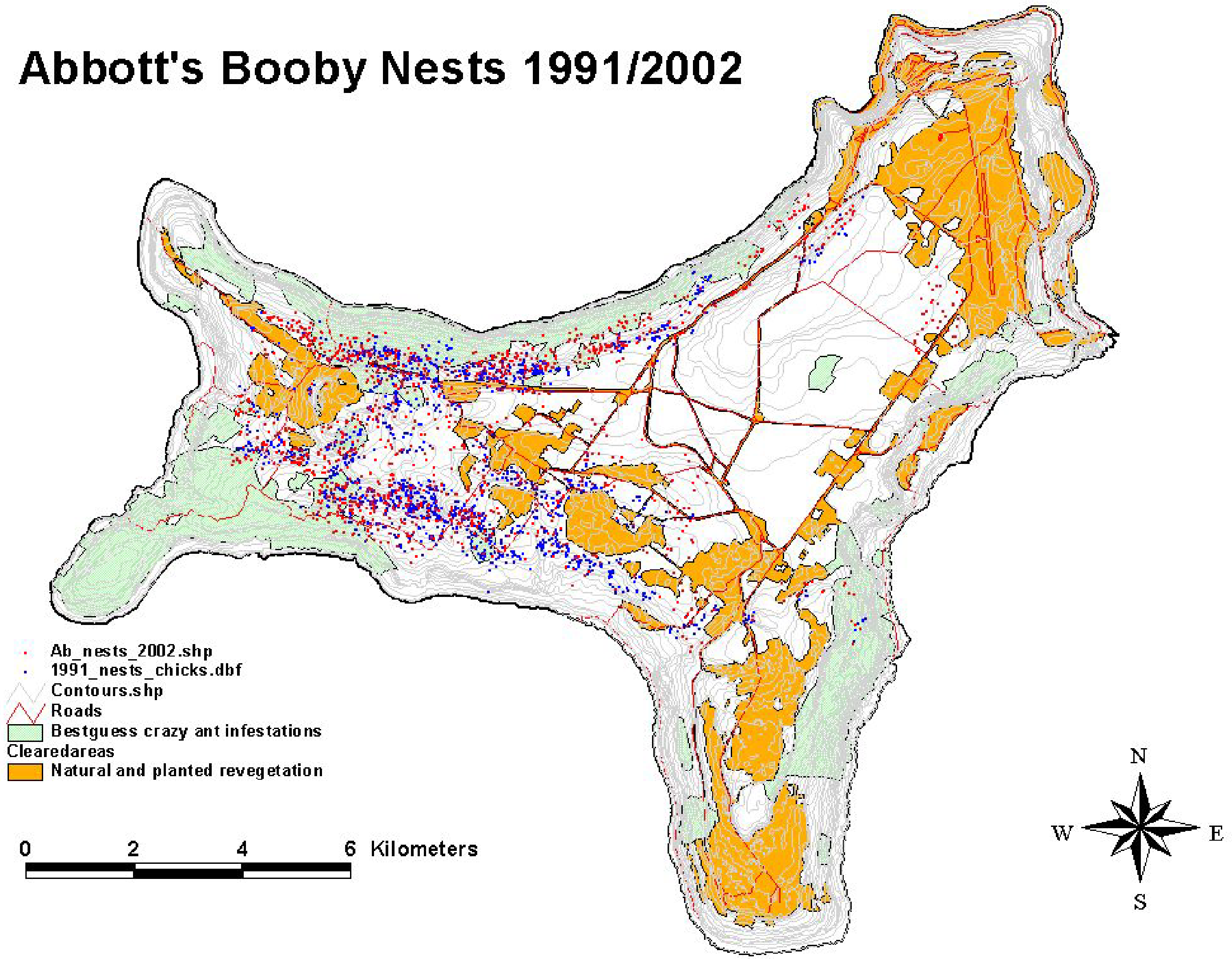


Figure 5. Results of helicopter survey of Abbott's booby nest sites September 2002 in relation to mining fields, contours and crazy ant distribution.

Attachment 3 – Past population monitoring

Previous monitoring programs (Reville *et al.* 1990a; Yorkston 1992) aimed to achieve the following objectives:

- compare the breeding success and cause of failure of Abbott's booby in habitat affected by mining with those in habitat not affected;
- measure the differences in breeding success between areas, especially near clearings as reafforestation proceeds;
- detect long-term changes in the breeding population, especially further evidence of a decline;
- detect long term changes in nesting distribution; and
- determine the effects of a storm which occurred in 1988 on adult mortality;

To meet these aims, two methods were employed, which are described in the table below.

	Method	**Abbott's booby monitoring program 1983-89**	**Reduced monitoring program 1989-1992**
1	A core sample of nests was monitored to determine breeding success. Initially there were 108 core sites, with a core sample originally including the core site plus the four nearest nests. Nests subsequently found closer to the core site were incorporated into this sample.	Nest activity checked fortnightly. Total sample 108 core sites containing 600 - 700 nest sites.	Nest activity monitored every three weeks (or seven times) from May to September 63 of the original core sites
2	The activity of nests within study blocks was monitored to determine nest density and movement of nest sites. A study block included all nests within a 61m radius of a core site.	Nest activity checked every three months	63 study blocks around the core sites were surveyed four times per year: twice between May and September; once in Nov/December; once in Feb/March.